ENVIRONMENTAL ASSESSMENT OF QARN ALAM 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 Qarn Alam asset, which is under the oil north directorate within PDO's concession area in the Sultanate of Oman. The first environmental assessment for Qarn Alam asset was carried out in June 1999. A separate EIA study for the steam injection project was initiated and an initial environmental examination for its Khaluf Bay development and the proposed pipeline route was completed in November 2000. 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. Qarn Alam is covering a land area of 18,900 km^2 and consisting of 14 operating fields and 161 oil producing wells and 55 gas producing wells.

This asset currently produces 14,462 m^3/d of oil and 3,084,000 Sm^3/d of gas (associated and non-associated). The total power generation in the asset is 83.3 MW and the total abstraction of groundwater in the asset is 4,007 m^3/d. The total length of roads in the asset is 1,360 km and the total length of flow lines is 832 km.

The asset has three oil production stations (in Al Ghubar, Saih Rawl and Qarn Alam) and four gathering stations (Barik, Ghaba North, Qarn Alam and Saih Nihayda). There are three gas stations in Barik, Saih Rawl and Saih Nihayda for processing non-associated gas. There are two gas fired gas turbine power station (located in Saih Nihayda and Saih Rawl). The asset has two water treatment plants, with one based on reverse osmosis (RO) process and another based on mechanical vapour compression (MVC) distillation. The asset also has a waste management centre including land farm for treatment of oily sand.

There is one permanent accommodation camp for PDO staff and four 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 camps.

The asset releases about 3009 tpd of CO_2, 7 tpd of NO_x, 7 tpd of CO and 8 tpd of SO_2 and 24 tpd HC into the atmosphere. The liquid effluents generated in the asset include 67,255 m^3/d of produced water and 556 m^3/d of sewage. The total hazardous waste produced is about 1,080 tpa. The total volume of accidental oil spills and leaks reported in the asset is 23 m^3 per year.

Description of Environment

Qarn Alam asset is located in central Oman about 360 km south 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. The elevation with reference to the mean sea level ranges from about 140 m. There is one major wadi (Wadi Umayri), which drains in the north west of the asset, and other smaller wadis (Wadi Majhul, Halibah, Thaylah and Wadi Qitfah). The geology of the asset comprises mainly carbonates and clastics.

Groundwater exists in Fars and UeR formations, which is the only water resource in the region. All the potable water for the population in Qarn Alam asset, including the PDO and contractor camps is supplied with desalinated water from RO and GOGD plants.

The asset has an arid climate with mean monthly temperatures range from 19.1°C in January to 35.5°C in June, and extreme temperatures ranging from a maximum of 47.9°C to a minimum of 7°C. The mean annual rainfall in Qarn Alam area is 1.1 mm.

The native vegetation is composed of desert plants and grasses, and trees, which are rarely seen. The fauna include a few species of largest mammals including the mountain gazelle and the Rheem gazelle, both of which qualify under the IUCN world Red List and the regional Red List threat categories. A few smaller mammals, mostly gerbils, 96 species of birds and jerboas are likely to be present in the vegetated areas.

The number of persons currently accommodated in PDO and contractor camps in the asset is about 1,229. A total of approximately 20 families are in the area known to PDO, which utilizes the wadis. There are no towns within the Asset area and Bedouin (nomadic or semi-nomadic) settlements are relatively few in number and nowhere permanent.

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 and heater stacks shall be monitored for compliance. • Ambient air quality shall be monitored in accommodation camps periodically.
SP-1006: Specification for Aqueous Effluents	• Due to ill design of the contractor's STP, frequently untreated sewage overflows from the holding tank into open lagoons. • 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.	• Contractor's STP shall be redesigned such that untreated sewage will not be discharged under any circumstances. • 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 and under-reported.	• 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. • Waste recycling is not significant. • There is no evidence of regular wetting of land farms.	• Compliance with waste handling procedures shall be enforced. • Waste segregation at source shall be enforced at rig sites. • 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
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

It may be noted that PDO has a comprehensive environmental management plan as a part of its HSE management system, which is implemented in the asset. No change in the existing environmental management system is required. However, the above findings and additional mitigation measures were recommended to reduce the potential environmental risk and improve the overall environmental performance.

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ABBREVIATIONS

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

PM_{10}	particulate matter of <10 µm size
$PM_{2.5}$	particulate matter of <2.5 µm size
RD	royal decree
RMS	remote manifold station
RO	reverse osmosis
SHOC	safe handling of chemicals
Sm^3	standard cubic meter (at 1atm and 20^{o}C)
SOGL	south Oman gas line
STOIIP	stock tank of oil initially in place
t	metric tonne (equal to 1000 kg)
TDS	total dissolved solids
tpa	tonnes per annum (year)
tpd	tonnes per day
tph	tonnes per hour
TSP	total suspended particulates
UeR	Umm er Radhuma
UNEP	United Nations Environmental Program
UNESCO	United Nations Scientific and Cultural Organisation
USEPA	United States Environmental Protection Agency
WHO	World Health Organisation
µg	micro-gram
µm	micro-meter (also known as micron)
µS/cm	micro-Siemens per centimeter (unit of electrical conductivity)

1 INTRODUCTION

1.1 Petroleum Development Oman

Petroleum Development Oman (PDO) is the largest petroleum exploration and production (E&P) company in the Sultanate of Oman, with over 113,550 km^2 of concession area, covering most of the central and southern parts of the Sultanate. The geographical map of PDO's concession area is shown in Figure 1.1. Presently, PDO's concession area is divided into two main 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 (including Rima) 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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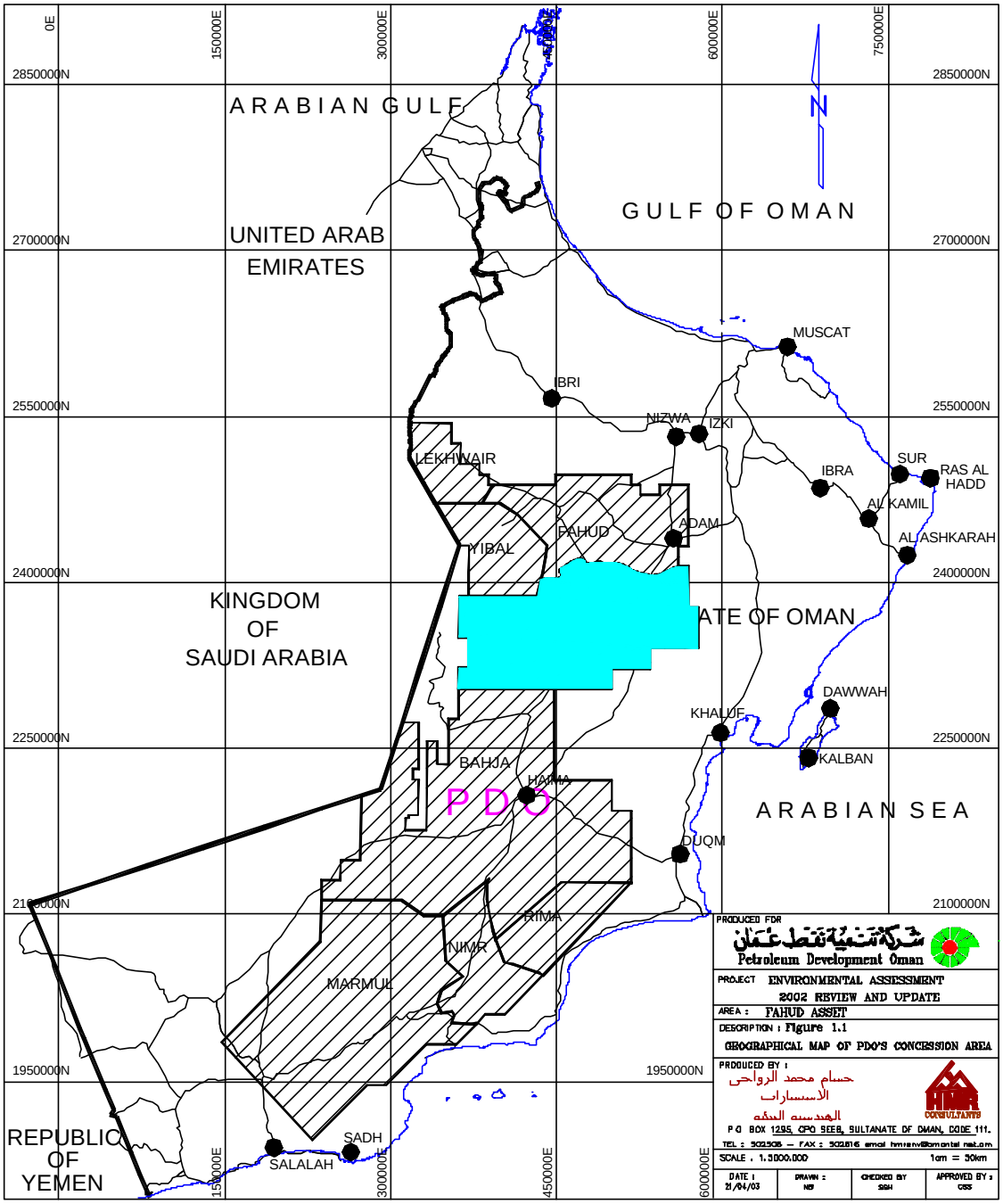

Figure 1.1: Geographical Map of PDO's Concession Area

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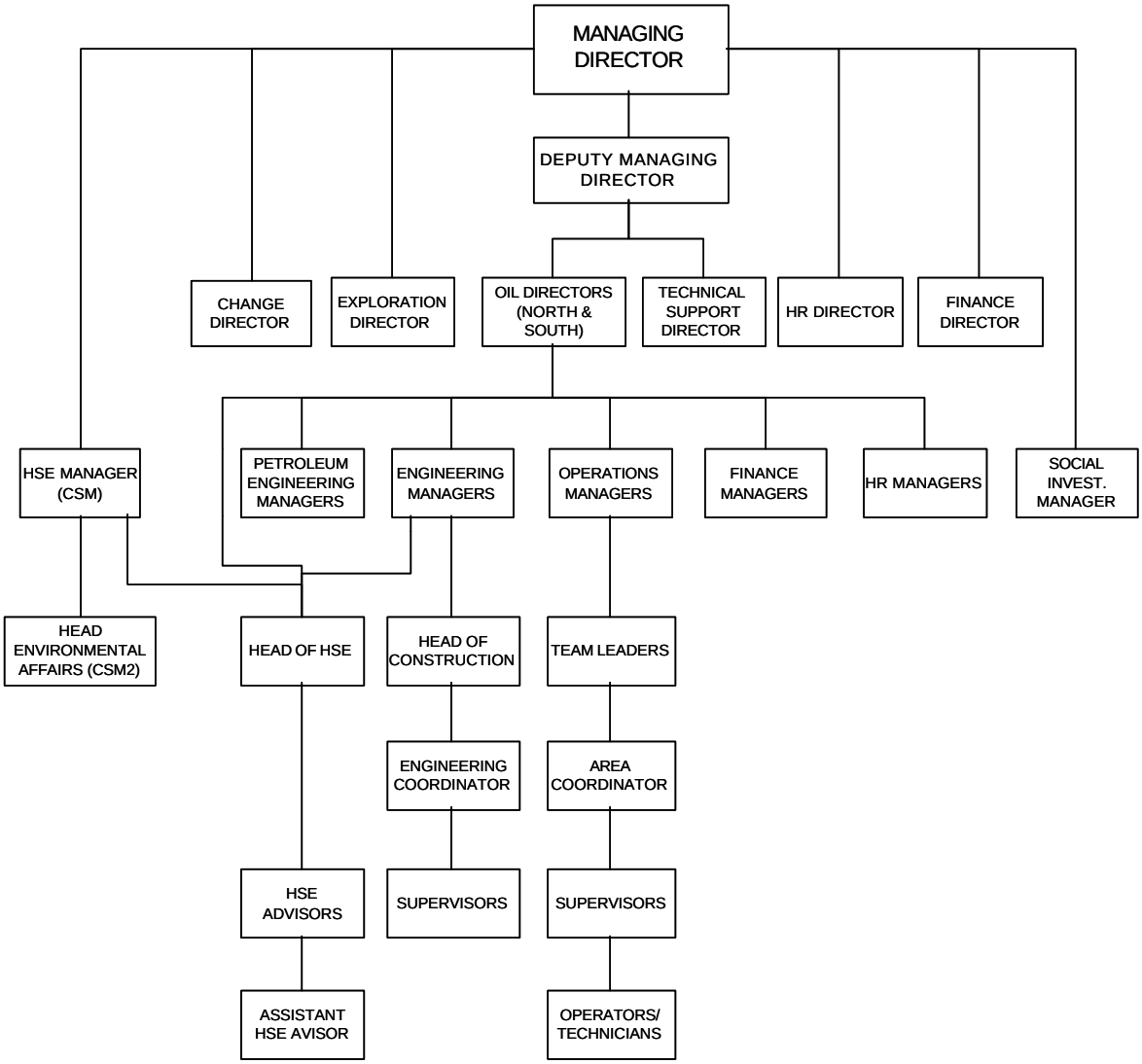

