ENVIRONMENTAL ASSESSMENT

CHAD PORTION

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Chad Export Project

ESSO Exploration and Production Chad Inc.

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CHAD INC.

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DAMES & MOORE

CHAD EXPORT PROJECT

This Environmental Assessment of the Chad Export Project is being made available for public review in Chad and Cameroon, and through the World Bank Public Information Center in Washington, D.C., United States of America.

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TABLE OF CONTENTS
CHAD EXPORT PROJECT
CHAD PORTION

Page

LIST OF TABLES

LIST OF FIGURES

1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION AND BACKGROUND

The objective of the Chad Export Project is to produce, transport, and sell oil from three oil fields in the Doba Basin of southern Chad (Komé, Miandoum, and Bolobo) to world markets in a manner compatible with the balanced environmental and economic needs of the people of Chad.

The proposed project includes the oil field development in Chad, and a pipeline transportation system originating in Chad that traverses Cameroon, including a marine terminal facility off the coast of Cameroon (Figures 1-1 and 1-2). This environmental assessment (EA) addresses the Chad portion of the project, including:

- Approximately 300 production wells and 20 water reinjection wells in the oil field development area
- A gathering system to transport produced fluids within the oil field development area
- A Central Treating Facility (CTF) in the oil field development area to produce export quality oil
- An Operations Center, consisting of the CTF, an airstrip, housing for 100 personnel, and a (100 MW) power plant to serve project needs
- A pipeline transportation system (including the pipeline and the pump station), 170 km long in Chad, contiguous with an 880 km pipeline transportation system in Cameroon
- Various infrastructure facilities and upgrades, including temporary storage areas, road system improvements, a satellite-based communications system, and an administrative office in N'Djamena, Chad.

The project is being considered by a consortium comprised of Esso Exploration and Production Chad, Inc., Société Shell Tchadienne de Recherche et d'Exploitation, and Elf Hydrocarbures Tchad (the Consortium). Esso will act as Operator for the oil field development. A pipeline transportation company, Tchad Oil Transportation Company (TOTCO) will be formed to operate the pipeline transportation system in Chad with equity participation of the Consortium and the Republic of Chad.

This EA has been prepared to meet the requirements of the project and to support funding applications from the Government of Chad to the World Bank and from TOTCO to the International Finance Corporation ([IFC] the private sector lending agency of the World Bank), international lending agencies, and export credit agencies. The EA responds to World Bank guidelines and Operational Directives and addresses project impacts on the human, biological, and physical environments. A separate EA has been prepared with respect to the Cameroon portion of the project.

Expert and independent environmental advice has been an integral part of the preliminary engineering of the project, reflecting a key project development strategy of minimizing the adverse environmental impacts of the project by the early recognition and, where possible, avoidance of sensitive issues. Environmental and socioeconomic inputs to project development and preparation of the EA have been the responsibility of an international consulting firm with extensive experience in the environmental assessment of complex projects, utilizing an array of specialist organizations and individuals, including Chadians, as subconsultants. Consultations with affected groups, including the local population, nongovernmental organizations (NGOs), and relevant government ministries and agencies, have been undertaken and will continue throughout project development.

Both beneficial and adverse impacts are recognized in the EA. Mitigation strategies have been developed to address all significant adverse impacts.

1.2 PROJECT DESCRIPTION

The Chad Export Project is being engineered to avoid incidents that would cause adverse environmental impacts by the appropriate design, construction, operation, monitoring and maintenance of project facilities and the operation of a comprehensive program for safety and environmental protection. This program will ensure regulatory compliance; provide appropriate health, safety and personnel training; and ensure that project-generated wastes are reduced where possible and appropriately handled, treated and disposed of, where necessary.

The project will be managed with the goal of preventing incidents that potentially cause adverse environmental or social impacts. Comprehensive risk assessments will be conducted throughout the design, construction, and operation of the project to reduce risk and mitigate the consequences of safety, health, and environmental incidents. Recognizing that accidents may occur, project policy will be to respond quickly and effectively to incidents resulting from operations while cooperating with industry organizations and authorized government agencies. Emergency response plans will be developed prior to startup and operation of the project to ensure that adequate resources are available in the event that an incident, such as an oil spill, should occur.

During project operations, oil, water, and limited gas will be produced by submersible electric pumps from wells in the three fields. These fluids will be transported by a gathering system to the CTF, where the gas will be used to satisfy a portion of the project's fuel needs for the generation of electricity. The water will be disposed of by pumping to the oil-producing horizons below ground, and the oil transferred to the pipeline transportation system. In addition to the CTF, the Operations Center includes a power plant to serve project needs, Pump Station Number 1, housing for 100 single status expatriate personnel, an airstrip, and various other facilities.

A major project component is a pipeline transportation system. This includes the pipeline and Pump Station No.1. The pipeline itself will be 760 mm in diameter and buried throughout its length generally with a minimum of one meter of cover. Cover will be increased for road crossings and other sensitive areas and reduced to a minimum of 0.5 m in rocky areas. The pipe will be protected with a corrosion protection coating and cathodic protection. Isolation valves will be installed at intervals for operational purposes and to minimize environmental impact in case of leaks. A combination of leak detection methods will be utilized for the pipeline leak detection system. The leak detection system will be fully automated and manned 24 hours a day.

Other project facilities include an administrative office in N'Djamena, a satellite-based communications system, upgrades to approximately 170 km of existing roads, and the construction of approximately 30 km of new road.

Construction of the proposed project facilities would result in a temporary change of land use for approximately 960 ha of land during construction in the oil field development area and a permanent land use change for another 920 ha of land for the life of the project.

Pipeline construction would involve the temporary clearing of a strip of land about 30 m wide along the pipeline route; digging a ditch to accommodate the pipeline; transporting and stringing pipe along the length of the route; welding the pipe; installing the pipe in the trench; backfilling the trench; and rehabilitating the cleared area along the pipeline route. Upon completion of pipeline installation, the area along the pipeline route will be returned to its prior use except for a 10 to 15 m wide area for maintenance and emergency response access that will be kept cleared of buildings and heavy vegetation but could be used for grazing or cropping.

Project construction would take place over 3.5 years and would involve a peak work force in Chad of approximately 4,000, of whom up to 60 percent are expected to be Chadian nationals. During the nominal 30 year life of the project, up to 550 personnel (approximately 70 percent contractors) would be required in Chad. An aggressive plan to hire and train nationals and to replace expatriate personnel to meet these goals will be instituted as operations progress.

1.3 PROJECT ALTERNATIVES

A number of alternatives were identified and considered in development of the envisioned project, including:

- **Alternative Oil Development Scenarios in Chad**–The proposed development of crude oil from the Doba Basin was determined to be the most economically feasible option when compared to the alternatives of developing oil from the Doba and Doséo basins or the alternative of developing oil from the Doba, Doséo and Lake Chad basins.
- **Project Transportation Alternatives**–Principal transportation needs will be met by ocean shipping of cargo to ports in Cameroon, from where shipments to Chad will be via the Cameroon rail network and upgraded roads in both Chad and Cameroon, with limited use of air freight flights to the project airfield at Komé. Of the various road alternatives in Chad considered for upgrading, the selected alternative of constructing a bridge over the Mbéré River and upgrading existing roads (with limited new road construction) close to the pipeline route was found to be the most cost effective and environmentally preferred.
- **Alternatives to Pipeline Transport of Produced Crude Oil**–Alternatives such as various combinations of trucking, rail, road, river, and small diameter pipeline transportation of crude oil have been considered. The determination has been that the development of a pipeline transportation system from the Doba Basin directly to the Cameroon coast for subsequent export by tanker is the only feasible alternative to export the volumes of oil necessary to maintain the project's economic viability.
- **Alternative Pipeline and Facility Sitings**–The selected locations and routes were assessed to be the most economical and to be technically and environmentally acceptable. Individual field facilities have been sited to minimize costs and limit impacts to sensitive resources such as villages, water resources, and known transhumant corridors. Criteria considered in evaluating corridor alternatives included avoidance of certain features such as:

    - Areas of high priority for protection or exclusion by the government and other organizations
    - Parks, reserves, and other areas of importance
    - Villages, related structures, and areas inhabited by indigenous peoples.

Other criteria including landforms, infrastructure, and development were evaluated to identify preferred areas for pipeline routing, such as existing infrastructure, access routes, and disturbed areas.

- **Well Clustering Development**–Alternative well configurations and layouts have been assessed, including the use of vertical and deviated (including extended reach) wells. While the use of deviated wells would permit the grouping of more than one wellhead at some well locations, there are significant technical and economic difficulties associated with deviated well drilling in the project oil fields, and current project planning calls for the drilling of vertical wells. New technologies will continue to be reviewed to assess whether deviated well drilling becomes economically feasible in the future.
- **Discharge of Produced Water to Surface Drainages**–The alternative of surface discharge of produced water was considered and eliminated. This was due to the high costs associated with the likely need for treatment of large volumes of water to stringent water quality standards, the implementation of a comprehensive monitoring program, and the significant changes that would ensue to riverine ecosystems and flow regimes. Produced water will be returned to the producing horizons through reinjection wells. These wells will be designed using corrosion prevention measures and using tubing by casing isolation packers to maintain wellbore integrity to protect shallow groundwater aquifers. The quality of the reinjected water will be managed so as to protect deep groundwater resources.
- **The No Project Alternative**–Should the project not be developed, the benefits to Chad realized by local employment, increased government revenues, improved infrastructure, and enhanced business opportunities, would not occur, nor would the potential adverse impacts of the project. As indicated in the environmental economic analysis conducted for the project, the project has been shown to be of net positive benefit to Chad. The no project alternative would be detrimental to the country.
- **The Proposed Project**–The proposed project is the basis for project development and is fully described in this EA.

1.4 LEGISLATIVE, REGULATORY AND POLICY CONSIDERATIONS

It is established policy to comply with all applicable laws and regulations. The principal legislative and regulatory considerations to which the project will be subject are those of the Republic of Chad. The project also will be developed in compliance with various international treaties and World Bank guidelines. Where no appropriate legislation, regulations, or guidelines exist, the project will adopt international industry standards.

Relevant Chadian legislation includes:

- The Forest Code (addressing protection, conservation, enhancement and use of forests, botanical resources, terrestrial fauna, aquatic resources and fisheries, and identifying plant and animal species protected under Chadian law)
- The Water Code (regulating the use of all surface waters and groundwaters)
- Laws (numbers 23, 24, and 25) addressing land tenure; defining property owned by the state and property classified as public domain; the rules for the registration of private land; and the rules for the expropriation of land in cases that benefit the general public
- An ordinance (number 7) providing regulations and guidelines for oil and natural gas exploration, production, and transport.

Relevant World Bank policies and guidelines will be complied with including:

- World Bank Environmental and Occupational Health and Safety Guidelines
- World Bank policy on social issues (including Operational Directives on Indigenous Peoples and Involuntary Resettlement)
- IFC Environmental Analysis and Review of Projects
- World Bank Environment, Health and Safety Guidelines for Onshore Oil and Gas Development.

1.5 ENVIRONMENTAL SETTING

Human Environment

The project area lies in the southwest of Chad, a country with a population of 6 million and a Gross National Product per capita of about U.S.$180 per annum. In Chad's economy, agriculture comprises 83 percent of the labor force, industry 4 percent, and services 13 percent.

The project will be located wholly within the prefecture of Logone Oriental (population 440,000), although the peri-urban population of 120,000 around the major regional center of Moundou in the prefecture of Logone Occidental will also be impacted. The oil field area had a population of approximately 28,100 in 1993, in the cantons of Béro, Komé, and Miandoum. The cantons of Timbéri, Gadjibian, Bessao, Mont de Lam, and Mbassay will be impacted by the pipeline transportation system and the upgraded infrastructure required for the project. Those cantons have a total population of about 63,000. The rural populations primarily engage in subsistence agriculture. Currently, the population density of the area is increasing, and the traditional cycles of cultivation and fallow are becoming shorter. This results in decreasing fertility of the already poor-soils, which itself leads to still shorter periods of fallow, and the conversion of more bush land to agriculture. Moreover, the traditional farming system in southern Chad integrates the bush as an active part of its productive system--the bush provides significant resources to the population and becomes diminished as the cycle of shorter fallows and conversion of bushland continues. Studies conducted for the EA estimated that without the proposed project, all village land in the project area would be under cultivation within 30 years.

The region has been characterized by civil strife and instability since precolonial times, and periodic civil disruption has inhibited economic growth. Most recently, Chad suffered civil war from the mid-1970s to the mid-1980s, and although the national government reestablished control in the project area in 1982, major hostilities continued until 1985, and occasional civil disruptions have occurred in recent years.

Civil unrest has had adverse impacts on the educational system in the project area, and although the local population is educationally motivated, difficulties result from a lack of resources such as buildings, educational materials, and the periodic non-payment of teachers' wages.

With the negotiation in 1996 of a peace agreement between the government and the rebels most active in the region, much desired stability has returned to the area.

The population of the project area is primarily Christian in religious belief, although animism is also widely practiced. The population in the center and north of Chad is predominantly Muslim, and Muslim herders regularly interact (and sometimes conflict) with the sedentary Christian population.

Relatively widespread animist beliefs are reflected in the presence of sacred sites in the project area. Such sites are not readily identifiable by outsiders and may constitute objects (which may be relocated) or landscape features (which are usually immovable).

Because of the almost total reliance of the local population on subsistence agriculture, land use and land tenure are critical issues, particularly in the oil field development area. National law in Chad is that all land belongs to the state unless the state confers ownership. Customary rights are recognized and may be enforceable within the community where they are exercised unless in direct conflict with written law or against public policy. Customary rights arising from land use apply to cultivated land, uncultivated land (fallow or bush), rights over forest land, rights to water, and religious sites.

Biological Resources

Vegetation of the project area consists primarily of wooded savanna, most of which has been heavily grazed, cultivated for cotton and subsistence crops, or is in various stages of fallow. Some gallery forests (forests along water courses in areas otherwise largely devoid of dense stands of trees) and floodplain wetlands are present and are important resources for seasonal agriculture and grazing.

Wildlife resources in the project area have suffered from extensive hunting and poaching, which has been particularly severe because the civil unrest of the past two decades has introduced many automatic weapons to the area and reduced law enforcement activities. Similarly, fishing in the area has been adversely affected by over exploitation, drought, the conversion of floodplains to grazing and agriculture, and the disruption of aquatic ecosystems by the elimination of large animals such as the crocodile and hippopotamus. Some mammal species whose status is considered sensitive on the regional scale have the potential to occur in the project area (including a number of antelope species and the elephant), as well as a recently discovered bird species, the River Prinia. However, the project is not expected to have a significantly adverse effect on the wildlife of the project area.

Several areas of biological significance, such as designated and proposed reserves and areas containing important biological resources and sensitive habitats, occur near the project area, including:

- Timbéri Forest Reserve
- Laramanay Reserve
- Logone floodplain
- Areas of bamboo.

As a result of early recognition and avoidance of such areas, none are expected to be impacted by the project.

Water Resources

The water resources of the project area are of great importance at the local, regional, and national levels. Surface drainages eventually discharge to the Logone River, which joins the Chari River at N'Djamena, the national capital. The Chari discharges into Lake Chad.

Most of the population in the project area obtains drinking water from hand-dug (and some drilled) wells which exploit the shallow aquifers of the Doba Basin, although some surface waters are also utilized. Groundwaters of the basin are considered to be unconfined and subject to substantial flow from recharge areas to the south of the project area to discharge areas to the north.

Because of the importance of water resources in the project area locally, regionally, and nationally, the project has been and will continue to be designed and developed to minimize risks of water pollution by incorporating measures such as disposing of produced water back into the oil reservoir.

Topography and Soils

The topography of the Doba Basin is generally flat with no distinct physical features. To the southwest the terrain becomes first rolling and then hilly towards the Cameroon border, although the hills tend to be isolated and have been avoided in pipeline route selection. Soils of the Doba Basin are sandy with scattered occurrences of laterite. Soils to the southwest, underlain by shallow bedrock, are more varied and more readily erodible.

Meteorology and Air Quality

The climate of the project area is dominated by a hot dry season which extends from November to May and a cooler wet season. The annual rainfall ranges from 1,000 mm in the north to 1,300 mm in the south. Because of the lack of industrial development and the low usage level of other potential sources of atmospheric pollutants (such as motor vehicles), the only significant contribution to air pollution in the project area is considered to be particulate matter from agricultural activities (dust and smoke from agricultural burning) and from dust storms.

Public Health

Chad, in common with most of sub-Saharan Africa, is characterized in public health terms by high rates of fertility, mortality, malnutrition, and infectious diseases. Important person-to-person infectious diseases include: acute respiratory infections; meningitis; and tuberculosis. Food, water and soil borne infectious diseases include: schistosomiasis; cholera; and food-borne illnesses such as salmonellosis and hepatitis A. Insect vector infectious diseases include: malaria; onchocerciasis; leishmaniasis; trypanosomiasis; and yellow fever. Animal borne infectious diseases and emerging diseases include: rabies; brucellosis; and antibiotic resistant strains of a variety of diseases such as malaria, cholera, dysentery and pneumonia. Sexually transmitted diseases, AIDS and Hepatitis B/C represent a serious and growing problem in Chad, exemplified by the quintupling of the reported annual incidence of AIDS over the five years to 1995.

Oil Exploration Activities

The environmental setting for the project has been modified by the effects of past exploration activities in the project area. These include the clearing of seismic survey lines, the drilling of a number of exploration wells, and the construction of various infrastructure items such as roads, airstrips, and camps. These past exploration activities were the subject of an environmental audit which found no serious threats to the environment.

1.6 ENVIRONMENTAL IMPACTS AND MITIGATIONS

The potential impacts of the proposed project have been classified into four categories:

- Beneficial
- Less than significant
- Significant but mitigable
- Significant and unavoidable.

Environmental Economic Impacts

World Bank guidelines advise that environmental costs and benefits should be quantified to the extent possible and economic values attached, if feasible. Economic values of impacts in the following nine major categories were estimated:

- Agriculture

- Forestry and bush products
- Livestock
- Petroleum production
- Job search
- Housing
- Health
- Transportation
- Multi-industry (multiplier) impacts.

Most cost categories are determined by changing current land use to uses related to petroleum production. Most benefit categories are determined by infrastructure investments and direct and indirect revenue flows.

The aggregate present value of the estimated impacts to Chad over the life of the project is a range of positive net benefits between 237 and 629 billion FCFA (U.S.$0.47 to 1.3 billion). Consistent with World Bank guidelines, the environmental economic impact analysis indicates that after taking into account estimates of environmental costs and benefits, the proposed project is a net positive benefit to Chad.

Beneficial Impacts

A variety of significant beneficial impacts will result from development and operation of the proposed project. Plans are being developed to focus benefits, such as employment and purchasing of goods and services, on groups and communities that would be in the vicinity of the project. The proposed project will also provide substantial financial revenues to the Government of Chad from royalty payments. The Government of Chad recognizes that these benefits will need to be equitably and effectively distributed by mechanisms such as: the financing of devolved Decentralized Territorial Communities from proceeds generated from the exploitation of subterranean resources in their territory; the continuation of a range of projects designed to address weaknesses in the Chadian administration associated with revenue collection, expenditure, and economic policy formulation; and the implementation of measures to ameliorate the negative impacts of the sharp and sudden rise in government revenues. Other benefits include:

- Provision of employment to Chad nationals during project construction
- Long-term employment of Chad nationals during project operations
- Provision of training for the Chad project work force
- Purchases for the project of locally sourced goods and services

- An increase in the overall level of economic activity in Chad as a result of project development and operations
- Upgrades to and maintenance of roads and other infrastructure needed for the project
- Upgrade of environmental health and infrastructure, particularly water, sanitation; and housing
- Increased disease surveillance and treatment for both vector-borne and sexually transmitted diseases.

Minimization of Adverse Impacts

The early and extensive integration of environmental inputs to the preliminary engineering of the project has resulted in the avoidance of many potentially significant adverse impacts and the reduction of many others to less-than-significant levels. It has also resulted in the incorporation of project design measures into the project which prevent or minimize adverse environmental effects.

Examples of impact avoidance by the integration of environmental inputs and incorporation of project design measures include:

- Pipeline corridor and route selection to identify and, where feasible, avoid potentially sensitive resources and locations
- Use of existing infrastructure and disturbed areas for facility siting and pipeline routing
- Early identification of environmental and socioeconomic issues
- Review of the Terms of Reference for the EA with the Government of Chad and the World Bank
- Consideration of environmental effects in the analysis of project alternatives such as the disposal of produced water
- Incorporation of drainage, erosion, and sedimentation control measures to protect water resources
- Preferential use of freshwater-based drilling muds
- Adoption of a well casing design to protect shallow groundwater resources
- Incorporation of an Occupational Health and Safety program
- Incorporation of sanitation, housing, vector-control, food and water supply, and workplace safety guidelines for the project
- Avoidance and minimization of potential waste management impacts by the early development of an integrated project waste management strategy and incorporation of a Waste Management Plan

- Development and implementation of a consultation and participation process with NGOs and local peoples that allowed for the identification of issues significant to the affected population.

Those impacts considered to be significant but mitigable or less than significant with implementation of a project design measure are listed in Table 1-1, as are the design measures and mitigations. Three issues predominate in Chad: potential impacts on the human environment, water resources, and public health.

Human Environment Impacts and Mitigations

- Changes in existing uses of land as a result of the project have the potential to result in isolated instances of displacement of the local population. Project development activities have included a variety of measures designed to minimize the necessity for displacement. While the exact numbers of people that would require resettlement cannot be determined at this stage of project planning, it is anticipated to be in the range of 60 to 150 households. A larger (as yet undetermined) number of households would be impacted at a level that would not require resettlement but would necessitate some form of compensation, for example, as a result of temporary changes in land use during construction. Mitigation for these impacts is the development and implementation of a comprehensive compensation plan which will include a resettlement plan to satisfy Government of Chad legislative requirements and World Bank Operational Directive 4.30, *Involuntary Resettlement*, and will involve compensation mechanisms such as: cash payments and in-kind replacements to compensate for short-term crop losses; technical assistance to improve agricultural productivity; direct assistance (in the form of land, building materials, etc.) to help displaced residents re-establish themselves; and community level compensation.

- The beneficial impact of employment generation has the potential to be reduced by the perception of inequitable distribution of jobs. Mitigation for this will be the implementation of a recruitment and training plan that will be based on matching the numbers and skills of workers with project employment needs in a cost-effective manner maximizing socioeconomic benefits to the project area. The plan will emphasize employment among impacted villages in the vicinity of the project. The recruitment process will be conducted in an open (transparent) manner to demonstrate fairness.

- Inflationary effects on area residents and the development of a boom-bust syndrome are potential negative aspects of another beneficial impact of the project (the generation of local business opportunities) and will be mitigated by the development of a process to distribute project purchases across a broad geographic area and to more than one supplier.

- The potential disruption of transhumant movements during the project construction period will be mitigated by consultation with nomadic group leaders and others such as veterinarians and village residents to provide adequate advance notice of project activities so that appropriate temporary adjustments to traditional migratory routes can be made.

Water Resources Impacts and Mitigations

- The impact of increased peak flows in the vicinity of cleared areas on sedimentation and erosion in minor water courses will be mitigated by the implementation of erosion control plans and design of appropriate drainage systems.

- Potential disruption to existing water supply wells from the development of project water supplies will be mitigated by locating project wells so that they do not interfere with village wells. In the event impacts do occur, alternative water supplies will be provided to impacted villages.

- Impacts on water quality will be mitigated by a variety of measures, including: treatment of sanitary wastewaters to World Bank effluent guidelines, reinjection of produced water to the oil-producing horizons from which it originates, and implementation of erosion and sedimentation control plans.

- Comprehensive risk assessments will be undertaken, and the potential effects of oil spills will be mitigated by incorporation of a variety of measures to prevent spills from occurring. The development of emergency response and spill control plans with the associated commitment of training, equipment, and infrastructure will mitigate impacts of any spill of fuels, chemicals, or oil in either the construction or operations phases.

Public Health

The project would affect six environmental health areas:

- Respiratory disease
- Vector-related disease

- Sexually transmitted disease
- Water and food-borne disease
- Accidents and injuries
- Exposure to potentially hazardous materials.

Associated environmental health impacts occur in four subsectors:

- Housing
- Transportation
- Water and sanitation
- Telecommunications.

Impacts arising from the linkage between the affected environmental health areas and the four project subsectors would be mitigated by a series of project design measures, Government of Chad public health strategies, and community outreach programs. These mitigation measures and programs build upon the inherent link between health outcome and infrastructure improvements in housing, transportation, and water supply and sanitation. Public health impacts are of greatest concern during construction of the project due to the influx of construction workers.

1.7 CONSULTATION WITH AFFECTED GROUPS

Business will be conducted in a manner that is compatible with the balanced environmental and economic needs of the community, including communication with the public on environmental matters. A program to effect consultation, coordination, and interaction with affected groups, NGOs, and government agencies has been developed and it includes:

- Identifying relevant government ministries and NGOs
- Canvassing key issues during preparation of the EA Terms of Reference
- Conducting fact-finding meetings in major regional towns
- Reviewing the TOR with the Chad government and the World Bank
- Consulting relevant ministries, NGOs, and groups within affected communities during EA development
- Reviewing the draft EA with government ministries
- Reviewing the draft EA with NGOs and the communities.

EA consultation, coordination, and in-country fact-finding meetings have been conducted in English, French, and local languages since November 1993. This has included government officials, NGOs, and affected groups in N'Djamena and near the pipeline route and project facilities. Information has been gathered directly or indirectly by allowing these entities to provide information of direct interest or concern to them. This approach, conducted during initial project planning, encouraged participants to contribute freely when project plans were still at an early stage of definition. This was followed (beginning in 1995) by significant communication and consultation with affected communities and NGOs during the human environment field program. This program was conducted by a team experienced in conducting field work in the project area and using local languages. A wide geographic area, including the entire administrative region around the production facilities, was surveyed.

In all, more than 600 questionnaires for individual local inhabitants have been collected, and in excess of 10,000 persons have had the opportunity to be consulted at pre-announced meetings in more than 50 project-area villages. In addition, more than 20 NGOs have been consulted, some at more than one location within Chad, and more than 10 NGOs with an interest in Chad have been consulted internationally.

Key issues identified in the consultation process leading up to EA development are related to land use, compensation, employment opportunities, and water resources. Specifically, accessing land and determining land ownership have been identified as areas of concern. Additionally, the hiring process and compensation in terms of openness and fairness is also of significant interest to the population. The project has been developed to address these issues. For example, project land requirements will be minimized to the extent feasible, a comprehensive compensation plan is being developed and implemented, a plan is under formulation to ensure equitable employment practices are adopted, and project design and mitigation measures will minimize impacts to water resources.

Continuing consultation is planned beyond finalization of the EA. This is an important component of the project to integrate public opinion and to promote understanding of potential impacts and proposed mitigation measures.

1.8 ENVIRONMENTAL MANAGEMENT PLAN AND MONITORING SYSTEM

The project is committed to conduct its operations in compliance with applicable laws and regulations and to design, construct, and operate project facilities to high standards. An Environmental Management Plan (EMP) is under development that will describe measures and actions that are planned to be undertaken during the design, construction, operation, and decommissioning of the project to eliminate or reduce key impacts to acceptable levels.

In order to accomplish this goal and function as an implementation plan for the project's environmental management actions, the EMP will:

- Denote the project's key biophysical, socioeconomic, and health topics and their associated issues/impacts
- Provide summaries of specific biophysical, socioeconomic, and health-related issues/impacts mitigation and monitoring actions planned for the Chad portion of the project
- Define and discuss the roles and responsibilities of the key project participants (i.e., the Consortium's designated operator, Esso; TOTCO; and the Government of Chad)
- Outline project and government oversight organizations as they relate to environmental matters
- Summarize the costs associated with these environmental oversight organizations
- Provide a milestone schedule that features important environmentally-related milestone linkages to project execution
- Introduce environmental management tools that are envisioned for the project and key activities/studies that will assist in the crafting of these tools.

The EMP will contain those measures to which Esso, as the Consortium Operator, TOTCO, and the Republic of Chad are committed to undertake.

1.9 CONCLUSIONS

The Chad Export Project is incorporating environmental inputs in all phases of project development. The early recognition of environmental issues and incorporation of project design measures which prevent or minimize adverse environmental effects has avoided many prospective adverse impacts and allowed others to be reduced to less-than-significant levels. Consequently, substantial beneficial impacts will be generated such that after taking in account estimates of environmental costs, the project is a net positive benefit to Chad.

TABLE 1-1
PROJECT IMPACTS WITH PROJECT DESIGN AND PROPOSED MITIGATION MEASURES

IMPACT DESCRIPTION	PROJECT DESIGN MEASURE OR PROPOSED MITIGATION MEASURE
HUMAN ENVIRONMENT	
Land use requirements of the project causing temporary or permanent displacement of the local population	Develop and implement a detailed compensation and resettlement plan
Potential boom-bust syndrome as workers are released from construction	Provide open communication during the recruitment process as to the temporary nature and duration of jobs on the project
Labor recruitment and the potential for inequitable distribution of jobs	Develop a plan for worker recruitment, with the following key attributes: • Ensure the employment of Chadians preferentially • All Chadians can apply • Applications will be accepted at local employment and business offices • No hiring at project work sites • Hiring preference given to candidates who meet job criteria and are directly impacted by the project • Compliant with Chadian laws and regulations
Inflationary effects on area residents from purchase of local goods and services for the project	Distribute purchasing to more than one supplier
Potential boom-bust syndrome for local suppliers as purchasing requirements for the project decline at the end of the construction	Distribute purchasing to more than one supplier
Dust generated by project activities resulting in unsafe traffic conditions and nuisance to local populations	Implement dust control protocol at appropriate project facilities
Disturbance to burial sites and sacred places and objects	Consult with village and religious leaders and local residents to identify areas to be avoided and/or to negotiate compensation for disturbance
Interference with transhumant migration patterns causing encroachment on neighboring landholdings or increased competition for food and water	Inform transhumant group leaders, veterinarians, and herders of interruptions to migratory routes
Migration of people to the project area increasing demand on existing social infrastructure and resources	Public information campaigns to ensure that: key information such as the number and timing of job opportunities, and that no hiring will take place at project work sites, are widely known; and control worker recruitment so that no encouragement is given that employment is available on the project other than through authorized hiring processes

TABLE 1-1
PROJECT IMPACTS WITH PROJECT DESIGN AND PROPOSED MITIGATION MEASURES

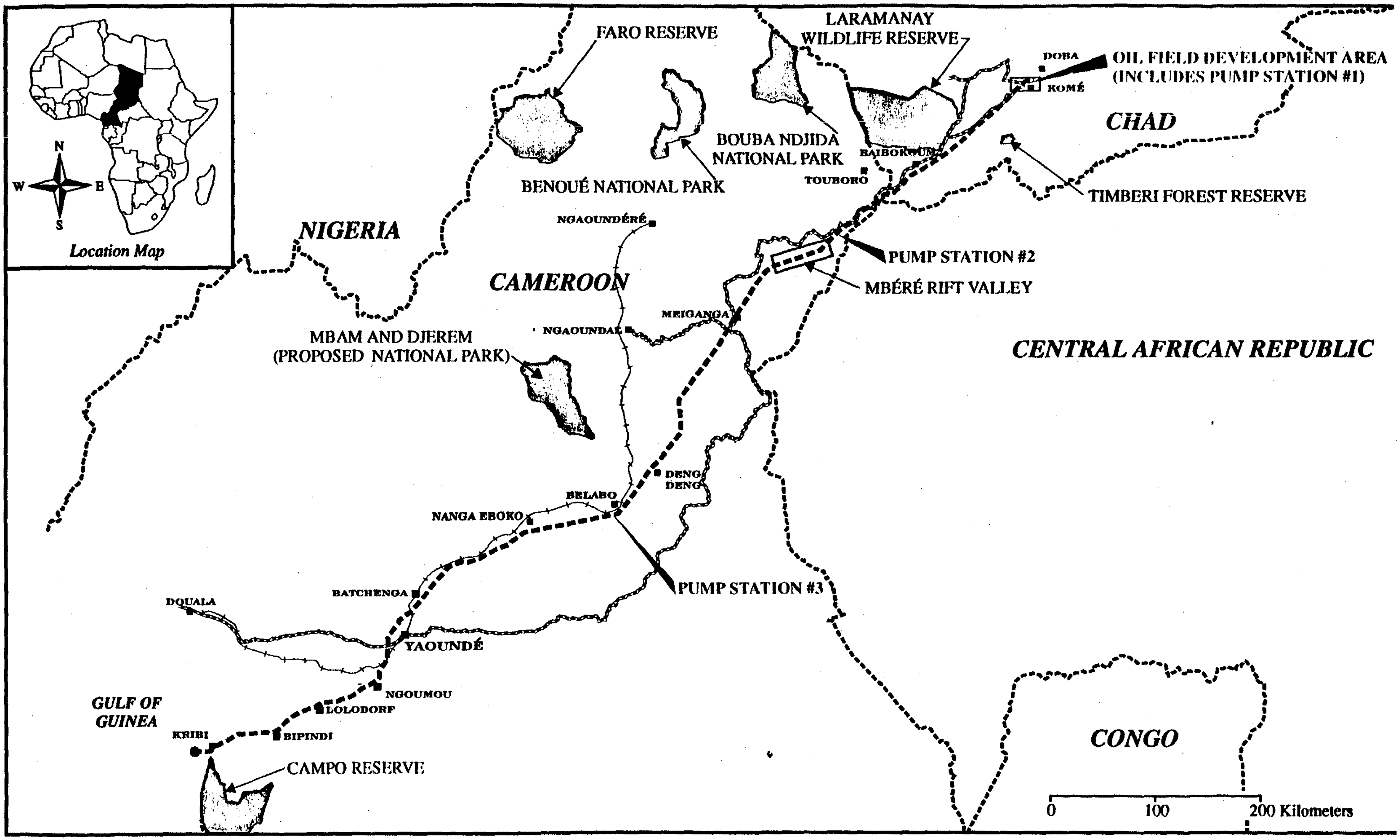
IMPACT DESCRIPTION	PROJECT DESIGN MEASURE OR PROPOSED MITIGATION MEASURE
BIOLOGICAL RESOURCES	
Movement, mixing, and compaction of soils by heavy equipment resulting in loss of topsoil and essential nutrients and other soil components	Incorporation of a soil erosion and sedimentation control program
Removal of vegetative cover and shade canopy increasing soil surface temperature, decreasing moisture content, killing soil organisms, and increasing potential for erosion in the oil field development area and along the pipeline	Provide buffer zones around sensitive areas
Increase in soil surface temperatures directly above the pipeline where it exits Pump Station 1	Extra depth of burial would be provided for the pipeline near Pump Station 1
Increased turbidity and reduced visibility impacting food gathering activities by aquatic organisms	Incorporate erosion and sedimentation control plan
Potential disturbance to aquatic resources from minor spills of diesel, gasoline, hydraulic, brake, transmission, and other equipment fluids or chemicals	Incorporate project safety and environmental measures and spill response plans for construction and operations phases
Damage to botanical, wildlife, and other aquatic resources and contamination of surface water bodies resulting from oil spills	Incorporate project safety and environmental measures and an oil spill response plan, associated training, equipment, and supporting infrastructure into the project
Induced access to relatively undisturbed wooded savanna and riverine vegetation during construction and operations leading to reduction in natural resources due to hunting, fishing, collecting of plant materials, etc.	Control unauthorized use of pipeline route during construction; provide work force with resource conservation/protection briefing and communicate that hunting or trade in bushmeat would result in instant dismissal; reinstate natural barriers after construction
HYDROLOGY AND WATER QUALITY	
Increased peak flows and sediment loads of small unnamed tributaries or drainages in the immediate vicinity of cleared areas	Design drainage systems to drain surface runoff to more than one tributary or in a manner that minimizes erosion
Disturbance to existing local supply wells caused by continuous withdrawal of project water supplies	Stagger project water supply wells to reduce the effect on nearby wells; provide alternative supplies in case of disruption to existing wells
Reduced water quality caused from wastewater discharge to relatively small tributary streams	Treat or dispose of sanitary wastewater in compliance with World Bank effluent guidelines
Decrease in water quality from surface runoff potentially contaminated with drilling muds	Incorporate erosion and sedimentation control plan and project waste management plan
Decrease in quality of groundwater in the potable near-surface aquifer due to casing leak	Injection well integrity program

TABLE 1-1
PROJECT IMPACTS WITH PROJECT DESIGN AND PROPOSED MITIGATION MEASURES

IMPACT DESCRIPTION	PROJECT DESIGN MEASURE OR PROPOSED MITIGATION MEASURE
GEOLOGY, SOILS, AND SEISMICITY	
Increased potential for wind and water erosion from ground disturbing activities	Incorporate soil erosion and sedimentation control plan
Increased potential for sedimentation in streams intersected during pipeline construction	Incorporate soil erosion and sedimentation control plan
Potential for erosion, scour, and changing bottom profiles to expose the pipeline	Assess scour potential in support of pipeline design
Potential for differential settlement and blasting induced localized slope instability causing structural damage to buildings or facilities	Incorporate recommendations of geotechnical engineering evaluation
METEOROLOGY AND AIR QUALITY	
Generation of particulates from earthmoving activities	Implement dust control protocol at appropriate project facilities
Compliance with World Bank NO_2 guideline values	Confirm modeled NO_x ground level concentrations meet guidelines with final design input parameters, or amend final design accordingly
PUBLIC HEALTH AND SAFETY	
Increased incidence of respiratory diseases	Implement measures in project housing, transportation, water and sanitation, and telecommunications; implement village-based education programs which address the recognition and prevention of respiratory diseases
Increased incidence of vector-related diseases, such as malaria, schistosomiasis, filariasis and onchocerciasis	Implement measures in the areas of project housing, transportation, water and sanitation regarding the prevention of vector-borne diseases
Increase in the incidence of STDs/HIV	The following would be implemented for the project work force and the Government of Chad would implement the same strategies for the community surrounding the project area directed toward the prevention of STDs/HIV: • Coordination with government national AIDS program, particularly programs directed toward female commercial sex workers and other vulnerable women • Surveillance and treatment of STDs, particularly genital ulcers • Information, education and communication (IEC) • Aggressive distribution of condoms • Surveillance activities to monitor HIV prevalence rates
Increase in incidence of water and food-related illnesses	Implement measures in project housing, transportation, water and sanitation directed toward water and food sanitation and hygiene
Increases in accidents and injuries, security incidents	Implement measures in the areas of project housing, transportation, water and sanitation, and telecommunications targeting the prevention of accidents and injuries

TABLE 1-1
PROJECT IMPACTS WITH PROJECT DESIGN AND PROPOSED MITIGATION MEASURES

IMPACT DESCRIPTION	PROJECT DESIGN MEASURE OR PROPOSED MITIGATION MEASURE
Increase in chemical exposures and environmental diseases	*Implement measures in the areas of project housing, transportation, water and* sanitation, and telecommunications targeting the prevention of chemical exposures and environmental diseases
WASTE MANAGEMENT	
Generation, treatment, and disposal of various types and volumes of solid, liquid, petroleum-based, and hazardous wastes	Incorporation of standard waste management practices in the project would include an overall waste management plan and facility-specific waste management plans



LEGEND

- Oil Field Development Area
- Pipeline
- International Boundaries
- Reserve or Biologically Sensitive Area
- Major Roads (In Study Area)
- Railroad
- Marine Terminal (FSO)

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PROJECT STUDY AREA

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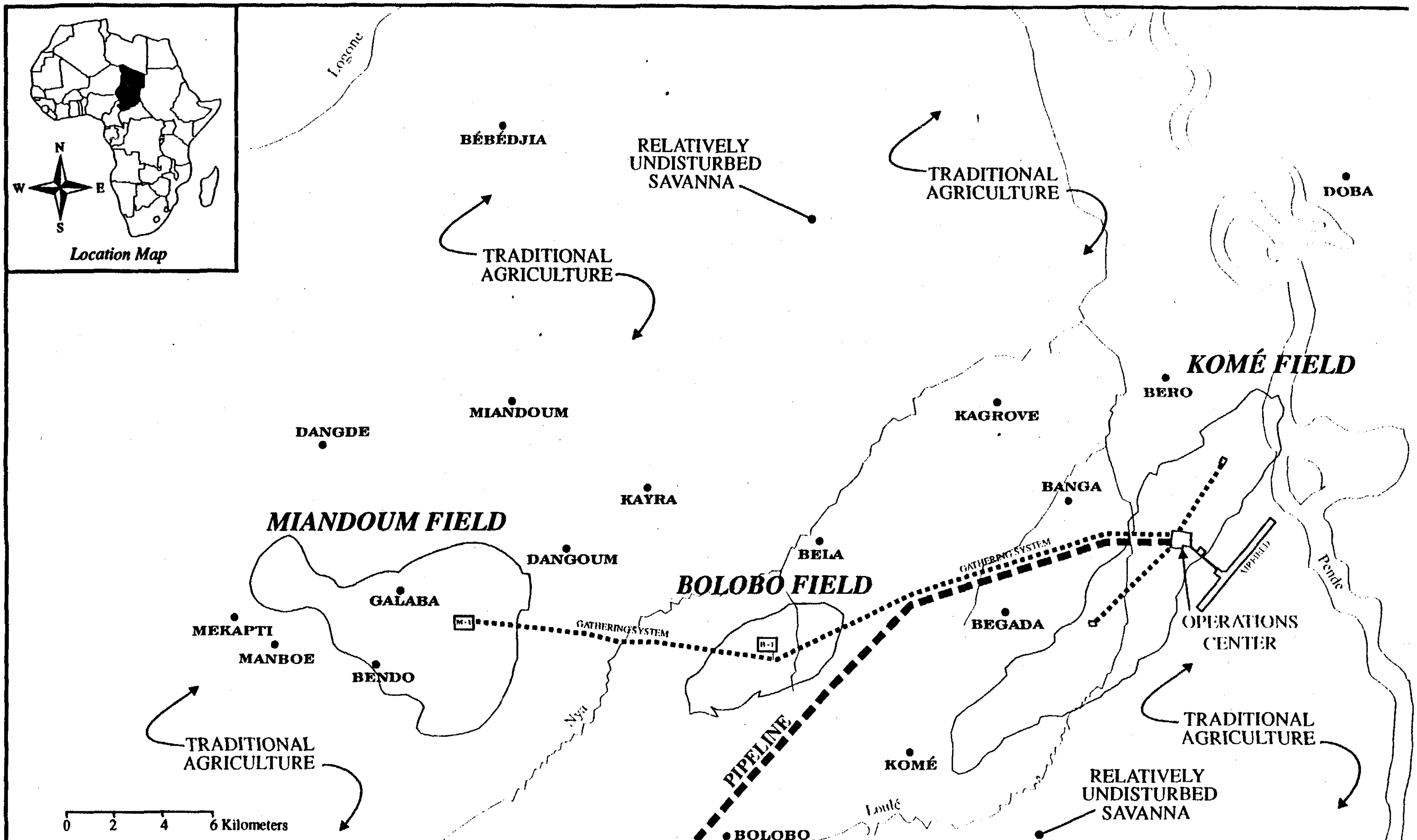
FIGURE 1-1



LEGEND

- Komé Field
- Miandoum Field
- Bolobo Field
- Villages / Towns
- Gathering Stations
- Rivers

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OIL FIELD PROJECT AREA

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FIGURE 1-2

2.0 INTRODUCTION

2.1 PROJECT BACKGROUND AND HISTORY

Oil exploration activities began in the Republic of Chad in 1969 and were continued through the 1970s and the 1980s by a consortium comprised of various international oil companies. Since 1993, the Consortium has consisted of Esso Exploration and Production Chad, Inc. (Esso) holding 40 percent, Société Shell Tchadienne de Recherche et d'Exploitation also holding 40 percent, and Elf Hydrocarbures Tchad holding 20 percent, with Esso designated as the Operator. By virtue of a convention signed in 1988 between the Republic of Chad and the Consortium (the Consortium Convention), the Consortium currently holds approximately 8.4 million hectares (ha) of exploration area in Chad under an exploration permit (Permit H). The exploration permit is valid through January 2004. The Consortium Convention provides for a 30 year concession period for the development and production of individual fields.

As a result of recent exploration activities, the Consortium is considering development and transport of crude oil reserves from the Doba Basin in southern Chad through Cameroon to the Gulf of Guinea coast for commercial export. The project in Chad will consist of oil field development and production and the portion of the pipeline transportation system that is located in Chad. The oil field development and production will be carried out by the Consortium through its Operator in accordance with the Consortium Convention.

As part of overall project development, a three dimensional (3-D) seismic exploration program was initiated in the oil field development area in 1995 and continued into the first half of 1996. Activities and related effects from the program have become part of the baseline conditions in the oil field development area for the purposes of this project. Information on changes to the oil field development area brought about by the program are provided in Section 6.2.2.

A Chadian company, the Tchad Oil Transportation Company (TOTCO), whose shareholders will be affiliates of each of the Consortium members and the Republic of Chad, will be formed. TOTCO will design, construct, operate and maintain the TOTCO Transportation System in accordance with the terms of the TOTCO Convention to be signed between TOTCO and the Republic of Chad. To carry out its activities, TOTCO will enter into contracts with other entities, such as Esso Exploration and Production Chad Inc. (EEPCI) or an affiliate of EEPCI, for the provision of services, such as the design and construction of the TOTCO Transportation System and the provision of the technical and administrative services and personnel.

2.2 PURPOSE AND NEED FOR THE PROPOSED PROJECT

The purpose of the project is to produce, transport, and ultimately sell oil from southern Chad to world markets in a manner compatible with the balanced environmental and socioeconomic needs of the people in the Republic of Chad. The project is needed at this time to help satisfy the world's growing energy needs. The need is based in part on the fact that alternative energy sources (including solar, geothermal, wind, and nuclear fusion) would not significantly reduce world dependence on petroleum in the foreseeable future.

The project is being designed to avoid or reduce to acceptable levels potentially significant adverse impacts to the human, biological, and physical environments. In addition, the project is consistent with Chad's, as well as the Consortium's, overall oil exploration, development, and production goals and objectives.

2.3 LOCATION OF THE PROJECT

The Republic of Chad is a landlocked country located in west-central Africa (Figure 2-1) and is bounded to the west by the countries of Niger and Nigeria, the southwest by Cameroon, the south by the Central African Republic (CAR), the east by Sudan, and the north by Libya. The Consortium's concession area is located in southern Chad and includes the Doba, Doséo, Salamat, Bongor, and Lake Chad basins (Figure 2-2). The EA study area, the oil field development area, and the pipeline corridor are shown in Figure 2-3.

2.4 GENERAL OVERVIEW OF THE PROJECT

Crude oil reserves produced from the Komé, Miandoum, and Bolobo fields in the Doba Basin would be transported through a buried pipeline from southern Chad to a floating storage and offloading (FSO) vessel located offshore the coastal town of Kribi, Cameroon. Oil tankers would load the oil from the offshore FSO for transport to international markets.

The Consortium estimates production of approximately 924 million barrels (MB) of oil from these fields in the Doba Basin over an approximately 30 year period. Estimated peak daily production rates would be approximately 225 thousand barrels of oil per day (KBOD). However, the pipeline and pump stations would be designed to accommodate a throughput of 250 KBOD.

Should additional reserves be identified, further production from Komé, Miandoum, and Bolobo, or from other fields, could be exported via the proposed pipeline system, with or without system upgrades such as additional pump stations. The project (in Chad) would consist of the following major components:

- **Production Wells**–Approximately 300 production wells would be drilled within the three-field area.
- **Gathering System**–Produced fluids from each well would be transported via a series of buried flow lines to a gathering station (one per field). At each gathering station a significant portion of the produced water would be removed, treated, and pumped to various injection wells for disposal. Crude oil with limited entrained water (approximately 20 percent) would be sent from the gathering stations in each field via buried main trunk lines to the Central Treating Facility.

- **Central Treating Facility (CTF)**–The CTF would receive oil from the gathering stations and remove the remaining entrained water to a level of less than 1 percent. Produced water from the CTF would be pumped to the Komé gathering station for disposal.
- **Operations Center**–The CTF is part of a larger complex designated as the Operations Center (OC). The OC would provide power generation and distribution, a pump station, a gathering station, operations and administration center, housing and support facilities, and an airfield.
- **Pipeline Transportation System**–Adjacent to the CTF would be Pump Station No. 1 and the beginning of the 760 millimeter (mm) diameter pipeline. Oil would be transported to market via the pipeline transportation system. No additional pump stations would be required along the pipeline transportation system in Chad. Approximately 170 kilometers (km) of the 1,050 km long 760 mm diameter buried pipeline transportation system would be located in Chad.

A more detailed description of the project is contained in Section 3.0 of this document.

2.5 OBJECTIVES OF THIS ENVIRONMENTAL ASSESSMENT

This EA has been prepared to meet the requirements of the project, and to support funding applications from the Government of Chad to the World Bank, and from TOTCO to the International Finance Corporation ([IFC] the private sector lending agency of the World Bank), international lending agencies, and export credit agencies.

The project is classified as a Category A project under the World Bank and IFC environmental review procedures, which means that it potentially could have significant adverse impacts on the natural environment or the social circumstances of the project area. For such projects, a full EA following appropriate World Bank guidelines is required. A Terms of Reference (TOR) document was prepared in early 1995 for preparation of the EA. The purpose of the TOR was to provide guidance for identifying and addressing impacts from construction, operation, and decommissioning of the proposed project. The TOR was developed utilizing information collected from a variety of sources, including consultation with the Chad government and several nongovernmental organizations (NGOs). A draft of the TOR was reviewed by the Chad government, the World Bank, and IFC prior to development of the EA.

The objectives of the EA are to ensure that the project is constructed and operated in an environmentally sound manner and that issues of concern relating to the human, biological, and physical environments (including applicable Republic of Chad regulations and World Bank environmental and health and safety guidelines) are recognized early and considered in the project design.

In addition to providing a detailed project description, the EA addresses a variety of topics, including a discussion of project alternatives; legislative, regulatory and policy considerations; a discussion of existing environmental (baseline) conditions; impacts identified that would result from project implementation; a discussion of mitigation measures and project design measures that would be implemented to reduce significant adverse project impacts to less-than-significant levels; and a discussion of the coordination that has taken place to date with relevant government agencies, affected communities, and NGOs as this project has developed.

Coordination and consultation with affected agencies, NGOs, communities, and individuals throughout the EA planning and development phase of the project has helped to identify potential impacts. As a result, measures to avoid, reduce, or compensate for such impacts have already been incorporated into the overall project design.

The following World Bank guidelines were recognized in the TOR and provide additional support for preparing a full EA:

- Environmental Assessment Sourcebook (1991a; updated 1993)
- Operational Directive 4.01 (Environmental Assessment) (1991b)
- Operational Directive 4.20 (Indigenous Peoples) (1991c)
- Operational Directive 4.30 (Involuntary Resettlement) (1990a)
- Operational Policy Note 11.02 (Wildlands) (1986)[1]
- Technical Paper No. 55 (Techniques for Assessing Industrial Hazards: A Manual) (1988a)
- Technical Paper No. 80 (Involuntary Resettlement in Development Projects) (1988b)
- Technical Paper No. 126 (Environmental Considerations in Port and Harbor Developments) (1990b)
- The Forest Sector: A World Bank Policy Paper (1991d)
- Environmental Guidelines (1988d, as updated, 1995c)
- Environmental Analysis and Review of Projects (IFC, 1993).

2.6 PROJECT PLANNING AND DEVELOPMENT

This EA has been prepared to identify and address issues related to project facilities located and operated in Chad. A separate EA document was prepared to identify and address issues related to those project facilities located and operated in Cameroon. Separate EAs have been

[1]Superseded by Operational Policy 4.04 (Natural Habitats) (1995)

prepared to support the separate applications of the governments of Chad and Cameroon to the World Bank for project funding and in recognition of the fact that separate pipeline companies will be established in Chad and Cameroon.

In addition to meeting requirements of the World Bank and other potential funding organizations, preparation and submission of this EA document provide a vehicle for presentation of the environmental aspects of the project. These aspects have been (and will continue to be) fully integrated into the planning, design, development, construction, operation, and eventual decommissioning of the project.

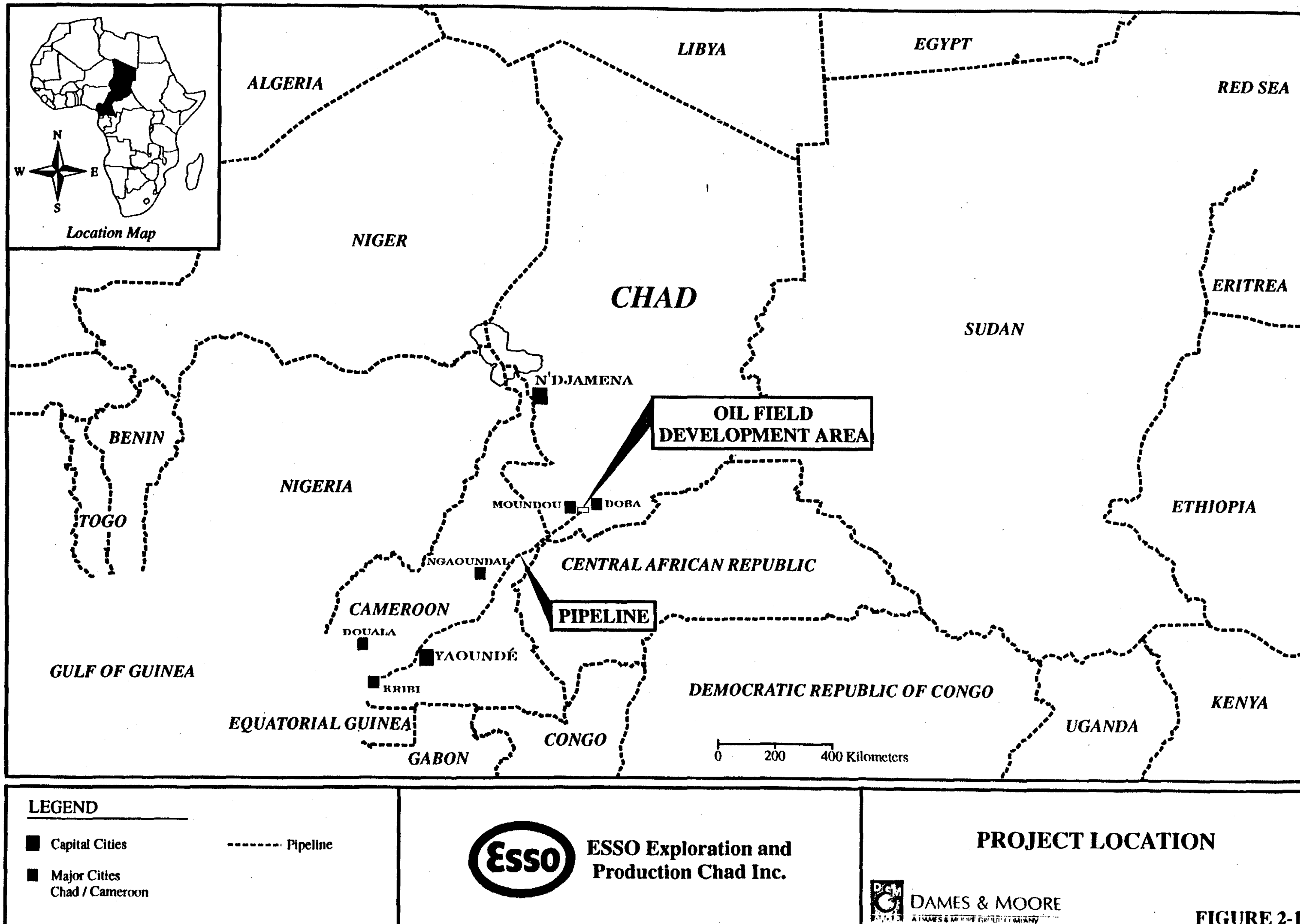
Expert and independent environmental advice has been an integral part of preliminary engineering for the project, particularly in the integration of environmental specialists in numerous field teams that have investigated, developed, and refined the corridor and route of the pipeline, and facility site locations for the project. This reflects a key project development strategy to minimize environmental impacts of the project by the early recognition and, where possible, avoidance of sensitive areas and locations.

Other environmental activities undertaken prior to conducting the environmental assessment field studies which were of direct relevance to the EA included:

- A comprehensive review and compilation of the published and unpublished environmental data relevant to the project
- Development of a project Geographic Information System (GIS) which has been used to capture environmental data
- Terrain analysis mapping (utilizing satellite imagery, aerial photographs, and published topographic and other mapping) of the field facilities and pipeline corridor in Chad
- Participation in field surveys
- Various fact-finding missions to Chad for the purpose of identifying data sources and identifying in-country expertise and capabilities of potential value to the project
- Visits to Chad to identify and consult with potentially affected communities.

The timing for the preparation and review of this EA has been driven by the financing schedule for the project. This required development of the EA at a stage in the project cycle when full details of the project were yet to be developed. In the absence of many key details relating to project execution and operation, it was neither appropriate nor desirable to develop prescriptive environmental management and monitoring plans, but rather to broadly recognize the scale and scope of the management and monitoring tasks, and to indicate how they will be implemented as an integral part of the overall management of the development and operation of the project.

More detailed information regarding environmental management and monitoring is provided in an Environmental Management Plan prepared for the Chad portion of the project.



Esso

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PROJECT LOCATION

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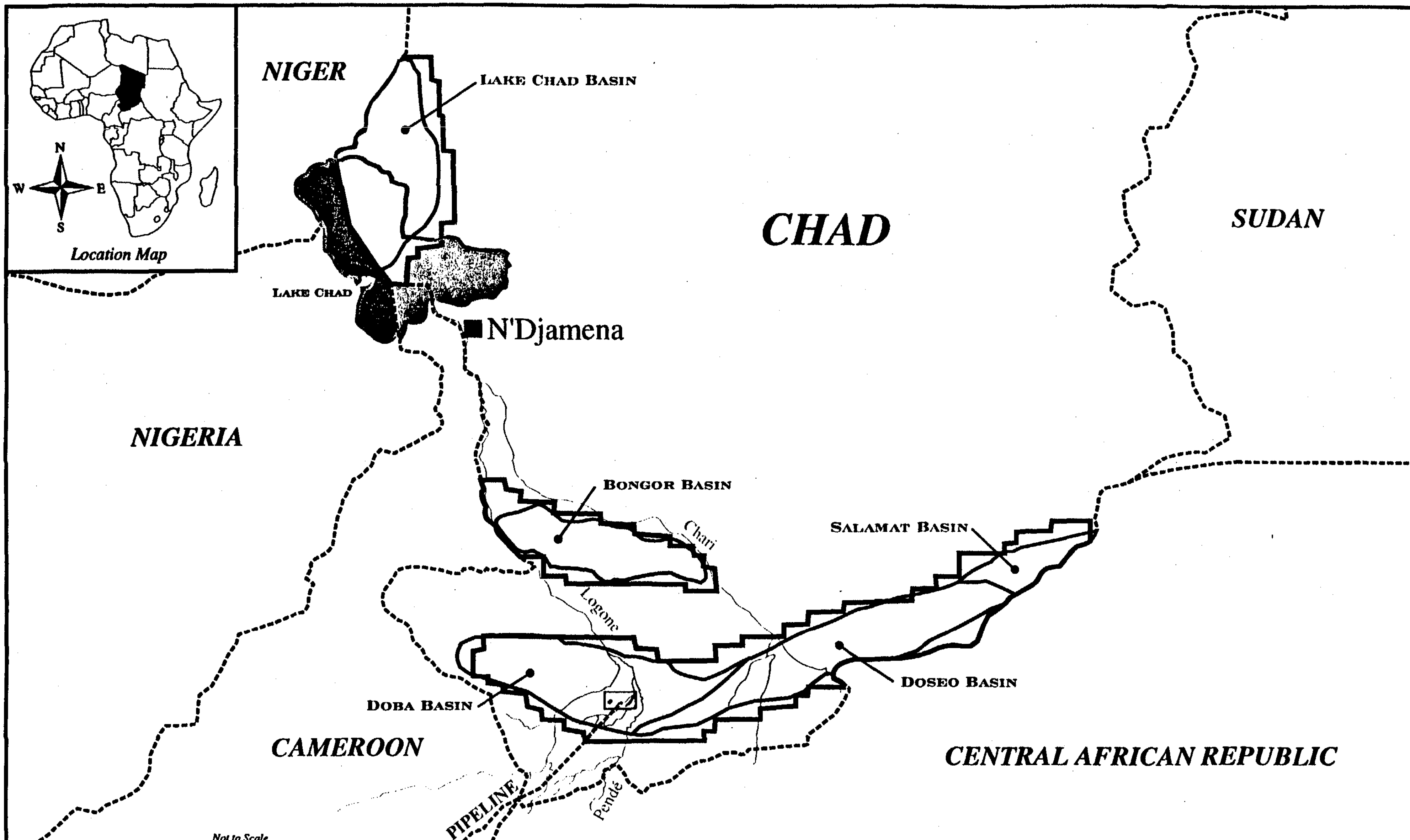
FIGURE 2-1



LEGEND

Esso-Operated Concession

Sedimentary Basins

International Boundaries

Rivers

Miandoum Oil Field

Bolobo Oil Field

Komé Oil Field

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OIL EXPLORATION CONCESSION AREA

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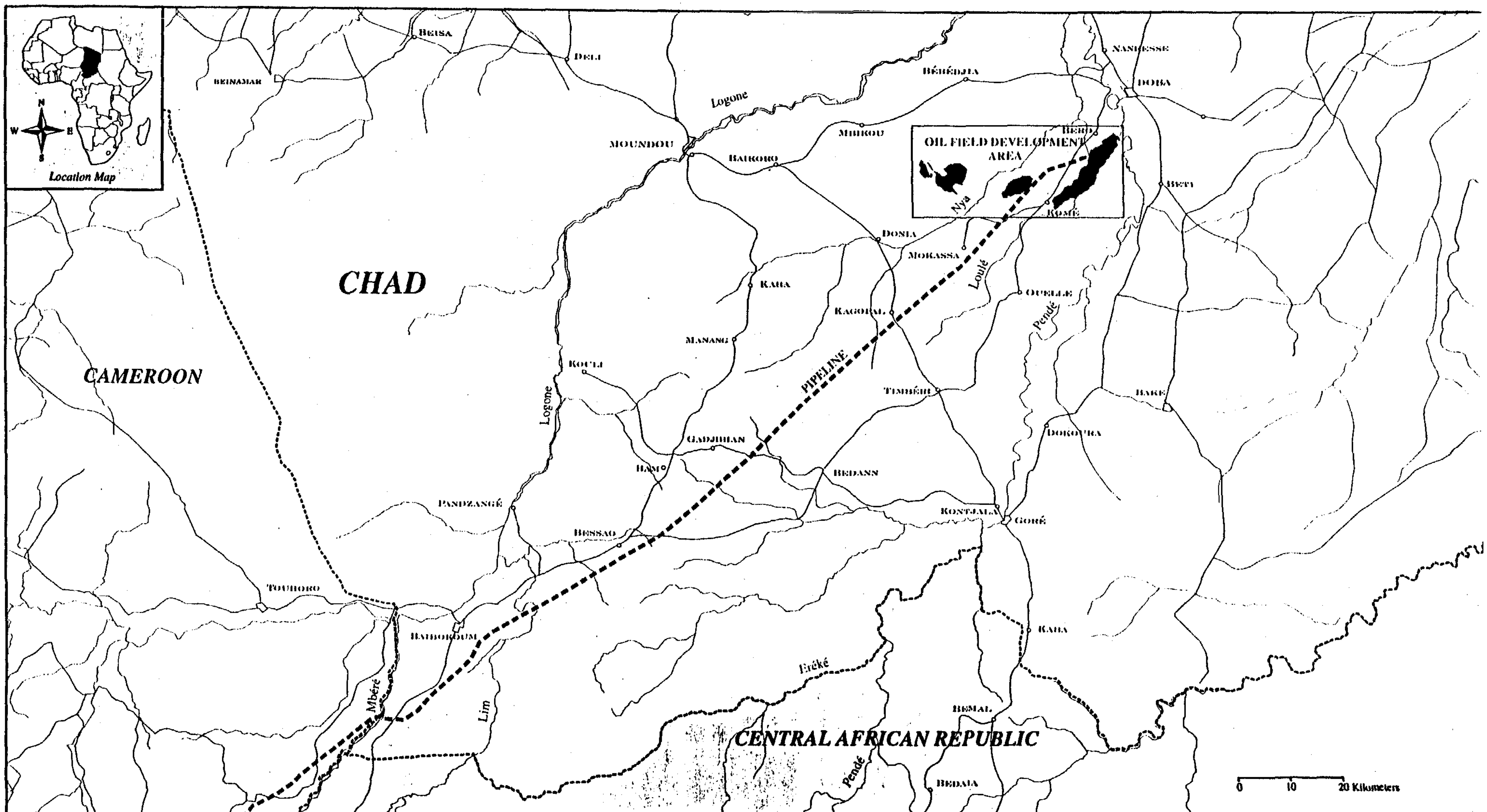
FIGURE 2-2



LEGEND

EA Study Area

Pipeline

Miandoum Oil Field

Bolobo Oil Field

Komé Oil Field

ESSO Exploration and Production Chad Inc.

STUDY AREA

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FIGURE 2-3

3.0 PROJECT DESCRIPTION

3.1 OVERVIEW

The proposed project consists of all phases of commercial development and transportation of certain crude oil reserves located in Chad, in the west-central portion of Africa. Development of three separate oil fields—the Komé, Miandoum, and Bolobo oil fields—form the basis of project activity. All three fields would produce oil from reservoirs of Cretaceous age.

A 3-D seismic survey was performed to assist in further evaluation of the reserves for development. The survey area covers approximately 600 square kilometers (km^2). Seismic lines were cleared using Row-King tractors and bulldozers. Row-King tractors cut and mulch standing vegetation without disturbing topsoil or rootstock. Bulldozing was generally performed with the dozer blade held above ground level, in order to preserve topsoil and rootstock. In addition, trees 15 centimeters (cm) in diameter and greater on the seismic lines were left intact. Clearing, completed in the summer of 1996, was minimized and caused only a temporary disruption in any one location. When approaching a village, steps were taken to avoid structures. Human environment issues were recognized and were addressed through compensation, hiring practices, and local purchases. Follow-up evaluation of the 3-D seismic survey program is being used to improve clearing techniques that will be implemented during the development phase of the project.

Facilities in each of the three oil fields generally would include oil, water, and gas handling facilities and flowlines. The Operations Center (OC), located in the Komé field, will include the Central Treating Facility (CTF), a power generation plant, and a gathering station. Pump Station No. 1 (PS1) will also be in the Komé field. An electric power distribution system, a pipeline transportation system, and road network would also be required in Chad. These facilities are summarized in Table 3-1 and discussed in more detail in the following sections.

The project will be constructed and operated in accordance with internationally accepted standards and guidelines (e.g., ASME (1994), World Bank (1995a)). These standards and guidelines specify a variety of measures in respect of environmental protection, including:

- Assessment of oil spill risks, and development and implementation of an oil spill contingency plan
- Implementation of positive pipe corrosion control measures
- Use of pressure sensors connected to alarms and automatic pump shutdown systems
- Provision of a metering system with continuous input/output comparison for leak detection
- Adequate engineering design providing adequate protection from likely external physical forces
- Accurate and complete records of all inspectons, leak incidents, unusual events, and safety measures taken
- Minimization of disturbance to natural vegetation, soils, hydrological regimes, and topography

- Positive measures to control population influx to remote areas due to increased access created by the pipeline land easement, and to prevent associated secondary impacts (e.g., encroachment on traditional indigenous population lands or preserves; uncontrolled exploitation of natural resources)
- Acceptable material specifications and component standards, including dimensional requirements and pressure-temperature ratings
- Requirements and data for evaluation and limitation of stresses, reactions and movements associated with pressure, temperature changes and other forces
- Guidance and limitations on the selection and application of materials, components, and joining methods
- Requirements for the fabrication, assembly, and erection of piping
- Procedures for operation and maintenance that are essential to public safety.

3.2 PROJECT FACILITIES

Oil, water, and limited gas would be produced in each of the Komé, Miandoum, and Bolobo fields. In each field there would be one gathering station where free water is separated from the oil, then treated and disposed of into the oil reservoir via injection wells. Water content in the oil will be reduced to about 20 percent at the gathering stations. The remaining oil and water, in the form of an emulsion, is piped to the CTF for processing to produce crude oil of a quality suitable for export sales ("sales quality crude"). These facilities are illustrated in Figure 3-1. A schematic illustrating the various steps in the product flow path is presented in Figure 3-2. Production data and fluid characteristics are provided in Section 3.2.3.

3.2.1 Production Fields, Wells, and Flowlines

Approximately 300 producing wells and about 20 reinjection wells currently are planned to be drilled for the proposed project. Approximately 213 wells would be drilled in the Komé field (including about 11 reinjection wells), approximately 24 (with up to 4 reinjection wells) in the Miandoum field, and approximately 50 (with up to 4 reinjection wells) in the Bolobo field. Additional reinjection wells are expected in each of the fields and are planned to be converted production wells. High angle extended reach wells would be drilled if technically feasible. Currently, about 24 extended reach wells are planned. The locations of the proposed wells in each field are shown on Figure 3-1. Continuing appraisal activities will provide better definition of the producing reservoirs. These activities may result in modifications to the proposed well locations and/or to the number and type of wells to be drilled.

The majority of well pads would have one well; however, opportunistic planning would place up to three producing wells at some well pads with each well producing from a different horizon. Each well located within the Komé, Miandoum, and Bolobo fields would be equipped with an electric submersible pump (ESP). Equipment would be provided at each well pad for downhole injection of a demulsifier chemical.

The producing formation in each of the three fields is overlain by a 60 to 200 meter (m) thick Miandoum Shale. The Miandoum Shale is overlain by a series of unconsolidated sands approximately 900 to 1,500 m thick. As a result, wells drilled in each of the three fields would have a variety of total depths depending on the field and the specific producing horizon.

The wells would be drilled as vertical or extended reach wells. The drilling program for vertical wells is in accordance with standard industry practice, utilizing water-based drilling muds to the extent feasible. Extended reach wells would also be drilled in accordance with standard industry practice, but require a technically more complex and challenging drilling and casing program. Extended reach wells would be drilled as a straight hole using water-based muds until the Miandoum Shale is reached. At that point, protective casing is set and the well is "kicked-off" from vertical to near horizontal. Drilling is then continued at a high angle within the targeted horizon. The advantages of an extended reach well over a vertical well is that it has a longer productive interval, making it a higher volume producer and reducing the total number of wells and well pads. However, the relatively low vertical permeability and multiple sub-zones separated by thin shale limit the applicability of extended reach wells. Figure 3-3 illustrates the difference between a straight (vertical) and an extended reach (or horizontal) well completed in the same producing horizon.

All wells will be designed and constructed with an objective of protecting the shallow freshwater aquifer overlying the Miandoum Shale. A risk assessment was conducted to determine the preferred well casing design. The risk assessment assumed a highly corrosive environment (low pH with oxygen) throughout the depth of the well bore and resulted in a design including:

- Surface casing to around 90 m
- Production casing from the surface to total depth
- Production tubing to the electric submersible pump for production wells
- A casing by tubing isolation packer for produced water disposal wells
- External protective coating and cathodic protection of casing if the groundwater is determined to be highly corrosive
- Internal corrosion protection of tubulars.

Other aquifer protection measures include grouting the top portion of the casing string in place, cementing the production casing in the drilled hole across the Miandoum Shale and into the upper sands, and using an inhibited packer fluid and monitoring the casing by tubing annulus on reinjection wells. The low reservoir pressure for producing wells and the expected low injection pressure for reinjection wells add a natural protection to the upper freshwater aquifer. These protection measures are illustrated in Figures 3-4 and 3-5.

All drilling wastes will be managed to protect the aquifer in the oil field development area. Drilling muds will be lightweight, freshwater-based, and will not contain hazardous substances. Disposal methods for drilling fluid will be developed and detailed in a Project Waste Management Plan. If oil-based muds are used, cuttings will be disposed of in a manner that protects the aquifer. This could include solidification and disposal in lined landfill cells, washing of cuttings prior to disposal, incineration, or bioremediation.

3.2.2 Field Manifolds and Field Pump Stations

Field manifolds serve two main purposes:

- To collect production from several individual wells and direct it via gathering lines to a gathering station or pump station (Komé only)
- To direct production from a selected well to a well test facility located at each manifold via a test header.

There would be approximately 10 field manifolds within the Komé field, up to three within the Miandoum field, and up to three within the Bolobo field. The approximate locations of some of the manifolds are shown on Figure 3-1.

Two field pump stations would be located within the Komé field on common sites with other facilities. There would be no field pump stations located within the Miandoum or Bolobo fields. The field pump stations would receive production from field manifolds and would be designed to pump a multi-phase mixture of oil, water, and gas. Incoming production would be pumped directly to the Komé gathering station (described in Section 3.2.4). Storage of field production would not be provided at the pump stations.

3.2.3 Produced Fluid Volumes and Characteristics

It is estimated that total crude oil recovery from the Komé, Miandoum, and Bolobo fields would be approximately 924 million barrels over the anticipated 30 year life of the proposed project. Estimated yearly average production rates would peak at approximately 225,000 barrels of oil per day. In addition to crude oil production, substantial quantities of produced water would be generated. As with oil, water production would vary during the life of the project. However, it is anticipated that the project would, during peak water production, produce approximately 900,000 barrels of water per day. Over the life of the project, approximately 7.5 billion barrels of produced water would be generated. The anticipated annual oil and water production over the life of the proposed project is shown in Figure 3-6.

Crude oil characteristics from each of the three fields have been determined based upon well test data and laboratory crude assay analyses. Table 3-2 summarizes the crude oil's thermodynamic and physical property data from producing zones in each field. Table 3-3 provides an analysis of produced water from one of the exploration wells (Komé 7).

3.2.4 Gathering Stations

Three gathering stations (GSs) would be constructed, one in each of the three fields. The GS proposed at the Komé field would be part of the OC. The approximate location of the GSs is shown on Figure 3-1.

The gathering stations would receive production from individual wells via manifolds, and in the case of the Komé field, from field pump stations. The gathering stations serve several different functions:

- Separate produced gas and sand from the incoming well fluids
- Dewater the incoming well fluids to produce a 20 percent water cut emulsion (a fluid comprising 80 percent oil and 20 percent water), and pump it via the emulsion trunk line to the CTF
- Measure the emulsion production rate and water cut to determine the oil production from the field
- Treat the produced water to reduce oil and sediment, and pump it to injection wells
- Compress the produced gas for transportation to the OC where required.

Major features for the design of the gathering stations are described below.

3.2.4.1 Free Water Knock Out

At the Komé GS, free water knock out (FWKO) tanks would be used to separate water that has not been emulsified with the oil. Two stages of separation are required. The first stage would be unheated and would be designed to produce a 40 percent water cut emulsion. The second stage would be heated and would reduce the water cut down to 20 percent. The heat source is waste heat recovery from the power plant. Heat input to the process would be via a produced water recirculation loop.

At the Miandoum and Bolobo GSs, lower crude oil viscosities allow use of unheated pressure vessels to separate free water from the inlet emulsion to produce a 20 percent water cut emulsion.

3.2.4.2 Emulsion Pumping

At the Miandoum and Bolobo GSs, pumps would be provided to pump the emulsion from the surge tanks to the CTF via an emulsion trunkline. Emulsion from the Komé GS is pumped to the adjacent CTF.

3.2.4.3 Produced Water Treatment

In each field a combination of skim tanks followed by induced gas flotation (IGF) units would be used to reduce oil and sediments in the produced water. The treated produced water, with an oil content of 50 ppm or less, would be disposed as described in Section 3.2.5. The Komé GS also would treat and reinject produced water from the CTF.

3.2.4.4 Sand Handling

At each GS the majority of produced sand would be removed in the FWKO tanks or vessels. The vessels would have an automatic desanding system that would use produced water to carry the sand to a sand-settling basin, where it would be stored until removed for permanent disposal. Sand from the Komé FWKO tanks would be removed manually.

3.2.4.5 Gas Compression Facilities

At each GS vapor recovery units and multistage reciprocating compressors would be provided to collect produced gas not consumed at the GS and compress it for pipeline transportation to the OC, where gas would be used to provide approximately one-third of the fuel requirements for the power plant.

3.2.4.6 Utility Systems

At each GS the following utility systems would be provided:

- Potable and utility water supply
- Emergency pressure relieving system
- Instrument and utility air
- Fuel gas
- Chemical (i.e., demulsifier) storage and injection
- Process heating (Komé GS only)
- Electric power
- Sanitary and oily water sewers.

3.2.5 Produced Water Disposal Systems

In addition to wells drilled specifically for reinjection, it is anticipated that dry holes and converted high water cut producing wells would also be used. The design basis for each reinjection well would be 25,000 barrels per day. Actual reinjection rates would depend on specific reservoir characteristics and production and reinjection experience. The total number of disposal wells and their distribution among the individual fields may change as the development drilling program progresses. All produced water would be injected below the Miandoum Shale, which represents the uppermost seal for the oil reservoirs.

The produced water disposal systems would consist of a water injection trunk line, a lateral system to the individual injection wells in the Komé field, and individual injection lines in the Bolobo and Miandoum fields.

3.2.6 Operations Center

The Operations Center (OC) would be the main operations base in Chad for the proposed project. The OC is located within the Komé field adjacent to the Komé GS. The principal components of the OC are presented in Figure 3-7 and consist of the following facilities:

- Central Treating Facility
- Pump Station No. 1
- Gathering Station
- An electric power generation plant (approximately 100 megawatts (MW) installed capacity)
- Warehouses, maintenance/operations training center
- Housing for 100 persons in a single status community
- A 3,200 m paved airfield capable of accommodating jet aircraft
- Administrative office buildings for managers and support staff
- A clinic for emergency and routine health care of the project work force.

3.2.6.1 Central Treating Facility

The CTF would receive emulsion and produced gas from the Komé, Miandoum, and Bolobo GSs. The main functions of the CTF are to:

- Dehydrate the incoming 20 percent water cut emulsion from each field to produce a blended sales quality crude oil meeting a 1 percent maximum basic sediment and water (BS&W) specification
- Handle the incoming produced gas and direct it to the power plant and CTF fuel gas systems.

Some key design features of the CTF are as follows:

- The emulsion production from each field would be commingled, heated to approximately 107°C to reduce viscosity and improve separation, and treated.
- The BS&W content of the oil would be measured after treating, and off-specification oil (bad oil) would be directed to a separate bad oil system. The bad oil either can be treated in the

bad oil system tanks by providing heat and retention time or recycled to the inlet of the emulsion treaters.

- Short-term surge capacity for the treated crude oil would be provided at the CTF, but there would be no storage facilities for treated oil within the CTF. The treated oil would be sent to PS1 for transportation via the pipeline.
- Gas production from the fields would be handled separately from the emulsion. The Miandoum/Bolobo gas would have separate inlet systems. The gas streams from the inlet separators would be combined and used as fuel gas for the power plant. Any liquids collected in this system would be sent to the emulsion treating system.
- Vapors from the crude oil surge tanks and bad oil tanks would be recovered by a vapor recovery system and would be sent to the fuel gas system inlet.
- Produced water from the emulsion treaters would be pumped to the Komé GS for treatment and reinjection.
- Waste heat from the power plant gas turbine exhaust system, recovered via the hot oil system, would be the main source of process heat.

The following utility systems would be provided at the CTF:

- Fire water
- Potable and utility water
- Pressure relieving and flare
- Instrument and utility air
- Chemical storage and injection
- Fuel systems (oil and gas)
- Process and sanitary drains
- Steam generation (portable)
- Hot oil
- Electric power.

3.2.6.2 Power Generation Plant and Distribution System

The power plant planned for the project is rated at approximately 100 MW. Electric power would be transmitted by high voltage pole lines to the Komé, Miandoum, and Bolobo fields. The plateau electrical power demand would be reached approximately four years after startup. Approximately 70 percent of the power demand is for the electrical submersible pumps.

Gas turbines would be used as the primary source of power. The power plant design is based on using turbine generators capable of burning natural gas or crude oil as fuel. The turbines have dual fuel capability due to the limited amount of natural gas available for fuel. Five turbines would also be located at the power plant of which four would normally be in operation.

The power plant would be self-contained and have all its own utilities and auxiliaries. These utilities and auxiliaries would include initial (black) start generator(s), diesel fuel storage, and starting and instrument air.

3.2.6.3 Fuel Systems

Crude oil fuel would be taken off the Miandoum/Bolobo trunkline and treated for use in the turbine gensets (combined turbines and generators). In order to reduce turbine maintenance and increase reliability, the crude oil would undergo secondary treatment at the power plant and would include heating for viscosity control, additional dewatering, and filtering. During normal plant operation diesel fuel would be piped from the COTP to the power plant storage tanks. The diesel fuel would be used for shutdown and/or startup. The gensets would also be capable of operating on diesel fuel from the COTP. Any fuel gas burned in the gas turbines would be supplied from the CTF, which would provide all necessary processing.

3.2.6.4 Crude Oil Topping Plant

A crude oil topping plant (COTP) would be installed at the OC. The COTP would have a feed capacity of 1,000 barrels of oil per day and would produce approximately 100 barrels of diesel per day. The diesel product would be used to support the drilling and operations activities after startup. A 3,000 barrel bermed diesel storage tank also would be provided.

3.2.6.5 Turbine Genset Enclosures

The gas turbine genset enclosures would be contained in individual enclosures including waste heat recovery units. These enclosures would provide noise attenuation. Appropriate fire detection and suppression systems would be installed to cover all areas.

3.2.6.6 Control Systems

The power plant would be designed to operate with minimum operator intervention. Power plant operating information would be available to the CTF plant operators located at the CTF control room. The power plant control room would house the electrical distribution control panel that could remotely control and monitor switching operations at the field electrical substations.

3.2.6.7 Power Transmission System

Electric power would be transmitted from the power plant to the distribution substations as follows:

- Field substations at Miandoum and Bolobo would be supplied by 66 kilovolt overhead transmission lines. Komé substations will be supplied by 11 kilovolt overhead transmission lines.
- Overhead power line design would consider the high incidence of lightning in the area.

- The main pipeline pump station (PS1) would be supplied by 11 kilovolt overhead cables.
- A number of 11 kilovolt overhead distribution feeders would supply power from each of the field substations (Komé, Miandoum, and Bolobo) to the producing wells.

3.2.6.8 Pipeline Pump Station No. 1

Pipeline Pump Station No. 1 (PS1) is the first station on the pipeline and is located within the OC. Treated crude from the CTF would be pumped to PS1, which has a 200,000 barrel storage capacity. Offices and warehouse facilities for PS1 would be integrated into the OC operations support facilities.

