

**VAALCO Gabon (Etame), Inc.**

**ENVIRONMENTAL IMPACT  
ASSESSMENT**

**Permis Marin D'Etame**

**La Republique Gabonaise**

**September 2001**

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## 1.0 INTRODUCTION

The Etame Marin permit was awarded in July 1995 to VAALCO Gabon (Etame) Inc. as operator. The block encompasses an area of approximately 3000 square kilometers (760,000 acres) in the Congo Basin offshore southern Gabon. The area has undergone substantial exploration during the past 25 years, which has resulted in several field discoveries within the block and the adjacent area.

Hydrocarbons were discovered in 1998 with the Etame-1 well, and a flow rate in excess of 3,700 barrels per day was established on DST. The field was confirmed by the Etame-2V well drilled in early 1999, which established an oil-water contact (OWC) at 1,862 meters. The Gamba sands indicate excellent reservoir potential, with porosities of more than 28% and permeabilities in excess of 1 Darcy.

Further testing has defined 1,800 acres of proven Gamba sand play that includes the area of the ET-1VA and ET-3V wells. This translates into 31.5 MMBO recoverable. Additionally, the ET-2V well proves up another closure of 250 acres (or 5 MMBO) recoverable, while the productive Dentale sands in the ET-3V well add another 4 MMBO. Consequently, combined proven recoverable reserves for the Etame structural complex are estimated at 40.5 MMBO. Most-likely (P-50) reserves are 65 MMBO recoverable and upper case reserves are estimated at 109 MMBO recoverable.

Ownership of the license is as follows:

	Exploration	Development & Production
VAALCO Gabon (Etame) Inc.(Operator)	30.350 %	28.074 %
VAALCO Energy (Gabon), Inc.	32.500 %	30.063 %
Western Atlas Afrique, LTD.	20.000 %	18.500 %
Sasol Petroleum	10.000 %	9.250 %
PetroEnergy Resources Corp.	4.525 %	4.185 %
Nissho Iwai Corp.	2.625 %	2.428 %
Energy Africa/Gabon Government	Carried	7.500 %

## 2.0 ENVIRONMENTAL POLICY AND LEGISLATION

### 2.1 VAALCO GABON

#### 2.1.1 Health, Safety and Environment (HSE) Policies

VAALCO Gabon is committed to excellence in the areas of health, safety and environment (HSE). Meeting this commitment is a responsibility shared by everyone, including contractors and third parties, and is a prerequisite of VAALCO Gabon. High standards of HSE performance will be directed by the following principles:

- ◆ **Commitment:** All Company employees will be expected to demonstrate strong commitment to high standards of HSE performance.
- ◆ **Trust:** The Company will conduct its operations in a manner of building trust on HSE issues with its employees, government, and the public.
- ◆ **Accident Prevention:** The Company's goal of no accidents, injuries, unsafe work practices, or unsafe conditions will also be the goal of all employees.
- ◆ **Emissions/Releases:** Reduction and prevention of waste and emissions/releases will be among the objectives of all operations.
- ◆ **Emergency Preparedness:** Emergency preparedness is a vital function and is the responsibility of management and supervision at all levels.
- ◆ **Compliance:** The Company will comply with all applicable environmental, health, and safety laws and regulations.
- ◆ **Training/Education:** The Company will proactively assure that employees are adequately trained and educated on HSE issues.
- ◆ **Measurement of Performance:** HSE performance will be measured and communicated company-wide. Compliance reviews and audits will be periodically conducted.
- ◆ **Effectiveness of HSE:** The Company's intent is to achieve continual improvement in the effectiveness of its health, environment, and safety efforts.



## **2.1.2 Site-Specific Safety and Health Policies**

### **2.1.2.1 Occupational Safety and Health Regulations/Guidelines**

VAALCO Gabon will follow all applicable occupational safety and health regulations and requirements of the government of Gabon, as well as applicable industry recommended guidelines developed by the E&P Forum and the American Petroleum Institute (API). Furthermore, VAALCO Gabon will follow the policies set forth in the *VAALCO Health, Environmental and Safety Policies and Procedures Manual*.

### **2.1.2.2 Contractor Safety**

VAALCO Gabon requires contractors and subcontractors to have and enforce acceptable safety and loss prevention standards as adopted by the API RP 2220 *Improving Owner and Contractor Safety Performance*.

### **2.1.2.3 Personal Protective Equipment (PPE)**

Protective head gear and footwear will be required at all times during drilling operations. Other protective equipment should be employed when necessary to safeguard against physical, chemical or other agents.

### **2.1.2.4 Hydrogen Sulfide (H<sub>2</sub>S) Exposure Control**

Hydrogen sulfide is not expected during drilling operations.

## **2.2 GABON ENVIRONMENTAL LEGISLATION**

Gabon protects natural resources with laws, regulations, and mandates. Law 3/77 requires that an environmental assessment for all new industrial ventures be conducted and submitted to the Ministère De La Planification, De L'environnement et Du Tourisme. In addition, environmental requirements specific to the petroleum industry are typically established within individual concession agreements. Pursuant to its agreement with the Government of Gabon, VAALCO Gabon will take special measures to ensure that it will:

- ◆ use technologies and equipment that minimize hazardous emissions and discharges into the environment and ensure the safety of personnel;
- ◆ properly treat drilling cuttings/solids/fluids; and
- ◆ use applicable technologies for water supply and wastewater treatment systems.

## 2.3 INTERNATIONAL CONVENTIONS

Conventions applicable to the oil and gas industry that have been ratified by Gabon and/or the United States are identified below.

### ♦ **Geneva Convention on the Continental Shelf - 1958**

Defines the geographical limits of the continental shelf and assigns sovereign rights to the coastal state to explore for and develop natural resources on its continental shelf. It refers to the prevention of pollution by requiring that coastal states should take appropriate measures for the protection of the living resources of the sea.

### ♦ **Geneva Convention on the Territorial Sea and Contiguous Zones - 1958**

Deals with the sovereignty of territorial waters and the rights of innocent passage.

### ♦ **Geneva Convention on the High Seas - 1958**

Requires states to introduce regulations preventing the pollution of the sea from ships, pipelines, and offshore exploration and development activities.

### ♦ **African Convention on the Conservation of Nature and Natural Resources - 1969**

Encourages individual and joint action for the conservation, utilization and development of soil, water, flora and fauna for the present and future welfare of mankind, from an economic, nutritional, scientific, educational, cultural and aesthetic point of view.

### ♦ **The Convention on Wetlands of International Importance, Especially as Waterfowl Habitat (Ramsar Convention) - 1971**

First global treaty concerning the conservation and wise use of natural resources. Specifically, the Ramsar Convention provides the framework for international co-operation on the conservation and wise use of wetland biomes.

### ♦ **Convention on the Prevention of Marine Pollution by Dumping Wastes and Other Matter (London Convention) - 1972**

Objective - to control pollution of the sea caused by dumping of wastes from vessels, aircraft,

and platforms, and to encourage regional agreements supplementary to the Convention. The convention excludes operational wastes resulting from the exploration, production, and associated offshore processing of seabed minerals.

♦ **International Conv. for the Prevention of Pollution From Ships (MARPOL) - 1973**

Objective - to preserve the marine environment by achieving the complete elimination of pollution by oil and other harmful substances and the minimization of accidental discharge of such substances. This convention and its 1978 update contain rules regarding pollutant discharge levels and prohibited discharge areas. Special requirements for deck drainage from rigs and platforms are incorporated into the text.

♦ **Convention on Civil Liability for Oil Pollution Damage Resulting from Exploration for and Exploitation of Seabed Mineral Resources - 1975**

Establishes strict liability for oil pollution damage resulting from exploration and development of seabed mineral resources. Also establishes a fund to compensate persons harmed by any oil pollution resulting from such activities.

♦ **United Nations Convention on the Law of the Sea (UNCLOS) - 1982**

This convention is probably the most wide-reaching of all conventions and pulls together many existing codified and customary laws of the sea into a single comprehensive treaty. It addresses coastal state jurisdiction over territorial waters, fisheries management, pollution control (marine and atmospheric), and seabed mineral exploration and development, together with a regime for controlling "international" waters.

♦ **Convention for Cooperation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region - 1984**

Objective - to protect the marine environment, coastal zones and related internal waters falling within the jurisdiction of the States of the West and Central African region.

♦ **International Convention on Oil Pollution Preparedness, Response, and Cooperation (OPRC) - 1990**

Provides a framework for international cooperation in combating major oil pollution incidents. Article 3 requires that both ships and offshore installations have oil pollution contingency plans. These should be coordinated with the national and regional systems in conjunction with the appropriate competent national authority.

♦ **Convention on Biological Diversity - 1992**

Establishes a system of protected areas to conserve biodiversity, sustain the use of its components, and fairly and equitably share the resulting benefits.

**2.4 INTERNATIONAL INDUSTRY STANDARDS, PROTOCOLS AND GUIDELINES**

Several industry organizations have developed environmental standards and/or guidelines for E&P activities that are intended to supplement rather than supersede a country's local environmental regulations. It is VAALCO Gabon's policy to utilize internationally recognized standards, procedures and practices as they relate to oil and gas exploration/production activities. Some of the more prominent of these include the Oil Industry International Exploration and Production Forum (E&P Forum), the International Association of Geophysical Contractors (IAGC) and the International Organization for Standardization (ISO).

## **3.0 PROJECT DESCRIPTION**

### **3.1 INTRODUCTION**

The Etame field will be developed using subsea well completions in combination with a Floating Production, Storage and Offloading (FPSO) vessel. The initial development will consist of three wells (ET-1VA, ET-3V and ET-4V). Production from the subsea wells will be delivered to the FPSO through subsea flowlines and risers. The FPSO will be located close to the ET-3V well.

Etame crude has cloud point of approximately 39°C and a pour point of approximately 27°C. Because of this high wax formation tendency, special care must be taken to ensure the reliable and continuous delivery of crude from the wells to the FPSO, and from the FPSO to the export tankers. Consequently, production flowlines will be insulated to maintain the crude oil above the wax appearance temperature as much as possible. The flowlines will be configured in a loop to allow pigging for wax removal and flushing with fluids in case of an extended well shut-in.

### **3.2 SUBSEA WELL COMPLETIONS**

The original Etame wells were drilled using the ABB Vetco Gray MLC mudline casing suspension system. The MLC system will be converted to provide a marine type wellhead that can support a subsea production tree. Kvaerner Oilfield Products will provide the mudline conversion system and the subsea production trees.

### **3.3 FLOWLINES AND RISERS**

Production from the subsea wells will be delivered to the FPSO through 4" flexible flowlines with a nominal pressure rating of 3000 psig. Two flowlines will be provided for each well: One will be for production and the other will be a well service flowline. The production flowline will be insulated to maintain the crude oil above the wax appearance temperature as much as possible. Flowlines will be configured in a loop to allow pigging for wax removal and flushing in the event of an extended shut-in of the wells.

Dynamic flexible pipe risers will be provided to bring the production from the seabed to the FPSO. These will be similar to the flowlines, except that they will be designed to accommodate the motions of the FPSO with a fatigue service life of at least 10 years.

### **3.4 PRODUCTION CONTROLS AND UMBILICALS**

The wells will be controlled by a “direct hydraulic” production control system that consists of a hydraulic well control panel, a hydraulic power unit and production control umbilicals. The well control panel and hydraulic power unit will be assembled as a system and installed on the FPSO. The production umbilicals will connect from the FPSO to the individual subsea wells.

### **3.5 FPSO**

#### **3.5.1 General**

The FPSO proposed for the Etame field development is the Petr leo Nautipa, which is owned by Tinworth Limited. The Petr leo Nautipa is currently operating at the Kiame Field in Angola. A Contractor will demobilize the vessel, move it to a ship yard, and refurbish and repair the FPSO. The work, which will be done in accordance with the requirements of the Classification Agency, will enable the vessel to remain at the Etame Field for a minimum period of 5 years without dry docking. After the modifications are complete, the FPSO will be moved to the Etame Field and installed with a spread mooring system. This is an eight-leg catenary chain system with 8 x 10 t Stevpris HHP anchors designed to withstand the 100-year survival conditions at site.

The Petr leo Nautipa is 266 meters long and 43.5 meters wide, with a hull depth of 23 meters. It is equipped with three diesel generators, one emergency diesel generator and one steam turbine-driven alternator. Derricks and crainage on-board consist of two, 15 tonne capacity derricks, one electro-hydraulic pedestal deck crane (9 tonnes capacity), two provision cranes (1 tonne each) and one engine room crane (6 tonnes capacity).

#### **3.5.2 Helicopter Deck**

The helideck is designed in accordance with 1989 MODU rules and sized to accommodate a SUPER PUMA helicopter or equal. The helideck includes safety nets, lights, navigation aids, fire fighting and safety equipment.

#### **3.5.3 Fire/Gas Detection and Shut Down Systems**

A fire and gas detection system will be integrated for the process area and marine areas, with alarm panels in the central Control Room. Manual alarm devices and remote stops will also be installed in the accommodation, engine and pump rooms, and process area. The vessel will be equipped with shutdown systems for fire and gas detection, process and manual ESD shutdown.

### 3.5.4 Oil Pollution Monitor

An oil pollution monitoring system complying with the MARPOL (1993) requirements will be installed for the engine room bilge.

### 3.5.5 Oil Storage Tanks

Oil storage tanks will be fitted with a radar-type tank level system for remote monitoring in the cargo control room. The tanks will also be provided with a high-level alarm system and have the following capacities:

**TABLE 3-1 OIL STORAGE TANK CAPACITY**

NUMBER	ITEM	CUBIC METERS	BARREL
1	Center Tank	15,360	96,612
2	Center Tank	18,278	114,965
3	Center Tank	10,154	63,867
4	Center Tank	16,247	102,191
5	Center Tank	16,193	101,837
	<b>Total Center Tanks</b>	<b>76,232</b>	<b>479,486</b>
1P	Wing Tank	10,780	67,804
1S	Wing Tank	10,780	67,804
2S	Wing Tank	13,660	85,918
2P	Wing Tank	13,660	85,918
4S	Wing Tank	12,079	75,975
5S	Wing Tank	7,305	45,947
5P	Wing Tank	7,305	45,947
1S	Slop Tank	3,569	22,468
2P	Slop Tank	3,569	22,468
	<b>Total Wing Tanks</b>	<b>94,786</b>	<b>596,187</b>
	<b>Grand Total</b>	<b>171,018</b>	<b>1,075,673</b>

### **3.5.6 Export System**

The FPSO cargo pumps will deliver crude oil from the cargo tanks to a 20" offloading line to the bow of the FPSO, where it will be connected to a 16" floating hose. The offloading rate will be approximately 24,000 bbl/h. A tandem mooring system for oil export tankers will be arranged for bow-to-bow mooring.

## **3.6 PROCESS SYSTEM DESCRIPTION**

The process system is based on API RP-14C, "Recommended Practice for Analysis, Design Installation and Testing of Basic Surface Safety Systems for Offshore Production Platforms." Piping design and fabrication is in accordance with ANSI B31.3.

### **3.6.1 Production Manifold**

Piping will be provided between the riser porch and the pigging/manifold deck for the tie in of six, four-inch risers (for three wells). A manifold system will be provided with the following:

- ◆ High pressure (HP), low pressure (LP) and test headers for three wells (expandable to a total of six wells)
- ◆ Gas lift header
- ◆ Pig launch header
- ◆ Pig return header (may be test header)
- ◆ Three pig launchers and three pig receivers, with space to accommodate an additional three launchers and three receivers
- ◆ Monitoring instrumentation for three wells
- ◆ Manual choke valves and esdv's for three wells
- ◆ Deluge / fire & gas systems

All piping and valves from the riser connections up to and including the manual choke valves will be rated ANSI Class 1500. Piping downstream of the manual choke valve will be rated ANSI Class 150.

### **3.6.2 Production Heaters**

Incoming produced liquids will be heated prior to processing. A production heater skid, with raised deck support structure, will be installed on the starboard side of the FPSO forward of the process deck. Space will be provided for up to four 1.5 Mw shell or tube or plate heaters, plus heater distribution manifold piping.



### **3.6.3 Production Separation System**

The HP production header will feed the first stage separator, where most of the water will be removed, and testing will be done in the test separator. The combined output of crude will be further degassed in the second stage separator. The separated gases will be used for fuel gas or flared. Sizing of the first and second stage separators is for nominally 30,000 barrels per day total fluids.

### **3.6.4 Electrostatic Treater**

The stabilized crude will then be pumped to a pressure sufficient to suppress vaporization and then dehydrated in the oil treater. The oil treater will have electrostatic grids that can be energized to enhance the coalescence and removal of the water.

### **3.6.5 Gaslift**

The FPSO may optionally be furnished with gas lift compressors at a future date. Initially, gas lift headers will be provided for up to three wells. In the event gas lift is needed, the subsea well service lines can be used for gas lifting the wells.

### **3.6.6 Fuel Gas**

Fuel gas will be taken from the first and second stage separators and treated in a scrubber. Condensate will be sent to the HP relief scrubber for recovery. The fuel demand is expected to be nominally 1 MMSCFD. If the gas production rate is insufficient to meet FPSO fuel requirements, it will be necessary to burn crude oil or diesel oil.