Figure 1.2: Organisation Structure in PDO

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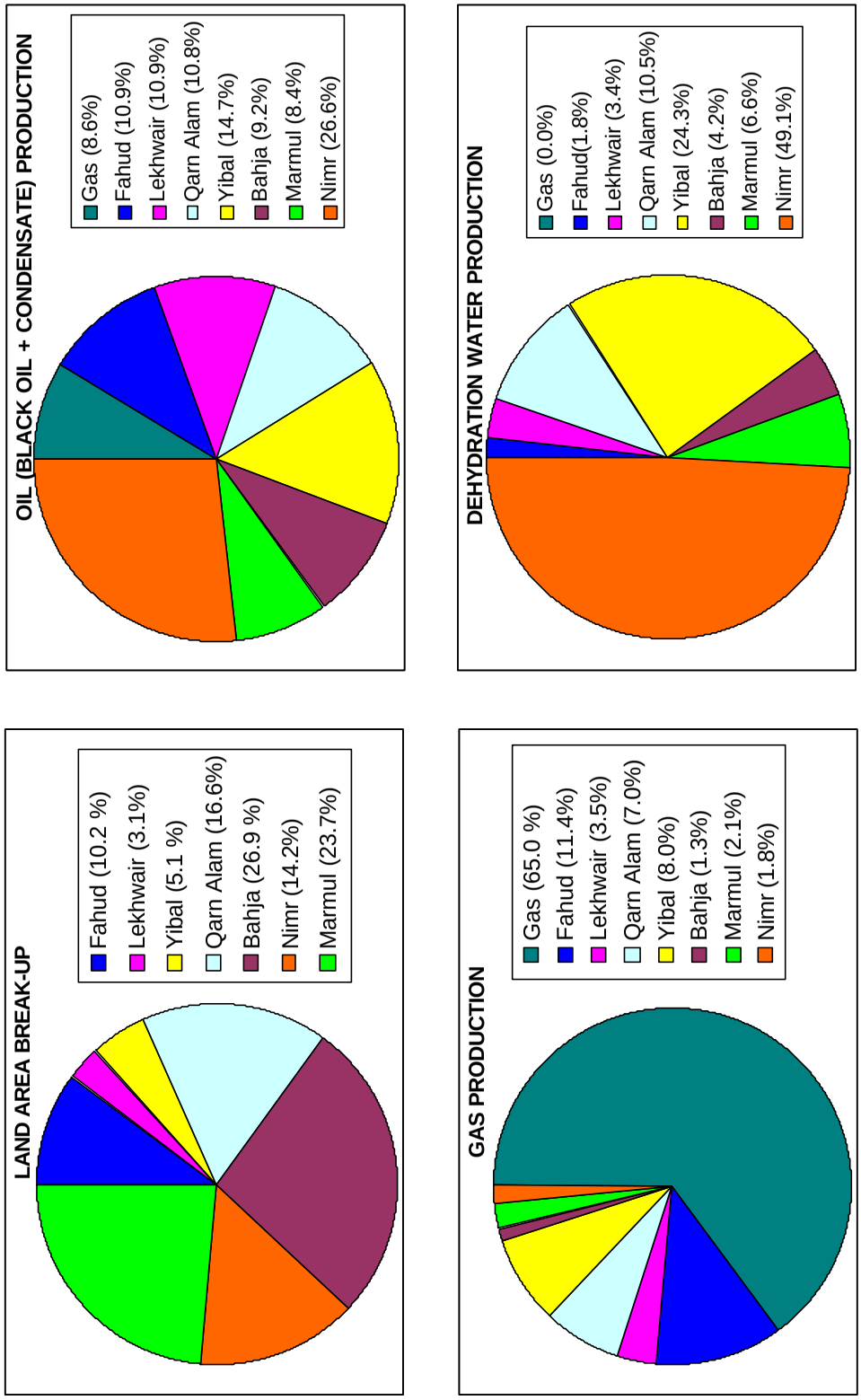

Figure 1.3: Asset-wise Break-up of Land Area, Oil, Gas and Produced Water

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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 Qarn Alam asset, which includes the Qarn Alam steam injection project. The previous environmental assessment study for Qarn Alam asset was completed in July 1999 (*Reference 1*). A separate EIA study for the steam injection project was initiated and an initial environmental examination for its Khaluf Bay development and the proposed pipeline route was completed in November 2000 (*Reference 3*).

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

2.3 PDO Corporate Environmental Specifications

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

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

Table 2.3: PDO's Environmental Specifications

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

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

2.4 Environmental Standards

2.4.1 Emissions to Atmosphere

PDO specification SP-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.

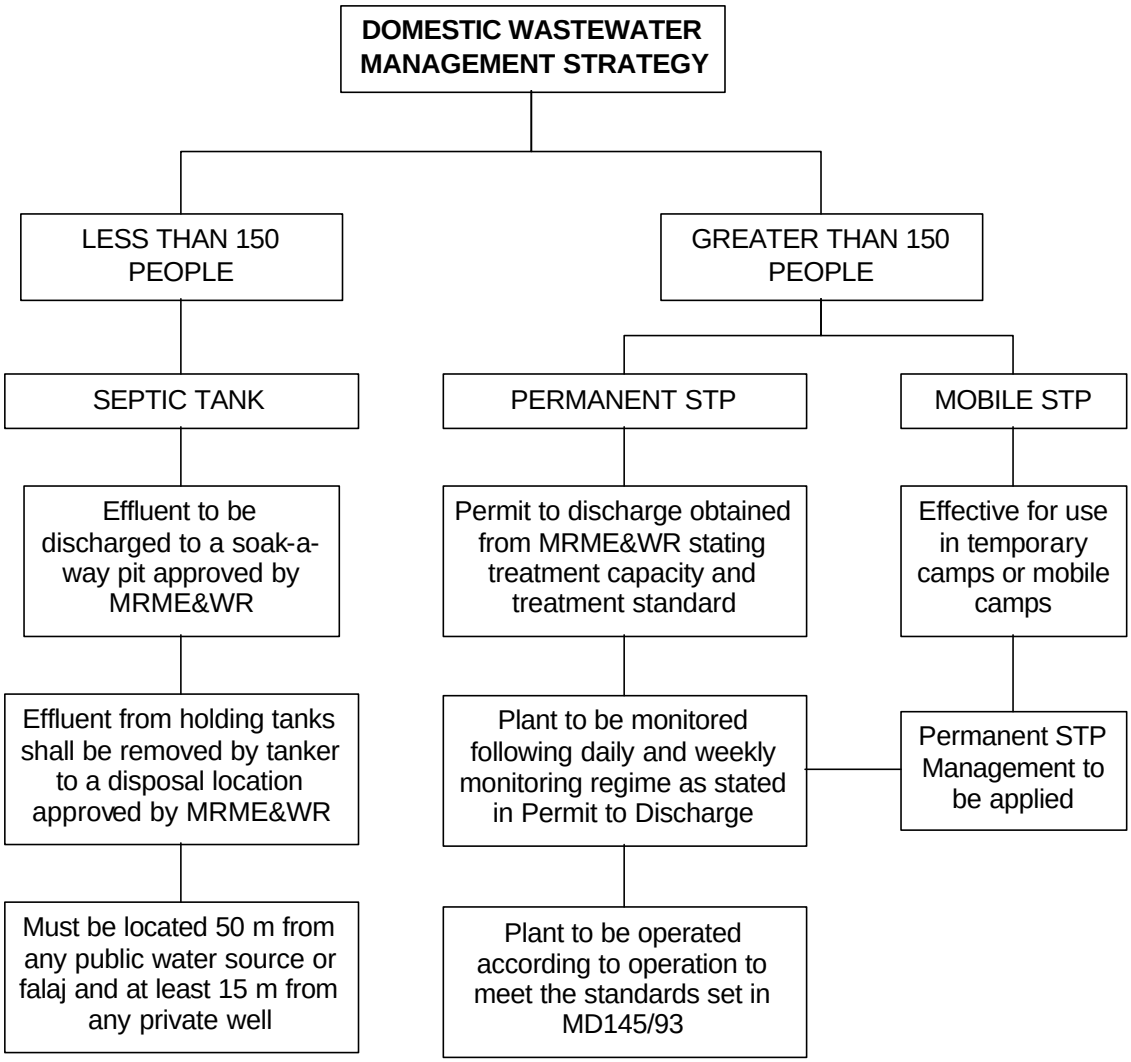
(e) Dispose surplus waters to formations, which have salinity greater than 35,000 mg/L, in conjunction with case-specific monitoring programs.

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

PDO's waste management hierarchy is as below:

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

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

2.4.7 Environmental Noise and Vibration

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

Table 2.12: Ambient Noise Standards

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

2.4.8 Flora and Fauna

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

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

Table 2.13: Classification of Environmentally Sensitive Areas

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

2.4.9 Land Management

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

Table 2.14: Land Management Requirements

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

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

2.4.10 NORM Waste Disposal

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

3 ASSET DESCRIPTION

3.1 Asset Organisation

Geographically, Qarn Alam asset is located in the central part of PDO' concession area, below Fahud and Yibal assets and above Bahja asset. It covers a total land area of 18,900 km^2, accounting for 16.6 % of PDO's total concession area. The asset consists of three oil production stations, three gas stations, four gathering stations, 14 operating fields, 161 oil producing wells and 55 gas producing wells. Qarn Alam field was discovered in 1972 and initially brought on stream in 1975. The asset organisation structure is shown in Figure 3.1. The asset management structure including the health, safety and environment (HSE) management structure as shown in Figure 3.2.

This asset produces 14,462 m^3/d of net crude (10.8 % of PDO's total crude oil production) and 3,084,000 Sm^3/d of gas (associated and non-associated) (7% of PDO's total gas production) as reported for the year 2002. The asset also produces 67,255 m^3/d of produced water. The total power generation in the asset is 83.3 MW and the total abstraction of groundwater in the asset is 4,007 m^3/d excluding water used by rigs. The total length of roads in the asset is 1,360 km and the total length of flow lines is 832 km.

The facilities available in the asset are listed in Table 3.1 below

Table 3.1: List of Facilities in Qarn Alam Asset

Name of Facility	Number of Units
Oil production stations	3 (Al Ghubar, Saih Rawl and Qarn Alam)
Crude stabilisation plant	1 (As apart of the Qarn Alam Production Station)
Gathering stations	4 (Barik, Ghaba North, Qarn Alam and Saih Nihayda)
Gas production stations	3 (Barik, Saih Nihayda and Saih Rawl)
Power stations	2 (Saih Nihayda and Saih Rawl)
Water treatment plant	2 (Contractor RO plant and GOGD plant)
Booster stations	None
Produced water injection / disposal plants	Part of the production station
Permanent PDO camps	1
Permanent contractor camps	4 (1 PAC and 3 Contractor Camp)
Permanent sewage treatment plants	3
Portable sewage treatment plants	2
Mobile sewage treatment plants	None
Central chemical stores	None
Waste management centre	1
Drilling rigs	12 (presently)

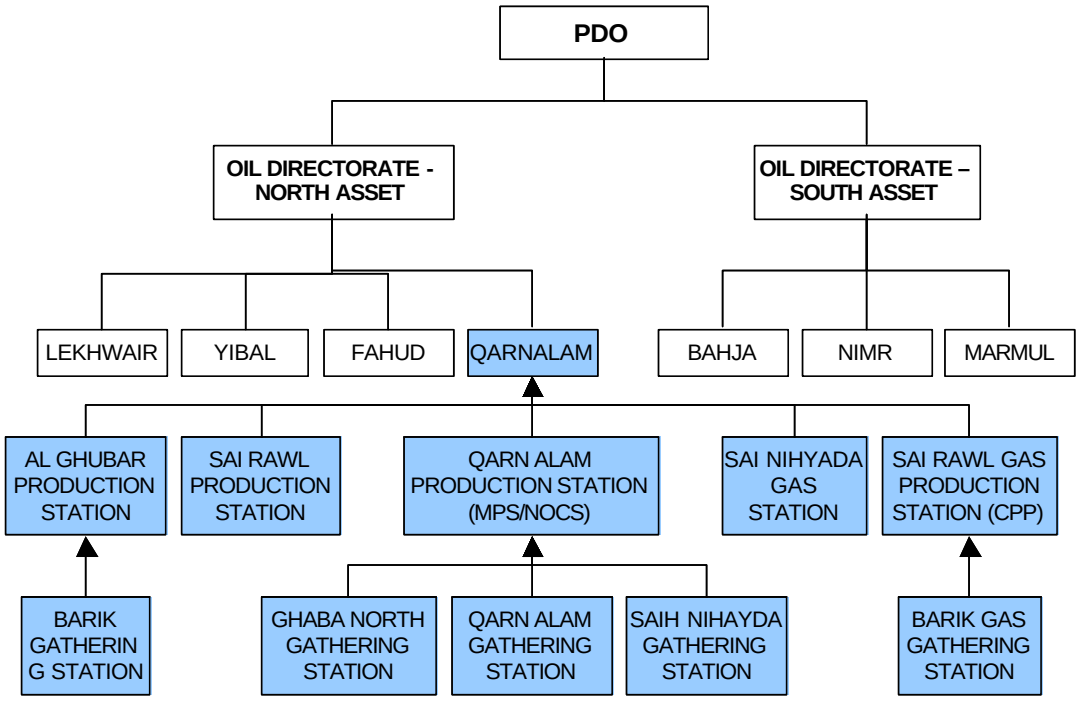


Figure 3.1: Organization Structure for Qarn Alam Asset

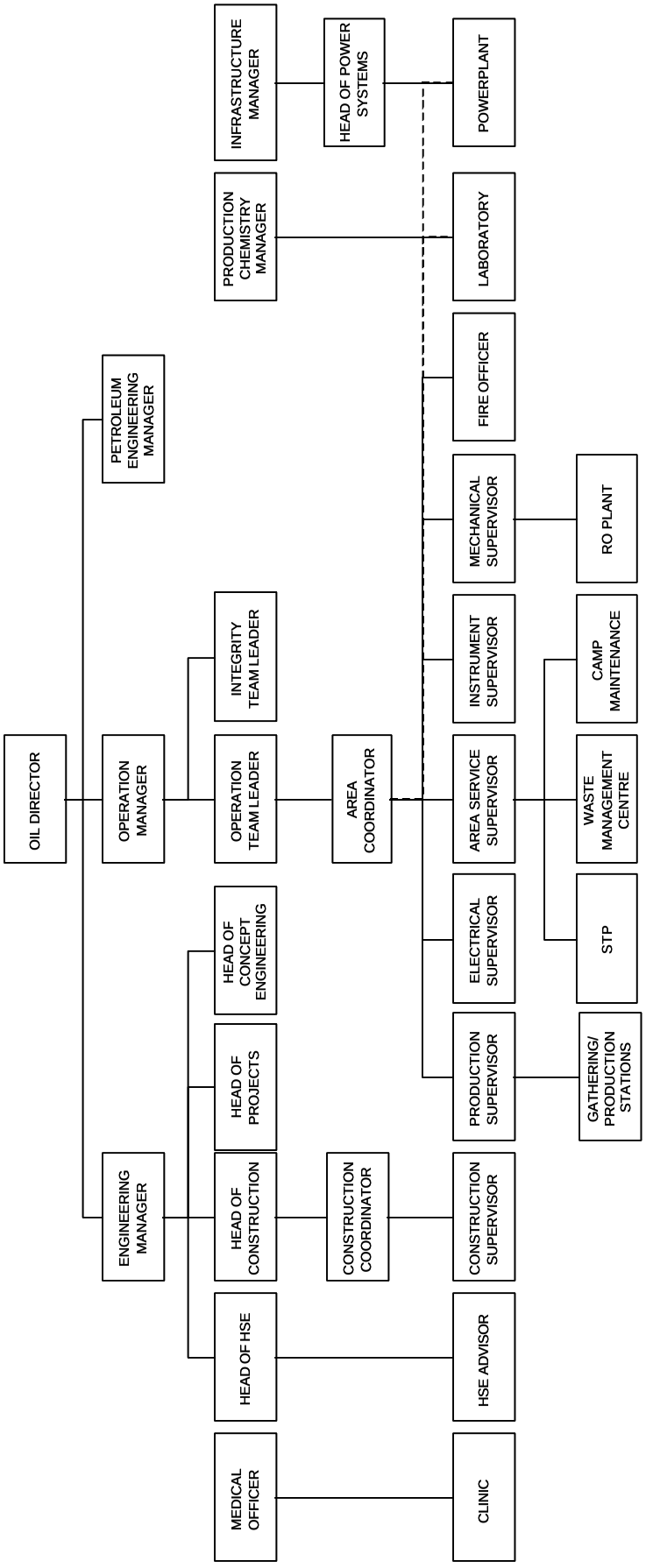


Figure 3.2: Asset Management Structure for Qarn Alam

There are three oil production stations in Al Ghubar, Saih Rawl and Qarn Alam and four gathering stations in Barik, Ghaba North, Qarn Alam and Saih Nihayda in the asset. There are three gas stations in Barik, Saih Rawl and Saih Nihayda for processing non-associated gas. There are two gas fired gas turbine power station located in Saih Nihayda and Saih Rawl. The asset has two water treatment plants, with one based on reverse osmosis (RO) process and another based on mechanical vapour compression (MVC) distillation. The asset also has waste management centre including land farm for treatment of oily sand. There is one permanent accommodation camp for PDO staff and four 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 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/ production stations
- Separation of associated gas from the reservoir fluid in the gathering stations/ production 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
- Extraction of non-associated gas from gas reservoir.
- Treating of associated and non-associated gas and export
- Production of groundwater
- Desalination of groundwater for process and domestic use
- Generation of power using gas fired gas turbines
- Disposal of produced water by injection into aquifers
- Treatment of liquid effluents
- Disposal of solid waste
- Flaring of associated gas that is unutilised or not re-injected

In addition to the production activities, several developmental and construction activities take place in the asset. The major developmental activity that is proposed in the asset is the steam injection plant at Qarn Alam. The initial environmental examination for the Khaluf Bay development and the proposed pipeline route as a part of the steam injection plant was completed in November 2000 (*Reference 3*).