3.2.6.9 Operations Center Infrastructure

The OC infrastructure facilities include:

- Community
- Airfield
- Municipal services for the GSs and OC
- OC plant buildings, in-plant roads and field roads.

Community–The community is located within the OC as shown in Figure 3-7. It would provide the following facilities (Figure 3-8):

- Living quarters to accommodate 100 persons in single rooms
- Cafeteria and kitchen to serve midday meals for 285 persons (185 day workers and 100 residents) and morning and evening meals for the 100 residents
- Laundry facilities to wash linen and personal clothing of residents and work clothes of all project workers
- Parking and sports facilities.

Fire protection for the community would include hydrants, emergency response vehicles, hose reels, sprinkler systems, smoke detectors, fire detectors (or equivalent), alarms, and fire extinguishers. Street lighting would be provided to illuminate the streets and perimeter road for safety and security. Support facilities such as offices and housing would be located in N'Djamena for personnel.

Airfield–A private airfield would be constructed to provide air transport during construction and subsequent operations. This would provide for freight transport, personnel rotation, medical emergency evacuation, and emergency evacuation of project workers.

The runway would have an asphalt or concrete surface to permit operation through the entire year. The runway length is expected to be approximately 3,200 m. The airfield would be located southeast of the community as shown in Figure 3-7.

Municipal Services–The following municipal services would be provided at the OC:

- Utility/Potable Water
- Fire Water
- Sanitary Sewer
- Oily Water Sewer
- Solid Waste Disposal
- Electricity.

Utility/potable water would be supplied from wells and treated by chlorination. Water wells would be drilled at the GSs and the OC. The water distribution system at the OC would supply both the OC plant and the community and also provide fire water for the community.

Sanitary sewerage networks would be gravity systems that drain to wastewater treatment or septic systems and leach fields.

Oily water sewer systems would be provided in the OC plant and at the gathering stations. The oily water system would collect water that may be contaminated with hydrocarbons from process units, open areas, tankage areas, floor drains, area drains, and hub drains. The oily water would be sent by gravity flow to a separator.

Solid wastes would be disposed of either by incinerator or by landfilling, depending on the waste classification. The incinerator would dispose of combustible industrial wastes, medical wastes, and some municipal wastes. The remainder of municipal wastes and construction wastes would be landfilled. The landfill site selection would take into account geologic and hydrogeologic conditions and would be designed for a minimum service life of 30 years. Further details on waste management are provided in Section 3.2.12.

Operations Center Plant Buildings–The OC plant would have the following major buildings:

- Administration Building
- Control Center Building
- Mechanical/Electrical/Instrumentation Maintenance Building
- General Warehouse
- Training Center and Vehicle Maintenance Building
- ESP Maintenance Building
- Power Plant Control Building
- Guard House.

3.2.6.10 Automation and Control

The automation system at the OC would be designed to meet the functional requirements of the process design with personnel protection, environmental safety, and appropriate equipment design given high priority. Other major considerations are reliability, cost, and accuracy over the life of the development.

Control of all plant and field facilities down to the wellhead level would be performed from the CTF. Control of the power plant at the OC would be performed from a power plant control room.

3.2.7 Pipeline Transportation System in Chad

A 760 mm diameter, 1,050 km pipeline would be constructed from the Doba Basin in Chad to the southern coast of Cameroon near Kribi. Approximately 170 km of this pipeline would be in Chad extending from the CTF to the Cameroon border (Figure 3-9). The entire pipeline would be buried with approximately one meter of cover. The cover would be greater at road and stream crossings and less in areas of rock, as shown on Table 3-4. Where the pipeline exits PS1 extra depth of burial to approximately 1.5 m for 20 km would be provided to reduce heating of surface soils. The pipeline would intersect two major waterways (Lim and Mbéré rivers) and four primary roadways in Chad. The pipeline would be protected with a corrosion coating and cathodic protection. All coatings and paint systems will be stable for service temperatures.

Intermediate mainline block and check valves would be installed near river crossings and close to existing roads (for easy access) to:

- Facilitate system operation and maintenance
- Minimize environmental impact in case of leaks
- Meet any local, legal, or regulatory requirements.

The mainline valve sites would include battery/solar-powered cathodic protection facilities and occupy an area of 500 square meters. The tentative locations of mainline valves along the pipeline route are provided in Table 3-5 and in Figure 3-9.

3.2.8 Communication Facilities

A comprehensive satellite-based telecommunications system has been designed for use on the project. This is to compensate for the lack of infrastructure in remote areas. A satellite-derived network is preferred because it may be rapidly implemented and does not require extensive site development. The integrated system employs conventional INTELSAT service to link the field sites, project offices, and the project base. Supplemental use would also be made of the public network in Chad, when it is available.

A VHF (very high frequency) radio system is proposed for communications between a fixed location (e.g., the CTF) and remote field areas such as the pipeline land easement. A series of VHF radio relay sites would extend the range of communications along the entire pipeline route. Land use would be minimized by combining the radio sites with other pipeline and production functions (e.g., pump stations, block valves), and through the use of free-standing (nonguyed) towers. These facilities are depicted on Figure 3-9.

3.2.9 Transportation Infrastructure

3.2.9.1 Access to the Oil Field Development Area

Upgrades to the transportation infrastructure in the project area in Chad are required for moving materials for construction and operation of the pipeline, field facilities, and to support the drilling program (Figure 3-10).

A total of approximately 160,000 metric tonnes (MT) of material will be transported into Chad. Most of the material destined for Chad will be carried from the port of Douala in Cameroon by rail to Ngaoundal, and then by road to a new crossing of the Chad-Cameroon border on the Mbéré River southeast of Touboro. In addition, an airfield will be constructed at Komé that will be capable of handling heavy cargo planes (Antonov 124 or similar). Approximately 50 heavy cargo flights will rotate through Komé over the construction period, carrying about 1 percent of the total material requirements of the project during construction.

Peak project traffic during construction is estimated to be approximately 35 truck movements between Ngaoundal (in Cameroon) and Komé per day, each way. Potential upgrades to the existing road system would involve repairing and improving the laterite road surface and improving drainage along road alignments. Several bridges would require modification, strengthening, or replacement with culverts.

A significant part of the transportation infrastructure that the project will develop is centered on the new border crossing between Chad and Cameroon, and includes a new bridge over the Mbéré River, new sections of road connecting the bridge with the existing roads in both Chad and Cameroon, and ancillary features including truck parks on either side of the border.

In addition to project needs during the construction period, appropriate transportation infrastructure will be required throughout project operations. These operational requirements will be met by the road system between Ngaoundal in Cameroon and Komé, including the new bridge at the border between Chad and Cameroon on the Mbéré River. The project airfield at Komé is also expected to remain operational throughout the life of the project. Transportation requirements during project operations will be significantly less than those during construction.

Proposed public road and bridge upgrades in Chad would include:

- Repair/upgrade of existing road sections over a total of 170 km

- Approximately 30 km of new road between the Mbéré Bridge and Komé
- Construction of a new bridge across the Mbéré River at the Chad-Cameroon border, which will constitute a border crossing between Chad and Cameroon for vehicular traffic
- Replacement of selected bridges with galvanized, corrugated steel culverts, backfilled with laterite
- Mechanical clearing of brush along roads for improved line of sight at critical locations
- Maintenance of the road between the Mbéré River bridge and Komé over the construction period
- Maintenance of the road in Chad during the period ending three years after commencement of operations.

Where operations access is not necessary, land used for construction access roads would be returned to its preconstruction use.

In addition, project storage yards will be developed at Komé and Gadjibian. The construction of project storage yards will involve the following:

- A survey of the site area
- Design of an overall site grading plan, with special attention to drainage measures
- Clearance of any vegetation on the site
- Stripping and conservation of topsoil
- Performing of any necessary earthworks, to provide a level site
- Installation of a gravel pad over the site (typically comprising 300 mm of laterite)
- Design and installation of a well to provide potable water at each site
- Fencing of the storage yard.

The layout of a typical storage yard is depicted on Figure 3-11.

The airfield will be used for project purposes only and will not support any commercial operations. Flights to Komé may originate from and depart to other airfields in Chad, or international locations. Any international flights will be subject to the regular customs and immigration requirements of the Government of Chad.

3.2.9.2 Within the Oil Field Development Area

Within the oil field development area, construction of new access roads, upgrading of existing access roads, and the development of new and/or upgraded secondary laterite field roads (primarily in the well field areas themselves) are proposed. Field layouts will evolve as development drilling allows progressively improved knowledge of the reservoir geometries, and it is therefore not possible at this time to be precise regarding the extent of new road construction that will be required. It is currently anticipated that about 50 to 60 km of new access and field roads will be developed throughout the entire field development area, based on a September 1996 estimate that approximately 35 km of additional field access roads will be required for the Komé field alone.

3.2.10 Construction

3.2.10.1 Oil Field Development Area Facilities

Construction of the oil field development area facilities includes individual well pads, connecting pipelines, gathering stations, field manifold systems, the OC (including the CTF), the initial pump station (PS1), the power generation facility, overhead electric utilities, the airfield facilities and the required new and upgraded roadways connecting each of these facilities. Although the number of infield facilities would vary depending upon the specific field, general construction techniques would be similar for all aboveground facilities.

Infield flowlines, which would be buried, would follow the same general construction techniques as for the pipeline (see Section 3.2.10.2), but on a smaller scale. Specific roadway construction for both new and upgraded roadways would conform to typical roadway cross sections as presented in Figure 3-12.

Each of the facility sites would be graded and temporary drainage and erosion control measures would be put in place. All topsoil removed during construction would be stockpiled and spread on disturbed surfaces upon completion of construction activities.

After earthwork has been completed, foundation construction would commence. All major mechanical equipment, process vessels and equipment, pipeline and other supplies would be transported to the site by truck, along upgraded roads from Ngaoundal in Cameroon.

During construction, old exploration infrastructure, well pads, and borrow pits would be rehabilitated. Laterite from abandoned well pads or airstrips would be reused in developing new well pads or other facilities to reduce the number of new borrow pits needed for construction of oil field development area facilities. This laterite may also be used to rehabilitate old borrow pits as well. Topsoil would be protected and conserved by reuse of laterite to the maximum extent feasible. Topsoil that is stripped for construction of the OC and field facilities would be used for rehabilitation of old facility sites and borrow pits. The field facilities and OC would be designed in a manner that avoids or minimizes topsoil stripping. Excess topsoil stored for more than six months would be fortified with fertilizers, soil enhancers, or other organic materials to maintain viability prior to use in rehabilitation.

The overall construction schedule for these facilities is presented in Section 3.2.15.

3.2.10.2 Pipeline Transportation System

General Configuration–An overall land easement width of 30 m on average would be required for the pipeline to allow flexibility in making adjustments during construction. Additional land easement width (up to a total width of 50 to 60 m) would be required for some locations with steep slopes or other terrain features such as river crossings.

Access to the Land Easement–Access to the land easement for the pipeline would be required for construction purposes, and during operations for maintenance and emergency response purposes. Construction access would be via existing, upgradable roads and tracks wherever possible, and should new access roads be required they would be routed to avoid or minimize effects on sensitive environmental resources. Operational access to the land easement would be via roads or tracks used during construction.

Land Easement Preparation–The land easement would be surveyed and staked to identify the pipeline centerline and land easement limits. The land easement would be prepared by clearing and grading as necessary. Clearing would include removal of aboveground vegetation and rocks to the side of the land easement. Any trees and large shrub debris that need to be removed would be felled and stockpiled alongside the land easement. The smaller shrub vegetation moved to the side of the land easement would be conserved and spread over the land easement after construction is completed to help control erosion, serve as a mulch, and provide a source of seed for revegetation. Where grading is required and sufficient topsoil is available, the topsoil would be removed, stockpiled, and eventually respread over the graded area.

Installation–A pipeline construction unit, or spread, carries out the full range of operations from land easement clearing through backfilling and final cleanup. The pipeline in Chad is expected to be constructed with one spread. All pipeline construction will be carried out in conformance with the American Society of Mechanical Engineers (ASME) and American National Standard Institute (ANSI) Code designated ASME B31.4 (Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids). The code states that its primary purpose is:

> " to establish requirements for safe design, construction, inspection, testing, operation and maintenance of liquid pipeline systems for protection of the general public and operating company personnel as well as for reasonable protection of the piping system against vandalism and accidental damage by others and reasonable protection of the environment." (ASME, 1994)

Project representatives would be on the spreads at all times to carry out or observe a number of inspections and tests that would assure conformance with ASME B31.4.

A brief summary of the overall construction activities on the spread is presented below.

The pipeline ditch would be centered on a line usually about 10 m from one side of the 30 m land easement. This provides a 10 m width for storing ditch spoil and up to a 20 m working area for construction equipment and pipe. The ditch would be excavated mechanically, and the limit of the open ditch would not exceed 10 km along the land easement. Equipment such as backhoes and clamshell buckets would be used in areas of loose or unconsolidated rock. The dimensions of the ditch would range generally from 1.2 to 1.4 m in width and 1.8 to 2.2 m in depth. A minimum of 1 m of cover from the top of the pipe to the ground surface typically would be provided. Cover would be greater at road and stream crossings. If solid rock is encountered, blasting would be required. A minimum of 0.50 m of cover would be provided when the ditch is located in rock.

Topsoil that is removed for subsequent reuse would be stored within the land easement in a manner that will allow retrieval during cleanup operations for redistribution over the graded area. Clearing and pipeline construction activities would be conducted over a period of approximately three months or one season in any one place.

Pipe would be transported to the land easement by tractor-trailer trucks. The pipe would be unloaded and strung along the land easement using sidebooms and other equipment. A hydraulic pipebending machine would introduce vertical or extended reach bends in the pipe in the field if needed, using cold bending.

Laying the pipe would involve swabbing, lining up, and welding. The pipeline contractor would secure all open ended pipes at the end of the work period with "night caps." Where practical, known wildlife crossing/migration zones exposed to open ditch areas would be secured to prevent danger to animals. Before a pipe length is joined by welds, swabbing would be performed to ensure foreign objects and materials inside each joint are removed. The pipe length would then be aligned with the end of the continuous string of pipe that has already been joined. Valves and pipe fittings would be installed as welding proceeds. After welds have been inspected and any required rewelding completed, the pipe joint would be cleaned and wrapped to provide a homogeneous protective coating.

The coating would be inspected and repaired if necessary prior to lowering the pipe into the ditch. Sideboom tractors would be used to lower the pipe into the ditch with slings made to minimize coating damage. In rocky areas, the bottom of the ditch would be padded to provide a uniform bearing surface for the pipe. Once in the ditch, the pipe would be padded with sand or soil where necessary to protect its coating during backfill operations.

Backfilling returns the spoil to the ditch. Backfill material displaced by the pipeline would be replaced in the ditch or crowned on top of the ditch to compensate for future settling. Excess backfill material would be spread over graded sections of the pipeline land easement. Ditching should produce sufficient backfill material; however, in some rocky areas, backfill may need to be imported. The land easement then would be returned to the approximate preconstruction grade, and cleanup and reclamation activities would commence.

All welds would be inspected both visually and by use of nondestructive testing methods. All nondestructive testing would be performed by qualified and experienced personnel in accordance with a set of written procedures for testing and determining the acceptability of welds. Welds that do not meet requirements would be repaired, or the weld would be removed, as appropriate. Records of nondestructive testing would be annotated and included on the project's as-built drawings.

Prior to commencing operations, the pipeline would be tested hydrostatically to ensure that it is strong enough to maintain internal pressure design and that there are no leaks. Testing would be conducted in manageable segments. Before hydrostatic testing is carried out, scrapers or pigs would be pushed through the pipeline with compressed air to remove welding slag, dirt, debris, or other items that may have accumulated during the construction process. The pipeline then would be filled with water, pressurized, and tested to established design limits. In accordance with accepted pipeline practice (e.g., Alberta Environment, 1988), the amount of water drawn from a stream or river would be limited to a maximum of 10 percent of the flow at the time of extraction. In conformance with the waste management plans, hydrotest water would be, to the extent practicable, disposed to the ground surface into infiltration beds or percolation ponds, incorporating erosion control measures (e.g., energy dissipation devices) and, if needed, filtering devices to remove sediments from the pipeline. A record of the hydrostatic test would be made and retained for the entire operational life of the pipeline.

Construction activities along any one location along the land easement are anticipated to be conducted over a period of three to six months, or one season. Cleanup and reclamation of the land easement would be undertaken when backfilling and compaction are completed. Materials removed during clearing and stockpiled on one side of the land easement would be spread over the cleared area. The land easement would be returned to its natural contours and grade, to the extent feasible, and topsoil would be spread back over those parts of the land easement from which it was removed. Ground and aerial markers with mileage indicators would be installed along the pipeline route to aid in maintenance and possible emergency response.

With the exception of areas occupied by valves, communication towers, pump stations, and other permanent aboveground facilities, and the 10 to 15 m strip of the land easement over the pipeline, all of the remaining cleared land easement area would be allowed to return to its former use after construction activities cease. The 10 to 15 m strip of the land easement over the pipeline would be available to return to grassland or field-crop agricultural use so long as it does not interfere with the functioning of the pipeline (no trees or permanent structures would be allowed).

3.2.10.3 Pipeline Construction Camps

Pipeline construction activities would involve a moveable construction base camp. The moveable camp would be located as close as possible to the pipeline land easement. The camp would support pipeline construction activities for a distance of approximately 80 km in both directions from the camp and would provide support and logistical functions associated with pipeline construction efforts. The camp would include office quarters, sleeping quarters, dining hall, bathrooms, laundry units, and a recreation hall. Support facilities would include power generation, potable water treatment/storage, sewage treatment, a solid waste landfill, communications, and medical facilities. Logistical support would include warehouse/small tool storage, material laydown areas, fabrication shops, equipment maintenance areas, petroleum and lubricant bulk storage, vehicle parking areas and possibly an aircraft runway. Construction camps would be sited to limit environmental impacts and any site works required at camp sites would be undertaken in accordance with the Soil Erosion and Sedimentation Control Plan measures described in Section 3.2.12. After construction is completed, the site of the construction camp would be returned to its natural contours and grade, and topsoil returned to those areas from where it was removed.

3.2.10.4 Main Line Valves

Main line valves would be installed along the pipeline in conformance with ASME B31.4 code to allow isolation of pipeline segments. Main line valves may also be utilized to facilitate maintenance operations. The proposed location of the valves (three check valves, and four block valves) are indicated on Table 3-5 and shown on Figure 3-9. Valve locations have been selected with an objective to protect environmentally sensitive resources. Valves would be installed within fenced enclosures. Valves would be regularly inspected, serviced and periodically operated to test their operating functions.

Manual valves would be hand-wheel operated with the valve normally chained open and locked. Remotely operated valves would be motor or hydraulic operated and connected to the pipeline automation system in the OC. Remotely operated valves may be powered by commercial power (where available) or by gas bottle. The operational backup for remotely controlled valves would be manual operation.

Radio telemetry will be solar (photovoltaic) powered at remotely controlled block valves which will relay the valve status (open/closed) to the pipeline operations center in the OC. Block valve sites would have their status information combined with other data collected from monitoring equipment along the pipeline to continually evaluate the overall operational integrity of the pipeline.

3.2.10.5 Scraper and Pig Launchers/Receivers

Scraper and pig launchers/receivers would be installed to permit internal cleaning and help determine the overall operating integrity of the pipeline. Scraper and pig launchers would be located at PS1.

Each launcher/receiver trap would be equipped with a quick-opening end closure and a safety device to prevent the closure from accidentally opening under pressure. The quick-opening closure would be rated for the full hydrotest pressure. Detection devices would be installed on the traps and at suitable locations along the pipeline to indicate successful launching and receipt of scrapers and pigs. The detectors can be read locally and reported via the automation system to the pipeline operations facility at the OC.

3.2.10.6 Road Crossings

The major pipeline crossings would be bored and the pipeline inserted in conformance with accepted industry standards. Traffic flow would not be interrupted.

All crossings of unpaved or lightly traveled roads would be open cut and the roads restored to preconstruction design specifications. A minimum of 1 m of cover would be maintained above the top of the pipe from the lowest point on the road crossing. Traffic flow would not be interrupted as the ditching occurs.

3.2.10.7 Stream and River Crossings

Stream and river trenching and pipe laying activity would be planned to occur during periods of low or no water flow. No trenching would occur during southern Chad's rainy season (approximately June to August). The minimum cover between the top of the pipe and the bottom of the channel would be 1 to 1.5 m to minimize the potential effects of scour and changing bottom profiles. The minimum cover depth would be greater at the Lim and Mbéré rivers, which present the highest potential for scour. This minimum cover requirement would be determined during the detailed design phase.

Typically, the ditch would be graded on each approach to the stream to fit the field overbends and sagbends prepared for the pipe to minimize potential exposure of the pipe at the banks. The channel and bank contours would be restored to approximate their original configurations after pipeline installation has been completed. Breakers or riprap would be placed over the pipeline and disturbed areas along the stream banks where necessary for erosion control. There would be no permanent blocking of surface drainages.

3.2.10.8 Need for Blasting

Use of blasting would be limited. The actual need for blasting would be determined during detailed engineering design and construction. If blasting is required, it would be performed by qualified, experienced personnel using approved written safety procedures. Blasting would be limited to the 30 m wide land easement. Vibration levels at the edge of the land easement are expected to be minimal. The following safety precautions would be taken:

- Blasting area would be checked immediately prior to detonation to ensure that all personnel, wildlife, and equipment are well away from the danger zone.
- Blasting mats would be used near power transmission or telephone lines or in areas of human use.
- Blasting would not be conducted in areas where it could induce slope instability.

3.2.10.9 Construction Records

A complete record that shows the following information would be maintained for the pipeline:

- The total number of girth welds (all nondestructively tested), the number of welds rejected during testing, and the disposition of each rejected weld
- The amount, location, and cover depth of each size of pipe installed
- The location of each crossing of another pipeline (none are expected)
- The location of each buried utility crossing (none are expected)
- The location of each aboveground crossing (none are expected)
- The location of each block and check valve, weighted pipe, corrosion test point, or other item connected to the pipe.

Most of this information would be available on the "as-built" drawings that would be prepared at the end of the installation phase.

3.2.11 Operations And Maintenance

3.2.11.1 Procedures Manual for Operations, Maintenance, and Emergencies

Manuals of written standard operating procedures for conducting normal operations, maintenance activities, abnormal conditions, and emergency response procedures would be prepared and followed. Procedures for the following would be included to provide safety when an emergency condition occurs:

- Receiving, identifying, and classifying notices of events that need immediate response by fire, security, or emergency response personnel, and communicating this information to appropriate project personnel for corrective action

- Responding promptly and effectively to a notice of emergency causing a hazardous condition or a natural disaster affecting oil field and pipeline facilities
- Having personnel, equipment, instruments, tools, and material available as needed at the scene of an emergency
- Taking necessary action to minimize the volume of fluid lost from the well field facilities and/or pipelines in the event of an incident
- Providing for a post-accident review of employee activities to determine whether the procedures were effective in each emergency and taking corrective action where necessary.

3.2.11.2 Patrol/Inspection

The pipeline route would be inspected at least once per month by aerial patrol. The patrol would check for signs of leakage or unauthorized encroachment along the land easement that might affect overall pipeline integrity. Other items that may require attention, such as soil erosion, watercourse changes, weathered pipeline markers, steep areas, road and stream crossings, and growth of brush and trees also would be observed. Visual inspections along the pipeline (line-walking) would be used to supplement aerial patrols of specific areas when necessary.

3.2.11.3 Pigging

The pipeline interior would be pigged or scraped on an as-needed basis during its operation to clear the pipeline of waxy deposits, debris, water, or other material. Instrumented pigs would be used to determine pipeline integrity where deemed appropriate.

3.2.11.4 Land Easement Maintenance

For the safety of the export facility, a strip of the land easement, expected to be approximately 10 to 15 m wide, would be maintained. This would allow use of the land easement by authorized vehicles for normal maintenance and emergency response. Vegetation that would limit aerial observation would be controlled by hand clearing as necessary, including removal of shrub and tree seedlings that could pose a threat to pipeline integrity. Grassland or agricultural areas would be returned to their former use within three to six months or one growing season, so long as it does not interfere with the functioning of the pipeline.

3.2.11.5 Corrosion Protection Activities

The cathodic protection system would be analyzed annually to determine that it provides adequate corrosion prevention and is maintaining mechanical integrity. In addition, some of the following activities or techniques would be used as necessary to protect against corrosion:

- Use of sacrificial anodes

- Coating of materials to protect against corrosive environments
- Use of corrosion inhibitors to coat the inside of the pipeline, flowlines, or other equipment to inhibit chemical corrosivity of produced fluids
- Pigging to remove scale and deposits that would cause corrosion
- Gas blanketing of oil and produced water tanks
- Use of non-corrosive pipe (fiberglass) for infield flow lines
- Selection of material in conformance with industry (National Association of Corrosion Engineers) standards.

Facilities and pipelines would also be subject to regularly scheduled integrity surveys. This would include both spot surveys and detailed surveys of facilities or areas subject to corrosion.

3.2.12 Safety And Environmental Protection

3.2.12.1 Regulatory and Environmental Management Systems

Operations will be conducted in a manner that is compatible with the balanced environmental and economic needs of the communities and countries in which it operates. It is established policy to comply with all applicable laws and regulations and design facilities to operate at high standards. A series of management systems to cover all phases of its business, from conceptual planning through operation has been developed. These management systems include a systematic approach for regulatory and environmental management, including assigning responsibilities, and providing mechanisms for receiving feedback to allow adjustments and incorporate change.

Regulatory Compliance System–The Regulatory Compliance System establishes a framework for identifying applicable legislation and regulations to ensure project compliance. It would be implemented by each field operational unit prior to beginning construction and operations in Chad. Activities would include establishing compliance procedures, communicating these procedures to all on- and off-site personnel, documenting compliance procedures to ensure timely response to review authorities, coordinating with governmental authorities, and monitoring compliance to improve operations. The Chad project manager has the overall responsibility for implementing the Regulatory Compliance System. This system involves on- and off-site in-country personnel.

Environmental Management Systems– Environmental management systems establish policies and activities for the project and project personnel, including service providers and contractors, to ensure that all phases of the project satisfy environmental policies, regulatory requirements and key stakeholders' expectations. The scope of this system includes (1) preliminary design activities, including environmental reconnaissance, assessment, and site selection; (2) detailed design and construction phase activities, including finalization of preliminary design; facilities siting and design; contractor management; development of construction practices, oil spill response, waste management, and health and safety plans; development of plans on hiring, training, compensation, resettlement, and site cleanup prior to startup; (3) environmental mitigation and control; and (4) operations phase activities including startup, review of construction phase impacts, environmental monitoring and waste management, and decommissioning and reclamation.

The objectives of the system are to (1) assure that standards and specifications have been established to protect biological resources and environmental resources such as surface waters and groundwater; (2) prevent unacceptable releases or levels of emissions or effluents; (3) provide emergency preparedness programs; (4) provide a mechanism for ongoing environmental reclamation; and (5) monitor and measure environmental performance. Documentation would be maintained to assure conformance with these objectives, among others. Examples of documentation include records of waste management practices and monitoring and maintenance performed for erosion and sedimentation control.

3.2.12.2 Environmental Management Plan

An Environmental Management Plan (EMP) would address all phases of the project, from construction through operation. The EMP would integrate the EA mitigation measures, EA project design measures and plans, World Bank guideline requirements, and project-specific requirements (discussed above in Section 3.2.12.1) into a program for environmental management of the project. The EMP would also specify the obligations to which each of the parties to the project are committed.

3.2.12.3 Personnel Selection and Training

Accident and pollution prevention are among the highest operational objectives. Personnel would be selected carefully, motivated to work safely, and trained in awareness and protection of personal well-being and the environment through the use of good working practices and routine training and environmental awareness programs.

A continuing training program would be established and conducted to instruct operating and maintenance personnel to:

- Carry out the operating, maintenance, and emergency procedures that relate to their assignments, as contained in the operating procedures manual
- Know the characteristics and potential hazards associated with the crude oil being produced and transported

- Recognize conditions that are likely to cause emergencies, predict the consequences of facility malfunctions or failures, and take appropriate preventive or corrective action(s)
- Take steps necessary to control any accidental spill and to minimize the potential for hazards or environmental damage
- Learn proper use of firefighting procedures and other safety equipment.

Periodically, management supervisors would review with personnel their performance in meeting the objectives of the training program. If necessary, changes would be made in the program to ensure that it continues to be up to date and effective.

3.2.12.4 General Safety Procedures

The field facilities and pipeline transportation system would be operated at or above the level of safety specified in the procedures manuals (Section 3.2.11.1). Whenever a condition is discovered that could adversely affect the safe operation of facilities, it would be corrected within a reasonable period of time. However, if the condition presents an immediate hazard to persons or property, the affected part of the system would be taken out of service until unsafe conditions could be corrected.

3.2.12.5 Occupational Health and Safety

As part of the project, an occupational health program to address health and safety concerns for project personnel is under development. The program includes both medical (clinical) and industrial hygiene components and will comply with the World Bank's Health and Safety Guidelines for Onshore Oil and Gas Development for workplace air quality and noise, work in confined spaces, hazardous materials handling and storage, general health and safety training, and recordkeeping. Specific detailed plans would be developed during final design of the proposed project. This occupational health program is outlined below.

Health Staff Facilities–Prior to the start of major construction activities, medical staff would be established in Chad to manage all occupational health activities associated with construction and operation of the project. A fully qualified, practicing occupational health physician would oversee all health-related services for the project. An industrial hygiene coordinator would oversee project construction and operations.

Medical resources based in N'Djamena, Chad will serve N'Djamena-based project personnel and dependents and assist with triage of field facility patients. A medical facility would be located at the Komé base camp and would serve as the site of major trauma care and inpatient treatment facilities.

During construction, the larger camp facilities would require additional medical personnel to supervise routine medical diagnostic/treatment needs and to supervise camp health/sanitation and screening and surveillance programs. These personnel could be medical doctors, physician's assistants, or nurses. The primary selection criteria would be experience providing medical and sanitation supervision in remote construction camp settings.

In addition to supervisory medical staff, each of the larger camps would have emergency medical technicians as primary care givers. Smaller project camps would be equipped with first aid supplies and a dispensary and would be visited regularly by trained medical staff or have a permanent emergency medical technician. Each of the facilities would be capable of performing an appropriate clinical assessment, providing proper treatment, and thereafter continuing with periodic assessment and monitoring of the patient until full recovery or until care is transferred to another provider.

Criteria for transfer of care include:

- The need for critical or convalescent health care or other appropriate specialty care
- The need for further examination and investigation to determine the diagnosis
- Likely fitness for duty within a limited/specified time.

Health Screening–Health screening and surveillance programs would be implemented for respiratory diseases (tuberculosis), vector-related diseases (malaria, schistosomiasis, onchocerciasis), sexually transmitted diseases (including human immunodeficiency virus [HIV]), and water and food-related diseases.

Camps and Catering–There is the potential for the spread of communicable disease in a camp setting. All workers, expatriate or Chadian, would undergo a pre-employment health physical. Persons with symptoms of communicable diseases, i.e., tuberculosis, would not be approved for employment. Kitchen and laundry staff would undergo a rigorous health examination prior to being accepted for employment and periodically thereafter.

Specific plans have been developed to address the following:

- Potable water recovery (wells or surface waters), treatment, storage, and transportation
- Sanitary sewage collection, treatment, and disposal
- Solid waste management including both nonhazardous and hazardous substances.

In addition to these plans, adequate vector and disease reservoir control would be provided. Control measures could include engineering controls (site design, storage facilities, building construction, source containment), personal protection (clothing, repellents, and prophylaxis), and appropriate use of biocides. Specifically, preventive programs would be developed to minimize the spread of mosquito-borne diseases such as malaria.

Safety–Safety and health would be the highest priority during operations. All project workers, expatriates, and nationals would receive up to three days of initial training covering safety and health issues and corporate policy. All project workers would receive personal protection equipment suitable for their duties. This could include hard hats, safety shoes, safety glasses, and hearing protection. As radioactive sources are commonly used in non-destructive testing by the petroleum industry, radiation safety procedures will be developed by contractors and approved by the project. Measures would typically include establishing a safety zone during radiographic work, each person using x-ray equipment to wear a radiation film badge and a pocket dosimeter, and possession by all radiographic personnel of current radiographer's registration.

A Project Safety Manual has been developed in order to:

- Assist individuals and teams in carrying out daily activities in a safe manner
- Help personnel identify potential safety hazards and actions necessary to avoid those hazards
- Serve as a resource for other documents that provide procedures, training materials, and job safety analysis
- Document minimum standards for safe behavior.

3.2.12.6 Waste Management

The project would generate various types and volumes of solid, liquid, petroleum-based, and hazardous wastes during the four phases of the project: construction; exploration and appraisal drilling; production and operation; and decommissioning. Waste management guidance that commits to the prohibition and/or substitution of certain chemicals and the reduction, reuse, treatment, and environmentally acceptable disposal of project-related waste has been prepared for the project. Waste facilities required for this project would be constructed and managed. Additional information on waste management facilities constructed as part of the project and potential waste impacts are presented in Sections 7.8 and 8.8. A Waste Management Plan would be prepared during the final detailed design and engineering phase of the project.

Waste management facilities that would be designed and constructed as part of the project and the respective wastes that would be disposed of or treated during construction and operation of the project are presented on Table 3-6. These facilities would be designed to meet applicable World Bank guidelines and international standards for waste management practices.

Waste Management Facilities–No pre-existing infrastructure is available in the project area for waste management and disposal. The project would include a landfill containing cells suitable for hazardous waste disposal and cells suitable for nonhazardous wastes. The landfill would be constructed prior to major construction of the project to allow for disposal of construction wastes. No radioactive wastes are expected to require disposal in Chad, and no such wastes will be accepted at project waste facilities. (Radioactive sources are commonly used in petroleum industry projects for quality assurance purposes, and any such sources imported to Chad for project purposes would be re-exported for disposal. Any radioactive sources originating in Chad would be subject to disposal according to the provisions of Chadian law, and would not be accepted for disposal in project facilities.) An incinerator appropriate for destruction of medical wastes, oily debris, domestic wastes, combustible chemicals, and oily process sludge would also be constructed about the same time as the landfill. During the construction phase, the landfill and incinerator would receive contractors' wastes for disposal on an "as approved" basis. Minimization of waste volumes and material hauled to the landfill for disposal would be emphasized.

Peak use of the incinerator is expected to occur at project startup (2001-2002). The incinerator would be in use constantly or fired on a periodic basis to handle wastes as they are generated (e.g., eight hours per day or every other day). Waste reduction and reuse programs and the solids content of the crude oil would influence the need for and rate of incinerator use. The incinerator ash would go to the landfill.

It is anticipated that contractors would have package wastewater sewage treatment plant(s) with effluent discharge to surface waters or natural drainages during the construction phase. Wastewater sewage treatment systems that may include using septic systems would be constructed to accommodate the needs of the operations staff.

Disposal wells would receive produced water after separation from the crude oil stream. Oily water separators would separate oils from equipment wash waters and process area runoff for addition to the crude oil stream. Other recycle and reuse opportunities would be explored and potentially utilized by contractors. Storage space would only be required for materials potentially reused or recycled. Some incinerator wastes may be suitable for fuel blends to power the incinerator. For some inert construction wastes, burial pits (rather than landfill cells) may be appropriate but would not be included in the formal infrastructure for the facilities.

Waste Volumes and Characteristics–Preliminary estimates of waste volumes have been made for the various locations and phases of the project (Table 3-7). These are order-of-magnitude estimates for determining disposal options, and these waste volume projections are based on the following:

- Well fields would be drilled using freshwater-based muds, to the extent feasible.
- Potassium chloride completion fluids may be used.
- The majority of the waste oil would be generated in the CTF since facilities are electric powered.
- Oil-contaminated soil may be generated from small spills and leaks from the well fields, gathering facilities, production facilities, and pipeline.
- Produced hydrocarbons would have a low sulfur content.
- The majority of produced water would be disposed in wells at each respective field.

- Produced water is expected to have a salinity of less than 3,000 parts per million (ppm); therefore, small produced water spills should not result in contaminated soils.

3.2.12.7 Soil Erosion and Sedimentation Control Plan

Erosion control measures would be implemented to prevent soil erosion as a result of the development of project facilities. Permanent and temporary control measures would be designed and implemented to reduce the impact of increased stormwater runoff and soil disturbances from construction activities. The following measures would be implemented as part of an overall erosion control program:

- Limit the extent of disturbed areas; construction activities would be sequenced to limit the amount of area disturbed at any one time.
- Divert upslope runoff; runoff would be diverted around disturbed areas to minimize erosion.
- Reduce runoff velocities to low levels; runoff would be diffused or diverted to stabilized outlets to reduce problems associated with concentrated flows and velocities from areas cleared of vegetation.
- Stabilize disturbed areas; temporary or permanent stabilization of exposed soils would be provided as soon as practicable after grading and other earthwork activities have ceased. This could include mulching, geotextiles, and stone riprap, as appropriate.

Temporary erosion control procedures (e.g., sediment barriers, riprap) would be directed toward preventing soil erosion at the source and preventing silt and sediment from entering waterways and migrating downstream if soil erosion cannot be prevented. Permanent erosion control measures (e.g., trench plugs, diversion dikes, erosion control blanket) would be implemented to prevent sedimentation of the drainage system and to prevent erosion of the project area. The soil erosion control and sedimentation plan would be prepared during the final detailed design and engineering phase of the project.

Whenever practicable, existing drainage would be rehabilitated. Existing and new watercourses that must cross the path of prepared surfaces would be conveyed by buried culverts. Existing culverts that are clogged or blocked would be cleared and surrounding vegetation and obstructions removed.

3.2.12.8 Leak Detection and Communication Systems

The project includes a comprehensive system to provide for the transmission of information needed for safe operation of the well fields, processing facilities, and pipeline. This system would include means for:

- Receiving notice of abnormal or emergency conditions and sending this information to appropriate personnel or other parties for corrective action

- Conducting two-way voice communication between the operations control center and the scene of abnormal operations or emergency
- Monitoring routine operational data
- Monitoring leak detection 24 hours per day.

In addition, special provisions would be made for facilities located in sensitive areas such as the well pads located in the Loulé River floodplain. Additional planning and safety measures for these well pads would include siting them a minimum prescribed distance away from the main channel of the Loulé River and other major stream courses or drainages in the floodplain, construction of containment systems such as berms around the pads, and frequent inspection, monitoring, and review of operating performance and conditions.

3.2.12.9 Fire Control and Protection

Fire hazards associated with construction of the project include welding sparks generated during installation and wildfires that encounter stockpiled installation materials that may be flammable.

All firefighting equipment would be maintained in proper operating condition at all times. It would be located where it would be easily accessible during a fire, and it would be plainly marked so that its identity as firefighting equipment is clear. Mobile fuel storage trucks would be used for refueling of equipment.

The potential exists for fire hazards to occur during the overall operation of the proposed project as well. Fire water demand for the OC and related facilities would be available at 1,900 liters per minute for 1 hour. Fire hydrants and valves would be located within the community in accordance with applicable international guidelines and requirements. Fire water pumps would be located at the CTF with a ring main and fire monitors surrounding vital equipment. Provisions for fire detection, fire extinguishers, and sprinkler systems also would be incorporated into the overall design of the buildings and structures as appropriate, including the cafeteria building and work force housing.

Fire protection for the airfield would be provided by a fire truck (stationed at the OC fire station) and appropriate fire extinguishers. The fire truck also would be available to cover structural fires, grass fires, and related emergencies elsewhere in the oil field development area and community.

Fire and hazard detection, alarming, and suppression that would be incorporated into appropriate project components for well field, production facilities, and PS1 would include:

- Ionization smoke detectors would be installed at strategic locations in the following areas:
  - Control rooms
  - Electrical rooms
  - Rack and equipment rooms
  - Radio rooms
  - Uninterruptible power supply equipment rooms
  - Under computer room floors
  - Camp buildings (living quarters, kitchen, etc.)
- Fire suppression would be automated from the smoke detection in the following areas:
  - Rack and equipment rooms
  - Under computer room floors
  - Radio rooms

Enclosed areas that normally are manned generally would have water sprinkler-type fire suppression systems, and all fire and gas detection systems would be alarmed remotely or locally. Gas detection systems in the gas turbine enclosure would be equipped with a fire suppression system. Gas detection systems would be considered during detailed design for any location where there is a high potential for resulting hazard to equipment or to personnel. During construction activities, appropriate measures also would be taken including spark arresters, heat shielding devices around catalytic convertors, fire watch personnel in welding areas, battery powered smoke/heat detectors, and chemical fire extinguishers.

3.2.12.10 Oil Spill Planning and Response

Oil Spill Planning–Prevention is the best means to avoid an incident, followed by contingency planning. Oil spill response and contingency planning for the project would provide the background information and response planning guidelines necessary to implement an effective spill response. Hazardous operations and risk assessments have been performed during the preliminary design phase to provide initial recommendations for prevention and contingency planning. During operations risk assessments would be performed, at a minimum, every five years.

Oil spill prevention and minimization measures have been incorporated throughout the design. Proven technology, design, materials, and construction techniques would be used to the maximum extent possible. To facilitate training and operations, standardized equipment and simple designs will be used. Additional prevention and mitigation measures planned for the project include: internal and external corrosion control measures, berms around oil storage tanks, burying flowlines, burying the pipeline, strategic placement of block valves or check valves to minimize spill potential, oily water collection systems at major facilities, 24 hour manned automated monitoring, leak detection systems, visual monitoring, and emergency shut down systems for the OC, CTF, PS1, and pipeline facilities. As the facility designs and operating plans for the project are not yet final, a project specific spill response plan is not currently available. However, once these plans are in place, a detailed and workable Oil Spill Response Plan (Appendix A) to cover all aspects of the operation from initial production through final transportation will be developed.

The Oil Spill Response Plan for the project would be divided into two parts: Part I - Response Action Plan and Part II - Supplemental Information.

Part I provides information to guide response teams during an incident. Information in the Response Action Plan will include: reporting and notification procedures, basic safety and health procedures, an internal and external communication plan, deployment and response strategies, and initial response procedures. Project personnel will be familiar with the contents of this plan and other manuals necessary to execute a successful response. Part II - Supplemental Information provides an overview of the facility, operations, environmental information, local community and government information, and supporting response information. In addition, this part may include management practices, prevention measures, identified risks, and measures taken to minimize potential impacts.

The final Oil Spill Response Plan would be developed by studying detailed project designs to determine the most likely and credible spill scenarios for the different operating environments and geographical areas. Information describing sensitive ecological habitats and wildlife areas, as well as local towns and communities would be gathered from various sources, including government, academia, private agencies, and through field studies (if necessary). This information, combined with spill scenarios will be used to design effective response strategies and equipment stockpiling requirements for the various project areas.

Oil Spill Response–When an incident occurs, Part I of the Oil Spill Response Plan would be implemented. This will help ensure the proper notifications are made and the correct response actions are implemented to minimize impacts of the incident. Deployment and response strategies provided in the Oil Spill Response Plan may include:

- Recovery and protective booming
- Mechanical recovery
- In-situ burning
- Sorbents
- Bioremediation
- Chemical treatment/washing
- Tilling and soil aeration.

Oil Spill Response Objectives–The focus of the oil pollution countermeasure activity will be prevention. Prevention and mitigation measures are achieved through design and operation of:

- Management commitment
- Well designed equipment systems and facilities
- Preventive maintenance
- Systematic training
- Project worker awareness.

It is recognized that despite best management practices an incident may occur. In the event of an incident, the objective of the oil spill response is to assure that response actions are compatible with the balanced environmental, social, and economic needs of the community. The response strategy includes all viable techniques to minimize damage from a spill. No oil spill response option will be ruled out or limited in advance. Notification will be given to appropriate government agency(s) and local residents in an affected area.

Response Organization–A three-tiered organizational response structure would be used to respond to an incident. The tiered response system is designed to expand as the situation, magnitude of the incident, and environmental conditions require. The initial response, Tier 1, is a local response to a spill of limited volume occurring at or near a facility and typically resulting from routine operations. Examples of Tier 1 response include a valve leak, pipeline rupture, tank overflow, or a small on-water spill. Sufficient equipment and manpower is available locally to protect local resources, mitigate damage, and clean up the spill.

A Tier 2 response would be initiated if an incident escalated to a level which required resources not involved in normal operations. The entire response team may be requested to respond. Tier 2 incidents can include multiple serious injuries/fatalities requiring public medical treatment or a major land spill in which the project utilizes mutual aid or cooperative support.

A Tier 3 response is for the most serious type of incidents. In addition to a spill, a Tier 3 response may include multiple injuries/fatalities, major fire, or loss of a large storage tank or pipeline resulting in a sizable environmental impact. In many cases these incidents are further complicated by bad weather or other circumstances. Tier 3 response includes support from regional and/or worldwide cooperatives.

The response to an incident would be tested through exercises and drills on a routine basis to ensure personnel demonstrate knowledge of oil spill planning and response procedures for the facilities. Equipment may be deployed, communications tested, and response needs evaluated during drills and exercises. As a result of an exercise or drill, the Oil Spill Response Plan may be revised.

3.2.12.11 Project Design Measures

A number of project design measures have been incorporated into the construction and operations phases of the project. These measures consist of optimized engineering design, good engineering practice (e.g., power plant stacks designed to reduce air pollutant concentrations), and plans (e.g., erosion and sedimentation control procedures implemented during construction) which have been incorporated to reduce potential environmental impacts associated with construction and operation of the project. Such measures have been described in Section 8.0 (Mitigation Measures and Monitoring) since they have been incorporated into the project to reduce environmental impacts to less-than-significant levels.

3.2.13 Termination and Decommissioning

Prior to the cessation of production from each of the three fields, a detailed termination and decommissioning plan would be prepared for review by the Government of Chad. It is anticipated that termination and decommissioning activities would include plugging each of the individual production and produced water injection wells in each of the three fields. Cement plugs would be set in each well in a manner to confine fluids in their parent formations to prevent them from intermingling or flowing to other formations. All well plugging and decommissioning operations would be conducted in conformance with accepted industry standards in place at that time. Assuming there is no other use for field facilities, all structures including production, processing, treatment, storage, pumping, power, and related infrastructure facilities would be dismantled. The foundations would be broken up and all refuse materials would be disposed properly. All disturbed sites then would be graded and reclaimed to pre-construction conditions to the extent feasible. All field-related pipelines (i.e., trunk lines, gathering lines, and flow lines) either would be purged and decommissioned in place or excavated, dismantled, and individual segments hauled away for disposal, salvage, or reuse. The pipeline would be purged and decommissioned in place.

Consistent with general industry practice, decommissioning activities would commence when facilities and/or wells are no longer necessary for the oil field operations and would be funded from project revenues at the time of decommissioning.

3.2.14 Work Force

3.2.14.1 Construction

To initiate the recruitment process the project contractors will be provided with a listing of prospective workers. This list will be developed following announcements in the local and national media and public meetings to explain the recruitment process. The process will involve publicizing the project's labor needs, registration of prospective workers at specified locations which will be distant from work sites, and the selection of the best qualified candidates.

The construction contractors (yet to be determined) ultimately would determine the size of the construction work force that would be used for the project. The anticipated breakdown of construction work force personnel is summarized below.

Oil Field Development Area–In the oil field development area, approximately 2,000 Chadian nationals and 1,000 expatriates would be required during the peak construction period. Chadians generally would provide their own housing, with the construction contractor providing transportation to the job site from collection points in local villages. For expatriates, the existing Komé drilling camp would be expanded to accommodate 150 to 200 people and would remain operational for project development purposes until completion of development drilling. The remaining number of expatriates would be housed in construction camp(s) in the oil field development area. These camps would house 800 to 1,000 people at peak occupancy. The actual number of construction camps could range from one to four, depending on the number of contractors in the field. The actual locations of the camps have not been determined yet, but would probably be in the vicinity of the OC and be separated from one another by a reasonable distance. The contractors in consultation with project management would determine the locations of the camps. Contractors would be responsible for their own electricity, worker accommodation(s), warehouse(s), laydown area(s), and temporary fabrication shop(s), water wells, potable water/treatment systems, and wastewater treatment systems.

Pipeline Transportation System–Unlike the oil field development area, camps for pipeline construction would be mobile and, because of their remoteness, would provide single status accommodations for Chadian nationals as well as expatriate personnel. Casual hire nationals who live near the camp would be housed in their own homes. The construction spread operating in Chad would have mobile camps that can accommodate approximately 800 people. This mobile camp would relocate along the route as pipeline construction progresses.

3.2.14.2 Operations

The number of operations personnel necessary to fully operate the facilities in Chad would be determined during the final design phase of the project. However, it is anticipated that approximately 320 Chadian nationals and 230 expatriates on rotating shifts (a maximum of 150 at any one time) would be needed to perform a variety of functions. The operations work force would vary in number and duration with specific job functions. Chadian nationals would live in nearby communities. A single status community would be located at the OC, which would be designed initially to accommodate expatriate personnel associated with the field productions, central treating, and development drilling operations. The ratio of expatriate workers to nationals would change over time as nationals replace expatriates. By the year 2020, there would be approximately 350 nationals and 50 expatriates. At the peak operations period, there would be approximately 600 workers total (i.e., nationals and expatriates) employed by the project.

3.2.15 Schedule

The proposed project has evolved and continues to evolve from preliminary planning and engineering studies from which a substantial amount of economic and engineering data has been developed and evaluated. In addition, reservoir characteristics and production development scenarios have been further identified and refined. As a result of these previous and ongoing investigations, an overall development program has been established as described in Section 2.0 of this document. The current overall schedule for construction and operation of the proposed project is presented in Figure 3-13.

As shown on Figure 3-13, in-country construction activities are scheduled to begin in the second quarter of 1998 and continue through the second quarter of the year 2001. First oil is scheduled to flow through the pipeline beginning in the third quarter of 2001 and oil production from the three fields is expected to continue for a nominal period of 30 years.

TABLE 3-1
PROJECT FACILITIES
CHAD EXPORT PROJECT

Facility	Components
Oil Producing Facilities	
Komé	213 Production Wells
Miandoum	24 Production Wells
Bolobo	50 Production Wells
Gathering Stations	
Oil flowlines, free water knock out, pump stations, produced water injection and manifolds at each field	
Produced Water Injection Systems	
Pipelines and reinjection wells at each field	
Operations Center (OC)	
Central Treating Facility	Oil and gas processing, water treatment and disposal, produced water reinjection, gas distribution to power plant
Power Generation Plant and Distribution System	Gas turbines and crude oil diesel engines rated at generating approximately 100 MW of electricity and heat, with power distribution lines and substations for each field
OC Infrastructure	Operations center buildings, warehouses; community living quarters; airfield (suitable for landing jet aircraft near the OC); municipal services and new roads
Pipeline Pump Station No. 1	First pump station with 200,000 barrel storage, along pipeline located within the OC at Komé, Chad
Pipeline	
Approximately 170 km of a 760 mm diameter pipeline to the Cameroon border	
Road Network	
Repair/upgrade 170 km of existing roads or construction of 30 km of new roads, concrete box culverting of existing bridges, bypass at Lim River, bypasses around villages, brush clearing for new roads	

TABLE 3-2
SUMMARY OF CRUDE OIL PHYSICAL PROPERTY DATA

Property	Units	Zone	Komé	Miandoum	Bolobo
API Gravity (density)		Y0	18.4	27.0	—
		M1	18.4	24.4	23.6
		M2	16.8	—	17.8
		M3	16.6	—	19.3
		A1	20.9	—	21.3
		A2	20.9	—	21.3
		Average	(Note 1)	(Note 1)	(Note 1)
Bubble Point @ 60°C (140°F) (Note 2)	kPag (psig)	Average	1275 (185)	3260 (473)	2310 (335)
Gas-Oil Ratio	Sm^3/m^3 (SCF/bbl)	Average	2.67 (15)	5.34 (47)	8.36 (30)
Pour Point	°C (°F)	Average	-2.2 (29)	-7.8 (18)	-10.6 (13)
		Max.	7.2 (45)	-2.8 (27)	-8.9 (16)
Cloud Point	°C (°F)	Average	63 (146)	NA	NA
		Max.	NA	NA	NA
Total Acid Number	mg KOH/g Crude Oil	Average	TBD	TBD	TBD
Heating Value	kJ/kg (Btu/lb)	Average	40.84 (17566)	41.57 (17873)	41.71 (17930)

Btu/lb = British thermal units per pound
kJ/kg = kilojoules per kilogram
KOH = potassium hydroxide
kPag = kiloPascal gage
NA = Not Available
psig = pounds per square inch gage
SCF/bbl = standard cubic feet of produced gas per barrel of produced oil
Sm^3/m^3 = standard cubic meters of produced gas per cubic meter of produced oil
TBD = To Be Determined

Notes:
1. Total API gravity for each stream is determined for each year from crude blend composition based on production profile.
2. Bubble point temperature is determined from plot of bubble point versus gas-oil ratio data from all well test data for field.

TABLE 3-3
PRODUCED WATER ANALYSIS
FROM KOMÉ 7 WELL

Dissolved Solids			Other Properties	
Cations	**mg/L**	**Meq/L**		
Sodium (Na) (Meas.)	301	13.1	pH Value	7.74
Potassium (K)	3400	87.0	Specific Gravity, 60/60 F	1.0040
Calcium (Ca)	176	8.8	Resistivity (Ohm-Meter)	0.76
Magnesium (Mg)	33	2.7	Total Dissolved Solids (TDS), ppm	8403.2
Barium (Ba)	1	0.0	Stability Index at 100° F	+0.69
Iron (Fe) (Total)	0	0.0	Stability Index at 200° F	+1.73
			Oxygen	Minimal (Assumed)
Anions				
Chloride (CL)	3982	112.2	% Deviation in Meq. Balance	2.25
Bicarbonate (HCO_3)	230	3.8	% Deviation in TDS	2.97
Carbonate (CO_3)	0	0.0		
Sulfate (SO_4)	2	0.0		
Bromide (Br)	61	0.8		
Iodine (I)	0	0.0		
Sulfide (S)	0	0.0		

Source: Project Correspondence E/S-M-169.DOC (Komé 7 Water Analysis, Log No. 10735, 94.01.10)

Notes:

mg/L = milligram per liter

Meq/L = milliequivalent per liter

TABLE 3-4
MINIMUM DEPTH OF COVER
FROM THE TOP OF THE PIPE TO GROUND SURFACE

Installation Condition	Depth (m)
Normal soils	1.00
Consolidated rock[1]	0.50
Rivers and streams	1.00 - 1.50
Pump station discharge	1.30

[1] The depth of cover specified for burial in consolidated rock can be used only if the pipe (and coating, if applicable) is situated entirely below the upper boundary of the rock. Otherwise, the burial condition is considered normal soil. If rock is encountered in the rivers listed in Table 3-5 the depth of cover would be 1.5 m. If rock is encountered in wetlands or pump station discharge piping, the depth of cover would be 0.50 m.

TABLE 3-5
MAIN LINE VALVE LOCATIONS

Main Line Valves	Pipeline km[1]	Type Valve Facility	Comments
1	0	Motor Operated	Pump Station No. 1
2	47	Check	
3	78	Manual	
4	106	Check	
5	135	Gas/Hydraulic	
River	138		Lim River
6	141	Check	
7	174	Gas/Hydraulic	
River	176		Mbéré River

[1] Pipeline kilometers are measured beginning at the Operations Center.

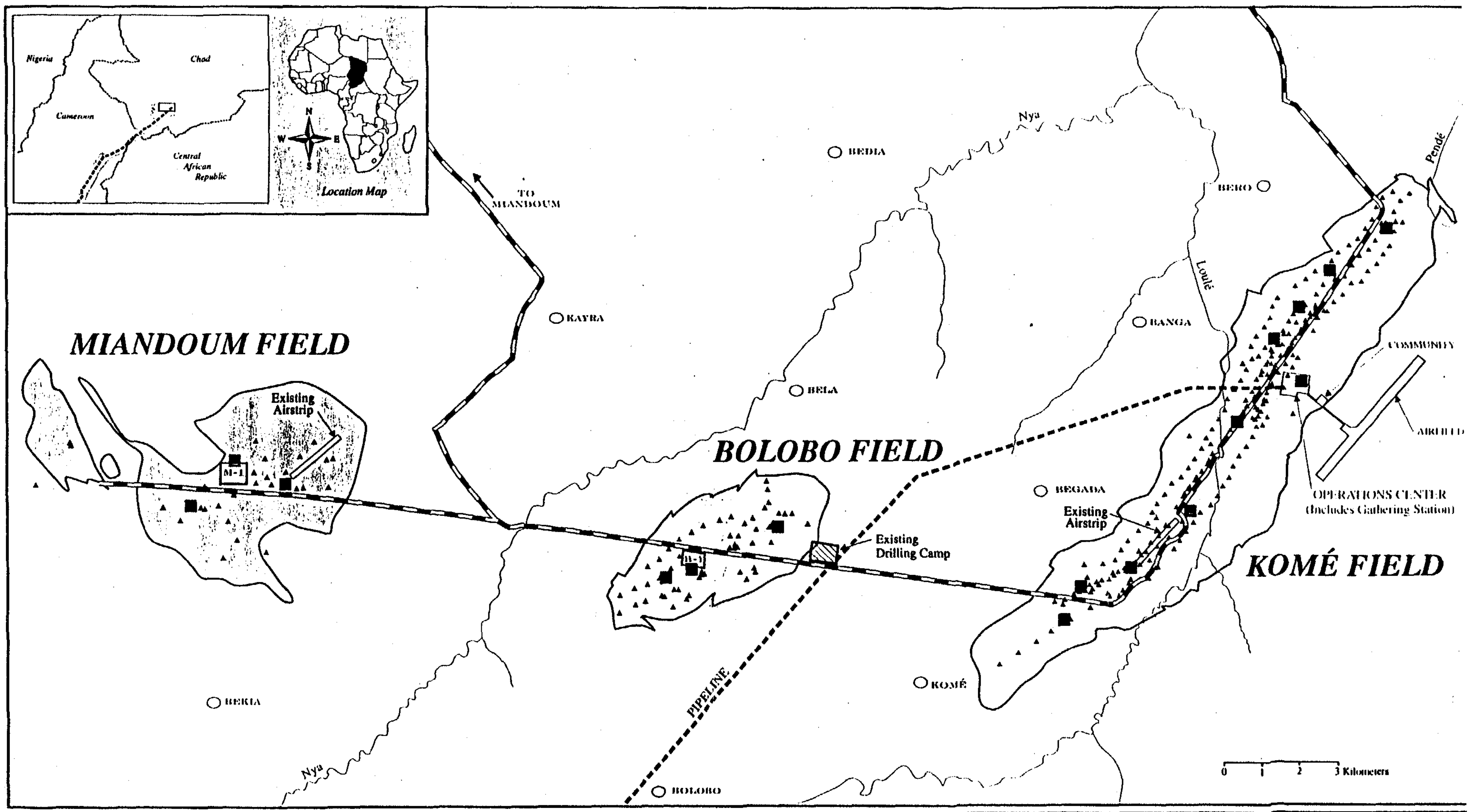
TABLE 3-6
PROPOSED WASTE MANAGEMENT FACILITIES

Facility		Expected Waste
Landfill	Nonhazardous waste cell	dewatered wastewater treatment sludge refuse tires scrap metal and plastic cement and concrete wastes used rags, brushes and other paint wastes (not including paint) solidified drilling fluids and cuttings drums, barrels, containers incinerator ash
	Hazardous waste cell	batteries noncombustible hazardous wastes incinerator ashes with high metals content
Incinerator		food wastes refuse medical wastes used lubricants, motor oil, transmission oils, drive grease, cleaning solvents oily filters oily rags scrap plastic solvent-based paints/coatings oil-based drilling fluids fuel and lube oil filter sludges used lube oil used solvents, chemicals, additives (with hydrocarbon bases) sludges, slop oil, and tank bottoms
Package water treatment plant		sewage wash water water from container washing operations
Produced water treatment system		produced water hydrotest fluid workover fluids water from container washing operations

TABLE 3-7
CHAD WASTE QUANTITIES

	Construction and Startup	Operations
FIELD FACILITIES AND CAMPS		
Landfill Municipal (Tonnes)	~36,000	~15,000
Landfill Hazardous (Tonnes)	~50	~10
Incinerator (Tonnes)	~11,000	~4,000
Wastewater Treatment Plant (m^3)	~500,000	~165,000
Produced Water Treatment System (m^3)	~1,080,000	~950,000

m^3 = cubic meters



LEGEND

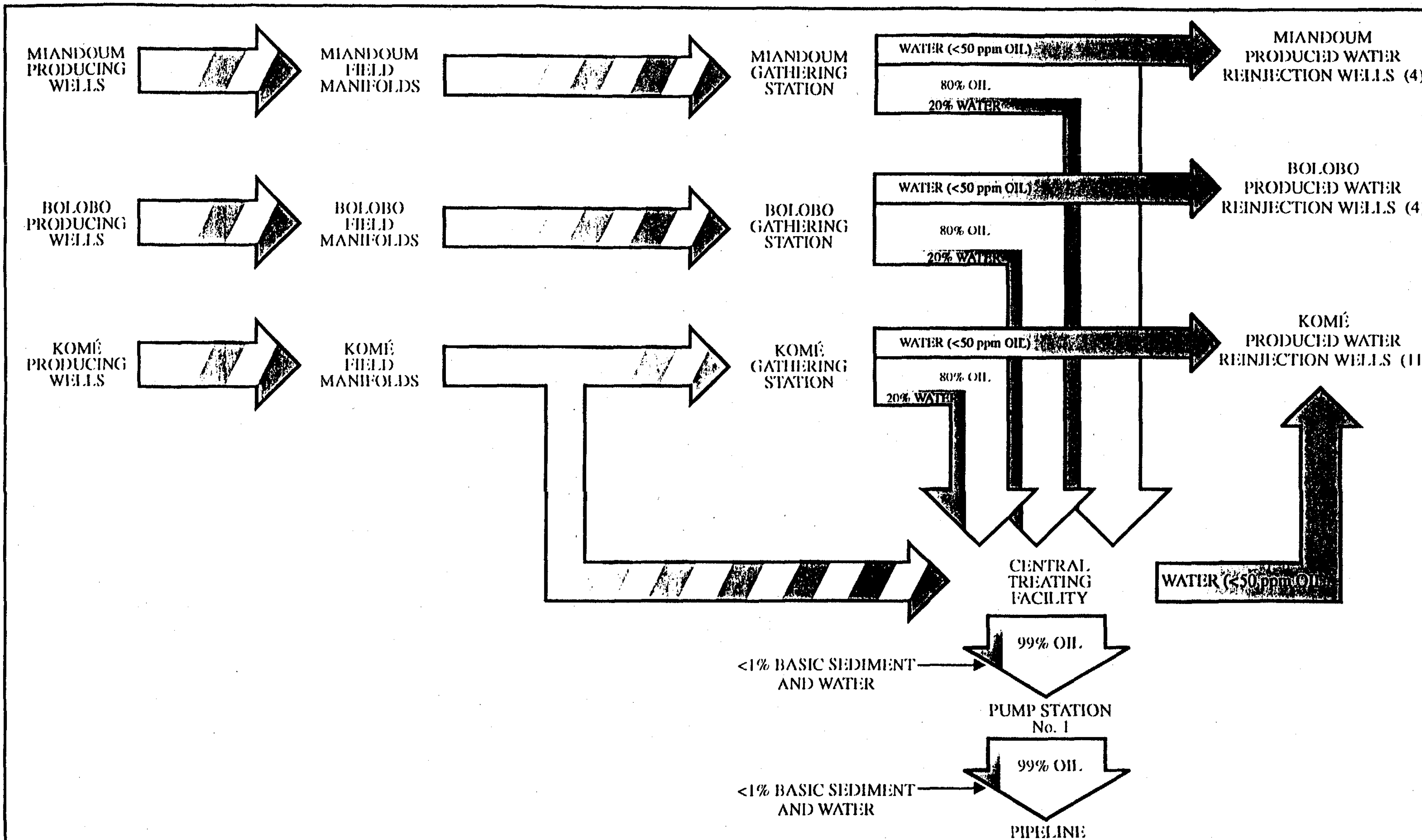
- ▲ Existing Wells
- ▲ Proposed Wells
- ■ Manifolds
- Komé Field
- Miandoum Field
- Bolobo Field
- M-1 Gathering Stations
- ○ Villages / Towns
- Roads
- Rivers

ESSO Exploration and Production Chad Inc.

OIL FIELD DEVELOPMENT AREA

DAMES & MOORE

FIGURE 3-1



LEGEND

WATER

OIL

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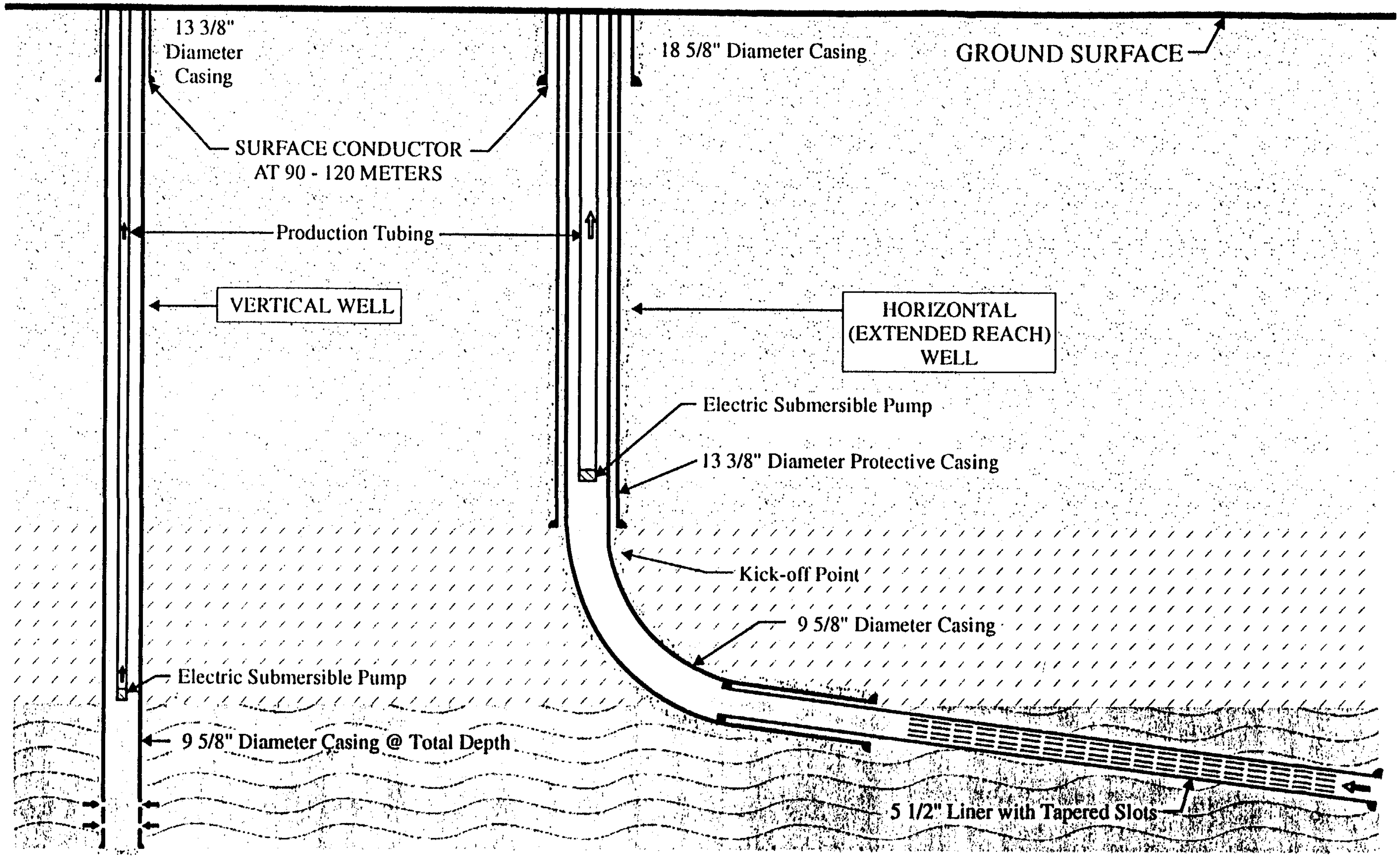
SCHEMATIC FLOW DIAGRAM FOR OIL PRODUCTION AND TREATMENT

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

FIGURE 3-2



Not to Scale

LEGEND

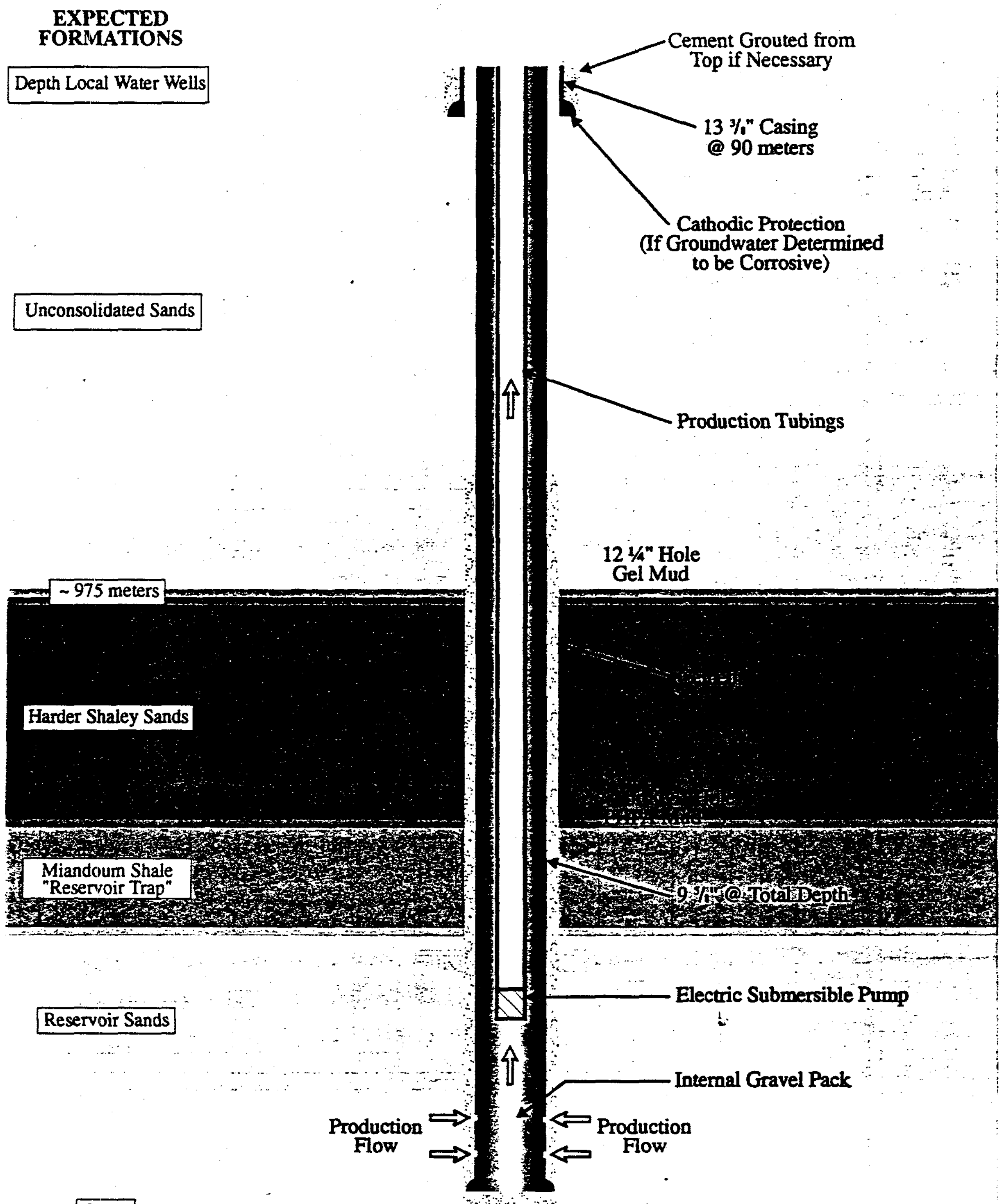
- Unconsolidated Sands
- Miandoum Shale
- Reservoir

ESSO Exploration and Production Chad Inc.

VERTICAL AND HORIZONTAL (EXTENDED REACH) WELLS

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

FIGURE 3-3

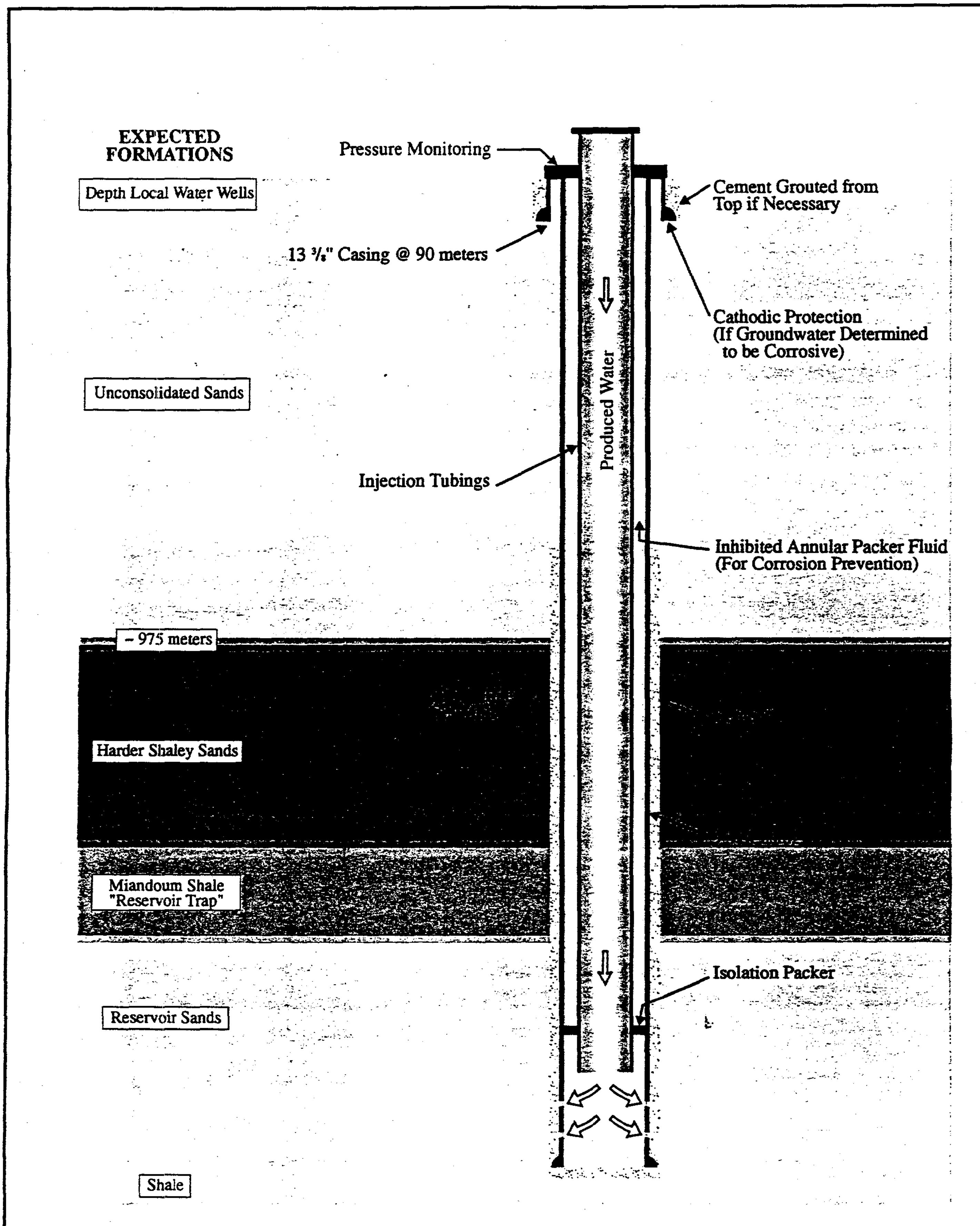


ESSO Exploration and Production Chad Inc.

TYPICAL PRODUCTION WELL

DAMES & MOORE

FIGURE 3-4

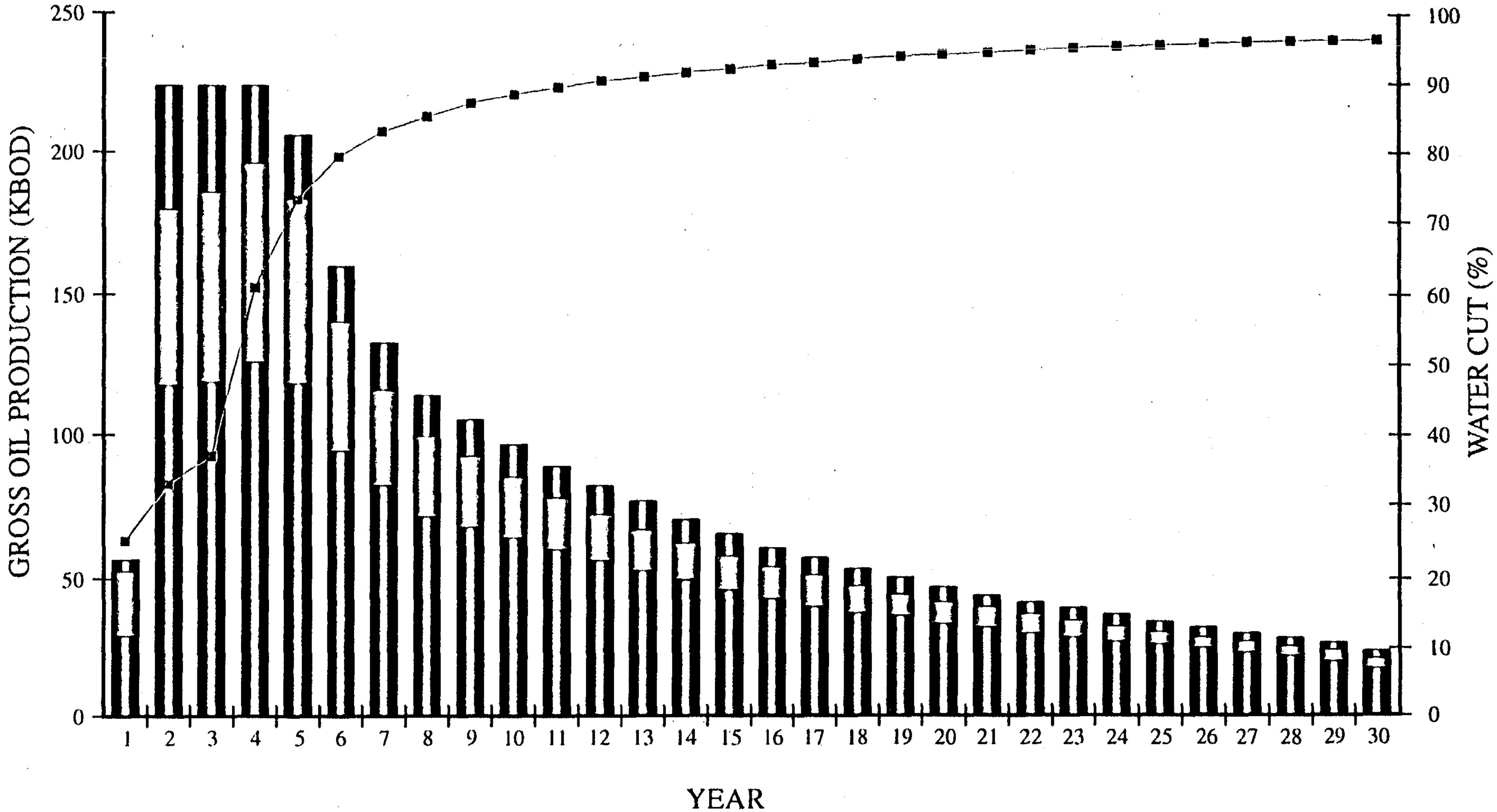


ESSO Exploration and Production Chad Inc.

TYPICAL INJECTION WELL

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

FIGURE 3-5



LEGEND

BOLOBO
KOMÉ
MIANDOUM
WATER CUT

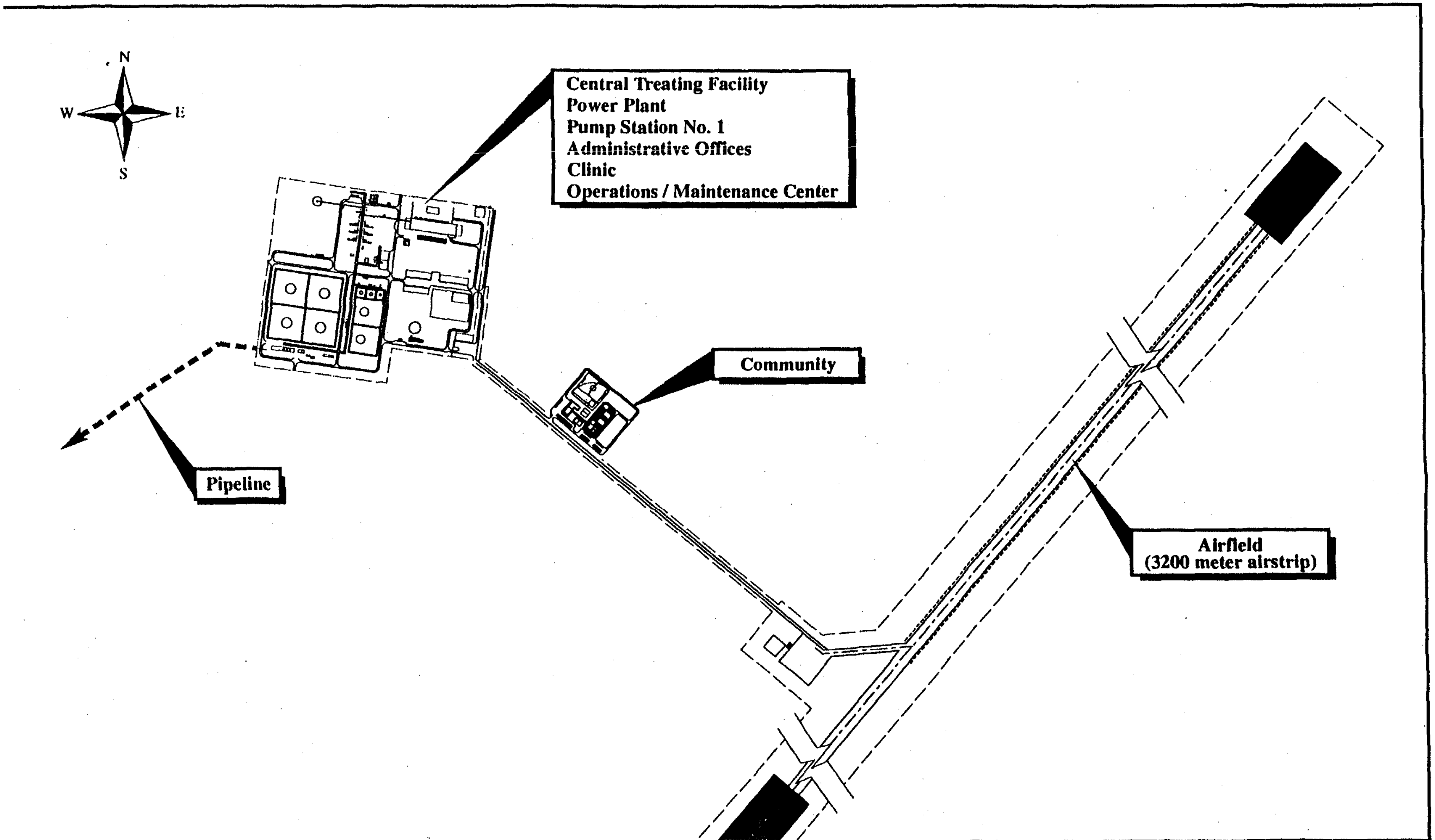
KBOD = Thousand Barrels of Oil Per Day

ESSO Exploration and Production Chad Inc.