### **3.6.7 Water Treatment & Slops**

Water from the separators will be treated for oil removal and degassing in the water treatment separator. Oil will be removed down to 40 ppm or less, and the water will be discharged overboard. Effluent water in excess of 40 ppm will be diverted to one of the slop tanks for further processing.

### **3.6.8 Vent System**

Equipment operating at atmospheric pressure will be vented to the LP Scrubber and equipment operating above atmospheric pressure will be vented to an HP scrubber. The gases will then flared in accordance with API recommendations as to maximum allowable noise and heat radiation levels.

### **3.6.9 Chemical Injection**

A chemical injection system will be provided with storage tanks and injection pumps for up to four separate chemicals (i.e., pour point depressors, corrosion inhibitors, anti-scale and anti-foam chemicals). Provisions will also be made for the injection of a wax crystal modifier (pour point depressant) at each of the subsea trees through the production umbilicals.

### **3.6.10 Flowline Pigging / Flushing System**

A flowline pigging/flushing pump and piping system will be provided to allow the production flowlines to be flushed upon shut-in. The flushing pump will also be used for pigging the flowlines. The pump will be arranged to pump diesel oil or seawater down the service line and back through the production line.

### **3.6.11 Bullheading / Gel Breaking Pump**

A bullheading/gel-breaking pump will be provided for two purposes: 1.) it can be used to “bullhead” diesel oil down the well bore in case of an extended shut-in, and 2.) if a flowline is shut in and cools down to ambient temperature, the gel-breaking pump can apply high pressure to the fluids in the production flowline, via the service line, and force them to flow to the FPSO.

## **3.7 WASTE MANAGEMENT**

VAALCO Gabon proposes to adhere to the waste management regulations of the International Maritime Organization (IMO) *International Convention for Prevention of Pollution of Ships – 1973 (as modified by Annex V of MARPOL 73/78)* and the E & P Forum.

### **3.7.1 Disposal of Drilling Fluids, Muds and Cuttings**

Drilling fluids are used as part of the safety system to prevent blowouts, as a lubricant for the drilling and to bring the cuttings to the surface. During the proposed project, drilling fluids will be pumped from tanks on the platform, down the center of the hollow drill string and through nozzles in the drill bit. The circulating fluids will then sweep the crushed rock cuttings (formation solids) from beneath the bit and carry them back up the annular space between the drill string and borehole or casing to the surface. The fluids will pass through mechanical separation equipment (an integrated system of shale shaker screens and hydrocyclones) to separate the cuttings and recover the drilling fluid.

VAALCO Gabon will use an oil base drilling fluid system comprised of a low toxicity mineral oil and additives for the wells. All additives will be chosen to minimize any adverse environmental impact. If it is necessary to utilize specialty materials to alleviate problems associated with the downhole drilling operation, they will be chosen similarly. Oil-based drilling fluids will not be discharged; instead, they will be returned to drilling fluid vendor for recycling.

The drill cuttings will be treated if necessary to prevent a sheen with a spray of dispersant before discharge to minimize or stop any surface sheens. While drilling is in progress, cuttings will be continuously discharged at a rate of approximately 1-10 bbl/h. Drilling mud will be collected and returned to the vendor for recycling.

### **3.7.2 Produced Water**

One of the slop tanks will serve as a produced water clean up system. Heating coils will be fitted to the slop tanks to assist water separation. Separated oil will be pumped back into the system, while segregated water will be discharged overboard. Oil content monitors with automatic diverter and recirculation valves will continuously monitor the overboard-fluid flow to ensure the oil content does not exceed a level of 42 ppm at any time. If the oil content exceeds acceptable limits, the produced water will be diverted back to the tank.

### **3.7.3 Shipboard Refuse**

The treatment of shipboard refuse is defined under the resolutions of MARPOL 73/78 and the *International Convention for Prevention of Pollution by Garbage from Ships*. These regulations require that a waste management plan must be present on board the fixed or floating platform, and only victual, dishwasher, treated sewage and spent water waste streams are allowed to be discharged overboard. Garbage generated on board will be segregated, stored and sent ashore for disposal at an approved and permitted waste disposal landfill. Hazardous waste will be separated, stored in clearly marked containers and eventually transported onshore to an approved and permitted facility.

### **3.7.4 Deck Drainage**

Deck drainage will be routed into a sump tank. Hydrocarbons will be skimmed off and either stored in the sludge tanks or taken to shore for treatment. The balance of the drainage will be discharged in compliance with the International Finance Corporation's *Guidelines for Oil and Gas Development*, which specify no visible sheen.

### **3.7.5 Vessel Machinery Washings and Ballast Water**

Machinery washings generally contain oil and grease. These will be put through an oil/water filter or sent to the sump tank prior to discharge. Discharge of oil and grease will be limited to the MARPOL 73/78 limit of 100 ppm oil and grease content.

Ballast water will be stored in specially designated ballast tanks and will not come in contact with any contamination. Therefore, ballast water discharged during rig maneuvering will be clean.

### **3.7.6 Used Engine Oils**

Waste lube oil will be collected and stored in sludge tanks until it is eventually transported onshore to a recognized waste oil recycling/disposal facility.

## **3.8 WELL SUSPENSION AND DECOMMISSIONING**

Each well will be suspended or abandoned upon completion of operations. Abandonment procedures will be consistent with industry-wide practices and procedures and will ensure safety and environmental protection.

If no commercially viable reservoir is found at a well, it will be permanently plugged with cement or mechanical plugs. In addition, zones in the wellbore known to contain moveable hydrocarbons will also be plugged and isolated. The BOP stack and riser will be removed and the conductor cleared below the mudline level, leaving a clean seabed.

If a commercially viable reservoir is located, the well will be suspended by installing cement or mechanical plugs to isolate the hydrocarbon intervals. A well suspension cap will be fitted, and the seabed surface equipment will be removed.

## **4.0 DESCRIPTION OF THE PHYSICAL ENVIRONMENT**

### **4.1 INTRODUCTION**

The Etame Marin Permit is located offshore Gabon within the northernmost portion of the Congo Basin. This basin contains some of the largest hydrocarbon accumulations within West Africa (See Figure 4-1). The offshore exploration blocks extend to deep water, as the continental shelf (seabed down to 200 meters) of West Africa is relatively narrow and approximately 50 km wide.

In 1998, Fugro-Geoteam Limited performed a rig site survey for VAALCO Energy. The survey was undertaken to provide bathymetric, seabed features, shallow soils and high-resolution geophysical data in the vicinity of the proposed Etame-1 location in Etame Block, Gabon (Fugro-Geoteam 1998). The SEADATA division of Fugro GEOS performed a meteorological and oceanographic design study at the Etame Field in 1999 (Fugro GEOS 1999). Data findings from both reports are summarized for the purpose of this EIA.

### **4.2 SEABED CHARACTERISTICS**

#### **4.2.1 Bathymetry**

Water depths in this report have been reduced to Lowest Astronomical Tide (LAT). The difference between Mean Sea Level (MSL) and LAT is approximately 0.85 meters in the Etame-1 area. The water depth at Etame-1 is 75.6 meters LAT. The water depths in the survey area range from a minimum of 71.8 LAT in the northeast to 78.5 meters LAT in the southwest. The seabed dips gently to the southwest with an average gradient of 1:370 (see Figure 4-2).

#### **4.2.2 Seabed Composition**

The shallow soils at the Etame-1 location consist of loose to dense fine silty sand and very soft to soft clayey silt to a depth of 3.4 meters sub-seabed, overlying a prominent angular conformity. Numerous to abundant pockmarks are present in the north to northwest of the survey area. The closest to the Etame site lies 260 meters to the east-southeast. A number of small objects up to 0.3 meters in height and one small mound (0.6 meters) were identified within the survey area. The closest object to the Etame location lies 510 meters west-southwest.

### **4.3 SUB-SEABED GEOLOGY**

The Etame structure is a presalt play in which the Gamba sandstone has been draped over a pre-existing Dentale fault block. An Aptian salt series (Ezanga) divides the underlying synrift sediments and tectonic structures from the overlying drift-sag sediments, which were dominated by post-Albian salt tectonics (see Figure 4-3).



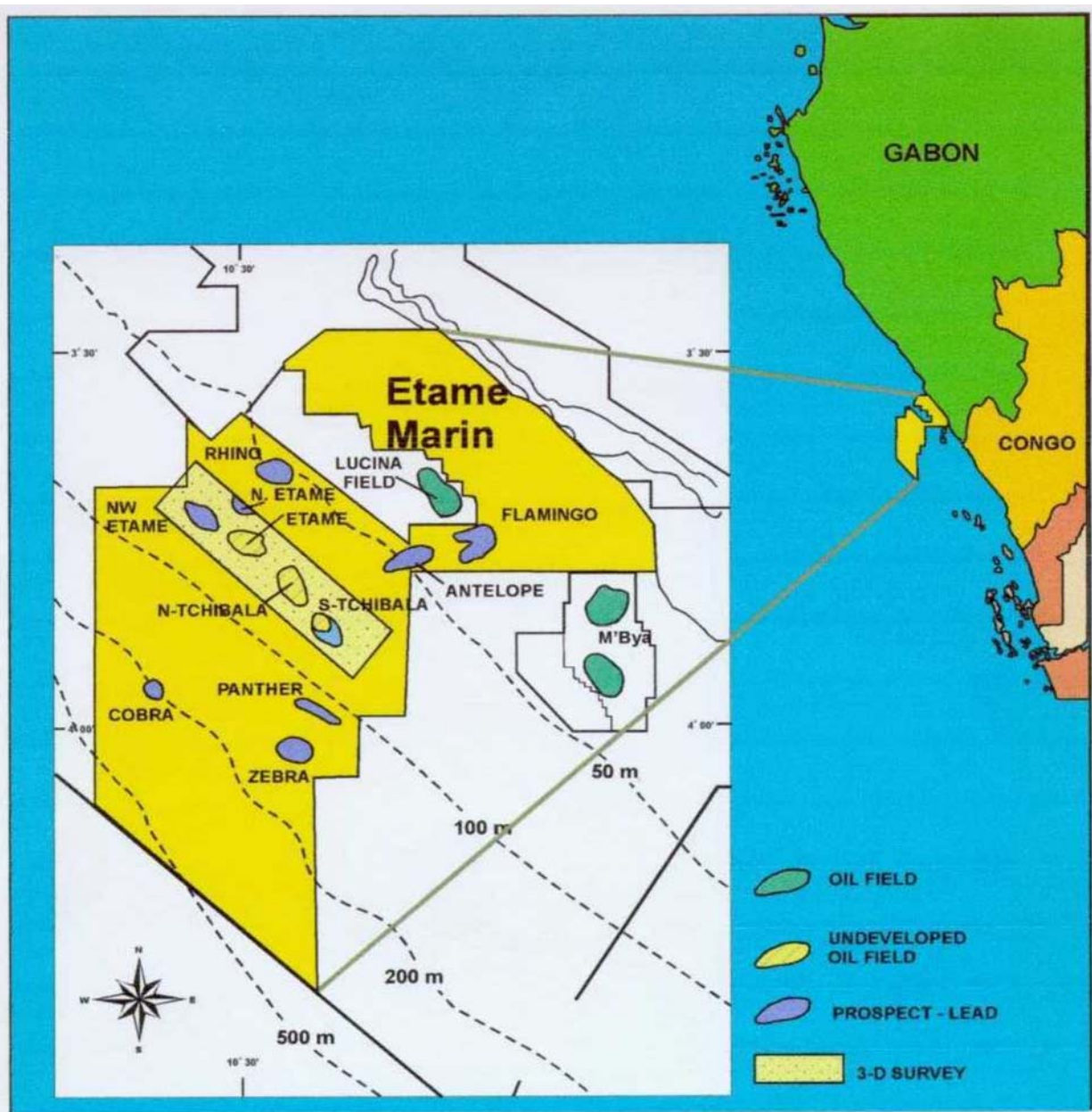


FIGURE 4-1

**FIGURE 4-2**



# ETAME BLOCK: PLAY TYPES

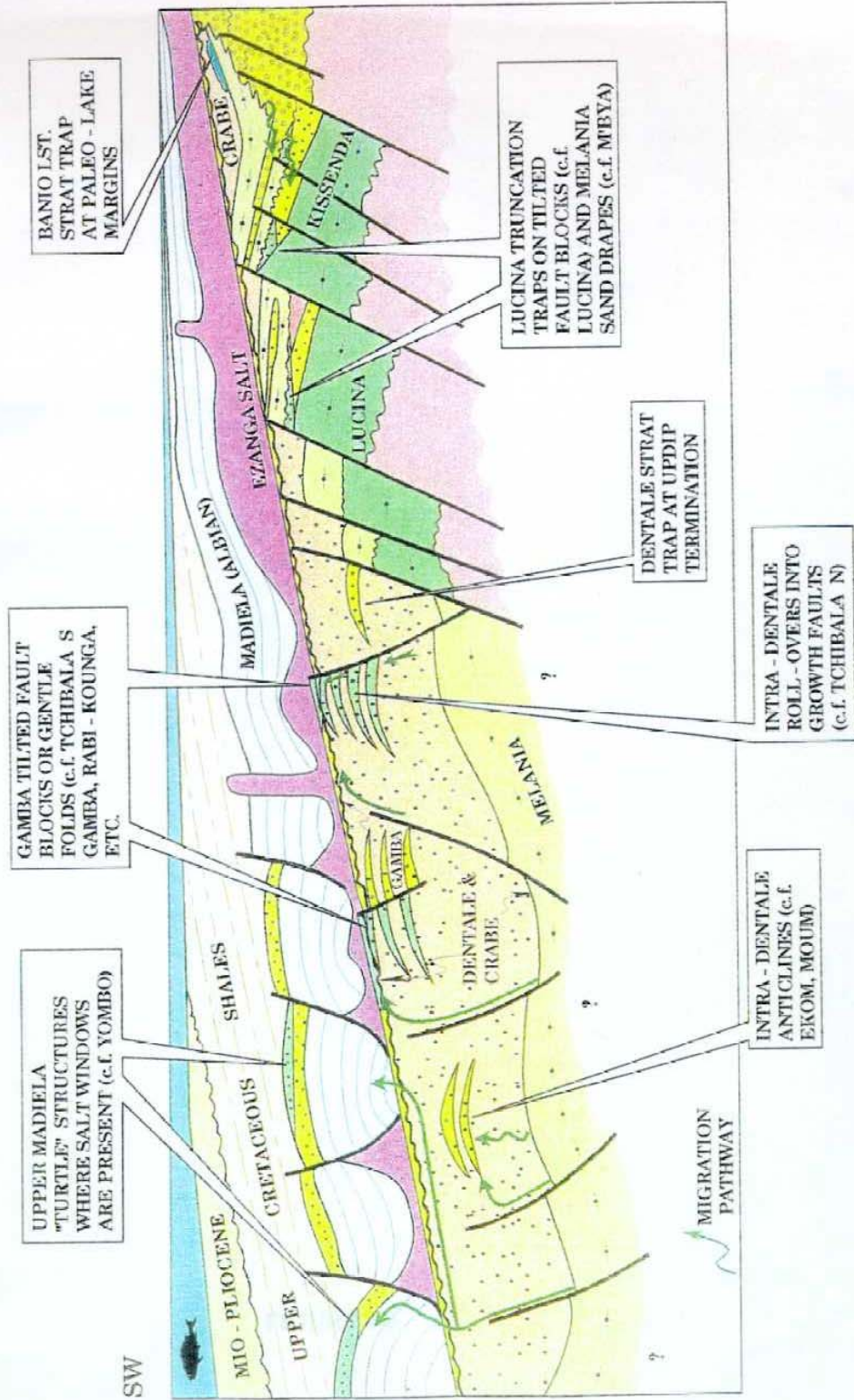


FIGURE 4-3

#### **4.3.1 Presalt**

The earliest sediments within the basin record several episodes of rifting and infilling of lacustrine basins during the early Cretaceous (see Figure 4-4). Thick deposits of mud and organic material accumulated within the deepest areas and became the Kissenda and Melania source rock formations. The early rifting was accompanied by an influx of turbidic sediments of the Melania and Lucina formations. During the later episode, sediment input consisted of fluvial-deltaic sediments of the Crabe and Dentale formations. As rift faulting subsided and the lakes were filled, the area was peneplaned and blanketed with a transgressive marine sand (Gamba) that varied in thickness from 50 meters to less than 5 meters in the distal offshore regions. Once marine circulation had been restricted, 15-20 meters of Vembo shale and several hundred meters of Ezanga salts were deposited over most of the West African basins.

#### **4.3.2 Postsalt**

With the establishment of marine conditions within the Congo Basin, the continents split and continued to drift apart. A thick, wide carbonate platform, the Madiela Formation, developed upon nearshore portions of the basin. Sediments derived from adjacent continental highlands began to fill the basin from the east. This sudden load of sediment deformed the underlying salt sequence, triggering the development of gravity-slide raft blocks, growth faults, and salt structures. As sedimentation forced the organic Melania source rocks deeper, hydrocarbons were matured and expelled into the surrounding Lucina, Dentale and Gamba sandstones.

#### **4.3.3 Reservoirs**

The primary reservoirs of the Etame Marin block are within the presalt section and include the Aptian Gamba sandstone and the Barremian-Aptian Dentale sandstones.