In addition to the above, the following developmental and construction activities are performed at some location or the other 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 3.3. A brief description of the major facilities and activities in the asset are discussed in the following sections.

3.3 Gathering Stations

3.3.1 General

Crude oil and gas are extracted from 14 operating fields and 161 wells in the asset. Out of the 161 wells, only 17 are natural flow wells. The pumped wells include 71 using electrical submersible pumps (ESP) and 73 using gas lift pumps. There are four oil gathering stations in the asset, in Barik, Saih Nihayda, Qarn Alam and Ghaba North, where the well fluid extracted from this field is degassed fluids before it is sent to the production stations for dehydration and export. The reservoir fluid extracted from all other fields in the asset is directly sent through flow lines to the production stations located in the asset for degassing and dehydration. The well fields connected to the gathering stations are as below:

Barik Gathering Station	- Barik field
Ghabha North Gathering Station	- Ghabha North and Qarat Almilh field
Qarn Alam Gathering Station	- Qarn Alam, Alam, Habur, and Saih Nihayda fields
Saih Nihayda Gathering Station	- Saih Nihayda field

Al Ghubar field is directly connected to Al Ghubar production station, Burhan fields is directly connected to Qarn Alam production station, and Saih Rawl, Mabrouk, Musallim and Ramlet Rawl fields are directly connected to Saih Rawl production station. A brief description of the gathering stations in the asset is presented below.

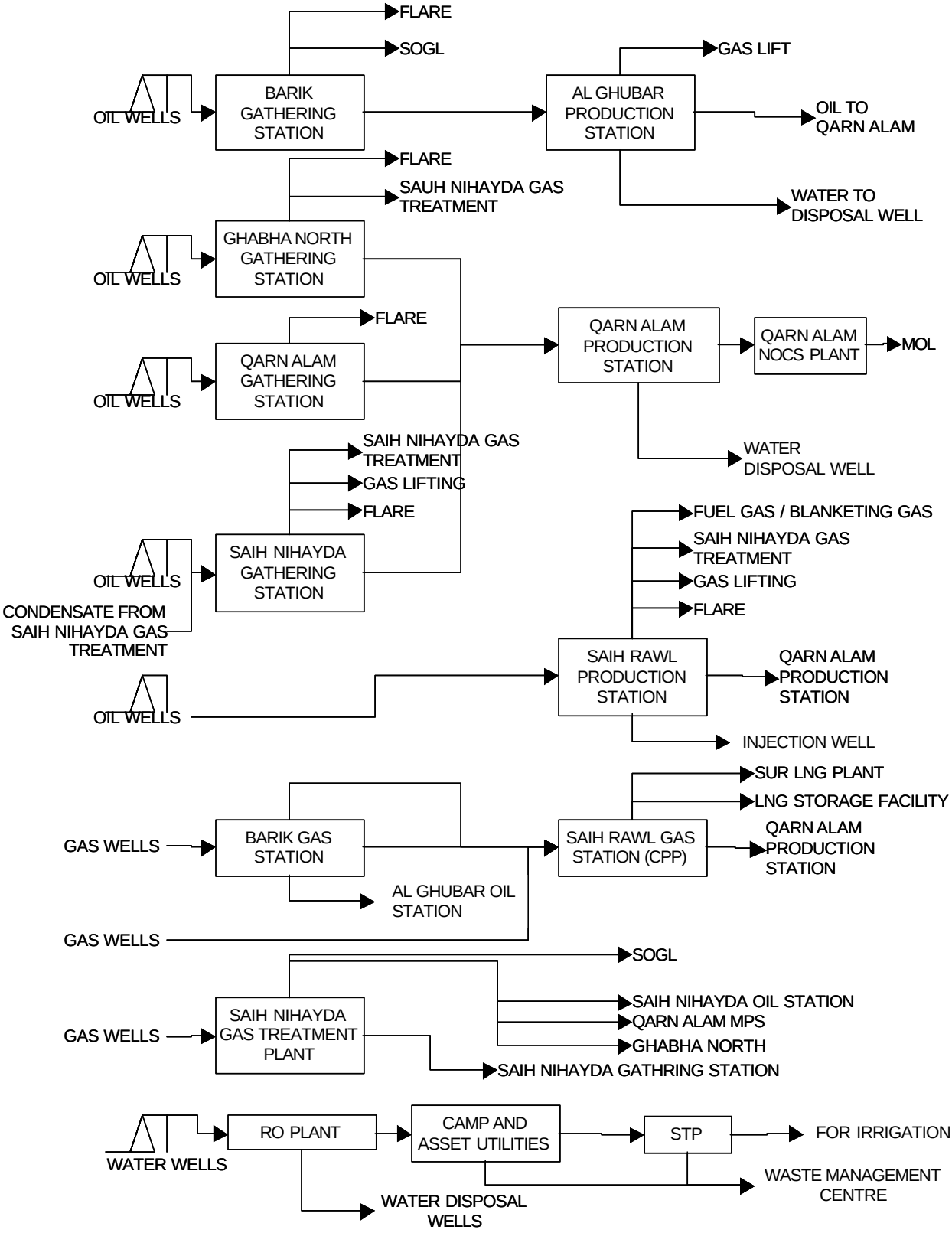


Figure 3.3: Schematic Diagram of Major Production and Associated Activities

3.3.2 Barik Gathering Station

The Barik gathering station is located approximately 100 km south west of Qarn Alam, and 25 km west of Al-Ghubar. All wells in Barik field are free flowing. The well fluid flows to bulk separators in the gathering station and the associated gas is separated in the bulk separators. The separated gas is treated in gas conditioning units for removal of water and low condensing hydrocarbons by chilling the gas to 6-8°C. The conditioned gas is then exported to the South Oman HP gas line. The degassed oil-water stream along with produced water from Barik gas station is sent to Al Ghubar production station for further treatment. There is no storage tank or gas compression facility in this station. A flare is provided for flaring any released gas.

3.3.3 Ghaba North Gathering Station

The Ghaba North Gathering Station is located approximately 25 km north-west of Qarn Alam. Reservoir fluid from the wells is extracted by gas lift pumps and ESPs. The reservoir fluid flows to the bulk separator for separation of associated gas. There are two production separators; one for sour fluid and the other is for sweet fluid. Associated gas from the sweet separator is compressed in two compressors and sent to Saih Nihayda gas treatment facility and also used as gas lift and fuel gas. The associated gas from the sour separator is flared in an LP flare. Extracted fluid from Qarat Al-Milh also flows to the Ghaba North Station. Degassed oil from the bulk separator flows to a surge tank and from there it is pumped to Qarn Alam Production station.

3.3.4 Saih Nihayda Gathering Station

The Saih Nihayda gathering station is located approximately 19 km north-west of Qarn Alam. Oil and gas production from the Saih Nihayda field started in 1975. The present facility configuration of manifolds, separators and gas compressors was established in 1975 and extensively modified in 1987. The Saih Nihayda gathering station gathers reservoir fluid from its own wells. The plant also handles condensate from both Saih Nihayda power station and Saih Nihayda gas treatment plant.

The reservoir fluid flows to the bulk separator for separation of associated gas. The wet crude oil from the separators along with condensate from Saih Nihayda Gas Treatment Plant and Saih Nihayda Power Station are routed to the surge tanks for further degassing and pumped to Qarn Alam MPS for further processing and onward pumping to the MAF. Separated gas from the production separator is compressed and used as lift gas. If the gas compressor is not operating the separated gas is flared.

Separated gas from the production separators is also used for purging and as a blanket gas. Associated gas from the separator is compressed in three gas lift compressors. The compressed gas is required for gas lifting the wells, any remainder being exported via gas export line to the Saih Nihayda Gas Treatment Plant and Qarn Alam Gathering Station. Degassed oil from the bulk separator flows to a surge tank and from there it is pumped to Qarn Alam Production station

3.3.5 Qarn Alam Gathering Station

Qarn Alam Gathering station is a part of the Qarn Alam Main Production station. The Qarn Alam field was discovered in 1972 and well QA-1 came into production in 1975. The Gathering Station processes the bulk fluids from the Qarn Alam field, Habur field, Alam and Saih Nihayda South East wells. Reservoir fluid from wells flows to two Production separators at the station. Associated gas is separated at Production separators from the liquid emulsion. The gas is then piped to the gas header for compression. Degassed oil/water from the Production Separator flows to two Surge Tanks. The emulsion is then pumped from these tanks to the Dehydration Tanks located in the adjacent Production Station.

3.4 Production Stations

3.4.1 General

There are three oil production stations at Qarn Alam Asset; they are Al Ghubar, Qarn Alam and Saih Rawl. Brief process description of each station is given below.

3.4.2 Al Ghubar Production Station

The Al Ghubar Production Station is located approximately 60 km south west of Qarn Alam. Oil and gas production started at the Al Ghubar Production Station in 1985. The produced water from Barik Gas Station together with oil/condensate from Barik Oil Station are stabilised in HP separator. The off gas from the HP stabiliser is compressed and used for gas lift. Reservoir fluid from the Al Ghubar field flows to the LP separator, where the crude is stabilised by removing part of the associated gas. Separated associated gas is compressed and used for gas lifting. Fluid from the LP separator split into two trains. One train consists of degassing and dehydration tanks and the other train consists of concentric wash tank. At degassing tank, the remaining associated gas is separated. The de-gassed oil flows to dehydration tank for removal of produced water. Water, which is removed from the dehydration tank, is pumped to local disposal wells. The crude is pumped to Qarn Alam Main Oil Line (MOL) for

onward pumping to Mina Al Fahal. In concentric wash tank, degassing and dehydration taken place. Produced water from the concentric wash tank is disposed to disposal wells and dehydrated crude sent to Qarn Alam Station. There is one gas engine driven compressor for gas compression. Compressed gas is used for gas lifting purpose.

3.4.3 Saih Rawl Production Station

The Saih Rawl Production station is located approximately 40 km north-west of Qarn Alam. Oil and gas production from the Saih Rawl Field started in 1975. The present facility configuration of manifolds, separators and gas compressors was established in 1988. This Station gathers the reservoir fluid from wells in the Saih Rawl, Mussalem, Ramlat Rawl and Mabrouk fields. However, at present, Mabrouk wells are not producing and all wells are closed. High-pressure reservoir fluid is connected to the high-pressure separator and the gas is separated. Separated fluid and low-pressure reservoir fluid flows to the low-pressure separator for initial degassing. Associated gas removed from the low-pressure separator is compressed and mainly used for gas lifting. Separated gas is also used for fuel gas, blanket gas and export to Saih Nihayda for gas treatment.

Separated fluid from the low-pressure separator flows to the dehydration tanks where produced water is separated and the dehydrated crude sent to Qarn Alam for onward pumping to Mina Al Fahal. Separated gas from the high-pressure separator directly used in the gas lift header. Off gas from the low pressure separator compressed in two electric driven compressors and used for gas lift purpose.

Produced water separated from the dehydration tank and imported water from Saih Rawl Central Processing Plant (gas plant) is injected back to reservoir for pressure maintenance. The produced water is disposed into disposal wells if the injection system is not working. This station has one atmospheric flare to flare purge gas from the dehydration tank. Other hydrocarbon releases from the station is flared at low-pressure flare, both flares having 10 m high and 20” diameter.

3.4.4 Qarn Alam Production Station (MPS/ NOCS)

The Qarn Alam Production station consists of Qarn Alam NOCS plant (also known as Vacuum Flash Plant) and Qarn Alam Gathering Station. This station is located 130 km south east of Fahud.

The crude oil/water emulsion from Ghaba North, Saih Nihayda and Qarn Alam Gathering Station enter the Qarn Alam Production Station through pipelines for

dehydration. There are three dehydration tanks at this station. Separated sour water is disposed off into 12 water disposal wells. Sweet water is sent to Saih Rawl station for injection. The dehydrated crude from this station mixed with crude from south Oman and fed into NOCS plant for stabilisation. At NOCS plant the crude is fed into two vacuum separators. The vacuum in the separator is created and maintained by two sets of liquid ring vacuum compressors, each set is comprised of a seal water separator, a set of seal water circulating pumps, filter, seal water air cooler, condensate pump, etc.

Stabilised crude from the vacuum separator pumped to Nahada Booster station. Off gas from the separator along with the seal water is fed into seal water separator where seal water is separated from the off gas. The seal water is re-circulated and the off gas is flared.

3.5 Gas Stations

3.5.1 General

There are three gas stations in Qarn Alam area that were developed as a part of the LNG upstream facilities. These include Central Processing Plant at Saih Rawl, gas gathering station at Barik and Saih Nihayda gas treatment plant. Brief process description of each station is given below.