PRODUCTION PROFILES OIL & PRODUCED WATER

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

FIGURE 3-6



ESSO Exploration and Production Chad Inc.

OPERATIONS CENTER COMPONENTS

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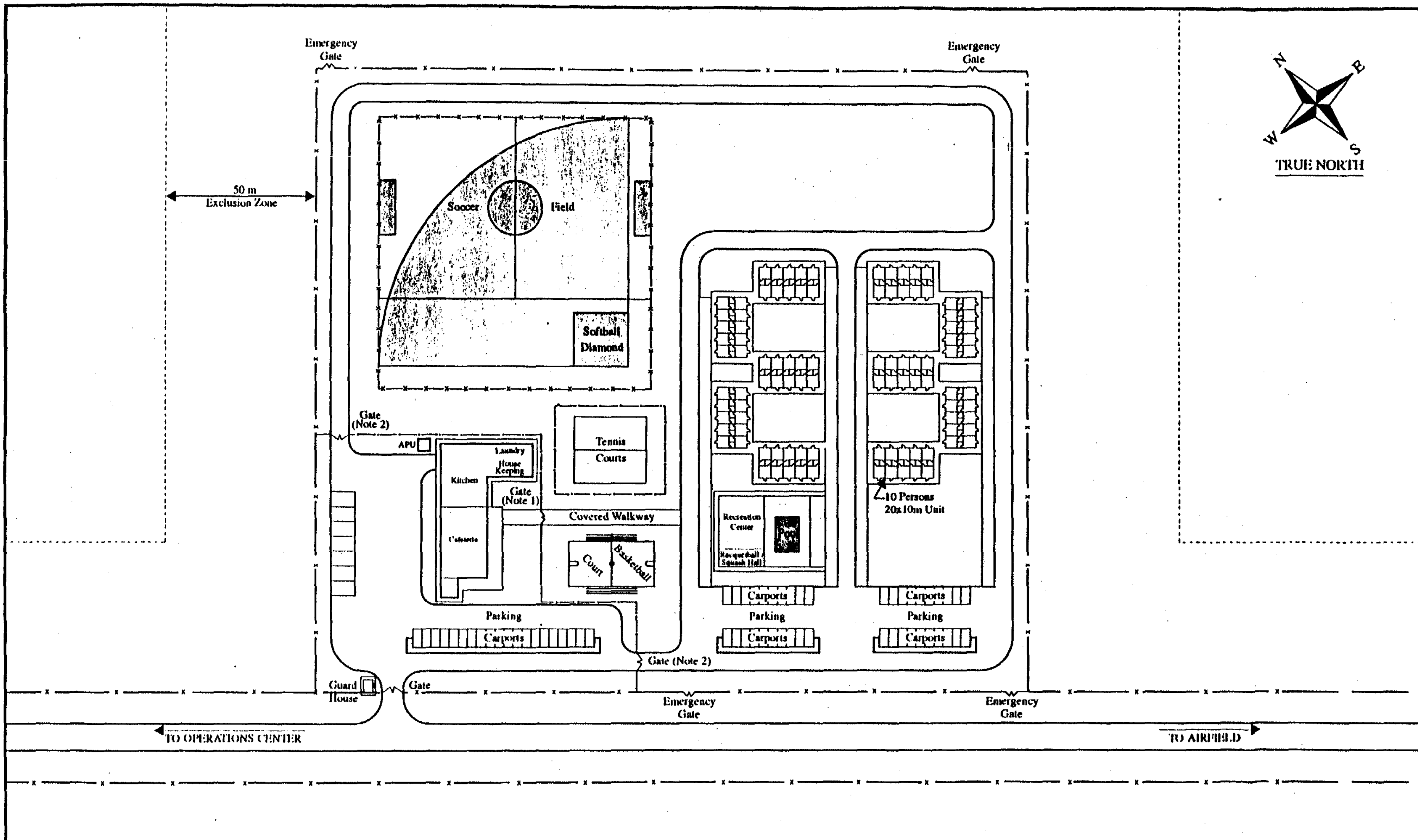
FIGURE 3-7



0 10 20 30 40 50 metres

NOTES:
1) 4.0m Wide Sliding Gate with Access Card Control
2) 6.0m Wide Automatic Sliding Gate

Esso

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OPERATIONS CENTER COMMUNITY LAYOUT MAP

DAMES & MOORE
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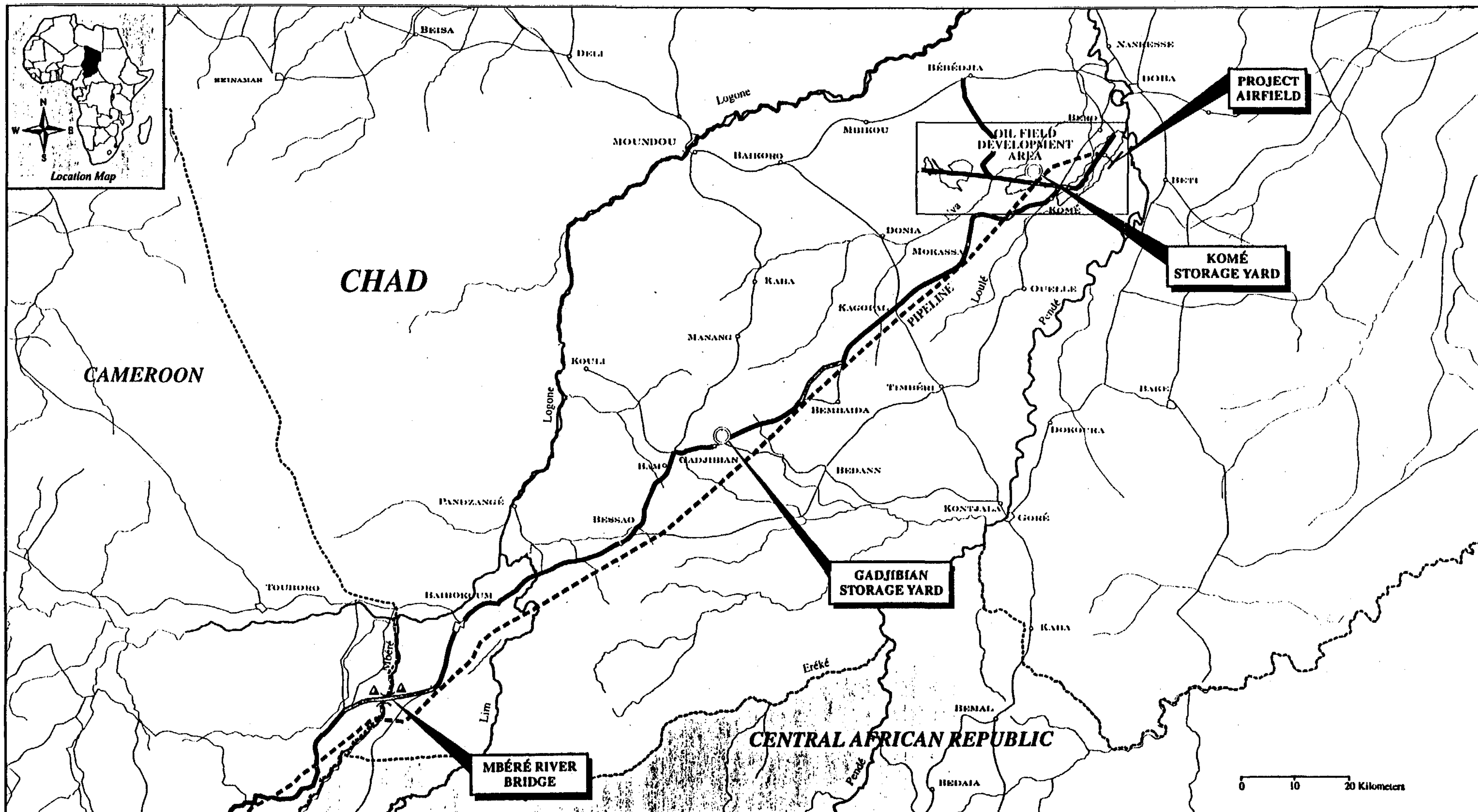
FIGURE 3-8



LEGEND

——	Primary & Secondary Roads	·····	Rivers/Streams
━━	Upgrade of Existing Road	◎	Storage Yards
━━	Possible Construction	▲	Truck Parks
■ ■ ■	Pipeline	⌶	Bridge
--------	International Boundaries		

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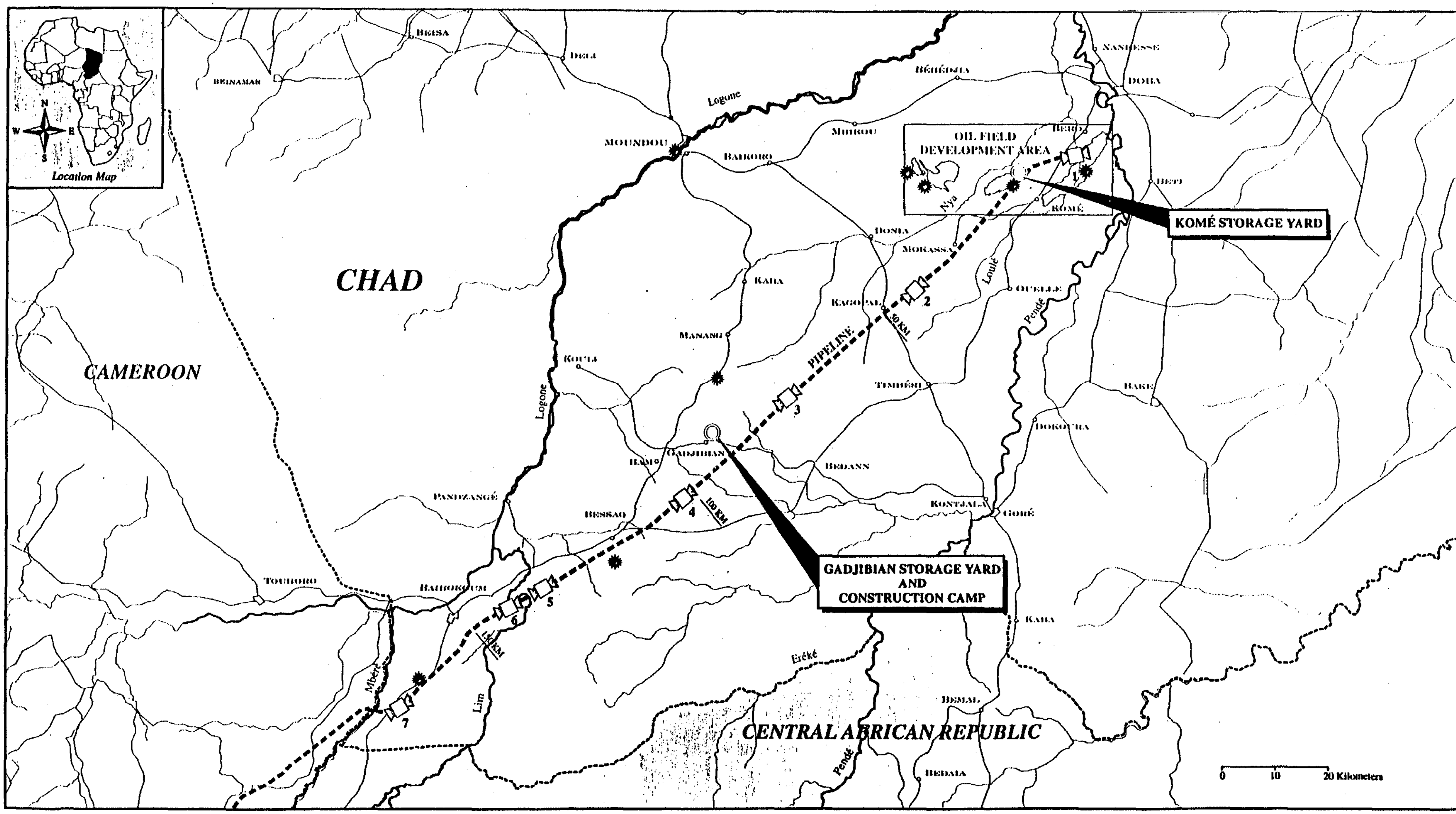
TRANSPORTATION INFRASTRUCTURE

DAMES & MOORE

FIGURE 3-10



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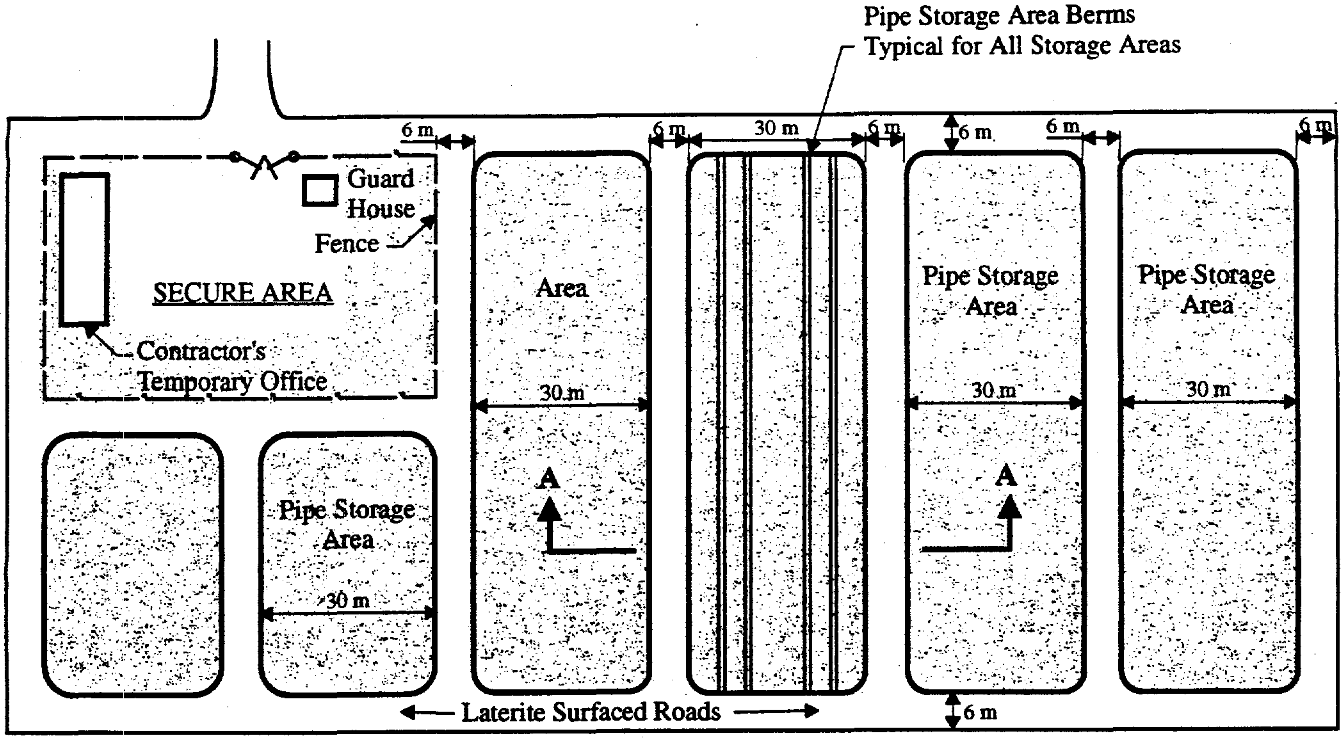
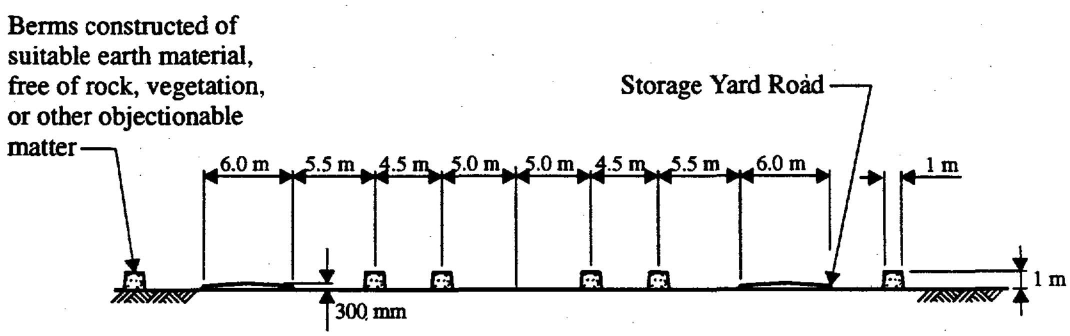
PIPELINE TRANSPORTATION SYSTEM IN CHAD

DAMES & MOORE

FIGURE 3-9



PLAN



SECTION A-A

TYPICAL STORAGE YARD LAYOUT

Note:
Drainage to be installed, culverts to be provided so that pools of water are not trapped or formed in the storage yard.

Not to Scale

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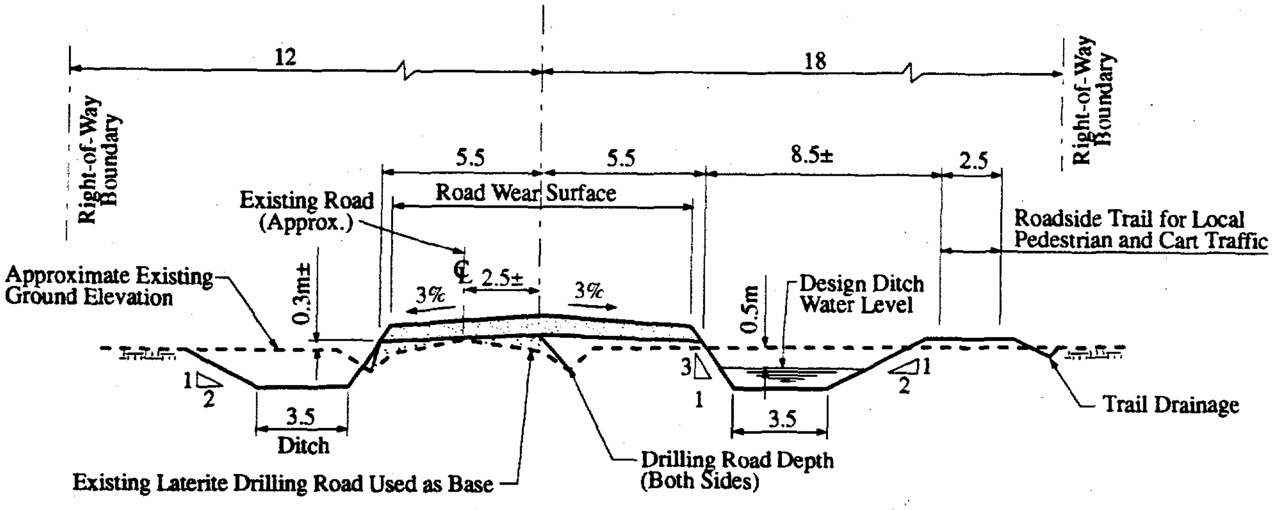
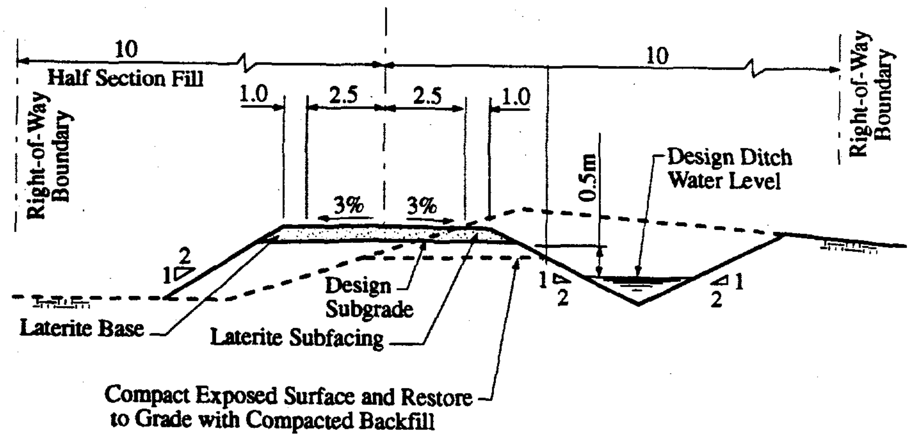
TYPICAL STORAGE YARD LAYOUT

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

FIGURE 3-11



REGIONAL ROADS



FIELD ROADS

NOTES:

DRAWING NOT TO SCALE
UNITS IN METERS

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TYPICAL ROADWAY CROSS SECTIONS

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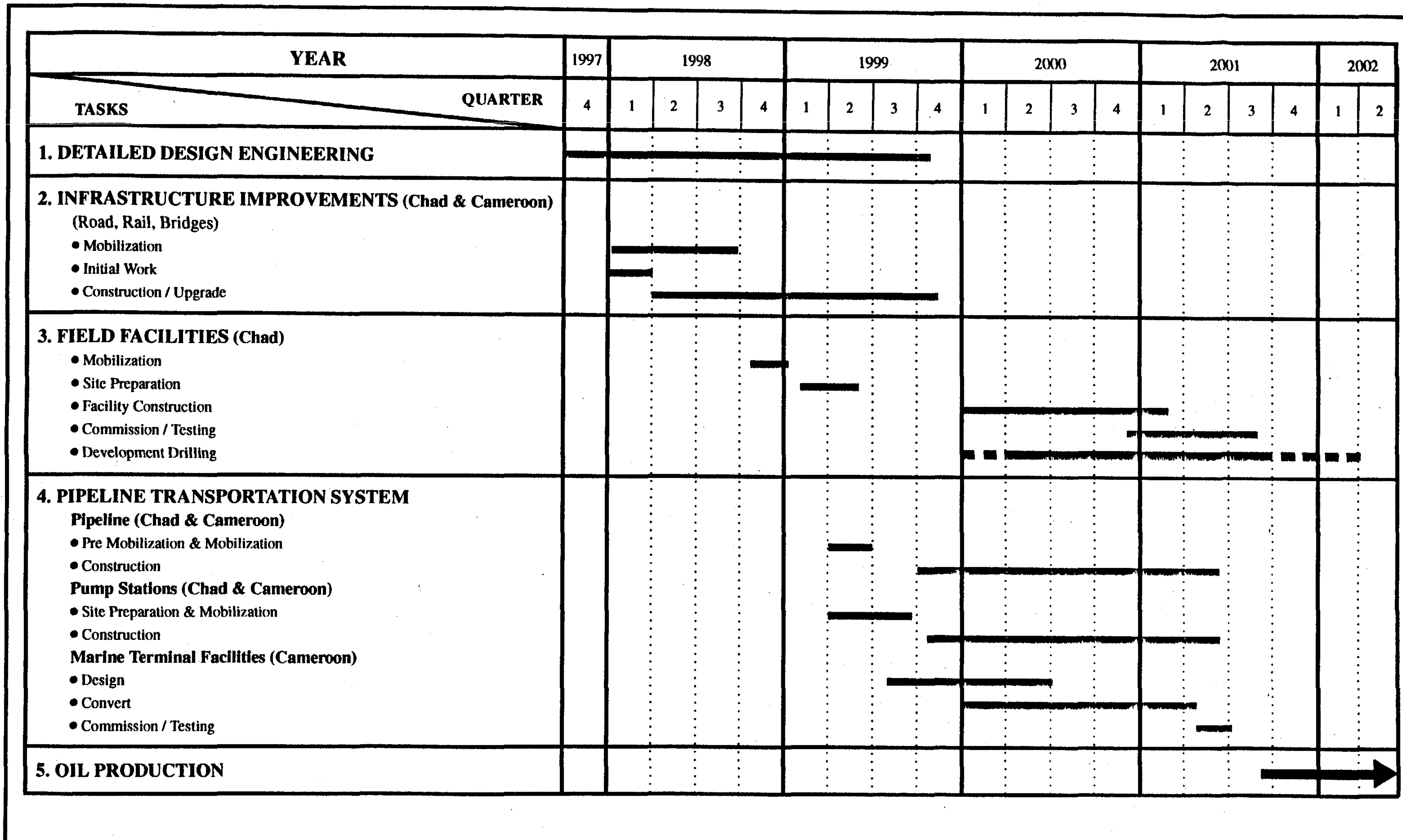
FIGURE 3-12



LEGEND

- Intermittent Activities
- Continuous Activities
- Continuous to Decommissioning

ESSO Exploration and Production Chad Inc.

PROPOSED PROJECT CONSTRUCTION AND OPERATION SCHEDULE

DAMES & MOORE

FIGURE 3-13

4.0 PROJECT ALTERNATIVES

4.1 PROJECT SELECTION CRITERIA

The proposed Chad Export Project would produce, treat, and export crude oil to world markets from the Komé, Miandoum, and Bolobo fields in the Doba Basin located in southern Chad. A buried 760 mm diameter oil pipeline would extend from the Operations Center in Chad across Cameroon to a floating storage and loading facility, located approximately 10.5 km offshore near the coastal town of Kribi. The following general criteria were considered in determining, to the extent feasible, development alternatives for oil field facilities, related infrastructure improvements (i.e., new roadways, airstrips, and utility corridors), and pipeline alignments:

- Design the overall project size and general field and facility configuration to maximize production efficiency within defined project constraints, both economic and environmental
- Maximize the use of existing disturbed areas (such as existing road corridors)
- Minimize disturbance to indigenous areas during oil field facility infrastructure and pipeline construction and operation
- Minimize effects to sensitive habitats, cultural resources, and related culturally sensitive areas
- Avoid existing villages and related structures
- Minimize possible effects from geologic hazards and constraints such as fault crossings, significant erosional features, and landslide prone areas.

Based on these general criteria, the following were among the alternatives identified and considered:

- Alternative oil development scenarios in Chad
- Alternatives to pipeline transport of produced crude oil
- Project transportation alternatives
- Alternative pipeline and facility sitings
- Deviated well clustering development
- Discharge of produced water to surface drainages
- The no project alternative
- The proposed project.

These alternatives, including the proposed project, are discussed in the following sections.

4.2 ALTERNATIVE OIL DEVELOPMENT SCENARIOS

Based on the exploratory program conducted to date in Chad, various scenarios for the development of oil discoveries were evaluated. These scenarios included:

- A small-scale development of only the lighter oils in the Doba and Doséo basins
- A moderate-scale development program to produce heavy and light crude oils from the Doba Basin
- A large-scale development program to produce the heavy and light crude oils of the Doba, Doséo, and Lake Chad basins.

It was determined, based on the interpretation of initial geophysical data and limited exploratory drilling, that an initial moderate-scale development program to produce heavy and light crude oils from the Doba Basin was the most economically feasible alternative. Therefore, this scenario is the current basis for the three-field Doba Basin development program considered as the project and described in detail in Section 3.0.

4.3 ALTERNATIVES TO PIPELINE TRANSPORT OF PRODUCED CRUDE OIL

Various oil export transportation alternatives have been considered. A 1985 feasibility study conducted by the Consortium to evaluate alternative transportation methods for exporting produced crude oil from Chad found that it would be possible to truck between 5 and 15 thousand barrels per day of oil (KBOD) from the Doba area in Chad to Ngaoundéré in Cameroon and then use the Cameroon railroad system to transport oil to the port of Douala for export by tanker. This alternative was not deemed feasible for the volumes of crude oil that the project is expected to generate (more than 15 KBOD). An update to this study performed in 1994 confirmed that trucking crude oil directly to Douala (i.e., no rail transport) was neither economically attractive, nor feasible above 15 KBOD.

Another transportation option considered was oil transport by river routes. This option was found to be impractical for several reasons, the most important being an inability to handle large volumes of oil, as well as navigability limitations, especially during the dry season. An additional transportation option was evaluated: the transportation of oil by pipeline to Ngaoundéré in Cameroon and then by rail to Douala. This option was limited to only 45 KBOD due to rail constraints and was, therefore, considered not to be feasible.

For the above reasons it was determined that the only feasible oil transport alternative to export the volumes of oil necessary to maintain the project's economic viability is to construct a pipeline transportation system from the Doba Basin directly to the Cameroon coast for subsequent export by tanker, as discussed in Section 3.0.

4.4 PROJECT TRANSPORTATION ALTERNATIVES

The extensive and complex transportation needs of the project (for both construction and operations) have been the subject of detailed evaluation, including an assessment of the following transportation infrastructure elements for the project as a whole (i.e., for both Chad and Cameroon):

- Air transportation
- Railways
- Roads and bridges
- Navigable waterways
- Ocean ports.

This assessment indicated that the project's transportation needs should be met by ocean shipping to one or more ports in Cameroon, combined rail/road transportation within Cameroon and for shipments to Chad, and limited air freighting.

A variety of road and rail route alternatives were then evaluated, which would lead to various road infrastructure alternatives in Chad (Figure 4-1):

- The existing main freight road from Cameroon to southern Chad

  This route, which crosses the border near Léré, provides road access from the railhead of the Cameroon rail system at Ngaoundéré to the Komé area via Moundou. A total of about 440 km of roads would require upgrading and maintenance in Chad (340 km between the Chad-Cameroon border and Moundou, and 100 km between Moundou and Komé), together with 395 km of roads in Cameroon.

- The proposed "Cotton Road" development

  This alternative consists of the upgrading of existing roads from Ngaoundéré via Touboro in Cameroon (most of which are maintained by the Cameroon cotton company SODECOTON) and a proposed major new bridge over the Logone River, to Moundou. This proposed development was investigated as a potential joint project with the European Development Fund (EDF), that would involve upgrading approximately 240 km of road from the border to Komé (140 km to Moundou, and a further 100 km from Moundou to Komé) together with about 350 km of road in Cameroon.

- Upgrading of existing roads in Cameroon and Chad close to the pipeline alignment

  This alternative utilizes the road from the railway at Ngaoundal, via Belel and Mbai Mboum (all in Cameroon) to a new crossing of the Mbéré River, and then by existing roads and tracks to Komé. A total of 170 km of road in Chad would require upgrading and maintenance, together with 440 km in Cameroon.

The existing main freight road alternative would involve the upgrade and maintenance of the greatest amount of road, upgrading of the Mayo Kebbi bridge at Léré, and would be constrained by the need to use the existing narrow bridge over the Logone at Moundou, and would therefore not be cost effective. In addition, the substantial distance of the existing main road from the pipeline alignment would require a significant amount of additional road upgrading and maintenance to support pipeline construction, resulting in more environmental impacts than the preferred alternative. This route was used to support exploration activities as the scale of those activities did not warrant substantial investments in infrastructure.

The "Cotton Road" alternative would require less road upgrading and maintenance in Chad than the existing main freight road alternative, but considerably more than the preferred alternative. This alternative was also found to be infeasible as a cooperative venture because of differences between the project and the EDF on financing and design issues. The "Cotton Road" alternative would involve more stream and river crossings than the other alternatives, and would also have more environmental impacts than the preferred alternative because of the need to upgrade and maintain significant lengths of other roads to support pipeline construction.

The alternative of upgrading existing routes close to the pipeline alignment results in the shortest length of roads requiring upgrading and maintenance in Chad. (While a greater length of roads is involved in Cameroon than is the case for the other alternatives, this is more than offset by the fact that 135 km of the extra distance involves an existing sealed road, and the proposed use of a railyard at Ngaoundal requires 110 km less railway haulage than does a railyard at Ngaoundéré). This alternative provides the shortest route to Komé, and provides the best access to the pipeline route for both construction and operations.

The alternative of upgrading and maintaining existing roads and tracks close to the pipeline alignment is the preferred alternative because it is the most cost effective. The preferred alternative would also involve the fewest river crossings and bridges or drainage structures. As it involves the least total road distance in Chad of the various alternatives, and will minimize the need to upgrade and maintain additional roads for pipeline construction purposes it is also judged to be environmentally preferred.

4.5 ALTERNATIVE PIPELINE AND FACILITY SITINGS

Although the physical location of the Komé, Miandoum, and Bolobo fields in the Doba Basin generally dictate the location of field facilities, a variety of alternative facility sitings were evaluated from a technical, environmental, socioeconomic, and economic basis. The environmental criteria for the field facility sitings and pipeline corridor and its final alignment are summarized below.

4.5.1 Introduction

In order to meet the objective of the Chad Export Project to produce, treat, and export crude oil from the Doba Basin to world markets, a pipeline is required to transport the oil from Chad to a marine terminal, from where it can be carried to market by sea-going tankers. As Chad is landlocked, any export route would necessitate traversing at least one other country in order to reach a coastline. From the Doba area the most direct route to a coastal site is via Cameroon (see Figure 2-1). Alternative routes through any other countries would be longer, and therefore more costly. Other routes involving more than two countries would also be longer, and would require more complex negotiations between three or more sovereign countries. Routing from the Doba area in southern Chad through Cameroon to a marine terminal site on the Cameroon coast in the Gulf of Guinea was therefore assessed to be the preferred alternative for export of Doba Basin crude oil.

Various alternative facility sites and pipeline routes through Chad and Cameroon have been evaluated in a continuing process that entails desktop studies followed by ground truthing in the field. These evaluations were conducted to incorporate both engineering and environmental inputs.

The first siting study was undertaken to fix the end point of the pipeline on the Cameroon coast (the location of the other end of the pipeline is relatively inflexible, as it must be located in the oil field development area). This study reviewed prospective marine terminal locations and determined that two locations, in the vicinity of Kribi and Limbé, were acceptable (GIE, 1993). A number of pipeline corridors terminating at the two possible marine terminal locations were then evaluated, and as the marine terminal locations themselves were assessed as being equally acceptable on engineering, economic, and environmental grounds, the terminal location corresponding to the most acceptable pipeline corridor was selected (see Section 4.5.2).

With the pipeline corridor and marine terminal location determined, additional studies were then performed to optimize the pipeline route within the selected corridor (see Section 4.5.3), including surveying a topographic profile along the corridor. This in turn allowed for an evaluation of fixed facility (i.e., pump stations and the pressure reducing station) requirements, principally location and size, and the notional locations of these surface facilities were then studied to ensure their engineering, economic, and environmental acceptability (see Section 4.6).

This process of refinement of pipeline routing and facility siting will continue throughout project development.

4.5.2 Pipeline Corridors

Based on a detailed evaluation of topographic features, demographic profiles, and environmental factors, three potential pipeline corridors were identified. A corridor was defined as a continuous strip of land starting at the production facilities in Chad, traversing Chad and Cameroon, and terminating on the Cameroon coast where a terminal site would be located in the vicinity of Limbé or Kribi. The corridor width was generally 30 km but could be as wide or narrow as necessary to generally define a pipeline route, depending upon terrain conditions and restrictions.

The operational criteria and considerations used to establish the three corridors included:

- Corridors should be as short as practicable to minimize material, land easement, and construction costs
- Corridors should avoid traversing mountainous areas because of the extra pumping horsepower (more pump stations or larger pumps) required to operate the pipeline and additional difficulties in pipeline construction
- Existing access within corridors, by road or other means, should be available for transporting construction materials and equipment and conducting pipeline inspection, maintenance, and repair
- Corridors must terminate near one of two potential export terminal sites (Limbé or Kribi).

Additional environmental, socioeconomic, and cultural criteria for evaluating these corridors were established using information presented in the *World Bank Sectoral Guidelines for Oil and Gas Pipelines* (1991a). Based on these guidelines, specific environmental criteria that were considered included avoiding, where feasible:

- Areas of high priority for protection or exclusion by the Chad or Cameroon governments and the World Bank
- Villages, neighboring gardens, and forests with high levels of traditional use
- Parks, reserves, and other areas of importance
- Areas settled by indigenous peoples defined by World Bank policy (Operational Directive 4.20) as leading traditional lifestyles
- Terrain with high agricultural land use or potential for future development
- Indurated lateritic soils and saline and waterlogged soil areas
- Zones with dense, relatively undisturbed vegetation
- Known archaeological sites, historical areas, or sites of geological, biological, or tourist interest
- Known areas of high biodiversity

- Known areas of threatened and endangered flora and fauna.

The three corridors selected (Corridors A, B, and C) for evaluation and field investigation are shown in Figure 4-2. The common corridor to the north of the project area, in both Chad and northern Cameroon, resulted from significant routing restrictions imposed by terrain, drainage channels, and international borders.

Following field investigations to confirm the viability of the three selected corridors and collect pertinent data, the corridors were evaluated by:

- Comparing the environmental and socioeconomic conditions of each corridor
- Reviewing the suitability of the two alternative terminal location areas
- Comparing estimated capital and operating costs.

Environmental evaluation of the three corridors was based on terrain unit mapping which covered a 30 km wide strip for each corridor. The terrain unit mapping and other pertinent data have been captured in a project Geographic Information System (GIS) which has allowed quantitative comparisons to be made when evaluating route and siting alternatives. Key terrain unit data for the three corridors are shown on Figure 4-2 and more detailed terrain unit mapping for the pipeline corridor in Chad is presented in Section 6.0.

Each rated element (i.e., environmental impacts, socioeconomic and cultural impacts, suitable terminal site, capital and operating costs) was compared by assigning suitability ratings to the three alternative corridors and two potential terminal site locations. Tables 4-1 and 4-2 present comparative suitability relative to the proposed corridors and terminal site locations, and Table 4-3 presents capital cost comparisons for the three corridors, with the least capital cost alternative (Corridor B) used as the base case. Based on a comparative evaluation of these rated elements, Corridor B, with a terminal site in the vicinity of Kribi, was selected as the recommended corridor for the pipeline. It was assessed to be the most economical, technically acceptable, and environmentally preferred corridor option, as further described below and as illustrated in Table 4-1:

- Corridor B was preferred from an environmental and socioeconomic perspective. Corridor A includes more undisturbed forests, and Corridor C includes more extensive swamps. Corridors B and C offered more options to avoid potential adverse socioeconomic issues than Corridor A, which passes in proximity to densely populated urban areas around Mt. Cameroon.

- Project costs were estimated to be lowest for Corridor B due to the least difficult construction conditions and the lowest requirement for infrastructure upgrades (as shown in Table 4-3). Corridor A, although the shortest in length, had the highest estimated construction and infrastructure costs because of the more isolated and rugged terrain. Corridor C, similar in cost to Corridor A, was more costly than Corridor B due mostly to the extensive lengths of swamp, for which mitigative designs and special construction techniques would be required, and the requirement for more infrastructure upgrades.

- The two potential terminal sites, Kribi and Limbé, both were deemed satisfactory for locating a marine terminal. Each site had some distinct advantages over the other (as shown in Table 4-2). Either location was acceptable; however, Kribi was chosen as a result of the selection of pipeline Corridor B.
- Hydraulic calculations indicated that each corridor would require similar pump station and terminal facilities, although there were some minor differences in pump horsepower requirements. The small differences in pipeline length among the corridors was not significant from a hydraulic perspective.
- Based on the similarities in the systems required for each alternative corridor, facility requirements and operating costs would be approximately equal.

4.5.3 Additional Routing Studies

Once Corridor B was selected as the most suitable, additional analyses were conducted to identify the preferred pipeline alignment and pump station locations within the corridor. The following criteria were identified as preferential for route selection and pump station location within the corridor:

- Existing road and railroad easements or areas already cleared
- Nearby existing infrastructure including electricity, water supply, towns, medical facilities, communications, and airstrips
- Siting that meets the development objectives of the Chad and Cameroon governments and the World Bank
- Relatively flat areas where a permanently cleared land easement does not leave an obvious visual impact likely to attract settlers, hunters, and travelers who might use the land easement
- Areas where land tenure and ownership is clear, and compensation and mitigation measures are realistic, implementable, and achievable.

Subsequently, a set of human, biological, and physical considerations was evaluated to determine the most economic, technically and environmentally acceptable pipeline alignment within this 30 km corridor and the location of fixed project facilities (principally the pump stations and the pressure reducing station).

Human considerations included:

- Sensitive land uses
- Traditional or high value land
- Sensitive traditional tribal communities
- Areas of cultural importance
- Designated areas of high priority for protection or exclusion
- Areas with significant ethnic and other cultural factors, in addition to those listed above.

Biological considerations included:

- Sensitive environmental habitats
- Primary forest reserves
- Rare and endangered species
- Biodiversity
- Cleared areas.

Physical considerations included:

- Stability and erodibility of soils
- Quality of soils to be used for agricultural purposes or as construction materials
- Damage to surface water resources and flooding due to diversion of natural drainage patterns
- Potential for contamination of groundwater resources
- Seismic and volcanic hazards.

Examples of route optimization in Chad include re-routes to minimize intersections with areas mapped as "Savanna Zones - Relatively Undisturbed" in the section of the pipeline alignment between Komé and Bessao, and around prominent hills in the region south of Baibokoum (Dames & Moore, 1995a). In the Komé - Bessao area a preliminary routing of the pipeline over a distance of 104 km included total intersections of 40 km with savanna mapped as relatively undisturbed. The route was optimized to reduce the overall length to 99 km and the intersections with relatively undisturbed savanna to approximately 10 km. Re-routing to the south and east of a prominent hill near Baibokoum has resulted in the route traversing an area of savanna mapped as disturbed, eliminating approximately 12 km of intersection of the previous route with areas to the north and west of the hill that are mapped as relatively undisturbed.

As was the case with the earlier corridor study, the further route evaluations were undertaken by combined engineering and environmental teams. Evaluations involved acquisition and interpretation of new, more detailed data, such as aerial photography at a scale of 1:30,000, to supplement the terrain unit mapping at 1:200,000 scale, and field surveys. In addition, field work and other studies performed specifically for purposes of this EA were integrated into the evolving route and site evaluation process. Further input to the route and site evaluation process will result from a pipeline centerline survey that is designed to provide project planners with site-specific engineering and environmental data along the pipeline route. The currently selected route and facility sitings are indicated in Section 3.0. Some flexibility exists to accommodate minor modifications should these be warranted as detailed design of the project progresses.

4.5.4 Alternative Facility Sitings

The specific locations for each of the major field components (i.e., gathering stations, Operations Center, field flowlines, utility corridors, airfields, etc.) were selected and configured in a cost-effective manner that optimizes technical efficiencies while considering potential impacts to the local human, biological, and physical environments. Specifically, the individual field facilities (with the exception of the well sites) have been sited to avoid, to the extent feasible, the following:

- Existing living space and areas of dense population
- Water resources, including existing wetlands and drainages in the field areas
- Known transhumant movement corridors
- Areas of vegetation with high conservation value
- Active agricultural areas.

In addition, acceptable balances have been sought between protecting areas of higher conservation value, areas of fallow agricultural land that provide a variety of resources for the local population, and actively worked agricultural land.

As a result of these considerations, the overall field development facilities design and configuration was developed as described in Section 3.0.

4.6 WELL CLUSTERING DEVELOPMENT

Alternative well configurations and layouts have been assessed, including the use of vertical and deviated wells. Under this alternative, deviated wells and/or a combination of deviated wells, vertical wells, and extended reach wells would be drilled to produce formation fluids from each of the three fields. This alternative would enable each well pad to accommodate "clusters" of wells (i.e., three or more wells from the same well pad), thus reducing the overall number of well pads to be constructed, along with a proportional reduction in well pad access roads, gathering system pipelines, and utility corridors in each of the three fields. Clusters of 3, 9, 15, and 21 wells were evaluated.

Although this alternative would reduce some land requirements as a result of consolidation of facilities, it presents significant technological difficulties that would increase technical uncertainties and capital costs and currently render this alternative economically unattractive. The relatively shallow reservoir depths of approximately 1,158 to 1,950 m coupled with the unconsolidated nature of the upper sand formations, present significant technological difficulties during the drilling and completion of deviated-drilled wells in this region. The unconsolidated nature of the sand formations above the producing horizons is such that they have a tendency to collapse during deviated well drilling when using currently available water-based drilling muds, thus jeopardizing hole integrity. Specialized muds (oil base or equivalent) and additional casing strings would be required to maintain hole integrity. Additionally, the mechanical process of deviating the well from the vertical position is not guaranteed at this time due to the hole washing out. Specialized muds and their associated cuttings are also more difficult to treat and properly dispose of than water-based muds and cuttings.

For these reasons the vertical well alternative with some extended reach wells is the current base scenario for the three field development. New technologies will continue to be reviewed to assess whether deviated well drilling becomes feasible in the future.

4.7 DISCHARGE OF PRODUCED WATER TO SURFACE DRAINAGES

Discharge of produced water to surface drainages would involve produced water being treated and then discharged to existing surface drainages. The major surface drainage features of the Doba Basin include the Pendé River (or Logone Oriental) and its tributaries, and the Loulé and Nya rivers, which drain from the west. The Pendé traverses the Doba Basin from south to north.

As discussed in more detail in Section 3.0, it is anticipated that the envisioned drilling and production program would, during peak water production, produce approximately 900,000 barrels of water per day at higher than ambient temperatures. Over its estimated 30 year life, the proposed project would produce approximately 7.5 billion total barrels of produced water. Based on this large volume of water, a variety of environmental, technical, and economic considerations were evaluated relative to the treatment and ultimate disposal of this water. These considerations included the following:

- Produced water would have to undergo a rigorous, and thus costly, treatment program in order to meet stringent water quality standards if discharged to surface drainages (i.e., due to the high volume of produced water relative to the volume of existing surface drainages). If discharges to surface water did not meet these standards, the volume of produced water could substantially alter receiving water composition to the extent that it could be harmful for human or plant/animal consumption, particularly as there is some usage of surface waters for potable supplies without prior use of purification facilities/systems.

- Surface discharge would require a significantly more complex and involved long-term water quality monitoring and equipment maintenance program.

- The discharge of large volumes of produced water to existing surface drainages would change nutrient, suspended solid, and other concentrations in the existing drainages, which would alter the existing ecological balance of the drainage systems. The water production would cease with the cessation of oil production. Any dependency or changes that occur over the life of the project from the discharge of produced water would no longer be supported.

- Surface discharge would increase drainage flows and cause alterations of river stage (differing during the wet and dry seasons), which could have adverse effects on drainage channel erosion, vegetation and habitat, access, and crossings.

Based on the above considerations it was concluded that this alternative would have the potential to cause significant adverse impacts to the human, biological, and physical environment. In addition, this alternative presents a variety of complex and challenging technical issues that are costly and jeopardize the economic feasibility of the project.

Conversely, the alternative of reinjecting produced water could reduce the quality of subsurface water bodies if not designed properly. However, a variety of design measures are available and will be implemented as part of this project to address this issue (e.g., corrosion prevention measures and tubing by casing isolation packers to protect shallow groundwater aquifers, and use of selected chemical additives at sufficiently low levels of concentration to protect deep groundwater aquifers).

Therefore, subsurface disposal is the selected alternative for this project, and produced water will be reinjected and returned to the producing horizon. The impacts and mitigations associated with this alternative are discussed in Sections 7.4 and 8.4.

4.8 THE NO PROJECT ALTERNATIVE

Under the no project alternative, the project area (oil field development area) would eventually return to pre-exploration environmental conditions. The environmental degradation of the project area that is resulting from increasing population pressure would continue. Potential adverse impacts on the human, biological, and physical environments resulting from project development would not occur. However, the potential beneficial impacts realized as a result of project implementation (i.e., increase in local jobs, increased revenues to the Chad government, new and improved infrastructure requirements, etc.) likewise would not be realized. As the project has been shown to be of net benefit to Chad, the no project alternative would be detrimental to the country.

4.9 THE PROPOSED PROJECT ALTERNATIVE

The proposed project was chosen because it was determined that it best satisfies the general development criteria described in Section 4.1. The project also was determined to best balance overall impacts to the human, biological, and physical environment while achieving the overall purpose of the project, which is to produce and export oil from the Komé, Miandoum, and

Bolobo fields in the Doba Basin to world markets through an environmentally conscious and economically viable program.

TABLE 4-1
CORRIDOR SUITABILITY IN BIOLOGICAL, PHYSICAL, AND SOCIOECONOMIC TERMS

CORRIDOR	FACTOR			COMPARATIVE OVERALL SUITABILITY
	BIOLOGICAL ENVIRONMENT	PHYSICAL ENVIRONMENT	SOCIOECONOMIC ENVIRONMENT	
A	M	L	L	L
B	H	H	M	H
C	L	M	M	M

Source: GIE/Dames & Moore, 1993.

Note:
H: High Suitability
M: Moderate Suitability
L: Low Suitability

TABLE 4-2
TERMINAL SITE ALTERNATIVE ANALYSIS

FACTOR	KRIBI	LIMBÉ
Land Availability	1	2
Suitable Elevation	1	1
Onshore Access	1	2
Nearby Onshore Services	2	1
Offshore Access	1	2
Environmentally Sensitive Areas	1	1
Weather Conditions	1	1
Support Vessel Berthing	1	1

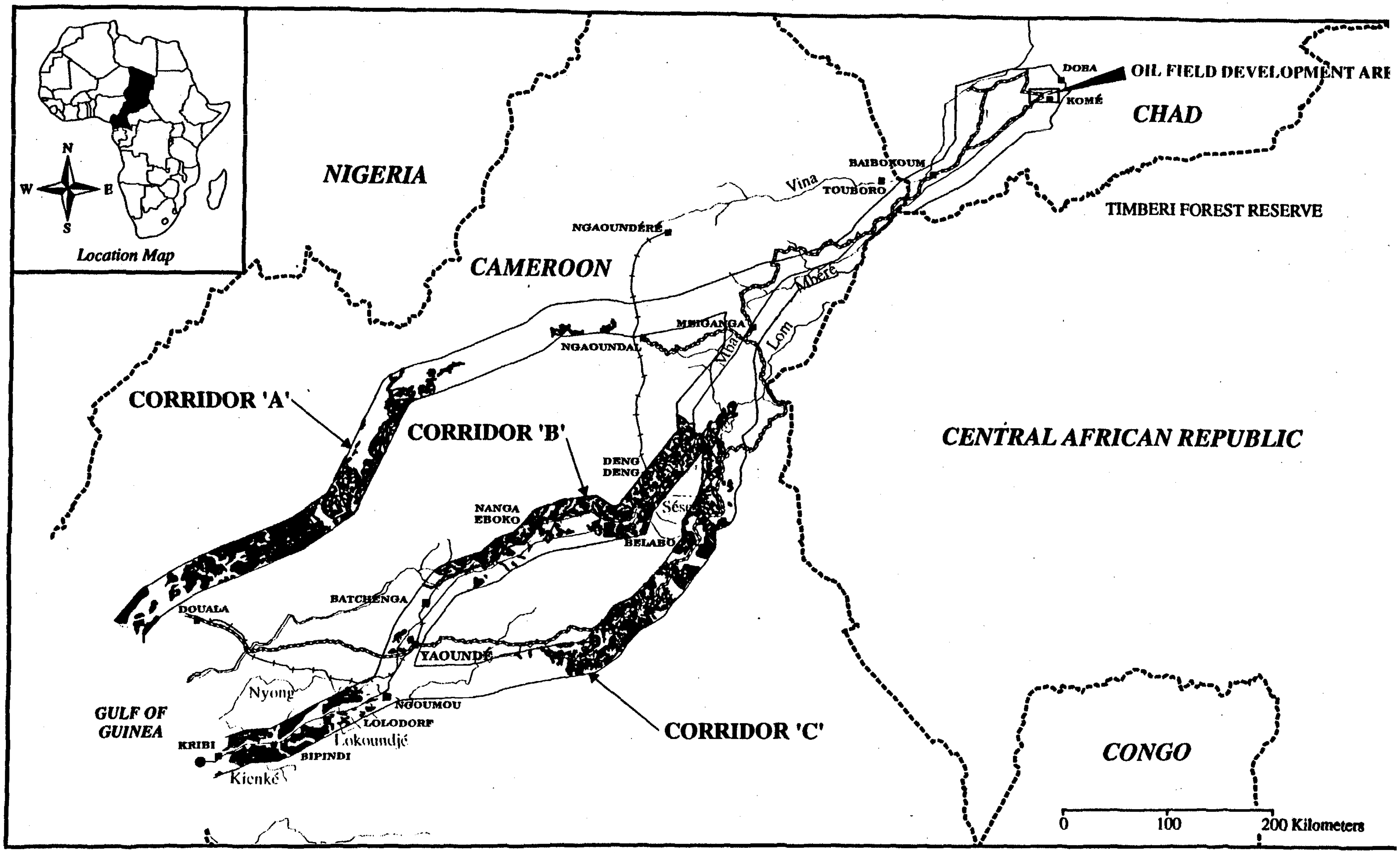
Source: GIE/Dames & Moore, 1993.

Note:
1: More preferred
2: Less preferred

TABLE 4-3
CORRIDOR CAPITAL COST COMPARISON

COST ITEM	ROUTE B (BASE CASE)	ROUTE A (% ROUTE B)	ROUTE C (% ROUTE B)
Pipeline			
Materials	100	94.8	103.6
Construction	100	115.8	108.7
Technical Services	100	100.0	100.0
Pump Stations			
Materials and Equipment	100	100.0	100.0
Construction	100	100.0	100.0
Technical Services	100	100.0	100.0
Marine Terminal			
Materials and Equipment	100	100.0	100.0
Construction	100	100.0	100.0
Engineering/Construction Management	100	100.0	100.0
Infrastructure	100	130.4	114.5
SCADA and Communications	100	100.0	100.0
TOTAL	**100**	**105.8**	**105.0**

Source: GIE/Dames & Moore, 1993.



LEGEND

- Oil Field Development Area
- Pipeline
- International Boundaries
- Rivers / Streams
- Major Roads (In Study Area)
- Railroad
- Marine Terminal (FSO)
- Undisturbed Evergreen Forest
- Undisturbed Semideciduous Forest
- Swamps

Esso

ESSO Exploration and Production Chad Inc.

PIPELINE TRANSPORTATION SYSTEM CORRIDOR COMPARISON

DAMES & MOORE

FIGURE 4.

5.0 LEGISLATIVE, REGULATORY, AND POLICY CONSIDERATIONS

5.1 INTRODUCTION

The project will be developed and operated pursuant to the Consortium Convention, the TOTCO Convention, and all applicable laws and regulations. The project also will be developed in compliance with various international treaties and World Bank guidelines. Where no appropriate legislation, regulations, or guidelines exist, the project would adopt international industry standards.

The purpose of a legislative and regulatory review is to summarize policy considerations that may apply to the project. Both Chad and World Bank regulations and guidelines have been reviewed. These regulations and guidelines are described below along with a description of their relevance to the project.

In addition, international treaties, agreements, and conventions on environmental and natural resources have been reviewed as they relate to the construction and operation of this project in Chad. Relevant conventions that Chad is signatory to are listed in Table 5-1.

5.2 CHAD LEGISLATION

The Chadian legislative and regulatory system is based on the Napoleonic Code and, in descending hierarchial order, consists of:

- The Constitution
- International treaties, conventions, and agreements that are signed by the Government and ratified into law
- Laws that are voted by the National Assembly and signed by the President
- Ordinances that under the previous constitution were signed by the President and had to be ratified into law at the earliest opportunity (not addressed in the current Constitution)
- Decrees that are issued by the Government (Prime Minister) and prescribe the means to achieve general objectives of the laws
- "Arrêtés" that are issued by the Ministers in the matters under their competence and provide specific guidelines for implementing laws and decrees.

In addition, the Government occasionally issues Manifests that have no legislative value but that define the policies and general objectives of the Government.

Chadian regulations that apply to the project have been grouped in the general categories of environmental protection, land tenure, and other relevant legislation (oil and natural gas exploration, production, and transportation) for this review.

5.2.1 Environmental Protection

The major legislation addressing environmental protection in Chad is the Forest Code, adopted by the Chad government (Tchad, 1989a). The Forest Code addresses the protection, conservation, enhancement, and exploitation of forests, botanical resources, terrestrial fauna, aquatic resources, and fisheries. The Forest Code also identifies plant and animal species protected under Chadian law. According to the legislation, the felling of trees is subject to authorization by the state. The project would impact forest (savanna), fauna, and fish resources during construction and operation. The impacts are described in Section 7.3 of this Environmental Assessment (EA).

In August 1976, the Chadian Conseil Supérieur Militaire issued a manifest for the Conservation of Chad's Natural Heritage, which includes air, water, forest, floral, and faunal resources. This manifest commits the Government of Chad to:

- Promote legislation and the creation of administrative bodies to encourage incorporation of ecological principles in planning and economic development
- Promote environmental education at all levels
- Conserve and manage national parks, faunal reserves, forests, and other natural reserves and open spaces representative of all varieties of natural resources of the country
- Protect plant and animal species in danger of extinction
- Combat the destruction or degradation of natural resources and prevent the pollution of air, water, and soil resources
- Support the efforts of companies to promote conservation by any means possible.

Ordinance No. 20, issued in August 1988, implements the Ramsar Convention of 1971 and subsequent amendments of the Paris Protocol of 1982, relating to the Conservation of Humid Zones and Aquatic Bird Habitats of International Importance. Ordinance No. 22 was also issued in August 1988 to implement the 1983 Accord of Central African States for the Conservation of Wildlife. The Ministry of Foreign Affairs, the Ministry of Tourism and Environment, and the Ministry of Finances and Information executed these ordinances. The project's biological impacts are described in Section 7.3 of this EA.

A National Technical Committee in charge of developing, monitoring, and supervising the execution of the Environmental Management Plan of the oil projects in Chad (CTNSC) has been created under the supervision of the Minister of the Environment. This committee shall develop the Environmental Management Plan and any other documents regarding environmental impacts. It shall monitor and supervise the execution of the Environmental Management Plan of all oil projects in Chad, particularly the socioeconomic, health, and ecological aspects, and the implementation of mitigating measures for such impacts, particularly compensation, damages, indemnification, and resettlement of affected populations. It shall also be in charge of protecting against accidents and disasters.

Arrêté No. 100 was issued by the Ministry of Agriculture and Environment in January 1995 to create an interdisciplinary work group to prepare Chad's *Project for the Management of Natural Resources*. The interdisciplinary work group has been charged to evaluate, under internal audit, the capacity of public services to follow, evaluate, administer, and reposition the project management operations of natural resources.

Decree No. 407, signed in December 1977 and issued by the Presidence du Conseil Supérieur Militaire in December 1977, modifies the scope of the Commission on Protection of Lake Chad. Some surface water runoff and water discharges from the project drain to rivers which eventually drain to Lake Chad. Potential water quality impacts are described in Section 7.4.

5.2.2 Land Tenure

Several laws issued in July 1967 address specific land tenure in Chad.

Law No. 23 defines public property of the state as natural or artificial, which includes lakes, rivers, groundwater, mineral springs, cultural artifacts, infrastructure, and the national defense system. A leasing contract on public property of the state is subject to all laws including property taxes, liens, and real estate taxes. Contract leases are good for 10 years and are renewable. On private property of the state or privately owned land, a leasing contract can be signed for up to 30 years. If negative impacts occur, the owner can sue for damages. On private property of the state, the project proponent is liable if negative impacts occur. The project would obtain rights-of-occupation for proposed facilities.

Law No. 24 defines the rules for the registration of private land. Public property of the state is not subject to registration. No foreign individual(s) can acquire registered property except on the authorization of the Minister of Finance. The project would require government authorization for land use.

Law No. 25 defines the rules for expropriation of land by the Minister of Finance in cases that benefit the general public, such as public utility work. Expropriation can occur on vacant and rural land as well. The law is relevant, as the Minister of Finance may expropriate land for the project.

Decrees No. 186, 187, and 188, issued in August 1967, are relevant because they provide the protocol for implementing Laws No. 24, 25, and 23, respectively.

5.2.3 Other Relevant Legislation

Ordinance No. 7 issued in February 1962 provides regulations and guidelines for oil and natural gas exploration, production, and transport. The titles of Ordinance No. 7 are outlined below:

- Title I discusses exploration of liquid hydrocarbon and natural gas beds.
- Title II discusses exploitation of liquid hydrocarbons and natural gas beds.
- Title III provides the specification for transportation of liquid hydrocarbon and natural gas by pipeline.
- Title IV discusses the rights ancillary to research and exploitation of liquid hydrocarbon and natural gas beds.
- Title V discusses financial and fiscal arrangements.
- Title VI discusses violations and penalties.
- Title VII discusses miscellaneous provisions.

The ordinance is relevant. The Operator would be exploring, and continuing to explore, for crude oil. The crude oil would then be transported by pipeline from Chad to the coast of Cameroon.

5.3 WORLD BANK REGULATIONS AND GUIDELINES

5.3.1 World Bank Group Environmental Review Procedure

The project is classified as a Category A project under both the World Bank and IFC environmental review procedures since it is a project that has the potential for diverse and significant environmental impacts. As such, the project sponsor is required to prepare a detailed EA for the project.

Key environmental issues associated with this type of project that must be addressed in the EA are discussed in three subsections of the World Bank's *Environmental Assessment Sourcebook* entitled "Energy and Industry" (Volume III, Chapter 10: Electric Power Transmission Systems; Oil and Gas Pipelines; Oil and Gas Development - Onshore). The EA also must evaluate the project's compliance with appropriate World Bank guidelines, including:

- Environmental Assessment Sourcebook (1991a) and updates (1993)
- Operational Directive 4.01 (Environmental Assessment) (1991b)
- Operational Directive 4.20 (Indigenous Peoples) (1991c)
- Operational Directive 4.30 (Involuntary Resettlement) (1990a)

- Operational Policy Note 11.02 (Wildlands) (1986)[1]
- Technical Paper No. 55 (Techniques for Assessing Industrial Hazards: A Manual) (1988a)
- Technical Paper No. 80 (Involuntary Resettlement in Development Projects) (1988b)
- The Forest Sector: A World Bank Policy Paper (1991d)
- Environmental Analysis and Review of Projects (IFC, 1993).

5.3.2 World Bank Environmental Policies and Guidelines

5.3.2.1 World Bank Environmental and Occupational Health and Safety Guidelines

World Bank policy requires that projects must be consistent with all relevant World Bank environmental and occupational health and safety guidelines. Guidelines exist for onshore oil and gas development and engine driven power plants. These guidelines address topics such as liquid effluents, ambient air, and stack emissions. These topics are discussed in more detail in Sections 5.3.2.7 and 5.3.2.8 of this EA. Environmental guidelines specific to oil pipelines are also provided by the World Bank. These guidelines relate to design of the pipeline including positive pipe corrosion control measures and programs for periodic inspection and maintenance. Guidelines for onshore oil and gas developments have been applied to the project. These guidelines are included in Appendix A. Project design measures have been incorporated into the project in response to these guidelines as discussed in Section 3.0.

Other World Bank Environmental and Occupational Health and Safety guidelines that are relevant to the project are workplace air quality, workplace noise, work in confined spaces, hazardous materials handling and storage, general health and safety, and recordkeeping and reporting (Appendix A). These guidelines have been incorporated into the design of the project's overall health and safety program (see Section 3.2).

5.3.2.2 World Bank Forest Policy

All relevant projects financed by the World Bank must conform with the spirit and intent of the World Bank Forest Policy Paper (World Bank, 1991d) and adhere to its principles. The Bank will finance sponsors who commit to follow World Bank guidelines and internationally accepted practices aimed at preserving existing tropical forests. The World Bank will finance the reforestation of degraded land in connection with industrial projects and will encourage the optimal use of wood resources by supporting secondary industries where the raw material is a waste product of other industrial operations.

The project has undergone review for consistency with the World Bank Forest Policy. Facilities and associated infrastructure for the project would be located in wooded savanna habitat and would not impact tropical moist forests. In addition, the project has been sited within existing degraded areas to the maximum extent possible to minimize impacts.

[1] Superseded by Operational Policy 4.04 (Natural Habitats) (1995)

World Bank Forest Policy also cites qualifications for financing to include, ". . . measures intended to secure benefits that will accrue partly or entirely outside the country . . ." (Examples are measures to preserve biological diversity of forests).

The World Bank has two policies directly relevant to biological diversity: preservation of endangered species and critical habitats and conservation and management of wildlands. The Bank's wildlands strategy includes the preservation of sufficient amounts of representative wildlands and protecting or managing them to sustain their viability as plant and animal habitat.

A number of measures recommended by the World Bank have been incorporated into project design, including:

- Avoiding impacts to wooded savanna and other sensitive habitats in the project's study area through construction of facilities and associated infrastructure within existing degraded areas to the extent possible
- Providing buffer zones at stream crossings to minimize impacts to remnant gallery forests.

5.3.2.3 World Bank Policy on Social Issues

Development projects are intended to modify social and natural environments to create or enhance economic, health, educational, and other benefits that are valued by society. Chapter 3 *(Social and Cultural Issues in Environmental Review)* of the *World Bank Environmental Sourcebook* (World Bank, 1991a) makes it clear that the social analysis of a project is not expected to be a complete sociological study nor a social cost/benefit analysis of the project. It should, however, identify social changes, evaluate the social costs of long-term operation of the project, and formulate strategies to achieve desired regional objectives. Specific social issues of concern to the World Bank include:

- Variation within communities in terms of ethnic/tribal groups, occupational groups, socioeconomic stratification, and age and gender
- Control over local resources
- Variation within production systems
- Consultation and participation of government agencies, NGOs active in the study area, and affected communities (Operational Directives 4.01 and 14.70, and environmental review procedures)
- Indigenous peoples (Operational Directive 4.20)
- Cultural property including sites, structures, and remains of archaeological, historical, religious, cultural, or aesthetic value (Environmental Assessment Sourcebook Update-Cultural Heritage in Environmental Assessment [September 1994])

- Involuntary resettlement (Operational Directive 4.30)
- Secondary or induced growth and development within the study area.

Impacts to the human environment resulting from the project are addressed in Section 7.2 of this EA.

5.3.2.4 World Bank Policy on Economic Analysis

Given the existing scarcities of financial and human resources in developing countries, the World Bank considers it important to invest limited resources to maximize economic benefits. Sound economic analysis of projects and policies is an important means of making the allocation process more efficient and systematically evaluating choices between competing uses of resources.

As opposed to a purely financial analysis, an economic analysis measures a project's effect on the efficiency and development of the affected regional economy. The World Bank, however, understands the difficulty of measuring environmental impacts of a project in environmental terms and subsequently valuing these impacts in monetary terms. The main purpose of an economic analysis is to ascertain whether the project can be expected to create more net benefits than any other mutually exclusive option, including a "no project" alternative.

Incorporation of the effects of environmental degradation into public decision making is an essential step toward achieving economically efficient management of natural resources. An economic analysis can help identify investments that contribute most to overall regional objectives. An economic analysis has been prepared as part of the project (Section 7.1.1).

5.3.2.5 World Bank Policy on Interagency Coordination

The World Bank indicates that, "Because environmental issues generally involve national, provincial, and local government agencies and cover a broad range of responsibilities, coordination among government agencies is crucial." (Paragraph 18 of the World Bank Operational Directive 4.01 - Environmental Assessment). Coordination of the project is being achieved through a series of meetings with government agencies to identify issues, types of analyses required, sources of relevant expertise, EA responsibilities and schedule, mitigation measures, and other recommendations (described in Section 9.0).

5.3.2.6 World Bank Policy on Community Involvement

The World Bank expects the borrower to consider views of affected groups and local NGOs in project design and implementation and in the preparation of EAs. The primary objective of consultation is to identify issues and concerns of affected groups and interested parties.

This EA is consistent with consultation requirements described in the *Environmental Assessment Sourcebook Update*, "Public Involvement in Environmental Assessment: Requirements, Opportunities and Issues" (World Bank, 1993), and the World Bank and IFC environmental review procedures. Consultation in preparation of the EA has taken the form of socioeconomic surveys of the study area and meetings with representatives of key sectoral government ministries and NGOs locally active in the study area (described in Section 9.0).

5.3.2.7 World Bank Policy on Air Quality

The World Bank has established air quality guidelines for governing both stack emissions and dispersed ground-level pollutant concentrations associated with various types of industrial developments; these guidelines vary according to the type of industrial development under consideration.

The applicable industrial operation for which the World Bank has established guidelines and which would be included in the project is *Onshore Oil and Gas Development* (World Bank, 1995a). Both air pollutant emission and ambient air pollutant concentration guideline values have been promulgated for this type of industrial operation. The application of emission guideline values depends upon the type of equipment used (e.g., boilers versus heaters). Table 5-2 summarizes current World Bank ambient air guidelines for particulate matter less than 10 microns in diameter (PM_{10}), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2), and stack emission limits for PM_{10}, SO_2, and NO_2. Section 7.6 describes potential air quality impacts of the project.

5.3.2.8 World Bank Policy on Water and Effluent Quality

The World Bank's liquid effluent guidelines for process wastewater, domestic sewage, and contaminated stormwater are included in Table 5-3. These data are abstracted from the World Bank's guidelines for onshore oil and gas development, which are included in Appendix A.

TABLE 5-1
CONVENTIONS TO
WHICH CHAD IS A PARTICIPANT

Date of Entry	Convention, Treaty, Agreement
11/10/60	Convention Concerning the Use of White Lead in Painting
05/22/64	Convention and Statute Relating to the Development of the Chad Basin (As Amended)
09/12/73	Convention Establishing a Permanent Inter-state Drought Control Committee for the Sahel
1976	Convention Regarding the Common Regulations on Fauna and Flora in the Chad Lake Basin
1979	Convention on the Conservation of Migratory Species of Wild Animals (with Appendices [amended 1985, 1988])
1986	Convention Regarding Coordination of the Activities in the Niger Basin
1988	Cooperation and Consultation Agreement Among the Central African Countries on the Conservation of Wildlife or Organization for the Conservation of African Wildlife (OCFSA), signed by Chad
02/02/89	Convention on International Trade in Endangered Species of Wild Fauna and Flora
05/18/89	Vienna Convention for the Protection of the Ozone Layer
11/28/89	Montreal Protocol on the Substances Impoverishing the Ozone Layer
06/13/90	Convention on Wetlands of International Importance Especially as Waterfowl Habitat
1992	The Hague Charter of Aid for the Environment
01/27/92	Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes Within Africa
06/12/92	United Nations Framework Convention on Climate Change
06/12/92	Convention on Biological Diversity
1994	International Convention on the Fight Against Desertification
1995	Convention on the Conservation of Migratory Species Belonging to Wildlife, named BONN Convention

Sources: Government of Chad
United Nations Environment Programme, 1993.

TABLE 5-2
WORLD BANK AIR QUALITY GUIDELINES

Pollutant Averaging Period	Onshore Oil and Gas Development
Ambient Air: Concentrations of contaminants measured outside the property boundary should not exceed the following limits:	
Particulate Matter (<10 μm diameter)	
Annual Arithmetic Mean	100 $\mu g/m^3$
Maximum 24-hour Average	500 $\mu g/m^3$
Nitrogen Oxides, as NO_2	
Annual Arithmetic Mean	100 $\mu g/m^3$
Maximum 24-hour Average	200 $\mu g/m^3$
Sulfur Dioxide	
Annual Arithmetic Mean	100 $\mu g/m^3$
Maximum 24-hour Average	500 $\mu g/m^3$
Stack Emissions: Pollutant emissions from facility stacks should not exceed the following emission limits:	
Particulate Matter	100 mg/m^3
Sulfur Dioxide	100 tpd
Nitrogen Oxides, as NO_2[1]	
Gaseous fossil fuel	90 g/million Btu of heat input
Liquid fossil fuel	135 g/million Btu of heat input

Source: World Bank, 1995a

[1]Applicable to oil-fired boilers and fixed heaters but not to diesel engines and gas turbines.
Btu = British thermal units
g = grams
$\mu g/m^3$ = micrograms per cubic meter
mg/m^3 = milligrams per cubic meter
tpd = tons per day

TABLE 5-3
WORLD BANK LIQUID EFFLUENT QUALITY GUIDELINES[1]

PARAMETER	SPECIFIED LIMITS
pH	6 to 9
BOD_5	50 mg/L
Oil and Grease	20 mg/L
Heavy Metals, Total (except Barium)	10 mg/L
Phenolic Compounds	100 mg/L
Total Suspended Solids	50 mg/L
Coliforms	Less than 400 MPN/100ml (MPN - Most Probable Number)
Temperature - at the edge of a designated mixing zone	Max 5°C above ambient temperature of receiving waters- max 3°C if receiving waters >28°C

Source: The World Bank, 1995a (unpublished)

[1] Process wastewater, domestic sewage and contaminated stormwater should be treated to meet the above specified limits before being discharged to surface waters.

6.0 ENVIRONMENTAL SETTING

6.1 INTRODUCTION

This chapter provides information which describes the existing environment of the study area. This information includes human, biological, and physical data, which together forms an environmental characterization of the actual environment in which the project will operate as it exists before the construction and operation of the project. The study area, defined broadly, includes the oil field development area located in the Doba Basin (approximately 400 km^2) and a pipeline corridor from Komé traversing southwest to the Chad-Cameroon border. The infrastructure study area that includes the system of necessary transportation facilities to support the proposed project is also a part of the study area.

Sources of information for the study area were identified in a *Data Assimilation and Review Report* (Dames & Moore, 1993). Additional information collected systematically and compiled over a two-year period during a pipeline route and facility site selection process has been utilized in this Environmental Assessment (EA). In addition to various engineering studies, specific environmental field studies were conducted in the study area by technical consultants to collect additional data on the human environment, botany, water quality, and hydrology. The scope and scale of the field studies are indicated in the introduction to the relevant subsections of Section 6.0 of this document. A Geographic Information System (GIS) was used to integrate a wide variety of data (i.e., published topographic mapping, terrain analysis, land use and vegetation mapping, project preliminary design data, etc.) for subsequent use in this EA.

The terrain analysis consisted of identifying land units (terrain units) in the study area which could be grouped together on the basis of their physical, biological, or land use characteristics (Table 6.1-1 and Figure 6.1-1). Preliminary terrain units have been developed for analysis of landforms or physiography of the study area. The evaluation was performed using various sources of information and interpretive methodologies, and results of the evaluation were used in the pipeline route selection process, development of the Terms of Reference (Dames & Moore, 1995c), and preparation of the EA. Terrain units are areas of land with similar topography, soils, drainage patterns, and natural flora and fauna. Summary descriptions of the terrain units are presented in Table 6.1-1. The land use units are areas of similar agriculture, demography, land tenure, community infrastructure, and state of preservation of the flora. Land use units are presented in Figures 6.2-2 and 6.2-3.

Principal applications of the terrain analysis and land use mapping have been in the selection of the most appropriate pipeline corridor and the selection of the preferred route within the selected corridor. Terrain analysis and land use mapping data were also applied to siting of project facilities in the oil fields and related operating facilities.

Terrain analysis commenced with a review of available published information to generate project-specific landform and land use classification systems. These classifications present the most common landforms and land use features plus an interpretation of their generic characteristics which were developed using a combination of remote sensing, interpretation, and limited on-site data collection.

The classified units provide a means of predicting the environmental sensitivity of various portions of the study area. The data were developed by assessing the environmental impacts likely to be associated with each type of landform unit and land use unit that has been identified and mapped. This information has been incorporated into the GIS and assimilated to support the development of the EA.

Landscape within the study area was divided into its component landform and land use units through the evaluation of the topography, geology, geomorphology, pedology, vegetation, and population distribution. The relevant physical, biological, and socioeconomic environmental factors which characterize each unit were used to assess potential impacts. A more detailed description of the terrain unit analysis is contained in a separate report prepared by Dames & Moore (Dames & Moore, 1994). In addition to this terrain analysis, aerial photography (1:30,000 scale) of the project area was acquired in January 1995 and interpreted for use in the EA.

The environmental setting for the project includes the effects of exploration activities that have led to the current stage of project development. These activities (in the project area) were the subject of an environmental audit that conformed with internationally accepted principles of such auditing. The objective of the audit was to observe and document the current environmental conditions at the exploration sites, and based on the findings, to develop recommendations for remediation actions that should be carried out in either the near-term or later during construction. The audit results will be used as part of the project's systematic approach to environmental management. The Government of Chad participated in this audit.

Overall, the audit found no serious threats to the environment. Some sites and facilities have not yet been fully reclaimed. Based on the conclusions and recommendations of the environmental audit of the zone affected by the past exploration activities in the Doba project area as well as the conclusions and recommendations of the recently performed woody vegetation survey (see Section 6.3.2), Esso, in consultation with the Chadian administration in charge of environmental matters, will develop and implement a plan for the impacted zones.

6.2 THE HUMAN ENVIRONMENT

The human environment of the project study area, including the geographical setting, historical setting, demographics, population distribution, and population density, are described in this section.

In addition to an extensive review of the literature and databases, the existing human environment has been assessed through a field program conducted by an anthropologist and assisted by two sociologically-trained assistants from the project area. The human environment study team utilized the project GIS-based mapping system in the field work, including terrain unit, land use and vegetation mapping at 1:200,000 scale based on satellite imagery, and land use and vegetation mapping at 1:30,000 scale based on aerial photography flown specifically for the project. On this basis the administrative areas enclosing the future oil field and field facilities development area were identified. A scientific random sample of villages in these administrative areas and a smaller random sample of villages in administrative cantons adjacent to the oil field area were studied. Ten kilometer-wide corridors along the pipeline route and the affected roadways were also randomly sampled. In addition, populations of the sample villages in the oil field area were interviewed (425 questionnaires). The study team targeted urban areas with economic links to the oil field area and local markets for other questionnaires and focus groups. In all, 13 person-months of study were spent gathering qualitative and quantitative data for the EA. The village surveys also provided the framework for in-depth public consultation with the populations likely to be affected. In over 100 meetings conducted for this study, the population inquired about the project, brought forward concerns and issues, and developed and proposed mitigation measures.

6.2.1 Introduction

The following entry from the 1996 World Factbook summarizes the economic, social, and political setting for the Chad project:

> "Climate, geographic remoteness, poor resource endowment, and lack of infrastructure make Chad one of the most underdeveloped countries in the world. Its economy is hobbled by political turmoil, conflict with Libya, drought, and food shortages. Consequently the economy has shown little progress in recent years in overcoming a severe setback brought on by civil war in the late 1980s. More than 80 percent of the work force is involved in subsistence farming and fishing. Cotton is the major cash crop, accounting for at least half of exports. Chad is highly dependent on foreign aid, especially food credits, given chronic shortages in several regions." (CIA, 1996)

The following section presents a summary of the findings of the Chad human environment study. Findings from the in-country study are based on data gathered in the study area and surrounding region, published government statistics and data provided by ministries, published and unpublished sociological studies of the region, unpublished NGO reports, and extensive interviews with government, NGOs, and others in the Doba and project area. An overview of the affected areas, geographic setting, history, demographics and population distribution, and density of the study area is presented.

6.2.2 The Human Environment Setting

A large geographic area was surveyed to establish the characteristics of the area involved, thereby providing data on villages for comparison, monitoring, and evaluation of impacts and mitigation strategies. The survey area was defined as:

- The oil field development area
- A 10 km wide corridor along the proposed pipeline
- A 10 km wide corridor along the road(s) to be improved.

To properly assess areas which would be influenced indirectly by the project, the human environment assessment study area was expanded to include the major city of Moundou to the north and villages, towns, and hinterlands in the surrounding areas, including Doba, Bébédjia, and Mbikou.

The project is located in the southwest of Chad, which is divided into two administrative regions, or prefectures: Logone Oriental and Logone Occidental. Administrative areas are further subdivided into subprefectures, then cantons. Towns are subdivided into quarters, villages into "carrés." Project facilities and the pipeline corridor would be located entirely within the prefecture of Logone Oriental. The land that will be developed for oil wells, treatment and pumping facilities, an airstrip and worker habitations falls in the cantons of Béro, Komé, and Miandoum; these cantons have been defined as "the oil field development area." The pipeline and roads will pass through these and the cantons of Timbéri, Gadjibian, Bessao, Mont de Lam, and Mbassay as well. Figure 6.2-1 shows the administrative jurisdictional boundaries of the subprefectures and cantons in Logone Oriental prefecture.

Between the time of the initial EA surveys (early 1995) and finalization of the EA, intensive seismic exploration activities in the oil field development area have been initiated. The 3-D seismic survey has brought more intense activity to the oil field development area in a shorter time period than any earlier exploration activity; some local residents have been hired for seismic work and support activities.

In all, an area of approximately 600 km^2 has been surveyed during 1995 and 1996. A seismic grid pattern of tracks used for recording data has been overlain on the entire oil field development area. The compensation for land use, added to income from hiring and commissary purchases in the local markets, has injected additional money into the economy. The 3-D seismic investigative activities are being used to predict some of the environmental and socioeconomic impacts of the project. The effects of the 3-D seismic survey activities have been considered in the detailed report on the human environment prepared for this EA (Appendix B).

6.2.3 The Geographical Setting

The physical geography of the study area has had a direct effect on the spatial distribution of the population, the location of villages and fields, transportation, and social contacts. The area is a flat, shallow basin. In the rainy season, the Nya and Pendé rivers readily overflow their banks and spread out into shallow but extensive floodplains. There is, therefore, land that makes good pasture but is flooded during the cultivation season and is not used. This land does, however, have excellent potential for recession agriculture and irrigation. Streams and swamps in full flood also limit traffic and social contacts; the area between two streams is closely integrated, but socially as well as geographically it is separated from groups on the other sides. Figures 6.2-2 and 6.2-3 show the land uses and general vegetation characteristics of the study area. Land use classifications shown on Figure 6.2-3 are described in Table 6.2-1.

The eastern edge of the oil field development area is bordered by the Pendé River (East Logone), a source of economically valuable fish, but which virtually cuts off the area from Doba and eastern Chad during the wet season. Only one bridge crosses the Pendé; the only other alternative is canoe or boat. Though Doba is the principal market for the area in the dry season, it is difficult to reach in the rainy season.