The Gamba Formation, which is the main presalt producing reservoir in Gabon, includes the Rabi-Kounga and Gamba-Ivinga fields. These two fields account for more than one billion barrels of recoverable oil. Reservoir properties are excellent, with porosities ranging from 17-33% and permeabilities of 0.5 to 2 darcies. Reservoir simulation and field analogs suggest that these excellent reservoir qualities, coupled with a moderate-to-strong water drive, could result in recovery efficiencies of 30-50%.

The Dentale Formation was deposited within a fluvial to nearshore lacustrine environment. Changes in sediment input rates and lake levels resulted in the formation of several stratigraphic sequences. A widespread shale unit associated with a maximum flooding unit separates each sequence. Sandstones within the Dentale could have excellent reservoir properties. Within the Etame Marin block, Dentale porosities range from 10-30% and permeability ranges from 10-1,000 md.

# OFFSHORE GABON GENERALIZED STRATIGRAPHIC COLUMN

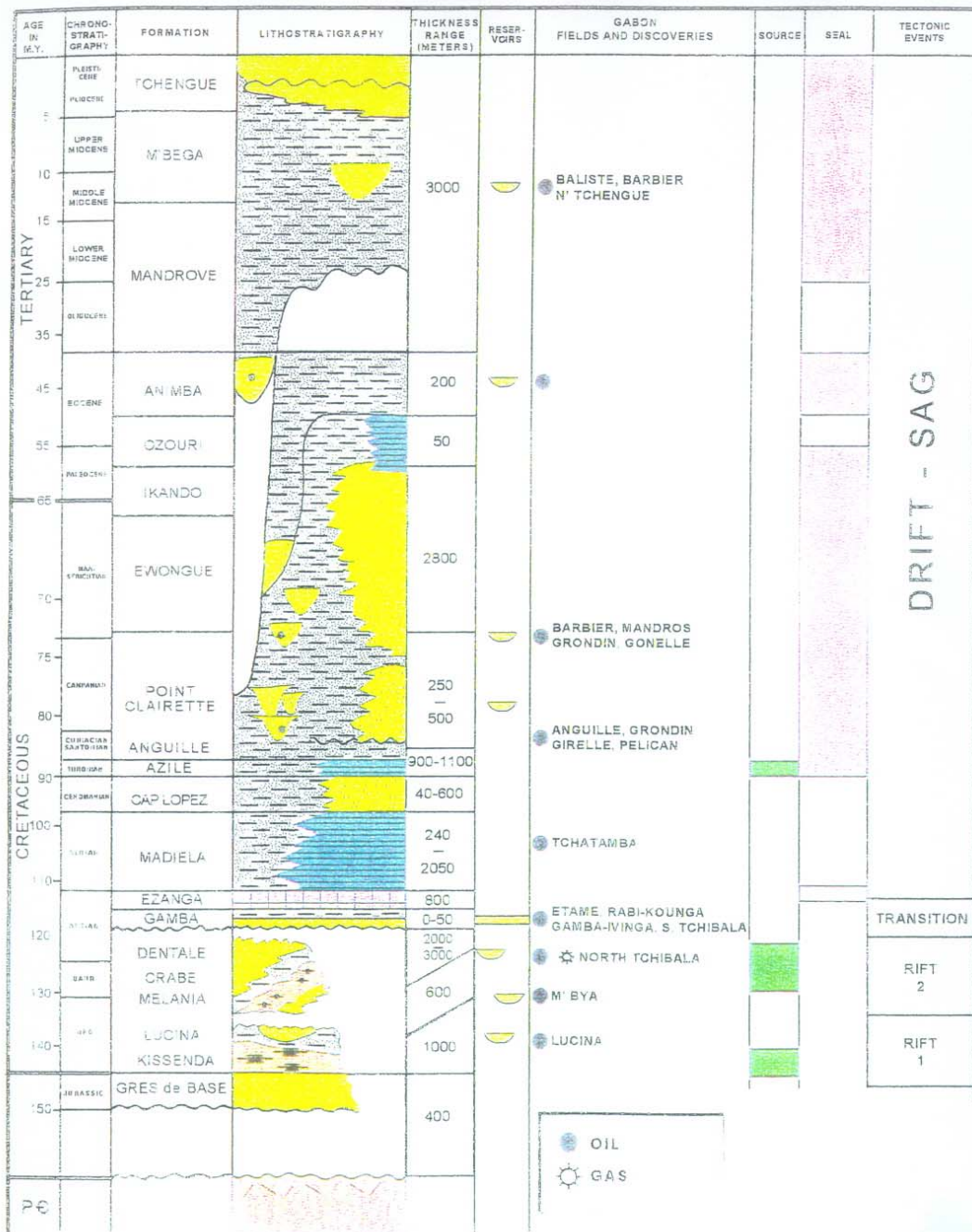


FIGURE 4-4

#### 4.3.4 Source Rock

Melania shale is the primary source rock within the presalt section in the area of the Etame Marin Block. It is a thick sequence of pyritic organic shales with a total organic carbon content that averages 6.1%. Organic matter is predominantly of type I and intermediate type I-II kerogen. Approximately 50% of the kerogen is type II.

#### 4.3.5 Seals

The Gamba sandstone, Vemba shale and evaporites of the Aptian Ezanga formation are extremely effective regional seals that separate the presalt and post salt migration pathways. Secondary seals for Dentale reservoirs are the shale flooding surfaces that separate the major Dentale sequences.

#### 4.3.6 Potential Trap Types

The primary traps for the Gamba sands are four-way structural closures formed over tilted Dentale fault blocks. Dentale reservoirs are both high-side fault closures and syndepositional four-way rollover structures. Dual targets of both Gamba and Dentale traps add to the prospectivity of the block.

### 4.4 CLIMATE AND METEOROLOGY

#### 4.4.1 Air Temperature

Gabon is located at the heart of the equatorial zone. The climate is generally hot and humid, with abundant and frequent precipitation. Seasons are more clearly distinguishable by rainfall and wind direction than by temperature. Temperatures tend to be cooler in the months of June, July and August and warmer in March and April. Table 4-1 shows the minimum and maximum design temperatures used for the project.

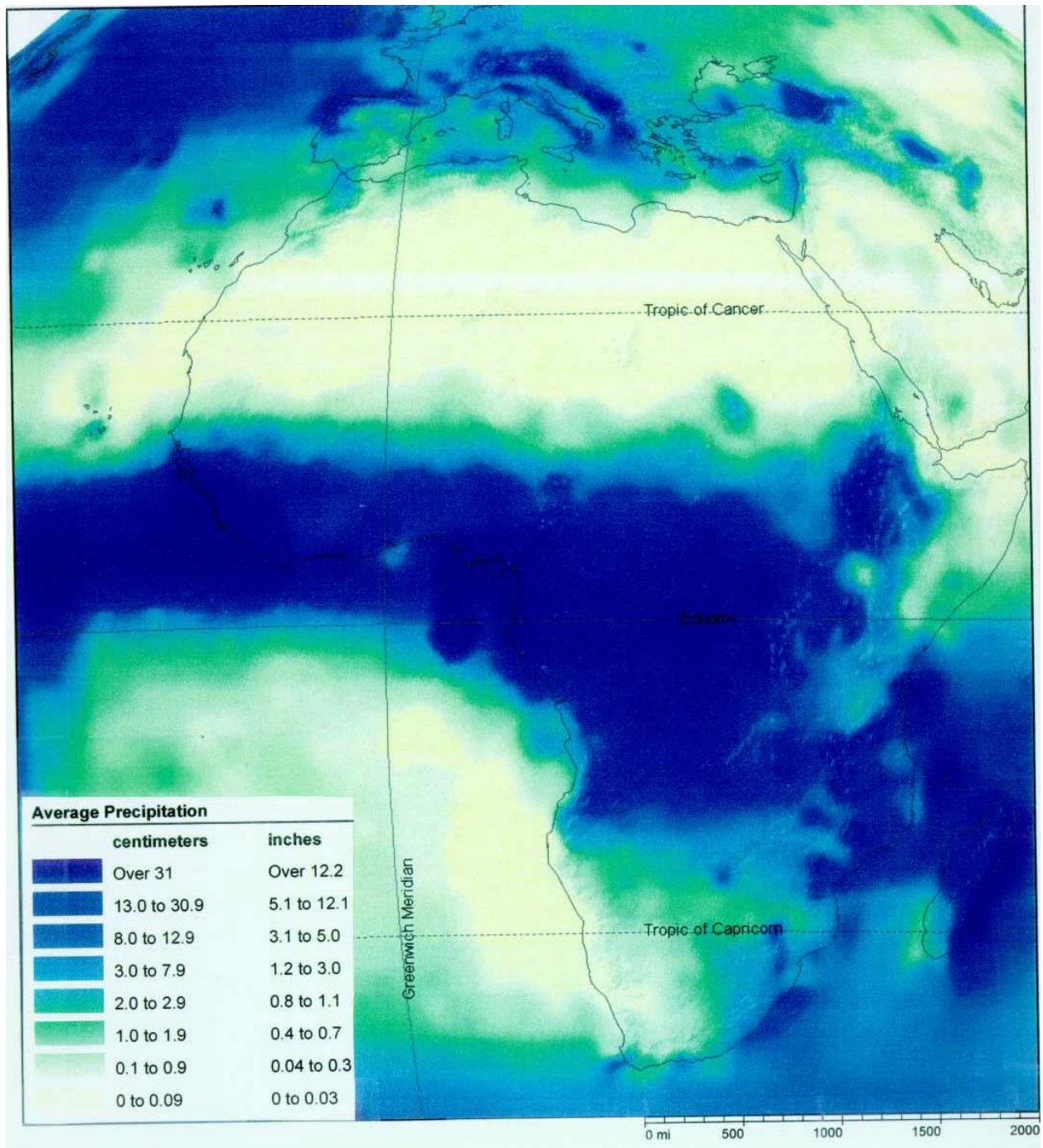
**TABLE 4-1 ETAME FIELD: EXTREME AIR TEMPERATURE**

	Return Period (years)				
	1	5	10	50	100
Maximum Air Temperature (C°)	32.4	32.9	33.1	33.5	33.7
Minimum Air Temperature (C°)	16.7	16.0	15.7	15.0	14.7



#### 4.4.2 Precipitation

Relative humidity is usually greater than 80% throughout the year. Average annual rainfall is 1.4 meters in southern Gabon. In general, precipitation decreases inland and to the south.



Depending on the area of the country, Gabon can have four distinct seasons:

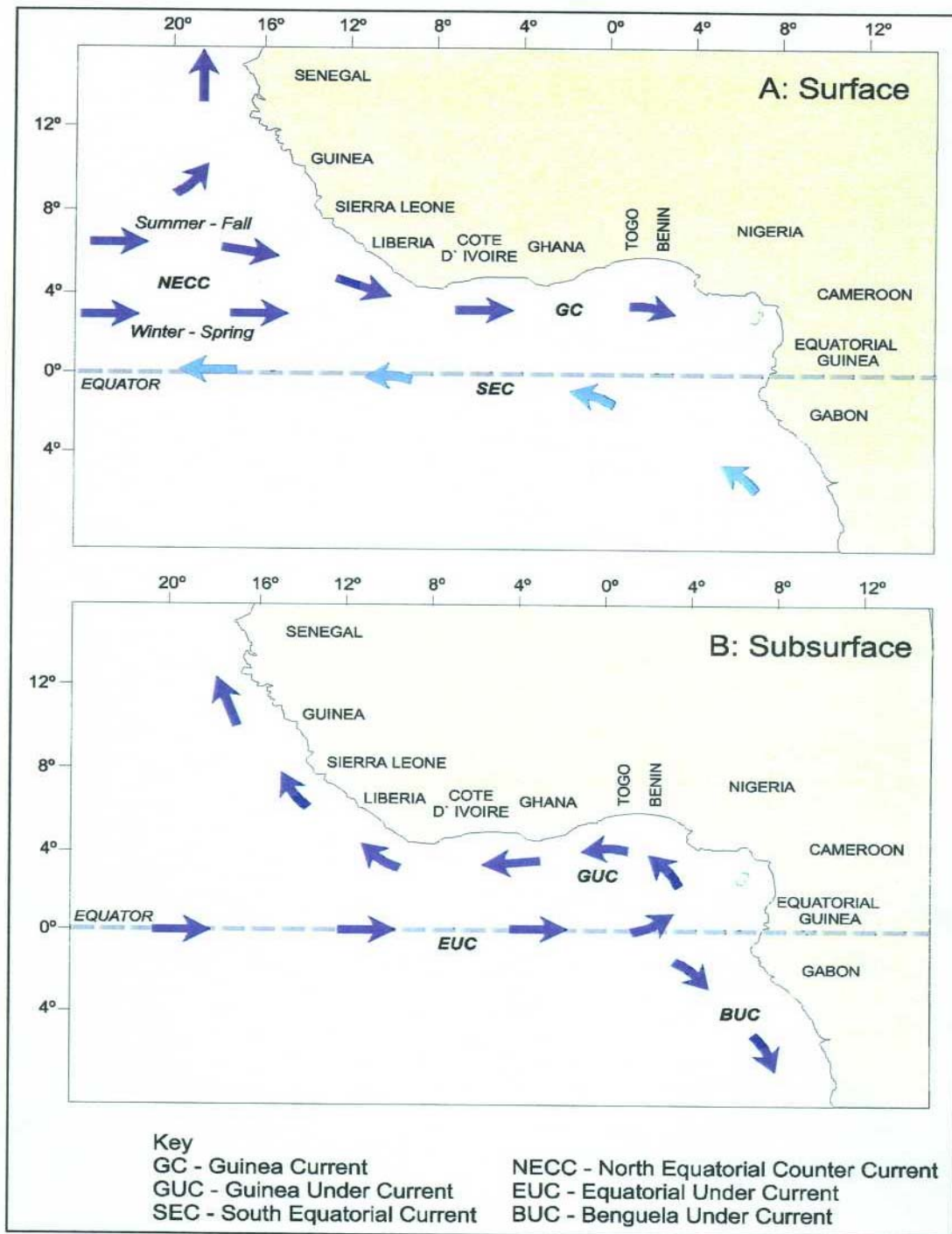
- ◆ The whole country experiences a dry season in July and August, with an increased dry season from the northeast (2 months) to the southwest (more than 4 months).
- ◆ Beginning in October, abundant rain reaches the southern part of Gabon.
- ◆ In January and February, southern Gabon sees a decrease in rain.
- ◆ Beginning in March-April, Gabon is again subjected to Monsoon rains that travel from south to north, producing the second rainy season of the year.

#### 4.4.3 Winds

Wind data from the SEADATA study show that wind speeds occur in all direction sectors, although the dominant directions are from southeast to the southwest quadrants. Almost 45% of all winds were from a southerly direction. Maximum wind speed ( $>17.5\text{ms}^{-1}$ ) occurred in the southeast direction. Table 4-2 provides a tabulated summary of the design wind criteria.

**TABLE 4-2 ETAME FIELD: MEAN AND GUST WIND SPEED**

	Return Period (years)					Return Period (years)					Return Period (years)				
	1	5	10	50	100	1	5	10	50	100	1	5	10	50	100
	U <sub>1-hr</sub> (ms <sup>-1</sup> )					U <sub>60-s</sub> (ms <sup>-1</sup> )					U <sub>3-s</sub> (ms <sup>-1</sup> )				
All-Year	16.1	18.1	18.9	20.8	21.7	19.2	21.6	22.6	25.0	25.9	24.0	26.9	28.2	31.1	32.3
Jan.	14.4	16.2	17.0	18.7	19.5	17.3	19.4	20.3	22.4	23.3	21.5	24.2	25.3	27.9	29.1
Feb.	14.3	16.1	16.8	18.6	19.3	17.1	19.2	20.2	22.2	23.1	21.3	24.0	25.1	27.7	28.8
March	14.3	16.0	16.8	18.5	19.3	17.1	19.2	20.1	22.2	23.0	21.3	23.9	25.0	27.6	28.7
April	14.5	16.3	17.0	18.8	19.5	17.3	19.5	20.4	22.5	23.4	21.6	24.2	25.4	28.0	29.1
May	14.6	16.4	17.2	18.9	19.7	17.5	19.6	20.5	22.6	23.5	21.7	24.4	25.6	28.2	29.3
June	14.3	16.1	16.8	18.5	19.3	17.1	19.2	20.1	22.2	23.1	21.3	23.9	25.1	27.6	28.7
July	14.2	15.9	16.7	18.4	19.1	17.0	19.1	20.0	22.0	23.9	21.1	23.7	24.9	27.4	28.5
August	14.6	16.4	17.2	18.9	19.7	17.5	19.6	20.5	22.7	23.6	21.7	24.5	25.6	28.2	29.3
Sep.	15.4	17.5	18.3	20.2	21.0	18.6	20.9	21.9	24.1	25.1	23.2	26.1	27.3	30.1	31.3
Oct.	16.1	18.1	18.9	20.8	21.7	18.2	21.6	21.6	25.0	25.9	24.0	26.9	28.2	31.1	32.3
Nov.	15.7	17.6	18.4	20.3	21.1	18.8	21.1	21.1	24.3	25.3	23.4	26.3	27.5	30.3	31.5
Dec.	15.0	16.9	17.7	19.5	20.3	18.0	20.2	20.2	23.4	24.3	22.4	25.2	26.4	29.1	30.2
N	12.0	13.5	14.1	15.6	16.2	14.3	16.1	16.9	18.6	19.4	17.9	20.1	21.0	23.2	24.1
NE	12.4	14.0	14.6	16.1	16.8	14.9	16.7	17.5	19.3	20.1	18.5	20.8	21.8	24.0	25.0
E	12.1	13.6	14.3	15.7	16.4	14.5	16.3	17.1	18.8	19.6	18.1	20.3	21.3	23.5	24.4
SE	15.6	17.6	18.4	20.3	21.1	18.7	21.0	22.0	24.3	25.2	23.3	26.2	27.4	30.2	31.4
SE	16.1	18.1	18.9	20.8	21.7	19.2	21.6	22.6	25.0	25.9	24.0	26.9	28.2	31.1	32.3
SW	15.6	17.6	18.4	20.3	21.1	18.7	21.1	22.0	24.3	25.3	23.3	26.2	27.5	30.3	31.5
W	13.5	15.2	15.9	17.5	18.2	16.2	18.2	19.0	21.0	21.8	20.1	22.6	23.7	26.1	27.2
NW	12.9	14.5	15.2	16.8	17.4	15.5	17.4	18.2	20.1	20.9	19.3	21.7	22.7	25.0	26.0



**FIGURE 4-6**

## 4.5 OCEANOGRAPHY

### 4.5.1 Currents

There are five distinct oceanic currents on the west coast of Africa (see Figure 4-6).