3.5.2 Barik Gas Gathering Station

At the Barik gathering station, well stream fluids from the flowlines are routed via an inlet manifold to two 3-phase inlet separators, where gas, free water and condensate are separated. The partially stabilized condensate is exported to the Saih Rawl central processing plant. Gas from the inlet separators is cooled in a gas/gas heat exchanger with cold gas from the cold separator then further cooled by an air-cooler to approximately 60^{o}C in summer and 40^{o}C in winter. Water and condensate are then separated from the gas in the cold separator and condensate routed to the condensate pipeline. The gas from the cold separator is heated by cross-exchange with the gas from the inlet separator and exported to Saih Rawl gas station for further processing. The cooling/reheating process ensures that the gas, under all operating conditions, arrives at Saih Rawl at a temperature of 5^{o}C above its water dew point. Water from the 3- phase inlet separators and the cold separator are mixed and routed to the Al Ghubar oil station for further treatment.

3.5.3 Saih Nihayda Gas Treatment Plant

The Saih Nihayda Gas Treatment Plant removes condensate from associated and non-associated gas and exports the dry (dew pointed) gas to the South Oman gas line (SOGL), and to Saih Nihayda Gathering Station, Qarn Alam MPS and Ghaba North Gathering Station for use as back-up gas for fuel and gas lift and to Qarat Al-Milh Station for gas lift. SOGL provides back-up gas for Al-Ghubar Production Station and gas for fuel and gas lift for Bahja/Rima, Nimr and Marmul asset teams. The condensate is recovered by exporting it to the Saih Nihayda Gathering Station where it is mixed with the crude oil and exported to Qarn Alam MPS for further processing.

Individual gas import lines containing associated and non-associated gas from Saih Rawl and Saih Nihayda are each fed to free water KO pot. The gas is then fed to two parallel gas treatment trains. The condensate is fed to the condensate handling facility.

In the gas treatment trains the gas is cooled with propane refrigerant and then partially expanded. The resulting chilled gas is at 6ºC. The condensate is separated and sent to the condensate handling system. The gas is exported to the South Oman gas line (SOGL) at a pressure of 6,900 kPa(g). Glycol is added to the gas in the treatment train to prevent hydrate formation. The glycol is separated from the condensate and regenerated.

Condensate from the free water KO pots and the gas treatment trains is stabilised first at high pressure and then low pressure. The temperature in both vessels is controlled at 45ºC, using hot water, and the off gas is routed to flare. The condensate is exported to the Saih Nihayda Gathering Station. There, it is recovered by adding it to the crude oil, which is exported to Qarn Alam MPS. Once NOCS is in operation the condensate will be transferred to Saih Rawl and spiked into the export crude and exported to Qarn Alam MPS.

3.5.4 Saih Rawl Gas Processing Plant

Barik gas and Saih Rawl well stream fluids are routed to four 3-phase production separators, for primary separation of gas, free water and condensate. Gas from the production separators is routed to two identical gas treatment trains and the condensate to two identical condensate stabilization trains. Water is disposed of by export to the Saih Rawl Oil Station, where it is re-injected into the Shuaiba reservoir for pressure maintenance purposes.

Gas from the production separators is pre-cooled with an air-cooler, to 60 ^{o}C and then is dried in the glycol contactor. The dry gas exiting the glycol contactor is cooled in exchanger and then further cooled in a turbo expander. Condensate from the cooled gas is separated in a low temperature separator and the gas is compressed in turbo expander driven recompressor that boosts the gas pressure to approximately 79 barg. Gas from both gas treatment trains is compressed to 90 barg and export to the LNG plant at Sur.

Condensate from the gas treatment is fed to the condensate treatment train. The condensate is cooled in an air-cooler to 60^{o}C, collected in a condensate flash vessel, and fed to the stabilizing column. The flash gas from the flash vessels, along with the stabilizer off-gas, is recompressed and returned downstream of the gas treatment train feed gas inlet air-cooler. The hot condensate bottom product is cooled in the side reboiler and further cooled in the condensate run-down air-cooler to 60 ^{o}C, before being pumped to main oil line at Qarn Alam.

Part of the bottom condensate from the stabilization column is fed into a de-butaniser column. The de-butaniser is a refluxed column with a total condenser and operates at a pressure of approximately 9 barg and a bottom temperature of 238 ^{o}C. The de-butaniser produces LPG product from the overhead and condensate from the bottom of the column. The condensate is pumped and recombines with the main stabilized condensate. Finally, the condensate is air-cooled to 60^{o}C before being pumped to Qarn Alam. LPG from the de-butaniser is air-cooled to 60^{o}C and accumulates in a total condenser vessel. Liquid LPG from this vessel is partly pumped to the LPG storage facilities and partly used as reflux for the de-butaniser.

The heat for the reboilers is supplied by a hot-oil circulation system that takes heat from waste-heat-recovery units installed on the gas-turbine exhausts of the Frame 6 power generators.

3.6 Gas Oil Gravity Drainage (GOGD) Plant

Gas Oil Gravity Drainage (GOGD) plant started as a pilot plant for the enhanced recovery of the oil by means of thermal stimulation in the reservoir. This plant was constructed in 1996 and started operation in 1998. This plant has a capacity of producing steam in the order of 1200 ton/day. This station consists of water treatment section and steam generation section. Water treatment section consists of two heat exchangers, evaporator and compressor. Fresh water from the wells are fed with calcium sulphide and recirculated within the treatment section till the water reaches sufficient temperature to start evaporating. Once the evaporation starts, the compressor comes in line, and the steam is compressed. Heat from the compressed

steam and brine outlet is used for the heat input to the feed water. The water treatment section is designed to have a production capacity of 1,500 m^3/day. The brine water is disposed off into evaporation ponds.

3.7 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 is 52.0 MW. Qarn Alam asset has two power plants one at Saih Rawl and the other at Saih Nihayda. Both power plants are based on open cycle gas turbine technology. The power plant at Saih Rawl is the only power plant in PDO operating with a waste recovery system. The power plant at Saih Nihayda is operated 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 Qarn Alam Asset

Specifications	Power Plant at Saih Rawl	Power Plant at Saih Nihayda
Total generating capacity	60 MW	30 MW
Number of gas turbines	2	1
Make and model of gas turbines	Frame 6	Frame 6
Fuel used	Associated gas	Associated gas
Fuel consumed per day	470,000 Sm^3	178,000 Sm^3
Emission control system used	Standard combustion system with no NO_X control	Standard combustion system with no NO_X control
Number of stacks	2	1
Stack height	12 m	15 m (approximate)
Stack exit diameter	3.5 m	4.3m
Stack gas exit temperature	284-278 ^oC	560 - 595^oC

3.8 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 abstracted from the Fars formation is desalinated in RO plant. The GOGD plant water treatment section is presently used for generation of the potable water for the PDO camps. This plant works on mechanical vapour compression distillation process. The total water requirement in the asset is presently 1,636 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 Qarn Alam

Specifications	RO Plant	GOGD plant
Total freshwater production capacity	1050 m^3/d	1500 m^3/d
TDS of treated water	351 mg/L	Unknown
Type of desalination	Reverse osmosis	Evaporation
Number of units	One	One
Total flow rate of inlet stream	1640 m^3/d	907m^3/d
TDS of feed water	21000 mg/L	Unknown
Total flow rate of reject stream	820 m^3/d	91m^3/d
TDS of reject stream	42000 mg/L	Unknown

3.9 Auxiliary Facilities

3.9.1 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.

3.9.2 Produced Water Injection System

Produced water generated at Al Ghubar production station is disposed off into the Umm Er Radhuma reservoir via two disposal wells by five water disposal pumps. Produced water separated at Saih Rawl Production station along with water from the Saih Rawl CPP is injected into oil reservoir for pressure maintenance. There are two water injection pumps at Saih Rawl Station. If the water injection is not working, the produced water is disposed off into UeR formations via disposal wells. Qarn Alam station produces sour water and sweet water for disposal. Sour water is disposed off into shallow aquifer and sweet water is injected to oil reservoir at Saih Rawl. There are 8 water disposal pumps in Qarn Alam station.

3.9.3 Sewage Treatment Plants

There are five sewage treatment plants in the asset. One plant of 170 m^3/d capacity is dedicated for the treatment of sewage generated from the PDO camp. Other four STPs consist of two permanent units and two portable units having a total capacity of 450 m^3/d. These are dedicated for the treatment of sewage generated from the contractor camps. The details of these facilities are presented in Chapter 4.

3.9.4 Waste Management Centre

Qarn Alam 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 treatment of oily sands. Qarn Alam 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.

3.9.5 Production Chemistry Laboratory

Qarn Alam 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 is available in the facility with resident analytical staff. This laboratory also serves the Lekhwair asset.

3.9.6 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 the work sites. Oily wastes generated from these workshops are collected separately and sent to the waste management centre for disposal.

3.9.7 Accommodation Facilities

There are five permanent accommodation camps located within the asset. The PDO camp is exclusive for the PDO staff and their visitors. There is one permanent accommodation for contractor (PAC) and other three small camps 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 Qarn Alam Asset

Item	Description
Total number of permanent camps	Five including one PDO main camp and four contractor camps (PAC: 1, AlHassen: 1, Gulfar: 1 and STS: 1)
Total number of mobile camps	Twelve (2002)
Total number of housing units and total number of PDO staff (and visitors) accommodated at any time in PDO main camp	Rooms: 201 Occupancy: 155
Total number of housing units and total number of contractor staff (and visitor) accommodated at any time in contractors camp	Rooms : 460 Occupancy: 1074
Typical number of staff accommodated at any time in each mobile camp	60
Total number of canteens in the permanent camps	PDO camp: 1 Contractor camps: 5
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

3.9.8 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.

3.10 Developmental and Construction Activities

3.10.1 Overview

Developmental and construction activities are carried out in the asset throughout the year, at some location or the other. 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.

3.10.2 Seismic Survey

Seismic survey is carried out for locating the new oil fields. The Exploration Asset Team carries out this survey. 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.

3.10.3 Drilling and Well Completion

Drilling of exploration and producing wells is a major construction activity with significant environmental aspects. Contractors under the supervision of the Exploration Asset Team carry out exploratory 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 mud 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.

3.10.4 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.

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

3.10.5 Well Closure and Site Restoration

As wells dry out over a period of time, well closure is also a continuing activity in the assets. The Well Engineering Asset also carries this activity.

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 it 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.

3.11 Planned Future Developments

It is proposed to have a steam injection plant at Qarn Alam as a part of the field development program. The steam plant will be constructed in three phases. Initial phase will start by the year 2004, and final phase will start by the year 2007. Initial phase will have a steam generation capacity of 12,000 ton/day and the final phase will have 18,000 tone/day. Water supply for steam generation will be taken from the Fars aquifer. An exploration programme is underway to further firm up this option. Re-use of back produced steam condensate is planned for the later phases of the project. The Nimr pipeline option is kept as a fallback.

3.12 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 are given in Table 3.5 below.

Table 3.5: Consumption of Process Chemicals in Qarn Alam Asset

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 de-oiling of production water	1468 L/d
Defoaming agents	Liquid; mixture of aliphatic and aromatic hydrocarbons; surface active agents	Used in dehydration of crude and de-oiling of production water	13 L/d
Scale inhibitors	Liquid; mostly organic phosphates	Used in RO plant for scale control	1150 L/month
Corrosion inhibitors	Liquid; surface active agents in alcohols	Used in RO plant pipelines for corrosion control	463 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	Sodium metabisulphate – 50 kg/ month Soda ash – 450 kg/month Calcium hypochlorite – 100 kg/month Citric Acid – 150 kg/ month
Chlorine or hypochlorite solution	Liquid or tablets; strong oxidant	Used in RO plant and STPs for disinfection	450 kg/month
Biocides	Liquid	Used in pipeline during pigging for control of fungal growth	Not in use
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 Qarn Alam 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	1946 MWh
Associated gas	Saih Rawl power plant for power generation	470,000 Sm^3
	Saih Nihayda power plant for power generation	178,000 Sm^3
	All stations for heaters and compressors	45,900 Sm^3
	Total	693,900 Sm^3
Freshwater (desalinated)	For process and domestic use	1,636 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 Qarn Alam 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, gas fields, gathering stations, production stations, 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 waste generated from these activities is not discussed in this study unless they have a long resident time (ex: drilling wastes). However, a detailed analysis of wastes arising for these wastes are considered separately under the relevant EIA study for the service asset.

The wastes released into the environment from all the above activities can be 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, there is other several temporary sources from which the emissions are intermittent and are 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 emissions 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 quantity. The sources of stack emissions include the gas turbines (used in power stations for power generation, 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 Qarn Alam Asset

Location	Gas Turbine Stacks	Heater Stacks	Total Number of Stacks
Barik Gathering Station	Nil	Nil	Nil
Ghaba North Gathering Station	2	Nil	2
Saih Nihayda Gathering Station	Nil	Nil	Nil
Barik Gas Station	Nil	Nil	Nil
Al Ghubar Production Station	7	Nil	7
Qarn Alam Production Station (including gathering station, NOCS, GOGD, MPS)	6	Nil	6
Saih Rawl Production Station	Nil	Nil	Nil
Saih Rawl Gas Station	Nil	Nil	Nil
Saih Nihayda Gas Station	Nil	Nil	Nil
Saih Rawl Power Station	2	Nil	2
Saih Nihayda Power Station	1	Nil	1
Asset total	18	Nil	18

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 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 Qarn Alam 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)
Ghaba North Gathering Station	5.54	NA	17.2	0.2	0.0	0.0	0.0
Al Ghubar Production Station	0.34	NA	1.1	0.0	0.0	0.0	0.0

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)
Qarn Alam Production Station	29.81	NA	85.3	0.6	0.2	0.1	0.0
Saih Nihayda Power Station	178.0	NA	421.0	0.0	1.0	0.4	0.1
Saih Rawl Power Station	470.0	Not reported	1111.6	0.0	2.7	1.1	0.2
Asset total from all stacks	683.7		1636.1	0.8	4.0	1.6	0.3

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 Qarn Alam asset, the hydrogen sulphide concentration varies widely from 0 to 7,000 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 be such that the ambient air quality standards (refer Table 2.5 in Chapter 2) are not breached.