The northern part of the oil field development area is bisected by the swampy stream of the Nya River, which runs from southwest to northeast. Late in the rainy season it floods the surrounding area, resulting in the growth of extensive grazing lands that are valuable to pastoralists. Few farmers use this floodplain for recession agriculture or irrigation because it is not part of the traditional agronomic system. It is utilized by locals for some limited fishing. Sedentary villages have been established outside the floodplain of the Nya, with fields located on higher ground. Lack of bridges constrains communication and trade; bridges and dikes were built at various times over the years, but they have fallen into disrepair.

The landscape in Baibokoum subprefecture, which the pipeline route traverses, is hilly with heavier rainfall than the oil field development area. The population density is high, and pastoral activities are less developed.

6.2.4 Historical Setting

6.2.4.1 <u>Precolonial Times</u>

Western explorers first reached the study area in 1892, but the French colonial presence was not established until 1905. The slave trade was not stopped generally until 1911 and lasted even to 1918 in some areas. Neighboring tribes kidnapped and pillaged local villages, and wars were incessant. These hostilities created a sense of insecurity and distrust of outsiders that persists today.

To reduce the chances of attack in precolonial times groups of close paternal kin, joined by other relatives who had fled from raids on their own homes, settled in tiny, isolated agricultural hamlets. These hamlets were inaccessible due to swamps and thickets of thorn trees. Residents also moved frequently to avoid discovery and to clear new fields. Behavior was governed by kinship and mutual support among brothers and sisters and antagonism to outsiders. There were no village chiefs who exercised political or judicial authority; decisions were made by consensus of the clan.

6.2.4.2 Colonial Period

Beginning in 1907, to keep order, French colonial administrators forced hamlets together into compact settlements along footpaths where they could be supervised more easily. The French created local chiefs and obliged them to provide food, porters, and taxes. With no traditional basis of authority, these chiefs had to resort to force, backed by the colonial authorities.

The Doba, Béro, and Komé areas lay on the German side of the border (i.e., the Pendé River) in the colony of Kamerun. As the German colonial authorities were harsher than the neighboring French, people migrated across the border toward Chad until Germany lost control of its colonies after World War I. But life under the French soon became difficult as well. During the 1920s and 1930s workers were forced to build the Congo-Ocean Railway; during the 1930s villages were uprooted and moved to combat sleeping sickness (trypanosomiasis). Beginning in the early 1920s, working-age people were regimented into tapping wild rubber, and then in 1929 were switched into growing cotton (which remains the country's principal export). Many young men joined the French armed forces in the 1940s and 1950s to escape this life and, paradoxically, in later years after service in Africa, Europe, and Indochina, returned home with ample military pensions to become men of influence, model farmers, and village leaders.

The first Protestant missionaries established themselves in southern Chad in 1925, followed by Catholics in 1929. The missionaries established churches, schools, and health facilities, which turned the study area into one of the best educated, healthiest, and most developed portions of the country. Because of churches' long-time presence in local communities, many people are practicing Christians, especially fundamentalist Protestants who do not drink alcoholic beverages or dance.

6.2.4.3 Independence

The colonial era provided some physical security from raiding and warfare but little respite from forcible removal or flight. Domestic production was still expropriated in the form of taxes, either in money or materials (i.e., rubber and cotton). After independence in 1960 the new government, through its cotton marketing monopoly (Cotontchad), continued to force cotton cultivation until farm prices were sufficiently raised in the mid-1980s to induce farmers to grow it voluntarily. This period of relative prosperity was short-lived, however.

Between the mid-1970s and mid-1980s, the country experienced civil war, ethnic conflict, and economic chaos. Attempts by the government to force different ethnic groups and religions to become initiated into the Sara culture led to widespread murder. From 1979 to 1982, no effective national government existed in the Logone and the Moyen-Chari prefectures. The national government reinstituted control over the area in 1982, with major hostilities continuing until 1985.

6.2.4.4 The Present

The economic security of today's inhabitants is not so different from earlier times. Fluctuations in world cotton prices, a 1994 currency devaluation that raised the price of imports, including agricultural inputs, and financial problems in the cotton industry, have made cotton cultivation difficult for half the farmers who depended on it as their main source of income. Continued lack of resources has reduced government services, which are practically non-existent in rural areas.

Periodic outbursts of civil disruption have inhibited economic growth. Recent conflicts occurred around Doba in 1992, Gore and Moundou in 1993, and in Bero, Komé, and Miandoum cantons in 1993 to 1995. In 1993 many people fled the region. Since then local NGOs have been working to repatriate and resettle the refugees. During this time, according to the local population, the continuous presence of Esso throughout the study area tempered hostilities. Prior to the 1996 presidential election, the rebels most active in the region negotiated a peace agreement with the national government. Lately, much desired stability has returned to the area.

6.2.5 Demographics

The total population of Chad (6 million) is growing at 2.4 percent per year according to the 1997 World Development Indicators (World Bank, 1997). The total fertility rate is 5.9 children born per woman, with the infant mortality rate at 117 per 1,000 live births. Life expectancy at birth is 47 years for males and 50 years for females. More detailed demographic data are provided in Appendices B and C.

The oil field project area had a population of approximately 28,100 in 1993, about 6,300 in Béro, 10,400 in Komé, and 11,400 in Miandoum cantons. Many of these 28,000 people may be directly affected by the project. The additional cantons through which the pipeline and improved roads will pass have a population of about 63,000 (Timbéri 10,300; Gadjibian 14,600; Bessao 21,000; Mont de Lam 6,700; and Mbassay 6,700). Some of these cantons are within the 10 km corridors and may be affected by the construction activities and road upgrades. Residents of the cantons and subprefectures where project construction and drilling occurs, approximately

171,000 people (Table 6.2-2), would be affected by any budgetary or administrative changes. Logone Oriental as a whole (approximately 440,000) would also be touched by budgetary and administrative changes. The urban and peri-urban population around Moundou (Logone Occidental), the region's main economic center, is likely to be indirectly affected as well. The population of this area is about 120,000 (Table 6.2-3). Logone Oriental contains seven percent of the country's people, and all of Logone Oriental and Occidental together make up 895,000 or approximately14 percent of Chad's population (Table 6.2-3).

The population of the project area, which includes the area around the production facilities and exploration base, corridor along the pipeline, corridor along the road to be improved, and villages and towns with regional economic ties (Logone Oriental, Doba, Bébédjia, Mbikou, Miandoum, Baibokoum, and Moundou in Logone Occidental) is approximately 240,000 or 3.8 percent of Chad's total population. The sedentary population in the oil field development area (Baibokoum, Bébédjia, Doba), according to 1993 census figures, is approximately 37,000 (approximately 6,200 households). This population includes approximately 28,000 farmers and 9,500 sedentary pastoralists.

6.2.6 Population Distribution

Rural sedentary farmers comprise the largest percentage (81 percent) of the total population of the study area. A mere 1.3 percent of the region's inhabitants are resident pastoral herders who move their cattle from pasture to pasture in the same region, residing permanently in the study area. A large number of transhumant and nomadic pastoralists (i.e., herders) with approximately 100,000 head of cattle and other livestock pass through the study area in November through January and again in May through July. Transhumant pastoralists take a variety of routes along floodplains (Figures 6.2-4 and 6.2-5). Timing and routes depend upon rainfall and the abundance of fodder. The remainder of the study area population lives in cities and towns.

Chad has become one of the most highly urbanized of all Sahelian countries, with about 20 percent of its total population in cities and towns. Over the past 30 years, the population has shifted from rural to urban areas. Except for a few well-to-do businessmen and civil servants in the big towns, urban dwellers have not, for the most part, abandoned farming. Most people who live in towns continue to farm nearby fields or hire others to work for them.

In Logone Oriental, population density was 8.4 people per km^2 in 1964 and ranged from 6 to 40 per km^2 in 1993. Since 1964, the population density in Logone Occidental has grown from 21.9 people per km^2 (the highest in the nation) to greater than 40 people per km^2 in 1993. Table 6.2-4 shows a clear gradient of declining density from north to south and west to east. Over the years, population in the south of Chad has become more dense in the northwest than the south and southeast, even though the south and southeast are zones of immigration. Population densities in the oil field development area in 1993 were increasing, approaching levels of those in both Logone Occidental and Tandjilé.

For the most part, the population of southern Chad and the oil field development area has responded to its increased population by placing more village land into cultivation and reducing the time that land is left fallow. When the fallow period becomes so short that productivity is reduced substantially, the population seeks secondary sources of income to purchase food no longer grown in sufficient quantities. These secondary sources usually include exploiting other bush resources, which puts considerable pressure on the environment. A 1992 study by the research institute CIRAD showed that the increase in population has been paralleled by an increase in the land area used for growing food. In Betima (near Donya), where demographics are similar to those of Canton Miandoum in the oil field development area, all village land will be under cultivation within 28 years and there will be no fallow.

6.3 BIOLOGICAL RESOURCES

The biological setting of the project area, including vegetation; exploitation and degradation of native floral and faunal resources; weeds and exotic plants; parks, reserves, and sensitive habitats; wildlife and fisheries resources; disease, disease vectors, and vertebrate and insect pests; is described in this section.

In addition to the extensive literature and database review that is documented in Dames & Moore (1993), terrain unit, land use and relative degradation mapping at 1:200,000 scale, and vegetation and land use mapping at 1:30,000 scale were undertaken utilizing the project GIS-based mapping system. Biological field work has comprised a reconnaissance level survey of the project area (including an aerial overflight and ground surveys at representative locations) and a botanical survey of the oil field development area (which also included an overflight of the pipeline route). The field teams for these surveys included a wildlife biologist, a botanist, and a representative of the Chad Ministry of Environment and Tourism. In all, approximately 35 person-days were spent in biological field work by professional members of the field team.

6.3.1 Vegetation of the Project Area

6.3.1.1 Soudanian Wooded Savanna

Vegetation in the study area consists primarily of wooded savanna characteristic of the Soudanian zone (Table 6.3-1). The vegetation of the study area is illustrated in Figures 6.3-1 and 6.3-2. Vegetation classifications shown on Figure 6.3-2 are described in Table 6.3-2. These maps were developed from 1:200,000 satellite imagery (Figure 6.3-1) and 1:30,000 aerial photography (Figure 6.3-2). Ground truthing in the oil field development area has confirmed that the mapped vegetation units of "agricultural," "savanna," and "wooded savanna" all represent stages in the shifting agricultural cycle. The "agricultural" unit is land mostly in cultivation, and scrubby fallow; "savanna" is mostly fallows under young woodland; and "wooded savanna" is mostly fallows under older woodland.

The wooded savanna of the Soudanian zone characteristically has a 15 m canopy of leguminous and combretaceous trees, such as *Isoberlinia doka*, *Anogeissus leiocarpys*, *Terminalia laxifolia*, *Pterocarpus lucens*, and *Daniella olivieri*. However, historical and current annual slashing and burning in the study area has made it more of a broadleaf shrubby savanna consisting primarily of cultivated and fallow agricultural fields with secondary growth under 5 m high and an occasional tree over 10 m high. The Rhum Palm (*Borassus aethiopium*), also known as "ironwood" for its strength and resistance to termites, was once abundant in the savanna in areas of deep sandy soils and a high water table but has since become less common in the area as a result of extensive harvesting for building materials. Many of the remaining trees stand in the cultivated fields surrounding the villages. Stands of other useful trees, such as Mango (*Mangifera indica*), Néré (*Parkia biglabosa*), Shéa butter tree (*Vitellaria* *paradoxa*), *Acacia albida*, and an occasional tamarind tree (*Tamarindus indica*) provide needed products for the village. No more than five tree species commonly occur together in open stands in the large, cultivated portions of the study area .

Most of the savanna zone within the study area has been grazed heavily or cultivated for cotton, sorghum, millet, groundnuts, legumes, and manioc, and is in various stages of fallow. Where grazed, annual grasses now comprise much of the herbaceous cover, and *Calotropis procera* and *Guiera senegalensis* are common shrubs on disturbed sites. Roots and stumps, common in most active and fallow fields, expedite bush fallow, provide protection from the elements, and promote recycling of nutrients.

The wooded savanna vegetation of the hills and mountains southwest of Bessao differs somewhat in composition from the savanna vegetation of the flatter areas to the northeast (Tables 6.3-3 and 6.3-1, respectively).

6.3.1.2 Gallery Forest

Along river banks and in damp watercourses, higher soil moisture and fertility support a more luxuriant vegetation than is possible in the drier savannas. These gallery forest strips are usually narrow, except in some floodplains. The types of trees are different from those in the adjacent savanna and are taller and more closely spaced, occasionally forming a closed evergreen canopy with a minimum of understory vegetation. Gallery forest fragments along the Nya, and especially the tributaries to the Pendé, contain a variety of tree, shrub, and herbaceous species, including: *Vitex cuneata*, *Szygium guineense*, *Anthocleista oubanguiensis*, *Tricalysia okelensis*, *Ficus capensis*, *Gardenia ternifolia*, *Nauclea latifolia*, *Tamarindus indica*, *Diospyros mespiliformis*, *Terminalia laxiflora*, *T. macroptera*, and *Acacia caffra* var. *campylacantha.*

In the oil field development area the Nya river valley has seasonally inundated grasslands and is bordered by mature savanna woodlands with *Daniellia oliveri*. There are also patches of riparian scrub along the watercourses. The grassland is mapped (Figure 6.3-2) as "marshland," and the mature savanna woodland is mapped as "riverine/gallery forest." The Loulé River has a narrower valley, and this is mostly wooded. The mapped unit "riverine/gallery forest" along the Loulé comprises two vegetation types: mature savanna woodland (like that along the Nya valley) which is over 90 percent of the mapped unit, and narrow gallery forest (with *Irvingia smithii*) along the watercourse.

These gallery forest corridors provide habitat for birds, butterflies and other insects, mammals, and reptiles that depend on the rich vegetation for food, cover, or breeding habitat. These forests are often an important source of medicines or fruits to local residents.

6.3.1.3 Floodplain Wetlands

The perennial and annual grasslands in the alluvial floodplains of the Pendé, Loulé, and Nya rivers is under continuous pressure from livestock and cultivation. These floodplains are distinguishable by their general lack of woody species; a perennial grass cover of *Hyparrhenia rufa*, *Elytrophorus spicatus*, *Vetiveria nigritana*; and annual grasses such as *Panicum* spp., *Loudetia simplex*, *Sporobolus* spp., and *Eragrostis* spp. in cultivated areas. Forbs such as *Hydrolea floribunda* and *Ammania auriculata* are also found.

These floodplains are increasingly being converted into recessional fields of white sorghum (Bérbéré), red sorghum, corn, millet, taro (cocoyam), rice, and vegetables. Extensive cultivation of these wetlands displaces grazing livestock and encourages them to forage and drink along the sensitive riparian corridors.

6.3.2 Exploitation and Degradation of Native Floral and Faunal Resources

The growing human population density in the region (see Section 6.2) creates pressure to convert more and more of the savanna to agriculture, influencing the length of time a field can be left fallow. As a result, more natural vegetation has been lost, and human and livestock populations have placed more pressure on the remaining natural vegetation for fodder and fuel. An increased pressure for more crops, pasture, and wood resources (e.g., fuelwood, charcoal, rough construction wood, and roofing poles) has changed the composition and reduced the number and variability of plant species, consequently affecting animal populations through loss and fragmentation of habitat. Replacement of the natural plant diversity with agriculture crops favors animal species that prefer these resources.

Expanded cultivation and shortened fallows (normally two to four years) have increased the potential for erosion on the less productive lands, compounding the risk of loss of vegetative cover. Consequent increases in the deposition of sediments in local waters may have inhibited the growth of aquatic vegetation, thereby affecting populations of water-dependent wildlife and Palearctic migratory birds that feed on them.

The traditional farming system in southern Chad integrates the bush as an active part of its productive system. Dependence on wild foodstuffs and, when rainfall is adequate, fishing, make wild areas as critical to the farming system as cultivated land. Food and material resources from the bush are used for supplementary income (e.g., karité butter and gum arabic) and become critically important where the soil has become less fertile. This type of system where the reliance on bush products for income and food is magnified due to reduced soil fertility (and lack of bush) is ultimately unsustainable.

Some of the local population attach a religious significance to certain trees. The Mourayye (*Khaya senegalensis*) holds a position of respect among local residents for its size and majesty, and the Karité (*Butyrospermum parkii*) and Néré (*Parkia biglabosa*) are also of significant cultural value to some local residents. Tables 6.3-4 and 6.3-5 list important local tree and plant species.

Past exploration activities, principally 2-D and 3-D seismic survey programs, construction of infrastructure such as roads and airstrips, and exploration well pads have resulted in some clearing of vegetation in the project area.

In late 1996 a field survey was conducted to assess botanical impacts from exploration activities and the effectiveness of the latest clearing techniques employed for the 3-D seismic program (Thomas, 1996). These new techniques, which preserve the topsoil and the rootstock, were implemented in response to the slow regeneration observed along early generation 2-D seismic lines, and to the higher density of the seismic lines planned in the 3-D program.

- **3-D Seismic Lines**–The 3-D seismic survey affected about five percent of the oil field survey area. Within this area, the main impact was the removal of aboveground woody vegetation for all shrubs and trees with trunks up to about 20 cm in diameter. Riparian scrub along steep river escarpments was often avoided during the 3-D survey.

  The botanical field work indicates that clearing the vegetation has not killed the plants. An assessment was made of recovery rates for the biomass, which will regenerate rapidly over the next few years. Impacts are small and are limited to a possible small lowering of soil fertility for the next agriculture cycle and loss of some regeneration for tree species important for food or income, such as *Parkia clappertoniana* and *Butyrospermum parkii*. There was no loss of other forest products such as fuelwood and building materials, since these are not harvested at full capacity. Impacts were short term, and restoration is occurring naturally.

- **2-D Seismic Lines**–Survey results show that the 2-D survey lines differ significantly from areas not cleared. Differences include far fewer individual woody plants and fewer species. These differences persist despite the age of these lines. Contributing factors include the scraping of the topsoil (and killing of the woody plants) during clearing, and the subsequent use of many of these lines as footpaths and livestock trails. The 2-D seismic lines are now beginning to regenerate naturally, or have been converted to roads and footpaths.

- **Well Sites And Other Infrastructure**–Well sites were examined, along with an old airstrip. In most of these areas a laterite cap has been placed over bulldozed soil surface. At one well site, laterite had not been used and slow regeneration had occurred, comparable to that on the 2-D survey lines. On laterite, regeneration is very slow and is limited at first to depressions where fine sediments and water accumulate.

6.3.3 Weeds and Exotic Plants

A genus of seed plants of the Scrophulariaceae (*Striga* spp.) is likely the single most pervasive weed problem associated with agricultural production in southern Chad. The plants live as root parasites on members of the grass family (*Andropogon* spp.), as well as on corn, sorghum, and millet. The plant appears later in the cultivation cycle and is blamed for substantial reductions in cereal crop yields. Many people falsely use the appearance and quantity of *striga* in a field as an indicator of progressive soil infertility, and fields are often abandoned as soon as *striga* appears. Fallowing a field for a minimum of two years is the only way local residents know to combat the infestation. The agricultural research station at Bébédjia is investigating other ways to combat the weed and has identified cultivars of sorghum indigenous to the study area which appear to be *striga*-resistant. Ethylene and weed killers have not proven to be economical anti-*striga* agents.

6.3.4 Parks, Reserves, and Sensitive Habitats

The following areas of special interest occur within southern Chad:

- The Timbéri Forest Reserve (88,200 ha), south of Timbéri (see Figure 6.3-3), is classified as a "collective forest," operated by village cooperatives. This reserve is approximately 22 km southeast of the pipeline route.
- The Laramanay Wildlife Reserve (431,000 ha) is a proposed hunting reserve (by permit) (Tchad, 1989b) approximately 7 km north of the proposed pipeline route, east of Bam and Bégangber (see Figure 6.3-3), which is reported to contain important habitat for elephants that may migrate between Chad and Cameroon. The boundaries of this reserve are still tentative subject to decision by the Ministry of Agriculture and Environment. Meetings have been held with the Cameroon government to study elephant populations and their coexistence with farmers in the region.
- The Logone floodplain is a wetland area of approximately 100,000 ha that is listed in the *Directory of African Wetlands* (Hughes and Hughes, 1992). It contains valuable gallery forest and marsh habitat that supports relatively diverse bird and mammal populations and provides important grazing habitat for resident and transhumant livestock.
- A large contiguous stand of African bamboo (*Oxyanthera abyssinica*) northeast of Bessao contains important timber and fuelwood resources for local residents and also provides important elephant habitat. This is not currently an official reserve, though it is a recognized area of value to local residents. Other smaller, isolated stands of bamboo occur near the pipeline route in the vicinity of Bessao and on either side of Baibokoum, in the area of the country's highest rainfall.

6.3.5 Wildlife and Fisheries Resources

Information on the conservation status of animals in Chad is contained in IUCN (1996). This lists 19 Threatened species in Chad ("Threatened" includes "Critically Endangered," "Endangered," and "Vulnerable") and 28 "Lower Risk" species. (See Glossary for definitions.).

The cultivated areas and cultivation practices (including widespread annual burning of vegetation) of southern Chad currently offer little habitat for most of the wildlife once found in the region. Few replacement species appear to occupy habitats created by cropping, although seeds of the weeds and grasses may provide food for some bird species. The strip-cropping of taro root (a food crop) on the Logone floodplain has created habitat attractive to flocks of red-billed quelea (*Quelea quelea*). The annual grass *Panicum laetum* that replaces the climax *Andropogon* spp. produces round seeds favored by the queleas. Other birds have also benefited from human expansion in Chad and are sufficiently common to be a threat to grain crops, such as golden sparrows (*Passer luteus*), village weavers (*Ploceus cucullatus*), and fire-crowned bishops (*Euplectes hordeaceus*).

Palearctic migrants use the savanna and woodland communities during migration. The warbler family (Sylviidae) are the most numerous, especially the whitethroat (*Sylvia communis*) and willow warbler (*Phylloscopus trochilus*). Swallows and shrikes are also common seasonal migrants. Very few raptors can be seen in the area; these are mostly black kites (*Milvus migrans*) and grasshopper buzzards (*Butastur rufipennis*).

The flat gradients of the rivers in southern Chad allow development of extensive sand banks which attract winter migrant wading birds as well as local black-crowned cranes (*Balearica pavonina*), Maribou storks (*Leptoptilus crumeniferus*), herons, egrets, and plovers. The vertical, sandy banks are well suited for nesting colonies of Carmine bee eaters (*Merops nubicus*) and red-throated bee eaters (*M. bulockii*).

The information available regarding fish of the Pendé River and its tributaries is primarily contained in Blache, Miton and Stauch, (1962) and Blache, et al., (1964). Floodplains are recognized as being important historically as nursery sites in Benech and Leveque (in Burgis and Symoens, 1987). The Lake Chad Basin once supported 130 species of fish, the most important to humans being the Characin (*Alestes baremoze*) and the Nile perch (*Lates niloticus*). The Characin have seen drastically declining populations. The Nile perch now seldom exceed 5 to 8 kg.

Overexploitation, drought, elimination of crocodiles and hippopotami, and conversion of floodplains to grazing and agriculture have reduced the catches of what had been a major fishing industry in Chad. A principal prey of crocodiles is catfish; when crocodiles are removed, catfish proliferate and consume the eggs and fry of tilapia and other fish. Formerly, hippopotami fertilized the water with their dung and stirred up sediments, improving nutrient distribution in the water column. The elimination of this activity combined with the proliferation of catfish have been major contributors to reduced catches.

Sensitive bird and mammal species that could potentially occur within the study area are discussed briefly below. For purposes of this study, wildlife species were considered "Sensitive" if mentioned in one of the following sources: IUCN, 1996; Hecht et al., 1993 (Appendix E-1); Chad National Ordinance 16/63 on Protected Species; ICBP, 1988; IUCN, 1982; ICBP, 1981; Robinson, 1989; and IUCN, 1989.

As a result of the civil and military disruptions referred to in Section 6.2, virtually all of the larger mammals have been killed during the past two decades as a result of automatic weapons used in hunting and an increase in four-wheel drive vehicles. Furthermore, the opening of boreholes (waterwells) has enabled formerly nomadic people and their livestock to remain continuously in areas that previously were grazed for only short periods (Hecht et al., 1993).

The following regionally sensitive mammal species have the potential to occur in the study area.

- Giant eland (*Tragelaphus derbianus gigas*)–This eland subspecies formerly occurred in the far southwestern portion of Chad in the wooded savanna zone of Logone Oriental and Moyen Chari prefectures, where it numbered in the thousands (Blancou, 1958). It may be completely absent from Chad today, due to illegal hunting, the rinderpest epizootic (an "epidemic" among animals of an infectious fever disease) of 1982-1983, drought, encroachment, and ongoing unrest within the country. No eland were observed during a 1986 aerial survey (East, 1988) of the region where this species formerly occurred (USAID, 1993). Ground searches also have failed to locate it within its normal habitat, and no elands have been seen in the region for some years.

- Red-flanked duiker (*Cephalophus rufilatus*)–This small antelope species was restricted to gallery forests in the wooded savanna zone of Logone Oriental and Moyen Chari prefectures. The population, if it exists, does not appear to be large.

- Grey duiker (*Sylvicapra grimmia*)–This small antelope species was, until recently, widespread throughout the savanna zone of southern Chad. Its total population today is not thought to be abundant overall.

- Bushbuck (*Tragelaphus scriptus*)–This species normally is confined to areas with sufficient cover near permanent water (i.e., gallery forest). Once locally common, total numbers today are unknown.

- Buffon's or western kob (*Kobus kob*)–This species occurs along permanent watercourses within the savanna zone. It was formerly abundant (with a population of 75,000) but has suffered from illegal hunting. It may still possibly occur on isolated floodplains in less populated areas.

- Roan (*Hippotragus equinus*)–This species' distribution once extended throughout most of the savanna zone of southern Chad, but it has been eliminated from densely populated regions. It exists in moderate numbers throughout its remaining range, despite illegal hunting and drought of recent years.

- Oribi (*Ourebia ourebi*)–This species was once widespread in the southern savannas of Chad, south of latitude 11 degrees north. Its numbers today are unknown.

- African elephant (*Loxodontia africana*)–As of 1993, only about 2300 elephant were estimated to occur in all of Chad. Zakouma National Park, east of the project area, supported approximately 1500 individuals at that time, while the region west of the Chari River supported only about 100 individuals (Hecht et al., 1993) While some elephant habitat exists within the Laramanay Reserve and the Chadian Ministry of Agriculture and Environment feels that there may be some use of this area by elephants migrating from Cameroon on a seasonal basis, there are no current records available which indicate the actual occurrence of elephants in this area.

The following sensitive bird species has the potential to occur in the study area:

- River prinia (*Prinia fluviatilis*)–This recently discovered bird species (ICBP/IUCN, 1985) in the grass warbler family was known only from waterside vegetation in a few localities in southern Chad (Chappuis, 1974). It is rarely known to be associated with gallery forest trees and prefers marshy floodplain vegetation for nesting and foraging.

In addition to the above, there are wildlife species whose status in Chad is thought to be reasonably secure at present, either within or outside existing parks. These species are partially protected under Article 25 of Chadian Wildlife Legislation. They include:

- Antbear, Aardvark (*Orycteropus afer*)–The status of this species is uncertain. It is a nocturnal animal relatively widespread in savanna areas where termite species occur.

- Serval (*Leptailurus serval*)–This felid is a hardy survivor in floodplains and near rivers.

- All vultures (*Gyps* and related genera)–All species currently appear to be stable, but the white-headed vulture (*Gypohierax angolensis*) is the least common.

- Cattle egret (*Bubulcus ibis*), little egret (*Egretta garzetta*), yellow-billed egret (*Egretta intermedia*), and great white egret (*Casmerodius alba*)–These species are widespread to occasional along rivers.

- Marabou stork (*Leptoptilus crumenifer*)–This species is common near water.

- Saddlebill stork (*Ephippiorhynchus senegalensis*)–This species is occasionally found along rivers, lakes, and open flooded areas.

6.3.6 Disease, Disease Vectors, and Vertebrate and Insect Pests

Tsetse flies (*Glossina* spp.), once occurring along much of the Chari River and elsewhere in southern Chad, have seen their range reduced considerably as a result of the elimination of game animals and deforestation. Unfortunately they, and consequently trypanosomiasis (sleeping sickness), are still endemic but localized in the southern portion of the Logones, around Timbéri, and along the proposed pipeline route, in Moundou, Tapol, and Maikoro. Onchocerciasis (river blindness), transmitted by blackflies (*Simulum damnosum*) that breed in and around rivers and streams, is common along the pipeline route, from Gadjibian to Baibokoum. Malarial mosquitoes (*Anopheles* spp.) are common in this portion of Chad, and 63 percent of all children in Moundou carry the parasite. More detailed information on disease is provided in Section 6.7, Public Health, and Appendix C.

A few bird species have benefited from agricultural expansion and are common enough to be a threat to grain crops, including the red-billed quelea, golden sparrow (*Passer luteus*), village weaver (*Ploceus cucullatus*), and fire-crowned bishop (*Euplectes hordeaceus*). Black/roof rats (*Rattus rattus*) and Norway rats (*Rattus norvegicus*) are major mammal pests. The black, cracking, clay soils in and around the floodplains and marshes are breeding grounds for the African migratory locusts (*Locusta migratoria*), Sudan plague locusts (*Ailopus simulatrix*), and tree locusts (*Anacridium melanorhodon*).

6.3.7 Agriculture and Livestock

Apart from cotton, principal crops in the savannas of southern Chad are sorghum on heavier soils (millet on dry or sandy sites), groundnuts, cowpeas (or other legumes), and manioc (cassava) in higher rainfall areas. Selected trees (*Khaya senegalensis*, *Ficus* spp. *Parkia biglabosa*, *Butyrospermum Parkii*, and *Balanites aegyptica*) remain for fruit or seeds, creating what are known as "parks." Rice is grown on floodplains and mango trees dominate the villages, but little other fruit is grown. Vegetable gardens occupy damp ground in grassy areas near habitations.

Based on current estimates, approximately 100,000 head of cattle, owned by sedentary farmers and resident and transhumant herders, move through the study area annually along fairly well-defined routes (see Section 6.2).

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6.4 HYDROLOGY, HYDROGRAPHY, HYDROGEOLOGY, AND WATER QUALITY

The hydrological, hydrographical, hydrogeological, and surface and groundwater quality conditions of the study area have been assessed through the project data review and assimilation process (Dames & Moore, 1993), and through data gathering performed in Chad (ANTEA, 1995a and 1995b; Dames & Moore, 1996b). Field work was performed by a hydrologist and with the participation of the Bureau de l'Eau of the Government of Chad, and the University of N'Djamena. In all, in excess of 50 person-days were spent in field work.

6.4.1 Hydrology and Hydrography

The major surface drainage features of the study area are the Pendé River and its tributaries, the Loulé and Nya rivers, which join the Pendé from the west. The Loulé River bisects the proposed Komé oil field. No streamflow records are available for the Loulé and Nya; low-flow estimates based on cross section surveys of the two streams are 17 to 21 and 18 to 24 m^3/second, respectively. It is considered that the low-flow estimates understate actual discharges, particularly for the Nya (ANTEA, 1995a). At the confluence of the two streams they drain areas of 750 and 1,750 km^2, respectively. The headwaters of the Pendé rise in the CAR, and the river flows generally in a northerly direction through the towns of Goré and Doba to its confluence with the Logone River near the town of Dogabara.

The Logone is formed by the Vina and Mbéré, the point of confluence of these two rivers being located west of Baibokoum. The Lim meets the Logone at a point located 15 km to the north-east of Baibokoum and flows in a northeasterly direction past Moundou.

The Pendé flows into the Logone. The Logone is one of the large Chari tributaries. The point of confluence of the two rivers is located in N'Djamena. The Chari is the main watercourse that flows into Lake Chad.

This regional hydrology is illustrated on Figure 6.4-1, and streamflow data for the Logone River at Moundou and the Pendé at Goré and Doba are presented in Table 6.4-1.

Available climatological data for the region include rainfall records from rain gauges at Baibokoum, Bébédjia, Doba, Moundou, and Koumra (a town approximately 90 km east of Doba) and are summarized in Table 6.4-2. More detailed data (comprising mean monthly temperatures, rainfall, and evapotranspiration) for Bébédjia are presented in Table 6.4-3.

The rainfall data indicate decreasing rainfall from southwest (e.g., Baibokoum) to northeast (e.g., Koumra). The maximum rainfall in the region falls in August, and July–September are generally the wettest months of the year.

The Pendé River flows northeast of the Komé field. Estimated peak flows, flood depths, and flood elevations of the Pendé River in the vicinity of the Komé field and the OC are shown in Table 6.4-4. The estimated drainage area of the Pendé River is about 13,940 km^2.

The Loulé River and one of its unnamed tributaries traverse the center of the Komé field from the south to the north. Estimated peak flows, flood depths, and flood elevations of the Loulé River in the vicinity of the Komé field and the OC are shown in Table 6.4-5. As shown in Table 6.4-5, the flood depths and flood elevations would vary along the course of the river within the Komé field boundaries.

The Nya River floodplains are separated from the Komé field by a local topographic ridge. The river course is more than 1 km away from the northern boundary of the Komé field. Therefore, flood flows of the Nya River are not expected to affect facilities located in the Komé field area.

6.4.2 Hydrogeology

The hydrogeology of the oil field development area is dominated by the Doba Basin, a rifted depression in Precambrian gneiss and quartz diorite that is filled with continental sequences of sandstones and claystones that can exceed 7,000 m in thickness. The basin is subdivided by a basement ridge located about 10 km north of Doba and oriented northwest–southeast.

The upper 1,000 m of the sediments of the Doba Basin comprise a relatively thin veneer of Quaternary sands and clays overlying sandy sediments (with several discontinuous clay layers) of Tertiary to Cretaceous age. In the oil field development area, the Cretaceous Miandoum Shale occurs from 1,000 to 1,300 m below ground level and provides the cap to the oil reservoirs in the Upper and Lower Cretaceous sands below (Figure 6.4-2). These sands outcrop to the west, where the recharge of the aquifer is also thought to occur along the Borogop fault. Fluid discharge from the Upper Cretaceous reservoir horizons may occur at areas where the Miandoum Shale pinches out or along faults through the shale. Evidence has been found of a discharge area approximately 16 km north of the Komé oil field.

Shallow aquifers of the Doba Basin provide almost all of the water supplies for the population of the area. There are four types of wells in use for domestic water supply. The traditional hand dug well is about 1.0 m in diameter and as much as 30 m in depth, with little protection against surface runoff, animal influence, and infiltration from the sides. The second category includes traditional hand dug wells with a concrete parapet around them to prevent surface runoff and animals from entering the well. The third, rather rare, type of well includes those lined with concrete up to the water level in the well and protected by a concrete parapet at the surface. The fourth type of well includes deep augered boreholes (56 to 68 m deep) with metallic casing and a concrete parapet at the ground surface. These wells are usually equipped with a foot pump (Dames & Moore, 1996b).

The most common domestic water supply source is through dug wells or occasional hand pumps. The depths, pumping rates, and estimated transmissivities for representative wells in the basin are shown in Table 6.4-6.

The data included in Table 6.4-6 indicate that shallow wells dug or drilled to 101 m below the ground surface produce specific discharges ranging from 0.38 to 39.2 m^3/hour/meter and the transmissivity of the aquifer in this zone varies from 1.5×10^{-4} to 7×10^{-2} m^2/second. The depths, pumping rates, and drawdown for additional shallow wells drilled in 1986 to 1987 are shown in Table 6.4-7. Using available data on transmissivities and approximate saturated depths, the hydraulic conductivity of the aquifer in this zone is estimated to vary from about 3.17×10^{-4} to 27.67×10^{-2} cm/second.

The data included in Table 6.4-7 indicate that shallow wells drilled to a depth of 60 m below ground surface produce specific discharges ranging from 0.12 to 5.61 m^3/h/m. This is lower than the range for the relatively deeper wells listed in Table 6.4-6 suggesting that the yield of the upper zones of the aquifer increases with the length of screen and depth of penetration.

The Doba Basin lies in a semi-humid tropical area where effective annual evapotranspiration is generally less than annual precipitation and the groundwater gradient follows the topographic slopes. A groundwater contour map for the upper shallow zones of the aquifer is included as Figure 6.4-3. The data indicate that the direction of shallow groundwater flow is toward the north and northeast, i.e., toward the Nya River, in the vicinity of the Komé and Bolobo well fields, and toward the east in the vicinity of the Miandoum well field.

6.4.3 Water Quality

6.4.3.1 Surface Water

There is no information on the surface water quality in the oil field development area. The groundwater in many of the shallow dug wells used by the local population exhibits bacteriological contamination mainly because of the entry or infiltration of contaminated surface water (Dames & Moore, 1996b). Some of these wells are located in the floodplains of nearby streams, are only 5 to 8 m deep, and presumably capture water of the same or similar quality as that contributing baseflows to the streams in the area. Therefore, it is reasonable to assume that the quality of surface water is similar to that of the shallow wells in the area.

6.4.3.2 Groundwater

Water quality data for shallow wells in the Koumra, Laï, Moundou, and Tapol areas are shown in Table 6.4-8. The total solids content of the water in the oil-bearing zones of the aquifer below the Miandoum Shale is relatively low. Analytical results for two other wells located in the Komé drilling camp are also shown in Table 6.4-9 for comparison.

A number of village wells in the vicinity of the Komé, Bolobo, and Miandoum well fields were sampled for water quality analysis in October 1995 (see Figure 6.4-4). The locations, sizes, and depths of these wells are shown in Table 6.4-10. The results of analyses for traditional water quality parameters and bacteriological parameters are shown in Tables 6.4-11 and 6.4-12, respectively. The concentrations of total petroleum hydrocarbons were found to be below the detection limit of 0.02 mg/L in all sampled wells (Dames & Moore, 1996b).

The temperature of shallow groundwater (between 3.0 and 30.6 m below ground surface) in the oil field development area varied from 28.6 to 30.9°C, pH varied from 4.72 to 6.69, dissolved oxygen from 0.92 to 4.65 mg/L, and conductivity from 23.9 to 453.0 micromhos/cm.

The total hardness, total alkalinity, and concentrations of magnesium, chlorides, sulfates, and orthophosphates were generally low. Six wells exceeded the drinking water standards of the World Health Organization for iron (i.e., 0.3 mg/L) and two for nitrate (i.e., 50 mg/L). The total suspended solids concentration varied from almost zero to 1,400.5 mg/L.

Fecal coliforms were detected in eight wells in concentrations varying from 2 to 30 germs/100 mL, indicating human fecal contamination. Total coliforms varying from 2 to 46 germs/100 mL were detected in all wells except the boreholes with pumps (i.e., Type 4 wells). The concentrations of all volatile organic compounds were found to be below the detection limits in all samples except one well in Komé Village (BEB1) where toluene and chloroform concentrations were found to be 58 and 15 µg/L, respectively. These are well below the World Health Organization's drinking water criteria of 700 and 200 µg/L, respectively.

6.5 GEOLOGY, SOILS, AND SEISMICITY

The assessment of project area geology, soils, and seismicity is based on an extensive literature review and database search, the project GIS-based mapping, which includes terrain unit mapping, and the acquisition of collateral data during more than three person-years of project-specific environmental field work and data collection.

6.5.1 Topography

The combination of geologic and erosional processes is predominantly responsible for the present day topography of the study area. The proposed oil field development area is relatively flat with a total relief of approximately 30 m. The most prominent geographic features in the area are the Nya and Loulé rivers. Both of the rivers generally flow in a northeast direction. The Nya River is situated between the Bolobo and Miandoum fields, and the Loulé River is situated between the Bolobo and Komé fields. The areas between the two rivers, as well as the areas to the west and the east of the rivers, form plateaus that range from approximately 400 to 415 m above mean sea level.

The pipeline transportation system would be constructed from the oil field development area southwest toward the border with Cameroon. The topography is relatively flat for the first approximately 35 km to the crossing of the Kagopal-Goré road. Continuing southwest of Kagopal, the route crosses generally rolling topography ranging between approximately 500 m and 550 m in elevation, with occasional stream crossings.

Near Gadjibian the route would have more frequent stream crossings. The topography generally would range between 460 m and 550 m in elevation, with the lower elevations continuing to reflect the bottoms of drainage features. This topography would generally continue for the route to the border with Cameroon. However, southwest of the community of Bessao the route begins to be bordered to the south by mountains in excess of 800 m in elevation. Near the border with Cameroon, two mountains in excess of 850 m in elevation are present north of and within 10 km of the pipeline route.

6.5.2 Tectonic Setting

The study area is a relatively stable intra-plate region of West Africa. The West African subregion rests on a Precambrian platform that has been stable during the last 1,700 million years. Earthquakes have occurred in the subregion but are considered to be geologically and seismologically anomalous. The epicenters of the major West African earthquakes apparently are associated with deep fractures and paleostructures.

The main tectonic features are the Pelusium megashear system and the Cameroon Volcanic Line (Neev and Hall, 1982; Neev, et al., 1982). The megashear system consists of a series of fault zones and lineament swarms. The Cameroon Volcanic Line is a northeast trending line of volcanoes extending 1,600 km from Pagalu Island in the Atlantic Ocean through northern Cameroon. The most recent volcanic activity of this chain occurred in 1982 on Mt. Cameroon, which is located roughly 50 km north of the coastal town of Limbé in Cameroon (Ambraseys and Adams, 1986).

6.5.3 Geology

The proposed oil field development area consists primarily of continental sequences of sandstones and claystones that exceed 7,000 m in thickness at the center of the basin and span from early Cretaceous to recent (Figure 6.5-1). The sediments are underlain by Precambrian gneiss and quartz diorite (Geocon, 1995). The bedrock throughout the study area generally is overlain by more recent Quaternary deposits exposed at the ground surface. The deposits are of continental origin and range from clay to sand, depending on climatic conditions and tectonic movements. In the Doba Basin the deposits range from 40 to 150 m in thickness. A consolidated stratum commonly is found below the Quaternary deposits.

The northern portion of the pipeline route is generally underlain by the same geologic materials as noted for the oil field development area (Figure 6.5-1). In contrast, the southern portion of the route is generally underlain by intercalated, or interbedded, bedrock of continental origin. The bedrock is noted to be mostly sandstone, and the age is noted as Mesozoic.

6.5.4 Soils

6.5.4.1 Soil Classifications

The principal soil type of the oil field development area, which is located in a drier region of southernmost Chad, includes mostly ferruginous soils (Ferric and Plinthic Luvisols) and various juvenile soils (Lithosols, Regosols, and Orthic Fluvisols) associated with eroded surfaces and late Quaternary sediments (Figure 6.5-2). The juvenile soils are often associated with alluvium in the river valleys and colluvium on hill slopes and pediments.

The pipeline route is underlain by ferruginous soils, as well as ferrallitic soils (Ferralsols of the Food and Agricultural Organization of the United Nations Soil Classification System and Oxisols and Ultisols of the United States Department of Agriculture Classification System). Recent sediments along rivers are generally only weakly ferrallitic or are non-ferrallitic.

The southern portion of the route is mapped as being underlain by zones of relatively shallow bedrock with erodible soils. Erosion of the landscape throughout the study area involves mainly incision of the surface by streams and rivers. Landsat imagery indicates accelerated erosion in several areas of southwest Chad. The largest of these areas were apparently locations of dense human settlement and land use, particularly on hillsides and along river valleys. High suspended sediment loads in the rivers and evidence of extensive overgrazing indicate that soil erosion is severe locally.

Fersiallitic soils, which are commonly sodic and are susceptible to erosion, are not widespread in southwest Chad. However, smectite-rich horizons associated with ferricretized ferrallitic soils have been reported. Extremely high rates of erosion and catastrophic gullying have been observed with similar soil horizons in southeast Nigeria.

6.5.4.2 Geotechnical Characteristics

Subsurface engineering soil data were collected at the proposed locations of various project facilities and infrastructure. Data collection included borings to a maximum depth of 10 m, dynamic cone penetration tests to a maximum depth of 20.4 m, and backhoe excavated test pits (Geocon,1995). The engineering characteristics of the soils were determined based on results of field data collected and geotechnical engineering-related laboratory testing.

Soil conditions were found to be variable. The primary soils encountered at the individual project facilities were as follows:

- The Operations Center (OC) plant, community, airfield sites, general areas of the Komé gathering station, and the field pump stations were characterized by sandy and clayey silts. These soils are moderately sensitive to settlement and have been found to be collapsible. Lateritic gravel was identified under the sandy and clayey silts.
- The Miandoum and Bolobo gathering station areas were generally found to be underlain by stratified layers of clayey sand and lateritic gravel. The soils were less sensitive to settlement than the soils encountered at the OC plant, community, and airfield sites but were considered to be collapsible. Maximum foundation settlements in excess of 30 mm were predicted based on the anticipated loads associated with the structures.
- The upper 1.0 m of sections of the pipeline route within the oil field development area was generally found to be underlain by clayey and/or silty sand, except across the Miandoum area where hard laterite soils were encountered at a relatively shallow depth. The clayey and/or silty clay soils were considered to be collapsible. No estimated maximum settlements were determined.

Topsoil overlaid some of the above-mentioned soils to a depth of up to 0.5 m in depth. The temperatures of the soils at depths of 1 and 2 m were found to range between 31 and 32°C. The soils were also found to be moderately corrosive. The pH of the soils generally ranged between 6.8 and 8.4. The sulfate content of the soils tested was found to be less than 0.005 percent, which is considered to be low (Geocon, 1995).

6.5.5 Seismicity

As noted in Section 6.5.2, seismicity in the Chad-Cameroon area is low relative to the east African rift zone or active mid-Atlantic plate boundary region. The oil field development area is roughly 1,500 km from the active continental rift zone in eastern Africa. The oil field development area and the pipeline route are located even farther away from the mid-Atlantic Ridge. Both the rift zone and the mid-Atlantic Ridge are considered to be a sufficient distance from the project area so as not to present a seismic hazard to the oil field development area or the pipeline.

Earthquake epicenter data recorded in the west-central African region during approximately the last 200 years were provided by the National Oceanic and Atmospheric Administration (NOAA) and indicate a relatively low level of seismic activity in the region, consistent with the tectonics. Of greater interest are the larger shocks of magnitude $M \geq 6$ or Modified Mercalli Intensity, $MMI \geq VII$.

Known earthquakes closest to the study area are small magnitude events that occurred over 200 km away. The two closest moderate earthquakes are the March 1911 event with reported magnitudes of 5.7 and 6.5, and the September 1945 event with reported magnitudes ranging from 5.5 to 6.2. The epicenters of both these events are more than 500 km from the project area. The low rate of seismicity in the region suggests that the likelihood of a moderate to large earthquake of $M \geq 5$ impacting the project during its lifetime is very low. The pipeline alignment was not found to cross mapped active faults.

6.6 METEOROLOGY AND AIR QUALITY

Descriptions of the climate in Chad and the study area, existing air pollution sources, carbon dioxide and methane levels, and ambient air quality are contained in this section. The assessment of the existing environment with respect to meteorology and air quality utilized the project literature review and data assimilation (Dames & Moore, 1993), more specialized literature on these subjects, and limited data collected during environmental data gathering trips and field studies in Chad. In addition, meteorological data have been collected at an automated weather station at Komé since 1995.

6.6.1 Environmental Setting

Regional air quality is generally determined by prevailing climatological and geographical conditions and the type and amount of air pollutants emitted. Climatological and geographical conditions affecting air quality include typical wind patterns, topography, temperature, and temperature inversions. These climate-related factors combine to determine how pollutants disperse or accumulate.

6.6.1.1 Climate of Chad

The African continent is affected by wind and pressure systems of equatorial, subtropical, and mid-latitude origins. In the tropics, including Chad, winds are predominantly easterly. The terrain of southern Chad is relatively flat, therefore topographical features do not affect predominant surface wind directions nor do they govern air pollutant accumulation and dispersal.

Annual rainfall in the Doba Basin is typically between 1,000 and 1,300 mm. Table 6.6-1 provides annual rainfall data for the Chad-Doba region averaged over a series of 10 year periods. The dry season extends from November to May in southern Chad. Temperatures in the area range from 20 to 25°C, rising to as much as 40°C.

6.6.1.2 Existing Air Pollution Sources

Typical air pollution sources include industrial facilities, automobiles, agricultural activities, and windblown dust. Generally, air pollutant concentrations are high in areas of heavy urbanization and development and low in undeveloped areas. In the study area, few air pollution sources exist other than agricultural activities. Agricultural activity, including slash and burn practices, would likely be a source of windblown dust, although dust emissions would be low since agricultural machinery is not in use and average annual rainfall is high.

6.6.1.3 Ambient Air Quality

Monitored air quality data for the Chad area are not available; however, air quality in the region can be characterized by reviewing the types and quantities of existing air pollution sources and comparing this information to similarly developed areas where pollutants are monitored. As described above, the study area is heavily agricultural with no appreciable industrial development. Accordingly, there are few sources of nitrogen oxide (NO_x), sulfur dioxide (SO_2), or ozone precursor emissions, and concentrations of these pollutants are expected to be low. Background data regarding ambient pollutant concentrations are summarized below.

The chief sources of NO_x, including nitrogen dioxide (NO_2) in developed societies, are motor vehicles and industrial developments. Because neither of these emission sources is readily present in the study area, estimated background NO_2 concentrations are expected to be low. NO_2 concentrations are monitored throughout the United States; in rural and undeveloped areas, annual average ambient NO_2 concentrations are typically less than one tenth of the U.S. standard of 100 micrograms per cubic meter.

Ambient SO_2 concentration levels in undeveloped regions of the United States are typically less than one tenth of the U.S. standard (365 micrograms per cubic meter). Therefore the assumed level in the study area of one-tenth the U.S. standard is considered to be conservative.

Based on the lack of hydrocarbon and NO_x emission sources in the study area, ozone concentrations are expected to be well below 0.10 parts per million (ppm). The U.S. standard for ozone is 0.12 ppm, and this standard is exceeded only in heavily urbanized areas of the United States. Ozone concentrations in the study area are likely to be in the range of 0.01 to 0.05 ppm.

Sources of particulates with diameters less than 10 microns (PM_{10}), namely agricultural operations and clearing, exist in the study area, although abundant annual rainfall in the area (shown in Table 6.6-1) would minimize airborne particulate concentrations.

6.6.1.4 Carbon Dioxide and Methane

Large variations exist in the scientific knowledge about the climatic impacts of these gases. The gas of primary global concern is carbon dioxide (CO_2), although methane (CH_4), nitrous oxide, and halocarbons, which constitute mainly chlorofluorocarbons (CFCs), are also of concern. Pollutants including NO_x, carbon monoxide (CO) and nonmethane hydrocarbons are also of concern not because of direct effects, but because of their potential to affect climate indirectly through chemical and physical processes in the atmosphere. Gases are well mixed in the atmosphere, a characteristic that renders climate impacts independent of the geographical location of the emissions.

In Africa the effects of these gases warrant particular attention because of the vulnerability of the continent to natural climate events. Africa faces land degradation from agriculture, deforestation, human settlements, desertification, poor crop choices, and poor land practices. As gaseous emissions increase, the effects of climate change could have repercussions on agricultural production, water availability, natural vegetation, pests and diseases.

A source of global CO_2 emissions is the combustion of fossil fuels. A broadly estimated summary of world CO_2 emissions from fossil fuels, industrial sources, and land use change by region is provided in Table 6.6-2. As shown, nearly 75 percent of worldwide CO_2 emissions result from solid, liquid, or gas fossil fuel use (Selrod et al., 1995).

In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted by more than 150 countries. The objective of the Convention was to regulate levels of CO_2 and CH_4 gas concentrations in the atmosphere to avoid the occurrence of climate change on a level that would impede sustainable economic development or compromise initiative(s) in food production. The Republic of Chad signed the Convention on June 12, 1992 and ratified the Convention on June 7, 1994.

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6.7 PUBLIC HEALTH

Discussions of the existing public health status, including disease incidence and prevalence rates, are presented as Appendix C to the EA. The public health and disease status in Chad was assessed through a combination of literature searches/reviews and by accessing Ministry of Health (MOH) data for each prefecture. MOH disease data for 1988 to present were reviewed and analyzed. Project-specific malaria data were based on actual medical records reviewed during the 1994-1996 time period.

The overall public health status of Chad can be analyzed by examining overall health morbidity and mortality statistics within the country. These statistics are a general reflection of the aggregate health situation in the country and can be compared with Sub-Saharan Africa and with other low income regions. Key demographic and disease rates are also compared to established market economies so that Chadian values can be placed in perspective. A major project such as the Chad Export Project has the potential to both positively and negatively impact the aggregate health care status in Chad. Appendix C discusses the health data currently available and relevant to the project. The linkages between health, the environment, and the project are explored in Section 7.0. Mitigation strategies are presented in Section 8.0.

The Public Health Appendix was based on data obtained from Chadian Government documents, World Bank reports and publications, World Health Organization publications, USAID reports and publications, and studies published in the scientific literature. There are 51 tables and 24 figures that are presented in the appendix in addition to detailed discussion and analysis. A complete bibliography is included as part of the appendix. The areas covered in the Public Health Appendix include:

- Project Setting
- Sources of Information
- Disease Data and the World Bank's "Bridging Environmental Health Gaps"
- Disease Control Priorities in Developing Countries
- Strategies for Public Health Intervention
- Demographic Data
- Population
- Core Demographic Data
- Demographics and Health of Adults
- Disease-specific Data
- Sub-Saharan Africa Disease Data
- Sub-Saharan Infectious Diseases
- Chad Infectious Disease Data
- Person-to-person Infectious Diseases
- Food, Water, and Soil Borne Infectious Diseases
- Insect Vector Infectious Diseases
- Animal Borne Infectious Diseases (Including New and Emerging Diseases)
- Emerging Diseases and Antibiotic Resistance in Infectious Diseases
- Sexually Transmitted Diseases (Including AIDS and Hepatitis B/C)

- HIV/AIDS in Sub-Saharan Africa
- Transmission Models of HIV and STDs
- HIV/AIDS in Chad
- AIDS/HIV
- Government Strategy for HIV/AIDS in Chad
- Conclusions and Summary.

TABLE 6.1-1
SUMMARY DESCRIPTION OF TERRAIN ANALYSIS UNITS
CHAD-CAMEROON PIPELINE SYSTEM

TERRAIN UNITS	GEOLOGY	SOILS AND POTENTIAL PHYSICAL ENVIRONMENTAL IMPACTS		NATURAL VEGETATION*	VEGETATION CODES*
M MOUNTAINS Rugged, heavily dissected terrain with moderate to steep slopes and rock outcrops	Mainly syntectonic granites and granulites; some lower gneisses and associated quartz diorites and conglomeratic quartzites (Lom Series); some Cretaceous plateau basalts and Quaternary volcanics	Raw mineral soils of non-climatic origin (Lithosols); weakly developed soils on colluvial materials and eroded surfaces (Regosols)	i: slopes greater than 20% accessible only with pioneer tracks ii: land easement requiring large excavation for greater than 12% haul roads iii: large volume of vegetation and soil/rock removal for battered road cuts iv: landslides possible v: fill and gully erosion on soil vi: natural surface flow permanently disrupted vii: surface water quality significantly affected during construction	a: wooded savanna (*Isoberlinia doka, Terminalia brownii, Monotes kerstingii, Boswellia dalzeili, Boswellia papyrifera, Sterculia tomentosa, Erythrina sp.*) b: wooded and bushy savanna often degraded through quasi-permanent pastoralism (*Daniellia oliveri, Lophira lanceolata, Hymenodictyon floribundum* and thorn brush) c: semi-deciduous forest (*Sterculiaceae* and *Ulmaceae*) with *Anogeissus leiocarpus* and areas of regrowth d: evergreen forest (*Caesalpiniaceae*), sub-montane forest and some pockets of *Monopetalanthus pellegrinii*	a: 17[P] (upland vegetation); 46 (more or less degraded Sudanian vegetation) b: 98 (Sudano-Guinean vegetation on rough terrain); 82 (wooded and bushy savanna); 90 (savanna degraded by overgrazing); 119 (degraded sub-montane forms) c: 159 (northern semi-deciduous forest); 160 (semi-deciduous forest); 172 (regrowth forest) d: 117 (sub-montane forest); 119 (degraded form); 205 (evergreen forest with rare *Caesalpiniaceae*); 216 (stands of *M. pellegrinii*); 228 (evergreen forest with *Caesalpiniaceae*); 231 (evergreen forest with *Caesalpiniaceae* and *S. gabonensis*); 233 (mixed semi-deciduous/evergreen forest); 245 (saxicole)

TABLE 6.1-1
SUMMARY DESCRIPTION OF TERRAIN ANALYSIS UNITS
CHAD-CAMEROON PIPELINE SYSTEM

TERRAIN UNITS	GEOLOGY	SOILS AND POTENTIAL PHYSICAL ENVIRONMENTAL IMPACTS		NATURAL VEGETATION*	VEGETATION CODES*
H HILLS Slightly to moderately dissected terrain comprising gentle to moderate slopes; may occasionally include small areas of pediment and associated rocky outcrops; sometimes represents severely dissected plains or dissected margins of plateaux where scattered hummocks or low outlying hills occur in the landscape	Variable; mainly granites, gneisses, and migmatites	Weakly developed soils on colluvium and eroded surfaces (Regosols); raw mineral soils of non-climatic origin (Lithosols); leached soils (Orthic Luvisols), fersiallitic soils (Chromic Luvisols), leached ferruginous tropical soils (Ferric Luvisols), and ferricretes (Plinthic Ferralsols and Plinthic Luvisols)	i: slopes of 10 to 20% accessible with steep haul roads ii: locally wide land easement with moderate to large excavation iii: moderate volume of vegetation and soil/rock removal iv: landslides low possibility v: moderate development of rills and gullies vi: locally as M/vi vii: as M/vii	a: wooded savanna (see M/a above) and also including *Afzelia africana, Anogeissus leiocarpus, Monotes kerstingii, Parinari curatellifolia, Uapaca togoensis*) b: wooded and bushy savanna (see M/b above) c: bushy near-forest savanna and shrubby intra-forest savanna (*Terminalia glaucescens, Annona senegalensis, Bridelia ferruginea* and *Imperata cylindrica, Pennisetum purpureum* in grassy areas d: evergreen forest mainly *Caesalpiniaceae* with pockets of *Monopetalanthus pelligrinii* and areas of *Saccoglottis gabonensis*	a: 17[P]; 67 (Sudanian wooded savanna) b: 82; 90; 91 (wooded and bushy savanna on eroded soils and severely overgrazed areas); 92 (bushy areas) c: 138 (near-forest savanna with Sudano-Guinean elements); 143 (near-forest savanna); 144 (transitional form); 149 (intra-forest and near forest savanna with *P. purpureum*); 150 and 182 (saxicole); 159 (northern semi-deciduous forest); 160; 169 (very degraded form); 170 (totally degraded form); 171 (very degraded mixed evergreen/semi-deciduous forest); 172 d: 169; 205; 216; 228; 231; 233; 251 (very degraded evergreen forest); 255 (oil palm plantations)
E ESCARPMENTS Mostly steep terrain along the edge of plateaux and tablelands; typically separates two landscapes at significantly different elevations	Typically syntectonic granites; some late syntectonic granites, migmatites, and migmatitic gneisses	See M above	i: as for M/i ii: as for M/ii iii: as for M/iii iv: as for M/iv v: as for M/v vi: as for M/vi vii: as for M/vii	a: wooded savanna (see M/a above with mainly *Boswellia papyrifera*) b: wooded and bushy savanna (see M/b above) c: bushy near-forest savanna and shrubby intra-forest savanna (see M/c and H/c above) d: evergreen forest (*Caesalpiniaceae* with *Saccoglottis gabonensis* locally)	a: 46 b: 90; 119 c: 159; 160; 172 d: 228; 231; 245

TABLE 6.1-1
SUMMARY DESCRIPTION OF TERRAIN ANALYSIS UNITS
CHAD-CAMEROON PIPELINE SYSTEM

TERRAIN UNITS	GEOLOGY	SOILS AND POTENTIAL PHYSICAL ENVIRONMENTAL IMPACTS		NATURAL VEGETATION*	VEGETATION CODES*
G PEDIMENTS, FOOTSLOPES AND PEDIPLAINS Lower hillslopes and plains made up of coalescing, low-angle slopes **1: Pediments and Footslopes** Concave slopes and low-angle footslopes bordering hills, escarpments, and mountains; also represents footslopes along dissected edges of plateaux and transitional zones between the margins of upland plains and adjacent valley floors	Various; generally similar lithologies to those associated with mountains and hills	Leached soils (Orthic Luvisols), fersiallitic soils (Chromic Luvisols), and leached ferruginous tropical soils (Ferric Luvisols); weakly developed soils on colluvium and eroded surfaces (Regosols); ferrallitic soils (Ferralsols)	i: slopes of 5 to 10% generally accessible with haul roads ii: occasionally wide land easement with moderate to large excavation iii: moderate volume of vegetation and soil removal iv: landslides unlikely v: as for H/v vi: surface water quality affected during construction	a: wooded savanna (*Isoberlinia doka, Anogeissus leiocarpus, Oxytenanthera abyssinica* locally) b: wooded and bushy savanna (*Daniellia oliveri, Lophira lanceolata*) c: bushy near-forest savanna (*Terminalia glaucescens, Pennisetum purpureum*); semi-deciduous forest (*Sterculiaceae, Ulmaceae*); and regrowth forest and cultivated forest (cocoa) d: evergreen forest dominated by *Caesalpiniaceae*	a: 2^P (wooded tree savanna transitional to gallery forest and marshy grassland); 17^I 67 b: 82; 92 c: 138; 143; 172; 174 (domestic forest agriculture - mainly cocoa) d: 124 (tea plantations); 169; 208 (very degraded evergreen forest); 228; 251 252 (totally degraded evergreen forest)
2: Pediplains Gently inclined plains often adjacent to river valley bottoms; generally slightly incised by small, often seasonal watercourses; pockets of ferricrete are common especially in the Chad Basin	Various	Leached soils (Orthic Luvisols), fersiallitic soils (Chromic Luvisols), and leached ferruginous tropical soils (Ferric Luvisols); ferrallitic soils (Ferralsols); ferricretes (Plinthic Ferralsols and Plinthic Luvisols)	i: slopes of 2 to 5% accessible with normal road ii: normal land easement (about 30 m wide) with typical excavation iii: normal volume of vegetation and soil removal iv: as G1 v: development of some rills vi: surface water quality only locally affected	a: see G1/a (above) b: - c: - d: degraded evergreen forest	a: 2^P b: - c: - d: 251

TABLE 6.1-1
SUMMARY DESCRIPTION OF TERRAIN ANALYSIS UNITS
CHAD-CAMEROON PIPELINE SYSTEM

TERRAIN UNITS	GEOLOGY	SOILS AND POTENTIAL PHYSICAL ENVIRONMENTAL IMPACTS		NATURAL VEGETATION*	VEGETATION CODES*
P PLATEAUX Relatively flat to undulating upland landscapes **1: Dissected Tablelands** Flat plateau remnants separated by a pattern of moderately to deeply incised principal watercourses creating a landscape of rough terrain (generally at elevations of 1,200 to 1,300 m above sea level)	Mainly syntectonic granites and Cretaceous plateau basalts	Weakly to moderately desaturated ferrallitic soils (Rhodic Ferralsols) and indurated ferrallitic soils (Plinthic Ferralsols); weakly developed soils on colluvium and eroded surfaces (Regosols)	i: slopes less than 5% ii: as for G2/ii iii: as for G2/iii iv: as for G2/iv v: development of occasional rill erosion vi: as for G2/vi	a: - b: bushy and wooded savanna (*Daniellia oliveri, Lophira lanceolata, Terminalia mollis, Terminalia macroptera*) with areas of degradation due to overgrazing and soil erosion c: - d: -	a: - b: 82; 90; 91 c: - d: -
2: Upland Plains Relatively flat to gently rolling landscapes moderately to deeply incised by numerous closely spaced water-courses forming dendritic networks; numerous small pockets of ferricrete occur on the interfluves (generally at elevations of 800 to 1,000 m above sea level)	Mainly syntectonic granites; also Cretaceous basalts and sandstones in the Mbéré-Djerem Graben	Weakly to moderately desaturated ferrallitic soils (Rhodic Ferralsols) and indurated ferrallitic soils (Plinthic Ferralsols); leached tropical ferruginous soils (Ferric Luvisols)	i: slopes generally less than 5% except in stream valleys ii: as for G2/ii iii: normal to locally moderate volume of vegetation removal iv: as for G2/iv v: localized rills and gullies vi: as for G2/vi	a: wooded savanna (*Isoberlinia doka, Prosopis africana, Anogeissus leiocarpus, Burkea africana, Amblynocarpus andongensis, Daniellia oliveri* also *Monotes kerstingii, Boswellia dalzielii, Sterculia tomentosa, Acacia hebe-cladoides, Erythrina sp.*) also fallow with *Terminalia laxiflora* and *Isoberlinia angolensis*; see VI/a for description of gallery forest in valleys b: see P1/b with areas of *Samanea eriorachis* and V1/b for description of gallery forest in valleys c: - d: -	a: 66 (degraded savanna on rocky soils); 67 b: 82; 90; 91; 92 c: - d: -

TABLE 6.1-1
SUMMARY DESCRIPTION OF TERRAIN ANALYSIS UNITS
CHAD-CAMEROON PIPELINE SYSTEM

TERRAIN UNITS	GEOLOGY	SOILS AND POTENTIAL PHYSICAL ENVIRONMENTAL IMPACTS		NATURAL VEGETATION*	VEGETATION CODES*
3: Rolling Plains Mostly rolling landscape, slightly incised by numerous moderately to closely spaced stream channels; in less dissected areas, ferricretes occur as scattered pockets and broad sheets of plinthite on the inter-fluves (generally at elevations of 600 to 800 m above sea level - mostly about 700 m in Cameroon, and at 460 to 560 m in the Chad Basin)	Mainly migmatites, migmatitic gneisses, gneisses, mica-schists, and schists	Weakly to moderately desaturated ferrallitic soils (Rhodic Ferralsols), strongly desaturated, yellow ferrallitic soils (Xanthic Ferralsols), and indurated ferrallitic soils (Plinthic Ferralsols) locally; in Chad, leached tropical ferruginous soils (Ferric Luvisols) which may be locally indurated (Plinthic Luvisols)	i: slopes 5 to 15% ii: as for G1/ii iii: as for P2/iii iv: as for G2/iv v: as for P2/v vi: as for G2/vi	a: see G1/a and P2/a b: - c: intra-forest and near-forest savanna (*Terminalia glaucescens* with *Annona senegalensis, Bridelia ferruginea* in bushy areas, and *Imperata cylindrica* in grassy areas); semi-deciduous forest (*Sterculiaceae, Ulmaceae*); and mixed semi-deciduous and ever-green forest (includes forest agriculture and degraded and regrowth phases) d: -	a: 2^P b: - c: 138; 143; 146 (bushy intra-forest and near-forest savanna); 147 (grassy intra forest and near-forest savanna); 149; 159; 160; 164 (mixed semi-deciduous/evergreen forest - Dja area); 169; 170; 171; 172; 174 d: -
4: Rift Valley Plains Mostly rolling terrain, changing to slightly undulated near the northern limits of the unit, generally bounded by hills and escarpments marking the margins of a graben or fault trough; the valley floor is moderately incised and repeatedly broken by watercourses; occurs along the Mbéré River and the Logone River in Cameroon and south-west Chad; scattered pockets of ferricrete occur especially in the northern end of the Valley toward the confluence of the Mbéré and Logone Rivers	Various; typically Cretaceous sandstones and conglomerates, late Tertiary continental sediments (associated with the Chad Basin), and syntectonic granites	Weakly to moderately desaturated ferrallitic soils (Rhodic Ferralsols); leached tropical ferruginous soils (Ferric Luvisols)	i: slopes irregular, <5% ii: normal to occasionally moderately wide land easement and excavation iii: as for G2/iii iv: landslides not present v: occasional rill erosion vi: as for G2/vi	a: see G1/a and P2/a also *Burkea africana* with *Butyrospermum parkii, Swartzia madagascarien-sis, Pseudocedrela kotschyi*) b: - c: - d: -	a: 1^P (wooded tree savanna); 2^P; 3^P (wooded tree savanna on ferricretes); 54 (Sudano-sahelian savanna fallow); 68 (degraded Sudanian fallows on stony soils) b: - c: - d: -

TERRAIN UNITS	GEOLOGY	SOILS AND POTENTIAL PHYSICAL ENVIRONMENTAL IMPACTS		NATURAL VEGETATION*	VEGETATION CODES*
D DURICRUSTS Indurated surficial or near-surficial horizons typically occurring on tablelands and upland plains; only occasionally incised by watercourses **1: Ferricretes** Surfaces cemented by iron minerals - either massive plinthites or gravelly pisolithic strata	Mainly syntectonic granites, migmatites, and migmatitic gneisses	Indurated ferrallitic soils (Plinthic Ferralsols); indurated, leached tropical ferruginous soils (Plinthic Luvisols)	i: as for P1/i ii: as for G2/ii iii: as for G2/iii but requiring additional ripping and blasting iv: no landslides expected v: limited rill and gully erosion vi: as for G2/vi	a: grassland and wooded savanna (*Hymenocardia acida, Combretum nigrescans, Monotes kerstingii, Eragrostis cambessiadana* and with *Oxytenanthera abyssinica* locally) b: Grasslands and wooded savanna with *Ctenium newtonii*, and *Oxytenanthera abyssinica* locally c: Grasslands and wooded savanna with *Terminalia glaucescens, Annona senegalensis, Bridelia ferruginea, Imperata cylindrica, Pennisetum purpureum* and *Bulbostylis laniceps;* some areas of semi-deciduous forest d: -	a: 3[P]; 69 (Sudanian vegetatior on ferricretes) b: 82; 90; 99 (Sudano-Guinean vegetation on ferricretes) c: 143; 146; 147; 149; 160; 172 d: -
2: Bauxites Aluminium-enriched surfaces - horizons rich in gibbsite often overlying buried ferricretes	Generally syntectonic gneisses though a close genetic association with plateau basalts has been reported	Indurated ferrallitic soils (Plinthic Ferralsols)	i: as for P1/i ii: as for G2/ii iii: as for G2/iii iv: as for D1/iv v: as for P1/v vi: as for G2/vi	a: - b: see D1/b c: - d: -	a: - b: 99 c: - d: -

TERRAIN UNITS	GEOLOGY	SOILS AND POTENTIAL PHYSICAL ENVIRONMENTAL IMPACTS		NATURAL VEGETATION*	VEGETATION CODES*
V VALLEYS Bottomlands and footslopes along seasonal and perennial watercourses; **1: Stream Valleys** Narrow bottomlands and valley sides along principal, mainly seasonal watercourses, usually devoid of appreciable alluvial deposits	Various	Various including indurated ferrallitic and hydromorphic soils (Plinthic Ferralsols and Gleysols), hydromorphic soils with little organic matter (Gleysols and Gleyic Luvisols), and both raw mineral soils and weakly developed soils on alluvium (Regosols and Fluvisols)	i: slopes 10 to 20% ii; typical land easement iii: moderate volume of soil removal for ditching pipeline below stream bed iv: as for G1/iv v: as for H/v vi: natural surface water flow permanently disrupted vii: as for M/vii	a: gallery forest (*Berlinia grandiflora, Vitex cuneata, Syzygium guineense, Anthocleista oubanguiensis, Tricalysia okelensis, Ficus capensis, Borassus aethiopum, Hyphaene thebaica, Dalbergia melanoxylon, Acacia seyal, Balanytes aegyptiaca, Lannea humilis, Capparis decidua, Maerua crassifolia*) b: gallery forest (*Syzygium guineense*). c: gallery and riverine forest (*Borassus aethiopum, Uapaca heudelotii, Mitragyna stipulosa, Raphia sp.*) and stands of *Gilbertiodendron dewevrei* d: riverine forest and grassland (*Caesalpiniaceae, Saccoglottis gabonensis, Raphia sp., Phoenix reclinata, Pennisetum purpureum*); some plantations of *Aucoumea klaineana*	a: 19^{P} (basin and riverine vegetation); 71 (Sudano-sahelian gallery forest); 73 (Sudanian and Sudano-Guinean gallery forest) b: 95 (gallery forest in ravines); 97 (Sudanian and Sudano-Guinean gallery forest) c: 151 (wooded and bushy river margins); 157 and 18((*Raphia* swamps and forest); 189 (stands of *G. dewevrei* on drier soils) d: 228; 231; 247 (littoral evergreen forest with *S. gabonensis*); 248 (plantations of *A. klaineana*); 250 (littoral evergreen forest with *S. gabonensis* and *L. alata*)

TABLE 6.1-1
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CHAD-CAMEROON PIPELINE SYSTEM

TERRAIN UNITS	GEOLOGY	SOILS AND POTENTIAL PHYSICAL ENVIRONMENTAL IMPACTS		NATURAL VEGETATION*	VEGETATION CODES*
2: River Valleys Bottomlands and adjacent valley sides along mainly perennial rivers usually having broad, flat bottoms often consisting of ferricretized alluvium	Various	Various including indurated ferrallitic soils (Plinthic Ferralsols), mineral hydromorphic soils with little humified organic matter and with iron accumulation (Plinthic Gleysols), and leached ferruginous tropical soils both indurated (Plinthic Luvisols) and hydromorphic (Gleyic Luvisols); also raw mineral soils (Regosols) and weakly developed soils on alluvium (Fluvisols)	i: slopes 5 to 10% ii: as for V1/ii iii: large volume of soil removal below river bed iv: as for G2/iv v: as for G2/v vi: as for V1/vi vii: as for M/vii but V2 rivers generally contain high sediment loads	a: see V1/a (also *Combretum glutinosum, Sclerocarya birrea, Anogeissus leiocarpus*); grasses include (*Andropogon gayanus, Pennisetum pedicellatum, Hyparrhenia rufa, Ctenium elegans*) b: - c: gallery and riverine semi-deciduous forest (*Sterculiaceae, Ulmaceae, Uapaca heudelotii, Borassus aethiopum, Raphia sp. (monbuttorum)*, and *Pennisetum purpureum* and *Imperata cylindrica* in open areas of grassland) d: riverine forest (*Caesalpiniaceae, Saccoglottis gabonensis, Phoenix reclinata, Raphia sp (monbuttorum)*)	a: 19P; 72 (Sudanian gallery forest); 131 (marshy grassland) b: - c: 147; 151; 160; 180 d: 231; 247; 251; 252

TABLE 6.1-1
SUMMARY DESCRIPTION OF TERRAIN ANALYSIS UNITS
CHAD-CAMEROON PIPELINE SYSTEM

TERRAIN UNITS	GEOLOGY	SOILS AND POTENTIAL PHYSICAL ENVIRONMENTAL IMPACTS		NATURAL VEGETATION*	VEGETATION CODES*
A ALLUVIAL PLAINS Extensive alluvial deposits accumulated along rivers and principal streams; most are subject to periodic inundation **1: River Flood Plains** Areas of alluvium on river and stream valley floors and adjacent older terraces	Various	Raw mineral soils and weakly developed soils on alluvium (Fluvisols); leached hydromorphic soils and leached gley soils (Gleyic Luvisols)	i: slope less than 5% - poor trafficability particularly during the wet season ii: normal to wide land easement if poor trafficability requires earthworks iii: normal to moderately large excavated volume iv: no landslides v: minimal development of sheet, rill, and gully erosion vi: flooding and surface and groundwater quality locally affected vii: higher rate of corrosion in periodically inundated soils	a: see V1/a; Grassy areas with *Pennisetum purpureum*; more extensively flooded areas with *Limnanthemum indicum, Ultricularia* sp. and *Dissotis incana* b: see V1/b; also riverine forest with *Brachystegia eurycoma, Uapaca togoensis, Syzygium guineense, Raphia sp.* c: see V1/c and V2/c; also *Loudetiopsis ambiens* and *Vetiveria nigritana* and belts of *Borassus aethiopum* in seasonal swamps; *Echinochloa pyramidalis* in inundated grasslands d: see V1/d (also *Uapaca sp.*)	a: 19^{P} b: 131 c: 152 (marshy depressions); 154 (marshy grasslands); 155 (swamp forest); 226 (grassy swamps) d: 252; 256 (swamp forest)
2: Deltas Broad areas of alluvium associated with estuarine sedimentation	Quaternary sediments	Raw mineral soils and weakly developed soils on alluvium (Fluvisols - Eutric, Dystric, Thionic); hydromorphic soils and gley soils (Gleysols)	i: slope less than 5% - extremely poor trafficability during wet season ii: as for A1/ii iii: as for A1/iii iv: as for A1/iv v: as for A1/v vi: as for A1/vi vii: as for A1/vii	a: - b: - c: - d: occasionally flooded estuarine flats (*Guibourtia demeusei, Oxystigma mannii, Raphia hookeri, Raphia vinifera, Rhizophora racemosa, Pandanus candelabrum, Avicennia nitida, Acrostícum aureum*); plantations of *Hevea brasiliensis* and *Elaeis guineensis*	a: - b: - c: - d: 251; 252; 254 (rubber plantations); 255; 256; 261 (*Raphia* stands adjacent to mangrove swamps)

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SUMMARY DESCRIPTION OF TERRAIN ANALYSIS UNITS
CHAD-CAMEROON PIPELINE SYSTEM

TERRAIN UNITS	GEOLOGY	SOILS AND POTENTIAL PHYSICAL ENVIRONMENTAL IMPACTS		NATURAL VEGETATION*	VEGETATION CODES*
S SWAMP AND MARSHLANDS Lowlying areas inundated for much of the year, but subject to periodic drying; **1: Riverine Swamps and Marshes** Wetlands along reaches of rivers and streams with minimal gradient, and bordering lakes and reservoirs	Various; the Nyong basin marshes are associated with upper gneisses and migmatitic gneisses but epeirogenic influences probably account for their location	Raw mineral soils and weakly developed soils on alluvium (Fluvisols); hydromorphic soils - gley soils, humic gley soils, and indurated hydromorphic soils (Gleysols - Eutric, Dystric, Mollic, Humic, Plinthic [?])	i: slope less than 2% ii: standard to wide land easement if buggies/barges or extensive fill required iii: standard to large volume of vegetation and shallow soil removal iv: natural surface and shallow groundwater flow and quality degraded during construction v: corrosion potential high, particularly if pipeline is not continually under water	a: grassland and marshes with hydrophytes such as *Nymphaea rufescens* in areas of prolonged, deep inundation; see A1/a for areas of shallow flooding; peripheral areas with gallery forest (V1/a) b: swamp forest (*Raphia mambillensis, Borassus aethiopum*) c: swamp forest and marshes (*Sterculia subviolacea, Macaranga sp., Loudetiopsis ambiens, Borassus aethiopum, Raphia cf. monbuttorum, Zanthoxylum zanthoxyloides*, and *Vetiveria nigritana, Pennisetum purpureum* and *Echinochloa pyramidalis* in open areas) d: -	a: 19^P b: 154; 155 c: 154; 155; 180; 193 (swamp forest) d: -
2: Estuarine and Littoral Swamps and Marshes Wetlands, generally brackish, associated with deltas and related coastal influences	Quaternary sediments	Raw mineral soils and weakly developed soils on alluvium (Fluvisols - Thionic); hydromorphic soils - gley soils, humic gley soils (Gleysols - Mollic, Humic)	i: as for S1/i ii: as for S1/ii iii: as for S1/iii iv: large volume of vegetation and shallow soil removal for barge v: normal corrosion if pipeline continually underwater vi: as for S1/vi	a: - b: - c: - d: mangrove swamps (*Guibourtia demeusei, Oxystigma mannii, Raphia hookeri, Raphia vinifera, Rhizophora racemosa, Pandanus candelabrum, Pandanus satabiei, Anthostema anbryanum, Ctenolophon engleranus, Avicennia nitada, Rhizophora harrisonii, Rhizophora mangle, Acrosticum aureum*)	a: - b: - c: - d: 262 (lowlying mangrove swamps); 263 (mangroves on ironpan); 264 (mangroves on higher ground)

TABLE 6.1-1
SUMMARY DESCRIPTION OF TERRAIN ANALYSIS UNITS
CHAD-CAMEROON PIPELINE SYSTEM

TERRAIN UNITS	GEOLOGY	SOILS AND POTENTIAL PHYSICAL ENVIRONMENTAL IMPACTS		NATURAL VEGETATION*	VEGETATION CODES*
B BASINS Shallow closed depressions, usually found along broad, flat river valleys; subject to seasonal inundation	Syntectonic granites and migmatites and migmatitic gneiss (in the case of basins associated with ferricretized plateaux)	Weakly developed soils on alluvium (Fluvisols); hydromorphic soils (Gleysols); Vertisols?	i: as for S1/i ii: standard to wide land easement for extensive fill requirements iii: as for S1/iii iv: as for S1/iv v: as for S1/v	a: wooded savanna (*Randia nilotica, Nauclea latifolia, Gardenia erubescens*) and grassy basins (*Hyparrhenia rufa Eragrostis cambessiadana*) b: grassy basins (*Hyparrhenia rufa*) c: marshes and grassland (*Raphia sp.*) d: -	a: 19[P] b: 154; 155 c: 152; 154; 180 d: -
C COASTAL PLAIN Lowland plains lying between the coast and the range of hills to the east which define the margin of the interior plains; landscape is flat near the coast and progressively more rolling further inland, and is generally incised by numerous watercourses; elevations are usually below 200 m	Gneisses (upper, lower, granitic, and migmatitic), mica-schists, Cretaceous sandstones, and Tertiary sandstones, marls, and sands and clays; some Quaternary volcanics	Weakly to moderately desaturated ferrallitic and yellow ferrallitic soils (Ferralsols - Orthic, Xanthic)	i: slope from less than 2 to 10% ii: standard land easement iii: standard volume of vegetation and soil/rock removal iv: localized shallow landslides on hillslopes v: development of rills and gullies on hillslopes vi: natural surface and groundwater flow and quality affected during construction	a: - b: - c: - d: evergreen forest (littoral) (*Caesalpiniaceae* dominates in some zones and *Saccoglottis gabonensis* and *Lophira alata* in others); many degraded areas; plantations of *Hevea brasiliensis* and Elaeis guineensis	a: - b: - c: - d: 231; 247; 248; 250; 252; 254; 255
R COASTAL SAND RIDGES Littoral sand accumulations including beach deposits and some stabilized dunes	Quaternary alluvium, aeolian sands (?), and littoral marine deposits	Raw mineral soils and weakly developed soils on aeolian and/or marine sediments (Regosols - Entric, Dystric)	i: slope less than 5% to 15% ii: as for C/ii iii: as for C/iii iv: dust and wind erosion	a: - b: - c: - d: littoral forest (*Saccoglottis gabonensis, Klainedoxa microphylla*); sand dunes and beaches (*Hibiscus tiliaceus, Ipomea pes-caprae*)	a: - b: - c: - d: 267 (vegetation of littoral sand ridges)
				*Note: a: Sudanian bioclimatic zone b: Sudano-Guinean bioclimatic zone c: Guineo-Sudanian bioclimatic zone d: Atlantic Evergreen bioclimatic zone	*Note: After Pias (1970) [(P)]; an Letouzey (1985)

TABLE 6.2-1
DESCRIPTION OF LAND USE MAP UNITS

UNIT	CLASSIFICATION
A	Intensive Agriculture - Zones of concentrated traditional agriculture and associated recent fallows including occasional small pockets of disturbed natural background vegetation. Degradation of the background natural vegetation is implicit.
A1	Low Density Agriculture - Mosaic comprised of scattered traditional fields, fallows and pockets of mostly disturbed natural background vegetation.
A2	Bottomland Agriculture - Areas of active or recent scattered to intensive fields and fallows found in river or stream bottoms and gallery forests (gallery discontinuity). Includes recessional agriculture along riverbanks and in floodplains.
G	Intensive Livestock Grazing - Zones of concentrated traditional livestock production. Confined mostly to seasonally inundated grasslands/marshlands and river bottomlands in the Chad Basin and to the savannas in Cameroon.
G1	Low Density Livestock Grazing - Areas of low volume or sporadic livestock production (generally relatively less disturbed).
V	Village/Town - Includes settlements and surrounding common use areas.
P	Plantation - Areas of commercial/mechanized farming including palm oil, rubber, tea coffee, tobacco and sugar production.
L	Logging - Areas presently and recently exploited by commercial timber harvesting operations.
S	Disturbed Savanna - Mosaic comprised of grassland broken by scattered trees and shrubs, occasional scattered fields, scattered young scrub and old wooded fallows, and small pockets of relatively undisturbed wooded cover. Occurs mostly in the Chad Basin.
S1	Disturbed Savanna - Prevailing grassland broken by scattered trees and shrubs and occasionally old fallows or small pockets of relatively undisturbed wooded cover. Generally, heavily grazed. Occurs mostly in Cameroon.
S2	Savanna (species-poor/sparsely wooded) - Prevailing natural grassland with scattered trees and shrubs ranging from relatively undisturbed in remote places to disturbed around settlements and agricultural areas. Occurs mostly in the mosaic of the semi-deciduous forest-savanna transitional zone.
W	Wooded Savanna - Mostly prevailing tree cover with conspicuous openings of grass and shrub cover. Generally older woodland ranging from dense and relatively undisturbed in remote places to more broken and disturbed near intensive land use areas. In Chad, includes areas of old regrowth fallows and occasional widely scattered fields.
W1	Stream-side Wooded Savanna - Mature savanna woodland which borders seasonally inundated grasslands or marshlands and low gradient watercourses in the Chad Basin.
D	Forest Disturbance (semi-deciduous forest) - Comprises mostly areas of logged-over forest with occasional small areas of secondary forest and relatively undisturbed mature forest. Includes widely scattered forest agriculture and fallows along roads.
D1	Forest Disturbance (mixed evergreen/semi-deciduous forest) - Mosaic comprising areas of degenerate forest, scattered forest agriculture/fallows and small isolated areas of relatively undisturbed forest.
D2	Forest Disturbance (evergreen forest) - Mosaic comprising mostly logged-over forest with patches of scattered forest agriculture, fallows, and relatively undisturbed old-growth forest.