All of the these currents are essentially wind-driven:

- ◆ Benguela Current - flows along the coast of the southwest African zone, veering offshore at about 6°S. With current speeds of approximately 20 centimeters per second, the Benguela Current transports cool water toward the Equator.
- ◆ Guinea Current - flows eastward and southeastward along the coast of the Gulf of Guinea, almost to the Equator.
- ◆ North Equatorial Counter-Current - In the Gulf of Guinea, high precipitation and numerous coastal rivers result in large masses of warm (above 24°C) and low salinity water circulating above colder water (UNEP/IUCN 1988).
- ◆ Equatorial Under Current (or Guinea Under Current) –Current flows eastward along the equator, eventually reversing in a westerly direction.
- ◆ South Equatorial Current - flows west from the coast between 10°S and the Equator.

Another dominant hydrographic feature in the Gulf of Guinea is the seasonal coastal upwelling that is very pronounced along the coast of Gabon. Upwelling systems are distinct regions of the ocean where water from shallow or intermediate depths is brought to the surface, replacing warm surface waters with cooler deeper waters. This supplies the photic zone with nutrients that stimulate and sustain a high planktonic community (Mensah and Koranteng, 1988). As the surface temperature falls, salinity increases and dissolved oxygen levels generally fall

#### 4.5.2 Surge

Table 4-3 provides a tabulated summary of the 1, 5, 10, 50 and 100-year design surge and total still waters design criteria.

**TABLE 4-3 ETAME FIELD: EXTREME SURGE/ TOTAL STILL WATER ELEVATION**

	Return Period (years)				
	1	5	10	50	100
Positive Total Elevation (m)	1.12	1.19	1.22	1.28	1.31
Negative Total Elevation (m)	-1.05	-1.11	-1.14	-1.19	-1.21
Positive Surge Elevation (m)	0.34	0.37	0.38	0.41	0.42
Negative Surge Elevation (m)	-0.30	-0.33	-0.34	-0.36	-0.37



### 4.5.3 Waves

Table 4-4 provides a tabulated summary of the 1, 5, 10, 50 and 100-year design wave criteria.

**TABLE 4-4 ETAME FIELD: EXTREME WAVE HEIGHT & ASSOCIATED PERIOD**

	Return Period (years)					Return Period (years)					Return Period (years)				
	1	5	10	50	100	1	5	10	50	100	1	5	10	50	100
	H <sub>s</sub> (m)					Swell T <sub>z</sub> (central) (s)					Total T T <sub>z</sub> (central) (s)				
All-Year	3.1	3.4	3.6	3.9	4.0	10.5	10.9	11.2	11.7	11.8	8.9	9.3	9.5	9.8	9.9
Jan.	2.5	2.7	2.8	3.1	3.2	9.4	9.8	10.0	10.5	10.6	8.2	8.4	8.6	8.9	9.1
Feb.	2.4	2.6	2.8	3.0	3.1	9.3	9.6	10.0	10.3	10.5	8.0	8.3	8.6	8.8	8.9
March	2.5	2.7	2.9	3.1	3.2	9.4	9.8	10.1	10.5	10.6	8.2	8.4	8.7	8.9	9.1
April	3.0	3.3	3.5	3.8	3.9	10.3	10.8	11.1	11.5	11.7	8.8	9.2	9.4	9.7	9.8
May	3.1	3.4	3.6	3.9	4.0	10.5	10.9	11.2	11.7	11.8	8.9	9.3	9.5	9.8	9.9
June	3.1	3.4	3.6	3.9	4.0	10.5	10.9	11.2	11.7	11.8	8.9	9.3	9.5	9.8	9.9
July	3.1	3.4	3.6	3.9	4.0	10.5	10.9	11.2	11.7	11.8	8.9	9.3	9.5	9.8	9.9
August	3.1	3.4	3.6	3.9	4.0	10.5	10.9	11.2	11.7	11.8	8.9	9.3	9.5	9.8	9.9
Sep.	3.0	3.3	3.5	3.8	3.9	10.3	10.8	11.1	11.5	11.7	8.8	9.2	9.4	9.7	9.8
Oct.	3.0	3.3	3.5	3.8	3.9	10.3	10.8	11.1	11.5	11.7	8.8	9.2	9.4	9.7	9.8
Nov.	3.0	3.2	3.4	3.7	3.8	10.3	10.6	10.9	11.4	11.5	8.8	9.1	9.3	9.6	9.7
Dec.	2.5	2.7	2.9	3.1	3.2	9.4	9.8	10.1	10.5	10.6	8.2	8.4	8.7	8.9	9.1
N	2.3	2.5	2.7	2.9	3.0	9.1	9.4	9.8	10.1	10.3	7.9	8.2	8.4	8.7	8.8
NE	2.1	2.3	2.4	2.6	2.7	8.7	9.1	9.3	9.6	9.8	7.6	7.9	8.0	8.3	8.4
E	2.3	2.5	2.6	2.9	2.9	9.1	9.4	9.6	10.1	10.1	7.9	8.2	8.3	8.7	8.7
SE	2.4	2.7	2.8	3.1	3.2	9.3	9.8	10.0	10.5	10.6	8.0	8.4	8.6	8.9	9.1
SE	3.1	3.4	3.6	3.9	4.0	10.5	10.9	11.2	11.7	11.8	8.9	9.3	9.5	9.8	9.9
SW	3.1	3.4	3.6	3.9	4.0	10.5	10.9	11.2	11.7	11.8	8.9	9.3	9.5	9.8	9.9
W	2.8	3.1	3.3	3.6	3.7	10.0	10.5	10.8	11.2	11.4	8.6	8.9	9.2	9.5	9.6
NW	2.7	2.9	3.1	3.3	3.4	9.8	10.1	10.5	10.8	10.9	8.4	8.7	8.9	9.2	9.3

### 4.5.4 Sea Temperature and Salinity

Sea temperature and salinity data were extracted from the NOAA archive, NODC (1991) to produce the minimum, mean and maximum sea temperature and salinity at standard oceanographic depths during each calendar month (see Figures 4-7 through 4-12). Like air temperatures, surface sea temperatures reach a maximum in March, April and May, and are at a minimum in June, July and August. Salinity fluctuations are relatively small. Surface salinity is generally less than salinity at depths greater than 50 meters.

Figure H1 - Sea Water Temperature Profiles: January, February, March and April

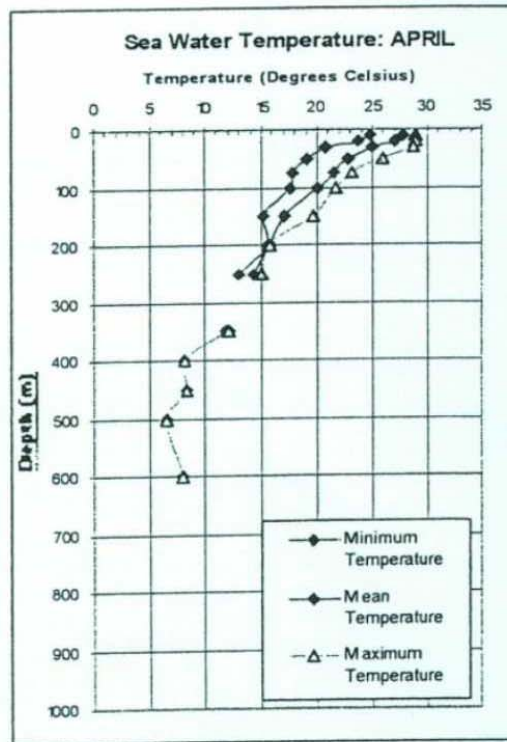
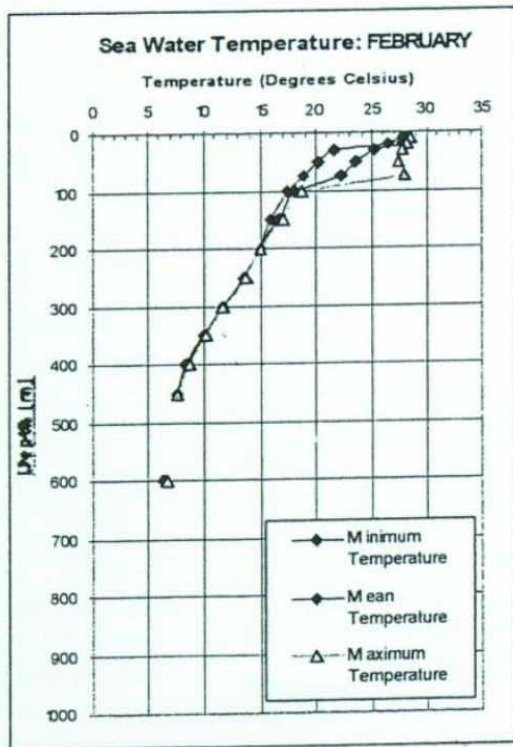
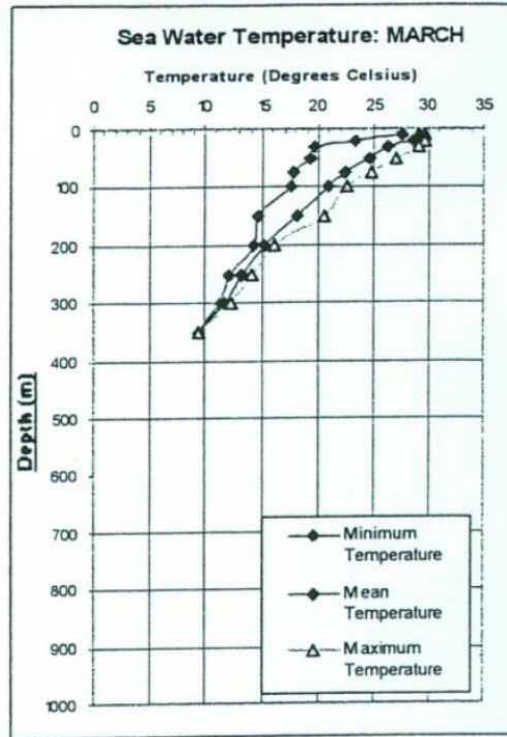
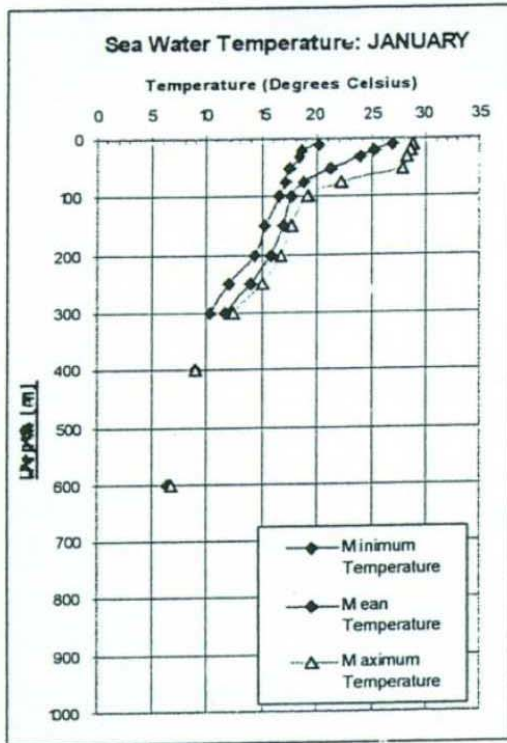


Figure H2 - Sea Water Temperature Profiles: May, June, July and August

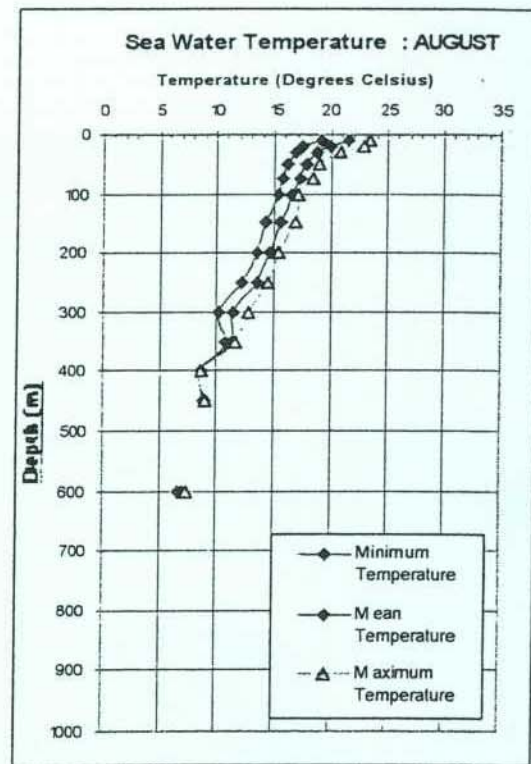
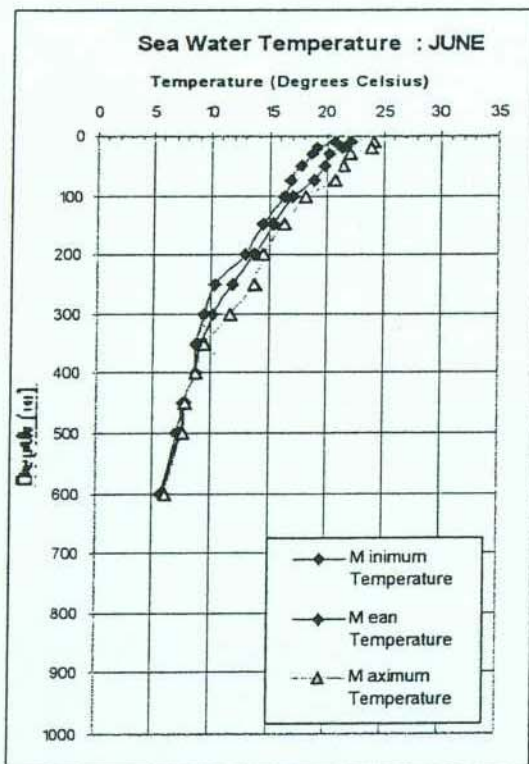
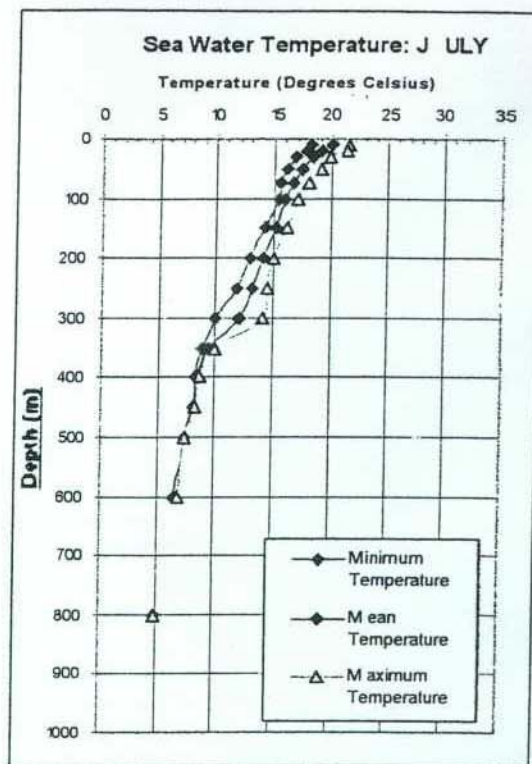
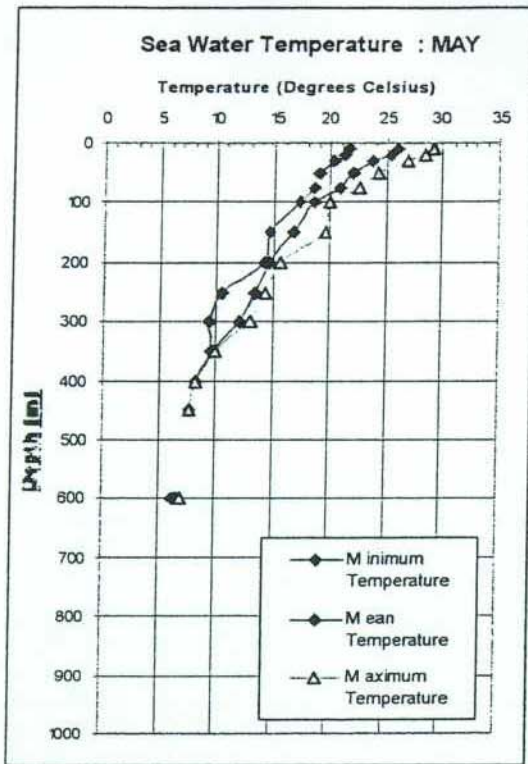