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 gauge 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 4*), 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 Qarn Alam 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)
Barik Gathering Station	1 (1 LP)	37.30	0	1.47	87.7
Ghaba North Gathering Station	2 (1 LP +1 AP)	48.01	0	2.23	141.7
Saih Nihayda Gathering Station	2 (1 LP +1 AP)	27.88	0	1.44	89.6
Barik Gas Station	1 (1 LP)	Data not available		Data not available	Data not available
Al Ghubar Production Station	2 (1 LP +1 AP)	151.44	0	7.45	458.9
Qarn Alam Production Station (including gathering station, NOCS, GOGD, MPS)	2 (1 LP +1 AP)	27.53	0	1.00	74.8
Saih Rawl Production Station	2 (1 LP +1 AP)	88.43	0	5.65	355.8
Saih Rawl Gas Station	4 (2 LP +2 AP)	Data not available		Data not available	Data not available
Saih Nihayda Gas Station	1 (1 LP)	6.27	0	0.22	14.4
Asset total	17 (10LP+7AP)	386.87		19.45	1223.0

4.2.4 Area Source Emissions

The area sources for air emissions in the asset include 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 dumpsites / 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 4*):

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 Qarn Alam Asset

Description of Source	Tank Type	Tank Capacity (m^3)	Throughput Rate (tpd)	Total Hydrocarbon Emission Rate(tpa)
Barik Gathering Station		No Tank		
Ghaba North Gathering Station Surge tank: One	Fixed roof	398 m^3	256	0 (See Note 1)
Saih Nihayda Gathering Station Surge tank: Two	Fixed roof	398 m^3	945	0 (See Note 1)
Barik Gas Station		No Tank		
Al Ghubar Production Station Degassing tank: One Dehydration Tank: One Surg Tank: Two Concentric Wash Tank: One	Fixed roof	 871 m^3 871 m^3 2 x 187 m^3 1765 m^3	152	0 (See Note 1)
Qarn Alam Production Station Surge tank: Two	Fixed roof	398 m^3 (each)	220	0 (See Note 1)
Qarn Alam MPS Dehydration Tanks: Three	Floating roof	9500 m^3 (each)	220	Negligible
Saih Rawl Production Station Dehydration Tanks: Two	Fixed roof	7070 m^3 (each)	9282	0 (See Note 1)
Saih Rawl Gas Station		No Tank		
Saih Nihayda Gas Station		No Tank		

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 4*). 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 as given in Table 4.5 below.

Table 4.5: Air Emissions from Mobile Sources in Qarn Alam Asset

Parameter	Quantity
Total number of land vehicles operating in the asset (PDO and Contractors)	Not available
Total quantity of fuel consumed – petrol	367 tpa
Total quantity of fuel consumed – diesel	16,781 tpa
Total quantity of fuel consumed – all fuels	17,148 tpa
Total emission of CO_2	54,873 tpa
Total emission of CO	463 tpa
Total emission of NO_x	652 tpa
Total emission of HC	96 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 which is finally disposed after the 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 Qarn Alam 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 Total	52166 0 15089 67255	Water content in the reservoir fluid with high dissolved inorganic salts, traces of oil and virtually free of organic matter
Water treatment effluents (Continuous)	RO plants and softening plants	RO plant reject + backwash Softening plants Total	820 91 911	Backwash with high dissolved inorganic salts and virtually free of organic matter
Sewage (Continuous)	Accommodation facilities, canteens, laundries, toilets and wash basins	PDO STP Contractor STP-1 Contractor STP-2 Portable STP 1 Portable STP 2 Total	98 100 112 85 92 487 (See Note 1)	Wastewater from domestic activities with mostly biodegradable nutrients as suspended and dissolved matter
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 disposed off by solar evaporation. 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 part of the produced water is directly sent for re-injection into the reservoir. Remaining produced water is disposed off into deep water disposal. The residual oil content in the produced water will be in the order of 50 mg/L..

- **RO Plant Rejects and Backwash**

RO plant rejects and backwash are sent to the lined evaporation ponds. There are two evaporation ponds, which are sand bunded and lined with a geomembrane. There are two evaporation ponds and both are up to its full capacity. During the visit, the bund wall of one of the evaporation ponds was broken and the surrounding area was contaminated with rejected water.

- **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 5*). 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, submerged air diffusers supply the oxygen necessary for oxidation. 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.

In addition to the above, two sequential batch reactor type STPs are also available at Qarn Alam. Raw sewage enters to a tank where aeration is given. Organic matter in the sewage is absorbed by the biomass in the aeration tank. After four hours of aeration, the mixed liquor is allowed to settle in the same tank for two hours. After settling the supernatant is decanted and the fresh sewage is added to the aeration tank. Decanted effluent then passes through multimedia filter to remove any suspended matter. Treated effluent is stored in holding tanks and used for irrigation.

There are three STPs in the asset. The first (STP/QA-1) of 170 m^3/d design capacity is dedicated for the sewage from PDO's camp, the other four (STP/QA-2 and STP/QA-3) having a total capacity of 250 m^3/d and two portable STPs of total capacity of 200 m^3/d are dedicated for sewage from the contractors' camps. The design details of the STPs in Qarn Alam are presented below in Table 4.7. Another STP at Saih Rawl area treats the sewage from the mobile camps at Saih Rawl. This STP does not have ministry permission for operation. Also no design or performance monitoring data was available.

Table 4.7: Design Specification of STPs in Qarn Alam

Design Specifications	STP/QA-1 (PDO Camp)	STP/QA-2&3 (Contractor Camp)	STP/Portable-1&2 (Contractor Camp)
Hydraulic flow rate (m^3/d)	170	125 (each)	100 each
Loading rate (kg/d) - TSS	Data not available	Data not available	35.0
Loading rate (kg/d) - BOD	Data not available	Data not available	21.7
Raw sewage holding tank capacity (m^3)	Data not available	Data not available	Data not available
Aeration tank volume (m^3)	170	128 each	56
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	2
MLSS maintained in aeration tank (mg/L)	Data not available	Data not available	4,000
Sludge settling tank volume (m^3)	70	58 each	56 (same as aeration tank)
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
Treated sewage tank volume (m^3)	Data not available	250 combined	6 nos of 80 m^3
Size of sludge drying beds (m x m x m)	4 nos	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 off 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 2001-2002 (*Reference 5*).

Table 4.8: Typical Characteristics of Treated Effluent Streams

Parameter	Units	Typical Characteristics		
		Produced Water	RO Plant Rejects	Sewage
pH	No units	Not reported	Not reported	5-8
Total suspended solids (TSS)	mg/L	Not reported	Not reported	0-42
Total dissolved solids (TDS)	mg/L	150,000 –267,000	Not reported	Not reported
Total salinity	mg/L	Not reported	Not reported	Not reported
Total hardness as $CaCO_3$		Not reported	Not reported	Not reported
Total chloride as Cl	mg/L	93,000 –165,000	Not reported	Not reported
Oil and grease (O&G)	mg/L	50	Not reported	Not reported

Parameter	Units	Typical Characteristics		
		Produced Water	RO Plant Rejects	Sewage
Biochemical oxygen demand (BOD)	mg/L	Negligible	Negligible	0-47
Chemical oxygen demand (COD)	mg/L	Negligible	Negligible	0-140
Total ammoniacal nitrogen	mg/L	Negligible	Negligible	0-10
Faecal coliform count	per 100mL	Negligible	Negligible	0-50

- **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 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, Upper Gharif or Lower Gharif, Al Khlata
Depth from ground level:	Aprox 2000m
Salinity of aquifer:	200,000 mg/l
No. of injection pumps:	2 (at Saih Rawl)
Total volume injected per day (2002 average):	52455 m^3/d
Deep Disposal (Produced Water)	
Nature of formation:	Natih, UeR
Depth from ground level:	UeR –105 m Natih – 200 m
Salinity of aquifer:	Natih – 200,000 mg/l UeR –100,000 mg/l
No. of disposal pumps:	Al Ghubar – 6 Qarn Alam MPS – 8 Saih Rawl - 3
Total volume disposed per day (2002 average):	15172 m^3/day
Shallow Disposal	No shallow disposal

- **Disposal of Treated Sewage**

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

- 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 Qarn Alam 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	QASTP-PDO	QASTP-Contr.1	QASTP-Contr.2
Volume of sewage treated	m^3/d	Average: 98 Max: 119	Average: 100 Max: 113	Average: 112 Max: 130
Biochemical oxygen demand	mg/L	Range: 0-140 Average: 10 XN: 1/51	Range: 0-17 Average: 7 XN: 0/51	Range: 0-47 Average: 9 XN: 1/50
Chemical oxygen demand	mg/L	Range: 0-82 Average: 32 XN: 0/51	Range: 7-114 Average: 41 XN: 0/51	Range: 0.2-85 Average: 30 XN: 0/50
Total suspended solids	mg/L	Range: 2-70 Average: 12 XN: 2/51	Range: 2-110 Average: 16 XN: 5/51	Range: 1-60 Average: 12 XN: 2/50
pH	None	Range: 7-8 Average: 8 XN: 0/51	Range: 7-7.9 Average: 7 XN: 0/51	Range: 0-8.1 Average: 7 XN: 2/50
Faecal coliforms	Nos./ 100 ml	Range: 0-50 Average: 6 XN: 0/49	Range: 0-30 Average: 4 XN: 0/51	Range: 0-60 Average: 5 XN: 0/50
Ammoniacal nitrogen	mg/L	Range: 0-10 Average: 4 XN: 0/50	Range: 0-10 Average: 3 XN: 0/51	Range: 0-10 Average: 1 XN: 0/50

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 sludge
- 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 the year 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 Qarn Alam Asset

Waste Group	Classification	Units	Quantity Generated in 2002 Jan - Sept (9 months)
Domestic and office waste	Non-hazardous	Tonnes	6,657
Water based drilling mud and cuttings	Non-hazardous	Tonnes	Data Not Available
Non-hazardous industrial waste	Non-hazardous	Tonnes	5,986
Total non-hazardous wastes			12,643
Oil based mud and cuttings	Hazardous	Tonnes	Data not available
Sewage sludge	Hazardous	Tonnes	Data not available
Waste lubricants	Hazardous	Tonnes	0
Oily sludge	Hazardous	Tonnes	767
Oily sand	Hazardous	Tonnes	234
Pigging sludge	Hazardous	Tonnes	0

Waste Group	Classification	Units	Quantity Generated in 2002 Jan - Sept (9 months)
Non-recyclable batteries	Hazardous	Pieces	0
Recyclable hazardous batteries	Hazardous	Pieces	79
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	0
Total hazardous wastes		Tonnes	1,080

Among the solid waste, the clinical wastes, mercury wastes and NORM wastes are of prime importance. Clinical wastes are the wastes such as used syringes, cotton / dressing containing blood and other body fluids, human tissue etc. generated in the PDO clinic. 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.

Recently, the gas wells at Qarn Alam were found to be contaminated with mercury. Details of the mercury waste sources and quantity is not fully known at this time.

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 Qarn Alam Asset

Waste Group	Waste Disposal Practice
Domestic and office waste	- 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.
Water based drilling mud and cuttings	- Unless total petroleum hydrocarbon content is >10 g/kg, they are disposed in a dedicated landfill in the Qarn Alam waste management centre. - Otherwise, they are treated as oily sand

Waste Group	Waste Disposal Practice
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 in Bahja for storage and disposal.
Non-recyclable batteries	- They are packaged in refuse bags and disposed in the landfill with domestic waste.
Recyclable hazardous batteries	- The terminal are taped, electrolytes are drained and then sent to an external facility for recycling.
Transformers and transformer cooling fluids	- 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.
NORM wastes	- All NORM are sent to waste management centre in Zauliyah for storage and disposal.
Mercury waste	- Presently no waste management centre for mercury waste
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

Qarn Alam has a centralised waste management centre for the disposal of both non-hazardous and hazardous wastes. Further, Qarn Alam has a dedicated land farming facility, Oil base mud pit and kitchen waste dumping site. The waste management centre does not handle either clinical waste or 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 6*). They are summarized below in Table 4.13.

Table 4.13: Details of Qarn Alam Waste Management Centre

Item	Description
Year of commissioning	Unknown
Types of waste handled	Non hazardous, hazardous and Chemical waste
Total site area (m^2)	Scrap Yard : 14.4 ha Kitchen Waste Dumping : 3.3 ha Land Farm : 1.3 ha OBM pit : 1.3 ha Total : 20.3 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. Four pits for oil based mud
Storage (holding) area for chemical wastes	No chemical storage facility at Qarn Alam.
Storage (holding) area for other miscellaneous hazardous wastes	Hazardous drums kept in separate area where drainage facility is provided to drain the 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 Qarn Alam waste management centre.
Land farm – total area, no. of windrows, size of each windrow	Presently 13 windrows are operated. Each windrows of about 60 m x 6 m x 0.3 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 and 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, 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 Qarn Alam asset are summarized in Table 4.14.

Table 4.14: Accidental Leaks and Spills in Qarn Alam Asset

Description	Incidents Reported in 2002 (Jan-Sep)			
	Oil Leaks and Spills	Chemical Leaks and Spills	Water Leaks and Spills	Releases of ODS (CFCs and Halons)
Total number of incidents	22	0	1	Unknown
Number of spills into wadis	0	0	0	-
Total volume leaked / spilled (m^3)	23	0	1	83.8 kg
Total land area impacted (m^2)	319	0	1	-
Total quantity of soil contaminated (t)	Data not available	0	Not applicable	-

While water leaks and spills do not lead to any environmental consequences, they are reported as a matter of water conservation issue.