TABLE 6.2-1
DESCRIPTION OF LAND USE MAP UNITS
(CONTINUED)

F	Forest - Relatively undisturbed old growth forest including some areas of mature or well developed secondary forest. Represents semi-deciduous, mixed evergreen/semi-deciduous forest, or evergreen forest according to location and climatic conditions.
F1	Hillside Forest - Relatively undisturbed forest stands on moderate to steep hill or mountain slopes (sometimes isolated).
F2	Forest Edge Habit - Relatively undisturbed immature forest which is seemingly overgrowing the species-poor savannas and characteristic of the semi-deciduous forest edge in the forest-savanna mosaic of the transitional zone.
F3	Forest - Relatively undisturbed forest on moderate to steep slopes along incised watercourses in forested zones.
R	Gallery Forest - Stands of trees on slopes and banks along watercourses running through savanna.
R1	Riverine Forest - Comprises riparian stands of trees along watercourses, riverbanks and river bottomlands, in forested areas where flooding is not prolonged, and wetland forest.
M	Marshland/Seasonally Inundated Grassland - Marshy vegetation, characteristic of basins and areas along low gradient watercourses subject to periodic or seasonal flooding. Includes grasses and sedges and may include some scattered cultivation near settlements.
B	Barren/Eroded - Areas of scant natural vegetation including rocky areas and areas eroded by wind or water.

TABLE 6.2-2
RESIDENT POPULATION OF THE STUDY AREA

<table>
<tr><th colspan="5">LOGONE ORIENTAL</th></tr>
<tr><th>Subprefecture</th><th>Urban</th><th>Rural Sedentary</th><th>Rural Pastoralist</th><th>TOTAL</th></tr>
<tr><td>Bébédjia</td><td>9,336</td><td>59,123</td><td>1,765</td><td rowspan="3">70,224</td></tr>
<tr><td rowspan="2">Totals</td><td>9,336</td><td colspan="2">60,888</td></tr>
<tr><td colspan="2">68,459</td><td>1,765</td></tr>
<tr><td>Baibokoum</td><td>10,756</td><td>86,376</td><td>3,438</td><td rowspan="3">100,570</td></tr>
<tr><td rowspan="2">Totals</td><td>10,756</td><td colspan="2">89,814</td></tr>
<tr><td colspan="2">97,132</td><td>3,438</td></tr>
<tr><td rowspan="6">Total Population of Baibokoum and Bébédjia Subprefectures</td><td>20,092</td><td>145,499</td><td>5,203</td><td rowspan="6">170,794</td></tr>
<tr><td>Urban</td><td colspan="2">Total Rural</td></tr>
<tr><td>20,092</td><td colspan="2">150,702</td></tr>
<tr><td colspan="2">Sedentary</td><td>Pastoral</td></tr>
<tr><td colspan="2">165,591</td><td>5,203</td></tr>
</table>

TABLE 6.2-3
RESIDENT POPULATION OF LOGONE ORIENTAL AND LOGONE OCCIDENTAL

Logone	Urban		Rural		Total
Logone Oriental	Doba Town	Other Urban	Sedentary Farmers	Resident Pastoralists	
	18,052	27,541	384,427	10,322	440,342
Totals	45,593		394,749		
	430,020			10,322	
Logone Occidental	Moundou Town	Other Urban	Sedentary Farmers	Resident Pastoralists	
	97,952	21,189	330,342	5,657	455,140
Totals	119,141		335,999		
	449,483			5,657	
Total Population of Logone Oriental and Logone Occidental	Urban		Rural		
	164,734		730,748		895,482
	Sedentary			Pastoral	
	879,503			15,979	

TABLE 6.2-4
POPULATION DENSITY GRADIENT
(PERSONS/KM²)

Prefecture	1964	1993 (National Census)		
		West	Middle	East
Tandjilé (NW)	12.6	40 +	15-40	10-15
Logone Occidental	21.9	40 +	40 +	40 +
Logone Oriental	8.4	SW/Baibokoum	Goré	NE/Bébédjia/Doba[1]
		10-15	6-10	15-40
Moyen-Chari (SE)	8.3	15-40	10-15	2-6

1 A 1985-6 report by the National Office of Rural Development provides the following population densities for cantons in the oil field development area (in persons/km^2): Bébédjia (32); Mbikou (53); Miandoum (24); Béro (20); and Komé (8).

TABLE 6.3-1
TYPICAL VEGETATION OF SOUDANIAN WOODED SAVANNA

TREES	
Daniella olivieri	*Burkea africana*
Terminalia laxiflora	*T. macroptera*
Pterocarpus lucens	*Borassus aethiopum* [1]
Parkia biglobosa	*Khaya senegalensis*
Prosopis africana	*Anogeissus leiocarpus*
Mangifera indica	*Diospyros mespiliformis*
Acacia albida	*Butyrospermum parkii*
Isoberlinia doka	*Hyphaene thebaica*
SHRUBS	
Mimosa pigra	*Capparis spp.*
Calotropis procera	*Guiera senegalensis*
Zizyphus spp.	*Lannea humilis*
Gardenia ternifolia	*Asparagus africanus*
Piliostigma reticulatum	*Combretum spp.*
Acacia spp.	*Ampelocissus spp.*
GRASSES AND FORBS	
Cochlospermum tinctorium	*Vetivaria nigritana*
Panicum spp.	*Andropogon spp.*
Hyparrhenia rufa	*Chloris spp.*
Shoenfeldia gracilis	*Papsalum orbiculare*
Echinochloa stagnina	*Eragrostis spp.*
Diheteropogon amplectens	*Ctenium spp.*
Elytophorus spicatus	*Panicum spp.*
Loudetia simplex	*Sporobolus spp.*
Schizachyrium sanquineum	*Beckeropsis uniseta*
Dactyloctenium aegyptiacum	*Setaria palide-fusca*
Aristida spp.	

Source: Gillet, 1964; Pias, 1970; FAO, 1981; Hecht, et al., 1993.

[1] Rare or threatened species

TABLE 6.3-2
DESCRIPTION OF VEGETATION MAP UNITS

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DESCRIPTION OF VEGETATION MAP UNITS
(CONTINUED)

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B	Barren/Eroded - Areas of scant natural vegetation including rocky areas and areas eroded by wind or water.

TABLE 6.3-3
TYPICAL VEGETATION OF THE WOODED SAVANNA OF HILLS AND MOUNTAINS

TREES	
Anogeissus leiocarpus	*Albizia chavalieri*
Combretum glutinosum	*C. nigricans*
Sclerocarya birrea	*Balanites aegyptia*
Ficus gnaphalocarpa	*Tamarindus indica*
Terminalia laxiflora	*Butyrospermum Parkii*
Acacia sieberiana	*A. scorpioides*
Faidherbia albida	*Dichrostachys glomerata*
Grewia spp.	
SHRUBS	
Zizyphus mauritania	*Guiera senegalensis*
Philostigma reticulata	*P. rufescens*
FORBS AND GRASSES	
Pennisetum pedicellatum	*Aristida stipoides*
Chloris spp.	*Schizachyrium exile*
Achyranthes aspera	

Source: Pias, 1970; FAO, 1981.

TABLE 6.3-4
TREE SPECIES OF LOCAL IMPORTANCE

Species	Use
Khaya senegalensis	construction, canoes
Butyrospermum Parkii	nuts, oil
Parkia biglobosa	seeds, fruit
Daniella olivieri	construction, furniture
Monotes kerstingii	construction
Tetrapleura andongensis	seeds
Parinari curatellaefolia	food
Detarium microcarpum	food
Sarcocephalus esculentus	food, wine, medicinal
Gardenia erubescens	food
Ficus glumosa	food
Bridelia feruginea	food
Crossopteryx febrifuga	medicinal
Grewia mollis	food, religious significance
Sclerocarya birrea	medicinal
Pterocarpus lucens	food

Source: Gillet, 1964.

TABLE 6.3-5
LIST OF USEFUL/NAMED PLANTS FROM THE OIL FIELD AREA
(Page 1 of 3)

SCIENTIFIC NAME	LOCAL NAME	REPORTED USE
Acacia ataxananta	ngar	
Acacia polyacantha	kun-gourain	
Annona senegalensis	mbor/mboro	fruits edible
Anogeissus leiocarpus	ddira	rafters, bark boiled for diarrhoea
Asclep. sp. (Apoc?)	singamadoul	shrub, small narrow lvs, erect paired fr, central column
Asparagus africanus	gergendi	edible
Balanites aegyptiaca	jang/danga	
Borassus aethiopum	kag-mar	wood used for building, fruits eaten, leaves used to make sieves, mats, baskets
Boscia senegalensis	bbol dodin	
Bridelia scleroneura	sin bian	
Burkea africana	wara	
Butyrospermum parkii Vitellaria paradoxa	roi	vegetable oil
Calotropis procera	kamnda bode	
Cassia occidentalis	gawa	
Cassia sieberana	mbareng	
Corchorus olitorus	iman-nang	
Cochlospermum tinctorium	mbai/ger-gourdin	starch extracted from the roots for flour, yellow tapioca
Combretum collinum	romee	
Combretum glutinosum	ddiro	
Combretum molle	ndei binan	
Cucurbita sp.	was	eat leaves and fruit (not seeds)
Daniellia oliveri	bbita	
Detarium microcarpum	koudou	fruits eaten
Dichrostachys cinerea	ber-geng	
Dioscorea sp.	ngoul kot	wild yam with narrow, hastate opp. leaves, tubers edible
Diospyros mespiliformis	kom-kag	
Dombeya multinervis	ndaji-daa	
Entada africana	ndang-keur	
Erythrina sigmoidea	dokanjegebao	medicinal
Ficus ingens	bbol	fruits eaten
Ficus sycomorus subsp. gnaphalokunda lol carpus	kag-kodee	

TABLE 6.3-5
LIST OF USEFUL/NAMED PLANTS FROM THE OIL FIELD AREA

SCIENTIFIC NAME	LOCAL NAME	REPORTED USE
Ficus ?platyphyllus	kob	fruits eaten
Gardenia erubescens	maji-kuso	fruits eaten
Grewia tenax	nganginau	fruits edible
Grewia mollis	gem	fruits edible
Guiera senegalensis	kamnda	
Hexalobus monopetalus	ntaam	
Hibiscus aspera	ngadngau	
Hymenocardia acida	kaira	fruits eaten
Hyperrhenia dissolita	boiyo	
Hyphaene thebaica	gaira	leaves used for construction
Indigofera garckeana	tarbourou	used in hunting, also, root treats stomache ache.
Indigofera nummulariifolia	doum-dog	
Isoberlinia doka	kaab	
Khaya senegalense	mbag	
Lannea schimperi	jeere	
Leptadenia hastata	rusa	leaves edible
Lophira lanceolata	koyoje	
Maerua angolense	bbol-dodin	
Mangifera indica	mongo	fruits eaten
Manilkara multinervis	gurmi	
Maytenus senegalensis	kad kun	burn leaves for salt treats engine (throat)
Moringa oleifera	kag mbogo	leaves in soup
Monotes kerstingii	koyo ubu	
Nauclea latifolia	ngo-daa	fruits edible
Parinari curatellifolia	kuman	fruits eaten
Parkia clappertoniana	kag mad	fruits edible
Pericopsis alata	kag-kor	
Piliostigma thonningii	mong	
Prosopsis africana	saam	
Pseudocedrela kotschyi	mbag-mbaw	chew bark for snake bite
Pterocarpus lucens	moundourou	young leaves eaten
Sanseveria liberica	tissi	
Sclerocarya birrea	lolo/robo	
Securidaca longipedunculata	pale-galle	fiber to make nets, medicinal
Securinega virosa	kase	goat fodder

TABLE 6.3-5
LIST OF USEFUL/NAMED PLANTS FROM THE OIL FIELD AREA
(Page 3 of 3)

SCIENTIFIC NAME	LOCAL NAME	REPORTED USE
Sterculia setigera	da/ndang-ngonnbian	
Stereospermum kunthianum	kunda lol	
Strychnos innocua	konje kolo	
Strychnos spinosa	din	fruits edible
Stylochiton sp.	bbad	
Swartzia madagascariensis	ndaji-sam	
Tamarindus indica	masse	fruits edible
Tacca longepedunculata	geur	white cassava (roots used to make flour)
Tephrosia bracteolata	reuin	
Tephrosia linearis	njiwi	
Terminalia laxiflora	ro ndah	
Terminalia avicennioides	ro	
Terminalia macroptera	ro mann	
Trichilia roka	ndaji-koyo	
Urena lobata	koula-goum	
Vitex madiense	goryo	
Vitex doniana	mi	fruit eaten
Ximenia americana	tindi	fruit eaten
Zizyphus abyssinica	ngogro-bissi	fruit not eaten
Zizyphus mauritiana	ngogro	fruit eaten
Zornia glochidiata	sobad	

Source: Thomas, 1996.

TABLE 6.4-1
STREAMFLOW DATA AT SELECTED STREAM GAUGES

STATION	LOGONE RIVER AT MOUNDOU	PENDÉ RIVER AT GORÉ	PENDÉ RIVER AT DOBA
Location	Lat. 8°32'2"N Long. 16°4'6"E	Lat. 7°57'N Long. 16°37'E	Lat. 8°39'N Long. 16°50'E
Drainage Area (km²)	33,970	12,020	14,300
Average Annual Rainfall (mm)	1,393	1,492	1,448
Observed/Estimated/Discharge (m³/s)			
Maximum Daily	2,650	983	1,090
Mean Annual	347	90.8	86.8
Minimum Daily	7.96	0.01	0.11
10-Year Daily Peak	2,384	918	993
20-Year Daily Peak	2,453	946	1,051
50-Year Daily Peak	2,587	1,000	1,172
100-Year Daily Peak	2,966	1,158	1,559
10-Year Daily Low	11.4	0.061	0.315
20-Year Daily Low	10.7	0.040	0.269
50-Year Daily Low	9.58	0.0002	0.195
100-Year Daily Low	6.95	0.0001	0.068
Period of Record	1960-1993 (with gaps)	1960-1993 (with gaps)	1969-1993 (with gaps)
Average Runoff Coefficient	0.245	0.168	0.14

Source: ANTEA, 1995a

km^2 = square kilometer
mm = millimeter
m^3/s = cubic meter per second

TABLE 6.4-2
MEAN ANNUAL AND MONTHLY RAINFALL

STATIONS	BAIBOKOUM	BÉBÉDJIA	DOBA	KOUMRA	MOUNDOU
Approximate Location	Confluence of Vina and Mbéré rivers to the Logone in Southern Chad near Cameroon border	Between the Pendé and the Logone rivers and between Moundou and Doba	On Pendé River about 19 km upstream of its confluence with Nya and Loulé rivers	About 90 km north and east of Doba	About 100 km west of Doba on the Logone River
Period of Data (approx.)	1930-1994	1930-1994	1930-1994	1930-1994	1920-1994
Average Annual Rainfall (mm)[1]	1,299.2	1,091.1	1,072.6	1,011.6	1,147.4
Mean Monthly Rainfall (mm)					
January	0.0	0.0	0.0	0.0	0.0
February	1.1	0.6	0.0	0.5	0.3
March	10.5	8.8	6.9	8.5	6.2
April	59.6	41.5	35.1	39.0	41.5
May	115.2	83.4	90.0	94.7	103.3
June	166.8	142.9	58.9	129.3	152.2
July	244.8	266.3	232.3	242.4	237.7
August	318.4	279.3	285.0	243.2	289.2
September	250.6	198.6	192.3	194.9	220.0
October	119.3	67.5	78.2	76.2	72.0
November	6.8	2.1	3.1	2.3	2.2
December	0.0	0.0	0.0	0.3	0.0

Source: ANTEA, 1995a

[1] Due to round-off computations, there are minor differences in the average annual rainfall and total of the 12 mean monthly rainfall values.

TABLE 6.4-3
MEAN MONTHLY TEMPERATURE, RAINFALL, AND EVAPOTRANSPIRATION AT BÉBÉDJIA, CHAD

Month	Temperature °C		Mean Monthly[1] Rainfall (mm)	Evapotranspiration (mm)			
					Effective		
	Mean of Monthly Max.	Mean of Monthly Min.		Potential	Medium Soil Water Storage	Soil Water Storage = 150 mm	Soil Water Storage = 300 mm
January	34.4	14.9	0.0	129	22	0	35
February	37.0	17.4	0.3	130	2	0	22
March	38.5	21.8	6.2	174	4	4	12
April	37.3	23.9	41.5	176	44	44	44
May	35.2	23.3	103.0	151	81	81	81
June	32.5	22.0	152.0	121	121	121	121
July	30.0	21.4	238.0	121	121	121	121
August	29.6	21.2	289.0	117	117	117	117
September	30.3	21.0	220.0	112	112	112	112
October	32.4	21.1	72.0	124	121	119	122
November	34.7	18.5	2.2	114	68	48	78
December	34.3	15.4	0.0	121	38	17	54
TOTAL	--	--	1,124.2	1,590	851	784	919

Source: ANTEA, 1995b

[1] These values are different from those in Table 6.4-2 because the data periods are different.

TABLE 6.4-4
ESTIMATED PEAK FLOWS, FLOOD DEPTHS, AND FLOOD ELEVATIONS OF PENDÉ RIVER (VICINITY OF KOMÉ FIELD AND OC)

RETURN PERIOD	PEAK FLOW (m^3/sec)	FLOOD DEPTH (m)	FLOOD ELEVATION (m)
10 - year	1,039 - 1,298	4.2 - 4.4	387.2 - 387.4
50 - year	1,467 - 1,638	4.5 - 4.6	387.5 - 387.6
100 - year	1,633 - 1,780	4.6 - 4.7	387.6 - 387.7
1,000 - year	2,129 - 2,295	4.9 - 5.0	387.7 - 388.0

Source: Dames & Moore, 1996a

TABLE 6.4-5
ESTIMATED PEAK FLOWS, FLOOD DEPTHS AND FLOOD ELEVATIONS OF LOULÉ RIVER (VICINITY OF KOMÉ FIELD AND OC)

RETURN PERIOD	PEAK FLOW (m^3/sec)	FLOOD DEPTH (m)	FLOOD ELEVATION (m)
10 - year	289	3.2 - 3.7	384.1 - 389.6
50 - year	329 - 406	3.4 - 3.9	384.3 - 389.8
100 - year	338 - 451	3.5 - 4.0	384.4 - 389.9
1,000 - year	355 - 589	3.7 - 4.3	384.6 - 390.2

Source: Dames & Moore, 1996a

TABLE 6.4-6
DEPTHS, PUMPING RATES, AND ESTIMATED TRANSMISSIVITIES OF SHALLOW WELLS
(Page 1 of 4)

WELL	TOTAL DEPTH (m)	SCREEN INTERVAL (m)	DEPTH TO WATER TABLE (m)	DRAWDOWN (m)	DISCHARGE (m^3/hour)	SPECIFIC DISCHARGE (m^3/hour/meter)	TRANSMISSIVITY (m^2/second)
Bédio (Koumra)	50	37.4-43.2	24.7	11.91	7.7	0.65	2×10^{-3}
Bedoada (Koumra)	51	38.4-50.0	29.2	11.27	6.2	0.55	6×10^{-3}
Befada (Koumra)	67	42.8-48.6 60.2-66.0	10.2	14.2	11.4	0.8	1×10^{-2}
Bodo (Koumra)	50	31.6-37.4 43.2-49.0	16.7	1.04	12	11.5	5×10^{-2}
Kara (Koumra)	47	28.6-40.2	11.7	0.5	12	24.0[a]	3×10^{-2}
Mango (Koumra)	70[1]	54.0-66.2	4.8	16	10.8	0.67	2×10^{-3}
Mbitenda (Koumra)	70	51.6-57.4 63.2-69.0	14.4	6.92	12	1.7	NA
Yel (Koumra)	59	29-34.8 40.6-46.4 52.2-58.0	7.3	1.4	12.3	8.8	NA
Bitakia (Lai)	50	31.1-48.5	24.3	2.91	11.3	3.9	9×10^{-3}
Madana (Lai)	60	41.6-53.2	34.3	0.25	9.8	39.2	6.6×10^{-2}
M'Beri (Lai)	65	46.6-58.2	39.7	0.83	9	10.8	7×10^{-2} 5×10^{-2}
Sama (Lai)	61	42.6-48.4 54.2-60.0	23.7	0.52	10.3	19.8	7×10^{-2}
Babalem (Moundou)	47	33.05-44.65	12.09	1.22	12	9.8	NA
Bébédjia (Moundou)	55	36.6-48.2	16.7	4.7	12.3	2.6	NA
Bébédjia IRCT (Moundou)	93	63.0-68.8 80.4-92.0	16	0.92	12.7	13.8	2×10^{-2}
Beboni (Moundou)	40	NA	10.7	0.68	12	17.6	6×10^{-2}
Bedoko (Moundou)	60	46.05-57.65	46.6	0.59	10.8	18.3	5.5×10^{-2}
Bekiri (Moundou)	35	22.4-34.0	17.9	0.49	12	24.5	1.2×10^{-2}
Bekondjio (Moundou)	35	13.6-28.2	3.7	2.2	12	5.45	NA

TABLE 6.4-6
DEPTHS, PUMPING RATES, AND ESTIMATED TRANSMISSIVITIES OF SHALLOW WELLS
(Page 2 of 4)

WELL	TOTAL DEPTH (m)	SCREEN INTERVAL (m)	DEPTH TO WATER TABLE (m)	DRAWDOWN (m)	DISCHARGE (m^3/hour)	SPECIFIC DISCHARGE (m^3/hour/meter)	TRANSMISSIVITY (m^2/second)
Benoye (Moundou)	52	39.4-51.0	24.2	0.57	10.8	18.9	5.5×10^{-2}
Besseye (Moundou)	54	40.2-51.8	30.7	0.37	10.8	29.2	NA
Beti (Moundou)	33	20.4-32.0	8.2	3.6	11.4	3.2	4×10^{-3}
Dangda (Moundou)	50	35.8-43.2	16	5.89	10.8	1.83	1×10^{-3}
Djanga (Moundou)	44	18.9-30.5	11.2	0.89	11.4	12.8	1.5×10^{-2}
Gore Nord (Moundou)	40	27.4-39.0	5.8	15.12	8	0.53	2.1×10^{-4}
Komé (Moundou)	39	20.6-26.4 32.2-38.0	16.4	11.8	6.75	0.57	1×10^{-3}
Koro (Moundou)	64	51.4-63.0	23.7	3.13	12	3.83	1×10^{-2}
Koutoubeti (Moundou)	68[1]	34.6-66.2	NA	0.58	11.4	19.66	NA
Lara (Moundou)	44.5	31.4-43.0	27.1	0.58	10.8	18.62[a]	NA
Maikag (Moundou)	64	51.9-63.5	43.4	2.25	10.8	4.80[a]	NA
Manga (Moundou)	35	16.6-28.2	5.2	1.57[a]	10.8	6.88	1×10^{-2}
M'Balla (Moundou)	67	48.6-66.0	45.2	1.57	10.8	6.88[a]	NA
M'Baouroye (Moundou)	381	25.4-37.0	20.4	0.97	10.8	11.13[a]	NA
M'Beari (Moundou)	46[1]	33.6-45.2	16.4	2.56	12	4.69[a]	NA
Miandoum (Moundou)	38[1]	20.0-37.2	14.1	3.89	12.3	3.16[a]	5.8×10^{-3}
Bere (Tapol)	66	47.1-52.9 58.7-64.5	18.7	28.83	11	0.38	1.5×10^{-4}
Dodinda (Tapol)	55	36.6-42.4 48.2-54.0	21.3	6.92	10.8	1.56	5.5×10^{-2}
Dotogo (Tapol)	48	29.6-41.6	18.3	3.13	11.4	3.64	9.8×10^{-3}
Maikane (Tapol)	65	40.3-46.1 51.9-57.7	15.3	10.34	11.4	1.1	3.9×10^{-4}

TABLE 6.4-6
DEPTHS, PUMPING RATES, AND ESTIMATED TRANSMISSIVITIES OF SHALLOW WELLS
(Page 3 of 4)

WELL	TOTAL DEPTH (m)	SCREEN INTERVAL (m)	DEPTH TO WATER TABLE (m)	DRAWDOWN (m)	DISCHARGE (m^3/hour)	SPECIFIC DISCHARGE (m^3/hour/meter)	TRANSMISSIVITY (m^2/second)
Makoula (Tapol)	64	51.4-63.0	23.6	2.62	11.7	4.47	NA
Mekapti	83	70.25-81.75	32.31	6.04	10.6	1.75	NA
Bemboura F1	67.6	54.7-66.1	16.88	6.85	6.8	0.99	NA
Bemboura F2	57.6	44.7-56.1	12.68	4.05	7.9	1.95	NA
Dandili F1	58	45.1-56.5	11.4	0.94	9.2	9.79	NA
Dandili F2	64.2	57.5-63.2	16.7	0.61	7.2	11.8	NA
Dodou	180	154.8-178.0	131	0.54	9	16.67	NA
Gueldobo F1	172	145.8-169.0	143.26	0.59	6.1	10.34	NA
Gueldobo F2	179	158.9-176.0	143.26	0.16	5.2	32.5	NA
Keikague	189.8	164.0-186.8	136.82	0.24	6.3	26.25	NA
Nangkassa	192	154.8-166.2 177.6-189.0	103.13	1.32	9.5	7.2	NA
Moundabou	147	126.9-144.0	103.13	1.32	9.5	7.2	NA
Lele	69	62.0-67.75	36.82	0.63	15.6	24.76	NA
Meikab	62	55.0-60.75	41.51	2.77	13.8	4.98	NA
Blando	47	39.25-45.0	26.4	1.93	17.1	8.86	NA
Togoro	68	61.0-66.75	22.87	7.9	16.4	2.08	NA
Mbagti	40	32.5-38.25	14.75	0.98	9.2	9.39	NA
Lara F2	44	37.2-43.0	23.18	1.32	17.1	12.95	NA
Galaba	83	63.75-69.5 75.25-81.0	21.23	31.45	3	0.09	NA
Begada	50	30.86-36.56 42.26-47.96	7.62	4.16	9.2	2.21	NA
Banga	53.5	44.8-50.5	6.67	5.16	9	1.74	NA
Kagroue	53.85	45.15-50.85	5.93	6.89	9	1.31	NA
Bébédjia F2	60	52.3-58.0	11.25	4.36	10.9	2.5	NA
Djeune	48.5	38.5-47.0	6.62	5.21	6.2	1.19	NA
Bero F1	42	35.8-41.5	11.81	1.09	7.8	7.16	NA
Bero F2	52	42.5-51.0	9.71	1.35	8.1	6	NA

TABLE 6.4-6
DEPTHS, PUMPING RATES, AND ESTIMATED TRANSMISSIVITIES OF SHALLOW WELLS

WELL	TOTAL DEPTH (m)	SCREEN INTERVAL (m)	DEPTH TO WATER TABLE (m)	DRAWDOWN (m)	DISCHARGE (m^3/hour)	SPECIFIC DISCHARGE (m^3/hour/meter)	TRANSMISSIVITY (m^2/second)
Dokapti	61.3	36.2-41.95 53.55-59.3	9.89	1.52	9	5.92	NA
Dangdein	67.5	60.80-66.50	25.07	2.29	7.2	3.14	NA
Bekia F2	53.25	34.0-39.75 45.5-51.25	25.16	7.92	11.6	1.46	NA
Bekia F1	64.75	51.25-62.75	25.06	1.17	12	10.26	NA
Sarah 1	55	41-54	2.6	22 to 27	108	4 to 5	NA
Koumra	76[1]	50-75	NA	1.81	17	9.4	NA
Moundou	41[1]	20-40	NA	13.14	180	13.7	NA
Kelo	123	26.5-111	3.7	3.79	106	28	NA

Source: Bureau de l'Eau, 1995b.

[1] Approximate Value
NA = Not Available

TABLE 6.4-7
DEPTHS, PUMPING RATES, AND DRAWDOWN DATA FOR SHALLOW WELLS DRILLED IN 1986-1987

VILLAGE	WELL NO.	TOTAL DEPTH (m)	SCREEN INTERVAL (m)	DEPTH TO WATER TABLE (m)	DRAWDOWN (m)	DISCHARGE (m^3/hour)	SPECIFIC DISCHARGE (m^3/hour/meter)
Balougou	26	27	17.20-25.0	7.1	7.13	7.56	1.06
Banga	23	35	23.10-33.0	11.97	7.54	9.5	1.26
Banga Deressia	32	27.35	18.43-25.35	3.45	3.63	9.5	2.62
Batouba	20	32.65	25.70-30.65	9.81	10.5	0.84	0.08
Boumaye	24	31	22.10-29.00	9.71	9.31	9.5	1.02
Darbe	22	36	24.10-34.00	12.94	13.17	5.4	0.41
Darmodelingar	16	32.5	20.60-30.50	12.07	13.97	9.5	0.68
Delem	18	37.8	25.90-35.80	19.74	20	5.8	0.29
Deressia	37	46	36.20-44.00	3.68	3.69	4.72	1.28
Deressia at Mire	38	45	31.15-43.00	3.77	3.82	1.3	0.34
Deressia Marche	39	23	14.10-21.00	3.24	3.24	4.7	1.45
Deressia Mbgogne	40	47.5	38.60-45.50	4.05	4.05	7	1.73
Dila	34	26	15.40-24.00	2.65	2.66	7.1	2.67
Djogo	41	58.55	48.85-56.55	8.67	8.72	9.5	1.09
Dono-Manga Est.	15	39	32.05-37.00	20.21	NA	0.9	NA
Dono-Manga Ouest	14	40.81	28.40-38.30	20	20.21	9.5	0.47
Goular 1	35	18.25	11.30-16.25	5.05	5.33	0.64	0.12
Goular 2	36	22	13.50-20.50	4.55	4.58	3.8	0.83
Kaga Palpagne	12	36	29.05-34.00	18.8	3.05	7.56	2.48
Kariadeboum	11	53.6	46.10-51.00	35.4	1.07	6.03	5.61
Kimbri	17	34	27.05-32.00	13.45	13.88	2.36	0.17
Lessemayo	28	26	17.25-24.00	8.69	8.72	9.5	1.09
Marou	19	36	24.10-34.00	16.96	16.97	9.5	0.56
Mibgue	25	30	19.15-28.00	7.48	7.48	9.5	1.27
Mourai	27	34	27.05-32.00	8.82	8.97	2.6	0.29
Ninga	30	24.5	16.25-22.00	7.07	7.09	9.5	1.34
Ninga Ouest	31	24	15.25-22.00	6.02	6.05	9.5	1.57
Pian	29	26	18.20-24.00	9.44	9.45	7.56	0.8
Tchere Aiba	21	31.85	19.15-29.85	11.03	11.11	3	0.27
Terre	13	32.15	20.25-30.15	10.13	10.39	3.43	0.33

Source: Bureau de l'Eau, 1995b.
NA = Not Available

TABLE 6.4-8
RANGE OF WATER QUALITY PARAMETERS FOR SHALLOW WELLS

AREA	NO. OF WELLS	RANGE OF RESISTIVITIES (Ohm-cm at 25°C)	RANGE OF CONDUCTIVITIES (micromhos/cm at 25°C)	RANGE OF DRY SOLIDS RESIDUE (mg/L)
Koumra	8	17,900-66,700	15-96	11-69
Laï	4	32,300-50,000	20-31	14-22
Moundou	22[1]	10,420-50,000	20-96	14-69
Tapol	5	12,200-45,450	22-82	16-59

Source: BRGM (undated)

[1] No data are available for Koutoubéti Village well

TABLE 6.4-9
RESULTS OF WATER QUALITY ANALYSIS
KOMÉ DRILLING CAMP WELLS

PARAMETER	CONCENTRATION/VALUE	UNIT
Sodium	7	mg/L
Potassium	1	mg/L
Calcium	0	mg/L
Magnesium	5	mg/L
Barium	0 -1	mg/L
Total Iron	0 -1	mg/L
ANIONS		
Chloride	1	mg/L
Bicarbonate	17 - 21	mg/L
Carbonate	0	mg/L
Sulfate	0	mg/L
Bromide	0	mg/L
Iodide	0	mg/L
Sulfide	0	mg/L
OTHER PARAMETERS		
pH	6.12 - 7.03	–
Resistivity	232.65 - 263.16	Ohm-meter
Total Dissolved Solids	30.04 - 34.40	ppm
Specific Gravity	0.9979 - 0.9983	–

Notes:

Concentration/value ranges are from wells used in drill area and water samples from two wells (52 and 56 m deep) on the northwest and west sides of Komé base.

TABLE 6.4-10
LOCATIONS, SIZES, DEPTHS, AND FIELD-MEASURED WATER QUALITY PARAMETERS OF WELLS

No.	Village	Longitude	Latitude	Alt. (m)	Diam. (m)	Type	Depth of Well (m)	Depth to Water (m)	Color	Temp. Water	pH	DO[a] (mg/L)	Cond. (Micro mhos/cm)
BEB 1	Komé Ndolebe	16°42'15"	8°28'05"	402	1.40	3	19.80	17.35	C	29.3	6.69	1.52	296.0
BEB 3	Mouarom	16°39'07"	8°28'56"	401	1.05	2	19.75	18.80	W	29.4	6.3	4.65	33.6
BEB 5	Mayongo	16°36'46"	8°25'58"	403	0.90	2	19.10	16.40	Y	28.7	5.68	4.24	25.9
BEB 7	Bero II	16°47'25"	8°35'13"	387	1.00	1	11.20	5.60	M	28.9	6.2	3.22	117.0
BEB 9[b]	Mbanga	16°45'34"	8°33'05"	389	--	4	56.00	6.20	C	30.9	5.7	1.27	52.7
BEB 10[b]	Kagroye	16°44'00"	8°34'20"	386	--	4	56.00	7.00	C	30.9	5.49	2.6	37.5
BEB 13[b]	Bekia II	16°32'13"	8°27'50"	421	--	4	56.00	25.70	C	30.7	5.3	3.03	25.7
BEB 14	Kayra	16°36'59"	8°32'22"	401	1.20	1	13.40	9.60	M	29	5.34	3.5	47.2
BEB 17	Begada	16°44'15"	8°30'47"	398	0.80	1	12.80	9.30	M	30.3	5.64	2.73	130.0
BEB 18	Bela	16°40'55"	8°32'04"	390	1.00	1	12.30	9.90	C	28.9	4.89	3.2	69.6
BEB 19	Madjio	16°49'47"	8°35'05"	387	0.80	1	7.40	4.20	C	29.2	6.62	4.8	165.0
BEB 21	Ndaba Bebo	16°49'09"	8°29'31"	395	1.00	1	12.70	10.30	C	29.2	5.5	2.64	65.6
BEB 22	Mainani	16°43'30"	8°29'42"	400	1.00	1	14.30	10.50	C	29.7	6.3	1.42	43.4
BEB 23	Madana Nadpeur	16°37'40"	8°30'35"	396	1.00	1	8.2	4.30	C	29.4	5.3	1.96	41.2
BEB 25	Missimadjia	16°46'42"	8°28'19"	397	1.00	1	13.40	11.00	C	29.1	5.71	0.92	43.9
BEB 26	Mogrom	16°48'29"	8°26'47"	400	1.20	1	14.80	13.80	C	29.3	5.63	2.86	50.1
BEB 27	Sindalolo	16°47'40"	8°23'46"	392	1.00	1	9.40	3.20	C	28.8	5.45	1.47	45.0
BEB 32	Bébédjia U	16°34'10"	8°40'53"	395	1.00	1	13.70	9.70	C	30.2	4.72	3.23	453.0
BEB 37	Dangndili	16°27'10"	8°36'45"	396	1.00	1	15.50	13.45	C	30.5	5.44	2.25	31.0

TABLE 6.4-10
LOCATIONS, SIZES, DEPTHS, AND FIELD-MEASURED WATER QUALITY PARAMETERS OF WELLS (CONTINUED)

No.	Village	Longitude	Latitude	Alt. (m)	Diam. (m)	Type	Depth of Well (m)	Depth to Water (m)	Color	Temp. Water	pH	DO[a] (mg/L)	Cond. (Micro mhos/cm)
BEB 43[b]	Dokapti	16°43'18"	8°41'25"	391	1.00	4	56.00	7.40	C	30.2	6.12	1.49	33.6
BEB 46	Manboye	16°29'39"	8°30'02"	421	1.00	1	24.3	24.50	Y	29.6	5.69	4.19	28.0
BEB 48	Kaga	16°29'14"	8°27'21"	428	1.40	1	31.20	31.00	P	29.8	5.49	4.31	33.3
BEB 52	Ngalaba	16°32'13"	8°31'23"	411	1.00	1	23.60	22.00	C	29.5	5.5	4	25.0
BEB 54	Kaba	16°45'49"	8°39'28"	383	1.00	1	6.20	3.00	C	28.6	6.05	2.93	25.3
DOB 56	Bedogo	16°49'28"	8°42'02"	387	1.00	1	9.90	9.50	C	30	5.75	4.4	25.0
DOB 60	Doba U	16°51'24"	8°38'52"	387	1.00	1	8.10	3.90	C	29.9	5.11	2.25	108.9
BEB 64	Karoua	16°36'40"	8°35'13"	401	1.00	1	13.00	7.40	C	29.7	5.56	3.15	40.9
BEB 67	Madana Koumamiar	16°42'03"	8°37'16"	388	1.00	1	10.60	9.80	C	29.8	5.65	2.5	65.6
BEB 69	Mainani	16°34'32"	8°37'34"	401	1.00	1	10.90	3.80	C	30.3	5.5	3.55	100.0
BEB 73[b]	Dang-Ndin	16°30'34"	8°34'45"	421	1.40	4	68.00	23.90	C	30.1	5.07	2.3	23.9

Source: Dames & Moore, 1996b

[a] DO = Dissolved oxygen
[b] Equipped with pump

Type = 1: Traditional well; 2: Traditional well with concrete slab; 3: Concrete lined well; 4: Borehole with pump
Color = C: Clear; Y: Yellow; M: Muddy; P: Slightly Pink

TABLE 6.4-11
CONCENTRATIONS OF TRADITIONAL WATER QUALITY PARAMETERS IN SELECTED WELLS
(mg/L)

No.	Chloride	Total Hardness	Calcium	Magnesium	Ammonia	Nitrate	Iron	Sulphate	Total Alkalinity	Nitrite	Orthophosphate	Suspended Matter
BEB 1	23	114	37	18.7	2.35	2	0.12	0	139.1	0.01	0.001	49.9
BEB 3	7	70	8	15	0	0	0.56	10	29.3	0.19	0.002	104.5
BEB 5	--	--	--	--	2.2	2.2	0.19	4	24.4	0.07	<0.001	49.9
BEB 7	11	36	10	6	1.58	18	0.74	6	22.0	1.07	0.03	74.1
BEB 9	6	7	2	1.2	3	2.6	0.35	1	19.5	0.04	0.000	24.8
BEB 10	4	10	2	2	0.01	0.8	0.01	0	31.7	0.02	0.000	~0,0
BEB 13	20	8	1.6	1.6	0.12	1.7	0.01	1	24.4	0.00	0.000	~0,0
BEB 14	3	20	4.4	3.8	0.68	20	0.23	4	22.0	0.45	0.012	1400.5
BEB 17	9	38	11	6.5	12	53	0.06	0	22.0	0.06	0.002	5.6
BEB 18	14	21	5	4.5	0.25	26	0.03	1	19.5	0.01	0.000	5.6
BEB 19	16	56	19	9	0.07	47.5	0.03	2	53.7	0.05	~0.000	11.0
BEB 21	5	11	4	1.7	0.04	22	0.06	1	24.4	0.06	~0.000	2.1
BEB 22	5	16	4	3	0.31	3.5	0.38	6	41.5	0.03	<0.001	231.5
BEB 23	4	9	2.4	1.6	0.20	13.6	0.04	1	17.1	0.07	<0.001	8.5
BEB 25	9	10	3.6	1.5	0.45	3	0.05	2	36.6	0.00	0.000	~0,0
BEB 26	4	10	2.8	1.7	0.12	4	0.17	3	43.9	0.05	0.001	8.9
BEB 27	10	8	2	1.5	0.42	4	0.25	3	31.7	0.17	0.007	14.1
BEB 32	55	140	40	24	0.13	176	0.04	1	26.8	0.04	0.002	3.6
BEB 37	9	14	2	3	0.22	4.8	0.02	1	26.8	0.03	0.000	3.4
BEB 43	6	8	2	1.5	0.01	3.5	0.04	3	36.6	0.00	0.000	0.7
BEB 46	48	11	2.6	2	2.5	1.3	0.15	1	29.3	0.08	0.001	39.3
BEB 48	5	14	4	2.4	0.77	4.4	0.06	0	24.4	0.04	0.000	56.9

TABLE 6.4-11
CONCENTRATIONS OF TRADITIONAL WATER QUALITY PARAMETERS IN SELECTED WELLS
(mg/L)
(CONTINUED)

No.	Chloride	Total Hardness	Calcium	Magnesium	Ammonia	Nitrate	Iron	Sulphate	Total Alkalinity	Nitrite	Orthophosphate	Suspended Matter
BEB 52	4	5	1	1	0.14	3.5	0.12	5	26.8	0.02	~0.00	5.2
BEB 54	8	4	0.8	0.8	0.54	4.8	0.50	6	34.2	0.40	0.011	13.3
DOB 56	6	5	1.4	0.9	0.13	7	0.09	3	22.0	0.05	0.002	16.6
DOB 60	18	22	6	3.9	0.16	36	0.10	2	26.8	0.11	0.002	11.6
BEB 64	11	11	4	1.7	0.11	17	0.10	4	19.5	0.04	~0.000	6.6
BEB 67	15	23	5	4.4	0.19	24	0.14	1	41.5	0.12	0.002	7.7
BEB 69	20	36	8.4	6.7	1	6.6	0.39	2	17.1	0.51	0.016	259.1
BEB 73	4	11	2.4	3	0.10	2.2	0.03	1	17.1	0.02	0.000	0.5
WHO	--	--	--	--	1.50	50	0.3	250	--	3.00	--	--

Source: Dames & Moore, 1996b

WHO = World Health Organization Criteria for Drinking Water, 1993.

-- = data not available

TABLE 6.4-12
RESULTS OF BACTERIOLOGICAL ANALYSIS FOR SELECTED WELLS

Sample Number	Global Flora (germs/ml)	Total Coliforms (germs/100 ml)	Fecal Coliforms (germs/100 ml)	Salmonella
BEB 1	>300	4	0	0
BEB 3	>300	18	0	0
BEB 5	>300	24	0	0
BEB 7	>300	6	2	0
BEB 9	BROKEN	–	–	–
BEB 10	$19x10^2$	0	0	0
BEB 13	0	0	0	0
BEB 14	>300	0	0	0
BEB 17	$214x10^2$	4	2	0
BEB 18	>300	6	0	0
BEB 19	>300	14	0	0
BEB 21	>300	8	18	0
BEB 22	>300	0	0	0
BEB 23	>300	46	30	0
BEB 25	$1.4x10^4$	0	0	0
BEB 26	$1.52x10^4$	18	0	0
BEB 27	$1.15x10^3$	8	0	0
BEB 32	>300	20	0	0
BEB 37	$2.93x10^4$	8	6	0
BEB 43	$1.8x10^3$	0	0	0
BEB 46	>300	0	0	0
BEB 48	>300	18	0	0
BEB 52	$9x10^3$	4	2	0
BEB 54	$3x10^5$	2	0	0
DOB 56	$8.5x10^3$	0	0	0
DOB 60	>300	16	6	0
BEB 64	>300	14	4	0
BEB 67	>300	7	0	0
BEB 69	>300	8	10	0
BEB 73	0	0	0	0

Source: Dames & Moore, 1996b

TABLE 6.6-1
HISTORICAL RAINFALL DATA FOR THE CHAD-DOBA REGION

10-Year Period	Average Annual Rainfall (mm)		
	Baibokoum	Bébédjia	Doba
1930-1940	1,241.0	1,142.8	1,121.0
1940-1950	1,365.5	1,222.9	1,150.9
1950-1960	1,361.8	1,065.6	1,137.0
1960-1970	1,273.4	1,060.0	1,028.0
1970-1980	1,241.1	980.7	975.5
1980-1990	1,239.6	1,057.8	1,022.8
Aggregate Mean	1,299.2	1,091.1	1,072.6

Source: ANTEA, 1995a

TABLE 6.6-2
CO_2 EMISSIONS FROM FOSSIL FUELS, INDUSTRIAL SOURCES, AND LAND USE CHANGE

Region	1990 CO_2 Emissions (billion tons per year)						
	Fossil Fuels			Industrial Sources		Land Use Change	Total[2]
	Solid	Liquid	Gas	Gas Flaring	Cement Production		
Africa[1]	0.27	0.26	0.05	0.05	0.02	1.50	2.15
North and Central America	1.96	2.62	1.11	0.02	0.06	0.42	6.18
South America	0.07	0.35	0.10	0.02	0.02	1.80	2.36
Asia	3.15	1.95	0.39	0.07	0.26	2.60	8.41
Europe	1.97	1.62	0.62	0.02	0.12	-	4.35
CIS (former USSR)	1.33	1.24	1.13	0.03	0.07	-	3.81
Oceania	0.15	0.10	0.04	0	-	0.01	0.30
TOTAL[2]	**8.76**	**8.86**	**3.47**	**0.21**	**0.56**	**6.40**	**28.20**

Source: Selrod et al., 1995

1 This information is based on all countries within the African continent. The country of Chad has no hydrocarbon production and little or no industry. The numbers, therefore, representing Africa are significantly greater than those that would be expected in Chad.

2 Totals may differ from the sum of individual components due to rounding of figures.

GLOSSARY OF TERMS

Agricultural–A vegetation/land use mapping unit comprising the highest intensity of cultivation in the project area.

Alluvium–A general term for clay, silt, sand, gravel or similar unconsolidated material deposited during comparatively recent time by a stream or other body of running water.

Annulus–The space between the casing and the wall of the well borehole.

Argillic–Pertaining to clay or clay minerals.

Baseline–A characterization of the existing conditions in the actual environment in which the proposed project will operate for purposes of assessing impacts. The data can be qualitative or quantitative, but not necessarily a measure of temporal and spacial variations.

Bedload–The larger heavier particles transported by a stream which are not in continuous suspension or solution.

Benefit and Cost Analysis (Benefit-Cost Analysis)–The economic analysis of projects or policies taking into account external impacts, especially environmental impacts. A systematic technique for judging among alternative ways of trying to achieve the same or related objectives, frequently requiring use of a computer to handle the large quantity of data and equations involved. In effect it consists of quantifying and comparing the expected cost and benefit of each alternative.

Biochemical Oxygen Demand–The amount of oxygen required by aerobic microorganisms to decompose the organic matter in a sample of water, used as a measure of the degree of water pollution.

Biocide–A chemical agent capable of destroying living organisms.

Biotreatment–A technology that enhances the ability of biological organisms to degrade or detoxify contaminated materials.

Breaker–A device that divides a ditch into sections to form internal barriers to water movement; used for pipelines in areas where washouts are a threat.

Buffer Zone–An identified area of reduced activity adjacent to the construction right-of-way that functions as a transition zone from zones of more intense project activity to natural habitat and as extensions of adjacent sensitive habitat types.

Campanian–European stage: Upper Cretaceous (above Santonian, below Maestrichtian).

Canton–A small administrative division of Chad.

Cathodic Protection–An anticorrosion technique used to protect buried pipelines from damage. A cathodic protection system reduces the corrosion of steel pipe by installing anodes and setting up a flow of current through the soil between the pipe and the anodes such that the anodes experience most of the corrosive effects.

Cenomanian–European stage: Lowermost Upper Cretaceous, or Middle Cretaceous of authors (above Albian, below Turonian).

Check Valve–A valve that permits flow in one direction only.

Chemoprophylaxis–The prevention of infectious disease by the use of chemical agents.

Closed Forest–Trees that are tall and generally closely spaced, forming a closed evergreen canopy with a minimum of understory vegetation.

Codos–Local resistors who fight with government military.

Colluvium–A general term applied to loose, heterogeneous, soil or rock material usually deposited at the base of a steep slope or cliff.

Commissary–A store where food and equipment are sold, as in an oil drilling camp.

Connate–Water trapped in sediments at the time of deposition.

Coupon–A small metal strip which is exposed to corrosive systems for the purpose of determining nature and severity of corrosion.

Cretaceous–The geological time period within the Mesozoic Era characterized by the disappearance of dinosaurs and the appearance of flowering plants (135 to 65 million years ago).

Upper Cretaceous - about 87 to 65 million years ago
Middle Cretaceous - about 95 to 88 million years ago
Lower Cretaceous - about 135 to 96 million years ago

Critically Endangered–A taxon which is facing an extremely high risk of extinction in the wild in the immediate future.

Crude Oil Topping Plant–A plant that processes raw crude oil to produce liquid fuels.

Cuttings–The fragments of rock dislodged by a drilling bit and brought to the surface in the drilling mud. Washed and dried samples of the cuttings are analyzed by geologists to obtain information about the formations drilled.

Debrouillardes–Women who eke out a living or earn necessary income by selling goods and sometimes sexual services in town markets.

Degraded Savanna–A vegetation/land use mapping unit comprising areas of savanna in the project area with a lower intensity of cultivation than "Agricultural," and a higher intensity than "Undegraded Savanna." Also referred to as "Savanna."

Demulsifier Chemical–Additive which prevents or minimizes formation of an emulsion of oil and water.

Desertification–The process of becoming arid land or desert (as from land mismanagement or climatic change).

Diorite–A dark granite-textured crystalline rock rich in a common rock-forming series of triclinic feldspars (plagioclase).

Discount Factor–Present value of $1 received at stated future date.

Discount Rate–Rate used to calculate the present value of future cash flows.

Discounted Cash Flow–Future cash flows multiplied by discount factors to obtain present value.

Diversion Dikes–Earthworks to control stormwater run-off.

Drilling Mud–Fluid made up of a mixture of clays, water (and sometimes oil), and chemicals, which is pumped down a well during drilling operations to lubricate the system, remove cuttings, and control pressure.

Drilling Program –The process of drilling straight vertical or horizontal wells. Involves all stages of drilling.

Duricrust–A hard crust on the surface of, or layer in the upper horizons of, a soil in a semiarid climate.

Emulsion–A mixture of crude oil and water for which oil-water separation may be difficult and which may have viscosity higher than that of water or crude oil alone.

Endangered–A taxon which is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future.

Entrained Gas–Gas suspended in bubbles in a stream of fluid, such as water or oil.

Eocene–An epoch of the Tertiary period: between 38 and 53 million years ago.

Epizootic–A disease which affects many animals of one kind at the same time.

Erosion-Control Blanket–Materials (such as natural fibers, geotextiles, matting) placed over potentially erosive soils.

Expatriate–One who resides in a foreign country.

Ex Situ Treatment–A remedial treatment for soil or groundwater that involves removing the affected media before treatment.

Extended Reach (or Horizontal) Well–An oil well that commences as a vertical well, but is deviated off vertical in a controlled manner to intercept a target zone (or zones) at some lateral distance from the well head.

ACRONYMS AND ABBREVIATIONS

ADB	African Development Bank
AFDI	French Association of International Development
AIDS	Acquired Immune Deficiency Syndrome
ANSI	American National Standards Institute
APICA	Association for Promotion of Africa's Community Initiatives
ASME	American Society of Mechanical Engineers
ASSAILD	Support Organization for Local Development Initiatives
BBLs	Barrels
BEHG	"Bridging Environmental Health Gaps"
BELACD	Bureau for Studies and Liaison for Charitable and Development Activities
BOD	Biochemical Oxygen Demand
BOD_5	Biochemical Oxygen Demand for 5 days
BRGM	Bureau de Recherches Géologiques et Minieres
BS&W	Basic Sediment and Water
CAR	Central African Republic
CBO	Community Based Organization
CEPRIC	Centre d'Etudes pour la Promotion et la Reutabilisation des Initiatives Communautaries
CFCs	Chlorofluorocarbons
CFPA	Center for Professional Training in Agriculture
CH_4	Methane
CILONG	Centre d'Information et de Liaison des ONG (Information and Liaison Center for NGOs)
CIRAD	Center for International Cooperation on Agronomic Research for Development
CNAR	National Center for Research Activities
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
COLONG	Coordination Locale Des ONG
COP	Community Outreach Program
COTP	Crude Oil Topping Plant
CREC	Rural Savings and Credit Bank
CTF	Central Treating Facility

CTNSC	National Technical Committee in charge of developing, monitoring, and supervising the execution of the EMP of oil projects in Chad
CTP	French Development Bank
CUMAC	Common Use of Agricultural Equipment
DCS	Distributed Control System
DPT	Diphtheria, Pertussis, Tetanus
EA	Environmental Assessment
E&S	Economic and Socioeconomic contractor
EDF	European Development Fund
EEPCI	Esso Exploration and Production Chad Inc.
EMF	Electromagnetic Field
EMP	Environmental Management Plan
ESP	Electric Submersible Pump
Esso	Esso Exploration and Production Chad, Inc.
FAO	Food and Agricultural Organization of the United Nations
FCFA	African Financial Community Franc
FONGT	Fédération des ONG Tchadiennes (Federation of Chadian NGOs)
FSO	Floating Storage and Offloading (vessel)
FWKO	Free Water Knock Out
GEP	Good Engineering Practice
GHG	Greenhouse Gases
GIS	Geographic Information System
GOC	Government of Chad
GOR	Gas-Oil Ratio
gpm	Gallons per minute
GS	Gathering Station
ha	Hectare
HIV	Human Immunodeficiency Virus
IEC	Information, Education, and Communication (Section 8.0)
IEC	Intergovernmental Environment Committee (Section 9.0)
IFC	International Finance Corporation
IGF	Induced Gas Flotation
IMC	Interministerial Committee
INADES Formation	Institute for Economic and Social Development
IRED	Innovation et Réseau pour le Développement (Development Innovations and Networks)
ISC	Industrial Source Complex
IUCN	International Union for Conservation of Nature and Natural Resources

KBOD	Thousand Barrels of Oil Per Day
KCl	Potassium Chloride
kg	Kilogram
KGS	Komé Gathering Station
km	Kilometers
km^2	Square kilometers
m	Meters
m^3	Cubic meters
M	Magnitude (of earthquakes)
m^3/day	Cubic meters per day
$\mu g/m^3$	Micrograms Per Cubic Meter
MAE	Ministry of Agriculture and Environment
MB	Million Barrels
MBtu	Million British Thermal Units
mg/L	Milligrams Per Liter
MMI	Modified Mercali Intensity
MMEWR	Ministry of Mines, Energy and Water Resources
MOH	Ministry of Health
MT	Metric Tonnes
MW	Megawatt
NGO	Nongovernmental Organization
NOAA	National Oceanic and Atmospheric Administration
NO_x	Nitrogen Oxide
NO_2	Nitrogen Dioxide
O_3	Ozone
OC	Operations Center
OIMS	Operations Integrity Management Systems
ONDR	National Office of Rural Development
ORT	Organization for Rehabilitation Through Training
OXFAM	Oxford Famine Relief
PAHs	Polynuclear Aromatic Hydrocarbons
PM	Particulate Matter
PM_{10}	Particulate Matter having a diameter less than 10 microns
PNLS	Chad National Program for AIDS Control
ppm	Parts Per Million
PS	Pump Station
PS1	Pump Station No. 1
PVO	Private Volunteer Organization

RFP	Request For Proposal
RRA	Rapid Rural Assessment
SO_2	Sulfur Dioxide
SPONG	Secrétariat Permanent des ONG
ssp	Species (plural)
STD	Sexually Transmitted Disease
TOR	Terms of Reference
TOTCO	Tchad Oil Transportation Company
UNAD	Union of Diocesan Associations for Development
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
UV/IR	Ultraviolet/Infrared
VHF	Very High Frequency
VITA	Volunteers in Technical Assistance
WB	World Bank
WVI	World Vision International
WWF	World Wide Fund for Nature

Extensification–The degree to which minerals have undergone changes in chemical composition.

External Impacts–Effects of a project or policy to those who are not directly involved in the purchase or sale of something. An example is those people who benefit from increased income and health although they are not directly employed by the project.

FCFA–The African Financial Community Franc, the currency of former French colonies.

Felid–The scientific family name for cats.

Ferrallite–A term used in the formerly French parts of North Africa for a soil that originated from basic crystalline rocks that have undergone chemical change and consists of a mixture of hydrates of iron, aluminum, and sometimes manganese and titanium.

Ferricretized–A conglomerate consisting of surficial sand and gravel cemented into a hard mass by iron oxide derived from the oxidation of percolating solutions of iron salts.

Ferruginous–Pertaining to or containing mineral iron (Fe).

Fersiallitic–Pertaining to or containing the mineral fersilicite (FeSi).

Field Manifold–A site where production from several wells is combined in a production header and is directed into a gathering line for transport to a gathering station; it will have a test header to isolate production from an individual well for routing to a test separator.

Field Pump Station–A pump station capable of pumping multiphase field production.

Fire Water–A source of water maintained for the purpose of extinguishing fires.

Fixed Assets–In accounting, any physical property or right that is owned and has a money value. Accountants view an asset as a source of wealth, usually expressed in terms of its cost, capable of giving its owner future benefits. Fixed assets are those which cannot easily be turned into money without disrupting business operations (plant and equipment, long-term investments).

Flare or Flaring–The burning of gas not worth commercial production that is extracted from an oil and gas reservoir.

Fluvisols–Sediments created by the action of a stream.

Forb–A broad-leaved herb other than grass.

Fossorial–Adapted to digging.

Francophone–A French-speaking person, especially in areas where two or more languages are spoken.

Free Water–Water in an oil/water stream that is not combined with the oil in an emulsion.

Gallery Forest–A forest growing along a watercourse in a region otherwise lacking trees.

Gendarmes–Para-military forces.

Genset–A combined motor and generator.

Geomorphology–The scientific study of the land and submarine relief features of the earth's surface.

GIS–(Geographic Information System) A computer program linking a database of relevant information and providing a means of graphically presenting the data.

Girth Welds–Circumferential welds that join lengths of pipe.

Gneiss–A banded or layered metamorphic rock.

Greenhouse Gases–Carbon dioxide, methane, nitrous oxide, and halocarbons (mainly chlorofluorocarbons).

Halomorphic–A type of soil whose characteristics have been strongly influenced by the presence of neutral or alkali salts or both.

Hydromorphic–A soil having characteristics that were developed in the presence of excess water.

Indurated–To make hard; harden.

Input-Output Model–An analysis, usually in table form, that shows statistically how a nation's industries interact with one another in terms of production and consumption of goods and services. They show, for each of several hundred industries, the amount of each industry's output that goes to every other industry in the form of either raw materials or finished products, as well as the amount that goes to its ultimate market in the economy. They also show, for each industry, its consumption of the products of other industries, as well as its contribution to the production process (in the form of value added). They thus permit tracing the industrial repercussions of changes in exports, government procurement, demand for investment goods, and other variables. The input-output table in turn gives rise to a set of structural equations whose simultaneous solution provides a numerical picture of a possible future state of the economy.

In Situ Treatment–A remedial treatment for soil or groundwater that can be accomplished with the affected media remaining in place.

Intensification–The stability of a mineral to withstand changes in chemical composition.

International Finance Corporation, The–An affiliate of the World Bank which financially supports private companies in developing countries.

Knockout–A type of tank or filter used to separate oil and water.

Lacustrine–Pertaining to, produced by, or formed in a lake or lakes.

Land Easement–An area nominally 30 m (100 feet) in width used to accommodate access to the operation and construction area for equipment needed to install the pipeline.

Laterite Soils–A soil group characterized by a thin A horizon and a reddish leached B horizon overlying laterite (a highly weathered red subsoil or material rich in secondary oxides of iron, aluminum, or both).

Leguminous–Characteristic or belonging to the legume family, which includes beans, peas, and clover.

Lithosol–An azonal soil characterized by recent and imperfect weathering.

Lower Risk–A taxon is Lower Risk when it has been evaluated and does not satisfy the criteria for any of the categories Critically Endangered, Endangered, or Vulnerable.

Maestrichtian (Maastrichtian)–European Stage: Upper Cretaceous (above Camparian, below Danian or Tertiary).

Main Line Valve–A valve in a large-diameter pipeline.

Mass Wasting–An erosion process by which the soil and rock are dislodged and transported downslope by gravity.

Mesozoic–The period in Geological Time which began over 230,000,000 years ago and ended 70,000,000 years ago.

Monetized (Not Monetized)–Placing a monetary value on impacts.

Morbidity–The rate of incidence of a disease.

Mortality–Death, involving large numbers of people.

Multi-Industry Impacts (also Multiplier Impacts)–The indirect and sequentially related impacts that result when all parts of the economy are considered together. One way of estimating these impacts is by use of multiplier values that are the result of an input-output analysis.

Mutually Exclusive–Alternatives that do not include parts of other alternatives so that a person can only choose to carry out one action.

Mycorrhiza–A symbiotic association of fungus with a root and/or rhizome of a higher plant.

Napoleonic Code–A form of government.

Net Present Value–A project's net contribution to wealth – present value minus initial investment.

Onchocerciasis–A human disease (river blindness) caused by a worm (Onchocerca volvulus) that is native to Africa and is transmitted by biting flies.

Opportunity Cost (also Alternative Cost)–The most favorable price that a factor of production (land, labor, or capital) can command.

Opportunity Cost of Labor–The highest valued alternative use of a person's labor.

Overbend–Bend in a pipeline that is convex upwards to negotiate a high point in the pieptrench.

Oxisols–In U.S. Dept. of Agriculture soil taxonomy, a soil order characterized by the presence of either an oxic horizon (a subsurface soil composed primarily of the hydrated oxides of iron and aluminum) within 2 meters of the surface, or a continuous phase of plinthite within 30 cm of the surface.

Package Water Treatment Plants–Sanitary wastewater treatment facilities which can be relocated as necessary.

Paleocene–An epoch of the tertiary period: between 53 and 65 million years ago.

Palearctic–Of or relating to the biogeographic region that includes Europe, the northwest coast of Africa, and Asia north of the Himalaya Mountains, especially with respect to distribution of animals.

Parastatal–Organizations that are chartered but not enforced by the Government.

Pastoralist–An individual who belongs to a social organization based on livestock raising as the primary economic activity.

Pediment–A broad, flat, or gently sloping, rock-floored erosion surface or plain of low relief.

Pediplains–A series of plains consisting of a broad, gently sloping bedrock with low relief that is situated at the base of a steep slope and thinly covered with alluvial gravel and sand.

Pedology–The science of studying soil.

Peri-Urban–Development occurring on the perimeter of a city or town.

Pig–A type of scraper used for removing deposits from pipes and flowlines.

Pigging–The scraping of the interior of a pipeline in order to clean and clear the pipeline of waxy deposits, debris, water, or other material as well as to inspect the interior (using an instrumental pig). Used on an as-needed basis during the project's operation.

Pipeline-Specification Crude–Crude oil or gas that meets the quality specifications for pipeline transportation.

Plinthite–In a soil, a material consisting of a mixture of clay with quartz with other diluents, that is rich in sesquioxides and poor in humus and is highly weathered.

Precambrian–The oldest division of geological time occurring prior to the Cambrian period of the Paleozoic Era; before 620 million years ago.

Prefects–A high administrative official or chief officer.

Prefecture–An administrative division of Chad administered or governed by a prefect.

Present Value–Discounted value of future cash flows; the result of adjusting benefits and costs received in different time periods for the time value of money so that the values are in comparable terms.

Produced Water–Component of reservoir fluid produced with crude oil and gas.

Producer Surplus–The net return to a producer over and above expenses, a normal return on investment and the unstated cost of any inputs that are not paid for in a market.

Productivity Impacts–Changes in the productivity of inputs due to changing the quality or the type of input.

Quaternary–A geological period from the end of the Tertiary period (2 million years ago) to the present time.

Receiver Traps–Areas where the cleaning and inspection of tubes and flowlines are terminated.

Recession Agriculture–Cultivation on floodplains as the water recedes.

Regosols–In the early U.S. classification systems, one of an azonal group of soils that develops from deep, unconsolidated deposits and that has no definite genetic horizons.

Riprap–Breakers made up of an assembly of loose stones placed along stream banks to control erosion or create a foundation.

Rinderpest–An acute infectious feverish disease.

Row-King Tractor–A tractor with a rotating flail at its front to mulch standing vegetation while leaving root stock intact.

Sagbend–Bend in a pipeline that is concave upwards to negotiate a low point in the pipetrench.

Sahel–A subarid climatic zone of north-central Africa south of the Sahara Desert. In Chad the Sahel, also called the *Sahelian* zone, forms roughly the central third of the country and supports subsistence farming and livestock raising.

Scour–The downward erosion by stream water in sweeping away mud and silt on the outside curve of a bend or during a flood.

Scraper–A device used to clean deposits from tubing or flowlines.

Scraper Launch–An area where the process of cleaning deposits from tubes and flowlines as well as inspection is initiated.

Sedentary–Settled, not migratory.

Sediment Barrier–A membrane placed across a drainage course that allows water to pass but intercepts its sediment load.

Senonian–European Stage: Upper cretaceous (above Turonian, below Danian).

Sensitive (Wildlife)–Species mentioned in one of the following sources: IUCN, 1996; Hecht, et al., 1993; Chad National Ordinance 16/63 on Protected Species; ICBP, 1988; IUCN, 1982; ICBP, 1981; Robinson, 1989; or IUCN, 1989.

Single Status Community–Residential community for individuals. The community does not provide residences for spouses, children, or others financially supported by the individuals residing in the community.

Smectite–The name for the montmorillonite group of clay minerals.

Sodic–Soil made up of at least 15 percent salt.

STDs–Sexually transmitted diseases excluding AIDS/HIV.

Taxon–A taxonomic category or group, such as a phylum, order, family, genus, or species.

Tertiary–A geological time period of the Cenozoic era, beginning after the Cretaceous period: from 2 million to 65 million years ago.

Thermal Desorption–A remedial technology that removes water, volatile, and semi-volatile compounds from soil using heat.

Threatened–Critically Endangered, Endangered, or Vulnerable.

Three-D (3-D) Seismic–A geophysical survey technique that allows three dimensional models of the earth's structures to be interpreted.

Traditional Agriculture–Also referred to as rainfed agriculture.

Transaction Costs–The costs, often unpaid, that are involved in the negotiations to buy, sell, or trade. This can include costs of talking among villagers, discussions about sacred sites, and extra time and inconvenience that the transaction requires.

Transhumance–The transferring of livestock from one grazing area to another with the changing of seasons (transhumant - adj.).

Trench Plugs–Barriers within a trench that restrict or control water flows in the trench.

Trenching–The act of digging a trench.

Trunkline–A line transporting gas of 20 percent water cut emulsion from a gathering station to a central treating facility.

Trypanosomiasis–An infection or disease (including sleeping sickness) caused by parasitic protozoans that infest the blood and are usually transmitted by insect bites.

Turbidity–The degree at which a solution is clouded from mixing of sediments.

Ultisols–A soil order characterized by the presence of a clay horizon, a low supply of bases, particularly at depth, and a mesic or warmer temperature regime (i.e., the mean annual temperature is at least 8°C (46.4°F but less than 16°C (60.8°F) with a summer/winter variation of more than 5°C (41°F).

Undegraded Savanna–A vegetation/land use mapping unit with the lowest intensity of cultivation in the project area. Also referred to as "Wooded Savanna."

Vector Control Measures–Measures to control pathways of disease.

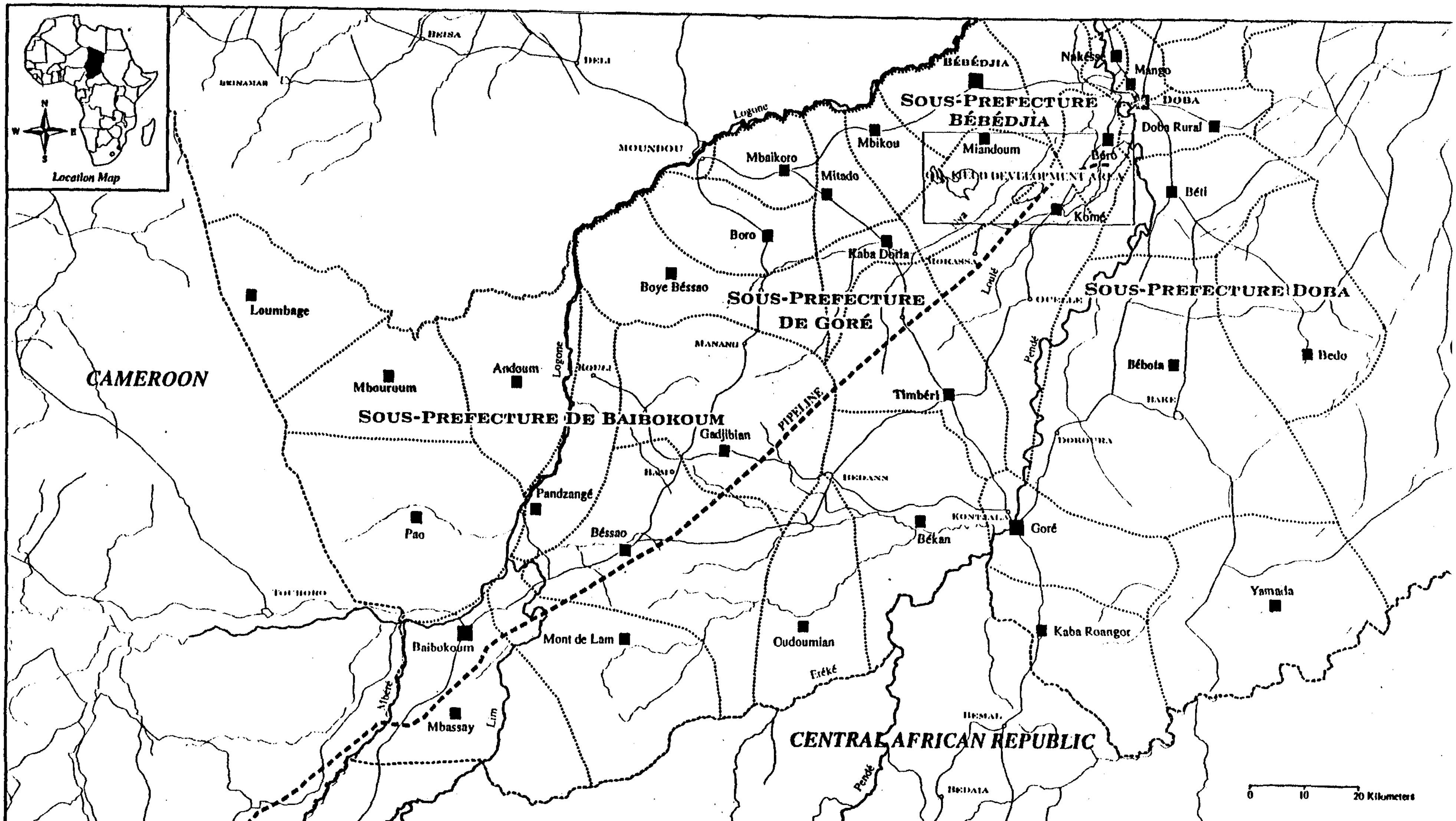
Vertical Well–Conventional oil well that is drilled vertically downwards.

Vertisol–A soil order that contains at least 30 percent clay, usually Smectite.

Vulnerable–A taxon which is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future.

Water Cut–Ratio of water to total fluid (oil and water) in a given stream, expressed as percent by volume.

World Bank–A financing and development institution aimed at promoting the economic growth and social welfare of its member countries.