Figure H3 - Sea Water Temperature Profiles: September, October, November and December

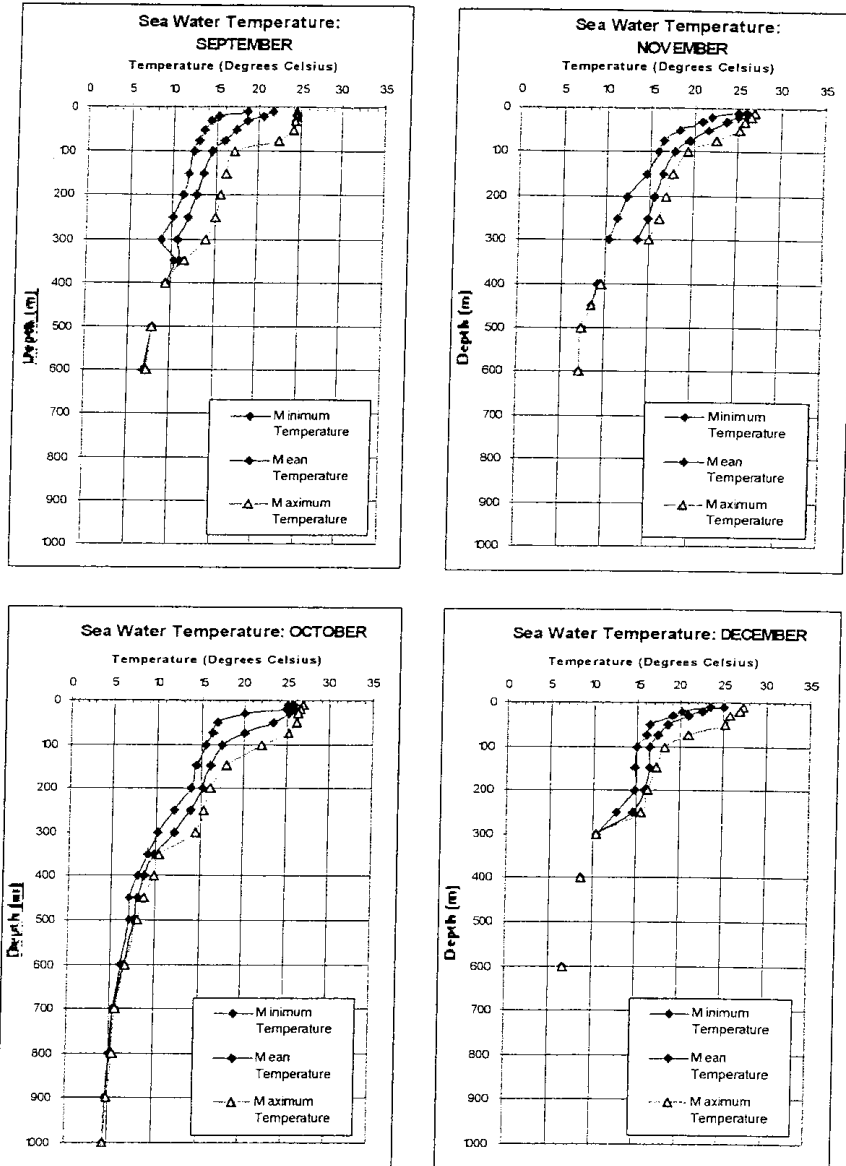


FIGURE 4-9

Figure H4 - Sea Water Salinity Profiles: January, February, March and April

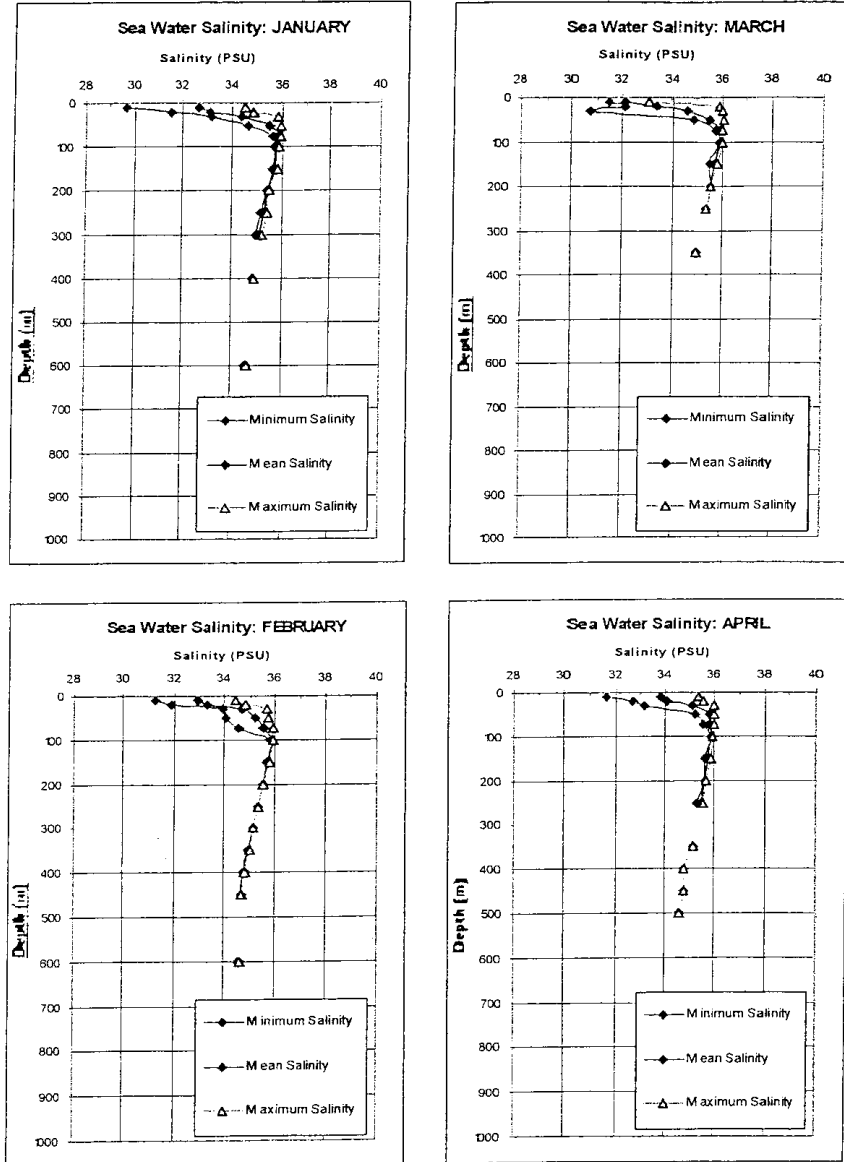


FIGURE 4-10

Figure H5 - Sea Water Salinity Profiles: May, June, July and August

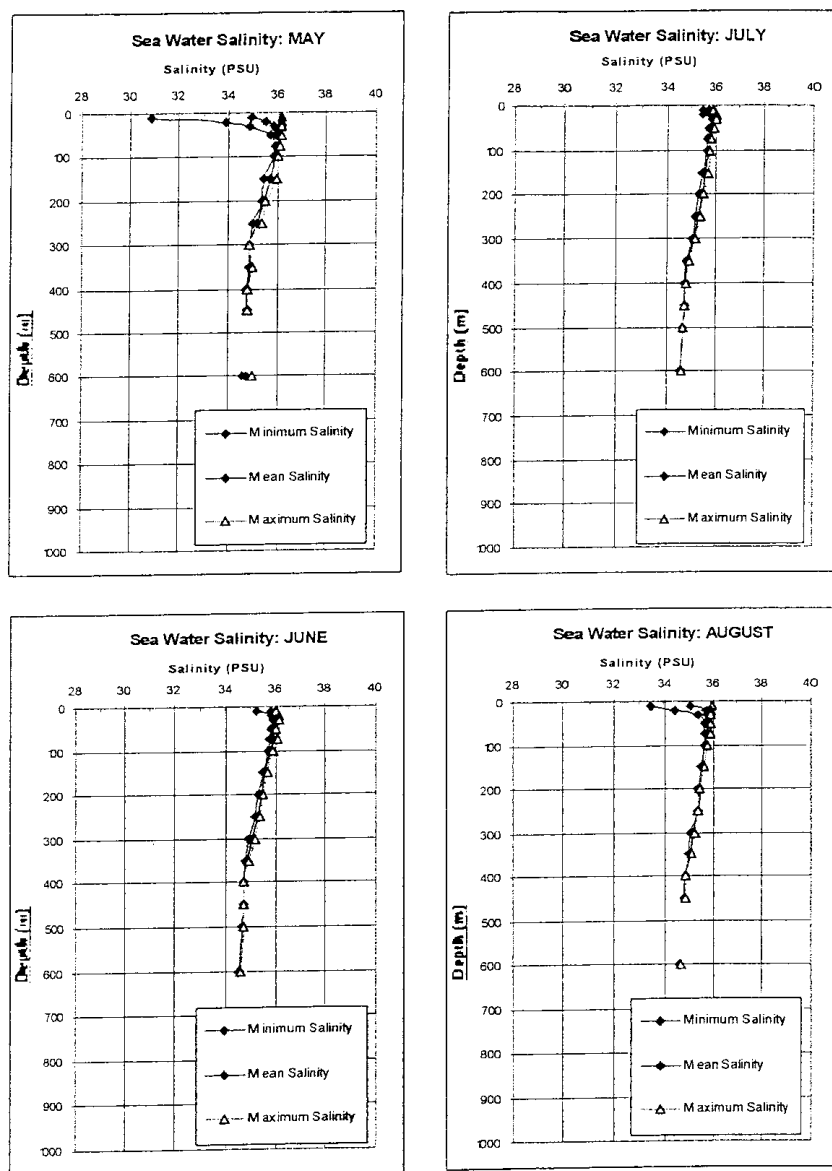


FIGURE 4-11

Figure H6 - Sea Water Salinity Profiles: September, October, November and December

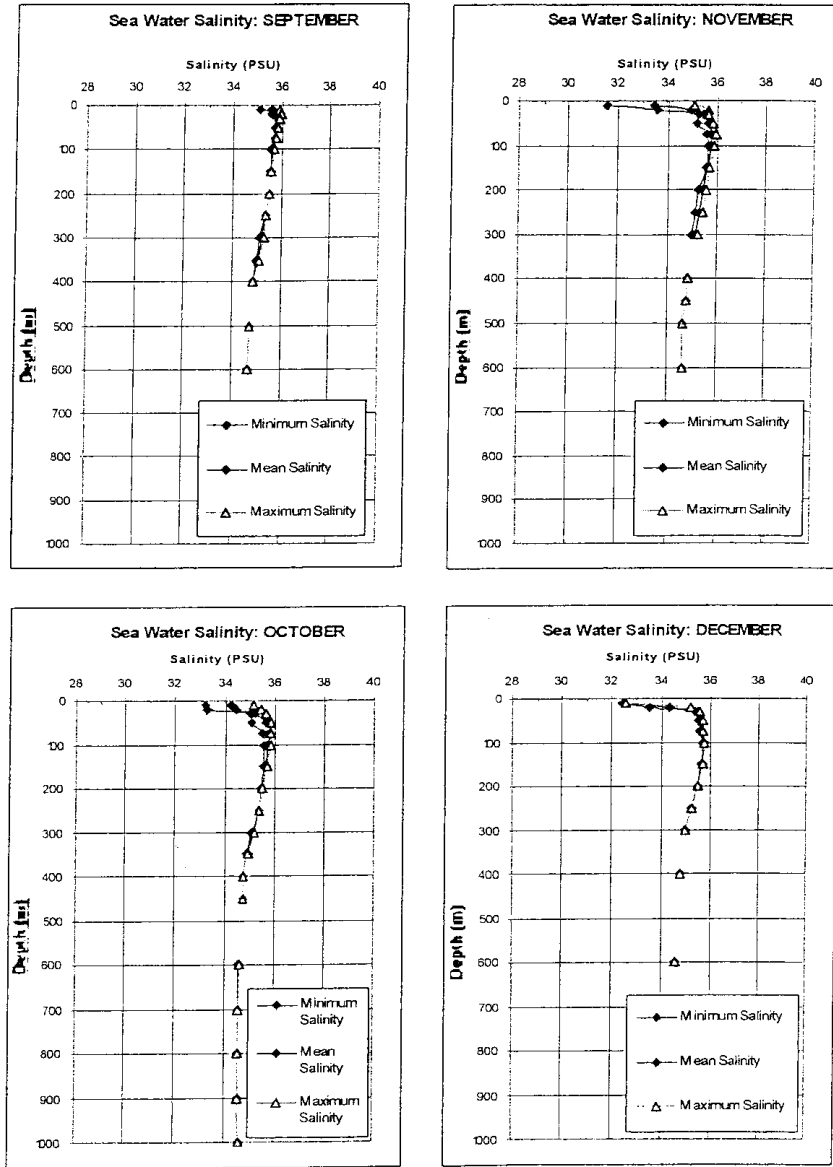


FIGURE 4-12

#### **4.5.5 Water Quality**

Data are lacking on the concentrations of contaminants in the waters of the Gulf of Guinea. With the increased oil and gas activity along the West Coast of Africa since the 1970's, it is possible that the levels of hydrocarbons in the environment has increased. However, monitoring data is not available for the Gulf of Guinea (and more specifically, southern Gabon), so this phenomenon has not been verified.

The large volumes of runoff and significant river flows of equatorial Africa result in a large input of nutrients to the Gulf of Guinea. Furthermore, it might be expected that certain rivers would transport a significant amount of pollution from domestic, agricultural and industrial sources inland. However, this has not been quantified and the significance of this remains uncertain.



## 5.0 DESCRIPTION OF THE BIOLOGICAL ENVIRONMENT

### 5.1 INTRODUCTION

Gabon lies entirely within the Guineo-Congolian regional center of endemism, and is the most biologically diverse region in the continent. The coast of Gabon comprises two distinct sections. The northern section lies on the Bight of Biafra and is characterized by areas of marsh and mangrove associated with the River Gabon and its tributaries, as well as a series of estuaries and lagoons associated with the northern part of the Fleuve Ogooue system. (Davis *et. al.*, 1989; Hughes and Hughes, 1991; McShane, 1990; Nicoll and Langrand, 1986).

The Etame Marin concession is located in the southern section, south of the Bight of Biafra. This area characteristically has no beaches or favorable conditions for the development of mangroves.

### 5.2 MARINE LIFE

#### 5.2.1 Plankton

Microscopic, free-floating organisms called plankton are present in the water column of all marine environments. Plankton consists of either plant (phytoplankton) or animal (zooplankton) microscopic organisms. Plankton is an essential part of the ecosystem because it represents the primary target species of all marine food chains. A measurement of planktonic productivity reflects the productivity of the ocean area. Hence, the higher the planktonic productivity, the more likely productivity of other marine species will be high.

The phytoplankton initiate planktonic productivity with a seasonal increase in production, known as a phytoplanktonic bloom. Such bloom patterns are triggered by a variety of physicochemical factors such as light, nutrient availability, salinity, water temperature and vertical depth of the organism in the water column. The productivity and availability of phytoplankton varies year round, depending on the water conditions. Zooplankton blooming often occurs once phytoplankton productivity has increased. Table 5-1 illustrates the likely timing of both life forms.

**TABLE 5-1     LIKELY TIMING OF PLANKTONIC BLOOMING**

Month	J	F	M	A	M	J	J	A	S	O	N	D
Phytoplankton												

Zooplankton												
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#### 5.2.1.1 Phytoplankton

To date, data on phytoplanktonic activity in the area of the proposed drilling are somewhat scarce. However, studies conducted closer to the Gabonese shore indicate phytoplankton cell counts, chlorophyll *a* concentrations and primary productivity rates are as high as >1,000 mg C/m<sup>2</sup>/day. It would be expected that this productivity would drop further out from the coast (150-250 mg C/m<sup>2</sup>/day) because of increases in water depths (and decreases in available light) and increases in the distance from nutrient-rich upwellings and river outfalls. The predominant species of phytoplankton found nearshore include *Skeletonema spp.*, *Nitzschia spp.*, *Thalassioria spp.*, *Peridinium*, *Ceratium*, *Prorocentrum* and *Dinophysis* (Anang 1979).