5 ENVIRONMENTAL SETTING

5.1 General

In this chapter, the existing environmental conditions in Qarn Alam asset is described and analysed. The description is largely based on the information provided from 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 area, only brief description and analysis are presented in this chapter. Detailed description and analysis are limited to the environmental 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 resources and groundwater quality
- Ambient air quality and noise
- Land use and human settlements

5.2 Location and Topography

Qarn Alam asset is located in central Oman about 360 km south of Muscat. It covers a total land area of 18,900 km^2, which is 16.6% of total PDO concession area. There are about 161 oil producing wells and 55 gas producers, 13 operating oil fields, 3 gas stations, four gathering stations and three production stations in the asset. Qarn Alam production station is located at 2355310 N and 510300 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: Qarn Alam Asset Boundary Coordinates

Site Boundaries	Clarke 1880 System (Easting or Northing (m))
Northern limit	2420800 N
Eastern limit	577686 E
Southern limit	2303586 N
Western limit	361961 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

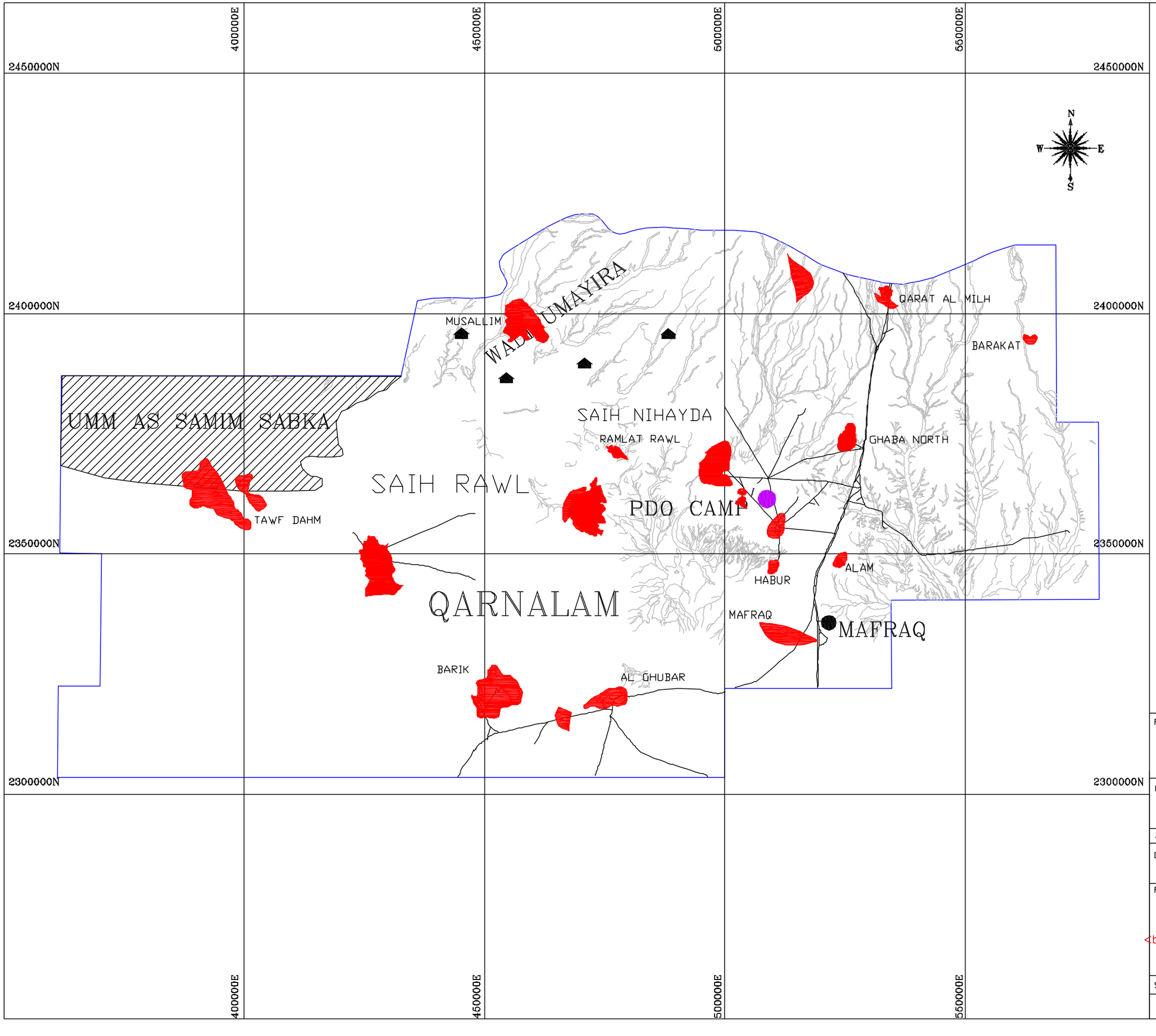
channels and occasional rocky outcrops. The elevation with reference to the mean sea level ranges from about 140 m.

Most of the Qarn Alam Asset area lies in the plains south of the foothills of the northern Hajar Mountains and consists of alluvial gravel fans arising from a number of wadis. One of the major wadis is Wadi Umayri, which drains into the Umm as Samim sabkha in the north west of the Asset. Other smaller wadis include Wadi Majhul, Halibah, Thaylah and Wadi Qitfah.

5.3 Geology and Soil

Most of the exposed surface formations in the asset are tertiary deposits. The geological cross section in the asset is shown in Figure 5.2. The shallowest formation belongs to the Fars group comprising carbonates and clastics. The deposits are mainly evaporative in nature. The thickness of the Fars group in this area varies from approximately 30 to 100 m with the thickness increasing from *Qarn Alam* towards Musallim. The Umm Er Radhuma (UeR) group consists of a thick assemblage of carbonates. The Shammar shale, belonging to the Aruma group, underlies the Umm Er Radhuma and is regarded as an aquitard. The thickness of Shammar shales is appreciable, ranging from 100 to 150 m in the Saih Rawl and Musallim areas. In the Qarn Alam area, however, the thickness of the Shammar shale is less than 20 m. The Wasi Kahmah and Sahtan groups belong to the Cretaceous and Jurassic period. They contain marine carbonates. The Akhdar group contain carbonates belonging to the Permian Triassic age and underlie the Sahtan group. The Haushi group, underlying the Akhdar group contains sediments, which are glacial, shallow marine siliciclastics. This group contains the hydrocarbon bearing Gharif and Al Aklata formation. The Haima group consists of clastic sediments and they are the deepest known aquifers. The oldest known sequence is the Huqf group consisting of siliciclastics, carbonates and thick evaporates.

No site specific data are available on the soil quality. Generally, the soils in the asset are classified as unsuitable for agricultural purposes, as per the Ministry of Agriculture and Fisheries “General Soil Map of Oman". The soil map of PDO’s concession area is shown in Figure 5.3.



LEGEND

- Permanent Human Settlements
- Bedouin Areas
- Groundwater Protection Site (YELLOW ZONE)
- Richly Vegetated Sites
- Umm As Samim Sabka
- Archealogical Sites
- Cultural Sites (Cemetary)
- Recreational Sites
- PDO Camp
- Road
- Wadi
- Industrial Site (Crusher)
- Oilfields

PRODUCED FOR :

شركة تنمية نفط عمان
Petroleum Development Oman

PROJECT :
ENVIRONMENTAL ASSESSMENT
2002 REVIEW AND UPDATE

AREA : QARNALAM ASSET

DESCRIPTION : Figure 5.1
TOPOGRAPHICAL MAP OF QARNALAM ASSET

PRODUCED BY :

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SCALE : 1:850,000 1cm = 8.5km

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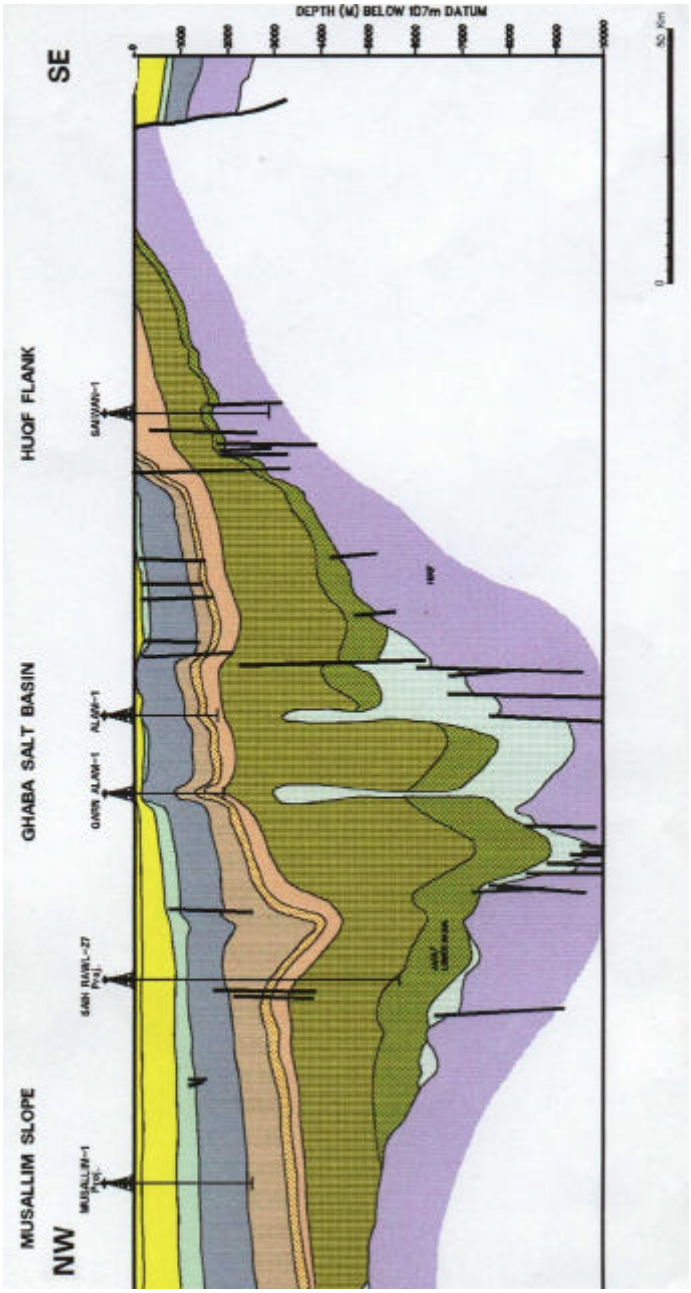

Figure 5.2: Geographical Cross Section in Qarn Alam

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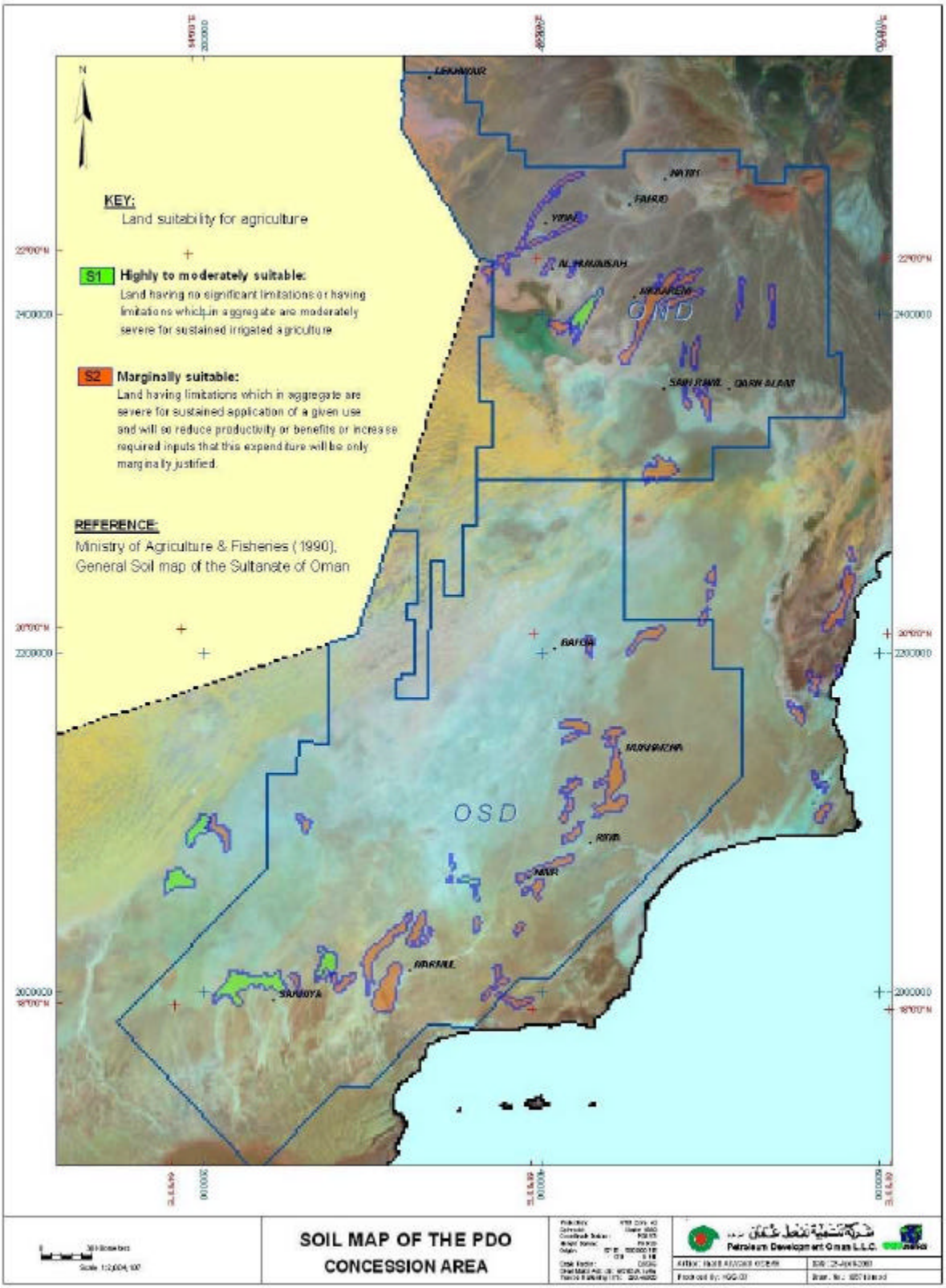

Figure 5.3: Soil Map of PDO's Concession Area

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5.4 Hydrogeology and Groundwater Quality

Groundwater exists in Fars and UeR formations. The water in fars formation is saline with a TDS ranging from 15,000 to 48,000 mg/l. Water wells in this formation have a yield of 700 to 1,200 m^3/d. The water table is at 76 m below ground level in Saih Rawl water disposal well. The Umm Er Radhuma (UeR) forms the principal aquifer in Central Oman. The yield of wells in the UeR varies from 800 to 2,600 m^3/d. Water quality in this aquifer is typically in the range of 30,000 to 120,000 mg/l TDS). The isosalinity map of Fars water and UeR water is given in Figures 5.4 and 5.5 respectively.