LEGEND

Sous-Prefecture De Baibokoum
Sous-Prefecture De Goré
Sous-Prefecture Bébédjia
Sous-Prefecture Doba

Canton Villages
Sous-Prefecture Center
Prefecture Center
Canton Boundaries
International Boundaries

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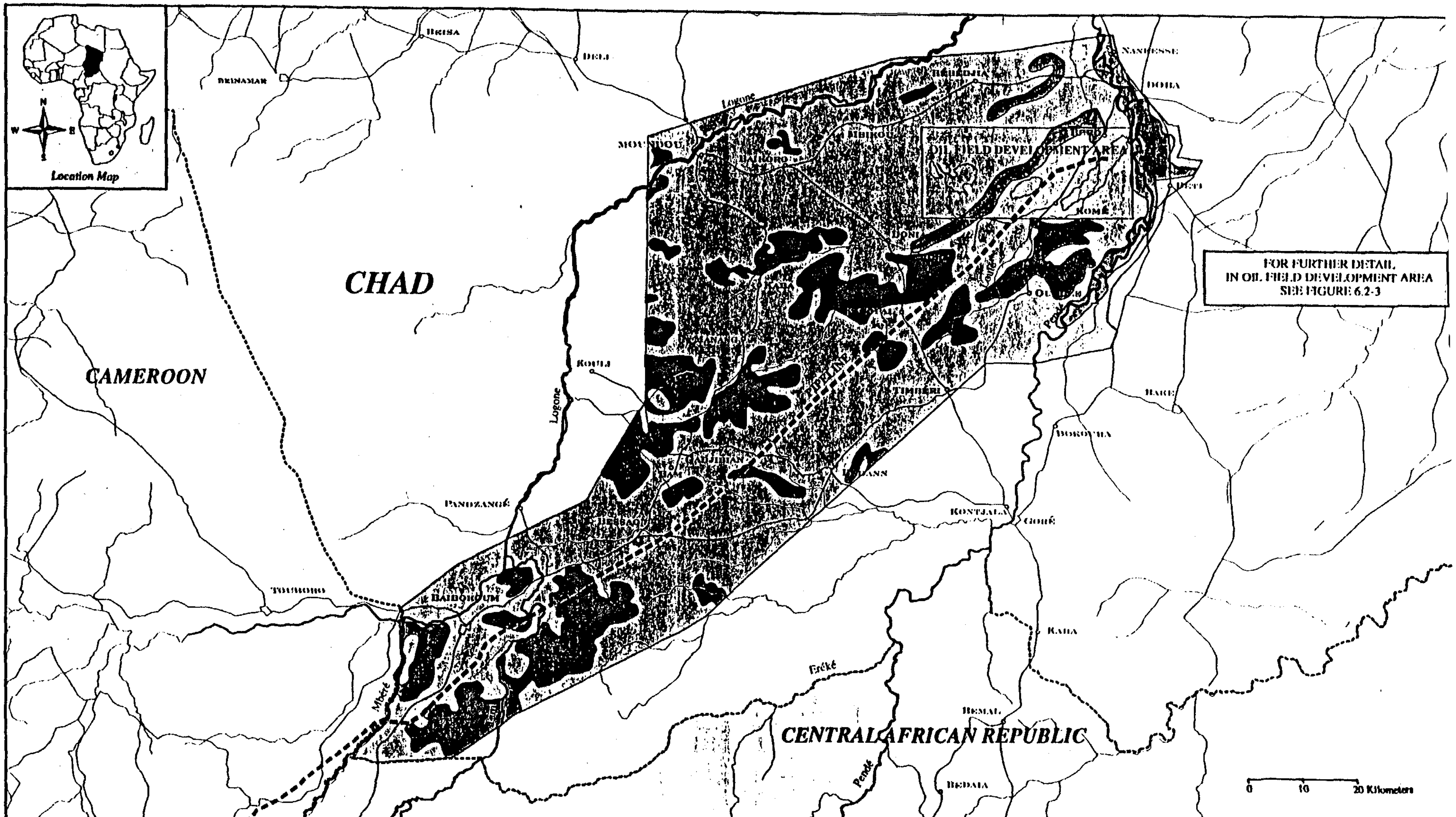
ADMINSTRATIVE BOUNDARIE
OF
LOGONE ORIENTAL PREFECTU



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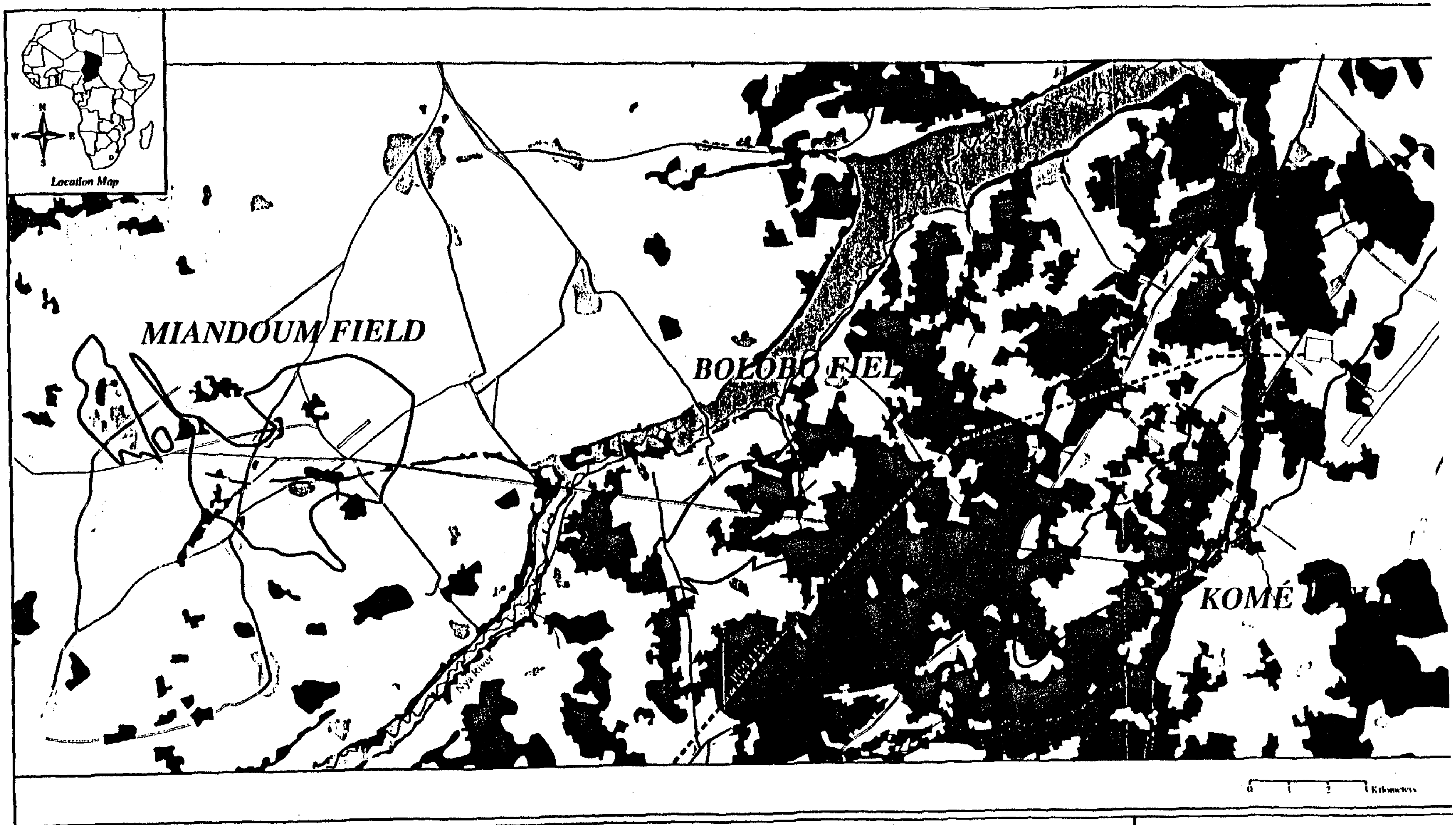
LAND USE IN THE STUDY AREA



LEGEND

Agricultural	Wooded Savanna	Riverine / Gallery Forest
Marshland	Village / Towns	Riverine / Livestock Grazing Zone
Savanna	Water	Marshland / Livestock Grazing Zone
		Existing Roads

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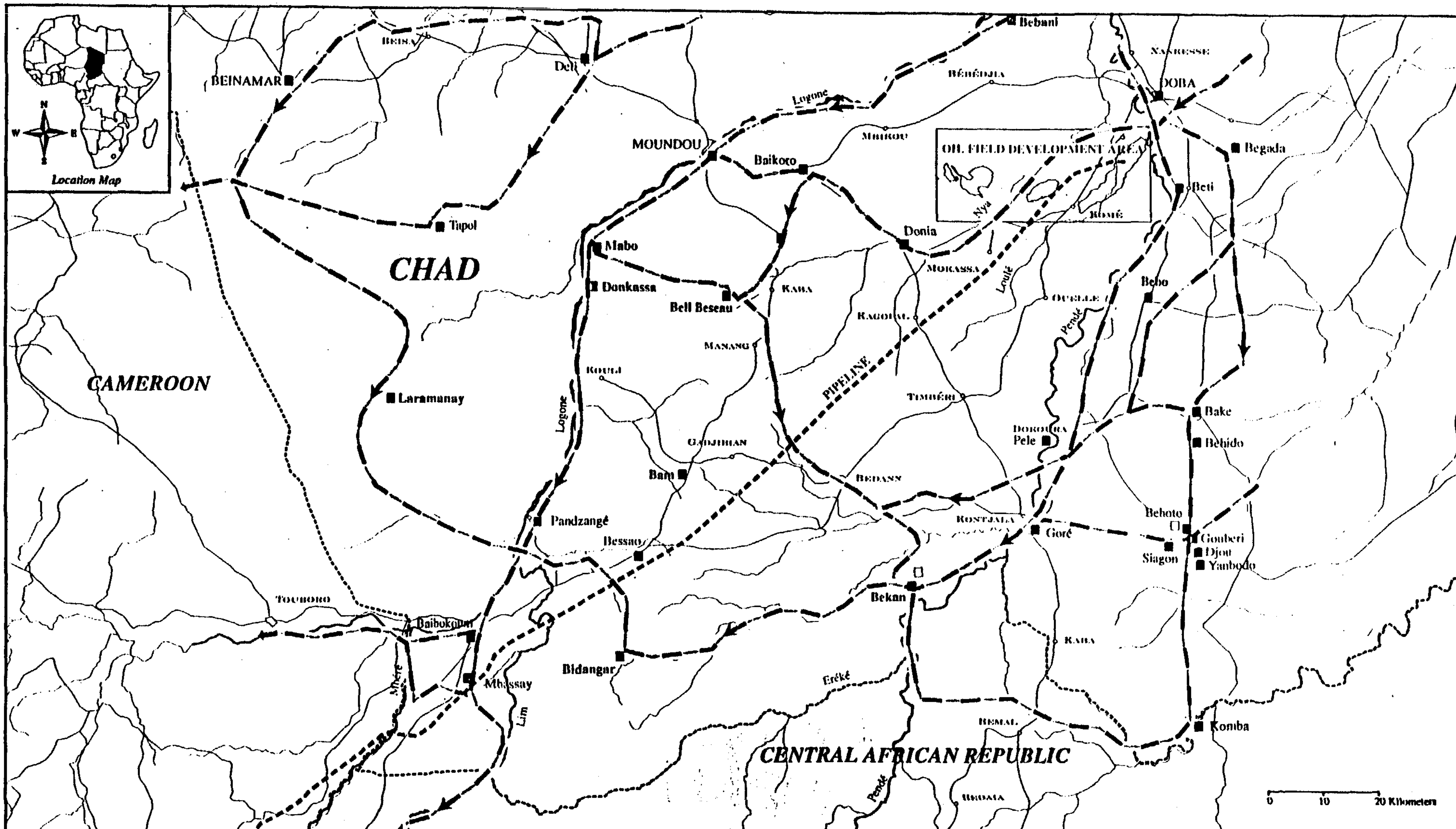
LAND USE IN THE
OIL FIELD DEVELOPMENT ARE/



LEGEND

- Pipeline
- Pastoral Routes
- International Boundaries
- Villages Sited on Pastoral Routes
- ☐ Pastoral Wells

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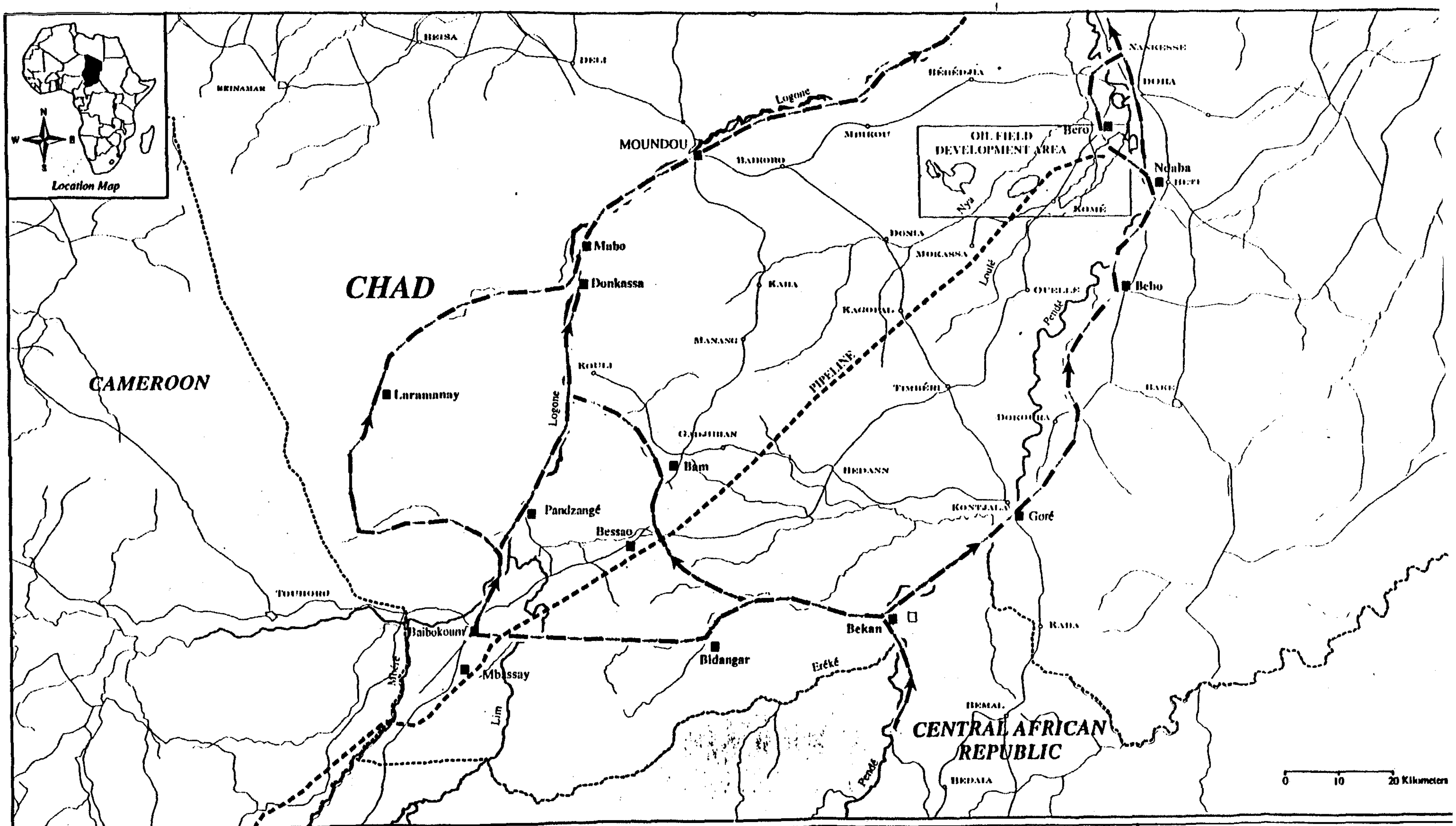
TRANSHUMANT PASTORALIST ROUTES

DESCENT FROM NORTH TO SOUTH (NOVEMBER THROUGH JANUARY)



LEGEND	
Pipeline	Villages Sited on Pastoral Routes
Pastoral Routes	Pastoral Wells
International Boundaries	

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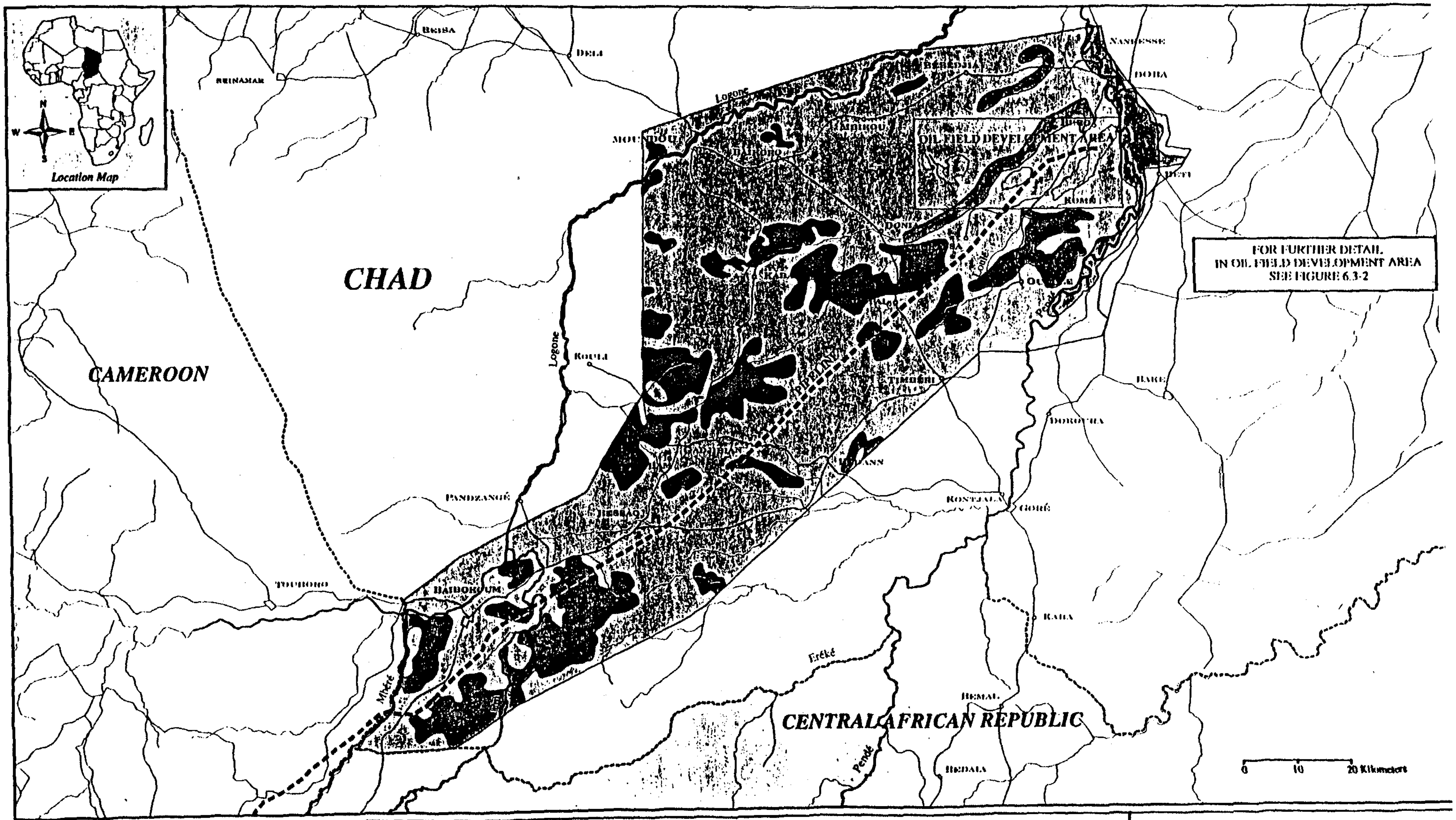
TRANSHUMANT PASTORALIST ROUTES

ASCENT FROM SOUTH TO NORTH (MAY THROUGH JULY)



LEGEND

- Agricultural Zones
- Livestock Grazing Zones
- Savanna Zones - Relatively Undisturbed

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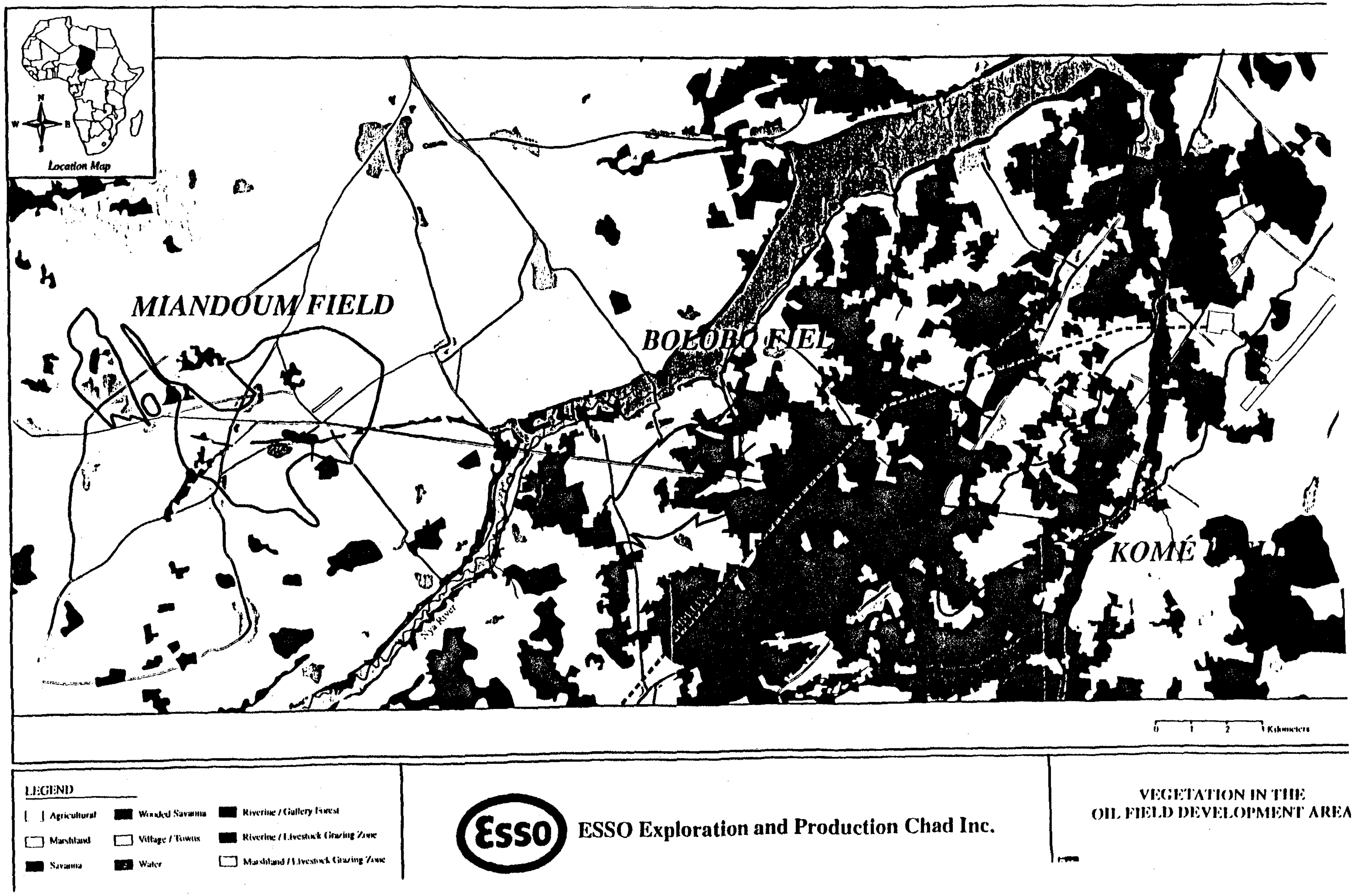
VEGETATION IN THE STUDY AREA


Location Map
N
W
E
S
MIANDOUM FIELD
Nya River
0 1 2 3 Kilometers
LEGEND
Agricultural
Marshland
Savanna
Wooded Savanna
Village / Towns
Water
Riverine / Gallery Forest
Riverine / Livestock Grazing Zone
Marshland / Livestock Grazing Zone
ESSO
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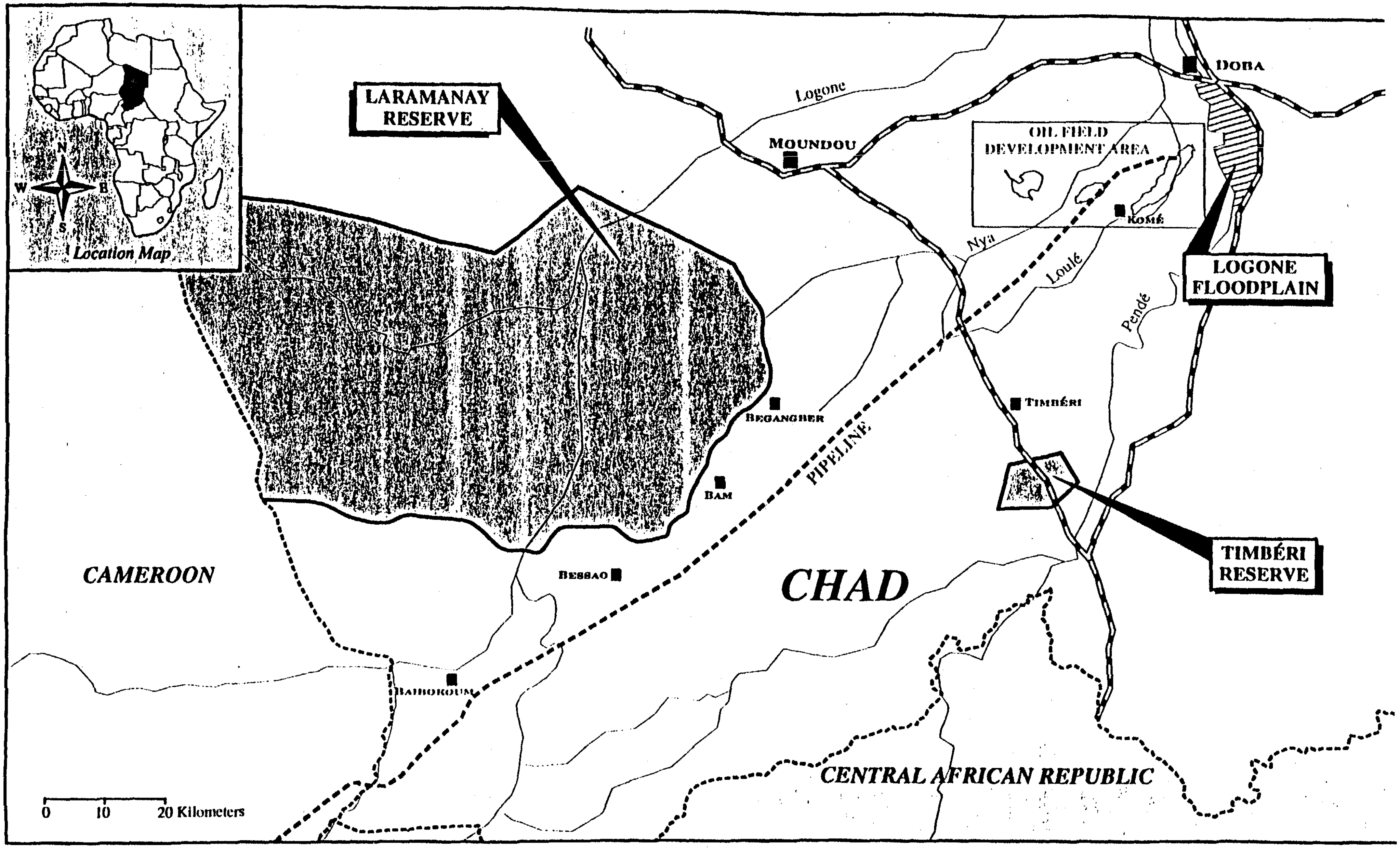
VEGETATION IN THE
OIL FIELD DEVELOPMENT AREA



LEGEND

- Pipeline
- Roads
- Rivers
- Logone Floodplain
- Reserves
- Cities
- Villages

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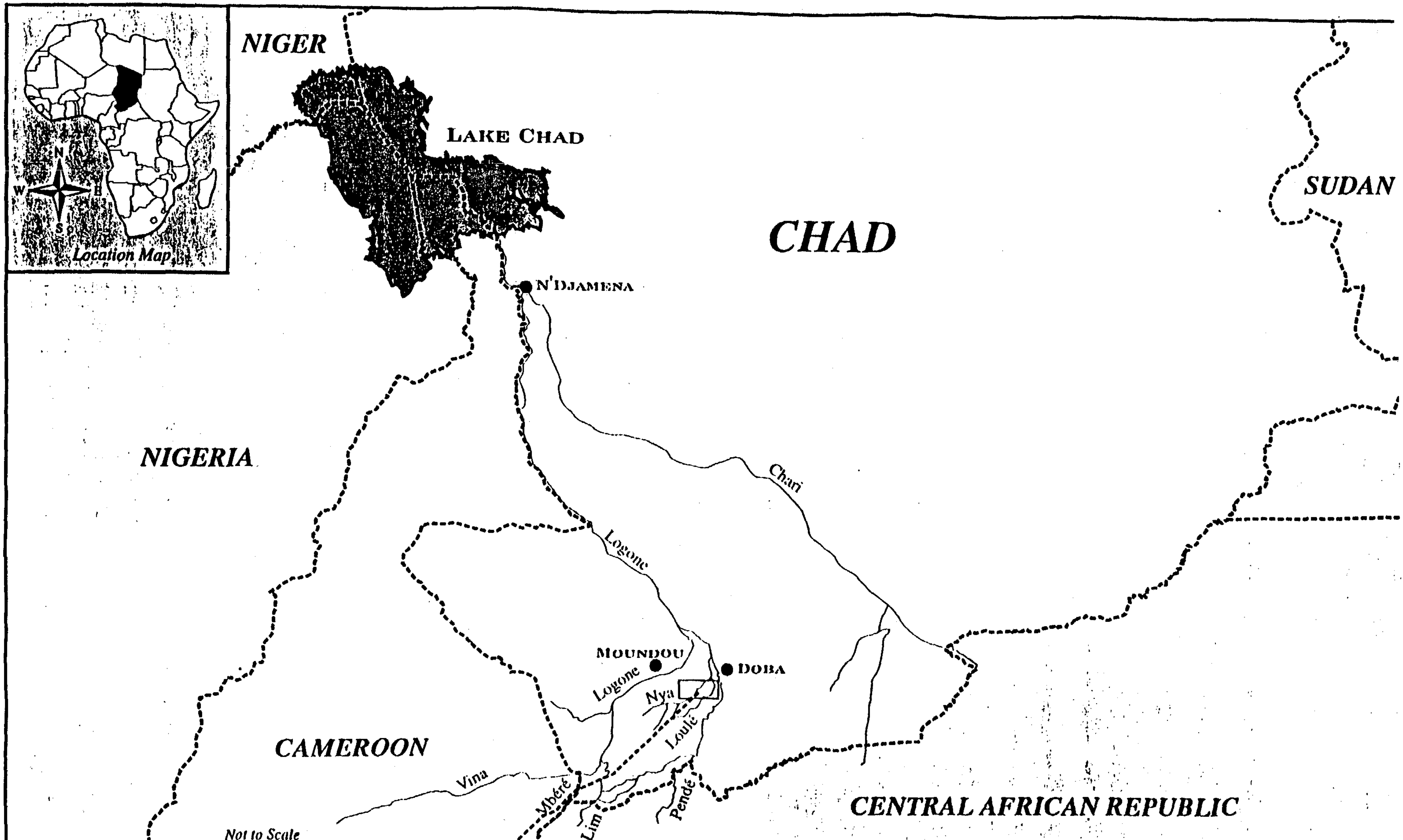
RESERVES AND SENSITIVE HABITAT

DAMES & MOORE

FIGURE 6.3



LEGEND

Oil Field Development Area

Rivers

Pipeline

Cities

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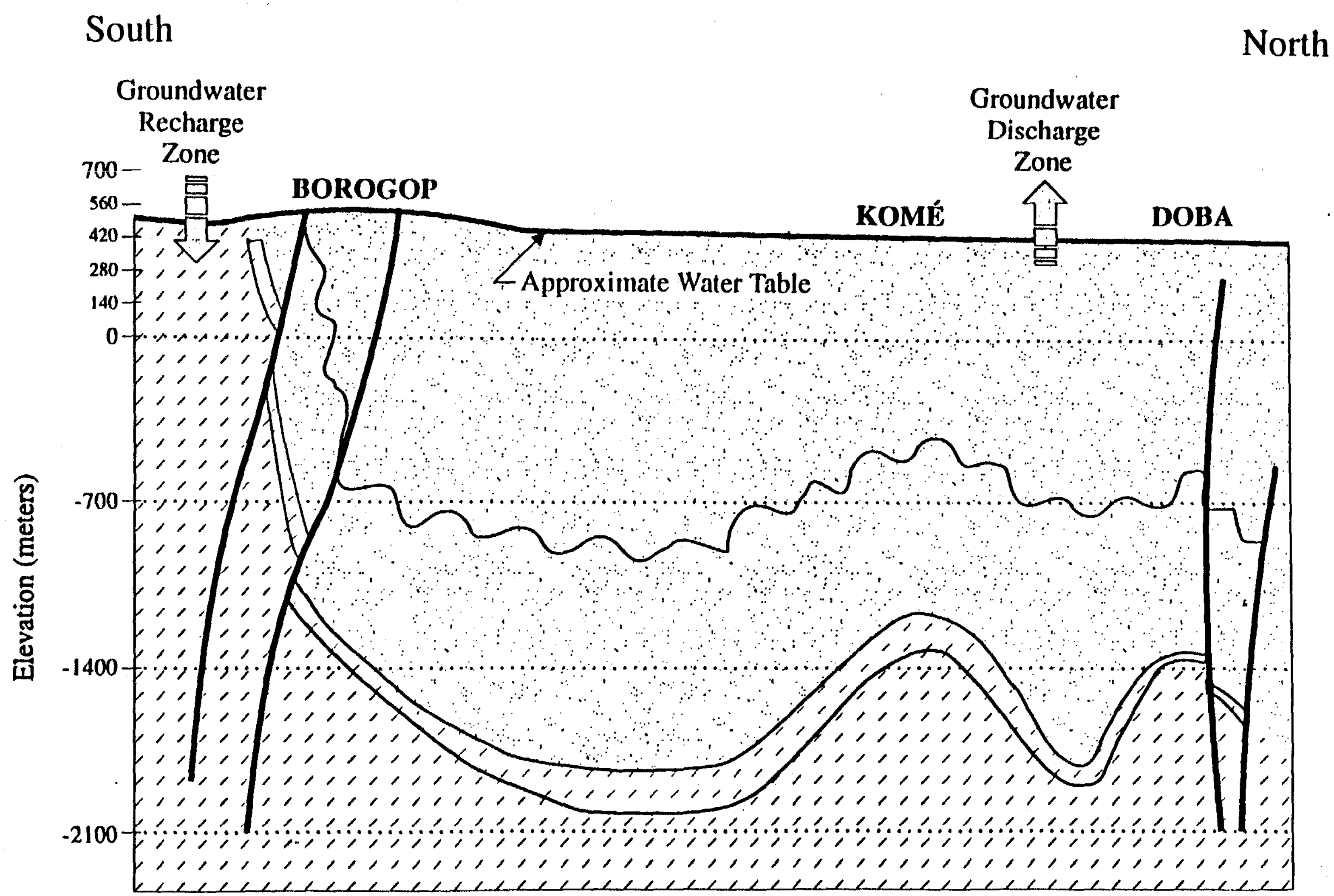
HYDROLOGY MAP

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

FIGURE 6.4-



LEGEND

Tertiary Sands

Maestrichtian-Campanian Sands

Miandoum Shales

Upper & Lower Cretaceous Zones

Fault

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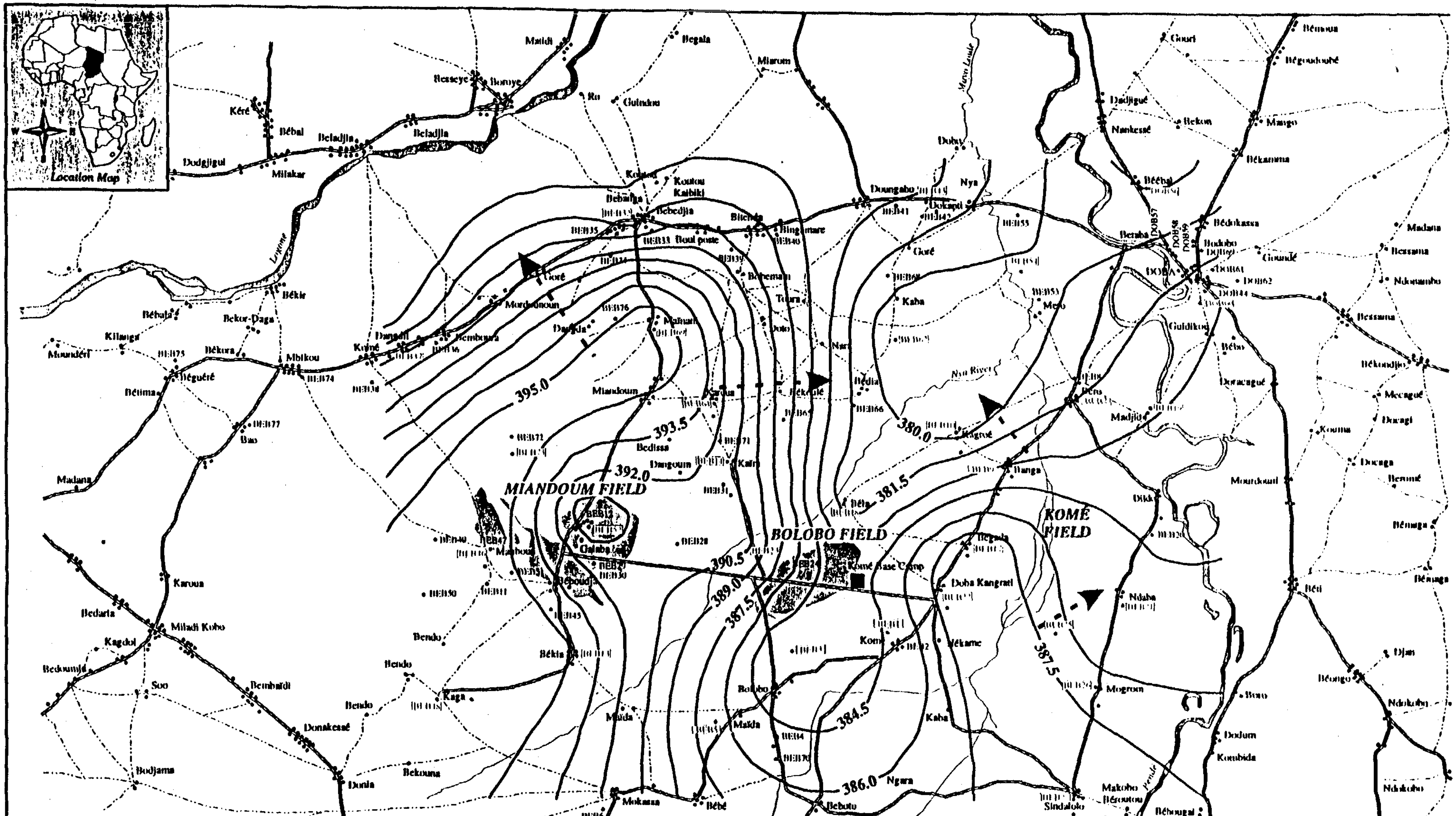
HYDROGEOLOGIC CROSS SECTIOI
NEAR KOMÉ WELL FIELD

DAMES & MOORE

FIGURE 6.



LEGEND
Komé Field
Miandoum Field
Bolobo Field
Well Sampled
Groundwater Flow Direction

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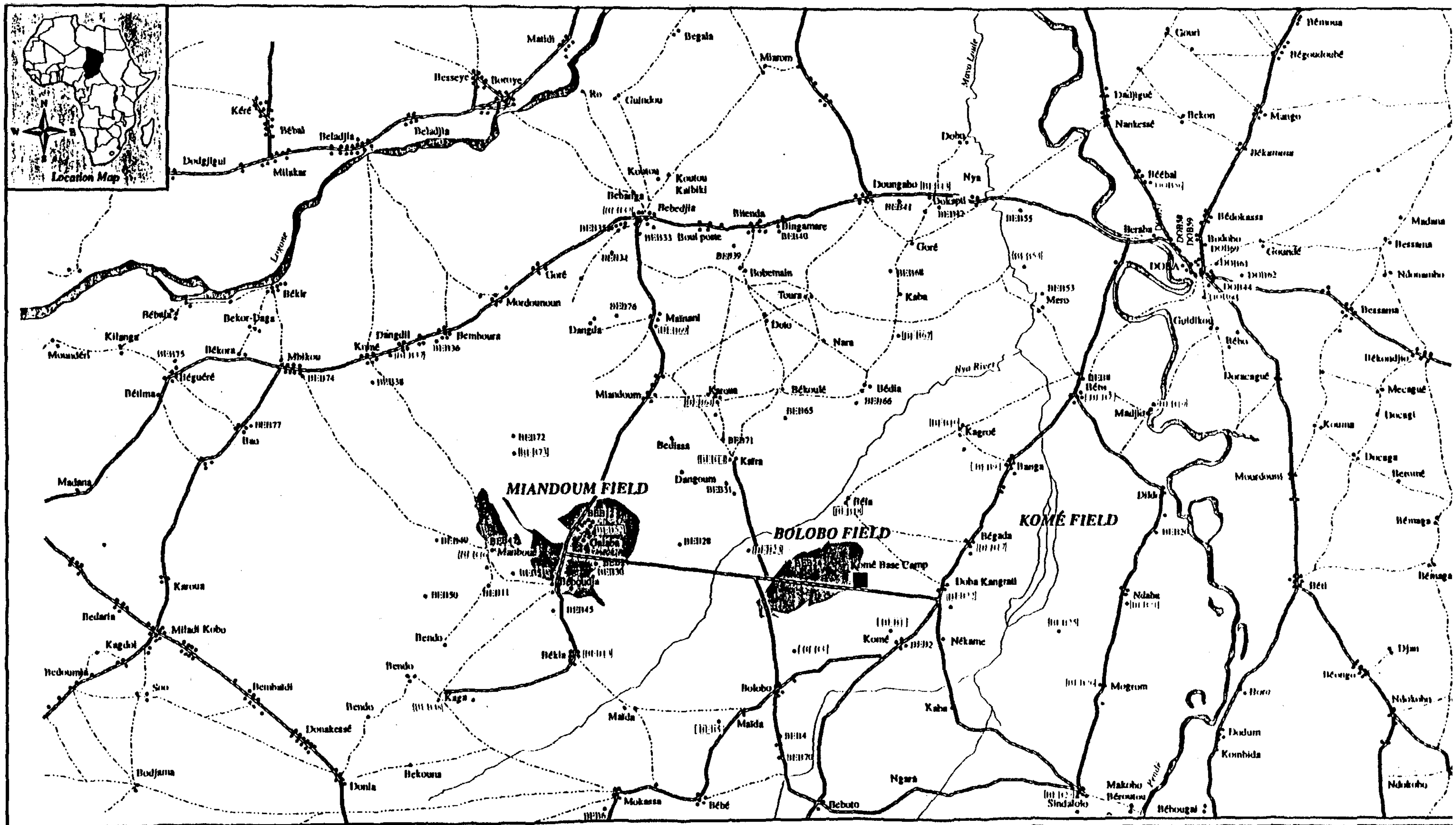
DIRECTION OF GROUNDWATER FL



LEGEND

- Komé Field
- Miandoum Field
- Bolobo Field
- Well Sampled

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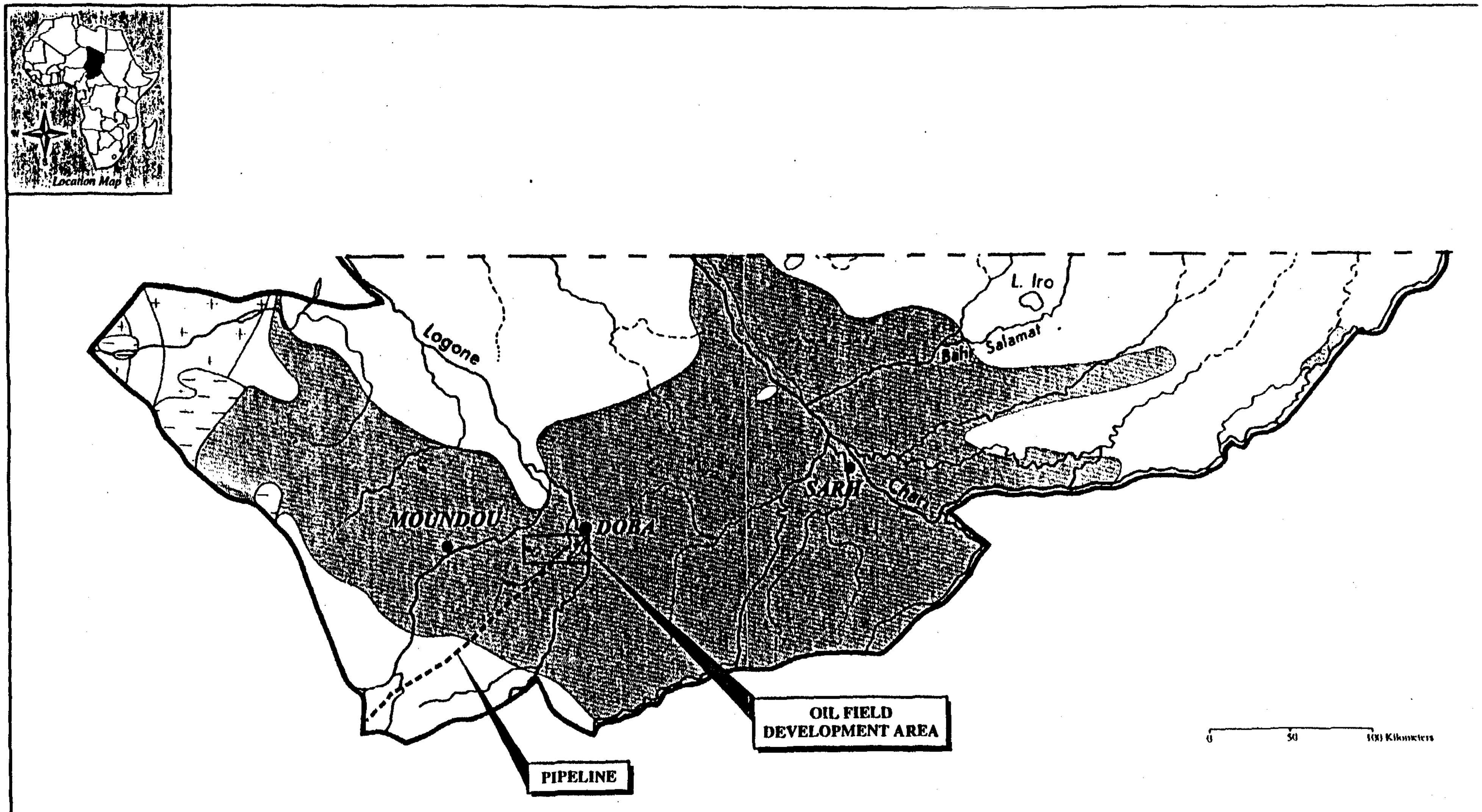
LOCATION OF SAMPLED WELL



Source: Institut National Tchadien pour les Sciences Humaines, 1972

LEGEND

- PRECAMBRAIN - (Tibestien)
- MIDDLE QUATERNARY - Ancient alluvium (sand, gravel)
- TERTIARY - Terminal continental (clay, clayey sandstone)
- PRECAMBRIAN - Granite Intrusive

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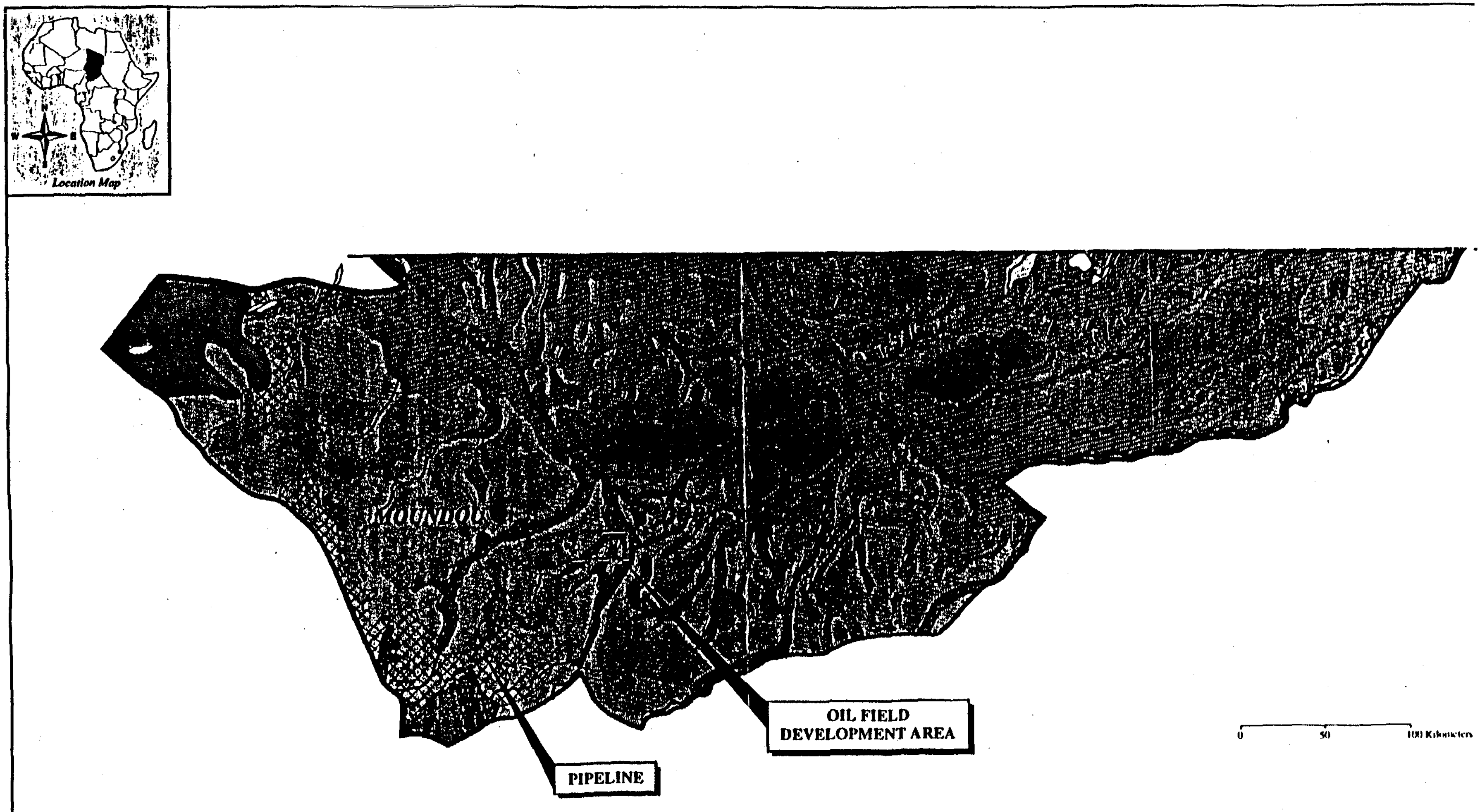
GEOLOGY OF SOUTHWEST CHA



Source: Institut National Tchadien pour les Sciences Humaines, 1972

LEGEND

- Deep Tropical Ferruginous Soils
- Red Ferrallitic Soils
- Vertisols
- Hydromorphic Soils
- Zones of Bedrock with Erodible Soils
- Hard Tropical

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PEDOLOGY OF SOUTHWEST CH/

7.0 ENVIRONMENTAL IMPACTS OF PROPOSED PROJECT

7.1 INTRODUCTION

Potential impacts on the existing human, biological, and physical environment resulting from the construction and operation of the proposed project are identified and described in this chapter. This includes both beneficial and adverse impacts and related significance. This EA focuses on the important environmental issues associated with implementation of the project. Impacts are defined as those changes to the existing conditions that are direct or indirect consequences of the project.

Where possible, impacts are described in quantitative terms. In other instances a qualitative evaluation was conducted based on the professional experience and judgment of the assessment team and importance to the people potentially affected by the project. Impacts from the project are classified in this EA in one of the following four categories:

- Beneficial – Beneficial impacts result in some improvement, or positive or desirable effects on the environment or future conditions of a resource or economy.

- Less than significant – These impacts would cause no substantial economic or environmental change to the resource; it is recognized that a low level of impact may remain. No mitigation is required for this type of impact. This category also includes impacts for which mitigation measures have been incorporated into the design and construction of the project (project design measures) reducing them to less-than-significant levels.

- Significant but mitigable – A significant but mitigable impact has the potential to cause a substantial, adverse change in the economy or environment it affects; however, mitigation measures can be implemented to reduce (but not necessarily eliminate) the impact and to render it less than significant.

- Significant and unavoidable – These are impacts that have the potential to cause a substantial adverse change in the economy or environment they affect, and for which no mitigation measures lessen the severity of the impact to a less-than-significant level.

To determine whether an adverse impact of the project was significant, the impact was, wherever possible, compared to some type of performance standard, policy, or significance criteria. These significance criteria can be either quantitative or qualitative. Quantitative significance criteria include pre-determined institutional criteria such as World Bank or WHO guidelines or policies on the environment, heath, and safety. Qualitative significance criteria are based on the accumulated knowledge, experience, information and best professional judgement of the environmental assessment team. Significance is also based on the context of the project impact such as the amount, number, or size of a resource affected relative to the total amount of the resource present in the project area or region. Significance criteria have been presented for each discipline at the beginning of their respective sections.

A common set of terms has been used for assessing and comparing impacts from the various facilities and activities associated with the project. The duration or actual time the resource would be affected by the project is provided for the resources being analyzed. Short-term, intermittent, or long-term are used, as appropriate to describe duration. Short-term and intermittent impacts are most often related to construction, which for most elements of this project is less than two years in duration. Long-term impacts are most often related to operations, which covers the remainder of the project (approximately 30 years). Duration of the impacts described in the following sections is discussed in terms of construction and/or operations impacts. The magnitude (i.e., local versus regional) is also provided where appropriate. Magnitude generally refers to the size or areal extent of the impact being described.

Impacts have been assessed based upon published and unpublished information, field surveys, laboratory testing programs, and a variety of analytical procedures, including numerical modeling of atmospheric emissions and a terrain unit analysis (described in Section 6.1). For those impacts described as being significant but mitigable, the mitigation is presented in Section 8.0 with a section number heading that can be referenced back to the impacts chapter (Section 7.0).

Impacts (both beneficial and adverse) associated with the project and corresponding mitigation measures are summarized in Table 7.1-1. A summary statement for each impact is cross-referenced to the section in the document where more information can be found on both the impact and corresponding mitigation measure, if one is required.

7.1.1 Environmental Economic Impacts

Environmental economics provides a method to integrate the various impacts identified (both positive and negative) in monetary terms as of a single point in time (i.e., at present day value). The analysis determines if the project will have a positive impact overall to the country. Environmental economics thus links the requirements of World Bank Operational Directive 4.01 regarding Environmental Assessments and World Bank Operational Policy 10.04 regarding Economic Evaluation of Investment Operations. Operational Directive 4.01 states, "...the environmental costs and benefits should be quantified to the extent possible, and economic values should be attached where feasible." Operational Policy 10.04 which is concerned with determining that the project promotes the development goals of the borrowing country, states that the criterion for accepting projects requires "(a) the expected present value of the project's net benefits must not be negative, and (b) the expected present value of the project's net benefits must be higher than or equal to the expected net present value of mutually exclusive project alternatives."

This section summarizes the results of a study to determine if the expected present value of the project's net benefits to Chad is positive after taking into account environmental impacts. In evaluating the project, the implications of doing nothing, and of delaying the project are also evaluated.

These background conditions provide the framework for the analysis:

- Measure the additional impact of the project by evaluating the economy without the project (the baseline) and with the project
- Impacts evaluated are benefits or costs to Chad
- Monetary values in different time periods are aggregated into the present value (a 10 percent real discount rate is used as typical of World Bank practice)
- Tax and royalty payments are not a transfer within the country, rather a real redistribution and benefit to Chad (taxes and royalties on oil production reduce the financial position of the implementing foreign organization but increase the economic position of the state)
- Currency units are in African Financial Community Francs (FCFA) with dollars converted at a rate of $1:500 FCFA.

7.1.1.1 Valuation of Physical, Biological, and Socioeconomic Impacts

Economic values of impacts in the following nine major categories were evaluated:

- Agriculture
- Forestry and bush products
- Livestock
- Petroleum production
- Housing
- Job search
- Health
- Transportation
- Multi-industry (multiplier) impacts.

The change in land use to petroleum production is a major source of many of the cost items. The valuation approach for each category is briefly summarized below.

Agriculture–For short-term costs, an average hectare is constructed to represent a mixture of crops for each type of agricultural land use. Market prices are used to value both marketed and unmarketed production with costs estimated as lost income net of opportunity costs (producer surplus). A cost for carrying out transactions is also included. The long-term agricultural impact in the oil field development area assumes that, after a two-year transition, the land used for petroleum production represents land taken from bush production in the initial years and land taken from cropped production in later years.

Forestry and Bush Products–Bush products are collected both from fallow portions of rainfed agricultural land, as well as from non-degraded savanna or grasslands. Using data on the share of total income from bush products, both monetized and not monetized, the value of bush production per average hectare per year in traditional agriculture and other land categories was estimated. A cost of carrying out transactions is also included.

Livestock–Livestock are important both to settled human populations in traditional rainfed agriculture as well as the transhumant and nomadic populations in the savanna. For the two land categories–traditional rainfed agriculture and savanna–changes in fodder availability due to the project were used to evaluate changes in the cash value of livestock for the concerned population. A cost of carrying out transactions is also included.

Petroleum Production–Substantial direct revenues to the Government of Chad are expected over the life of the project, and payments to the Government of Chad are expected to primarily consist of payments for the natural resource in the form of a royalty, a tax on net income, and income from operation of the pipeline. The actual payments received by Chad depend upon many factors including: rate of production, price of oil, contractual terms for depreciation, transportation costs, timing of production, and so on. The analysis assumes a $20 per barrel real price of oil based on U.S. Department of Energy forecasts before any adjustments for quality and location. Chad will receive approximately $6 per barrel in nominal terms before discounting for the time in which it is received. A sensitivity analysis utilizing an alternative price scenario is conducted at the request of the World Bank using a $15 per barrel price before adjustments for quality and location.

Housing and Other Fixed Assets–Housing and other fixed assets have the potential to be major impacts if individuals need to relocate their households. Relocation would involve numerous costs in addition to the short- and long-term agricultural costs identified above. In addition to buildings, households have a substantial investment in cleared land which, if used by the project for other purposes all at one time, represents a loss in value. The valuation of fixed assets, including cleared land, was estimated by computing the replacement cost of fixed assets. A cost of carrying out transactions is also included.

Job Search–The new employment created by the project in its various locations can indirectly lead to unplanned settlements and job search activity by people both in the local area and from more distant areas. While the economy is improved by shifting labor to more beneficial locations and projects, it is also possible that there are costs that result from people being diverted from their normal activities and not finding comparably productive activity in the project area. An estimate of this latter impact is developed based on people looking for jobs until expected incomes are equal for the job searcher. Those job searchers who are temporarily not able to find productive work are assigned a social cost of 50 percent of their normal income.

Transportation–The benefits of improved transportation due to infrastructure investments are related to the value of products that move over the improved roads. A model of cost savings and induced demand from reduced transportation expenditures was used to estimate the value of infrastructure improvements. Transportation of petroleum also has a potential cost. While oil spill prevention is a key emphasis of the project, a low probability exists of major oil spills from the project facilities and the pipeline. Such events may result in land use damages if the spill extends beyond the land already used by the petroleum industry or if a spill contaminates surface or ground water. Since data on risk of a pipeline spill, size of a potential spill, and impacts resulting from a spill were not identified for the project region, the analysis has used data from the U.S. and Europe. Using these data, information on the probability of a pipeline spill and reported clean-up costs are used as an estimate of the potential costs to Chad.

Multi-Industry (Multiplier) Impacts–There are expected to be large multi-industry effects resulting from the project. The major paths of impact are changes in economic activity caused by the construction and operation of the new petroleum operations and the injection of added revenue to the government after the year 2000. An available input-output model based on Cameroon data was used to present indicative results of the economic sectors that might be affected. It was necessary to adjust the impact data for the economic value of the output changes. The total expansion of labor from the project is assumed to have an opportunity cost of labor equal to 50 percent of its market value. Consequently, 50 percent of the value added of national labor due to the project is assumed to be a measure of benefits.[1]

The construction period impact is geographically and temporally concentrated and so may have a large local impact. Consistent with the multi-industry economic analysis above, the net economic impact of construction is based on the value added of underemployed labor.

Health and Productivity Impacts–The project likely will have positive impacts on the health of the broad population while some potential exists for negative impacts on some parts of the population as described in Section 7.7. On the positive side, health and productivity will improve as income improves on a broad basis in the country. Presented in Section 7.7 are a number of other beneficial impacts that have been identified. The project also has the potential to increase accidents and to increase or decrease disease rates although quantification is not feasible as described in Appendix C. These positive and potentially negative effects are assumed to be approximately offsetting so that the net health benefits are estimated to be zero.

Environmental Benefit and Cost Analysis–Estimates from each of the above categories are combined in several scenarios for a benefit-cost analysis. The Basic Scenario assumes that there is no alternative use of the petroleum resource. This scenario is most consistent with a standard "do nothing" assumption for the base conditions. A second scenario, 25 Year Delay,

[1] The Korup project in Cameroon used an opportunity cost of labor of 50 percent as the base case.

assumes that the alternative to the project is to delay extraction for 25 years but with the same price and cost assumptions in the Basic Scenario. A third scenario, Theoretical Rising Prices, assumes that the alternative to the project is delayed extraction but that prices and costs evolve according to economic theory in a way that keeps present value of the resource constant. The effect is to reduce the benefits of this particular category to zero for the project. This scenario is an extreme sensitivity test of the timing and market assumptions of an alternative project as it is incorporated into the base condition values. A fourth scenario, an Alternative Price Scenario changes the price of oil in the Basic Scenario.

Table 7.1-2 summarizes the results of the analysis. The present value of the estimated impacts is a range of positive net benefits between 237 and 629 billion FCFA (U.S.$0.47 to 1.3 billion). (The Gross Domestic Product for Chad in 1995 was U.S.$1.04 billion.) The absolute magnitude of the benefits of the project is affected by the price of oil and the timing of the alternative project. Net benefits in the amount of 629 billion FCFA (U.S.$1.3 billion) are largest in the Basic Scenario (for an assumed oil price of $20/barrel (bbl)). Net benefits are only somewhat less in the 25 Year Delay Scenario in which they are 571 billion FCFA (U.S.$1.1 billion) (which also assumes a $20/bbl oil price), although they are 58 billion FCFA (U.S.$116 million) less than the basic scenario. In the Theoretical Scenario the present value net benefits decline to 271 billion FCFA (U.S.$0.54 billion) (also for a $20/bbl oil price). The Alternative Price Scenario, with a gross decline in price of 25 percent to an assumed price of $15/bbl, results in net benefits of 237 billion FCFA (U.S.$0.47 billion).

Compensation and mitigation are a part of the project. Economically, compensation can reduce or eliminate a cost to those being compensated. When Chad does not have to provide the compensation funds, the economic effect is to reduce the costs incurred by Chad. It is presumed that all costs except Job Search costs would result in compensation to those affected that is at least equal to the economic costs identified here. Compensation at such a level increases the present value of the project by approximately $2 million.

While the exact numbers can be changed somewhat by modifying the scenario or by additional details in some categories, the overriding conclusion is that the net present value of benefits of the project exceed the costs in all scenarios. The environmental economics analysis therefore indicates that the project represents a positive net gain for Chad. That the benefits exceed the costs is determined by the value of beneficial impacts such as transportation improvements, the multi-industry impacts, and direct revenue from the resource. The costs for changing land use, particularly short- and long-term changes in traditional agriculture, are also significant. The second conclusion is that the project remains economically preferable after evaluating alternatives.

7.2 HUMAN ENVIRONMENT

The following section describes potential impacts to the human environment as a result of construction and operation of the proposed project. Additional details are presented in Appendix B. For purposes of this section, impacts would be considered significant if the proposed project conflicts with established uses or customs of an area.

The project's impacts on the human environment would originate from the following principal sources:

- Changes in uses of the land
- Increases and subsequent decreases in employment
- Changes in local business opportunities
- Increases in government revenues
- Improvements in infrastructure
- Changes in sociocultural aspects of the study area
- Effects to transhumant pastoralists (i.e., migratory herders)
- Migration of people to the project area as a result of project development.

These changes would result in a variety of both beneficial and adverse impacts, sometimes affecting different groups at different times. The nature of impacts would vary with project activities (i.e., construction and operations) and locations of project elements (i.e., facility, pipeline, roads, etc.). Impacts (both beneficial and adverse) associated with the project and corresponding mitigation measures are summarized in Table 7.1-1. Some adverse impacts would require mitigation measures to reduce their severity to less-than-significant levels. These measures are discussed in Section 8.2.

7.2.1 Land Use

Changes in land use are expected to occur as a result of the project. As much land as possible would be reinstated throughout project development, construction, and operations. Conversion of land from farming, grazing, fallow, and bush to oil production has the greatest potential to create adverse social and economic impacts to rural households. Three levels of land use impacts are expected to occur. In order of increasing severity they are:

- Temporary conversion of land for pipeline and facility construction resulting in the loss of one to two years' plantings, but no displacement of households

- Permanent loss of a portion of landholdings (including fallow and bushlands) at facility sites impairing, but not eliminating, the economic viability of a household

- Permanent loss of land that results in household resettlement.

Approximately 1,880 ha of land used for farming and actively exploited savanna and bushlands would be affected by the project. Estimates of the land area affected by both the oil field development area and the pipeline transportation system are shown in Table 7.2-1. Approximately 920 ha of the various land types depicted in Table 7.2-1 would be utilized permanently for the proposed project. Approximately 960 ha would be returned to former uses after construction. Land use requirements of the project would be considered a significant but mitigable impact. These requirements are presented below.

During preliminary design of the project, the facilities and the pipeline corridor were sited to avoid as many populated areas as possible. However, it is possible that as a result of final detailed design and population movements occurring after the EA has been prepared, that limited physical disturbances to housing could occur resulting in removal or displacement. It is anticipated that, out of the oil field development area population of approximately 6,200 households, a relatively small number (a likely range of 60 to 150 households) have the potential to be displaced due to loss of agricultural land. Exact numbers of displaced households cannot be determined until the final design phase of the project. Affected households are expected to be restricted to the oil field development area. Displacements in the vicinity of the pipeline land easement and the upgraded road system are considered highly unlikely due to the efforts taken to date during project routing and site selection studies to avoid this impact. Further refinements of project routing and site selection will also have the avoidance of populated areas as an important criterion, and therefore no displacement of households is expected.

Land use patterns also may be impacted indirectly by relocation of displaced households and agricultural activities. Households and agricultural activities would relocate or expand into nearby open land (either older fallow parcels of land or bushland). The study area's farmlands already are experiencing shortened periods of fallow due to pressures from immigration and natural population growth, and unless more intensive (and expensive) farming methods are adopted, the land may not be able to sustain its residents even under current conditions (i.e., without the proposed project) in the long-term. It is estimated that at current rates of population growth and extension of cultivation, present agricultural methods would exhaust the supply of cultivable land within 30 years. In addition, loss of land in the oil field development area would accelerate the use of land. An induced element of land use changes also may result from relocation of nonlocal households. People would likely be attracted to areas adjacent to improved roads and to towns providing supplies and services to the project.

As noted above, after construction is completed, approximately 960 ha would be returned to former use. Approximately 500 ha in the oil field development area which would be disturbed temporarily during construction will revert to traditional uses after construction is completed. The pipeline land easement (460 ha) would be allowed to revert to former uses (except at isolated valve sites), and people and livestock would be able to use them to the extent that the activities do not interfere with the maintenance and operations of the pipeline. There would, however, be prohibitions on the construction of buildings, planting of trees, etc., on the land easement. With decommissioning and abandonment, virtually all areas occupied by project facilities would be reclaimed to open land with very few restrictions on future use.

Mitigation measures are presented in Section 8.2.

7.2.2 Employment

7.2.2.1 Hiring and Wages

Preliminary estimates of personnel requirements indicate that during the peak construction, approximately 2,000 of 3,000 jobs in the oil field development area and pipeline land easement would be held by Chadian nationals. Wages for these Chadian workers over the three year construction period are projected at approximately U.S.$16 million (Table 7.2-2). (The Gross National Product per capita of U.S.$200 per annum translates to a purchasing power parity of approximately U.S.$700 per capita per annum [World Bank, 1995]). The provision of wages and other benefits to Chadian nationals would be considered a beneficial impact of the project.

Increased employment during construction would be followed by a retraction in incomes as workers are released. This potential boom-bust syndrome would be considered a significant but mitigable impact. Mitigation measures are discussed in Section 8.2. In addition, it is expected that some of the Chadian construction work force would be recruited as operations and maintenance personnel.

During the 30 year operations phase the project would generate a lower but longer term level of employment and income for some Chadian nationals. An aggressive nationalization plan will be implemented to replace expatriates with nationals. This would have a beneficial impact on the local economy.

During decommissioning, employment of Chadian nationals would decrease and eventually terminate. This cessation of employment and the effect on the local communities would be considered a less-than-significant impact given the low number of operations personnel and the ability of the local communities to absorb these workers.

7.2.2.2 Labor Recruitment

The availability of employment during the construction and operations phases of the project is a major expectation of the local population. The equitable distribution of jobs among people in the study area is a real concern of the local population. Residents of villages in and near the oil field development area and pipeline route are interested in securing jobs on the project to supplement inadequate farming incomes. The primary concern of residents is that no single group would be favored over another and that outsiders (non-local Chadians as well as foreigners) would not be recruited for work that locals are capable of performing. It is recognized that expatriate personnel would fill many of the supervisory, technical, and skilled craft jobs on the project; however most of the manual labor work is expected to be allocated to

Chadians. Labor recruitment and the potential for inequitable distribution of jobs would be considered a significant but mitigable impact. Mitigation measures are described in Section 8.2.

7.2.2.3 Education and Training

Chadian and expatriate project personnel would receive training in safety measures and basic work practices. Comprehensive training would be provided to craftsmen in their respective crafts to develop entry level and mid-level construction workers. Technical training would be administered to project workers to prepare them for their assignment. Supervisory personnel would receive training in safety, human relations, planning and scheduling, problem solving, decision making, etc. This education and training would be considered a beneficial impact of the project on the Chadian national work force.

7.2.2.4 Accommodations

Accommodations would be required for both the construction and operations phases of the project. During construction, the expatriate work force will be accommodated in construction camps. A majority of local labor will be recruited from nearby villages and towns. These workers will either reside in their existing accommodations and be bussed to the construction site or will be accommodated at the construction site. Larger towns such as Bébédjia and Doba will be key collection points for the bussing, however stops would also be made at select villages between the larger towns and the job site.

The remaining Chadian nationals will occupy skilled and semi-skilled positions and may come from anywhere in the country. A range of accommodation options for these workers is being evaluated including: assimilation of workers into nearby villages and towns, accommodating the workers in a construction camp, or a combination. The availability of local accommodations would be assessed and the local community consulted in advance of construction activities to develop a plan to house the workers without adversely affecting existing inhabitants of the area. If necessary, local business development would be encouraged (Section 7.2.3) to ensure adequate accommodations are available for construction workers without displacing existing inhabitants. If this is not feasible then construction camp accommodations would be provided.

It is recognized that the potential exists for the development of unauthorized and unplanned settlements in the vicinity of project camps and facilities. While the project accommodations strategy is designed to ensure that no project worker has to resort to such informal accommodation, such unplanned settlements could result from the migration of project worker families to the project area and also from the attraction to the project area of people who do not have jobs with the project but who are opportunistically seeking work.

The movement of project worker families to informal camps in the project area has been experienced in short duration exploration activities (such as the 3-D seismic programs), and in these circumstances the project has tolerated the location of such camps and has ensured that the resident local population was supportive of the temporary arrangement.

The local population sees providing lodging and board in the existing villages and towns as an important economic opportunity for them. Often, by contracting with the women of the household in which they are lodging to provide cooked food and water, workers need not bring their families to live with them. The workers prefer this arrangement since living costs in the development area are high and their family is productively engaged at home on the farm. Housing the work force in local villages and towns and providing bus service will thus reduce the potential for unplanned settlements. Some workers will be able to continue living at home. Many non-local workers will have relatives in area towns who can provide accommodations for the workers, and their families if they come, and thus integrate them socially.

Action, including collaboration with the Government of Chad to identify provisions for accommodations, is being taken to ensure that a range of appropriate accommodation options are available for all project workers. The Government will be responsible for the control of the development of unplanned settlements in the vicinity of project camps and facilities. Consequently, impacts would be less than significant.

Expatriate and long-term Chadian pipeline construction workers would be accommodated in mobile construction camps. Chadians hired on a short-term basis would continue to reside in their own homes.

As a result of the incorporation of accommodation plans, the impact on local accommodations during construction is considered to be less than significant.

During operations some Chadian workers (operating and maintenance work force) would require permanent housing within commuting distance of the Operations Center. It is expected that Chadian workers would assimilate into nearby towns. Transportation would be provided to Chadian workers as necessary. Given the relatively low number of operations personnel and the ability of local towns to accommodate them, the need for housing during operations would be considered a less-than-significant impact. During decommissioning the reduction in labor force may result in a surplus of housing in local villages and towns. This housing surplus should be absorbed by the community and would be considered a less-than-significant impact.

7.2.3 Local Business Opportunities

Goods, services, and some additional infrastructure would be required to support construction and operations personnel. A portion of these procurements can be purchased from local markets. To spread the project's economic effects to local communities, plans are being developed to encourage local business development so that goods and services can be purchased locally, and infrastructure made available. This purchase of local goods and services would also create indirect market changes for foodstuffs, construction materials, and transportation. The purchase of local goods and services would be considered a beneficial impact of the project.

Based on projected manpower loading for the project, goods and services expenditures for camp operations during the three-year construction period would be on the order of U.S.$23 million (Table 7.2-2). Increased demand for goods and services may cause prices to increase. While higher prices may benefit suppliers, local residents would be affected adversely by these inflationary prices. This inflation would be considered a significant but mitigable adverse impact to local residents. Mitigation measures are described in Section 8.2.

In addition, local suppliers may increase production to maximize benefits from the project's purchasing of local goods and services. Purchasing would decline as construction is completed. This may create a potential boom-bust syndrome for local suppliers. This would be considered a significant but mitigable impact. Mitigation measures are discussed in Section 8.2.

Consumption spending by workers would stimulate additional spending as money circulates through the local economy. Based on experience in other African countries, the multiplier effect of the construction wages and procurements on the overall value of economic output in Chad (most of which would occur in the study area) would be equivalent to an increase in Gross Regional Product of approximately FCFA 12.1 billion (U.S.$24 million) over the three-year period of construction.[2] The increase in economic output would include the U.S.$16 million paid to Chadian workers.

The total value of output of the study area is estimated to be about FCFA 28 billion per year, or U.S.$57 million[3]. The additional regional output due to demand increases from project wages and procurements, averaged over three years, would be about FCFA 4.8 billion per year (U.S.$9.7 million), which would represent a major increase in annual gross regional product. This increase in total product would be considered a beneficial impact of the project.

During operations, purchasing activity would be somewhat constant, although at a lower level than during construction. The local economy should have no difficulty meeting the project's requirements and infusion of monies to local and regional markets would be considered a beneficial impact.

After decommissioning, the source of provisioning and procurement demand would disappear. However, it is expected that the regional economy would have developed sufficiently to

[2]Present worth basis, using a 10 percent discount rate over 3 years. The equivalent annualized value would be FCFA 4.8 billion (U.S.$9.7 million) per year during construction.

[3]Based on an average level of gross domestic product per capita of U.S.$237 (FCFA 118,500) per year (as reported by the Economist Intelligence Unit in its 1995 report for Chad).

accommodate the change. As a result, decommissioning would have a less-than-significant impact on the local and regional economy.

7.2.4 Government Revenues

The project's royalty and tax payments would provide a substantial long-term benefit to the project region and the country. Assuming a real price of U.S.$20 per barrel, the government should receive 2,359 billion FCFA (U.S.$4,718 million) in actual revenue over the life of the project or $6 per barrel. Extrapolated over the 30 year production life of the project, the present worth of those tax and royalty earnings is estimated at FCFA 358 billion, or U.S.$716 million. Assessing the sensitivity of a lower price for oil of U.S. $15 per barrel, the government would then receive 848 billion FCFA (U.S. $1,696 million) in actual revenue over the life of the project or $2 per barrel. Extrapolated over the 30 year production life of the project, the present worth of the earnings is estimated at 128 billion FCFA (U.S. $256 million). For comparison, the average per capita income in Chad is less than U.S.$250 per annum. The generation of government revenues would be considered a beneficial impact of the project.

Improvement in local personal incomes from the project would enable people to pay government taxes that are currently uncollected due to the local population's lack of resources. These taxes represent a principal source of government revenue, and tax payment compliance has been minimal in recent years. Improved government finances would lead to restarted economic development projects, adequate staffing of prefectural governments and government agencies, and improved levels of public services. Such long-term gains in government spending would benefit all levels of government and complement and enhance the work of nongovernmental organizations (NGOs) operating in the study area. They also may serve as a basis for generating development activities in the country. The increase in governmental revenues associated with the project would be considered a beneficial impact.

The consultation process that has been undertaken as part of project development (and which is summarized in Section 9.0) has identified concerns regarding the possibility of inequitable distribution of the project benefits that will flow to the Government of Chad. In addition, there is a substantial body of evidence (World Bank, 1995b) demonstrating that the onset of relatively large revenue flows from natural resource development projects can severely strain the capability of governments to realize the maximum long-term economic benefits from a finite revenue windfall. However, these impacts would be less than significant because they have been recognized by the Government of Chad and would be addressed in a number of ways, such as:

- The Government of Chad would be bound under the ratified Constitution to devolution to Decentralized Territorial Communities, whose administrative, financial, patrimonial, economic, cultural and social autonomy is guaranteed by the Constitution. Under Article 212 of the new Constitution the Decentralized Territorial Communities' financial resources include a share of the proceeds generated from the exploitation of the land and subterranean resources in their territory. Key sectors to which project-generated financial resources would be applied include health care (which has consistently been identified through consultation as a sector that the local population expects to see improved as a result of project development), sanitation, water supply, education and poverty alleviation. The evaluation of programs for funding by project-generated financial resources and the disbursement of funds would be undertaken by the appropriate Decentralized Territorial Community in a manner that emphasizes transparency.

- The continuation of a range of projects designed to address basic weaknesses in the Chadian public administration, including:

  - revenue collection
  - rationalization of expenditures
  - economic policy formulation.

  In particular, the Government of Chad is seeking to improve its public finance management and improve the quality and efficiency of public expenditures.

- Various mechanisms are potentially available to ameliorate the negative impacts of the sharp and sudden increase in government revenues, including diversification of economic activity away from the income producing activity, hedging to increase the predictability of future revenues, and the development of revenue stabilization funds. The Government of Chad would develop appropriate mechanisms to ensure the prudent management of project-generated revenues for the long-term benefit of Chad.

7.2.5 Infrastructure

The condition of roads, often impassable in the rainy season, is a major impediment to trade and commerce in southern Chad. To facilitate movement of supplies for the project, approximately 170 km of roads would be upgraded in southern Chad from the Cameroon border near Baibokoum to the oil field development area in Komé and northward to Bébédjia. Road upgrades associated with the project would ease transportation problems for local residents, permit safer driving conditions, help reduce transportation costs associated with imports and exports, and open up inaccessible foreign markets for cash crops. These road improvements may also give locals the ability to move medical patients from remote villages. Upgrade and maintenance of roads in the study area for the project would be considered a beneficial impact.

The upgrading of existing roads in Chad and Cameroon has the potential to modify regional traffic patterns, drawing some non-project traffic travelling between Cameroon and Chad to the new route. The impacts of modifying regional traffic patterns are considered to range from beneficial (where economic activity increases along the upgraded roads) to less than significant (where economic activity decreases along roads from which traffic has been diverted).

Increased traffic on roads upgraded for the project may lead to an increase in traffic accidents involving the local population and its livestock. Local usage of the roads in the project area is low, and where roads pass through or close to houses and villages various project design measures will be implemented with the goal of causing zero accidents. For this reason, the impact of increased traffic leading to increased accident levels is considered to be less than significant.

Increased traffic on roads upgraded for the project may lead to an increase in dust levels. Such increases could result in unsafe road conditions and dust nuisance in nearby villages. These impacts would be considered less than significant with the proposed dust control protocol discussed in Section 8.2.

7.2.6 Sociocultural

The principal sociocultural resources that may be impacted by the project are burial sites and sacred places and objects. Each village has a number of such sites, the locations of which are known only to the residents. Because of shifting villages, it is not unusual for people to move sacred objects for convenience.

Based on socioeconomic studies conducted in the study area, villagers usually are willing to relocate movable sacred objects provided they are consulted in advance and compensated for any expense. For immovable sacred objects or sites that cannot be avoided, consultation will be required to gain the concurrence of the local population that the disturbance of such objects or sites accords with the principle of "common good." This should allow the issue to be resolved by further consultation and compensation. Sociocultural impacts to these objects and sites from disturbance or destruction may occur during the construction phase and would be considered a significant but mitigable impact. Mitigation measures are discussed in Section 8.2.

7.2.7 Transhumant Pastoralists

Approximately 100,000 head of cattle and other livestock are herded by transhumant pastoralists (i.e., migratory herders) through southern Chad to and from grasslands and markets every year. Transhumant pastoralists take a variety of routes along floodplains; timing and routes depend upon rainfall and the abundance of fodder. Because of this, it is not possible to predict where they will be and when. Transhumants' herds often encroach on sedentary and semi-sedentary grazing and cultivation areas. Encroachments often lead to confrontations and violence.

Project construction activities may interfere with traditional transhumant migrations. Diversion of herds away from construction areas could increase encroachment on neighboring landholdings causing impacts to areas of cultivation. Redistribution of cattle in the study area also could result in increased competition for relatively limited food and water resources. These construction impacts would be considered significant but mitigable. Mitigation measures are described in Section 8.2.

During operations, the project's aboveground facilities are expected to cause a minor alteration of transhumant migration patterns. Floodplain areas of the oil field development area would not be occupied by major structures, and the well head at each well pad would be fenced separately allowing herds to pass through the oil field development area easily. Impacts to transhumant pastoralists during operations would be considered less than significant.

7.2.8 Population Migration to the Project Area

The term population migration is used here with respect to the longer term movement of people on a voluntary basis. Shorter term population movements are addressed in Section 7.2.2.4 in the discussion of unplanned settlements.

Project development would result in an increased level of economic activity in the project area, and many people would anticipate employment opportunities working on the project itself (i.e., direct employment) or supporting the project work force (i.e., indirect employment). It is anticipated that Chadian nationals will migrate to the project area in search of employment. However, the total number of jobs associated with the project is small relative to the expectations of the nationals. This migration of people (over and above the numbers who would be recruited to the project) could increase demand on the existing social infrastructure and resources near the project. These potential impacts would be considered significant but mitigable. Mitigation measures are described in Section 8.2.

The new infrastructure that will be developed by the project will include a bridge over the Mbéré River where it forms the international border between Chad and Cameroon. The construction of this border crossing will provide a new access route between Chad and Cameroon, and can be expected to facilitate cross-border population movements. The movement of people into Chad in general and the project area in particular would have the potential to result in additional pressures on land use, and could cause social unrest. However, the fact that the infrastructure will be upgraded to facilitate the movement of goods to the project area via Cameroon means that any substantial movements of people via the infrastructure will require that those people negotiate the international border between Chad and Cameroon. The impact will be mitigated by the Government of Chad's enforcement of the national immigration laws to restrict access to Chad via the new border crossing to bona fide travelers, and to control the movement of economic migrants, and is therefore considered to be less than significant.

7.3 BIOLOGICAL RESOURCES

The following section discusses the impacts of the proposed project on biological resources in the study area. General biological impacts, including impacts on biological diversity and habitat fragmentation, are discussed first, followed by a discussion of resource-specific impacts (i.e., soil, botany, wildlife). For impacts to biological resources discussed in this chapter, the project would be considered as having a significant effect on biological resources if it would change the diversity of plant or animal species; affect a rare or endangered species of animal or plant or the habitat of the species; result in the introduction of new species of plants or animals into the area; create a barrier to or interfere with the movement of any resident or migratory fish or wildlife species; or substantially diminish or otherwise cause deterioration of habitat for fish, wildlife, or plant species.

Impacts on biological resources resulting from the project would be related to the following activities or sources:

- Movement of soils during construction
- Loss of gallery forest vegetation
- Establishment of introduced plant species (such as weeds) in disturbed areas
- Disturbance to sensitive or protected habitats
- Effects of sedimentation, and spills of equipment fluids and oil
- Potential increase in sustainability of wetlands.
- Induced access effects
- Biodiversity

Both beneficial and adverse impacts would arise from the activities or changes listed above. Impacts would also vary from construction to operation. Impacts (both beneficial and adverse) associated with the project and corresponding mitigation measures are summarized in Table 7.1-1. Some impacts would require mitigation that would reduce their severity to less-than-significant levels. These are presented in Section 8.3.

7.3.1 Impacts

The following sections address potential impacts on various biological resources from construction, operation, and maintenance activities associated with the oil field development area and the pipeline transportation system. The duration and magnitude of impacts vary according to project activities (construction versus operations) and various elements of the project (oil field development area, pipeline transportation system). Some impacts would require mitigation measures to reduce impacts to less-than-significant levels. These mitigation measures are presented in Section 8.3.

7.3.1.1 Soils

When soils are moved and compacted by heavy equipment, the particle size and porosity can be altered, important soil components such as mycorrhiza and seeds can be destroyed, and a loss of soil nutrients by leaching can occur. Mycorrhiza associated with the root systems of many tropical plants influence nutrient cycling and germination processes. Construction activity would cause a mixing of soil layers and movement of organic materials. Once mixing occurs, essential nutrients would be leached from topsoil by underlying substrates. This impact would be short-term (during construction only) and limited to the area cleared for pipeline construction (20 to 50 m). The impact would be considered less than significant with incorporation of project design measures presented in Section 8.3.

Harvesting and clearing of wooded savanna for site preparation during construction of well pads, gathering stations, the pipeline transportation system, and other related infrastructure may adversely affect soils over the short term by removing vegetative cover and exposing soil to more direct and intense wind and rainfall. This would result in increasing the fluctuation in soil temperature by exposure to direct sunlight and some soil movement, causing a more rapid decomposition of humus layers. Removal of the existing shade canopy within the gallery forest along the Nya and Loulé rivers for pipeline crossings would result in increased temperatures at the ground surface and decreased moisture content of the soil, killing soil organisms. Although localized, these construction impacts would be considered significant but mitigable. Mitigation measures are presented in Section 8.3. Soil temperatures would be expected to increase directly above the pipeline as a result of the elevated temperature of the oil exiting PS1. The temperature differential between the pipeline and the ground will decrease with distance from PS1. Surface soils would be drier and water availability would change in the immediate vicinity of PS1, but as the pipeline would be buried deeper than normal at this location in order to mitigate this effect, the impact would be considered less than significant.

7.3.1.2 Botanical Resources

Effects of project construction and operations on botanical resources could include direct disturbance to, or loss of, individuals or populations of plant species. These impacts would occur in the oil field development area where well pads, pipelines, and roads impinge on the Nya, Loulé and Pendé river floodplains. Because the oil field development area in general has already been disturbed by grazing and cropping, this impact would be considered less than significant.

Temporary and permanent loss of riverine (gallery) vegetation could occur from construction of the pipeline, infrastructure upgrades, and oil field facilities. The World Bank (1994a) estimates that 500 ha of closed forest exists along rivers and streams in Chad. The project may require clearing of riverine vegetation at pipeline crossings at two rivers (the Lim and the Mbéré), an additional crossing of the Mbéré for the new road bridge, and crossings of the Nya and Loulé rivers in the oil field development area. The preliminary location of the Mbéré Bridge minimizes impacts on vegetation, and all final locations will be selected during detailed design to avoid or minimize the clearing of riverine vegetation. Mitigation measures described in the EA (Section 8.3.1) will further reduce the impact. If each river crossing is conservatively assumed to result in the clearing of a total of 1,200 m^2 (0.12 ha) of riverine vegetation, such a scenario would result in the temporary clearance of a total of 0.6 ha of riverine vegetation, of which 0.3 ha would subsequently be allowed to regrow (0.3 ha represents 0.06 percent of the closed forest area of Chad and 0.6 ha represents 0.12 percent).

Pipeline routing has been undertaken to minimize impacts on riverine vegetation by selecting crossing locations that are less densely vegetated than adjacent locations, or are more disturbed. Final routing to be undertaken as part of detailed design will also have this objective and impacts are therefore considered to be less than significant.

In addition, the pipeline has been routed to avoid impacts to large stands of native bamboo near Bessao, though some small, isolated stands may be affected by pipeline or access road construction. If these impacts were to occur, they would be short-term and localized, and therefore, impacts on bamboo resources are considered to be less than significant.

The overall impact of the project on the total area of the wooded savanna in Chad can be evaluated by comparing impacts associated with the project on wooded savanna with the total estimated wooded savanna in Chad. It has been estimated (World Bank, 1994a) that the forest cover of Chad is some 31,170,000 ha, almost all of which is classified as woodland or woodland savanna. The permanent change in land use resulting from the project will reduce this by a maximum of 0.003 percent (on the conservative assumption that all of the 920 ha of land that will be converted to oil production is currently woodland or woodland savanna). The temporary land use of 960 ha would reduce the forest cover by a similar amount, under the same assumptions. Consequently, due to the small amount of wooded savanna affected by the project relative to the total estimated for the country, the impact of the project on wooded savanna in Chad as a whole is considered to be less than significant.