#### 5.2.1.2 Zooplankton

Zooplanktonic sampling along the coast of Gabon has shown that the most prominent taxonomic groups include Copepoda, Ostracoda, Cladocera, Decapoda, Larvacca, Thaliacea and Chaetognatha. Importantly, copepods are prevalent throughout the area where the species *Calanoides carinatus* is the most abundant. *Calanoides* spp. provides the principle target species for commercially important pelagic and demersal fish populations. Copepods may constitute up to 88% of plankton in the coastal areas and up to 20-40% in open waters during the upwelling season (Mensah, 1995).

### 5.2.2 Benthos

A number of animal species utilize the seabed or benthic environment as a habitat. Benthic species may colonize the sediment surface (epifauna) or burrow beneath the sediment (infauna). Most benthic species are generally sedentary, consisting of deposit feeders and small predators.

Previous studies that have been completed in the Gulf of Guinea indicate that the region exhibits high benthic diversity and that no one species dominates (Sanders & Hessler 1969). At water depths of approximately 80 meters, there is a notable change in the community structure. Table 5-2 provides a summary of typical deepwater benthic communities typically present in the area.

## 5.3 TURTLES

The beaches along southern Gabon hold the largest number of leatherback turtles (*Dermochelys coriacea*) in the world (IUCN 2001). Leatherback turtles are listed as an endangered species by the ICUN. Between 1,300 to 2,600 female leatherbacks are estimated to lay their eggs there. Each year, from the end of September through November, these amphibians swim ashore, dig nests, lay dozens of eggs, and return to the sea. The green turtle, the hawksbill, the olive ridley and the loggerhead turtle are less in evidence in Gabon.



**TABLE 5-2 TYPICAL GULF OF GUINEA DEEPWATER BENTHIC COMMUNITIES**

<b>COMMUNITY</b>	<b>HABITAT</b>	<b>CHARACTERISTIC SPECIES</b>	<b>PHYLOGENETIC GROUP</b>
<b>Deep Shelf Community</b>	Shelly sand and shelly mud	Leptometra celtica Hyalonoeia tubicola	Crinoid Echinoderm
		Ophiothrix tormentosa Cidaris cidaris Cuspidaria cuspidata Stichopus regalis	Ophiuroid Echinoderm Echinoid Echinoderm Bivalve Mollusc Holothuroid Echinoderm
<b>Deep Water Community</b>	Silty sand and clay	Schizammia furcata Pannatula rubra Harmothoe antilopis Leanira yhleni  Choloeia venusta	
<b>Continental Slope Community</b>	On the continental edge	Geodia sp. Quadrangularis Stereomastis sculpta Polychaetes typhlops Ophiacantha abyssicola Aerosoma hystric Theana muricata Eunoe nodosa Lepidasthenia brunnea Paramphionome trionyx	Porifera (sponge) Decapod Crustacean Decapod Crustacean Ophiuroid Echinoderm

## 5.4 FISH

The variety of fish is less diverse off southern Gabon than in other tropical areas because of water turbidity and a lack of coral reef deposition. Species are categorized depending on whether they are bottom-dwelling (demersal) or open water (pelagic). The distribution of fish in the Gulf of Guinea is mainly influenced by the bathymetry of the area. Table 5-3 summarizes the deepwater demersal and pelagic species that are typically present in the Gulf of Guinea.

Commercial fishing is not particularly important and is mainly carried out by independent fishermen. In 1998, the European Community and the Republic of Gabon signed a fishing agreement that set protocol for fishing opportunities in Gabonese waters, as well as terms of financial compensation.

**TABLE 5-3 TYPICAL GULF OF GUINEA  
DEMERSAL AND PELAGIC SPECIES**

<b>TYPE OF SPECIES</b>	<b>SPECIES</b>	<b>COMMON NAME AND FAMILY</b>
<b>Large Pelagic</b>	Thunnus albacares, Thunnus obesus, Katsuwonus pelamis, Euthynus alletteratus, Istiophorus albicans, Xiphias gladius, Makaira nigricans, Tetrapturus albidus	Tuna (Thunnidae)
<b>Deepwater Demersal</b>	Geryon maritae, Ariomma bondi Penteroscion mbizi  Parapenaeus longirostris	Deep sea crabs Croackers, drums (Scianidae)  Geryonidae Shrimp Penaeidae

## **5.5 INVERTEBRATES**

Lobsters are fished throughout the region, while deepwater shrimp and prawns are trawled as well. Intertidal mollusks are harvested on a daily basis.

## **5.6 MARINE MAMMALS**

The humpback whale (*Megaptera novaeangliae*) is known to inhabit or migrate through an area offshore Port Gentil, which is more than 200km north of the Etame Marin concession. A research project led by the Wildlife Conservation Society (WCS) recently confirmed that the site compares with some of the largest breeding areas in the world (WCMC 2001). The whales spend the summer in the cold waters around Antarctica and then migrate northwards along the coast of Gabon at the onset of winter (See Figure 5-1). Whale surveys are now being expanded to areas offshore southern Gabon. According to some marine biologists, the humpbacks are particularly attracted to the multitude of oil rigs in the area.

## Probable Distribution of Cetaceans: West Africa

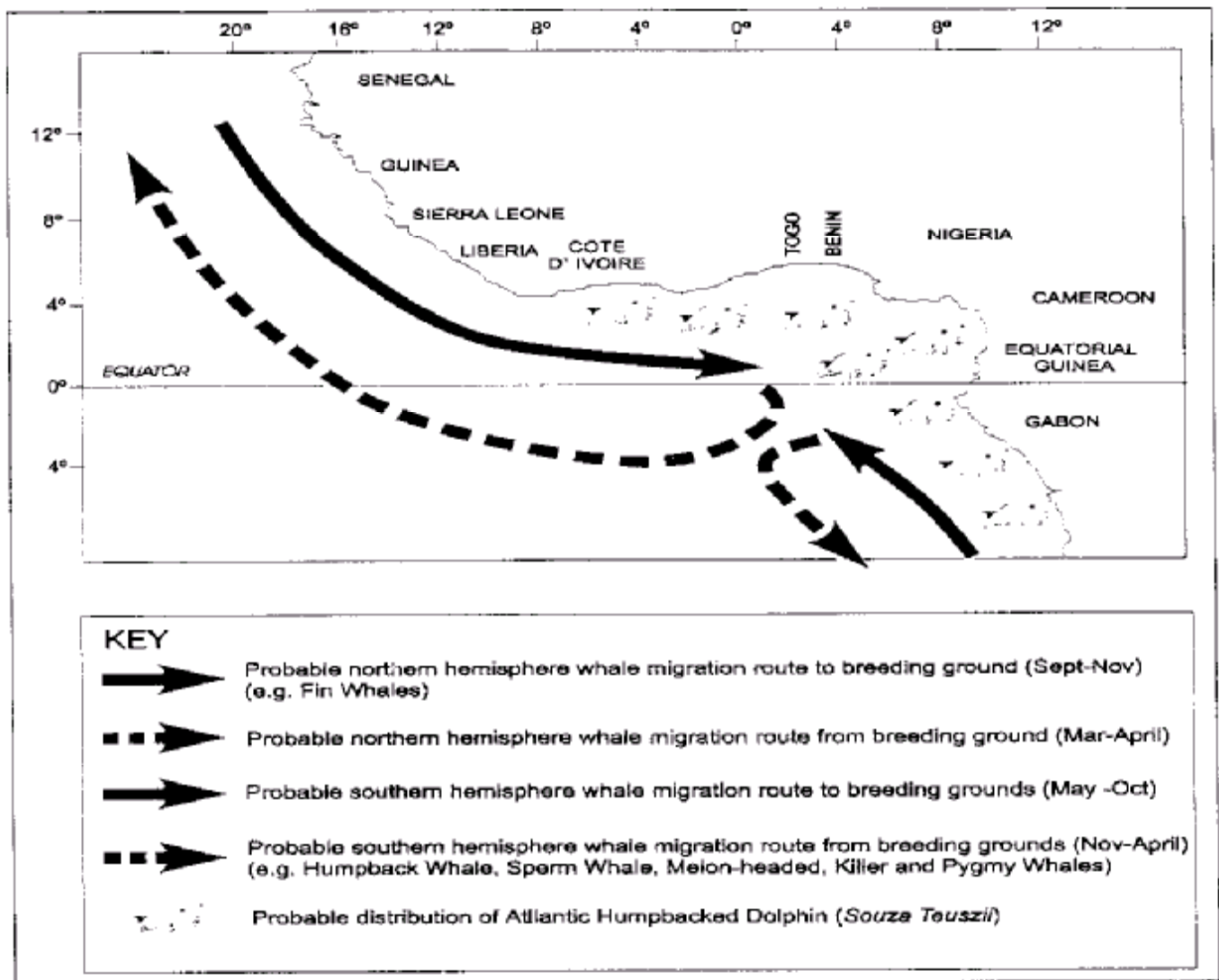


FIGURE 5-1

## **5.7 BIRDS**

The coast of Gabon is visited seasonally by millions of migratory birds, especially waders. Descriptions of important sites can be found in Hughes and Hughes (1992). The only large concentrations of seabirds are in Mauritania, the Gambia and Senegal, where the hinterland is arid and coastal deposition of sand creates predator-free islets (Cooper, Williams, and Britton 1984). There are no known migratory routes for land birds in the concession.

## **5.8 SENSITIVE HABITATS**

### **5.8.1 Coral Reefs**

There are no true reefs along the West African coast or in the archipelagos of the Gulf of Guinea and Cape Verde because of the cool waters of the Benguela and Canary currents.

### **5.8.2 Mangroves**

Over 25,000 square kilometers of mangroves extend along the West African. The northern limit of mangrove distribution is just north of Tidra Island in Mauritania; further north the cold Canary Current and a lack of coastal alluvium inhibits mangrove growth (CEC 1992; Hughes and Hughes 1992).

Along the southern coast of Gabon where oil and gas activity is concentrated, strong southeast/northwest currents overcome the accumulation of sediments and materials carried to the ocean by the large rivers of the area. This area has characteristically no beaches or favorable conditions for the development of mangroves.

### **5.8.3 Marine Protected Area (MPA)**

The protected area system had its beginnings in 1946 with the creation of Lopé-Okanda Reserve by the administration of French Equatorial Africa (of which Gabon was then part). Since then, administration of the reserve has been modified by a number of different laws, and the government has expanded the protected area system (IUCN/UNEP 1987; World Bank 1993a; Jones 1993). There are several major wetlands located along the coast of southern Gabon. Conservation status of these wetlands is uncertain. A large Ramsar site is located at Sette' Cama, incorporating part of Lagune N'dogo.

## **6.0 DESCRIPTION OF THE ECONOMIC ENVIRONMENT**

### **6.1 INTRODUCTION**

Gabon has a mixed economy of public and private sectors. It is characterized by the dominant role of the petroleum industry and, to a smaller extent, by the mining and forestry sectors. The upstream oil industry is Gabon's major source of foreign exchange, accounting for 81% of total export revenues, almost 60% of government revenues, and over 40% of gross domestic product (GDP). The burgeoning petroleum industry of the '70s and '80s created new economic opportunities in the cities, which in turn sparked a rural exodus. As a result, 73% of the population now live in urban areas.

Although Gabon has enjoyed prosperity for much of the past two decades, the economy has not been predictable. From 1965 to 1980, the average annual growth rate of the GDP was 9.5%. Then the 1985 crash in oil prices devastated the country's economy. Gabon's Francophone currency was devalued by 50% in 1994, sparking an inflationary surge to 35% and a 16% drop in GDP. Both the International Monetary Fund (IMF) and the French government stepped in with financial support, enabling the Gabonese economy to slowly recover.

The collapse of oil prices in 1998 once again sent Gabon into a serious economic recession. Real GDP contracted by 9.6%, and non-oil GDP declined an estimated 8.9%. In response to the fiscal crisis, the government attempted to increase economic growth by diversifying the structure of its exports, restructuring and reducing its civil service, and privatizing several industries. This is an ongoing effort, and economic conditions have stabilized. Gabon's real GDP grew by 2.1% in 2000 and is expected to grow by 2.5% in 2001.

In a plan targeted for 1984-1988, that was later extended to include up till 1990, economic liberalism and privatization were the focus. When the collapse of oil prices came, diversification was pushed harder and more attention was being paid to developing productive industries other than petroleum. In the early 1990s the focus was put on "developing agriculture and forestry, infrastructural rehabilitation and maintenance, education and training and the promotion of small and medium sized enterprises."

### **6.2 UPSTREAM OIL SECTOR**

Gabon is sub-Saharan Africa's third-largest oil producer, behind Nigeria and Angola. It exported about 44% of its crude oil to the United States in 2000. According to U.S. Department of Energy statistics, Gabon's oil production of 330,900 barrels per day (bbl/d) in 2000 represented a 3% decline from the previous year and a 9% drop from 1998 production levels. At the same time, Gabon's proven oil reserves have increased to 2.5 billion barrels. Although Gabon's reserves have nearly doubled in the last three years, the government is concerned about a longer-term



trend of diminishing oil reserves. To help boost reserves and production, Gabon's oil ministry has revised its production-sharing contracts to attract new investors. The number of exploration permits issued has also increased. The government hopes to maintain production levels at approximately 350,000 bpd until new oil is brought on stream in 2001. Gabon left OPEC in 1996, citing OPEC's annual dues of \$1.9 million as the determining factor.

Ownership of oil, gas and mineral rights is vested in the State. E & P companies provide services on behalf of the State and are licensed under the Exploration and Production Contract established by Law No.14/82 in January 1983.

### **6.3 REFINING AND DOWNSTREAM OIL ACTIVITIES**

The Sogara refinery at Port Gentil is Gabon's only refinery. Opened in 1967, Sogara is jointly owned by the Gabonese government (25%), private investors (9.2 %), and a consortium of international oil firms led by TotalFina Elf. The refinery is currently operating at 82% of its 21,000 bbl/d nameplate capacity. The refinery has a modest retail network of approximately 100 sites. The main onshore oil terminals are Cap Lopez, Oguendjo, Gamba and Port Gentil and offshore oil terminals include Lucina and M'Bya.

The Gabonese government determines the wholesale price levels of crude and petroleum products. A range of taxes on downstream oil products also applies. Annual revenues from these taxes represent a substantial share of the country's indirect tax base.

### **6.4 FORESTRY**

Almost 85% of Gabon is covered by dense tropical forest. Not surprisingly, tropical timber, shipped largely as unprocessed logs, was Gabon's main resource before oil began to dominate the scene. Forest products still account for 14% of Gabon's exports. The country's logging industry focuses almost entirely on okoumé, a prized hardwood found only in Gabon and neighboring portions of Cameroon and the Republic of the Congo (Tutin and Fernandez, 1987). In order to extract this single species, forests containing up to 100 other species of trees with potential commercial value have been leveled.

Prior to 1982, Gabonese forest law had become progressively more complicated and difficult to apply. This was resolved by the promulgation in 1982 of Forest Law No. 1/82/PR, which covers the forest domain. The forest domain comprises state-classified forests and state-protected forests, which in effect cover the whole country. State-classified forests include:

- ◆ permanent production forests,
- ◆ reforestation areas,
- ◆ "parcs nationaux vocation forestière",
- ◆ protection forests,
- ◆ recreation forests,

- ◆ botanic gardens,
- ◆ arboretums and sanctuaries and,
- ◆ wildlife management areas (aires d'exploitation rationnelle de faune).

State-classified forests are considered part of the public domain and may be declassified for reasons of “public need”. The Gabonese government is actively looking at the country’s wood resources as a means of diversifying and expanding its export earnings.

## **6.5 MINING**

Gabon is still the world’s second largest manganese dioxide producer. Estimated total exports of manganese and uranium in 1998 were \$165 million, and the mining industry generates approximately 8% of the country’s total exports. Two companies dominate the mineral resources of Gabon: COMILOG for manganese and COMUF for uranium. For much of the 1990s, Gabon’s yearly uranium output placed it in or near the 10 top producing countries. The mines in operation during that time, however, have exhausted their deposits and this industry is unlikely to be revived. A new Gabonese company called SOMIMO is seeking to develop phosphate deposits in central Gabon. Several other companies are engaged in prospecting for gold and diamonds.

## **6.6 AGRICULTURE**

Since Gabon is so heavily forested, little land is left for agriculture and farming. As a result, Gabon is not self sufficient in its food production and must rely on imports from France, South Africa, and Cameroon. Land area devoted to cash crop agriculture is, however, increasing. Gabon's agricultural policy calls for increased investment in this sector. Cash crop agriculture covers 13,000ha in the forest zone and includes oil palm, rubber, cocoa and coffee. Products grown in the savannas include sugar cane, pineapple and various fruits and vegetable (McShane, 1990; Nicoll and Langrand, 1986). Small fishing operations provide a catch of about 30,000 metric tons.

## **6.7 ELECTRICITY**

The Société d'Energie et d'Eau du Gabon (SEEG) is responsible for electricity generation and supply. In 1997, a 20-year concession to run the state-owned SEEG was awarded to Vivendi, a French firm. The privatization included a commitment from Vivendi for future investment in plant upgrades and equipment modernization.