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 Qarn Alam Asset

Location	Representative Water Well	Name of Aquifer	Water level		Total Dissolved Solids (TDS)		Yield	
			(m)	Date	(g/L)	Date	(m3/h)	Date
Al Ghubar	Al Ghubar WSW-4	Fiqa+ Natih	74.95 73.92	Jan'88 Mar'96	40.78	Nov'94	-	-
Alam	Alam WSW-4	Fars+ UeR	47.92 57.41	Sep'89 May'99	36.541	Jul'88	-	-
Barik	Barik North WSW-1	Taqa+ Rus	59.27 59.08	Jan'87 Jan'97	54.017 3.12	Dec'85 Oct'91	-	-
Burhaan	Burhaan WSW-1	UeR	9.9 17.53	Feb'91 Jan'01	14.561 6.86	Jan'88 Aug'91	20.0	Dec'00
Burhaan	Burhaan WSW-2	Fars+UeR + Arada	11.86 13.54	May'88 May'99	29.23	Jul'91	18.0	Nov'00
Ghaba North	Ghaba North WSW-2	UeR	51.3 48.71	Apr'87 Mar'96	17.24 16.30	Aug'80 May'89	-	-
Habur	Habur WSW-1	UeR	26.3 25.44	May'89 May'99	121.83	Feb'83	-	-
Mabrouk	Mabrouk WSW-3	Dammam	36.05 35.61	Feb'97 May'99	118.15	Feb'97	28.0	Feb'97
Musallim	Musallim WSW-1	Rus+ UeR	-	-	44.89	Nov'81	-	-
Musallim	Musallim WSW-5	-	10.84	Oct'00	-	-	66.0	Oct'00
Qarat Al Milh	Qarat Al Milh WSW-2	Quaternary + UeR+ Fiqa	7.25 6.95	Apr'87 Jun'97	36.71	Aug'85	-	-
Qarn Alam	Qarn Alam WSW-3	UeR	35.82 28.76	Nov'89 Nov'00	97.72 19.73	Mar'82 Apr'94	-	-
Ramlat Rawl	Ramlat Rawl WSW-1	Fars+ UeR	57.0 58.37	Jun'90 Jun'99	24.174 97.916	Nov'80 Oct'89	-	-
Saih Nihayda	Saih Nihayda WSW-1	Fars+ UeR	60.77 52.12	Aug'88 May'99	41.414 55.443	May'81 Mar'82	-	-
Saih Nihayda	Saih Nihayda WSW-2	UeR	60.12 56.65	Jun'90 May'99	31.568 36.243	May'81 Aug'86	-	-
Saih Rawl	Saih Rawl WSW-4	Rus+ UeR	55.89 39.58	Oct'94 Oct'02	74.805	May'77	-	-

5.5 Climate

Meteorological data are not available for the Qarn Alam asset. The nearest meteorological station is located at Fahud. Considering the proximity of Fahud to Qarn Alam, the climatic conditions in both assets will be similar.

Meteorological data were recorded in Qarn Alam asset for the year 2002. Based on these data, the mean annual temperature is 28.5°C. The mean monthly temperatures range from 19.1°C in January (with mean minimum 7°C of and mean maximum of 29.2°C) to 35.5°C in June (with mean minimum 23.8°C of and mean maximum of 47.2°C). The maximum and minimum absolute temperatures are 47.9°C and 7°C respectively.

The relative lack of vegetation indicates that rainfall in Qarn Alam may be somewhat lower than Fahud. The mean annual rainfall in Qarn Alam area is 1.1 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. The climatic charts are presented in Figure 5.5.

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 Qarn Alam 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 emissions sources in PDO and the emission loads are not considered very significant.

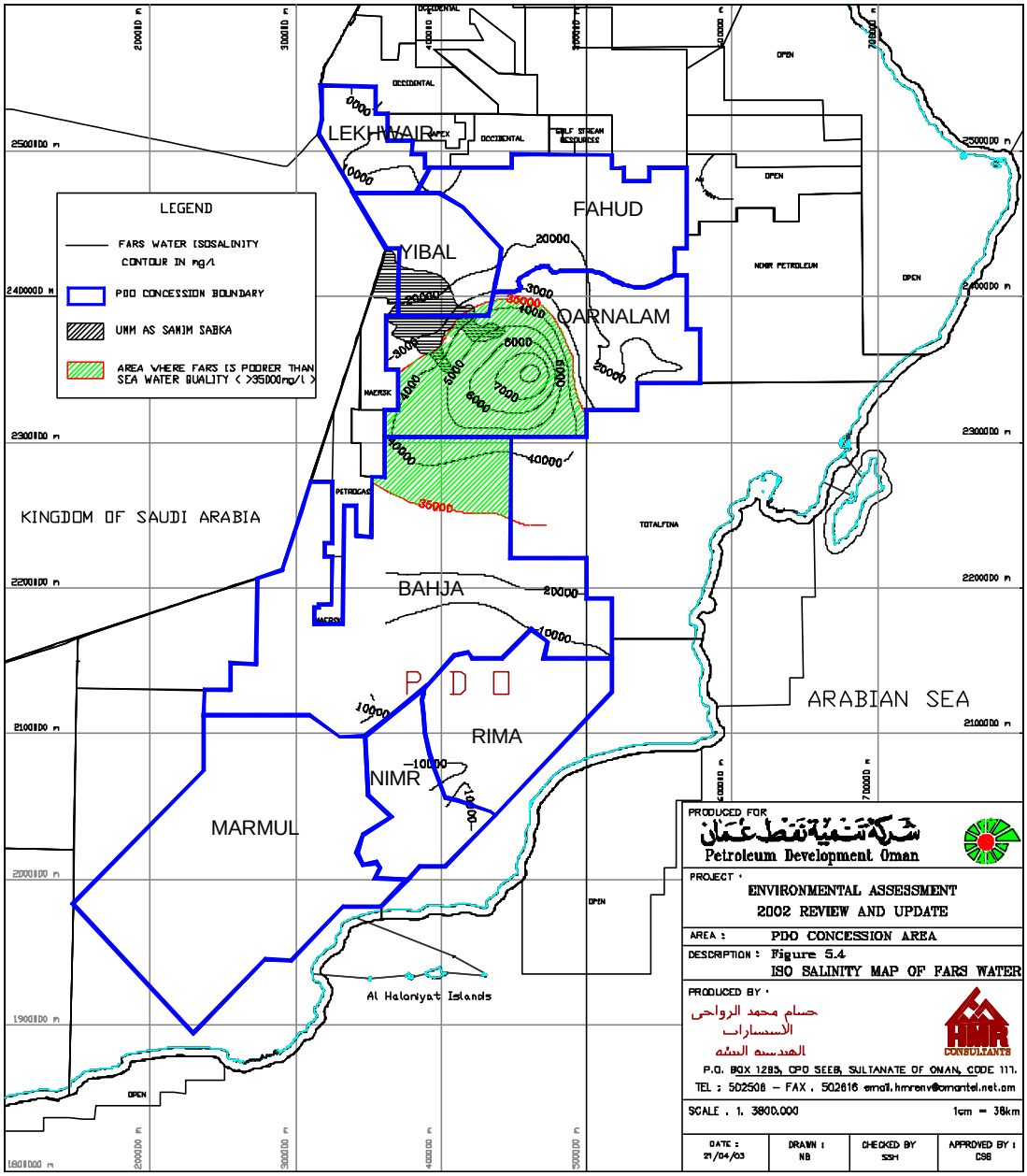

Figure 5.4: Isosalinity Map of Fars Water

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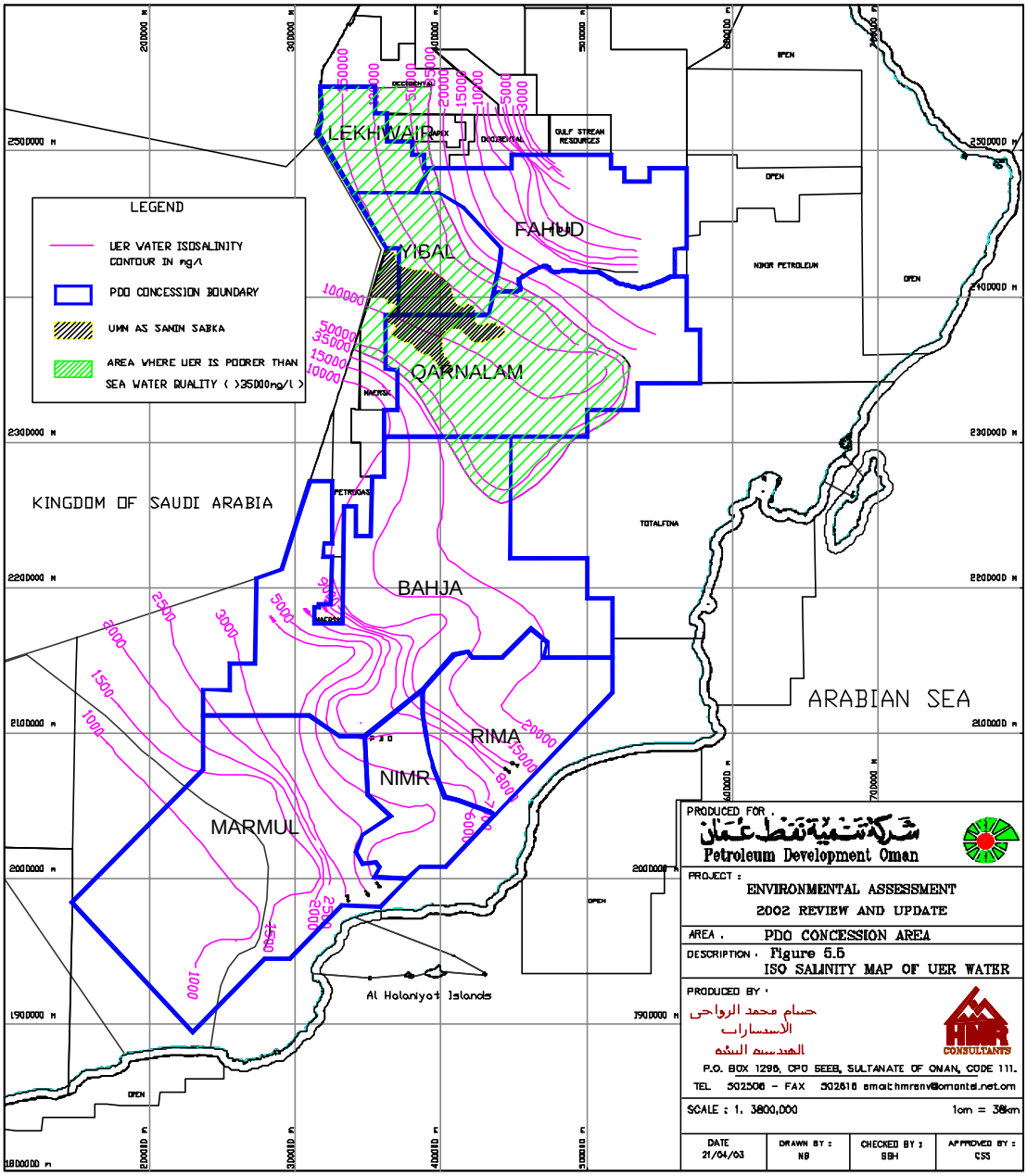

Figure 5.5: Isosalinity Map of UeR Water

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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 stations, gathering stations, and RO plant are unlikely to have any impact on the human settlements. However, they may have an impact on the noise levels in the PDO and contractor camps.

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

5.8 Flora and Fauna

With rainfall being very scanty and erratic, the fog moisture largely influences the vegetation in this region. The native vegetation is composed of desert plants and grasses, and trees, which are rarely seen. The distribution pattern of vegetation depends on the water drainage pattern and the presence of adequate sand or fissures in the bedrock for plant establishment.

The vegetation of Qarn Alam Asset Area can be broadly classified as the *Acacia-Zygophyllum-Heliotropium* Vegetation Type. This vegetation type is typical of the central gravel plains of Oman. Further classification recognizes two plant communities occupying two habitats, the gravel plains and the wadis. The gravel plains have very sparse vegetation consisting of no more than 10 species most of which are unpalatable subshrubs. The wadis and drainage channels contain trees of *Acacia tortilis* and in a few places *Prosopis cineraria*. There are no endemic or regionally endemic species in the Asset Area.

The largest mammals that occur in the Qarn Alam Asset area are the mountain gazelle and the rheem gazelle, both of which qualify under the IUCN world Red List and the regional Red List threat categories. A few smaller mammals, mostly gerbils, birds and jerboas are likely to be present in the vegetated areas. Distribution records for Wagner's gerbils, bird and jerboa and the sand fox are inadequate for classification and therefore they are placed under the Data Deficient category.

Bird surveys at Qarn Alam Asset area reveal an estimate of 96 species, 78 at Qarn Alam and 18 at Saih Rawl. The majority of the species are migratory. However, there are 12 species, which are believed to breed in the Qarn Alam Asset. Of these, breeding records are confirmed for 4 species, 5 species probably breed, and 4 species possibly breed in the area. There is no regional Red List for birds, and their threatened status in Oman is yet established.

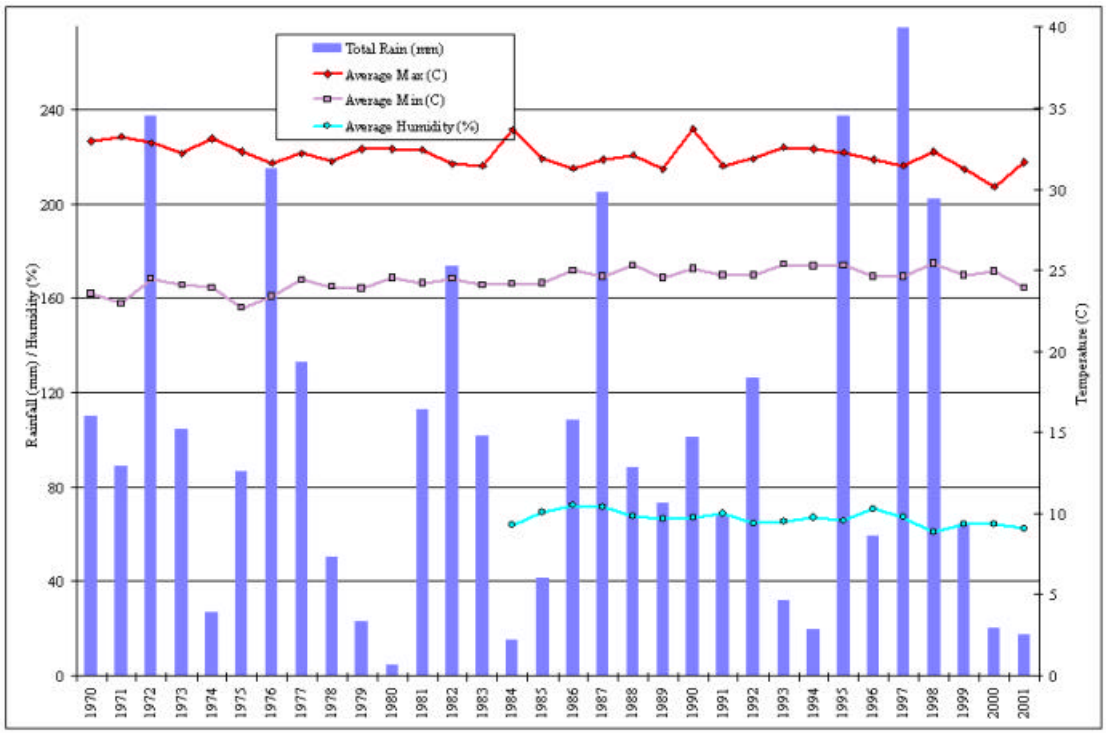
Various species of reptiles are recorded or expected in the Qarn Alam Asset area. These include the agamid lizards, lacertid lizards, skink, geckoes and snakes.