If soil structure and fertility are degraded by repeated disturbance, re-establishment of the native vegetation may be greatly retarded. An alternate, and less desirable, successional sequence could occur, resulting in the rapid establishment of introduced plant species or undesirable weeds such as *striga*. When this occurs, the normal successional sequence halts or is dramatically slowed. The regenerative capacity of savanna habitat could be impaired. Weedy shrubs and woody pioneer species readily re-establish themselves, but re-establishment of the normal successional habitat is less assured. This results from lack of seed input from tree species, whose seeds tend to be large, relatively short-lived, and dependent upon animal dispersal. A secondary successional habitat could become established, but the process may take longer. These kinds of impacts would be considered less than significant because of the disturbed condition of the study area and the localized nature of the construction impact.

Furthermore, during operations most of the pipeline corridor would be allowed to return to its former use. The 10 to 15 m wide strip of the land easement above the pipeline would be allowed to return to grassland or agricultural uses, so long as it does not interfere with the functioning of the pipeline.

7.3.1.3 Wildlife Resources

Construction activities are expected to have little impact on those wildlife resources that remain in the study area. Agricultural activity has long since displaced most of the natural habitats and associated wildlife of the region. Impacts would consist of temporary and permanent disturbance of wildlife habitat and displacement of native fauna in affected areas of the floodplain wetlands and any remaining gallery forests associated with the Loulé, Nya, Lim, and Mbéré rivers. Impacts would result from the construction of well pads, gathering lines, the pipeline, upgraded infrastructure, and from increased human activity associated with construction and operation of these facilities. Because these impacts would be short term and affect limited wildlife resources, they are considered less than significant.

The potential for habitat fragmentation as a result of the project would be considered relatively limited in scale and has been minimized by pipeline routing and facility site selection. During pipeline corridor evaluation and preliminary site selection studies, an important criterion was environmental suitability, including areas of high biodiversity, reserves and undisturbed forests. Pipeline routing studies within the selected corridor have also had the goal of minimizing intersections with important wildlife habitats. This has been accomplished by mechanisms such as locating pipeline and infrastructure stream and river crossings where riverine vegetation has been converted to agriculture or has otherwise been disturbed; consequently, the impact of habitat fragmentation would be considered less than significant.

Other related wildlife effects could include non-savanna species exploiting savanna habitat. Different species have different tendencies to disperse (e.g., migratory versus nonmigratory species) and require different home ranges or territories. The amount, configuration, and duration of habitat disturbance at a given site, along with the home range and territory size of affected species, determines the impact on wildlife. Individual animals, especially fossorial (digging) or sedentary species such as some reptiles and smaller mammals, could be lost during construction, and further losses of individuals could occur due to traffic accidents on project-upgraded roads and tracks. Temporarily disturbed areas could be recolonized and repopulated by the same species, but probably not by the same individuals, depending on the degree and extent of disturbance. Such differences could affect the ability of certain species to return and persist in remaining natural habitat fragments. Consequently, a limited number of individuals would be affected during both construction and operation. These impacts are expected to be short term (in the case of construction activities), intermittent, and limited in extent, and would be considered less than significant.

7.3.1.4 Barriers to Animal Movements

The construction and operation of permanent oil field facilities and associated infrastructure may create barriers to the traditional movement of livestock through the study area. The effect on livestock and transhumant pastoralists is discussed in Section 7.2.7. Potential impacts to elephant migration patterns from the Laramanay Reserve to Cameroon during construction would be considered less than significant. This is due to the project facilities (including both the pipeline and the infrastructure upgrades) not interfering with migration routes between Laramanay and Cameroon; the short duration of any migration (1 month per year); and the short duration that a potential barrier (i.e., open trench) would be in place.

7.3.1.5 Aquatic Impacts

The erosion of soils from areas cleared for construction in the oil field development area, the pipeline transportation system, and for associated activities including transportation infrastructure upgrades could result in the transport of organic materials and sediments to streams and rivers in the immediate vicinity of the proposed project. During storm events suspended sediment transport could increase turbidity and reduce visibility which may impact food gathering activities by fish, invertebrates, and other organisms. However, streams and rivers in the project area appear to support relatively small populations of fish, invertebrates, and other organisms. Erosion and sediment transport would be minimized during construction by the use of prudent erosion control practices (see Sections 7.4 and 8.4). Limited surveys and monitoring of physical parameters are planned both before and during construction at major stream crossings in order to ensure the effectiveness of these control measures. Therefore, this impact is considered to be less than significant.

The sediment reaching drainages close to project-cleared areas could eventually reach the main streams of the Loulé, Nya, Lim, Mbéré, or Pendé rivers. As discussed in Section 7.4, the increase in suspended sediment loads due to construction-related activities would be a very small portion of the total flows or normal suspended sediment loads of these relatively large streams. Therefore, the impact on the aquatic organisms of the main streams is considered to be less than significant.

It is recognized that despite best management practices the potential exists for accidental releases of vehicle and equipment fluids, and oil to occur. The potential for a spill to occur during operations, coupled with the pipeline crossing rivers allows for the possibility that areas near the pipeline in Chad could be affected.

Spills of diesel, gasoline, hydraulic, brake, transmission, and other equipment fluids, as well as other chemicals, could have an impact on aquatic resources if they enter surface waters. However, spills of this nature would be isolated, and generally limited to access roads, maintenance facilities, and other areas where vehicular traffic is common during construction and operations. Because these impacts would be minimized by control measures implemented as part of project design (see Section 3.2) and any incidents that occur would be small, localized, and intermittent, they would be less than significant.

Crude oil spills could occur in the oil field development area or along the pipeline transportation system during the operational lifetime of the project. If spills are allowed to enter surface waters, the decrease in water quality following such an event could adversely affect botanical, wildlife, and other aquatic resources. Crude oil is generally lighter than water and floats on the surface, potentially coating or causing damage to animals and plants that it may contact. While these impacts would be significant, their likelihood of occurrence would be minimized by the implementation of oil spill response countermeasures which would be outlined in the project Oil Spill Response Plan and associated safety and environmental protection measures. Well pads located in the Loulé River floodplain would include additional safety measures such as locating them away from river banks and stream courses, containment berms, and frequent inspections and monitoring while in operation. The project safety and environmental protection measures and the implementation of the oil spill response countermeasures outlined in the Oil Spill Response Plan discussed in Sections 3.12 and Appendix A are oil spill prevention and preparedness measures which reduce the potential for significant impacts. Damage to botanical, wildlife, and other aquatic resources and contamination of surface water bodies resulting from oil spills would depend upon spill size, location, environmental conditions, and other variables. The potential for a significant oil spill during the life of the project is considered to be low. However, if such a spill were to occur the resulting impacts would be considered significant. Mitigation is discussed in Section 8.3.

Wetland vegetation in the floodplains of the Loulé, Nya, and Pendé rivers and their tributaries is supported by seasonal rainfall and periodic flooding and seepage from wetted surfaces of these streams. As stated in Section 7.4, most of the water requirements of the project would be met by groundwater withdrawal from the shallow zones of the regional aquifer. There would be a less-than-significant impact on the base flows of these rivers from shallow groundwater withdrawal. During the construction phase, a portion of the water withdrawn from the aquifer would be returned to these rivers as treated sanitary wastewater. This addition of continuous discharge would tend to increase dry weather flows and result in a less-than-significant impact on wetland vegetation and fish populations. During the operations phase, treated sanitary wastewater would be discharged to the groundwater regime through septic systems or to surface waters from wastewater treatment plants. Water from the septic systems would eventually find its way to the rivers which would constitute a less-than-significant impact on wetland vegetation and fish populations.

During the construction phase there would be temporary lowering of the groundwater table within the cones of influence of project water supply wells. In some areas wells utilized by locals run dry during the dry season. Because the impact from lowering the groundwater table would be temporary and limited to the cones of influence of the water supply wells, it would be considered less than significant. See Section 7.4 for additional information.

During the operations phase groundwater withdrawal for project water supply would be relatively small and a portion of the extracted water would be returned to the aquifer as treated septic system or wastewater treatment plant effluent (see Sections 7.4 and 8.4). Also, water supply wells would be located to avoid wetland areas. Therefore, the impact of this withdrawal on wetland vegetation would be less than significant.

The withdrawal of water through oil producing wells could lower the regional groundwater table and dry weather flows of surface streams which may affect their ability to support fish populations and other aquatic organisms. As explained in Sections 7.4 and 8.4, a major portion of the extracted water would be reinjected into the deeper zones of the aquifer, where it originated. The withdrawal would be from a relatively large area and aquifer matrix which has an equally large recharge potential. The estimated net withdrawal constitutes a very small fraction of the quantity of recoverable water present in aquifer storage and would be replenished continuously by natural seepage due to infiltration of rain water. As a result, the impacts on surface streams and fish or aquatic organisms supported by these streams would be considered less than significant.

7.3.1.6 Parks, Reserves, and Sensitive Habitats

The pipeline corridor has been routed to avoid impacts to both the Timbéri Forest Reserve and the proposed Laramanay Wildlife Reserve and relatively undisturbed wooded savanna in the vicinity of the pipeline route. Pipeline construction activities would occur no closer than 22 km from the Timbéri and at least 7 km from the Laramanay, far enough away to prevent disturbance to their biological resources. This would be a less-than-significant impact.

Approximately 30 km of the pipeline route traverses savanna mapped as "relatively undisturbed" (Figure 6.3-1). The land area of "relatively undisturbed" savanna that will not be allowed to revegetate to wooded savanna, because of the prohibition on deep-rooted vegetation, within the 10 to 15 m wide strip over the buried pipeline is approximately 45 ha. This impact on the "relatively undisturbed" savanna ecosystem is considered to be less than significant as the construction impacted area comprises 0.06 percent of the total area of "relatively undisturbed" savanna in the project area and 0.03 percent in terms of the long-term impacted area.

7.3.1.7 Induced Access Effects

Induced access can result from project activities (such as the development and maintenance of a cleared strip along the pipeline route, and the construction and maintenance of limited sections of new road) making limited areas of relatively undisturbed savanna and riverine vegetation more accessible. This can lead to increased hunting, fishing, collection of wildlife and plants, and land clearing pressures, with associated impacts on biodiversity. Induced access as a result of the project is considered to be a significant but mitigable impact in those few locations where access would not otherwise be readily available. Mitigation measures are discussed in Section 8.3.

7.3.1.8 Biodiversity

The persistence of biological diversity in remaining natural habitat in the study area (especially gallery forests and wetlands) is a central concern in evaluating the potential biological impacts of the project. Impacts to remaining natural habitat could occur from direct modification of the landscape through construction of project facilities (i.e., well pads, treating facilities,pipeline transportation system). Habitat could also be disturbed by equipment staging areas, materials and stockpile locations; work space requirements; and infrastructure such as worker camps, villages, electrical transmission lines, pipelines, and roads. Loss, fragmentation, or disturbance of already stressed communities in this portion of the country could continue to reduce their capacity to sustain the remaining biological diversity.

Habitat loss reduces biological diversity by elimination of locally adapted populations of plants and animals. Habitat fragmentation reduces the contiguous area of a particular habitat type (e.g., wooded savanna) as well as the total area of the habitat, while simultaneously increasing the areas of others (e.g., agriculture). Plants and animals confined to fragmented areas have to cope with two basic problems: (1) whether the remaining fragments are large enough and close enough to each other to provide living space and opportunities for dispersal, and (2) the impact of the surroundings (the external threat). Man-made habitats support predators (e.g., dogs and cats), competitors (e.g., cattle, goats, pigs, rats), and parasites and diseases that can spread into the fragments and interact with natural plants and animals.

The project is expected to have relatively little direct, indirect, or cumulative effects on the already degraded biological environment of the study area. The only significant biological habitat remaining in the vicinity of the oil field development area and pipeline consists mainly of remnant gallery forest and herbaceous wetland vegetation in the alluvial floodplains of major watercourses, and occasional stands of African bamboo (*Oxyanthera abyssinica*) in the region around Bessao and Baibokoum. The pipeline has been routed to avoid large stands of bamboo. The extent and nature of these habitats, and of the wooded savanna predominant throughout the region, have been extensively modified by conversion of the region to agricultural production, significantly reducing overall biological diversity and habitat value. Wildlife that may have occupied these habitats at one time has either been removed by hunting or displaced as a result of competition with domestic livestock and other introduced species. Therefore, losses of or temporary impacts to remaining biologically significant habitat or general biological diversity in the immediate vicinity of the oil field development area and along the pipeline route during construction and operation would be minimal and considered less than significant.

7.4 HYDROLOGY, HYDROGRAPHY, HYDROGEOLOGY, AND WATER QUALITY

The following section identifies the potential impacts of the proposed project in terms of hydrology, hydrography, hydrogeology, and surface and groundwater quality. Both construction and operation impacts are described. An impact is considered significant if it could cause substantial changes in existing streamflows; lowering of groundwater levels; increased erosion, deposition, or transport of sediments; or deterioration in water quality.

Potential impacts identified related to hydrology, hydrography, hydrogeology, and water quality are associated with the following activities or conditions in the study area:

- Changes in base flows of nearby streams and rivers
- Changes in peak flows of nearby streams and rivers
- Groundwater withdrawal to support both construction and operations
- Reduction in groundwater recharge
- Reduction in groundwater or surface water quality
- Increased sediment loads.

Impacts (both beneficial and adverse) associated with the project and corresponding mitigation measures are summarized in Table 7.1-1.

7.4.1 Hydrology and Hydrography

Major activities during the construction phase of the project would include tree and brush clearing; earthworks, including grading, excavation, filling, storage, and hauling; and construction of access roads, road improvements, bridges, culverts, bypasses, housing complexes, the OC, well pads, gathering stations, pump station, power plant and power distribution systems, and installation of buried pipelines. The arrival of construction personnel at the site would involve additional water withdrawal from the shallow zones of the regional aquifer to meet increased water demands and discharge of treated wastewater and stormwater from project facilities to surface streams. Additional quantities of water would also be withdrawn for dust control, concrete work, hydrotesting of the pipeline, and other construction activities.

The estimated average year water requirement during construction is shown in Table 7.4-1. Most of this water would be withdrawn from the shallow zones of the aquifer. Water for domestic uses would be withdrawn on a nearly continuous basis. Assuming that the maximum daily requirement would be 1.5 times the mean daily requirement, the maximum daily withdrawal for domestic use is estimated to be approximately 2,160 m^3/day. The remaining water requirements shown in Table 7.4-1 would be limited to specific time periods (i.e., hydrotesting, drilling, etc.).

Most water withdrawal would occur in the vicinity of the Central Treatment Facility; Komé, Miandoum, and Bolobo oil fields; and construction camps in three drainage basins (i.e., Loulé, Nya, and Pendé river basins). The effect of water withdrawal from the shallow zones of the aquifer would be distributed over a large areal extent depending upon the location and spacing of water supply wells for construction activities at different locations (e.g., well fields, OC, and construction camps). The resulting surface water impact also would be distributed over several small and unnamed tributaries of the above-named water courses.

During the construction phase of the proposed project, package treatment units would likely be used to treat sanitary wastewater (septic systems may also be used). For purposes of this EA, it is assumed that approximately 70 percent of the water used for domestic purposes would be returned to the nearby surface water bodies in the form of treated effluents from package treatment units. If septic systems are used, approximately 60 percent of the water would be returned to the environment. The annual domestic water use during construction is estimated to be about 526,000 m^3/year (see Table 7.4-1). Thus, an average of 1,000 m^3/day of treated effluents would eventually be returned to the Loulé, Nya, and Pendé river basins if package treatment units are used. If septic systems are used, approximately 860 m^3/day of effluent would percolate through the soil, be treated, and eventually be returned to the groundwater. The net average water loss to the regional aquifer or watersheds providing base flows to the Loulé, Nya, and Pendé rivers would be a small fraction of the base flows of any of these rivers. Therefore, the impact of groundwater withdrawal on major surface water bodies in the site vicinity would be considered less than significant.

The majority of the water used for hydrotesting of the pipeline is expected to be withdrawn from surface waters. The pipeline would be filled with water and hydrotested in segments of approximately 30 km pipe lengths. The maximum volume of water required for hydrotesting is estimated to be about 26,200 m^3. Hydrotest water withdrawal from surface sources would be limited to 10 percent of the surface flow at the time of extraction. Based on the relatively small amount of water needed for hydrotesting the impact of withdrawals from surface streams would be considered less than significant.

The hydrotest water would be discharged at the end of each test segment (approximately 30 km) and would incorporate appropriate erosion control measures and volume controls. The impact on the local ground surface and soils would be considered less than significant.

Clearing and grubbing activities would result in increased stormwater discharges. The total cleared area in the Loulé, Nya, Lim, Mbéré, and Pendé river watersheds is estimated to be about 12 km^2. This is a relatively small fraction of the watersheds of the affected rivers. Therefore, the impact of increased stormwater discharges on the peak flows of these rivers would be considered less than significant. However, peak flows of the small, unnamed tributaries or drainages in the immediate vicinity of the cleared and grubbed areas would experience discernible increases. These increases would be considered a significant but mitigable impact. Mitigation measures are described in Section 8.4.

The pipeline transportation system will cross four relatively small streams (i.e., a tributary of the Loulé River near Komé, a tributary of the Nya River near Kagopal, and two tributaries of the Mbango River south of Bédan) and two major waterways (i.e., the Lim and Mbéré rivers northeast and southwest of Baibokoum, respectively). Normally, the pipeline would be placed in a trench excavated in the respective waterways which would be backfilled up to the existing river bed elevation after installation of the pipeline. To the extent possible, backfill material would be stockpiled outside the floodplains of the respective streams and blocking of waterways would be avoided. Thus the impacts of pipeline construction on the flows of streams would be less than significant.

During the operations phase, the project would create approximately 12 km^2 of heavily compacted areas in the watersheds of the Loulé, Nya, Lim, Mbéré, and Pendé rivers for the construction of well pads, gathering stations, OC, roads, pump station, housing complexes, pipeline, and other ancillary facilities. This would reduce infiltration and increase surface runoff from these areas. Assuming the rainfall-runoff coefficient to be about 0.30, the net increase in peak flows would be about 3.7 percent in the Loulé river watershed (750 km^2) where most facilities are located and 1.6 percent if all facilities are located in the Nya river watershed (1,750 km^2). The impacts of these relatively small increases of surface runoff in the project vicinity are considered less than significant.

The compacted areas for well pads, gathering stations, OC, roads, pump station, housing complexes, and along the pipeline land easement would be spread over several relatively large watersheds and would constitute a small fraction of the respective drainage areas. Facilities associated with the Miandoum and Bolobo fields would likely impact the Nya River, and facilities associated with the Komé field would impact the Loulé River. Compacted areas along the pipeline route would impact the Lim, Mbéré, Logone, and Pendé rivers and their various tributaries. The overall impact of surface runoff on the rivers in the site vicinity would be less than significant. However, there would be some minor changes in local stormwater flow patterns in the immediate vicinity of compacted areas.

The OC and associated facilities would be located within an area potentially susceptible to flood hazards from the Loulé and Pendé rivers. However, project components are outside of flood elevations, and therefore impacts from flood hazards are considered less than significant.

Because of reduced infiltration from increased compacted areas, there would be a small reduction in groundwater recharge. However, since the area available for groundwater recharge to the shallow zones of the aquifer by infiltration of rainwater is much larger than the proposed compacted areas, the impact would be less than significant.

Domestic and process water requirements of the project would be met by groundwater extraction. Groundwater withdrawal from the upper zones of the aquifer (comprised of Tertiary and Cretaceous sands) may impact surface water bodies in the immediate vicinity. During the operations phase of the project, up to 500 persons would be located at or in the vicinity of the OC. The annual domestic water demand for these persons is estimated to be 65,750 m^3/year. The mean daily water requirement would be 180 m^3/day (see Table 7.4-2). Assuming the maximum daily demand would be 1.5 times the mean daily demand, the maximum daily domestic water requirement for the project is estimated to be 270 m^3/day.

During the operations phase, sanitary wastewater would be treated through either package treatment plants or septic systems. Approximately 125 m^3/day of effluent from package treatment plants or 110 m^3/day of effluent from septic systems would be returned to the environment. The net average loss to the Loulé, Nya, and Pendé river watersheds would be about 0.0008 m^3/second.

The 10 year daily low flows of the Logone River at Moundou and Pendé River at Doba are 11.4 and 0.315 m^3/second, respectively (see Table 6.4-1). Using the 10 year daily low flow of the Pendé River at Doba (Drainage Area = 14,300 km^2) as the basis, the corresponding 10 year daily low flows of the Loulé and Nya rivers are estimated to be 0.016 and 0.038 m^3/second. Since the projected loss of 0.0008 m^3/second would be dispersed over a large portion of the shallow zones of the aquifer contributing base flows to the Loulé, Nya, and Pendé rivers, its impact on the base flows of any of these streams would be considered less than significant.

Continuous discharge of treated wastewater from the septic systems (if used) to the groundwater regime may result in a relatively uniform temporal distribution of streamflows by way of increased base flows. This would be considered a less-than-significant impact to downstream users of surface waters.

7.4.2 Hydrogeology

During the construction phase of the project, groundwater withdrawal for water supply, dust control, concrete work, hydrotesting of the pipeline transportation system, and other construction activities would result in lowering the water table in the shallow zones of the aquifer.

Assuming that the capacity of each water supply well for the project would be 1.26 liters/second, a single well may be adequate for a construction camp of about 250 workers with about 0.22 liters/second remaining for nondomestic miscellaneous uses at the camp. This assumes a per capita water requirement of 0.360 m^3 per day. If the well is installed in a zone having a relatively high hydraulic conductivity of 27.67×10^{-2} cm/sec (Section 6.4.2), then the above yield would be available from a saturated aquifer depth of about 3.05 m with a drawdown of 0.10 to 0.14 m. Using empirical equations, the radius of influence of this well is estimated to be 6.1 to 24.4 m. If the well is installed in a zone having a relatively low hydraulic conductivity of 3.17×10^{-4} cm/sec (Section 6.4.2), then the required saturated depth would be about 61 m with a drawdown of 6.2 to 6.8 m. The corresponding radius of influence is estimated to be 30.5 to 53.3

m. The estimated drawdowns are within the range of those reported for existing wells in the area (Tables 6.4-7 and 6.4-8). Construction camps housing lower numbers of workers may require lesser rates of pumping and those housing more workers may require more than one well or larger size wells.

The quantity of water required for hydrotesting of the pipeline transportation system is estimated to be about 26,200 m^3. This water is expected to be withdrawn from surface waters. If hydrotest waters were to be withdrawn from shallow zones of the aquifer, it would require continuous pumping by eight 1.26 liters/second wells for a period of about 30 days.

Depending upon aquifer hydraulic conductivity and location, spacing, depths, and withdrawal rates of individual wells, the average water table decline in the vicinity of individual wells may range from 0.1 to 6.8 m. However, since the upper zone of the aquifer is over 1,000 m in thickness and very large in areal extent compared to the anticipated area of influence of pumping wells and the aquifer recharge by infiltration is substantial (approximately 32.5 cm per year), groundwater recharge by lateral flow toward these wells would be substantial and would tend to minimize the water table decline. Therefore, the impact of groundwater withdrawal associated with construction would be considered less than significant.

During the operations phase, groundwater withdrawal from the upper zone of the aquifer would be required for domestic water supply and process water requirements. The average groundwater withdrawal for these purposes is estimated to be about 180 m^3/day (see Table 7.4-2). As explained previously, the overall impact of this withdrawal on the regional hydrogeology and aquifer water balance would be considered less than significant. However, continuous withdrawal over a period of 10 to 20 years is likely to impact the hydroperiods, water depths, and water supply of wetlands within the zone of influence of project pumping wells. Also, continuous withdrawal by project wells may significantly reduce the yield of the open dug wells and shallow pumping wells in the immediate vicinity used by the local population. These impacts would be considered significant but mitigable. Mitigation measures are presented in Section 8.4.

The creation of compacted areas (approximately 2 km^2) in the vicinity of the oil field development area would reduce groundwater recharge by infiltration. This would reduce the rate of groundwater recovery. However, this impact would be considered less than significant because the recharge area for the aquifer is several orders of magnitude larger than the compacted areas.

A total of approximately 1.35 billion m^3 of oil and water is expected to be withdrawn from the producing formation of the Komé, Bolobo, and Miandoum oil fields. As a result of reinjection of produced water to the producing formation, between 80 and 87 percent of the volume extracted will be returned to the reservoir. The potential impact of surface subsidence resulting from the creation of low pressure zones within the producing horizon is considered to be less than significant due to; the reinjection of the greater part of produced fluids to the producing horizon; the natural recharge of the aquifer; and the lateral flow of groundwater into the producing horizon.

7.4.3 Water Quality

Surface runoff from construction-disturbed areas would carry relatively larger amounts of suspended sediments. These sediments would temporarily increase the total suspended solids content of small tributaries, but because of the large volumes of water available for dilution, the incremental increase in the total suspended solids concentrations of the Loulé, Nya, Lim, Mbéré, and Logone rivers would be considered less than significant. The excavation and backfilling of trenches for the installation of the pipeline for stream and river crossings would result in increased sediment loads downstream of the respective crossings. However, due to the temporary nature of this activity, this impact would be considered less than significant.

Discharge of sanitary wastewater from package treatment units (if used) may impact surface water quality. The quality of shallow groundwater in the immediate vicinity also may be impacted because of its hydraulic connection with surface water. Sanitary wastewater would be discharged to surface waters or natural drainages to ensure that dilution and dispersion of effluents occur. For large streams or rivers the impact would be less than significant. For relatively small tributary streams, this impact would be significant, but mitigable. Mitigation measures are described in Section 8.4.

Septic systems associated with the project (if used) would be designed to accepted engineering standards. The system would be designed according to site constraints such as soil permeability, depth to bedrock or impermeable zones, depth to the water table, and slope of the terrain. The depths of the filter beds would take into account estimated wastewater quantities and sewage loading into the septic systems. Typical industry accepted treatment performance of onsite septic systems would be achieved. Thus the impacts of individual septic systems on the soils and groundwater in their vicinity would be considered less than significant. The effluents from individual septic systems would be further diluted by ambient groundwater flow and by the base flows of nearby streams before appearing in the nearest surface water body. Thus the impacts of the effluents on the water quality of surface water bodies in the vicinity would be considered less than significant.

Surface runoff from the oil field development area would transport portions of drilling fluids that may be contaminated with mud additives and oils. Also, surface runoff from compacted surfaces and dust-covered roofs would transport chemical contaminants to surface streams. Project design measures, including preparation of erosion and sedimentation plans and waste management plans, would help prevent substantial quantities of contaminants from reaching surface streams. Therefore, the impact would be considered less than significant.

During peak production, oil and water withdrawals from deeper zones of the aquifer are estimated to be 35,800 m^3/day and 143,100 m^3/day, respectively. Assuming that only approximately 90 to 98 percent of the water withdrawn from the aquifer can be reinjected due to system losses, the rate of injection would be about 128,800 to 140,000 m^3/day. This water may contain trace amounts of polynuclear aromatic hydrocarbons (PAHs), oil reservoir workover fluids, excess completion fluids, emulsion breakers, corrosion inhibitors, fugitive injectates, and oils.

Results of water quality analysis for inorganic and organic chemicals for aquifer water samples from the Komé 5 Well and for a synthetic mixture of Bolobo crude oils and Komé 5 Well aquifer water subjected to demulsification testing are shown in Table 7.4-3. The results of this testing show that chemicals may be found in produced water.

An assessment of the fate of oil and chemical additives in reinjected produced water (EPRCO, 1996) concluded that the small quantity of oil that is not separated from the produced water during surface treatment and that is reintroduced into the reservoir is not expected to significantly affect water quality. With regard to the chemical additives that are likely to be utilized (bactericide, corrosion inhibitor, demulsifier and oxygen scavenger), conservative analysis results show that the concentrations found in the reinjected produced water for all but one component are less than concentrations that would be of concern for a drinking water supply. The one exception (glutaraldehyde in the bactericide) will be managed by mechanisms such as batch rather than continuous treatment or reduction of injection concentration so that its concentration in injection waters will be below levels of concern for drinking water. The impact of the injection of produced water on the quality of deep aquifers is therefore considered to be less than significant.

The reinjection of produced water may also impact the water quality of the potentially potable near-surface aquifer if leakage from a well casing of the reinjected produced waters into the near surface aquifer were to occur. This impact would be considered significant but mitigable. Mitigation measures are described in Section 8.4.

7.5 GEOLOGY, SOILS, AND SEISMICITY

The following section identifies the potential impacts of the proposed project in terms of geology, soils, and seismicity. Both construction and operations impacts are described. An impact is considered significant if it could cause substantial erosion or siltation, post-construction settlement and/or loss of foundation support of facilities and/or structures, or slope instability resulting in damage to facilities and/or exposure of people to danger.

The potential impacts identified related to geology, soils, and seismicity are associated with the following activities or conditions in the study area:

- Ground disturbance resulting in wind and water erosion
- Damage to project facilities from differential settlement
- Localized ground disturbance from blasting
- Damage to project facilities from geohazards.

With implementation of project design measures, these impacts would result in less-than-significant impacts during construction and/or operation. No mitigation measures are required. Impacts (both beneficial and adverse) associated with the project and corresponding mitigation measures are summarized in Table 7.1-1.

7.5.1 Erosion and Sedimentation

The construction of facilities associated with the oil field development area, pipeline transportation system, and necessary roads would require a variety of earthworks. All newly constructed facilities and roads would require site clearing and removal of topsoil for foundation preparation. Construction of staging areas for boring under paved roads would also expose soils. The exposed soils would consist of clay, silt, sand, and gravel. Although construction would be staged and disturbed areas minimized, the clay, silt, and sand would be susceptible to water and wind erosion when exposed to the elements. The project includes the construction of temporary drainage and erosion control measures. Consequently, the erosion would be considered less than significant with implementation of proposed soil erosion and sedimentation control procedures.

The pipeline transportation system would cross two rivers (the Lim and Mbéré) and four relatively smaller streams. All crossings would use open cut trenching methods. Excavation could suspend sediment in the streams during periods of flow. All crossings would occur during periods of low flow to minimize sedimentation and facilitate construction. Consequently, sedimentation would be considered less than significant.

Portions of the pipeline installed within streams and rivers would be susceptible to scour and changing bottom profiles. Banks of streams may become more susceptible to erosion after the soils are disturbed. Slopes leading into the streams also may become more susceptible to erosion after pipeline installation. The pipeline is proposed to be installed deep enough (1 to 1.5 m) to minimize the potential effects of scour and changing bottom profiles. The channel and bank contours would be restored to their original configurations to the extent feasible after pipeline installation has been completed. Breakers or riprap would be placed over the pipeline along the stream banks where necessary for erosion control. Consequently, erosion would be considered less than significant with implementation of soil erosion and sedimentation control procedures.

7.5.2 Geotechnical Concerns

Engineered fill material would be placed for some building foundations, the airfield, and the roads. The sandy, clayey silt encountered throughout the study area was found to be sensitive to settlement, especially when water was introduced. The settlement of foundation soils during construction or operation could result in differential settlement, which has the potential to cause structural damage to facility foundations, pavements, and utilities. A detailed geotechnical engineering evaluation would be required prior to final design. Foundations of the facilities and structures would be designed to accommodate potential settlement. Consequently, the potential for post-construction settlement of facilities and structures would be considered less than significant with implementation of project design measures.

The pipeline transportation system would use the spoil removed from the excavation as backfill and would therefore not require off-site fill soil except in limited quantities in rocky areas. Installation of the pipeline would generate excess soil that would be spread evenly over the top of the pipeline alignment. The soil would be crowned over the ditch, which would compensate for possible future settlement of the backfill. Consequently, the potential for settlement would be considered less than significant.

7.5.3 Blasting

Blasting will be required to remove bedrock exposed during site preparation. Blasting typically generates ground vibrations which would have the potential to induce localized slope instability. A blasting plan would be developed and implemented as part of the project. Given the implementation of a blasting plan and the relatively short-term nature of this impact, this impact would be considered less than significant.

7.5.4 Seismic and Volcanic Hazards

Seismic events have the potential to adversely impact structural elements due to ground motion, ground rupture, liquefaction, or faulting. However, the likelihood of a moderate to large earthquake of $M \geq 5$ impacting project facilities is low. The relatively silty native soils would not be susceptible to liquefaction. Project facilities do not cross mapped, known, or active faults. Consequently, the potential for post-construction damage to project facilities resulting from a seismic event would be considered less than significant. In addition, the likelihood for post-construction damage to project facilities resulting from a volcanic eruption would be low as the nearest area of active volcanism (at Mt. Cameroon) is distant from project facilities; therefore, the impact would be considered less than significant.

7.6 METEOROLOGY AND AIR QUALITY

Air quality impacts of the proposed project were evaluated by estimating the potential pollutant concentrations that could be generated by project activities, adding to those "project-generated" concentrations an ambient or background concentration, and comparing the total value to the World Bank guideline values for pollutant concentrations. Guideline values for onshore oil and gas development were applied to the project. For this analysis, an air quality impact would be considered significant if proposed project operations would cause or contribute to ground level pollutant concentrations exceeding these guideline values. The following discussion identifies potential sources of air pollutant emissions that would be introduced by the project, provides an overview of the impact assessment methodology, and describes project air quality impacts. Impacts (both beneficial and adverse) associated with the project and corresponding mitigation measures are summarized in Table 7.1-1.

7.6.1 Project Pollutant Emission Sources

Emission sources would be created during both the construction and operations phases of the project. These sources are described below.

The project would introduce temporary emission sources during construction. Project construction would generally consist of site grading and preparation activities, and road and building construction activities. These activities would occur in the oil field development area, along the pipeline transportation system, and at locations of roadway improvements. The primary pollutant emission associated with construction activities would be dust, or particulate matter less than 10 microns in diameter (PM_{10}), from site grading and other earthmoving activities. Other pollutants including sulfur dioxide (SO_2) and nitrogen oxides (NO_x) would also be emitted through construction equipment exhaust and welding activities.

Uncontrolled dust emissions from earthmoving activities would likely lead to high concentrations of particulates in the area immediately surrounding the construction area. Construction-related PM_{10} emissions would be substantially reduced by implementing project design measures such as watering active construction sites. Emissions of SO_2 and NO_x would not be likely to result in high concentrations of these pollutants, as construction equipment exhaust emissions would be minor and would be dispersed throughout the area in which construction equipment operates. Impacts associated with construction emissions would be considered less than significant due to their localized and short-term nature (and the inclusion of project design measures for PM_{10} emissions).

For purposes of analyzing potential air quality effects during operations, pollutant emissions generated primarily through waste incineration and through the combustion of a combination of natural gas and crude oil were analyzed. These pollutant emissions include NO_x, SO_2, and PM_{10} (USEPA, 1995a). The primary pollutant of concern generated by combustion of any of these three fuels is NO_x, although PM_{10} emissions from crude oil and diesel combustion and waste incineration were also assessed in detail.

The oil field facilities addressed in the analysis include the three well fields: Komé Miandoum, and Bolobo. Oil fields would have gathering stations from which the crude oil and a small amount of natural gas are transported to the Operations Center (OC).

The OC would contain the major sources of air pollutant emissions associated with the project. These sources include: five turbines fired by either natural gas or crude oil (of which four normally would be in operation) that drive electric power generators; a natural gas flare that would operate intermittently and would serve to burn excess natural gas; a small crude oil topping plant including a crude oil heater rated at about 11 million British Thermal Units (MBtu); and a waste incinerator that would be used to combust processing byproducts, construction debris, medicinal waste, and other municipal-type wastes. In addition to these emission sources, a gas-burning spare start-up heater would be operated periodically while a turbine is out of service.

The turbines at the OC would include a heat recovery system to use waste heat for increasing the crude oil temperature as part of the treating process without requiring supplemental fuel combustion. Emission controls at the OC may include low NO_x burners, however for conservatism this air quality impact analysis assumes that no low NO_x burner emission controls would be included as part of the project.

7.6.2 Impact Assessment Methodology

7.6.2.1 Overview

Air quality effects associated with the project were quantitatively assessed using an iterative design optimization approach. This design optimization approach combined conservative assumptions and standard U.S. Environmental Protection Agency (USEPA) and World Bank impact assessment methodologies. Using these assumptions and methodologies, maximum potential ground-level concentrations of air pollutant emissions were quantified, added to estimated "background" or pre-existing ambient concentrations of these pollutants, and compared to World Bank concentration guideline values described in Table 5-2 of Section 5.0.

While the World Bank Guidelines provide threshold values for both stack emission rates and ground-level concentrations of air pollutants, generally if ground-level concentration guideline values are met, then pollutant emission rates are considered acceptable. For this reason, the focus of the air quality impact analysis was on worst-case potential ground-level pollutant concentrations generated by the project; stack emission rates for all major sources, however, are provided for informational purposes.

The design optimization methodology used in the air quality analysis entailed identifying potential pollutant emission sources associated with the project; estimating pollutant emissions from each of these sources based on their operating parameters, equipment type, and equipment specifications; and using atmospheric dispersion modeling to optimize facility design so as to minimize the potential for high off-site air pollutant concentrations.

7.6.2.2 Emission Estimation

Emissions of NO_x, SO_2, and PM were determined in order to compare emission rates (pollutant pounds per unit fuel energy, or pounds per unit time) with applicable World Bank guideline values summarized in Table 5-2 and to use as input for the dispersion modeling effort, in which ground-level pollutant concentrations were estimated.

Emission rates typically are estimated by multiplying an emission factor by an equipment operating parameter. Emission factors for most industrial operations have been developed and compiled by USEPA; emission factors for many equipment types are also often determined by the equipment manufacturer. Emission factors for fuel combustion would vary according to the equipment fuel type, size and design, and operating conditions.

Estimated rates of uncontrolled emissions from combustion equipment at the OC and the gathering stations were developed based on a combination of USEPA emission factors, equipment manufacturer-supplied emission rates, applicable technical support documentation, and engineering calculations. Tables 7.6-1, 7.6-3 and 7.6-5 summarize emission rates for each equipment type at the OC in terms of the rate applicable for comparison to World Bank guideline values.

7.6.2.3 Industrial Source Complex Dispersion Modeling

Estimating maximum ground-level concentrations from industrial air emission sources typically entails atmospheric dispersion modeling. The USEPA has a standard set of regulatory computer models that have been approved for use in obtaining EPA permits, and these USEPA mathematical models are commonly used throughout the world. The Industrial Source Complex (ISC) atmospheric dispersion computer model, one of the most widely used of the regulatory models, was determined to be the model applicable for assessing impacts of the project (USEPA, 1995b).

ISC incorporates characteristics of pollution sources, hourly meteorological data, potential receptor locations, and a number of other parameters into a mathematical model that estimates ground-level concentrations at any specified point. Characteristics of pollution sources include source-specific design parameters such as stack locations, pollutant emission rates, stack heights and exhaust exit velocities; meteorological data includes hourly wind speeds and directions and atmospheric stability. Other parameters include surface roughness, which affects wind gradients, and building downwash, which can have substantial effects on near-field concentration estimates.

The potential for air pollutant emissions to disperse or accumulate is based on a number of site-specific design parameters, including stack heights, stack diameters, exhaust velocities, and aerodynamic downwash from nearby buildings. Of these parameters, design of the emission point (stack height) and the potential for stack emissions to become entrained close to nearby buildings (building downwash) are often important.

The dispersion modeling analysis was used to optimize facility design. Based on emission source locations and building configurations, a preliminary modeling analysis was conducted to evaluate where potential pollutant accumulation would be likely to occur under worst-case circumstances. Using results of this preliminary modeling analysis as a basis, a number of different emission source design scenarios were modeled to evaluate which design scenarios would achieve the best dispersion results, resulting in the lowest potential for pollutant accumulation. Finally, optimized design characteristics were integrated into the facility design and were used to assess worst-case potential air quality impacts of the project.

7.6.2.4 Modeling Methodologies for the Proposed Project

Dispersion modeling methodologies for the project include the items briefly summarized below.

- Emission Source Parameters: Data used were based on engineering details for the proposed project. These data include physical parameters such as exhaust flow rate, stack height and diameter, and exhaust temperature.
- Meteorological Data: The modeling analysis included a set of conservative, worst-case meteorological data assumptions typically used for USEPA screening air quality analyses and in instances where site-specific meteorological data are not available. These conservative hourly data include very low wind speeds and stable atmospheric conditions which are conducive to pollutant accumulation.
- Receptor Locations: Receptors were modeled in a dense grid extending in all directions from each property boundary. Receptors were placed at 25 to 50 m increments on the property boundary lines, in a 100 m grid extending to 1 km, in a 500 m grid extending to 5 km, and in a 1 km grid extending to 10 km.
- Averaging Periods: Dispersion modeling was used to estimate maximum hourly pollutant concentrations; 24 hour and annual average concentrations were extrapolated from modeled hourly values using conservative scaling factors. The USEPA recommends using these scaling factors for screening level air quality impact analyses.

Annual average concentrations were assumed to be 10 percent of maximum hourly concentrations; 24 hour average concentrations were assumed to be 40 percent of maximum hourly concentrations.

- Conversion of NO_x to NO_2: Nitrogen oxides, or NO_x, would be emissions from all combustion-related project emission sources; however, the World Bank guideline values (as well as USEPA ambient standards) are in terms of nitrogen dioxide, or NO_2. Because NO_2 is a component of NO_x and is generated through reactions of NO_x with other airborne chemicals, only a portion of the modeled ground-level NO_x concentrations is NO_2. USEPA recommends application of the Ozone Limiting Method to determine NO_x to NO_2 conversion (USEPA, 1993). The amount of NO_x that is converted to NO_2 depends upon the "oxidizing potential" of the atmosphere and relies upon the amount of available ozone; the higher the ambient ozone concentration, the more NO_x is converted to NO_2 in the atmosphere.

Limited meteorological data are being collected at the project site. Site dispersion modeling conducted with one year's worth of these data indicate that the screening meteorological data assumptions used for this EA yield more conservative predictions of maximum pollutant concentrations than actual meteorological data.

7.6.3 Project Impacts With Respect to World Bank Guideline Values

This section provides a summary of air quality effects with respect to World Bank Health and Safety Guidelines. Air quality impacts from NO_x, SO_2, and PM emissions were quantified and compared to World Bank guideline values.

7.6.3.1 Nitrogen Dioxide

Table 7.6-1 provides a summary of NO_x emission rates and estimated maximum ground-level concentrations of NO_2 and compares these values to applicable World Bank guideline values. Modeled worst-case annual average and maximum 24 hour NO_2 concentrations would not exceed ambient concentration trigger levels identified in the World Bank Guidelines. Therefore, the project would have a less-than-significant impact with respect to NO_2 concentrations with the incorporated project design measures.

The concentrations shown in Table 7.6-1 would occur near the fenceline of the OC property. Worst-case NO_2 concentrations at a distance further from the facility, such as at the locations of local villages, would be substantially lower. Table 7.6-2 shows estimated maximum 24 hour and annual average NO_2 concentrations at nearby village locations.

These results are based on a number of worst-case assumptions, including the following:

- Worst-case meteorology: As discussed in Section 7.6.2, meteorological assumptions used in the modeling analysis incorporated worst-case conditions for atmospheric dispersion. The use of actual monitored meteorological data where available could reduce estimated maximum concentrations by a factor of 10 or more.

- Uncontrolled emission rates: NO_x emissions were estimated assuming no NO_x controls are used at the OC sources. The use of NO_x control technology at various OC sources could reduce unit NO_x emissions by 30 to 50 percent. NO_x controls are being considered for incorporation into the project design.

- Screening Averaging Techniques: Annual average and 24 hour average maximum concentrations were extrapolated from one hour maximum modeled concentrations using screening methodologies that over predict actual time-averaged concentrations over long periods. The extrapolation method used in this impact assessment is commonly used for screening air quality analyses for USEPA permitting and consists of scaling maximum hourly concentrations by 0.4 to yield 24 hour averages and by 0.1 to yield annual averages.

- Background NO_2 concentrations: Long-term monitoring data for background NO_2 concentrations in the study area are not available, therefore conservative assumptions were used to develop estimates of worst-case background concentrations. As described in Section 6.6.1, the primary source of NO_x emissions is fuel combustion, such as from automobiles or industrial operations. The extreme remoteness of the project site and the absence of large or numerous small combustion sources in Chad indicates that background concentrations would be extremely low.

- Background average annual NO_2 concentrations were assumed to be one tenth of the USEPA standard of 100 micrograms per cubic meter ($\mu g/m^3$); background average annual concentrations are more likely to be 0 to 5 $\mu g/m^3$. Background 24 hour NO_2 concentrations were conservatively assumed to be 40 $\mu g/m^3$, or four times the average annual concentration.

- Background ozone (O_3) concentrations: Use of the Ozone Limiting Method to estimate NO_x to NO_2 conversion entails estimating background O_3 concentrations; as with ambient NO_2 concentration data, no background ozone concentration data exist. O_3 is generated through photochemical reactions in the atmosphere involving NO_x and reactive organic compounds, which are generated chiefly by human sources. Background O_3 concentrations were assumed to be 0.05 ppm, or slightly less than half of the USEPA ozone standard of 0.12 ppm.

- Applicability of emission rate "trigger levels": The World Bank guideline values for NO_x emission rates from onshore oil and gas development facilities are designed to apply to oil-fired boilers and fired heaters and are not applicable to NO_x from diesel engines and gas turbines. The World Bank governs NO_2 through recommended ground-level concentration guideline values.

7.6.3.2 Sulfur Dioxide

Estimated maximum ground-level SO_2 concentrations and applicable World Bank guideline values for SO_2 are shown in Table 7.6-3. Modeled worst-case maximum 24 hour and annual average SO_2 concentrations would be below ambient concentration trigger levels identified in the World Bank Guidelines. Additionally, total uncontrolled SO_2 emissions associated with the project would be well below the World Bank guideline of 100 tons per day. The maximum concentrations presented in Table 7.6-3 would occur at the OC fenceline. SO_2 concentrations farther from the property boundary would be considerably lower. Table 7.6-4 shows estimated maximum 24 hour and annual average SO_2 concentrations at nearby village locations. Because project sources would generate SO_2 concentrations below World Bank guideline values, project impacts with respect to SO_2 would be considered less than significant.

Maximum modeled impacts for SO_2 emissions are based on a number of worst-case assumptions, which are described above for NO_2 and include the following:

- Worst-case meteorology
- Uncontrolled emissions
- Screening averaging techniques
- Background SO_2 concentrations. Because long-term monitoring data for background SO_2 concentrations in the study area are not available, conservative assumptions were used to develop estimates of worst-case background concentrations. Background annual average and 24 hour average SO_2 concentrations were assumed to be one-tenth of their respective USEPA ambient standards.

7.6.3.3 Particulate Matter

Table 7.6-5 summarizes estimated maximum ground-level PM concentrations and applicable World Bank guideline values for PM_{10}. The dispersion modeling analysis estimated the maximum ground-level PM concentrations associated with emissions from sources at the OC. As described in Section 6.6.1, ambient concentration guideline values for particulates are in terms of PM_{10}, or particulates with diameters of 10 microns or less. The particulate emissions analysis employed a conservative approach, assuming that all particulate emissions from the facilities would be PM_{10}.

Maximum estimated ground-level PM concentrations associated with power plant operation would be below applicable World Bank PM_{10} guideline values of 500 $\mu g/m^3$ for 24 hour average concentrations and 100 μg/m^3 for annual average concentrations. Maximum impacts would occur near the property fenceline of the OC and would decrease considerably with distance from the emission source. Table 7.6-6 shows estimated maximum 24 hour and annual average PM concentrations at nearby village locations. These project-generated worst-case impacts would be considered less than significant.

Maximum modeled impacts for PM emissions are based on a number of conservative assumptions, including the following:

- Worst-case meteorology
- Uncontrolled emissions
- Screening averaging techniques
- An assumption that all stack emissions of PM from all sources would be PM_{10}; realistically, only a portion of these emissions (estimated at between 25 and 50 percent) would consist of PM_{10}, effectively reducing estimated maximum ground-level concentrations by 50 to 75 percent
- Background PM concentrations: Project-generated PM emissions were added to background PM_{10} concentrations to determine project impacts; background PM_{10} concentrations were conservatively assumed to be half of USEPA standards.

7.6.3.4 Carbon Dioxide and Methane

The project would introduce new sources of carbon dioxide (CO_2) and methane (CH_4) gases to the atmosphere which are considered greenhouse gases. Carbon dioxide is a product of combustion sources (i.e., engines, turbines, etc.); methane is a primary constituent of natural gas and is associated with the oil reservoirs underground.

The United Nations Framework Convention on Climate Change (UNFCCC), to which Chad is a signatory, recognizes that:

> "human activities have been substantially increasing the atmospheric concentrations of greenhouse gases, ...which will result on average in an additional warming of the Earth's surface and atmosphere and may adversely affect natural ecosystems and humankind."

However, the Convention also explicitly acknowledges that:

> "the largest share of historical and current global emissions of greenhouse gases has originated in developed countries, and that the share of global emissions originating in developing countries are still relatively low and ... will grow to meet their social and development needs."

The Convention also recognizes:

> "the legitimate priority needs of developing countries for the achievement of sustained economic growth and the eradication of poverty." (UNFCCC, 1992)

Natural gas is found at the oil fields in a relatively minor quantity and would be routed to the project's gas turbines and crude oil heaters for use. The CO_2 formed in the project's combustion processes is directly related to the emission of another pollutant of concern – carbon monoxide (CO). Carbon monoxide is a pollutant with both local and regional effects and is generally formed as a result of incomplete fossil fuel combustion. Typically, as CO emissions decrease, CO_2 emissions increase. The project's combustion processes are designed to minimize incomplete combustion with the goal of maximizing energy efficiency and reducing CO emissions. This results in maximizing CO_2 emissions. Any reduction in CO_2 emissions from a specific combustion unit would result in lower energy efficiency and increased CO emissions, causing potentially significant localized and regional impacts. With less efficient power sources, additional power sources would be needed, thereby contributing greater net amounts of both CO and CO_2 emissions. Therefore, a goal of higher energy efficient processes was incorporated into the project.

Based on order-of-magnitude estimates, CO_2 emissions from major project-related combustion sources (i.e., power plant turbines) were conservatively estimated at approximately 550,000 tons per year, or 0.0006 billion tons per year. These CO_2 emissions are from project sources alone and do not account for the secondary emissions that would result from use of fossil fuels produced and exported by the project. This compares to the estimated 1990 CO_2 emissions to Earth's atmosphere of 28.2 billion tons per year (Selrod, et al., 1995).

Generation of CO_2 and the associated increase in gases would be considered a less-than-significant impact.

7.7 PUBLIC HEALTH AND SAFETY

Public health is the combination of sciences, skills, and beliefs that are directed to the maintenance and improvement of the health of all people. Therefore, the potential impacts of a major infrastructure project to public health can be substantial in both an adverse and a beneficial manner. Historically, there has not been a set of generally accepted standard guidelines or checklists to direct the public health impacts evaluation of large infrastructure projects, particularly in developing countries. Typically, public health evaluations have primarily focused on morbidity, mortality, and disability. Both the impacts and potential mitigation measures have generally been viewed through a health sector or disease specific perspective (e.g., malaria control programs) and have not necessarily considered the overall potential available to the infrastructure sector to positively impact and improve the quality of life and affect disease rates. Since the project is a major infrastructure effort, it is equally appropriate to evaluate its potential impacts in a broader perspective than traditional evaluation of disease morbidity, mortality, and disability.

Recently (July 1996), the World Bank's Environmentally Sustainable Development Division – Africa Technical Department released a three volume report titled "Bridging Environmental Health Gaps, Lessons for Sub-Saharan Africa Infrastructure Projects" (Listorti, 1996). This document recognizes the impacts that infrastructure projects can have on overall health outcomes. In addition, in "Bridging Environmental Health Gaps" (BEHG), there is a clear differentiation between the traditional definition of "public health" with its disease specific focus and "environmental health."

According to the formulation constructed in BEHG, "Environmental health differs from public health in that it stresses prevention and concentrates on the human living environment" (Listorti, 1996). Within this context, the focus is shifted towards a consideration of potential impacts in both broad and narrow contextual settings, i.e., the broad perspective associated with development and mitigation of adverse environmental conditions and the more narrow context of diseases and injuries associated with water, sanitation, solid waste, housing, vector control and hazardous materials, and occupational injuries and illnesses. Hence, the approach emphasizes the potential linkages between infrastructure-related activities and overall environmental health.

While this is a shift from a pure disease specific focus towards an examination of the interconnectedness between overall disease burden and infrastructure impacts, the importance of certain diseases like malaria and the sexually transmitted diseases is not ignored. For example, both malaria medical control programs and HIV/AIDS prevention are traditional health sector goals and are important considerations for the project. However, a cross sectoral examination that combines and integrates the potential adverse and beneficial effects of non-health sectors, e.g., transportation, housing, and urban development, can conceivably accomplish more than interventions initiated by separate sector initiatives (Listorti, 1996).

Since as much as 44 percent of the Sub-Saharan African disease burden is amenable to infrastructure investments (Listorti, 1996), it is critical that the overall approach carefully consider the role of infrastructure impacts. With the release of BEHG, the World Bank has changed its perspective toward environmental health evaluations; therefore, the analysis of potential health impacts for an infrastructure project should be conducted in a manner that is philosophically consistent with this shift from pure disease specific morbidity, mortality, and disability towards a broader consideration of the linkages between the proposed project and environmental health. In this setting, environmental health is the prevention of disease through the control of biological, chemical, or physical agents in the air, water, and food, and the control of environmental factors that may have an impact on the well-being of people (Lisella, 1994).

7.7.1 Approach

The approach of this section of the EA is to incorporate the previously developed disease data (Appendix C) into the concept of environmental linkages and the overall analysis of impacts and development of mitigations. The impacts and mitigations are presented in Table 7.1-1 (Impact and Mitigation Summary Table) for each major infrastructure subsector under consideration. Based on the BEHG approach, four subsectors were selected:

- Housing and Urban Development
- Transportation
- Water and Sanitation
- Telecommunications.

As illustrated in Table 7.1-1, each of these subsectors is first compared to six major environmental health areas:

- Respiratory diseases
- Vector-related diseases
- Sexually-transmitted diseases
- Water and food-borne diseases
- Accidents and injuries
- Exposures to potentially hazardous materials.

As illustrated in Table 7.1-1, beneficial and potential adverse impacts within key health areas are expected to occur during construction and operation of the project. Throughout the EA, the terms "beneficial," "significant," "mitigable," and "unavoidable" have been used to categorize potential impacts from the project. From a public health perspective, these terms do not convey a clear and consistent meaning unless they are redefined. As presented in the Public Health appendix (Appendix C), the public health situation in Chad is extremely complex due to the lack of health infrastructure and the formidable number of diseases present in the project area.

There are fundamentally two types of impacts that are associated with the project: 1) those impacts that arise out of or are a consequence of the project's presence and 2) those impacts that affect the project arising out of or as a consequence of the inherent disease burden in the project area. In this analysis, "impacts" refers to any change, beneficial (positive) or adverse (negative), above the hypothetical baseline that currently exists. A "significant" impact occurs when a meaningful change from existing conditions is either predicted or documented. The definition of "meaningful change" can be described qualitatively, semi-quantitatively, or fully quantitatively. The metric selected is a function of both the assessor's belief (professional judgement) and the size and numerical depth of the data characterizing existing conditions. For this section of the EA, a qualitative assessment is provided.

Impacts are broadly categorized as having the potential to cause a change. "Significant" is used as a descriptor to imply that the change represents a meaningful movement, either up or down, from current conditions. If an impact is categorized as "mitigable," there is an assumption that 1) the impact is adverse and 2) a series of measures can be prescribed which will modify the effect such that projected deviations from existing conditions are judged to be less than significant. "Unavoidable" is a term that is used when permanent and adverse impacts are expected despite a series of scientifically and ethically appropriate countermeasures.

As previously discussed, the project is capable of potentially producing effects in the surrounding area substantially above the existing levels identified and documented. The thrust of this section is to identify those impacts flowing from the project to the surrounding population. In this context, an "unavoidable" impact is one that is expected to represent substantial change despite a series of mitigation measures. In this section, impacts are categorized qualitatively (using professional judgment). A series of mathematical confidence intervals and significance values could be hypothesized; however, the biological and sociological complexity of establishing both rigorous baseline and surveillance programs are substantial. There is tremendous seasonal and cyclic variation in the natural level of each disease described in the Public Health Appendix (Appendix C). Hence, a unitary baseline does not exist across all diseases. For example, a 10 to 20 percent increase in malaria, depending upon the time of year, may be natural variation while a similar increase in hemorrhagic fevers could represent a new serious impact.

Table 7.1-1 also presents a qualitative estimate of the duration, magnitude and significance of the linkage between the impact and the subsector. A mixture of beneficial and significant but mitigable impacts is anticipated. The analysis is further expanded by presenting a summary of specific subsector impacts and mitigations. Within this format, detailed potential impacts are presented that are based on and expand upon the checklists in BEHG. This methodology inevitably produces some level of redundancy and overlap; however, the effect is to clearly delineate both the overall environmental linkages within the proposed project and the opportunities for net environmental health improvement. In order to address each of the highlighted items in BEHG, Table 7.1-1 is structured and formatted to parallel the published subsector checklists. Every item presented and analyzed in Table 7.1-1 is not discussed in this section in order to avoid repetition. For example, in the Housing and Urban Development & Transportation subsectors, there is a section in Table 7.1-1 covering "Capacity/Institution Building." This is a general topic that is presented by analyzing specific impacts in each subsector. In addition, Section 8.7 addresses specific short- and long-term mitigation measures and relations with NGOs and/or private volunteer organizations (PVOs) and the external community.

In general, impacts exist in two broad categories: those that are internal (within the project facilities) and are therefore directly amenable to some level of technical and managerial control, and those that are external to the project facilities. This distinction between "internal" and "external" is a useful construct because project design measures can be more readily incorporated into internal activities, e.g., water supply and sanitation for the work force as opposed to external or adjacent community (village) activities. The internal-external dichotomy is reflected in the Table 7.1-1 analysis by distinguishing between project design measures (internally controlled), Government of Chad responsibilities and community outreach initiatives (external measures). In some situations there is not a clear distinction between internal and external, e.g., project design specifications for worker housing in the external community. Nevertheless, internal and external adverse impacts requiring mitigation are anticipated during both construction (short-term impacts) and operations (long-term impacts). Overall, most of the impacts and associated mitigation measures would occur during the short-term construction phase of the project. The long-term operations phase is not as work intensive and will require substantially fewer personnel and less external logistical support. As a result, the magnitude of potential effects and associated need for mitigation measures will be significantly reduced. Beneficial impacts are also present in each of the major environmental health areas.

Problems and Approaches to Data and Surveillance

There are two different targets for baseline and surveillance data that are appropriate to consider: 1) work force within the project and 2) the external population within the presumed zone of potential project influence. These are two different groups that require substantially different approaches. The work force is a controlled group of adults that can be easily assessed and periodically monitored for a wide variety of medical issues. The work force can be carefully examined on pre-employment evaluations such that rigorous, consistent and laboratory confirmed data are produced. At appropriate intervals, repeat testing can be performed such that problems can be detected early.

Theoretically, a methodologically analogous situation exists in the potentially affected population in the zone of project influence. However, the complexity and expense of performing detailed epidemiological studies of sufficient statistical power and scope is significant. There have been studies of this type performed in the Logone Valley, Cameroon (Audibert, 1990) for a large water resources project; however, there are no data of this type available for Chad. An epidemiological study for a project of this scale and sensitivity is of necessity designed, controlled, and sponsored by the national government.

The public health analysis of the EA is focused on potential impacts within both the project work force and the proximate zone of project influence. As previously described, these potential impacts are qualitatively categorized from the perspective of flowing from the presence of the project to the work force and the surrounding population.

Beneficial Impacts

In general, increased personal disposable income as a direct result of project employment, business opportunities, and associated effects would result in an increase in spending on preventive and curative health services.

Respiratory Diseases

- Local entrepreneurs would obtain information regarding building sanitation requirements which should positively influence future housing projects.
- New project workers would receive sanitation/hygiene training which should positively impact home environments.
- Diseases discovered during the project worker screening process would be identified for possible treatment.

Vector-Related Diseases

- Local contractors/entrepreneurs would obtain design measures for vector control which should beneficially affect other local projects.
- Existing roads needed for the project will be improved, particularly drainage and the minimization of standing pools of water that provide vector habitats.
- Vector-related diseases which are discovered during new project worker screening would be identified for possible treatment.
- Communities would receive vector control training which should positively impact home environments.

- Integrated disease control programs are part of the project design, e.g., malaria control programs.

Sexually Transmitted Diseases (STDs)

- New project workers would receive STD/HIV information, education and communication during orientation which should positively influence sexual behavior in the local community.
- Limited and directed funding would be provided to NGO/PVO programs which provide effective STD/HIV information, education and communication programs.
- STDs discovered during new project worker screening would be identified for possible treatment. This has the potential to significantly reduce HIV transmission rates.

Water and Food-Borne Diseases

- Project water wells used during the construction phase and no longer needed for operations will be donated to the community providing a source of clean water, if feasible.
- Local entrepreneurs/contractors involved in housing construction would obtain guidelines in the areas of water and food sanitation which should have a positive impact on future local projects.
- New project workers would receive food/water sanitation and hygiene training which should have a positive impact on the home environment.
- Communities would receive training in the investigation of food and waterborne epidemics which would have a potential positive impact on food/waterborne disease prevention.

Accidents and Injuries, Security

- Driver safety training would be provided to all project drivers thereby positively impacting overall road safety.
- Site-specific safety training received during new project worker orientation should positively influence safe work practices at other local projects.
- Pictorial road safety signage would remain in place after construction of roadways, thereby serving as a safety measure for all users of the roadway.
- Cross cultural training for new personnel would address misunderstandings between ethnic groups represented at the work site.

Chemical Exposure - Environmental Disease

- Programs would target potential chemical exposures and the prevention of environmentally related diseases, thereby positively impacting local health education.

7.7.1.1 Housing and Urban Development

Housing and urban development impacts are divided into three subsections: 1) temporary housing related to construction activities, 2) permanent housing associated with operations, and 3) urban development impacts during both construction and operations. There are potential impacts in all six key environmental health areas; however, mitigation strategies have been developed for these impacts.

Among the significant impacts are increased incidence of vector-borne diseases, respiratory illnesses, food supply and quality issues, injuries, and solid/liquid waste disposal problems for sanitary and non-sanitary wastes. Vector-borne diseases are represented by malaria, filariasis, yellow and dengue fever which are spread by mosquitos. Other vector-related diseases include schistosomiasis, spread by snails; guinea worm, spread by water fleas; leishmaniasis which is spread by sand flies (dogs and rodents are the reservoirs); and onchocerciasis, spread by the blackfly. These diseases may increase due to either enhancement or disruption of breeding grounds for mosquitos and flies (pools of standing water) or habitats (rodents) which may be affected as a result of:

- Construction activities (temporary and permanent housing) and pipeline construction
- Inadequate drainage within the project's camp area and external to the project (worker housing areas constructed locally)
- Clogged storm drains
- Poor drainage at water distribution sites
- Improper trash collection and disposal both within the project facilities and external to the project
- Increased activity at public facilities due to influx of workers/worker families.

The potential increase of vector-borne disease would be a significant-but-mitgable impact. Mitigation measures are discussed in Section 8.7.

Respiratory illnesses may increase as a result of poor ventilation within temporary and permanent housing facilities both within the project facilities and external to the project facilities. Air emissions from the project incinerator and inadequately ventilated motor parks may increase respiratory disease. Cooking in living quarters is a common factor in the increase of respiratory illnesses. The impact on respiratory diseases would be a significant-but-mitigable impact. Mitigation measures are discussed in Section 8.7.

The potential for increases in food-borne illnesses would impact the internal project facilities and external community. Improper food sanitation practices could create epidemics of transmission both within project facilities and in the communities. Workers who contract a food-borne illness at project food facilities may transmit the disease to family members who could transmit the infection within the community. Increased utilization and demand on local facilities could impact overall food supplies. Potential impacts from food-borne illnesses are significant but mitigable. Mitigation measures are discussed in Section 8.7.

Accidents and injuries may increase as a result of construction activities and workplace violence. There may also be increased rates of confrontations, fights, and crime both internal and external to the project facilities. This impact would be significant but mitigable. Mitigation measures are discussed in Section 8.7.

7.7.1.2 Transportation

The road improvements and pipeline portion of the project is fundamentally a transportation infrastructure project since a material will be moved over long distances during construction; therefore, there are a range of potential impacts. According to the BEHG external and World Bank literature review, transportation-related environmental issues with health repercussions are mainly concentrated on pollution control, i.e., air emissions from construction and work camp related activities. The impacts of STDs are considered significant because the oil field and pipeline construction and operation will require road construction and maintenance and the transportation of materials via trucks and railroads. The role of truckers in spreading STDs has been described in the public health data (Appendix C). Truckers are widely acknowledged to be major contributors to the spread of HIV and other STDs.

In Chad, women known as "debrouillardes" are associated with the spread of STDs/HIV. The interaction between truckers and debrouillardes presents an opportunity for STD/HIV spread and amplification. Amplification refers to the potential increased additional STD/HIV burden produced via the transportation subsector.

STD and vector-borne disease transmission associated with road transportation, construction, and operational maintenance is considered significant but mitigable (Section 8.7). As discussed in the baseline health data section, STD/HIV transmission is a complex mixture of biologic and sociologic factors that are not within the control of a private sector project. The role of government throughout the National AIDS Program (PNLS) is critical and must be coordinated with project initiatives, particularly those involving community information, education, and communication activities. In addition, project work force HIV/AIDS surveillance activities must be coordinated with existing government activities and programs. Other significant but mitigable impacts are accidents and injuries associated with road construction. Increases in vehicular traffic, workers, and pedestrians on new roadways, and road hazards created by construction equipment can enhance the risk of injuries. These potential impacts are significant but mitigable. Mitigation measures are discussed in Section 8.7.

The transportation and handling of hazardous materials creates the risk of leaks, spills, and accidental releases. This is a significant-but-mitigable impact. Mitigation measures have been proposed to reduce these impacts (Section 8.7). Impacts due to increased use and upgrades to aviation services are not expected to be significant since aviation activities are controlled by traffic management plans and would have closely managed frequency and duration. Aviation services are not the major route of project material transportation and movement; hence, the overall impact is expected to be less than significant.

7.7.1.3 Water Supply and Sanitation

According to BEHG, there is an extensive body of literature describing the health impacts of water and sanitation projects in developing countries. There are however, five areas where this body of literature, particularly World Bank-related projects, is less definitive:

- The role of privatization
- Food chain contamination due to pesticides, fertilizers, and animal wastes
- Fragmentation of project objectives due to the different perspectives held by health professionals and civil/municipal engineers
- Worsening of vector-related diseases, particularly due to drainage problems
- Relationship of air pollution and solid waste management.

These areas, with the exception of privatization considerations which are viewed as not relevant to this project, are considered within the context of five general impact categories:

- Construction-related activities
- On-site (i.e., within project boundaries) environmental engineering
- Water supply
- Solid waste management
- Food service.

Construction-related activities that impact water supply and sanitation include:

- Spread of vector-borne diseases
- Storm drainage-related problems
- Water utilization and availability problems.

Project water supplies would be obtained by using subsurface aquifers through a series of wells. Hence, the water quality can be closely monitored and maintained. Therefore, spread of waterborne diseases through inadequate sources is expected to be a less-than-significant impact.

Impacts surrounding storm drainage and runoff are significant but mitigable through the use of project design measures during both the construction and operations phases of the project. All waste effluents are to be treated and monitored so that storm drains do not become open sewers and trigger waterborne disease episodes. Similarly, water utilization at active project sources by the external community would be prohibited so that cross contamination and over-utilization are prevented. Conversely, project wells would be given to the community, if feasible, at project completion. The transfer of secure water supplies to the external community is a beneficial impact.

On-site sanitation impacts are related to domestic and industrial solid waste management and environmental control. The large mobile work force associated with construction activities could produce significant solid and sanitary waste impacts; however, standard waste management and environmental control measures are included in the project design. Therefore, impacts are less than significant. Sanitary and environmental waste issues could spread outside the confines of the project area and impact surrounding communities. These impacts could be produced by storm water/sewer overloads.

The spread of waterborne diseases across the project-community boundary is a significant impact since workers would be moving back and forth between the community and the project zone. Contaminated water and interpersonal contact are considered the main route of transmission of cholera epidemics which can rapidly spread. However, project design and mitigation measures would be implemented to reduce this impact to levels which are less than significant. Mitigation measures for impacts from waterborne epidemics are discussed in Section 8.7. Moreover, mitigation measures would provide contingency plans for supplemental chlorination, water delivery, and logistical support.

Increases in food/waterborne illnesses as a result of improper food/water sanitation practices both within the project and externally, are a significant but mitigable impact. Workers who contract a food-borne illness at project food facilities may transmit the disease to others within the community. Food management plans would reduce the potentially significant but mitigable impact on local food supply resources. Mitigation strategies and measures are discussed in Section 8.7. Accidents associated with recycling and handling of hazardous materials affecting project water supplies are not considered significant since mitigation measures would be incorporated into the project (Section 8.7).

7.7.1.4 Telecommunications

Analysis of potential impacts demonstrates that overall beneficial impacts should be derived, particularly in the area of emergency services and reduced air pollution as a result of decreased vehicular use. The project's telecommunications systems would decrease the need for vehicular use for the transport of project-related messages, thereby decreasing vehicular air pollution which may increase respiratory diseases. Enhanced telecommunications systems would improve responses to emergency health needs as well as responses to fires, flood, and disaster. These are viewed as beneficial impacts both internally and externally.

Potential increases in vector-borne diseases due to pooling of water in holes dug for transmission line poles is not considered significant. Coordination of scheduling for installation and addition of light oil to holes dug would deprive larvae of oxygen.

7.7.1.5 Discussion

As illustrated in Table 7.1-1, there are a number of potential beneficial and significant, but mitigable impacts across the different subsectors. The process of analyzing impacts and mitigations through key environmental health areas and relevant subsectors illustrates the myriad linkages that are present in a major infrastructure project. The environmental linkages approach illustrates that infrastructure activities have the opportunity to significantly and beneficially impact overall disease levels in the community. Each subsector has a potential set of beneficial and significant, but mitigable impacts. The environmental linkages approach clearly delineates the overall significant impacts that may be produced by the project. Section 8.7 discusses the potential mitigation strategies and their interconnectedness. Overall, the potential impacts that have been identified are primarily associated with activity during the relatively short-term construction phase of the project. There are impacts that are expected during the long-term operations phase; however, the magnitude and complexity of impacts should be significantly less during operations.

7.8 SOLID, LIQUID, AND HAZARDOUS WASTES

The proposed project would generate various types and volumes of solid, liquid, petroleum-based, and hazardous wastes during various phases of the project: construction, exploration and appraisal drilling, production and operation, and abandonment. For this analysis, impacts would be considered significant if proposed project waste management operations would result in the discharge of pollutants at levels exceeding World Bank guidelines and international standards for waste management practices.

Wastes generated from the project would come from four primary sources:

- Wellfields at Komé, Miandoum, Bolobo, and associated facilities
- Central Treating Facility
- Pipeline Transportation System, including Pump Station No. 1
- Operations Center and associated community.

Potential waste impacts from the project would be associated with construction solid waste materials, drilling waste fluids, drilling waste solids, produced water, production chemicals and volatile organics, tank and vessel bottom wastes, domestic wastewaters, solid wastes, and demolition wastes. The waste management facilities that would be constructed as part of the project to control, manage, and treat wastes generated from the project are listed below.

- Landfill (including municipal and hazardous waste cells)
- Incinerator
- Wastewater treatment
- Produced water treatment

More detail on the estimated volumes of waste generated by the project and the waste management facilities designed to treat or dispose of them are presented in Section 3.2.12.6.

Waste management guidance which outlines practices for the reduction, reuse, treatment, and environmentally acceptable disposal of all wastes generated has been prepared for the project. This guidance recognizes the lack of waste management facilities and supporting infrastructure in Chad and the fact that waste facilities required for the project will need to be constructed and managed. An overview of the project's waste management guidance and prescribed practices is included in Section 8.8. A Waste Management Plan including area-specific waste management plans for major construction and operation activities would be prepared during the final engineering and design phase.

With the incorporation of the waste management facilities outlined above, waste generated from the project would be managed in a manner to meet applicable World Bank guidelines and international standards for waste management practices. For the project overall, the adoption of the waste management guidance and activity-specific plans at the final engineering and design phase would provide effective prevention and control of waste-related impacts to the environment or public health. Consequently, impacts from wastes generated during construction, operation, and decommissioning of the project and managed during its operations are expected to be less than significant.

A brief description of the waste management facilities and operating parameters that contribute to effective prevention and control of waste impacts is provided below. These facilities include a landfill, incinerator, wastewater treatment, and produced water treatment.

7.8.1 Landfill

A landfill with nonhazardous and hazardous waste cells would be constructed prior to the construction of the project to provide for disposal of construction wastes. The landfill would be located near the OC where natural erosion or future land use would not result in excavation or exposure of buried wastes. It would be sized to contain the appropriate anticipated wastes generated during the life of the project. Design characteristics and features for the hazardous waste cell would include double liners, leachate collection and circulation, and groundwater monitoring. Liners would be designed to provide a sufficient barrier under all conditions (both active and closed). Specific liner materials would be identified during detailed engineering design. The landfill site would also include appropriate security and fencing.

Transportation of wastes to the landfill would be conducted utilizing identified transportation routes, procedures, and equipment that would minimize the opportunity for accidents or spills. Closure of the landfill would also be consistent with future land use and would include appropriate capping and protection.

Final engineering design would take into account topography and hydrogeology in designing liners, drainage, and the need for groundwater monitoring. Final engineering design would also provide security specifications, closure sequencing of landfill cells, and ultimate disposition of the landfill after closure. With the practices implemented as part of the waste management guidance (Section 8.8) and design features identified during detailed engineering design, impacts from development, operation, and closure of the landfill would be less than significant.

7.8.2 Incinerator

An incinerator would also be constructed in the earliest stages of project development to allow for incineration of selected construction wastes. The incinerator would most likely be located near the landfill described above, because incinerator ash would go to the landfill. The incinerator would be designed for complete burn of combustible waste components and it would be a fixed or mobile facility. It would contain storage for treated and untreated wastes and would be secured to prevent unauthorized access. Waste identified for incineration (Table 3-6) would be transported along previously identified transportation routes according to safety procedures that would minimize the opportunity for accidents. During construction, smaller mobile incinerators may be used to reduce transportation demand. Design parameters for emissions would be developed during final engineering design based on the analyses presented in Sections 7.6 and 8.6 (Air Quality). This would include meeting applicable World Bank guidelines for air quality. With implementation of the waste management guidance (Section 8.8) and final engineering design, impacts from operation of the incinerator would be less than significant.

7.8.3 Wastewater Treatment Facilities

Wastewater treatment would include package wastewater treatment facilities used during construction and wastewater treatment facilities and/or septic systems for operation. Some of the package treatment systems used during construction would also be used during operation. Water reuse would be emphasized to minimize volumes of water used for project or domestic purposes. Effluents from the package treatment plants would meet applicable World Bank guidelines for wastewater, domestic sewage, and contaminated stormwater prior to discharge to surface waters. Management of these systems would also be in conformance with the waste management guidance (Section 8.8) and final engineering design; therefore, impacts would be less than significant.

7.8.4 Produced Water Treatment

A majority of the produced water would be separated from the produced oil at the gathering stations and reinjected into the aquifer associated with the oil reservoir. A 20 percent water cut emulsion would be sent to the CTF for further separation. The separated water would be returned to the Bolobo oil field for reinjection as described in Sections 3.2.4 and 3.2.5. Since the produced water is being reinjected into the producing zone after treatment, impacts would be less than significant.

CHAD TABLE 7.1-1
IMPACT AND MITIGATION MEASURE SUMMARY TABLE

Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
HUMAN ENVIRONMENT (SECTION 7.2)							
Land use requirements of the project causing temporary or permanent displacement of the local population	✓	✓	✓	✓	⊡	Develop and implement a detailed compensation and resettlement plan. See Section 8.2.1 for further information.	Monitoring would be performed to ensure compliance with the detailed Compensation and Resettlement Plan.
Provision of wages and other benefits to Chadian nationals	✓			✓	+	None required. See Section 7.2.2.1 for further information.	None required.
Potential boom-bust syndrome as workers are released from construction	✓		✓	✓	⊡	Provide open communication during the recruitment process as to the temporary nature and duration of jobs on the project. See Section 8.2.2 for further information	Ensure that adequate information is made available to workers through audio-visual presentations, print media, and signage at recruitment offices and/or project sites.
Long-term level of employment and income for Chadian nationals		✓	✓		+	None required. See Section 7.2.2.1 for further information.	None required
Cessation of employment after operations		✓	✓		□	None required. See Section 7.2.2.1 for further information.	None required
Labor recruitment and the potential for inequitable distribution of jobs	✓	✓	✓	✓	⊡	Develop a plan for worker recruitment, with the following key attributes: • Ensure the employment of Chadians preferentially • All Chadians can apply • Applications will be accepted at local employment and business offices • No hiring at project work sites • Hiring preference given to candidates who meet job criteria and are directly impacted by the project • Compliant with Chadian laws and regulations See Section 8.2.2 for further information.	Monitoring would continue regularly throughout the construction and operations recruitment phases to verify adherence to the plan and its effectiveness.
Education and training of Chadian nationals	✓	✓	✓	✓	+	None required. See Section 7.2.2.3 for further information.	None required
Potential development of unplanned settlements	✓		✓	✓	□	None required. See Section 7.2.2.4 for further information.	None required

Notes:
1. Duration: Construction - 2 years or less
Operation - Approximately 30 years

3. Key to Significance
+ Beneficial
⊡ Significant but Mitigable

IMPACT AND MITIGATION MEASURE SUMMARY TABLE

Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
Housing needs of project work force during construction	✓		✓	✓	☐	None required. See Section 7.2.2.4 for further information.	None required
Housing needs of project work force during operations		✓	✓		☐	None required. See Section 7.2.2.4 for further information.	None required
Potential housing surplus during decommissioning of operations		✓	✓		☐	None required. See Section 7.2.2.4 for further information.	None required
Purchase of local goods and services	✓	✓	✓	✓	+	None required. See Section 7.2.3 for further information.	None required
Inflationary effects on area residents from purchase of local goods and services for the project	✓		✓	✓	⊡	Distribute purchasing to more than one supplier. See Section 8.2.3 for further information.	Monitoring would be conducted on the effectiveness of purchasing and procurement processes.
Potential boom-bust syndrome for local suppliers as purchasing requirements for the project decline at the end of the construction	✓		✓	✓	⊡	Distribute purchasing activities to more than one supplier. See Section 8.2.3 for further information.	Monitoring would be conducted on the effectiveness of purchasing and procurement processes.
Increase in overall economic output from the increase in wages and project purchases during construction	✓			✓	+	None required. See Section 7.2.3 for further information.	None required
Infusion of monies to local and regional markets from purchasing activities during operations		✓	✓	✓	+	None required. See Section 7.2.3 for further information.	None required
Cessation of provisioning and procurement demand after operations		✓	✓	✓	☐	None required. See Section 7.2.3 for further information.	None required
Increase in government revenues associated with royalty payments		✓		✓	+	None required. See Section 7.2.4 for further information.	None required
Increase in government revenues associated with ability of work force to pay currently uncollected taxes	✓	✓	✓	✓	+	None required. See section 7.2.4 for further information.	None required
Inequitable distribution of project benefits		✓	✓	✓	☐	None required. See Section 7.2.4 for further information.	None required
Upgrade and maintenance of roads in the study area	✓	✓	✓	✓	+	None required. See Section 7.2.5 for further information.	None required
Economic impacts to roadside villages from modified regional traffic patterns	✓	✓	✓	✓	☐/+	None required. See Section 7.2.5 for further information.	None required

Notes:

1. Duration: Construction - 2 years or less; Operation - Approximately 30 years
2. The general size or areal extent of the impact
3. Key to Significance
   - + Beneficial
   - ☐ Less than Significant
   - ⊡ Significant but Mitigable
   - ■ Significant and Unavoidable

CHAD TABLE 7.1-1
IMPACT AND MITIGATION MEASURE SUMMARY TABLE

Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
Increase in traffic accidents involving the local population and its livestock on roads upgraded for the project	✓	✓	✓	✓	☐	None required. See Section 7.2.5 for further information.	None required
Dust generated by project activities resulting in unsafe traffic conditions and nuisance to local populations	✓		✓		☐	Implement dust control protocol at appropriate project facilities. See Section 8.2.4 for further information.	Monitoring would be conducted regularly during construction activities verifying that appropriate dust control protocols were implemented.
Disturbance to burial sites and sacred places and objects	✓		✓		⊡	Consult with village and religious leaders and local residents to identify areas to be avoided and/or to negotiate compensation for disturbance. See Section 8.2.5 for further information.	Monitoring would be performed during final design of the project and prior to construction verifying that field reviews and consultation with village leaders and local residents has been conducted. Monitoring would be conducted throughout the construction phase to ensure avoidance or that appropriate compensation is made.
Interference with transhumant migration patterns causing encroachment on neighboring landholdings or increased competition for food and water	✓			✓	⊡	Inform transhumant group leaders, veterinarians, and herders of interruptions to migratory routes. See Section 8.2.6 for further information.	Monitoring would be conducted during the construction phase to verify communication with transhumant group leaders and veterinarians regarding project construction locations and schedules.
Minor alteration of transhumant migration patterns from project facilities		✓	✓	✓	☐	None required. See Section 7.2.7 for further information.	None required
Migration of people to the project area increasing demand on existing social infrastructure and resources	✓	✓	✓		⊡	Public information campaigns to ensure that: key information such as the number and timing of job opportunities, and that no hiring will take place at project work sites, are widely known; and control worker recruitment so that no encouragement is given that employment is available on the project other than through authorized hiring processes. See Section 8.2.7 for further information.	Monitoring would be conducted to ensure that potential workers understand the nature of the job opportunities.