The majority of Gabon’s generating capacity is centered around Libreville, Port-Gentil and the inland city of Franceville. Libreville and Franceville operate limited transmission networks. Two hydroelectric stations on the M’bei River and one on the Ogooe River supply the majority of Gabon's power. Oil-fired thermal stations provide the remainder of the country's power supply.

## **6.8 PHYSICAL INFRASTRUCTURE**

Gabon's infrastructure, built mostly during the boom years of 1974-78 and 1982-85, is fairly sophisticated when compared to that of its neighbors, but does not extend far outside of Libreville.

### **6.8.1 Ground and Rail Transportation**

Gabon has only 650 miles of paved roads in its 4,300-mile road network, but the principal inter-city routes are being upgraded and extended with financing from the African Development Bank and the European Investment Bank. The government devoted a significant amount of money in the '80s to extend and upgrade the trans-Gabon railway as part of its plan to diversify its economic base. With an improved railroad system, forestry products and mineral ores could be transported easily, and at a lower cost.

### **6.8.2 Marine Transportation**

Gabon's two modern ports, Owendo and Port-Gentil, handle around 21 million tons of cargo each year. Port-Gentil is a deep water port and handles 85% of the traffic by volume. Owendo's approach is shallow and requires dredging

### **6.8.3 Air Transportation**

Air transportation has played a critical role in Gabon because of the natural and economical characteristics of the country. The rugged relief, the equatorial forest, and the density of the river system have all served as obstacles to the development of a ground-based transportation system in Gabon. Furthermore, the low density of rural populations has made air transportation an attractive alternative to cars and buses.

The national airline, Air Gabon, serves the entire western coast of Africa. It also has direct flights to France, Italy and the United Kingdom. Within the country, Air Gabon serves 11 cities on a regular schedule. Local airlines that use small airplanes and helicopters carry passengers on request.

### **6.8.4 Telecommunications**

Gabon's telecommunications system is fairly advanced, with direct dial services from Libreville to almost anywhere. The Office des Postes et Telecommunications du Gabon (OPT), has a monopoly on the telecommunications network and most telecom services in Gabon. In a first step towards privatization and liberalization, two licenses for competing cell phone operation have been awarded (Celtel and Telecel).

## **7.0 DESCRIPTION OF THE SOCIAL ENVIRONMENT**

### **7.1 POPULATION CHARACTERISITICS**

Gabon is a small oil-producing country on the western shore of the Gulf of Guinea. It has a population of roughly 1,300,000, with a very high proportion living in urban centers. While there are more than 40 different ethnic groups in Gabon, a small number of these dominate in terms of numbers. For example, Fang is the largest ethnic group and makes up almost one-third of the population.

Almost 20% of Gabon's population are French nationals, and they have greatly influenced the country's development. Forty years after decolonization, France still has a significant amount of money invested in Gabon. The relatively large resident French community is engaged in all sectors of business. French firms often benefit from concessional financing and mixed credits from the French government. Not surprisingly, French is the official language of Gabon and 97% of the population practice Christianity.

Tropical diseases and AIDS have caused fluctuations in the population growth rate of Gabon, making it difficult to come up with reliable demographic figures. Experts agree, however, that the median age of the population has dropped noticeably. Less than 5% of the population is above 65.

Efforts to improve educational opportunities are important, both for individual advancement and to meet the increasing demands for a trained work force. Gabon's educational system is modeled after the French system; in fact, French is the sole language of instruction.

### **7.2 NONGOVERNMENTAL ORGANIZATIONS (NGOs)**

The NGO movement in Gabon is recent and has not reached an advanced stage in development. With a few exceptions these NGOs have no real associative base (few or no sympathizing or fee-paying members, no general assembly). Often they are small cores of individuals operating on a non-permanent basis. Very few NGOs have permanent staff and offices, and most are not formally recognized by the government. Because of this lack of government support, NGOs have to rely on outside funding.

NGO initiators come from a variety of backgrounds and the movement is primarily urban. Most NGOs are based in Libreville; consequently, links between NGOs and rural people are scarce and weak. There is practically no fabric for organizations for local development (Associations Locales de Développement) and village groups. Very few NGOs have been established with the aim of supporting the geographic area where the founders are from.

There are approximately a dozen national NGOs concerned with environmental issues on a regular basis. The three major sectors for NGO focus and operation are environmental education, urban rehabilitation activities and lobbying activities. Gabonese NGOs are rarely involved in activities directly related to natural resource management. Presently, the strongest and most energetic structures involved in the environmental sector are the Amis du Pangolin, Jeunesse et Environnement (CIAJE ), FOGAPED, and Humanitas. Because these NGOs are relatively young (less than ten years), turnover is still extremely rapid and these groups cannot be considered stable.

In the last few years, the government of Gabon has taken several measures to protect the environment that will have implications for NGOs:

- The 1995 National Environmental Action Plan (NEAP), which defines Gabon strategies and priorities in the fields of ecosystem management and pollution control.
- The Tropical Forest Action Program (TFAP), which defines general policies that will guide future projects based on sustainable management.

Since Gabon is considered a middle-income country in Africa, there are not as many bilateral and multilateral cooperative programs as there are in less advanced countries. The majority of international cooperative efforts focus primarily on the forest sector. The World Wide Fund for Nature (WWF), in line with its mission to conserve nature and natural processes, has selected Gabon as a priority country for action in Africa. Gabon is one of the six WWF focal countries in Africa, with eight WWF projects (Nicoll and Langrand, 1986; WWF, 1991).

The following table presents some of the most active environmental NGOs in Gabon as well as the most prominent international donors.

<b>Designation</b>	<b>Major Environmental Activities</b>	<b>Contact Person</b>
<b>Collectif Inter Association Jeunesse et Environnement (CIAJE)</b>	<ul style="list-style-type: none"> <li>♦ Urban rehabilitation, forest policy monitoring, Influencing national legislation, environmental education (EE)</li> <li>♦ Group includes 30 associations (High school/college ecological clubs; youth and environmental associations; Pangolin's Friends, etc.)</li> </ul>	Constant Allogho, President
<b>Amis Du Pangolin</b>	<ul style="list-style-type: none"> <li>♦ EE, Influencing national legislation</li> <li>♦ Publishes "Cri du pangolin", the only environmental publication for the public, and the most elaborate magazine on environment in the subregion among publications by NGOs;</li> <li>♦ CIAJE member; one of the associations with the most developed base.</li> </ul>	Serge Akagah Les, Director BP 2103 Libreville Tel: 77 54 57 Fax: 74 63 13
<b>Gabonese Foundation for Development and Environmental Protection (FOGAPED)</b>	<ul style="list-style-type: none"> <li>♦ EE, Influencing national legislation</li> <li>♦ Includes primarily civil servants (members of the General Directorate for Environment, IRET researchers)</li> </ul>	Jean Hilaire Moudziegou, Treasurer, BP Libreville Tel: 72 27 00
<b>Direction Nationale de l'Environnement</b>		Mrs. Koko BP Libreville Tel: 72 27 00
<b>Femmes Environnement et Développement</b>	<ul style="list-style-type: none"> <li>♦ Work in the field</li> <li>♦ Chairwoman conducts an Environmental Program on Africa</li> </ul>	Mrs. Eugénie Dicki BP Libreville Tel: 76 00 01
<b>National Director for Wildlife</b>		J. Hubert Eyi-Mbeng BP Libreville Tel: 76 14 44

<b>Designation</b>	<b>Major Environmental Activities</b>	<b>Contact Person</b>
<b>Gabon Environnement Développement Sans Frontières (GEDS)</b>	<ul style="list-style-type: none"> <li>◆ Multi-sector interests, including environment</li> <li>◆ Bridge construction for Hydroelectric Power Mini-plant Project</li> <li>◆ Wants to work at Regional Level</li> </ul>	
<b>Adventures Without Frontiers</b>	<ul style="list-style-type: none"> <li>◆ EE; Turtle egg-laying site protection</li> </ul>	
<b>Institut Gabonais d'Appui au Développement (IGAD)</b>	<ul style="list-style-type: none"> <li>◆ Gabonese Development Support Institute</li> </ul>	Denis Dravet BP 20423 Libreville Tel: 73 07 84 Fax: 73 10 93
<b>Coopération Française</b>	<ul style="list-style-type: none"> <li>◆ French Fund for Development</li> </ul>	Jean Marc Bouvard, Advisor BP Libreville Tel: 73 94 25
<b>Jeune Chambre Economique</b>	<ul style="list-style-type: none"> <li>◆ Urban rehabilitation</li> <li>◆ Rather strong associative base, approximately 200 members</li> </ul>	François Epouta BP 9079 Libreville Tel: 78 75 52 Fax: 77 36 30
<b>Humanitas</b>	<ul style="list-style-type: none"> <li>◆ Multi-sector interests, including environment</li> <li>◆ Responsible for Literacy</li> <li>◆ Includes teachers and university students.</li> </ul>	Mr. Okogo, President BP 9569 Libreville Tel: 75 04 85

## **8.0 POTENTIAL ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES**

### **8.1 INTRODUCTION**

Once an understanding of the baseline environment has been obtained, potential impacts that may result from project activities must be identified. The impact assessment process identifies all of the routine drilling and production activities that will have, or are potentially perceived to have, an impact on the surrounding environment. This section addresses potential environmental impacts that the proposed project could reasonably be expected to cause, their significance and their duration. Emphasis is placed on identifying specific cause-effect relationships established by previous studies carried out for similar activities offshore. Table 8-1 summarizes the routine activities that will be carried out during the project, their potential impacts on the environment and their significance.

Environmental impacts can be classified as physical (e.g., the seabed is disturbed by the placement of anchors); chemical (e.g., the discharge of drilling mud and cuttings into the water); or biological (e.g., the discharge of a chemical into shallow water that has a toxic effect on the fauna in the area). The significance of these impacts, based on the estimated recovery time and the sensitivity of the affected environment, must be considered.

Typically, environmental impacts are classified as minor (between 1 month -1 year); moderate (1 to 3 years) or significant (3 to 10 years), depending upon the estimated recovery time. The World Bank and other internationally accepted standards recommend that mitigation methods be investigated to address all moderate and significant impacts.

### **8.2 DRILLING FLUIDS AND CUTTINGS DISCHARGE**

#### **8.2.1 Fate of Drilling Fluids and Cuttings**

The fate of discharged drilling fluids and cuttings is determined by diverse physical processes (current, gravity, and water body characteristics), chemical processes (reaction and sorption) and biological processes that all serve to disperse or concentrate constituent materials. Nevertheless, some important generalizations can be made.

- ◆ The dilution of drilling fluids to low concentrations is very rapid, usually within 2-3 hours of discharge (ECOMAR, 1978, 1982; Ayers, et. al., 1980a, 1980b; Ray and Meek, 1980; Houghton, et. al., 1980; Northern Technical Services, 1982). Suspended solid concentrations are reduced to 1,000 ppm within 2 minutes of discharge and below 10 ppm within 1 hour. Dilutions of 1,000 ppm or more generally occur within 1 to 3 m of the discharge point.



- ◆ Solids may accumulate on the bottom beneath the discharge plume. The distance it takes the solids to become dispersed depends upon the quantities discharged, hydrographic conditions during and after the discharge, and the height of the discharge pipe above the seabed.

The Gulf of Mexico Offshore Operators Committee and Exxon funded the development of a computer model that accurately calculates dispersion of drilling fluid solids in the water column and predicts where the particles initially settle on the sea (Brandsma et. al., 1980, 1983a, 1983b). Numerous laboratory and field tests (O'Reilly et. al., 1989) have verified the model, which is now used to simulate offshore drilling fluid discharges throughout the world. For example, the model was used recently to simulate a 1000 bbl/hr drilling fluid discharge off the coast of Sakhalin Island (Ayers, 1994). The results showed that in 1.2 minutes, the concentration of solids in the plume dropped below limits allowed for discharge in the U.S. (96 hr LC 50, which is the concentration that will cause 50% of the sensitive test organisms to die within 96 hours). This corresponds to a down-current distance of 15 m. Field tests further verify that drilling fluid solids concentrations entering a water column quickly drop below toxic levels because of rapid settlement and dilution. Even with the most toxic fluids, water column concentrations fall below 96 hr LC 50 concentrations in minutes.

### **8.2.2 Impacts**

Discharged drilling fluids and cuttings generally impact the aquatic environment in one of two ways: through the temporary smothering of non-mobile benthic organisms or by a brief elevation in toxicity levels. The physical burial of benthic organisms by drilling discharges beneath or near the drilling rig can temporarily reduce abundance levels of macrobenthos. The degree of impact can vary, depending upon the local environment and the nature and volume of the discharges. However, any effects are typically localized, and benthic communities quickly recolonize and recover.

The second type of impact, raised toxicity levels, can be divided into two categories: acute toxicity (a measure of immediate danger of poisoning) and chronic toxicity (a measure of long-term effects such as growth inhibition, reproductive interference, etc.). Both impacts have been discussed at length in numerous articles and reviews (see Courtesy Associates, 1980; Dames and Moore, 1980; National Academy of Sciences, 1983; Ayers, et. al., 1980c; Gallaway, 1981).

Oil-based drilling fluids are prohibited from discharge throughout the world. However, the discharge of cuttings associated with mineral oil-based fluids is permitted in many offshore areas, including those of West Africa. Oil-covered cuttings settle quickly and do not remain in the water column long enough to cause toxic effects (E&P Forum, 1996). Furthermore, numerous studies have also demonstrated that cuttings are widely scattered in deep water, high-energy environments such as the drilling area proposed by VAALCO Gabon. This distributive action results in lower oil concentrations in the sediment (E&P Forum, 1996).

### **8.2.3 Prevention and Mitigation**

Biological impacts diminish if the quantity of oil associated with the cuttings is reduced. It appears that if sediment oil concentrations remain below a threshold value of about  $10^3$  ppm (depending on the oil type and seafloor environment), oxygen/nutrient replenishment will occur fast enough to allow aerobic biodegradation to proceed, thus avoiding adverse biological effects (E&P Forum, 1996). VAALCO Gabon intends to minimize any potential impact by treating the cuttings prior to disposal.

### **8.3 BIOACCUMULATION/MAGNIFICATION OF HEAVY METALS**

Heavy metals in drilling muds and cuttings are present in insoluble forms or are adsorbed on clay particles and have limited bioavailability (National Research Council, 1983; Neff et al, 1988, 1989, 1989a; E&P Forum, 1996). Limited bioaccumulation of barium and chromium by marine animals has been observed in the laboratory and occasionally in the field; however, levels of uptake are too low to affect the health of the marine organisms. A great deal of research has been done on heavy metal biomagnification by marine organisms (Bascomb, 1983, Neff 1988, Bryan 1982, Kay, et al 1984, Schaefer et al, 1982). Many of these studies addressed metals from all sources - not just mud and cuttings discharges. Results have demonstrated that concentrations of most metals in natural marine food webs show either no relation, or an inverse relation to trophic levels, indicating that food chain biomagnification of inorganic metal does not occur.

### **8.4 WASTE DISCHARGES**

The following measures will be included in the design and operation of offshore pipelines to avoid or minimize the potential impacts on marine water quality:

- ◆ Oil-contaminated solids, paints and solvents, radioactive materials, etc. may not be discharged overboard. They will be packaged appropriately and sent ashore for disposal in a properly equipped, permitted facility.
- ◆ Design features will be provided to prevent the discharge of visible oil or floating solids.
- ◆ All wastewater and contaminated deck drainage will be processed through an oil-water separation system before disposal.
- ◆ Curbs, gutters, drip pans, and drains will be provided in platform deck areas to collect all contaminants not authorized for discharge. Discharge will be in accordance with IFC requirements.
- ◆ Oil drainage will be piped to a properly designed, operated, and maintained collection and treatment system to prevent discharge of oil into offshore waters.

- ◆ Drains and sumps will be adequately sized to handle anticipated flows.
- ◆ Bilge water will be processed through an oil-water separator before disposal. It will be disposed of with the produced water.
- ◆ Equipment, cables, chains, containers, or other materials will not be discharged into offshore waters.
- ◆ Ballast water from the drill rig is stored in specially designated ballast tanks and will not come in contact with any contamination. Consequently, any ballast water discharged during rig maneuvering will be clean.
- ◆ MARPOL 72/78 (IMO, 1992) specifies that all food wastes should be macerated to 25 mm prior to discharge. All non-food wastes (garbage) generated by the drilling unit will be collected and disposed of at an appropriate onshore disposal site. Drilling waste will not be commingled with trash and garbage.

## 8.5 AIR EMISSIONS

Emissions to the atmosphere from drilling operations are limited in scope. The majority of these emissions come from the exhaust of diesel powered generators and associated machinery from the drilling operations. These exhaust emissions should not have any measurable impact on the environment (see Table 8-1). The dispersive wind conditions in the project area and the anticipated low levels of emissions also indicate negligible impacts. No mitigation measures above routine maintenance of engines are required.