5.9 Human Settlements

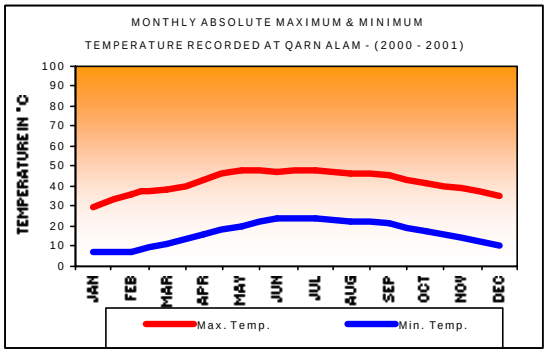
There are no towns within the Asset area and bedouin (nomadic or semi-nomadic) settlements are relatively few in number and nowhere permanent. A total of approximately 20 families are in the area known to PDO. These families utilize wadis in particular, exploiting browsing/grazing opportunities for their livestock, comprising goats and camels. Additional camels and goats belonging to settlements in the Fahud/Lekhwair area or from south of the Qarn Alam Asset also use wadis to browse and graze.

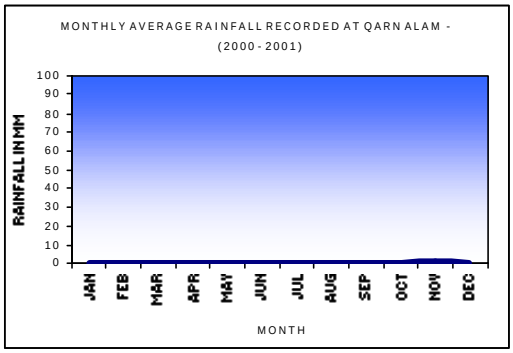
Ghaba Guest House/Motel with accompanying filling station and shop is situated on the main Muscat-Salalah highway, close to Ghaba North Gathering Station.

The details of the settlements located within Qarn Alam asset area, population break-up and occupations are summarised in Table 5.3 below.



Climatic Variation in Oman
(Recorded at Muscat)





Monthly Variations
(*Recorded at Qarn Alam)*

Figure 5.6: Climatic Charts for Qarn Alam Asset

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Table 5.3: Human Settlements in Qarn Alam Asset

Village / Camp	Location and Total Land Area	Current Total Population	Total Number of Housing Units	Main Occupations
PDO camp	Main Camp	155	201 rooms	PDO staff
Contractor camp	Outside main camp	1,074	460	Contractor staff
Wadi Alumayri	130 km west of Qarn Alam Camp	102	27	Farming and trading
Sayh Ar Rul	40 km west of Qarn Alam Camp	331	7	Farming and trading
Wadi Mihul	45 km northwest of Qarn Alam Camp	77	19	Farming and trading
Ghabah	16km northeast of Qarn Alam Camp	23	1	Trading
Al Haqaf	40 km northeast of Qarn Alam Camp	64	15	Farming and trading
Qarat Al Malh	45 km northeast of Qarn Alam Camp	25	9	Farming and trading
Wadi Al Ghubur	86 km southwest of Qarn Alam Camp	15	1	Farming and trading
Bedouin population	Not reported	None	None	None

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 and significant extent of land area is not vegetated. There is no subsistence farming or date orchards within the Qarn Alam asset area.

The details of land area developed by PDO for locating the production and associated facilities are summarised below in Table 5.4.

Table 5.4: Land Use in Qarn Alam Asset

Facility	Total Area
Total asset area	18,900 km^2
Production stations	836,000 m^2
Gathering stations	132,800 m^2
Power stations	35,000 m^2

The locations of these facilities are shown in Figure 5.1.

5.11 Social Infrastructure and Public Services

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

- **Water and Electricity**

Groundwater is the only water resource in the region. All the potable water for the population in Qarn Alam asset, including the PDO and contractor camps is supplied with demineralised water from RO and GOGD plants.

Oil exploration and production camps are constructed to be self-sufficient with respect to electrical power. Currently, the entire power is generated from two power plants; one at Saih Rawl and the other at Saih Nihayda. The rated capacity of the power plants at Saih Rawl and Saih Nihayda are 60 MW and 30 MW respectively.

- **Roads and Communications**

Qarn Alam is connected to Fahud by graded road. No major road passes through the Qarn Alam asset. PDO maintains an extensive network of graded roads, which are open to local population. PDO also maintains an airstrip at Qarn Alam, with regular flights. However, these flights are restricted only to PDO staff and their 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 no towns and villages located in the concession area of Qarn Alam asset. Bedouin population are also not reported. Therefore there are no education facilities in the asset area.

- **Health Services**

There are no government health care facilities in Qarn Alam asset. Private health-care facilities (clinic and ambulance services) are available within PDO's residential camps. These facilities are generally made available to outsiders, if the need arises.

5.12 Archaeological Cultural and Recreational Resources

The literature search and a walk-through field survey have shown no evidence of archaeological sites in Qarn Alam asset. The cultural resources are limited to a mosque located in PDO’s main camp. There are also no recreational facilities, other than those located within PDO’s main camp.

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 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, Qarn Alam asset accounts for about 10.8% 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 Qarn Alam asset is about 300. The number of permanent staff employed by PDO’s contractors in Qarn Alam asset is about 1500. In addition, a large number of persons, including local population are also provided indirect employment to provide a number of supporting services. Providing services 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 oil (14,462 m^3/d) and some gas (3,084,000 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)	Adverse
Duration of impact (short term / long term)	Long term
Likelihood of occurrence (very low / low / medium / high / very high)	Low
Significance of impact (slight / minor / localized / major / massive)	Slight
Potential risk level (low, medium, high and extreme)	Low

- **Depletion of Groundwater Resources**

Currently, 4007 m^3/d of groundwater on average is abstracted continuously from the Fars aquifer for process and domestic use in this asset. Some additional groundwater is also used in drilling. Further, the future planned developments will require significant groundwater. The phase I thermal development of Qarn Alam field alone will require 13500 m3/d of groundwater from Fars aquifer. Thus, though the total quantity of groundwater abstracted currently in this asset is not very significant, it will significantly increase in the immediate future. Therefore, it has the potential to cause adverse impact on future groundwater availability in this region. The magnitude of the impact depends on the groundwater balance. Currently, sufficient information is not available on the groundwater recharge rate and on 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 to medium.

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 to medium
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 of 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)	Adverse
Duration of impact (short term / long term)	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
- Air pollution
- Noise pollution

- **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 3,200 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

- **Air Pollution**

Dust emissions from construction activities, 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 in the asset are estimated to be <10 tpd for CO and NO_x and <1 tpd for SO_2 and hydrocarbons. Considering that they are released over a large area, they are not expected to lead to any significant degradation of air quality. Further, most of the asset areas are uninhabited.

For these reasons, it is assumed 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 at locations close to the major emission sources 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	**Air Pollution**
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Long term
Likelihood of occurrence (very low / low / medium / high / very high)	Medium
Significance of impact (slight / minor / localized / major / massive)	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
- Disposal of produced water
- Disposal of RO plant rejects + backwash
- Land discharge of treated sewage effluent
- Accidental spillage of hazardous liquids
- Release of leachates from landfill sites

Potential Environmental Effects
- Groundwater pollution

The disposal of highly saline produced water and RO plant rejects + backwash into the aquifer system can result in degradation of groundwater quality if injected into an exploitable aquifer, particularly the shallow aquifer. Currently, in the asset, only about 78% of the produced water re-injected into the producing oil reservoir (Shuaiba, Kharaib formations). Remaining 22% is disposed into deep aquifer (Natih E formation). 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 surface discharge treated sewage effluents, accidental spillages of RO reject water, oils and chemicals and the release of leachates from the landfill sites can affect the groundwater quality provided they could percolate into the groundwater table.

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

Impact Rating	Groundwater Pollution
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Long term
Likelihood of occurrence (very low / low / medium / high / very high)	High
Significance of impact (slight / minor / localized / major / massive)	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
- Land contamination

- **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)	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

- **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

- **Land Contamination**

The discharge of treated sewage effluents on land, accidental spillage of hazardous liquids and landfilling of solid wastes can potentially degrade the soil quality. There is no hazardous waste landfill in the asset. The current data on the treated sewage effluent quality in the asset indicate that the regulatory standards are frequently exceeded. The margin of exceedance is also quite high. Hence, there is a potential risk of soil contamination due to land discharge of treated sewage.

The accident spillage of crude oil, mainly due to pipeline and flowline leaks leads to soil contamination. In the period of (Jan-Sep 2002), 26 incidents of oil spills were reported in the asset. The total volume of the oil spill was reported as 13 m^3 and the total land area contaminated was reported as 318 m^2. The oil spill occurrence frequency is low and the extent of soil contamination is negligible compared to the total land area of the asset. However, there is a possibility of under-estimation of the oils spills and area contaminated, as in any PDO 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	**Land Contamination**
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Long term
Likelihood of occurrence (very low / low / medium / high / very high)	Low
Significance of impact (slight / minor / localized / major / massive)	Localised
Potential risk level (low, medium, high and extreme)	Medium

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 in the asset are very limited. The environmentally significant Arabian Oryx Nature Reserve boundary is just touches the asset boundaries. 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, which 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 significant 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 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
Groundwater contamination	• Adverse • Long term • High occurrence • Localized significance	• High risk	• The asset has a long legacy of shallow disposal of produced water. Further, shallow disposal is still in practice in the asset. • Significant quantity of untreated sewage is disposed off into open lagoons in the asset.
Groundwater depletion	• 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.
Land contamination	• Adverse • Long term • Medium occurrence • Slight significance	• Medium risk	• It is suspected that accidental leaks and spills of oils are significant in the asset, even though fewer incidents are reported. • NORM survey not completed to ensure that the tank bottoms and sludges are free of NORM. • Frequent overflow of untreated sewage from contractor's STP into open lagoons and occasional exceedence of land discharge standards for treated effluents are also partly responsible.
Air pollution	• 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.

Noise pollution	• 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

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 and heater stacks shall be monitored for compliance. • Ambient air quality shall be monitored in accommodation camps periodically.
SP-1006: Specification for Aqueous Effluents	• Due to ill design of the contractor's STP, frequently untreated sewage overflows from the holding tank into open lagoons. • 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.	• Contractor's STP shall be redesigned such that untreated sewage will not be discharged under any circumstances. • 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 and under-reported.	• 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. • Waste recycling is not significant. • There is no evidence of regular wetting of land farms.	• Compliance with waste handling procedures shall be enforced. • Waste segregation at source shall be enforced at rig sites. • 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
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, *Qarn Alam asset area Environmental Assessment Report*, PDO, July 1999

2. PDO, *Health, Safety And Environment Guideline - Environmental Assessment* GU 195, July 2002

3. HMR, *Initial Environmental Examination for Khaluf Bay*, PDO November 2000

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

5. HMR, *Environmental Audit Report of Sewage Treatment Plants in PDO*, April 2003

6. 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 Qarn Alam 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	Ahmed Al Sabahi	Environmental Advisor
ONS	Devendra Upadhyay	HSE Team Leader – North
		Area Coordinator – Qarn Alam

APPENDIX 2: FUEL GAS ANALYSIS

Parameter	Burhan	Qarn Alam	Saih Rawl	Saih Nihayda	Saih Nihayda gas plant	Al Ghybar	Barik	Ghaba North	Saih Rawl Power Plant	Saih Nihayda Power Plant
Methane, in % v/v	73.14	82.71	0.00	62.63	81.70	64.91	81.43	67.42	85.01	85.01
Ethane, in % v/v	8.09	5.76	76.41	9.92	4.78	11.01	7.26	9.10	6.54	6.54
Propane, in % v/v	5.68	1.89	6.80	9.39	2.08	7.63	3.63	7.27	2.68	2.68
i-Butane, in % v/v	1.69	0.62	2.79	2.72	0.61	3.22	0.75	3.02	0.66	0.66
n-Butane, in % v/v	2.67	0.60	1.39	4.15	0.79	2.58	1.21	2.54	0.61	0.61
i-Pentane, in % v/v	0.84	0.21	0.73	1.18	0.36	1.50	0.32	1.58	0.20	0.20
n-Pentane, in % v/v	0.75	0.18	0.76	1.20	0.33	1.01	0.29	0.21	0.19	0.19
Hexane +, in % v/v	1.39	0.57	2.91	3.35	0.41	2.43	0.63	1.56	0.26	0.26
Nitrogen, in % v/v	4.44	4.93	6.14	3.47	8.52	4.79	3.95	2.30	3.01	3.01
Carbon Dioxide in % v/v	1.20	1.87	1.04	1.99	0.42	0.92	0.54	3.52	0.85	0.85
Hydrogen Sulphide in % v/v	0.46	0.67	1.03	0.00	0.00	0.10	0.00	1.48	0.00	0.00

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)
Ghaba North Gathering Station: Gas Turbine	2	-	-	-	261	723.8	9.6	1.7	0.8	0.0
Al Ghubar Production Station: Gas Turbine	7	-	-	-	16	49.2	0.0	0.0	0.0	0.0
Qarn Alam Production Station: Gas Turbine	6	-	-	-	1,093	2,903.8	20.0	7.1	2.9	0.4
Saih Rawl Power Station: Gas Turbine	2	-	-	-	6,378	17,382.0	0.0	0.0	16.7	2.9
Saih Nihayda Power Station: Gas Turbine	1	-	-	-	16,842	45,896.0	0.0	0.0	44.2	7.5
Total					24,590	66,955	30	9	65	11

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: QARN ALAM 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 Sensitivities	**Social Environment**	Landscape & Aesthetics									
		Public Health & Safety									
		Cultural Heritage									
		Native Lifestyle									
		Agriculture & Animal Husbandry									
		Employment									
	Ecology and Wildlife	Wildlife Habitats									
		Fauna									
		Flora									
	Land Environment	Soil Quality			X	X				X	X
		Loss of Vegetation									
		Land Use									
	Water Environment	Marine Water Quality									
		Hydrogeology & Ground Water Quality		X	X	X					
		Surface Hydrology & Water Quality									
	Air Environment	Ambient Noise									
		Ambient Air Quality									
		Climate (Global Warming)									
	Natural Resources	Claim on Local Assets									
		Groundwater Resources									
		Mineral Resources									
Environmental Hazards			**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	Agric ulture & 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.