**TABLE 8-1 TYPICAL EMISSIONS**

	tonnes/day
CO <sub>2</sub>	54.0
CO	0.32
NO <sub>x</sub>	1.16
N <sub>2</sub> O	0.004

Additional air emissions will be generated by positioning and operating the supply boats and during refueling operations. Levels of pollution are expected to be insignificant. Flares will be designed for proper burner management to achieve 98% combustion efficiency. This measure will minimize hydrocarbon and carbon monoxide emissions to the atmosphere through nearly

complete combustion of the gas (CIDAC, 1998). Emissions will be limited as follows, in accordance with state-of-the-art flare design:

**TABLE 8-2 FLARE EMISSION LIMITS**

	<b>Kg/1,000 M<sup>3</sup> Gas</b>
Nitrogen Oxides	1.0
Carbon Monoxide	1- 6.0
Non-Methane Hydrocarbons	1.2

## **8.6 INTERFERENCE WITH SHIPPING**

The major shipping routes around the African continent are situated offshore Gabon. Libreville and Port Gentil are major ports in the local context. Coastal shipping will pass inshore of the concession area and will not be affected by the proposed project.

## **8.7 DISTURBANCE OF MARINE WILDLIFE**

Impact on marine wildlife will be minimized and mitigated, through the following actions:

- ◆ The flight path and altitude of helicopters used during construction and operations will be determined to avoid or minimize disturbance of sensitive marine wildlife species.
- ◆ Construction activities will be scheduled to minimize impacts during critical seasons (e.g., breeding, and migration) for wildlife.
- ◆ All personnel will be prohibited from feeding, harassing, or hunting marine wildlife.
- ◆ All project vessels will be required to maintain a minimum distance of 1600 meters from whales and to observe the following guidelines:
  - Support vessels will not cross directly in front of migrating whales.
  - When moving parallel to whales, support vessels will operate at a constant speed no faster than the whales.
  - Care will be taken not to separate female whales from their calves.
  - Support vessels will be prohibited from herding or driving whales.

## 8.8 UPSET CONDITIONS

VAALCO Gabon will design, construct, and operate the offshore drilling facility to stringent standards to minimize accidents; however, the potential for upset conditions cannot be ignored. This section addresses non-routine events that could occur during the construction and operation of the platform. Potential consequences are discussed, along with prevention and mitigation measures proposed by VAALCO Gabon.

### 8.8.1 Fuel Releases

Fuel releases occasionally occur during ship-to-rig transfer and as a result of leaking storage facilities. Since most of these releases involve light oil containing several aromatic components, up to 70-80% of the released oil would be lost to evaporation within the first 24 hours of release, depending upon prevailing environmental conditions (National Research Council, 1983). If left alone, the impact on the marine environment would be negligible.

The project will establish procedures to prevent the occurrence of small spills, and personnel will be trained to observe operations to ensure that small spills are rapidly detected.

### 8.8.2 Well Blowouts

A “blowout” is the sudden, unplanned release of oil and/or gas out of a well. In such situations, the sea is sprayed with an oil jet for a period of time until the blowout is controlled. Fortunately, technological developments have reduced the risk of an old-style “blowout” during drilling to less than one well out of 10,000 wells drilled worldwide (Environmental Resources Management, 1996). Nevertheless, an unauthorized release of oil offshore Gabon could temporarily impact the water quality in the immediate area.

#### 8.8.2.1 Potential Impacts

Studies have demonstrated that while differences in environments can affect recovery rates, open water oil releases do not cause excessive adverse effects on water column organisms (API Publication No. 4398). In fact, the sensitivity of offshore areas to an oil spill is considered to be low because crude oil is a very hydrophobic mixture. If mixed with water, the large droplets return to the surface oil slick, while the smaller droplets tend to disperse into the aqueous phase. The crude is adsorbed to particulate matter in seawater and quickly sediments with it to the bottom.

The following biological species within the open sea have been rigorously studied and evaluated as to their sensitivity to oil.

- ♦ Plankton - Some components of crude oil are deleterious to a wide range of planktonic organisms. However, because they have a high recovery potential, impacts to the plankton population are usually limited to very transient effects in the vicinity of the spill release.

- ◆ Deep Sea Benthos - Long-term studies of spill sites where hydrocarbons remained in the sediments demonstrate that the effect on benthic communities covers a small area and damage is reversible if contamination stops.
- ◆ Fish - Adult fish typically exhibit avoidance behavior when they detect the odor of hydrocarbons. This reaction reduces the likelihood of their exposure to harmful effects of discharged oil. On the other hand, fish eggs and larvae can be quite susceptible to adverse impacts caused by petroleum-tainted water.
- ◆ Seabirds - The most important factors to consider when assessing the potential damage to seabirds are abundance and diversity, moulting and migration patterns. There are no known migratory routes for land birds in the concession.
- ◆ Marine Mammals - Contact with oil could be injurious, particularly during the breeding period.

#### 8.8.2.2 Prevention and Mitigation

VAALCO Gabon will apply both primary and secondary well control measures. Primary well control principally comprises the maintenance of sufficient hydrostatic head of drilling mud in the well bore to balance pressures exerted by fluids in the formation being drilled. Secondary well control is provided by the installation of a blowout preventer (BOP) stack. BOPs are high-pressure safety valves that rapidly close following an influx of formation fluid into the well bore, preventing or reducing losses from the well. The BOP stack must be periodically tested to ensure operability.

In addition, VAALCO Gabon has established an emergency response organization to provide rapid response and control of emergency situations that may develop. During an emergency, this management system will organize, mount, and sustain response operations to properly control the situation, ensure the safety of personnel, maximize the protection of the environment, and minimize damage to property and the environment. Emergency response equipment will be strategically positioned to ensure a rapid, efficient, and effective response to "most likely" events. An Emergency Response Contingency Plan will be provided to the members of the emergency response organization that will contain information on:

- ◆ Relevant policies and guidelines
- ◆ Composition of the emergency response organization
- ◆ Notification and activation procedures
- ◆ Emergency response procedures and resources
- ◆ Site-specific details / information
- ◆ Nature and location of sensitive areas and protection strategies
- ◆ Training programs

**TABLE 8-1 POTENTIAL ENVIRONMENTAL IMPACTS OF DRILLING AND PRODUCTION**

<b>ACTIVITY</b>	<b>IMPACT</b>	<b>ZONE OF EFFECT</b>	<b>DURATION</b>	<b>SIGNIFICANCE</b>
<b>Anchoring</b>	<p>Disturbance to seabed sediments resulting in the suspension of surface sediments in the water column.</p> <p>Resettlement of suspended sediments will smother some filter-feeding benthic species.</p>	<b>Highly localized</b>	<b>Short</b>	<p><b>Low</b></p> <p>No known unique benthic communities in project area.</p> <p>Recolonization of benthic fauna expected to be rapid.</p> <p>Suspended sediments rapidly dispersed by bottom currents.</p>
<b>Discharge of Oil-Based Cuttings</b>	<p>Discharge of cuttings will cause solids to be suspended in the water column. Can result in increased turbidity &amp; decreased oxygen levels close to the point of discharge.</p> <p>Potential chemical contamination of seabed sediments with residual drilling chemical additives attached. Possible toxic effects could result.</p> <p>Potential for increase in sediment heavy metal content from contaminants in barites.</p> <p>Oil on cuttings provide a source of organic carbon, increasing oxygen demand.</p>	<p><b>Localized</b></p> <p>Area impacted depends on the dispersion of solids after discharge, which in turn depends on:</p> <ul style="list-style-type: none"> <li>◆ Solids particle size</li> <li>◆ Discharge point</li> <li>◆ Currents</li> <li>◆ Prevailing conditions</li> </ul>	<b>Short</b>	<p><b>Moderate</b></p> <p>Total effect on planktonic communities negligible. Recolonization of benthic fauna expected to be rapid.</p> <p>Water turbidity will quickly dissipate.</p> <p>Low-toxicity mineral oil will be used.</p> <p>Planktonic communities not expected to be exposed to cuttings long enough to cause any long-term impacts.</p> <p>No known unique benthic communities in the project area.</p> <p>Heavy metals not considered to be bioavailable because they are tightly bound to solid particles or are present in insoluble forms.</p>

<b>ACTIVITY</b>	<b>IMPACT</b>	<b>ZONE OF EFFECT</b>	<b>DURATION</b>	<b>SIGNIFICANCE</b>
<b>Discharge of Sanitary System Waters</b>	Organic enrichment of the localized environment  Deoxygenation of receiving waters and sediments.	<b>Highly localized</b>	<b>Short</b>	<b>Low</b>  Rapid dilution and dispersion upon release.  Anaerobic digestion of effluent will reduce BOD to insignificant levels.  Maceration of solids will aid dispersion and biological breakdown.
<b>Air Emissions from Vessels, Drilling Activity and Flaring</b>	Release of exhaust emissions to the atmosphere.	<b>Localized</b>	<b>Short</b>	<b>Low</b>  Emissions are of short duration, will be dispersed rapidly and will not contribute significantly to ambient levels.
<b>Transfer and Storage Of Fuel</b>	Spill of fuel into the water	<b>Localized</b>	<b>Short</b>	<b>Low</b>  Up to 70-80% of the released oil would be lost to evaporation within the first 24 hours.
<b>Well Testing</b>	Release of combusted and non-combusted products as the result of hydrocarbon flaring.	<b>Localized</b>	<b>Short</b>	<b>Low</b>  Testing will only take place if a hydrocarbon-bearing formation is found.  Atmospheric emissions rapidly disperse and are insignificant in global terms.



**TABLE 8-1 POTENTIAL ENVIRONMENTAL IMPACTS OF DRILLING AND PRODUCTION**

ACTIVITY	IMPACT	ZONE OF EFFECT	DURATION	SIGNIFICANCE
<b>Well Blowout</b>	Water sprayed with oil	<b>Localized/ Regional</b>  Area impacted will depend upon the amount of oil lost and prevailing conditions (water/air temperature, wind speeds, water currents, etc.)	<b>Short</b>	<b>Moderate</b>  Spill has the potential to affect a wide area.  Sensitivity of offshore areas to an oil spill is expected to be low because crude oil is a very hydrophobic mixture. Small droplets will quickly disperse. Larger droplets will first form a surface sheen. They will then be adsorbed to particulate matter and quickly sediment with it to the bottom.  Effects on seabed are normally insignificant.  Sea birds are the most vulnerable species.  Fish detect oil and avoid it.  Organisms floating in the water may experience short-term effects because of the initial toxicity of the water.

## 9.0 ENVIRONMENTAL HAZARD AND RISK ASSESSMENT

### 9.1 INTRODUCTION

The assessment of system safety and risk differs from the assessment of environmental impacts, because an upset does not occur in the normal mode of operations; consequently, it is viewed only as a potential risk. An Environmental Hazard and Risk Assessment (EHRA) is used to identify potential hazards, gauge their severity and determine the probability of their occurrence. With this information in hand, an informed decision can be made as to whether the impact is acceptable or requires mitigation.

A team of SES professionals with considerable experience in the assessment of impacts and risks associated with offshore oil and gas exploration recently completed an EHRA for the Etame Marin Project. As part of this work, SES examined the proposed project to identify potential hazards and gauge their severity and impact on the environment. The team estimated the probability of the hazard occurring by using the ranking systems described below. Finally, environmental risk was calculated by multiplying the severity of the impact by the probability.

### 9.2 DEFINITION OF SEVERITY

The severity of a particular hazard is defined in terms of factors (see Table 9-1).

**TABLE 9-1 SEVERITY FACTORS**

<b>Severity</b>	<b>Description</b>
1 - Serious	Major environmental incident causing significant regional damage to the environment. Recovery time greater than 20 years.
2 - Significant	Environmental incident resulting in off-site clean up. Recovery time 10-20 years.
3 - Moderate	Environmental incident resulting in onsite clean up, but which could impact local resources. Recovery time 5-10 years.
4 - Minor	Environmental incident where impact is limited to the immediate site. Recovery time 2-5 years.
5 - Very Small	Release of material that causes little or no environmental impact. Recovery time less than 2 years.

### 9.3 DETERMINING PROBABILITY OF OCCURRENCE

There are a number of ways to determine the probability of a particular occurrence. For the purposes of this study, the probability was determined by ranking the historical frequency of occurrences per year (see Table 9-2).

**TABLE 9-2 PROBABILITY FACTORS**

Frequency	Definition
1 - High	> once per year
2 - Moderate	> once per 10 years
3 - Medium	> once per 100 years
4 - Low	> once per 1,000 years
5 - Very Low	> once per 10,000 years

## 9.4 RISK EVALUATION

The team then performed the risk evaluation by multiplying the severity and probability of each identified hazard. As the severity and probability factors are on a scale of 1 through 5, the risk assessment scale ranges from 1 to 25. The risk assessment numbers are further grouped into three orders, namely High, Medium and Low. Table 9-3 is based on Soregard *et al.*, 1997.

**TABLE 9-3 EVALUATION CRITERIA**

<i>f</i>	5	4	3	2	1	
$>10^{-1}$	5	4	3	2	1	1
$10^{-1} - 10^{-2}$	10	8	6	4	2	2
$10^{-2} - 10^{-3}$	15	12	9	6	3	3
$10^{-3} - 10^{-4}$	20	16	12	8	4	4
$<10^{-4}$	25	20	15	10	5	5

**Key:**

	High
	Medium
	Low

## 9.5 PREVENTION AND MITIGATION OF IDENTIFIED RISK

Table 9-4 summarizes the results of the EHRA along with actions to prevent or mitigate the potential environmental impacts.

**TABLE 9-4 RISK ASSESSMENT OF NON-ROUTINE EVENTS**

<b>Activity</b>	<b>Hazard</b>	<b>Agent</b>	<b>Severity</b>	<b>Probability</b>	<b>Risk</b>	<b>Action Plan</b>
<b>Capsize of drill ship or semi-submersible drilling rig</b>	Disturbance of the benthos. Release of hydrocarbons and other chemicals.	Physical disturbance of the sediment. Chemical effect from release of hydrocarbons and chemicals.	<b>Moderate</b>	<b>Low</b>	<b>Low</b>	Pre-installation surveys will ensure that the drill ship or semi submersible is in good condition, and that there are no conditions at the drill site that could cause a problem.
<b>Blowout during drilling</b>	Release of hydrocarbons, fire	Physical and chemical	<b>Moderate</b>	<b>Low</b>	<b>Low</b>	Operating plans and procedures will be followed to ensure that all drilling is conducted safely, and that all safety equipment is in good operating condition.
<b>Dropped Object</b>	Discharge of drilling fluids, cement and/or completion fluids	Release of chemicals to the environment. Potential physical smothering	<b>Very small</b>	<b>High</b>	<b>Low</b>	Operating plans and procedures will be followed to ensure that drilling is done in a manner to minimize the potential for dropped objects.  If an object is dropped, the company will follow written plans that address how to contain, minimize, mitigate and clean up any release.

**TABLE 9-4 RISK ASSESSMENT OF NON-ROUTINE EVENTS**

<b>Activity</b>	<b>Hazard</b>	<b>Agent</b>	<b>Severity</b>	<b>Probability</b>	<b>Risk</b>	<b>Action Plan</b>
<b>Stuck Pipe</b>	Use of additives in the drilling mud to free stuck pipe.	Release of chemicals, including hydrocarbons, in the drilling mud and cuttings discharges.	<b>Moderate</b>	<b>Low</b>	<b>Low</b>	Pre-established procedures will be followed to minimize the risk of getting the drill pipe stuck.  The potential toxicity of any additive will be considered when choosing which one to use.
<b>Logging</b>	Loss of low level radioactive device.	Release of radioactive source.	<b>Very small</b>	<b>Moderate</b>	<b>Low</b>	Pre-established procedures will be followed when running radioactive logs.  If a tool is lost down hole, the equipment will be retrieved by fishing whenever possible.
<b>Drilling through gas-containing zones</b>	Release of high pressure gas and other formation and drilling fluids.	Explosion and/or fire, release of chemicals to the environment.	<b>Moderate</b>	<b>Low</b>	<b>Low</b>	No gas zones have been identified. Effective well control safety equipment, such as blow out preventers and shear rams, will be maintained.
<b>Well testing</b>	Uncontrolled release of hydrocarbons	Release of hydrocarbons, drilling or well completion fluids.	<b>Very small</b>	<b>Medium</b>	<b>Low</b>	Pre-established procedures will be followed when testing any well.

**TABLE 9-4 RISK ASSESSMENT OF NON-ROUTINE EVENTS**

<b>Activity</b>	<b>Hazard</b>	<b>Agent</b>	<b>Severity</b>	<b>Probability</b>	<b>Risk</b>	<b>Action Plan</b>
<b>Integrity of transfer equipment for well testing</b>	Potential release of hydrocarbons or other chemicals	Release of hydrocarbons to the environment	<b>Very small</b>	<b>Moderate</b>	<b>Low</b>	Pre-established procedures will be followed when handling transfer equipment.
<b>Transfer and storage of fuels</b>	Release of hydrocarbons	Release of hydrocarbons to the environment, fire, explosion	<b>Very small</b>	<b>High</b>	<b>Medium</b>	Pre-established procedures will be followed when transferring fuel. Whenever possible transfers will be done during daylight hours. A spill response plan will be maintained.
<b>Transfer and storage of chemicals</b>	Release of chemicals	Release of chemicals into the environment	<b>Minor</b>	<b>Medium</b>	<b>Low</b>	Pre-established procedures will be followed when transferring chemicals. Whenever possible transfers will be done during daylight hours. A spill response plan will be maintained. Rig and supply vessel crews will be trained, familiar with their responsibilities, and know how to enact the spill response plan.

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