Notes:

1. Duration: Construction - 2 years or less
   Operation - Approximately 30 years

3. Key to Significance
   ✚ Beneficial
   ⊡ Significant but Mitigable

CHAD TABLE 7.1-1

IMPACT AND MITIGATION MEASURE SUMMARY TABLE

Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
Cross-border population movements into Chad over a new Mbéré River bridge, potentially resulting in additional pressures on land use and causing social unrest	✓	✓	✓		□	None required. See Section 7.2.8 for further information.	None required
BIOLOGICAL RESOURCES (SECTION 7.3)							
Movement, mixing, and compaction of soils by heavy equipment resulting in loss of topsoil and essential nutrients and other soil components	✓		✓		□	Incorporation of a soil erosion and sedimentation control program. See Section 8.3.1 for further information.	Field verification would be conducted regularly during pipeline, oil field, and infrastructure construction activities verifying that topsoils were conserved in conformance with the project's soil erosion and sedimentation control procedures.
Removal of vegetative cover and shade canopy increasing soil surface temperature, decreasing moisture content, killing soil organisms, and increasing potential for erosion in the oil field development area and along the pipeline	✓		✓		▣	Provide buffer zones around sensitive areas See Section 8.3.1 for further information.	Monitoring would be conducted prior to the beginning of construction activities verifying that buffer zones have been established and that personnel have been apprised of and understand the buffer zones. Mitigation monitoring would be performed during regular daily construction activities, verifying that encroachment of identified sensitive areas is avoided.
Increase in soil surface temperatures resulting in drier soils directly above the pipeline where it exits Pump Station 1		✓	✓		□	Extra depth of burial would be provided for the pipeline near Pump Station 1. See Sections 3.2.7.8 and 8.3.1 for further information.	None required during operations. During construction, ensure pipeline burial depth is correct.
Disturbance to, or loss of, sensitive individuals or populations of plant species in the oil field development area	✓		✓		□	None required. See Section 7.3.1.2 for further information.	None required
Temporary and permanent loss of riverine (gallery) vegetation in areas where the pipeline and infrastructure cross the Lim and Mbéré rivers and oil field facilities cross the Nya and Loulé rivers	✓		✓		□	None required. See Section 7.3.1.2 for further information.	None required

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CHAD TABLE 7.1-1
IMPACT AND MITIGATION MEASURE SUMMARY TABLE

Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
Losses of or temporary impacts to less densely vegetated biologically significant habitat or general biological diversity in the study area	✓		✓		☐	None required. See Section 7.3.1.2 for further information.	None required
Potential loss of bamboo resources near Bessao	✓		✓		☐	None required. See Section 7.3.1.2 for further information.	None required
Temporary and permanent loss of wooded savanna from changes in land use resulting from the project	✓	✓	✓		☐	None required. See Section 7.3.1.2 for further information.	None required
Impairment of the regenerative capacity of study area savanna habitat	✓	✓	✓	✓	☐	None required. See Section 7.3.1.2 for further information.	None required
Temporary or permanent disturbance of wildlife in wetlands and gallery forests	✓	✓	✓		☐	None required. See Section 7.3.1.3 for further information.	None required
Fragmentation of wildlife habitat	✓		✓	✓	☐	None required. See Section 7.3.1.3 for further information.	None required
Habitat disturbance resulting in wildlife displacement or loss	✓	✓	✓		☐	None required. See Section 7.3.1.3 for further information.	None required
Changes to elephant migration patterns during pipeline construction	✓		✓		☐	None required. See Section 7.3.1.4 for further information.	None required
Increased turbidity and reduced visibility impacting food gathering activities by aquatic organisms	✓		✓		☐	Incorporate erosion and sedimentation control plan. See Section 8.3.2 for further information.	Field verification would be conducted regularly during pipeline, oil field, and infrastructure construction activities and during the wet season verifying conformance with erosion and sedimentation control procedures.
Increase in suspended sediment loads due to construction-related activities	✓		✓		☐	None required. See Section 7.3.1.5 for further information.	None required.
Potential disturbance to aquatic resources from minor spills of diesel, gasoline, hydraulic, brake, transmission, and other equipment fluids or chemicals	✓	✓	✓		☐	Incorporate project safety and environmental measures and spill response plans, during construction and operations. See Section 7.3.1.5 for further information.	Monitoring would be performed to verify that construction and operations phase spill response plans have been prepared and can be implemented as intended.

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⊡ Significant but Mitigable

IMPACT AND MITIGATION MEASURE SUMMARY TABLE

Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
Damage to botanical, wildlife, and other aquatic resources and contamination of surface water bodies resulting from oil spills		✓	✓	✓	⊡/■	Incorporate project safety and environmental measures and an oil spill response plan, associated training, equipment, and supporting infrastructure into the project. See Section 8.3.2 for further information.	Monitoring would be performed prior to initial construction and annually thereafter verifying that an oil spill response plan is in place and updated as necessary. Conformity to the plan's requirements for personnel resources, response equipment and associated training would also be monitored.
Potential impacts to wetlands of the Loulé, Nya, and Pendé rivers from shallow groundwater withdrawal	✓	✓	✓		☐	None required. See Section 7.3.1.5 for further information.	None required
Continuous discharge of treated sanitary wastewater from package treatment plants to the Loulé, Nya, and Pendé rivers increasing dry weather flows and sustaining wetlands.	✓		✓		☐	None required. See Section 7.3.1.5 for further information.	None required
Discharge of treated sanitary wastewater to the groundwater regime from septic systems eventually supplementing the flow of the Loulé, Nya, and Pendé rivers and associated habitat		✓	✓		☐	None required. See Section 7.3.1.5 for further information.	None required
Temporary lowering of groundwater table within the cones of influence for project water supplies during construction	✓		✓	✓	☐	None required. See section 7.3.1.5 for further information.	None required
Potential impacts to wetland vegetation from groundwater withdrawal for project water supply during operations		✓	✓	✓	☐	None required. See Section 7.3.1.5 for further information.	None required.
Water withdrawal through oil producing wells potentially affecting surface waters, aquatic habitat, and organisms		✓	✓	✓	☐	None required. See Section 7:3.1.5 for further information.	None required
Potential disturbance to the Timbéri Forest Reserve and the Laramanay Wildlife Reserve	✓		✓		☐	None required. See Section 7.3.1.6 for further information.	None required

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IMPACT AND MITIGATION MEASURE SUMMARY TABLE

Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
Temporary and permanent loss of relatively undisturbed savanna	✓	✓	✓		☐	None required. See Section 7.3.1.6 for further information.	None required
Induced access to relatively undisturbed wooded savanna and riverine vegetation during construction and operations leading to reduction in natural resources due to hunting, fishing, collecting of plant materials, etc.	✓	✓	✓		▣	Control unauthorized use of pipeline route during construction; provide work force with resource conservation/protection briefing and communicate that hunting or trade in bushmeat would result in instant dismissal; reinstate natural barriers after construction. See Section 8.3.3 for further information.	Monitoring in the form of regularly scheduled patrols or surveillance would be conducted ensuring that adequate public access control measures have been implemented and maintained along the land easement.
Losses of or temporary impacts to remaining biologically significant habitat or general biological diversity in the immediate vicinity of the oil field development area and along the pipeline route	✓	✓	✓		☐	None required. See Section 7.3.1.8 for further information.	None required
HYDROLOGY AND WATER QUALITY (SECTION 7.4)							
Reduction in base flows of the Loulé, Nya, and Pendé rivers and associated tributaries caused from domestic and process water requirements during construction	✓		✓		☐	None required. See Section 7.4.1 for further information.	None required
Reduction in surface streamflow caused from withdrawal of water for hydrotesting	✓		✓		☐	None required. See Section 7.4.1 for further information.	None required
Potential erosion from hydrotesting water discharge	✓		✓		☐	None required. See Section 7.4.1 for further information.	None required
Increased peak flows of the Loulé, Nya, Lim, Pendé, and Mbéré rivers caused from increased stormwater discharges from cleared areas	✓	✓	✓		☐	None required. See Section 7.4.1 for further information.	None required
Increased peak flows and sediment loads of small unnamed tributaries or drainages in the immediate vicinity of cleared areas	✓		✓		▣	Design drainage systems to drain surface runoff to more than one tributary or in a manner that minimizes erosion. See Section 8.4.1 for further information.	Monitoring would be performed verifying that the planned stormwater drainage systems have been constructed. Monitoring would also be conducted during the wet season to verify that the systems operate as designed.
Change in peak flows from construction of pipeline river crossings	✓		✓		☐	None required. See Section 7.4.1 for further information.	None required

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IMPACT AND MITIGATION MEASURE SUMMARY TABLE

Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
Increase in surface runoff caused from an increase in impervious or heavily compacted areas		✓	✓		☐	None required. See Section 7.4.1 for further information.	None required
Exposure of people or property to flood-related hazards near the OC from the Loulé and Pendé rivers		✓	✓		☐	None required. See Section 7.4.1 for further information.	None required
Reduction in base flows of surface streams caused from an increase in impervious areas and a reduction in groundwater recharge		✓	✓		☐	None required. See Section 7.4.1 for further information.	None required
Reduction in base flows of the Loulé, Nya, and Pendé rivers and associated tributaries caused from domestic and process water requirements during operations		✓	✓		☐	None required. See Section 7.4.1 for further information.	None required
Increased base flows caused from continuous discharge of treated wastewater from septic systems during operations		✓	✓		☐	None required. See Section 7.4.1 for further information.	None required
Disturbance to existing water supply wells caused by groundwater withdrawal during construction	✓		✓		☐	None required. See Section 7.4.2 for further information.	None required
Disturbance to existing local supply wells caused by continuous withdrawal of project water supplies		✓	✓		▣	Stagger project water supply wells to reduce the effect on nearby wells; provide alternative supplies in case of disruption to existing wells. See Section 8.4.2 for further information.	Monitoring would be conducted on a regular basis during construction and regularly thereafter to verify that the placement of the project water supply wells has not affected the local community's existing water wells.
Reduction in groundwater recharge caused by the creation of compacted areas		✓	✓		☐	None required. See Section 7.4.2 for further information.	None required
Development of surface subsidence resulting from the creation of low pressure zones in the producing horizon		✓	✓		☐	None required. See Section 7.4.2 for further information.	None required
Increased amounts of suspended sediment caused by surface run-off from construction-disturbed areas in the Loulé, Nya, Lim, Mbéré, and Logone rivers	✓		✓		☐	None required. See Section 7.4.3 for further information.	None required

Notes:
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CHAD TABLE 7.1-1
IMPACT AND MITIGATION MEASURE SUMMARY TABLE

Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
Increased sediment loads downstream of stream and river crossings	✓		✓		☐	None required. See Section 7.4.3 for further information.	None required
Reduced water quality from wastewater discharge to large streams and rivers	✓	✓	✓		☐	None required. See section 7.4.3 for further information.	None required
Reduced water quality caused from wastewater discharge to relatively small tributary streams	✓	✓	✓		▣	Treat or dispose of sanitary wastewater in compliance with World Bank effluent guidelines (Appendix A). See Section 8.4.3 for further information.	Regularly scheduled sampling of project-generated effluents would be conducted during construction and operation to ensure that the discharged water meets adopted guidelines.
Effects of individual septic systems on soils and groundwater	✓	✓	✓		☐	None required. See Section 7.4.3 for further information.	None required
Effects on surface water quality from septic system effluents	✓	✓	✓		☐	None required. See Section 7.4.3 for further information.	None required
Decrease in water quality from surface runoff potentially contaminated with drilling muds	✓		✓		☐	Incorporate erosion and sedimentation control plan and project waste management plan. See Section 8.4.3 for further information..	Monitoring would be performed verifying that the planned storm water drainage system provides for the control of potentially contaminated runoff from the oil field development area. The project waste management plan (Section 8.8.2) will include facility-specific waste management practices for the handling and control of drilling muds. Field verification would be conducted regularly during drilling activities and during the wet season. See Section 8.4.3 for further information.
Decrease in groundwater quality of deep aquifers due to disposal of produced water		✓	✓		☐	None required. See Section 7.4.3 for further information.	None required
Decrease in quality of the groundwater in the potable near-surface aquifer due to casing leak		✓	✓		▣	Injection well integrity program. See Section 8.4.3 for further information.	Monitoring would be conducted during operations to verify that the integrity of the injection wells is unimpaired.

Notes:
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Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
GEOLOGY, SOILS, AND SEISMICITY (SECTION 7.5)							
Increased potential for wind and water erosion from ground disturbing activities	✓		✓		□[1]	Incorporate the project soil erosion and sedimentation control plan. See Section 8.5.1 for further information.	Monitoring would be conducted regularly during pipeline, oil field, and infrastructure construction activities verifying conformance with erosion and sedimentation control procedures.
Increased potential for sedimentation in streams intersected during pipeline construction	✓		✓		□	Incorporate soil erosion and sedimentation control plan. See Section 8.5.2 for further information.	Field verification would be conducted regularly during pipeline construction activities verifying conformance with erosion and sedimentation control procedures.
Potential for erosion, scour, and changing bottom profiles to expose the pipeline		✓	✓		□	Assess scour potential in support of pipeline design. See Section 8.5.3 for further information.	Monitor to verify pipeline integrity at stream and river crossings.
Potential for differential settlement and blasting induced localized slope instability causing structural damage to buildings or facilities	✓	✓	✓		□	Incorporate recommendations of geotechnical engineering evaluation. See Section 8.5.3 for further information.	Monitoring would be conducted during the construction phase to ensure that construction activities comply with the geotechnical engineering recommendations.
Potential for settlement of backfill over the pipe trench		✓	✓		□	None required. See Section 7.5.2 for further information.	None required
Potential for post-construction damage to project facilities from seismic events or volcanic eruptions		✓	✓		□	None required. See Section 7.5.4 for further information.	None required.
METEOROLOGY AND AIR QUALITY (SECTION 7.6)							
Generation of particulates from earthmoving activities	✓		✓		□	Implement dust control protocol at appropriate project control facilities. See Section 8.6.1 for further information.	Monitoring would be conducted regularly during construction activities verifying that appropriate dust control protocol were implemented.
Generation of SO_2 and NO_x emissions from construction equipment	✓		✓		□	None required. See Section 7.6.1 for further information.	None required

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CHAD TABLE 7.1-1
IMPACT AND MITIGATION MEASURE SUMMARY TABLE
(Page 11 of 23)

Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
Compliance with World Bank NO_2 guideline values		✓	✓		□	Confirm modeled NO_2 ground level concentrations meet guidelines with final design input parameters, or amend final design accordingly. See Section 8.6.2 for further information.	Perform stack testing at project start up to verify predicted dispersion of NO_x and compliance with guidelines.
Compliance with World Bank SO_2 guideline values		✓	✓		□	None required. See Section 7.6.3.2 for further information.	None required
Compliance with World Bank PM guideline values		✓	✓		□	None required. See Section 7.6.3.3 for further information.	None required
Generation of CO_2 and the incremental increase in greenhouse gases	✓	✓	✓	✓	□	None feasible. See Section 7.6.3.4 for further information.	None required
CHAD - PUBLIC HEALTH AND SAFETY (SECTION 7.7) - Environmental Health Linkages							
Increased incidence of respiratory diseases	✓	✓	✓		⊡ ✚	Implement measures in project housing, transportation, water and sanitation, and telecommunications; implement village-based education programs which address the recognition and prevention of respiratory diseases. See Section 8.7.2 for further information.	Monitoring would be conducted during construction and installation of construction camps and project housing to ensure that proper guidelines have been incorporated.
Increased incidence of vector-related diseases such as malaria, schistosomiasis, filariasis, and onchocerciasis	✓	✓	✓		⊡ ✚	Implement measures in the areas of project housing, transportation, water and sanitation regarding the prevention of vector-borne diseases. See Section 8.7.3 for further information.	Monitoring would be conducted prior to construction and occupancy of housing units to ensure that proper design measures aimed at minimizing water accumulation have been incorporated into the construction design.

Notes:

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IMPACT AND MITIGATION MEASURE SUMMARY TABLE

Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
Increase in the incidence of STDs/HIV	✓	✓	✓	✓	⊡ ✚	The following would be implemented for the project work force and the Republic of Chad would implement the same strategies for the community surrounding the project area directed toward the prevention of STDs/HIV: • Coordination with government national AIDS program, particularly programs directed toward female commercial sex workers and other vulnerable women • Surveillance and treatment of STDs, particularly genital ulcers • Information, education and communication (IEC) • Aggressive distribution of condoms • Surveillance activities to monitor HIV prevalence rates See Section 8.7.4 for further information.	Monitoring would be conducted during construction and operations to ensure that all new project workers attend IEC programs addressing the prevention of STDs. Monitoring would be conducted prior to construction and periodically thereafter.
Increases in incidence of water and food-related illness	✓	✓	✓		⊡ ✚	Implement measures in project housing, transportation, water and sanitation directed toward water and food sanitation and hygiene. See Section 8.7.5 for further information.	Monitoring would be conducted during construction and installation of construction camps and project housing to ensure that proper sanitation guidelines have been incorporated. Mitigation monitoring would also be conducted regularly during operations to verify that sanitation guidelines related to food and water supplies are being implemented.

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CHAD TABLE 7.1-1
IMPACT AND MITIGATION MEASURE SUMMARY TABLE

Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
Increases in accidents and injuries, security incidents	✓	✓	✓		⊡ ✚	Implement measures in the areas of project housing, transportation, water and sanitation, and telecommunications targeting the prevention of accidents and injuries. See Section 8.7.6 for further information.	Monitoring would occur prior to construction to verify that specific safety measures including provision of new worker orientation, medical emergency response plans, and accident investigation have been implemented. Mitigation monitoring would also be conducted during construction and operations to ensure that project workers adhere to safety guidelines established for the project and that adequate safety signage has been posted.
Increase in chemical exposures and environmental diseases	✓	✓	✓		⊡ ✚	Implement measures in the areas of project housing, transportation, water and sanitation, and telecommunications targeting the prevention of chemical exposures and environmental diseases. See Section 8.7.7 for further information.	Monitoring would be conducted prior to the construction period to verify that waste management plans and an occupational health program have been developed and implemented. Monitoring would also be conducted throughout construction and operations to ensure that project workers adhere to the subject plans and associated procedures established for the project and that adequate training has been provided.
CHAD - PUBLIC HEALTH AND SAFETY (SECTION 7.7) - Housing and Urban Development							
HOUSING - TEMPORARY							
Pools of standing water, heavy rainfall conditions leading to increased incidence of mosquito-borne diseases, vector diseases, both within the project's camp area and external to the camp	✓		✓		⊡	Measures to eliminate breeding/feeding ground; proper drainage for facilities during rainy season; spraying, netting, education, health screenings and surveillance. See Section 8.7.3.	Ensure use of design measures to minimize water accumulation; monitor management of water accumulation in and around project facilities throughout operations.

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IMPACT AND MITIGATION MEASURE SUMMARY TABLE

Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
Poor ventilation associated with temporary housing with impacts on respiratory disease rates, both within the camp and external to the camp	✓		✓		▣	Ventilation to camp housing; minimize cooking in living quarters by centralizing food service; housing specifications to avoid epidemics of respiratory diseases. See Section 8.7.2.	Ensure incorporation of proper sanitation guidelines into construction design; ensure adherence to sanitation and hygiene procedures.
Epidemic spread of food-borne illnesses within camp and to surrounding villages	✓		✓		▣	Implement specifications for preparing and operating food supply and services in camp. See Section 8.7.5.	Ensure incorporation of proper sanitation guidelines into construction design; ensure adherence to sanitation guidelines related to food and water supplies.
Accidents during construction	✓		✓		▣	Implement project occupational health and safety plan; review of safety features in building/camp design; limit access of non-essential personnel; root cause analysis; safety training for drivers and transportation contractors, signage program. See Section 8.7.6.	Prior to construction, implement safety measures such as new worker orientation, medical emergency response plans, and accident investigation; ensure adherence to safety guidelines throughout construction and operations.
Workplace violence and security; potential increased rates of confrontations, fights, and crime, both internal and external to the work camps	✓		✓		▣	Prepare security assessment; implement security policies, cross cultural training during employee orientation. See Section 8.7.6.	Prior to construction, implement safety measures such as new worker orientation, medical emergency response plans, and accident investigation; ensure adherence to safety guidelines throughout construction and operations.
Camp sites/services - potential for excreta/vector-related diseases due to clogged storm drains, poor drainage at water distribution sites, improper trash collection/disposal	✓		✓		☐	Incorporation of standard waste management practices including a waste management plan. Incorporation of drainage design measures. See Sections 8.7.3, 8.7.7.	Ensure use of design measures to minimize water accumulation; monitor management of water accumulation in and around project facilities throughout operations. Prior to construction, implement waste management plans and occupational health program; ensure adherence to plans and program throughout construction and operation.

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CHAD TABLE 7.1-1
IMPACT AND MITIGATION MEASURE SUMMARY TABLE

Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
HOUSING - PERMANENT							
Standing water/drainage leading to mosquito-borne diseases		✓	✓		⊡	Project design measures to eliminate breeding/feeding grounds; proper drainage for facilities during rainy season; spraying, netting, education, health screenings, also malaria screening/surveillance program. See Section 8.7.3.	Ensure use of design measures to minimize water accumulation; monitor management of water accumulation in and around project facilities throughout operations.
Ventilation/respiratory impacts, including project air emissions		✓	✓		⊡	Minimum number of square meters per occupant; cooking area exhausts; project facilities designed to meet World Bank guidelines. See Sections 8.7.2, 8.7.7.	Ensure incorporation of proper sanitation guidelines into construction design; ensure adherence to sanitation and hygiene procedures. Prior to construction, implement waste management plans and occupational health program; ensure adherence to plans and program throughout construction and operation.
Accidents, injuries and security issues		✓	✓		⊡	Education/prevention/incorporation of safety features, accident investigation procedures, occupational health programs, alcohol and drug policies, community awareness. See Sections 8.7.6, 8.7.7.	Prior to construction, implement safety measures such as new worker orientation, medical emergency response plans, and accident investigation; ensure adherence to safety guidelines throughout construction and operations. Prior to construction, implement waste management plans and occupational health program; ensure adherence to plans and program throughout construction and operation.
URBAN DEVELOPMENT							
Public Facilities: Public Market Places Vehicular congestion, secondary air pollution and injuries	✓	✓	✓	✓	□	Temporary increase during construction with low likelihood of long-term impact. Implementation of project design measures during construction. See Section 8.7.6.	Prior to construction, implement safety measures such as new worker orientation, medical emergency response plans, and accident investigation; ensure adherence to safety guidelines throughout construction and operations.

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	Construction	Operation	Local	Regional			
Environmental Services, i.e., solid waste management - impacts to surrounding villages	✓	✓	✓		□	Implementation of project waste management practices and waste management plan to manage solid/liquid waste within project/camp areas; plan for ongoing O&M during operational phase of project. See Sections 8.7.5, 8.7.7.	Ensure incorporation of proper sanitation guidelines into construction design; ensure adherence to sanitation guidelines related to food and water supplies. Prior to construction, implement waste management plans and occupational health program; ensure adherence to plans and program throughout construction and operation.
Public Facilities Increased activity with potential for increased pools of water and vector-borne diseases	✓	✓	✓		□	Community awareness. See Section 8.7.3.	Ensure use of design measures to minimize water accumulation; monitor management of water accumulation in and around project facilities throughout operations.
Increased utilization of local facilities, particularly food supply (meat, vegetables)	✓		✓		⊡	Supplier, contractor specifications regarding food supply maintenance and food sanitation. See Section 8.7.5.	Ensure incorporation of proper sanitation guidelines into construction design; ensure adherence to sanitation guidelines related to food and water supplies.
Motor Parks Covered motor parks can lead to build-up of air pollution from vehicle exhausts	✓	✓	✓		□	Design facility to incorporate adequate ventilation measures. See Section 8.7.7.	Prior to construction, implement waste management plans and occupational health program; ensure adherence to plans and program throughout construction and operation.
CHAD - PUBLIC HEALTH AND SAFETY (SECTION 7.7) - Transportation							
<u>ROADS: CONSTRUCTION AND MAINTENANCE</u>							
Work activity can spread vector-borne diseases by extending breeding areas due to temporary water accumulation	✓	✓	✓		⊡	Provisions for mosquito control, netting, spraying, grading, malaria surveillance, education. See Section 8.7.3.	Ensure use of design measures to minimize water accumulation; monitor management of water accumulation in and around project facilities throughout operations.

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	Construction	Operation	Local	Regional			
Accidents associated with construction: workers, pedestrians, vehicles	✓		✓		▣	Occupational Health and Safety Plan, inspection and education; signage program. See Sections 3.2.12.4, 8.7.6.	Prior to construction, implement safety measures such as new worker orientation, medical emergency response plans, and accident investigation; ensure adherence to safety guidelines throughout construction and operations.
Increase in local air pollution due to construction and traffic	✓	✓	✓		□	Construction equipment maintenance programs. See Section 8.7.7.	Prior to construction, implement waste management plans and occupational health program; ensure adherence to plans and program throughout construction and operation.
Lack of community familiarity on road hazards	✓	✓	✓		□	Community consultation, signage, education. See Section 8.7.6.	Prior to construction, implement safety measures such as new worker orientation, medical emergency response plans, and accident investigation; ensure adherence to safety guidelines throughout construction and operations.
Spread of STDs/AIDS from truckers, work camp personnel	✓	✓	✓	✓	▣	Worker education, directed funding, community education and outreach. See Section 8.7.4.	Ensure that new project workers attend IEC programs for STD prevention; regularly monitor STD prevention signage at project sites and availability of condoms.
Inadequate drainage of general road area causing flooding and increase in vector-borne disease spread, including extending snail habitat and spread Schistosomiasis	✓	✓	✓		▣	Drainage design and maintenance plans incorporated as appropriate for project area and contiguous areas/spraying, inspection, surveillance. See Section 8.7.3.	Ensure use of design measures to minimize water accumulation; monitor management of water accumulation in and around project facilities throughout operations.

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Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
Handling of potentially hazardous materials with accidental releases, liquid and solid chemical waste from construction affecting local surface and groundwater	✓	✓	✓		⊡	Emergency response, waste management plans, education and training. See Sections 3.2.12.5, 8.7.6, 8.7.7.	Prior to construction, implement safety measures such as new worker orientation, medical emergency response plans, and accident investigation; ensure adherence to safety guidelines throughout construction and operations. Prior to construction, implement waste management plans and occupational health program; ensure adherence to plans and program throughout construction and operation.
AVIATION							
Air and noise pollution due to use of airplanes, helicopters	✓	✓	✓		☐	None required. For additional information, see Section 7.7.	None required
CAPACITY/INSTITUTION							
Public health/safety, road and driver safety	✓	✓	✓	✓	⊡	Driver training, signage, drug and alcohol policy. See Section 8.7.6.	Prior to construction, implement safety measures such as new worker orientation, medical emergency response plans, and accident investigation; ensure adherence to safety guidelines throughout construction and operations.
Spread of STDs including AIDS	✓	✓	✓	✓	⊡	Worker education/potential for surveillance/community education and outreach. See Section 8.7.4.	Ensure that new project workers attend IEC programs for STD prevention; regularly monitor STD prevention signage at project sites and availability of condoms.
Transportation of food materials for camp services and inadvertent spread of vectors and pathogens and other noxious plant species	✓	✓	✓	✓	☐	Food supply/service O & M plans. See Section 8.7.5.	Ensure incorporation of proper sanitation guidelines into construction design; ensure adherence to sanitation guidelines related to food and water supplies.

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	Construction	Operation	Local	Regional			
CHAD - PUBLIC HEALTH AND SAFETY (SECTION 7.7) - Water Supply and Sanitation							
CONSTRUCTION AND MAINTENANCE-RELATED ACTIVITIES							
Excavations, deposition, and temporary storage of construction/excavation debris for water/waste management facilities creating pools of standing water with enhancement of vector-borne disease	✓	✓	✓		▣	Incorporation of design measures to eliminate breeding/feeding grounds; proper drainage for project facilities. See Section 8.7.3.	Ensure use of design measures to minimize water accumulation; monitor management of water accumulation in and around project facilities throughout operations.
Accidents - workers and nearby residents because of flooding, heavy rain, erosion mudslides, after hours playing by children	✓	✓	✓		▣	Occupational Health & Safety plans/limit access to facilities; community education. See Section 8.7.6.	Prior to construction, implement safety measures such as new worker orientation, medical emergency response plans, and accident investigation; ensure adherence to safety guidelines throughout construction and operations.
ON-SITE ENVIRONMENTAL ENGINEERING							
Solid/liquid excreta treatment and disposal with direct surface soil and surface and groundwater impacts	✓	✓	✓		▣	Incorporation of standard waste management practices and waste management plan; community education as necessary. See Sections 8.7.3, 8.7.5, 8.7.7, 3.2.12.5.	Ensure use of design measures to minimize water accumulation; monitor management of water accumulation in and around project facilities throughout operations. Ensure incorporation of proper sanitation guidelines into construction design; ensure adherence to sanitation guidelines related to food and water supplies. Prior to construction, implement waste management plans and occupational health program; ensure adherence to plans and program throughout construction and operation.

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Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
Vector-borne disease enhancement from standing water and waste accumulation thereby increasing feeding grounds	✓	✓	✓		⊡	Project design measures to eliminate breeding/feeding grounds; proper drainage for facilities during rainy season; spraying, netting, education, health screenings, also malaria screening/surveillance programs. See Section 8.7.3.	Ensure use of design measures to minimize water accumulation; monitor management of water accumulation in and around project facilities throughout operations.
WATER SUPPLY							
Spread of vector-borne diseases	✓	✓	✓		☐	Project water supply from subsurface aquifer.	Ensure use of design measures to minimize water accumulation; monitor management of water accumulation in and around project facilities throughout operations.
Storm drains becoming open sewers with increase in waterborne diseases	✓	✓	✓		⊡	Waste effluents treated and monitored to meet World Bank guidelines, incorporation of drainage design measures. See Sections 8.7.3, 8.7.5.	Ensure use of design measures to minimize water accumulation; monitor management of water accumulation in and around project facilities throughout operations. Ensure incorporation of proper sanitation guidelines into construction design; ensure adherence to sanitation guidelines related to food and water supplies.
Inappropriate utilization of project water by local communities/villages	✓	✓	✓		⊡	Incorporation of design measures for project wastewater and stormwaters; community education See Sections 8.7.3, 8.7.5.	Ensure use of design measures to minimize water accumulation; monitor management of water accumulation in and around project facilities throughout operations. Ensure incorporation of proper sanitation guidelines into construction design; ensure adherence to sanitation guidelines related to food and water supplies.

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	Construction	Operation	Local	Regional			
Water availability to locals	✓	✓	✓		▣	If drawdown affects locals, water will be supplied, project wells will be given to community at project completion. See Section 8.7.5.	Ensure incorporation of proper sanitation guidelines into construction design; ensure adherence to sanitation guidelines related to food and water supplies.
SOLID WASTE MANAGEMENT							
Hospitals/Clinics - Overflow to local community, spread of blood-borne pathogens	✓	✓	✓		▣	Segregation from other waste streams with separate collection, storage, and disposal. Medical waste incineration plan. See Section 8.7.7.	Prior to construction, implement waste management plans and occupational health program; ensure adherence to plans and program throughout construction and operation.
Sanitary landfill, air, water pollution potential	✓	✓	✓		▣	Incorporation of standard waste management practices and waste management plan. See Sections 8.7.5, 8.7.7.	Ensure incorporation of proper sanitation guidelines into construction design; ensure adherence to sanitation guidelines related to food and water supplies. Prior to construction, implement waste management plans and occupational health program; ensure adherence to plans and program throughout construction and operation.
Accidents associated with recycling and hazardous materials handling	✓	✓	✓		☐	Inventory types, potential health hazards/appropriate segregations/worker and community education. Incorporate waste management plan and Emergency Response Plan. See Section 8.7.7.	Prior to construction, implement waste management plans and occupational health program; ensure adherence to plans and program throughout construction and operation.
Drainage - potential for increased spread of vector-borne diseases	✓	✓	✓		☐	Incorporate design measures for the project area as appropriate; spraying; worker/community education. See Section 8.7.7.	Prior to construction, implement waste management plans and occupational health program; ensure adherence to plans and program throughout construction and operation.

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Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
Waterborne epidemics - rapid spread both within work camp and to surrounding villages	✓	✓	✓		□	Contingency plans for supplemental Chlorination/water delivery truck, lab and testing facilities and support staff. See Section 8.7.7.	Prior to construction, implement waste management plans and occupational health program; ensure adherence to plans and program throughout construction and operation.
<u>FOOD SERVICE</u>							
Increased demands on local food supply resources	✓	✓	✓		▣	Food supply/management plan. Sanitation inspections/audit and management systems. See Section 8.7.5.	Ensure incorporation of proper sanitation guidelines into construction design; ensure adherence to sanitation guidelines related to food and water supplies.
Potential increase and spread of food-borne illness/epidemics/vector spread	✓	✓	✓		▣	Food supply/management plan. Sanitation inspections/audit and management systems. See Section 8.7.5.	Ensure incorporation of proper sanitation guidelines into construction design; ensure adherence to sanitation guidelines related to food and water supplies.
CHAD - PUBLIC HEALTH AND SAFETY (SECTION 7.7) - Electronic/Telecommunications							
<u>TELECOMMUNICATIONS</u>							
Decreased air pollution due to decreased vehicle use	✓	✓	✓		✚	Positive benefit. See Section 7.7.1.4.	None required
Enhanced notification related to emergency health services	✓	✓	✓	✓	✚	Positive benefit. See Section 7.7.1.4.	None required
Enhanced notification related to emergency services - fire, flood, disaster	✓	✓	✓	✓	✚	Positive benefit. See Section 7.7.1.4.	None required

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CHAD TABLE 7.1-1
IMPACT AND MITIGATION MEASURE SUMMARY TABLE

Impact Description	Duration[1]		Magnitude[2]		Significance[3]	Project Design Measure or Proposed Mitigation Measure	Monitoring
	Construction	Operation	Local	Regional			
Potential increase in vector-borne diseases from pooling of water in holes dug for transmission line poles	✓	✓	✓		□	Coordinating schedules for installation/addition of light oil to holes to deprive larvae of oxygen. See Sections 8.7.3 and 8.7.7.	Ensure use of design measures to minimize water accumulation; monitor management of water accumulation in and around project facilities throughout operations. Prior to construction, implement waste management plans and occupational health program; ensure adherence to plans and program throughout construction and operation.
Potential exposure and release of wood preserving chemicals from hard transmission line poles	✓	✓	✓		□	Occupational H & S plan during installation. See Section 8.7.7.	Prior to construction, implement waste management plans and occupational health program; ensure adherence to plans and program throughout construction and operation.
Potential microwave/EMF exposure	✓	✓	✓		□	Expected limited access, low exposure duration, frequency.	None required
WASTE MANAGEMENT (SECTION 7.8)							
Generation, treatment, and disposal of various types and volumes of solid, liquid, petroleum-based, and hazardous wastes	✓	✓	✓		□	Incorporation of standard waste management practices in the project would include an overall waste management plan and facility-specific waste management plans. See Section 8.8.2 for further information.	Monitoring would be conducted prior to construction to verify that waste management plans have been developed and implemented. Monitoring would also be conducted during construction and operations to ensure that project activities adhere to the subject plans and associated procedures established for waste management.

Notes:
1. Duration: Construction - 2 years or less
Operation - Approximately 30 years

3. Key to Significance
+ Beneficial
☒ Significant but Mitigable

TABLE 7.1-2

RESULTS OF ENVIRONMENTAL ECONOMIC ANALYSIS

SCENARIO	ASSUMED OIL PRICE	NET PRESENT VALUE OF PROJECT IMPACTS	
		Billion FCFA	Billion US$
Basic Scenario	$20/bbl	+629	+1.3
25 Year Delay Scenario	$20/bbl	+571	+1.1
Theoretical Rising Prices Scenario	$20/bbl	+271	+0.54
Basic Scenario (Alternative Price)	$15/bbl	+237	+0.47

Source: Dames & Moore, 1997a.

TABLE 7.4-1
ESTIMATED PEAK PERIOD WATER REQUIREMENT DURING CONSTRUCTION

Facility/Usage	No. of Persons	Mean Daily Demand[a] (m^3/day)	Mean Yearly Demand (m^3/year)
Central Treatment Facility, Gathering Stations, and Construction Camps	3,000	1,080	394,500
Personnel for Pipeline Construction (approx.)	1,000	360	131,500
Total Domestic Usage	**4,000**	**1,440**	**526,000**
Hydrotest of Pipeline	–	–	26,200
Concrete Work	–	–	800
Dust Control	–	–	1,500
Miscellaneous Works	–	–	3,700
Fire Fighting Reserve[b]	–	–	5,000
Drilling Water Requirement[b]	–	–	20,000
Total	**–**	**–**	**583,200**

[a]Based on 0.360 m^3/capita/day.
[b]Assumed values.

TABLE 7.4-2
ESTIMATED WATER REQUIREMENT DURING OPERATIONS

Facility/Usage	No. of Persons	Mean Daily Demand[a] (m^3/day)	Mean Yearly Demand (m^3/year)
Project Personnel (located near Operations Center)	500	180	65,750
Process Water[b]	–	10	3,650
Fire Fighting Reserve[b]	–	–	5,000
Total	**–**	**120**	**74,400**

[a]Based on 0.360 m^3/capita/day
[b]Assumed values.

TABLE 7.2-1
LAND USE ESTIMATES
(CONSTRUCTION AND OPERATIONS)

Type of Land	Oil Field Development Area Land Hectares	Pipeline Land Hectares	Total Land Hectares
Traditional Agriculture[1]	1,400	330	1,730
Market Gardens	25	35	60
Undegraded Savanna	0	70	70
Other	0	25	25
Total	1,425	460	1,885

[1] Includes cropland, pastures, fallow, and degraded savanna.

TABLE 7.2-2
CONSTRUCTION WAGE AND PROCUREMENT ESTIMATES
(In Millions of U.S. Dollars)

Source	1998	1999	2000	Total
Chadian Worker Wages	1.97	9.21	4.46	15.64
Local Project Procurements	3.05	14.04	6.31	23.40
Total	5.02	23.25	10.77	39.04

Source:SNC-Lavalin, 1995

TABLE 7.4-3
QUALITY OF WATER PRODUCED WITH OIL

Analyses	Units	Komé 5 Well Aquifer (average)	Bolobo Blend Oil, Komé 5 Water*
pH		8.23	
Conductivity	µmhos/cm	0.723	
Total dissolved solids	mg/L	351.33	
Total suspended solids	mg/L	23	
Total organic carbon	mg/L	4.93	
Chemical oxygen demand	mg/L	11.3	
Hardness	mg/L $CaCO_3$	251.33	
Sodium	mg/L	115	
Potassium	mg/L	42.13	
Calcium	mg/L	6.14	
Magnesium	mg/L	0.66	
Bicarbonate	mg/L $CaCO_3$	251.33	
Chloride	mg/L	54.67	
Sulfate	mg/L	7	
Fluoride	mg/L	1.43	
Arsenic	mg/L	0.0010	
Barium	mg/L	0.279	
Iron	mg/L	1.007	
Manganese	mg/L	0.04	
Molybdenum	mg/L	2.32	
Zinc	mg/L	0.063	
Gross Alpha	pCi/L	<3.0	
Benzene	µg/L		3.8
Toluene	µg/L		11.2
Ethylbenzene	µg/L		9.0
Xylenes	µg/L		122.6
Isopropylbenzene	µg/L		1.4
Naphthalene	µg/L		23.9
1,3,5-trimethylbenzene	µg/L		12.8
1,2,4-trimethylbenzene	µg/L		28.0
Chloroform	µg/L		1.6
Fluoranthene	µg/L		10.7
Pyrene	µg/L		4.86
Oil and grease	mg/L	5.3	
Total organic carbon	mg/L		26.6

*These results are for a synthetic mixture of Bolobo crude oils and Komé 5 Well produced aquifer water subjected to demulsification testing.
Gross alpha = the number of alpha particles emitted per unit of time.
pCi/L = picocuries per liter.

TABLE 7.6-1
NO_x EMISSION RATES AND MAXIMUM NO_2 CONCENTRATIONS
UNCONTROLLED NO_x EMISSIONS, OZONE LIMITING METHOD[1]

Source	Fuel	Capacity (Each)	NO_x Stack Emission Rate (Each)	World Bank Guidelines	Units
NO_x Emission Rates					
Operations Center					
Power Plant Turbines (4)	Natural Gas/Crude Oil	33,000 HP	2.6[2]	N/A[3]	lb/MBtu
Topping Unit Fired Heater (1)	Crude Oil/ Natural Gas	11.2 MBtu/hr	0.3[4]	0.3	lb/MBtu
Waste Incinerator	Waste	3,800 ton/yr	0.4	N/A[5]	lb/MBtu
24 Hour Average NO_2 Concentrations					
	Project Contribution	**Background Concentration**	**Project Contribution plus Background**	**World Bank Guidelines[6]**	**Units**
Maximum Concentration-All Sources	62	40	102	200	μg/m^3
Average Annual NO_2 Concentrations					
	Project Contribution	**Background Concentration**	**Project Contribution plus Background**	**World Bank Guidelines[6]**	**Units**
Maximum Concentration-All Sources	14	10	24	100	μg/m^3

1. Stack NO_x emission rates were taken from Air Emission Screening Study for the Project. NO_x to NO_2 conversion using the ozone limiting method and assumed a background O_3 concentration of 0.05 ppm (Dames & Moore, 1997b).
2. Worst case (conservative) NO_x emission rate is presented. Actual NOx emission rate would be lower depending on ambient temperature conditions and fuel type (crude and/or natural gas).
3. World Bank guidelines do not recommend emission thresholds for NO_x but instead govern NO_2 through recommended ground-level concentration guidelines.
4. Emission Rate of 0.4 lb/MBtu was used for conservative worst-case modeling. The project would incorporate heaters with maximum emission rates of 0.3 lb/MBtu.
5. World Bank guidelines do not contain emission thresholds for waste incinerators.
6. World Bank Guidelines for Onshore Oil and Gas Development

TABLE 7.6-2
MAXIMUM NO_2 CONCENTRATIONS AT VILLAGE RECEPTORS (in $\mu g/m^3$)

Village	Maximum Estimated NO_2 Concentration[1]	
	24 Hour Average	Annual Average
World Bank Guideline Value	200	100
Mékapti	83	20
Manboe	87	21
Dangde	79	20
Bendo	82	20
Galaba	79	20
Miandoum	83	20
Dangoum	82	20
Kayra	84	21
Bolobo	81	20
Béla	87	21
Komé	92	22
Bégada	86	21
Kagroue	85	21
Banga	90	22
Béro	92	22

Source: Dames & Moore, 1997b.

1. Based on background 24 hour average NO_2 concentrations of 40 $\mu g/m^3$ and annual average NO_2 concentrations of 10 $\mu g/m^3$. Maximum NO_2 concentrations were calculated using the Ozone Limiting Method, and are based on an estimated ambient ozone concentration of 0.05 ppm.

TABLE 7.6-3
SO_2 EMISSION RATES AND MAXIMUM SO_2 CONCENTRATIONS[1]

Source	Fuel	Capacity (Each)	SO_2 Stack Emission Rate (Each)	World Bank Guidelines	Units
SO_2 Emission Rates					
Operations Center					
Power Plant Turbines (4)	Natural Gas/Crude Oil	33,000 HP	1.1	100	ton/day
Topping Unit Fired Heater (1)	Crude Oil/ Natural Gas	11.2 MBtu/hr	< 0.1	100	ton/day
Waste Incinerator	Waste	3,800 ton/year	0.7	N/A[2]	lb/MBtu
24 Hour Average SO_2 Concentrations					
	Project Contribution	**Background Concentration**	**Project Contribution plus Background**	**World Bank Guidelines[3]**	**Units**
Maximum Concentration-All Sources	200	37	237	500	μg/m³
Average Annual SO_2 Concentrations					
	Project Contribution	**Background Concentration**	**Project Contribution plus Background**	**World Bank Guidelines[3]**	**Units**
Maximum Concentration-All Sources	50	8	58	100	μg/m³

1. Stack SO_2 emission rates were taken from Air Emission Screening Study for the Project.
2. Word Bank guidelines do not contain emission limits for waste incinerators.
3. World Bank Guidelines for Onshore Oil and Gas Development

TABLE 7.6-4
MAXIMUM SO_2 CONCENTRATIONS AT VILLAGE RECEPTORS (in $\mu g/m^3$)

Village	Maximum Estimated SO_2 Concentration[1]	
	24 Hour Average	Annual Average
World Bank Guideline Value	500	100
Mékapti	46	9
Manboe	56	11
Dangde	40	8
Bendo	45	9
Galaba	39	8
Miandoum	46	9
Dangoum	46	9
Kayra	50	10
Bolobo	43	9
Bela	57	12
Komé	65	13
Bégada	56	11
Kagroue	53	11
Banga	77	17
Béro	74	15

Source: Dames & Moore, 1997b.

1. Based on background 24 hour average SO_2 concentrations of 37 $\mu g/m^3$ and annual average SO_2 concentrations of 8 $\mu g/m^3$.

TABLE 7.6-5
PM EMISSION RATES AND MAXIMUM PM_{10} CONCENTRATIONS[1]

Source	Fuel	Capacity (Each)	PM Stack Emission Rate (Each)	World Bank Guidelines	Units
PM Emission Rates					
Operations Center					
Power Plant Turbines (4)	Natural Gas/Crude Oil	33,000 HP	NC	100	mg/m^3
Topping Unit Fired Heater (1)	Crude Oil/ Natural Gas	11.2 MBtu/hr	NC	100	mg/m^3
Waste Incinerator	Waste	3,800 ton/year	0.07	N/A[2]	lb/MBtu
24 Hour Average PM Concentrations					
	Project Contribution	Background Concentration	Project Contribution plus Background	World Bank Guidelines[4]	Units
Maximum Concentration-All Sources	19	75	94	500	µg/m^3
Average Annual PM Concentrations					
	Project Contribution[3]	Background Concentration	Project Contribution plus Background	World Bank Guidelines[4]	Units
Maximum Concentration-All Sources	3	25	28	100	µg/m^3

1. Stack PM emission rates were taken from Air Emission Screening Study for the Project.
2. World Bank guidelines do not contain emission limits for waste incinerators.
3. Assumes all project-generated particulate concentrations would be PM_{10}
4. World Bank Guidelines for Onshore Oil and Gas Development

NC: Not Calculated

TABLE 7.6-6
MAXIMUM PM CONCENTRATIONS AT VILLAGE RECEPTORS

Village	Maximum Estimated PM Concentration[1]	
	24 Hour Average	Annual Average
World Bank Guideline Value	500	100
Mékapti	79	26
Manboe	83	26
Dangde	76	25
Bendo	78	26
Galaba	76	25
Miandoum	79	26
Dangoum	79	26
Kayra	80	26
Bolobo	78	26
Bela	83	26
Komé	86	27
Bégada	82	26
Kagroue	81	26
Banga	86	27
Béro	87	27

1. Based on background 24 hour average PM_{10} concentrations of 75 $\mu g/m^3$ and annual average PM_{10} concentrations of 25 $\mu g/m^3$.

8.0 MITIGATION MEASURES AND MONITORING

8.1 INTRODUCTION

This section outlines the mitigation measures that have been developed to mitigate potentially significant adverse impacts identified in Section 7.0. Proposed mitigation measures are presented by discipline (e.g., human environment, biology, hydrology, etc.) in the same order as discussed in Section 7.0. The sections vary in length due to the nature of the impacts and related mitigation measures required. Physical impacts, such as those for biology and water quality, and associated mitigation measures are described succinctly. Impacts on the human environment and public health and safety, however, require more discussion to summarize mitigation measures appropriately. A tabular summary of all significant impacts and mitigations (Table 1-1) is presented in Section 1.0.

Project design measures have also been incorporated in the preliminary engineering of the proposed project. These include the use of accepted engineering practices and implementation of management and control plans that would avoid many significant impacts or reduce them to less-than-significant levels. These measures were presented in Section 3.2.12 and Table 3-8. A brief description of the relevant project design measures for impacts reduced to less-than-significant levels has also been included in this mitigation section, where applicable.

The mitigation and project design measures presented in this section are a precursor to the Environmental Management Plan (EMP) which is under preparation. The EMP provides the plans for implementing measures to be taken during construction and operation of the project to avoid or reduce identified impacts to acceptable levels consistent with those required under the World Bank's Operational Directive 4.01-Annex C and the International Finance Corporation's guidance for preparation of an EA. The EMP will include information on the project's environmental oversight organization and management, and the responsibilities of project participants, including the Government of Chad. The EMP will also provide information on monitoring plans and quality assurance mechanisms. Refer to Section 8.9 for additional information on the EMP.

8.2 HUMAN ENVIRONMENT

Impacts of the proposed project to the human environment of the study area are analyzed and described in Section 7.2. Both beneficial and adverse impacts would occur, mainly in association with construction activities. All significant adverse impacts would be reduced to less-than-significant levels with implementation of mitigation measures and project design measures.

Potentially significant project impacts to the human environment, both adverse and beneficial, would be associated with the following:

- Displacement of households and displacement of individuals from farm lands
- Employment expectations and boom-bust in job demand
- Pressure on existing housing; inadequate housing for project workers
- Inflation, economic distortions, and boom-bust in demand for goods and services
- Increased traffic risks
- Drawdown of water table
- Disturbance of sacred sites; intergroup rivalry
- Interference with livestock movements
- Migration of people to the project area as a result of project development.

Mitigation and project design measures for avoiding or reducing adverse impacts are presented in the following sections, along with a summary of the impact.

8.2.1 Land Use

Impact: Land use requirements of the project causing temporary or permanent displacement of the local population

Significance: Significant but mitigable

Mitigation: Develop and implement a detailed compensation and resettlement plan

Monitoring: Monitoring would be performed to ensure compliance with the detailed Compensation and Resettlement Plan, and confirmation that the plan meets the requirements set out below. Monitoring would then be conducted regularly during implementation of the plan to confirm that all the requisite procedures have been followed. Monitoring would also be conducted after resettlement is completed to verify that all landholders have received appropriate compensation and the objectives of the plan have been achieved.

A detailed compensation plan including a resettlement plan to satisfy World Bank Operational Directive 4.30 requirements is under development. The compensation plan will include a process to promote public awareness and cooperation with appropriate agencies of the

Government of Chad and local residents in areas of construction and operations. Information and formal requests for land needs will be disseminated to local residents well in advance. Meetings at various levels of the national, regional, and local administrations (such as government ministries, prefectures, cantons and villages) and with the local population will take place to discuss the compensation plan.

For those land occupants who experience temporary conversion of their land resulting in the loss of one to two years' plantings, payment in kind or cash payment to compensate for short-term crop losses will be provided. The compensation philosophy will be based on the following main principles:

- As soon as specific land parcels required by the project are known, the land occupants will be identified. The occupant will be informed of the project land need through both formal notification in writing and by a verbal notification.
- A meeting will be arranged with the occupant for discussion of the compensation process. Land use(s) for the current and previous growing seasons and eligibility for compensation will be determined.
- Compensation will be paid according to the traditional measure of land, the "corde." A corde is 50 × 50 m. The value of the compensation will be determined based on:
  - The labor cost for preparing replacement fields
  - Highest market value of staple crops
  - Highest market value of cash crops.
- Compensation contracts will be entered into with each land occupant. The compensation contract will be read in the presence of the affected occupant, village chief, and village elders. Compensation will be made thereafter in a timely and transparent manner.
- A grievance procedure will be established.

For those land occupants who experience a permanent loss of a portion of landholdings that impairs, but does not eliminate, their economic viability, payment in kind or cash to compensate for short-term crop losses will be provided. This will be consistent with the process described above and may include the provision of technical assistance to improve agricultural productivity on their remaining landholdings.

For those residents who experience permanent loss of land that impedes their economic viability, a mitigation and resettlement plan will be developed. This plan, which is to be made available publicly, will:

- Provide for the clear and concise recording of the interaction with the local population (both prospective relocatees and those in areas where relocatees may settle) to be undertaken in developing the plan

- Involve the affected population during the planning of the resettlement process through communications, consultation, and participation
- Continue the existing public consultation process throughout the resettlement process
- Include a cost estimate for implementing the resettlement plan
- Provide for an appropriate level of monitoring after resettlement is completed.

The project is not expected to directly displace any human habitations but it will remove some parcels of agricultural land from production. No forced resettlement is anticipated and many people can continue living as before. However, the project has the potential to displace some households or individuals whose fields are on plots of land required for the project. This is envisioned only if the land lost is a significant portion of the total amount of land utilized by that individual or household.

Those affected would be assisted in making an informed choice from amongst a range of mitigation options that will be provided to compensate for this land loss, including:

- Adoption of new farming methods to enable higher production from remaining land. Training and economic assistance in intensified farming would be provided.
- Relocation to another area where affected persons have relatives or friends to offer them access to adequate land. Aid and compensation for such relocation would be provided.
- Relocation to another unfarmed area and establishment of a new farming hamlet. The project would provide aid and compensation for the relocation.
- Relocation of a number of individuals or households to a new location, forming a new village. The project would assist with constructing the new village and providing families with aid and compensation for the relocation.

Only the last option (relocation of a number of individuals to a new location) resembles "resettlement" as it is commonly understood by development organizations. All of the other options are already currently and commonly practiced by people in the area. For example, it is common for people to set up new hamlets in unfarmed areas. In the oil field development area, 63 out of the 90 official "villages" there have given rise to such new settlements. Forty-one percent of all settlements there started out as farming hamlets. It is also a common cultural phenomenon for individuals and families to leave their village to reside with relatives elsewhere, either to find better farm land or for social reasons. Forty-seven percent of people sampled for the EA reported that they had left their natal village to settle elsewhere. The project compensation process would assure that relocatees' economic and social circumstances in their new location will be at least as good as those in the location from which they move.

Intensified farming is also a viable option. Farmers in the project area have indicated that they would like to intensify their farming, but they have been hampered in the past in adopting appropriate techniques by lack of equipment, the limited availability of improved seeds and inputs such as fertilizers, and the lack of agricultural credit.

Resettlement policies, planning principles, institutional arrangements, and design criteria are discussed below, and specifics such as how resettlement would be implemented, possible resettlement sites, the specific population to be resettled, or per person/household resettlement costs will be discussed in the project Compensation Plan.

The criteria for identifying families that require compensation measures that may include resettlement would be households that fall below a viable level of landholding. Exceptions to this criterion would be dramatic reduction of bush land in a given area that would impact the local population's access to bush produce; and if project changes in land uses cause food production levels to fall below international standards (i.e., Food and Agriculture Organization of the United Nations) and cash incomes are insufficient to purchase supplemental food.

Who will be resettled

Project land needs would depend upon the actual size and placement of oil wells, treatment facilities, roads and housing, all of which have not been finalized. Estimates of the range of households to be resettled have been calculated on the basis of the amount of land that would probably be needed for well pads and roads in Cantons Komé, Miandoum and Bébédjia, population density, and the average landholding. The limited number of people likely to be affected and the amount of land at their disposal reduce the likelihood of resettlement in these cantons. In Canton Béro, where the Operations Center would be constructed, there is a greater chance that people would elect to resettle; much of the land in Canton Béro is already farmed or owned and most of the unfarmed land is flooded during the growing season. If affected farmers do not choose to intensify their farming, they would have to settle with kin in parts of Béro outside the reach of the project or resettle in another canton. Moving from one canton to another is not uncommon; however, it increases the number of administrative arrangements that must be made. The compensation plan would facilitate these arrangements by providing transportation during relocation planning and compensating the host canton.

Traditional resettlement, as practiced by people in the region, takes about 21 months. The critical element in relocation is sufficient lead time to build new houses and prepare new fields before giving up the old. These activities are weather dependent and can therefore be carried out only in certain months of the year, thus dictating the schedule for relocation in the traditional manner. From the date that project construction work is scheduled to begin, relocation activities must begin 21 months earlier for farmers using traditional techniques for clearing fields and building new homes. Relocation activities can begin later if a farmer will move to new fields, with the project providing mechanical help to assist the farmers in clearing their new fields.

It will not be possible or necessary to identify all of the individuals and households that will be affected until all aspects of the project (particularly the location of oil wells) have been finalized. Those persons identified at a later date as being affected may have less lead time and would therefore be given more direct help if they should choose the relocation option. This shortened lead time between identification of affected members of the local population and commencement of project construction is not likely to affect large numbers of people, since construction activities (such as the clearing and development of well pads) will take place over a period of several years. Some of those affected will have a year or more from the commencement of construction to the time when they will be required to resettle, if they so choose.

Once the numbers and identities of affected residents are determined, options of resettlement, assistance, or compensation can be finalized, with input from the affected population. Recognizing the overlapping and varied levels of claims to the same land, successful compensation planning is dependent upon securing the consent of the government and local community leaders responsible for the distribution of land use rights. This consent process reflects accepted practice in the study area and is a means by which openness in the process can be promoted. Openness in the mitigation process is essential so that residents understand that their interests are being protected.

8.2.2 Employment

Impact: Labor recruitment and the potential for inequitable distribution of jobs

Significance: Significant but mitigable

Mitigation: Develop a plan for worker recruitment, with the following key attributes:

- Ensure the employment of Chadians preferentially
- All Chadians can apply
- Applications will be accepted at local employment and business offices
- No hiring at project work sites
- Hiring preference given to candidates who meet job criteria and are directly impacted by the project
- Compliant with Chadian laws and regulations

Monitoring: Monitoring would continue regularly throughout the construction and operations recruitment phases to verify adherence to the plan and its effectiveness.

Impact: Potential boom-bust syndrome as workers are released from construction

Significance: Significant but mitigable

Project Design: Provide open communication during the recruitment process as to the temporary nature and duration of jobs on the project

Monitoring:	Ensure that adequate information is made available to workers through audio-visual presentations, print media, and signage at recruitment offices and/or project sites

Prior to commencement of large scale project activities, the numbers and skills of workers in Chad would be assessed. Emphasis would be placed on hiring qualified people that meet project employment needs in a cost effective manner and providing socioeconomic benefits to the project area.

Project area residents and all other Chadian nationals would be considered during the hiring process. These people would need to meet the required minimum employment skills. The hiring process would be conducted in an open (transparent) manner to demonstrate fairness.

A recruitment and training plan would be prepared with a view to an ever increasing participation by Chadian personnel. The plan would be structured to emphasize employment among impacted villages in the project area. Workers will also be drawn upon at the national level. Project contractors will also follow this system for hiring. A well conceived structure and wide publicity would help ensure a fair process for hiring.

In association with labor recruitment, one of the main functions of a structured and open hiring process would be to apprise potential workers and the population at large of the nature and temporary duration of the positions available on the project. Potential hires would be encouraged to retain existing livelihoods to the extent possible to minimize the potential for a boom-bust syndrome as construction activities subside. This information then would be reinforced during a new hire orientation program to those who are eventually hired for the project.

8.2.3 Local Business Opportunities

Impact:	Inflationary effects on area residents from purchase of local goods and services for the project
Significance:	Significant but mitigable
Mitigation:	Distribute purchasing to more than one supplier
Monitoring:	Monitoring would be conducted on the effectiveness of purchasing and procurement processes and that information has been made available to local and national businesses regarding the business opportunities, contract and procurement policies/procedures, and ways to become involved with the project.

Impact:	Potential boom-bust syndrome for local suppliers as purchasing requirements for the project decline at the end of the construction
Significance:	Significant but mitigable
Mitigation:	Distribute purchasing to more than one supplier

Monitoring: Monitoring would be conducted on the effectiveness of purchasing and procurement processes and that information has been made available to local and national businesses regarding the business opportunities, contract and procurement policies/procedures, and ways to become involved with the project.

An assessment would be made of the local economy's ability to supply goods and services to the project. The Ministry of Commerce and Industrial Promotion would be consulted regarding companies that could supply goods and services to the project. The ability of individual suppliers to accommodate project purchasing would also be assessed. Using this information a process would be developed to distribute purchasing among a number of suppliers. Distribution of purchasing would discourage individual suppliers from engaging in discriminatory pricing which would serve to minimize inflationary effects on local residents. Distribution would also prevent any one supplier from becoming too dependent on purchases for the project. This approach would help minimize the potential for a boom-bust syndrome as purchases decline at the end of construction.

8.2.4 Infrastructure

Impact: Dust generated by project activities resulting in unsafe traffic conditions and nuisance to local populations

Significance: Less than significant with project design measure

Project Design: Implement dust control protocol at appropriate project facilities

Monitoring: Monitoring would be conducted regularly during construction activities verifying that appropriate dust control protocols were implemented.

A dust control protocol such as a regularly scheduled watering program or application of dust control agents along roadways and disturbed construction zones would be implemented.

8.2.5 Sociocultural

Impact: Disturbance to burial sites and sacred places and objects

Significance: Significant but mitigable

Mitigation: Consult with village and religious leaders and local residents to identify areas to be avoided and/or to negotiate compensation for disturbance

Monitoring: Monitoring would be performed during final design of the project and prior to construction verifying that field reviews and consultation with village leaders and local residents has been conducted. Monitoring would be conducted throughout the construction phase to ensure avoidance or that appropriate compensation is made.

During the project design phase village leaders would be consulted to identify burial sites and sacred places and objects. Proposed project facilities would be sited, to the extent feasible, to avoid these areas. For sacred areas or burial sites that cannot be avoided during final design, village leaders would be consulted to discuss appropriate measures to minimize disturbance. These measures could include assistance in relocation and/or compensation.

8.2.6 Pastoralists

Impact: Interference with transhumant migration patterns causing encroachment on neighboring landholdings or increased competition for food and water

Significance: Significant but mitigable

Mitigation: Inform transhumant group leaders, veterinarians, and herders of interruptions to migratory routes

Monitoring: Monitoring would be conducted during the construction phase to verify communication with transhumant group leaders and veterinarians regarding project construction locations and schedules.

To minimize interference with transhumant pastoralists' herds, public announcements of construction locations and anticipated interruptions to migratory routes would be made. Information would be disseminated by word of mouth through transhumant groups' leaders and veterinarians. Historically, herders frequently have received information causing temporary alteration in traditional migratory routes. With adequate advance notification, transhumant pastoralists are able to adjust to temporary interruptions. After operations commence, conflicts with transhumants should not be a problem because fencing around well heads and other facilities would be minimal and would not substantially affect livestock.

8.2.7 Migration of People to the Project Area

Impact: Migration of people to the project area increasing demand on existing social infrastructure and resources

Significance: Significant but mitigable

Mitigation: Public information campaigns to ensure that key information such as the number and timing of job opportunities, and that no hiring will take place at project work sites, are widely known; control worker recruitment so that no encouragement is given that employment is available on the project other than through authorized hiring processes

Monitoring: Monitoring of the public information campaign, and that signs are posted at recruitment offices and project sites would be conducted to ensure that potential workers understand the nature of the job opportunities.

The economic stimulus that would result from project development is anticipated to draw to the project area more people than would be able to find employment on the project or associated with the project. The influx of a large surplus of people would be expected to lead to increased pressures on the environment of the area. Consequently, the number of people migrating in search of economic opportunity will be minimized through a public information campaign and recruitment practices that make information widely available on the extent and limitations on employment opportunities associated with the project.

8.3 BIOLOGICAL RESOURCES

The following mitigation measures and project design measures are proposed to reduce potential significant adverse impacts on biological resources identified in Section 7.3. It is anticipated that these measures would be refined in the future to address site-specific conditions and actual construction practices in response to final engineering design. Further refinement over time is expected as various measures are implemented and experience gained in the field provides data on effectiveness.

Significant adverse impacts to biological resources have been identified for the following issues or project-related activities:

- Movement, mixing, and loss of topsoil
- Removal of vegetative cover and shade canopy affecting soils and erosion
- Effects on aquatic resources from erosion, sedimentation, and oil spills
- Disturbance of sensitive habitat, parks, and reserves by construction workers.

Recommended mitigation for avoiding or reducing these impacts is presented in the following sections, along with a summary of the impact.

8.3.1 Soils

Impact:	Movement, mixing, and compaction of soils by heavy equipment resulting in loss of topsoil and essential nutrients and other soil components
Significance:	Less than significant with project design measures
Project Design:	Incorporation of a soil erosion and sedimentation control program
Monitoring:	Field verification would be conducted regularly during pipeline, oil field, and infrastructure construction activities verifying that topsoils were conserved in conformance with the project's soil erosion and sedimentation control procedures.

Topsoil will be conserved by removal from impacted areas, stockpiling and replacement over cleared areas, or by other mechanisms that will provide at least the same level of resource protection, including:

- Surface texturing
- Mulching (including crimping, imprinting, and the use of mulch binders/tackifiers)
- Fertilizing
- Seeding
- Scarification
- Active revegetation through the use of seedlings

In the oil field area topsoils would be removed from areas required for the construction of project facilities and would be stockpiled. The stockpiles would be protected from surface drainage, would not cross watercourses, and would be stored separately from subsoils and spoils.

Topsoil stockpiling for longer than three to six months can lead to loss of soil and seed viability, and would therefore be avoided to the extent possible. Topsoils would be spread over cleared areas once any regrading is complete. Excess subsoils would be spread over cleared areas before topsoil is replaced.

Impact:	Removal of vegetative cover and shade canopy increasing soil surface temperature, decreasing moisture content, killing soil organisms, and increasing potential for erosion in the oil field development area and along the pipeline
Significance:	Significant but mitigable
Mitigation:	Provide buffer zones around sensitive areas
Monitoring:	Monitoring would be conducted prior to the beginning of construction activities verifying that buffer zones have been established and that personnel have been apprised of and understand the buffer zones. Mitigation monitoring would be performed during regular daily construction activities, verifying that encroachment of identified sensitive areas is avoided.

Provide buffer zones around sensitive areas (e.g., gallery forests) and watercourses to minimize damage, exploitation, and/or disturbance of these areas. Large trees would be left wherever possible to provide shade, shelter, seeds, and habitat and to maintain the resource value of the area after construction. An erosion and sedimentation control plan, as discussed in Sections 3.2 and 8.4, would be incorporated into the project to protect soils.

Impact:	Increase in soil surface temperatures resulting in drier soils directly above the pipeline where it exits Pump Station 1
Significance:	Less than significant with project design measures
Mitigation:	Extra depth of burial would be provided for the pipeline near Pump Station 1. See Section 3.2.7 for further information.
Monitoring:	None required during operations. During construction, ensure pipeline burial depth is correct.

8.3.2 Aquatic Resources

Impact:	Increased turbidity and reduced visibility impacting food gathering activities by aquatic resources
Significance:	Less than significant with project design measure
Project Design:	Incorporate erosion and sedimentation control plan
Monitoring:	Field verification would be conducted regularly during pipeline, oil field, and infrastructure construction activities and during the wet season verifying conformance with erosion and sedimentation control procedures.

An erosion and sedimentation control plan would be implemented, together with associated procedures for the control and reduction of suspended sediments in streams and rivers from construction activities.

Impact: Potential disturbance to aquatic resources from minor spills of diesel, gasoline, hydraulic, brake, transmission, and other equipment fluids or chemicals

Significance: Less than significant with project design measure

Mitigation: Incorporate project safety and environmental measures and spill response plans during construction and operations

Monitoring: Monitoring would be performed to verify that construction and operations phase spill response plans have been prepared and can be implemented as intended.

Impact: Damage to botanical, wildlife, and other aquatic resources and contamination of surface water bodies resulting from oil spills

Significance: Significant (whether mitigable or unavoidable would depend upon spill size, location, environmental conditions and other variables)

Mitigation: Incorporate project safety and environmental measures and an oil spill response plan, associated training, equipment, and supporting infrastructure into the project

Monitoring: Monitoring would be performed prior to initial construction and annually thereafter verifying that an oil spill response plan is in place and updated as necessary. Conformity to the plan's requirements for personnel resources, response equipment and associated training would also be monitored.

Spill response equipment would be maintained at the oil field development area and various locations along the pipeline land easement for deployment in the event of a spill incident. This, coupled with the preparation of a detailed and comprehensive oil spill response plan (see Section 3.2.12 and Appendix A) which would address notification procedures, training programs, personnel requirements, mobilization processes for additional equipment, containment strategies, and cleanup techniques (among other things), would help reduce impacts in the unlikely event that an oil spill incident occurs.

8.3.3 Induced Access Effects

Impact: Induced access to relatively undisturbed wooded savanna and riverine vegetation during construction and operations leading to reduction in natural resources due to hunting, fishing, collecting of plant materials, etc.

Significance: Significant but mitigable

Mitigation: Control unauthorized use of pipeline route during construction; provide work force with resource conservation/protection briefing and communicate that hunting or trade in bushmeat would result in instant dismissal; reinstate natural barriers after construction;

Monitoring: Monitoring in the form of regularly scheduled patrols or surveillance would be conducted ensuring that adequate public access control measures have been implemented and maintained along the land easement.

Construction area limits would be established to restrict construction activity to the smallest area feasible for safe and efficient construction, drilling, production, and transportation. Access to construction work sites will be restricted to existing, upgradable roads whenever possible, and any new access roads will be routed to avoid or minimize effects on sensitive environmental resources. Induced access effects on previously undisturbed areas will be restricted by controlling access to work sites and project access roads by persons other than project personnel. Vehicle barriers will be erected during construction to prevent unauthorized vehicular traffic from using project work areas or access routes.

Conditional to beginning work, all construction and operations workers would receive a resource protection briefing. The program would contain information on sensitive and protected biological resources, mitigation measures and environmental management prescriptions, and the importance of mitigation compliance. It is anticipated that this information, along with a safety briefing, would be presented as the workers are being inducted into the on-site work force. Poaching by workers would be specifically prohibited and would result in instant dismissal.

8.4 HYDROLOGY, HYDROGRAPHY, HYDROGEOLOGY, AND WATER QUALITY

Impacts of the proposed project to the hydrology and water quality of the study area were analyzed and described in Section 7.4. Measures proposed to mitigate significant impacts to hydrologic resources are described below.

8.4.1 Hydrology and Hydrography

Impact:	Increased peak flows and sediment loads of small unnamed tributaries or drainages in the immediate vicinity of cleared areas
Significance:	Significant but mitigable
Mitigation:	Design drainage systems to drain surface runoff to more than one tributary or in a manner that minimizes erosion
Monitoring:	Monitoring would be performed verifying that the planned stormwater drainage systems have been constructed. Monitoring would also be conducted during the wet season to verify that the systems operate as designed.

To mitigate the impact of increased peak flows and sediment loads of small tributaries, stormwater control plans would be implemented. Specific measures would include conveyance of storm flows through man-made erosion protected channels and construction of temporary retention, detention, or sedimentation basins.

8.4.2 Hydrogeology

Impact:	Disturbance to existing local supply wells caused by continuous withdrawal of project water supplies
Significance:	Significant but mitigable
Mitigation:	Stagger project water supply wells to reduce the effect on nearby wells; provide alternative supplies in case of disruption to existing wells
Monitoring:	Monitoring would be conducted on a regular basis during construction and regularly thereafter to verify that the placement of the project water supply wells has not affected the local community's existing water wells.

The short-term impacts of groundwater withdrawals on wells used by the local population would, as far as practicable, be mitigated by staggering project water supply wells so that their cones of influence do not interfere with those of existing wells. Wells would be drilled deeper and screened in a lower water-bearing layer; or alternative water supply would be provided to the users of impacted wells.

8.4.3 Water Quality

Impact: Reduced water quality caused from wastewater discharge to relatively small tributary streams

Significance: Significant but mitigable

Mitigation: Treat or dispose of sanitary wastewater in compliance with World Bank effluent guidelines (Appendix A)

Monitoring: Regularly scheduled sampling of project-generated effluents would be conducted during construction and operation to ensure that the discharged water meets adopted guidelines.

Wastewater discharges from project facilities would be treated and monitored before being discharged into surface waters. World Bank effluent guidelines for wastewater discharge for onshore oil and gas developments would be adopted for the project. These effluent quality guidelines would ensure that the impacts of these discharges are mitigated both within and outside the mixing zones in the receiving streams.

If package treatment plants are used, the domestic sewage effluents would be measured and sampled regularly and tested for common parameters such as BOD_5, suspended solids, pH, and oils and grease before being discharged to surface waters. In addition, biannual testing would be conducted for project-specific water quality parameters including selected bacteriological parameters, volatiles, and semi-volatiles.

Other wastewater disposal options would be considered depending upon site conditions, location of surface waters, and rate or volume of wastewater discharge. These could include evaporation ponds during the dry season or rapid infiltration which combines evaporation ponds and subsurface soil absorption (septic systems).

Impact: Decrease in water quality from surface runoff potentially contaminated with drilling muds

Significance: Less than significant with project design measure

Project Design: Incorporate soil erosion and sedimentation control plan and project waste management plan

Monitoring: Monitoring would be performed verifying that the planned storm water drainage system provides for the control of potentially contaminated runoff from the oil field development area. The project waste management plan (Section 8.8.2) will include facility-specific waste management practices for the handling and control of drilling muds. Field verification would be conducted regularly during drilling activities and during the wet season.

The project would implement an erosion and sedimentation control plan for the control and reduction of suspended sediments in streams and rivers from operation activities at the oil field development area. The erosion and sedimentation control procedures would reduce the potential of contaminated sediments reaching streams or rivers.

Impact: Decrease in quality of the groundwater in the potable near-surface aquifer due to casing leak

Significance: Significant but mitigable

Mitigation: Injection well integrity program

Monitoring: Monitoring would be conducted during operations to verify that the integrity of the injection wells is unimpaired.

The produced water would be reinjected to the same formation from which water was withdrawn and would be separated from the upper zones of the aquifer by the Miandoum Shale (see Figures 3-4 and 3-5). The design of the reinjection well would include placing cement in the casing annulus across the Miandoum Shale. Injection tubing with an isolation packer would be installed in the reinjection wells that will allow the casing and tubing integrity to be monitored such that problems can be detected and repaired, if necessary. When injection or producing wells are decommissioned, cement plugs, or similar will be placed in the wells to prevent fluid migration.

8.5 GEOLOGY, SOILS, AND SEISMICITY

Impacts of the proposed project to geology, soils, and seismicity were analyzed and described in Section 7.5. Measures implemented as part of project design, including preparation of a soil conservation, erosion and sedimentation control plan, a geotechnical engineering evaluation, and a blasting plan would reduce impacts to less-than-significant levels; therefore, additional mitigation measures are not needed or proposed. A summary of relevant project design measures is provided below.

8.5.1 Erosion and Sedimentation

Impact: Increased potential for wind and water erosion from ground disturbing activities

Significance: Less than significant with project design measure

Project Design: Incorporate soil erosion and sedimentation control plan

Monitoring: Monitoring would be conducted regularly during pipeline, oil field, and infrastructure construction activities verifying conformance with erosion and sedimentation control procedures

The project includes the construction of temporary drainage and erosion control measures. Topsoil will be conserved by removal from impacted areas, stockpiling and replacement over cleared areas, or by other mechanisms that will provide at least the same level of resource protection (see Section 8.3.1). Any excess soil generated from installation of the pipeline would be crowned to compensate for possible future settlement of backfill. A detailed erosion and sedimentation control plan describing all necessary measures would be completed prior to construction.

8.5.2 Stream and River Crossings

Impact: Increased potential for sedimentation in streams intersected during pipeline construction

Significance: Less than significant with project design measure

Project Design: Incorporate erosion and sedimentation control plan

Monitoring: Field verification would be conducted regularly during pipeline construction activities verifying conformance with soil erosion and sedimentation control procedures.

Impact: Potential for erosion, scour and changing bottom profiles to expose pipeline

Significance: Less than significant with project design measure

Project Design: Assess scour potential in support of pipeline design

Monitoring: Monitor to verify pipeline integrity at stream and river crossings.

At stream and river crossings the pipeline would be installed deep enough to minimize potential effects of scour or changing bottom profiles. The channel and bank contours would be restored to their original configurations to the extent feasible after pipeline installation has been completed. Breakers or riprap would be placed over the pipeline along stream banks for erosion control where necessary. An assessment to address scour potential would be completed in support of the pipeline design. Measures would be implemented into the pipeline design to minimize adverse impacts.

8.5.3 Geotechnical

Impact: Potential for differential settlement and blasting induced localized slope instability, causing structural damage to buildings or facilities
Significance: Less than significant with project design measure
Project Design: Incorporate recommendations of geotechnical engineering evaluation
Monitoring: Monitoring would be conducted during the construction phase to ensure that construction activities comply with the geotechnical engineering recommendations.

A geotechnical engineering evaluation would be conducted prior to the final design of the pipeline and facilities. Excavations would be monitored during construction by a qualified inspector to verify proper excavation and boring methods for the soils and/or rock encountered and to confirm proper placement and compaction of fill soils. To the extent possible, fill placement of moisture sensitive clayey or silty soils would be avoided during Chad's rainy season. Geotechnical engineering studies would further investigate potential sites for liquefaction, faulting, and mass wasting (e.g., landslides, rockslides). Areas found to be affected by such conditions would be designed to minimize potentially adverse impacts.

The project would not include blasting in areas found to be susceptible to slope instability. A blasting plan would be developed and implemented for the project and blasting of bedrock would be conducted by an experienced blasting contractor who would control overblasting.

8.6 METEOROLOGY AND AIR QUALITY

Impacts of the proposed project to air quality were analyzed and described in Section 7.6. Measures implemented as part of the project design, including stack design parameters and construction particulate controls, would reduce impacts to less-than-significant levels. A summary of relevant project design measures is provided below.

8.6.1 Construction-Related Dust

Impact: Generation of particulates from earthmoving activities
Significance: Less than significant with project design measure
Project Design: Implement dust control protocol at appropriate project facilities
Monitoring: Monitoring would be conducted regularly during construction activities verifying that appropriate dust control protocols were implemented.

Uncontrolled dust emissions from earthmoving activities would likely lead to high concentrations of particulates in the area immediately surrounding the construction site. Construction-related PM_{10} emissions would be substantially reduced by implementing project design measures such as watering active construction sites.

8.6.2 Stack Design Parameters

Impact: Compliance with World Bank NO_2 guideline values
Significance: Less than significant with project design measure
Project Design: Confirm modeled NO_2 ground level concentrations meet guidelines with final design input parameters, or amend final design accordingly
Monitoring: Perform stack testing at project start-up to verify predicted dispersion of NO_x and compliance with guidelines.

The primary pollutant of concern generated by project operation would be NO_x from the facility power plant sources. Accordingly, the two stacks for these sources would be designed at a height of 10 m or more above ground level to maximize pollutant dispersion. Resulting concentrations associated with operations of all facility sources would be below World Bank ambient guideline values.

8.7 PUBLIC HEALTH AND SAFETY

Section 7.7 presented the potential impacts to public health based on the linkages that exist among four subsectors, (housing and urban development, transportation, water supply and sanitation, and telecommunication) and six key environmental health variables. In addition, potential impacts of the project to the four subsectors were presented. Impacts exist in two broad categories: internal within the project facilities and directly amenable to technical and managerial control, and external to the project facilities and therefore not as amenable to direct project control, but addressed by government programs. Impacts exist during both construction and operations phases of the project; however, the operations phase would require substantially less ongoing effort since lower activity levels are anticipated. The process of monitoring and assessing general population effects at a community or village is quite complex for both sociological and biological reasons. If this external monitoring effort is undertaken it would be sponsored, designed, and controlled by the national government of Chad.

The community will not have access to the project occupational health facilities, and project occupational health personnel will not provide health care in community clinics.

Potential internal and external health impacts include:

- Increased incidence of respiratory diseases
- Increased incidence of vector-related diseases such as malaria, schistosomiasis, filariasis, and onchocerciasis
- Increased incidence of sexually transmitted diseases, including HIV
- Increases in incidence of water and food-borne illnesses
- Increases in accidents and injuries
- Increase in chemical exposures and environmental diseases.

8.7.1 Community Outreach Program

A cost-effective Community Outreach Program (COP) directed at addressing some of the external impacts will be developed and implemented. One target of the COP is health issues of communities potentially affected by project personnel and activities. It will therefore be confined to project operating areas near permanently staffed project facilities. Potential strategies of the COP are:

- Behavioral and information, education and communication (IEC) emphasis versus extensive technical and physical interventions

- Culturally acceptable interventions (Long-term sustainability would be the responsibility of the local health system and government.)

- Approaches that build on and utilize existing PVO and/or NGO programs whenever possible and are aligned with government programs
- Target specific diseases and public health conditions that have impact on the community, the project's personnel and expatriates, and/or the potential project work force
- Maximize use of the current health care infrastructure/system as the community health care provider
- Capitalize on the project's favorable impacts on the overall disease burden. Infrastructure projects have the ability to favorably impact approximately 40 percent of the overall existing disease burden.
- Seek to address health impacts through project contracting requirements with clear specifications relative to housing, water supply, sanitary services, environmental services, and vector control
- Prevent health incidents related to water shortage and contamination by facilitating the installation of water wells in the project area
- Limited direct funding to PVO/NGO programs which are focused on educational and other preventive/curative initiatives that address project issues, which may include medical prophylactics and other technologically appropriate supplies.

Approach

The COP must have the support of local people if it is to be firmly established and maintained. This is especially true for rural-based projects which involve the change of working or living habits. Grassroots, village-based initiatives can bring considerable success in community involvement projects. Village health committees can become successful in exerting peer pressure on villages in facilitating clean up campaigns and in promoting health education. These committees are typically composed of schoolteachers, health personnel, midwives, religious leaders, and other respected community leaders. A critical element in the success of these committees is the involvement of women. Internalization of community-based programs, which otherwise would seem alien and external, is a key to making a program effective. The participation of women, who are the critical actors and beneficiaries in improvement, is crucial to the success of community programs.

The COP will have the goal of accessing skills and expertise already available in the community. This is expected to take the form of involvement by women leaders in the community and existing PVOs and NGOs that have proven to be effective in attaining positive and efficient community health outcomes. Precisely how the COP will be organized will be determined as project development proceeds, however a typical structure could involve the establishment of an organizing body with the participation of selected NGOs and PVOs. Such a body could be tasked with a variety of functions, including:

- Determining matches between the project's environmental health objectives and local health needs
- Initiating intervention by forming village health committees
- Acting as interface between the local population and the COP
- Mobilizing village health committees to undertake local projects that meet the objectives of the COP.

8.7.2 Respiratory Diseases

Impact:	Increased incidence of respiratory diseases
Significance:	Significant but mitigable
Mitigation:	Implement measures in project housing, transportation, water and sanitation, and telecommunications; implement village-based education programs which address the recognition and prevention of respiratory diseases
Monitoring:	Monitoring would be conducted during construction and installation of construction camps and project housing to ensure that proper guidelines have been incorporated.

To mitigate internal impacts, sanitation guidelines would be provided in the contracts for companies who are responsible for the construction and operation of temporary housing, mobile construction camps, and permanent housing. These include living space guidelines such as minimal square footage per occupant, ceiling height, floor elevation, ventilation, exterior openings, lighting, and sanitation. These guidelines also address toilet facilities, potable water, sewage disposal facilities, laundry, hand washing, and bathing facilities. Stewardship measures would be included to determine whether guidelines are met, to provide adequate audit, and to evaluate the program. Sanitation and hygiene training would be incorporated into new employee orientation programs. Initial medical screening programs provided through the occupational health program would preclude workers with active respiratory diseases such as tuberculosis from working at the site. Transportation modes provided by the project to locally employed workers to and from the project would not be overcrowded, thus reducing the risk of respiratory disease transmission.

The COP would focus its strategies on those temporary and permanent housing conditions for workers residing in the community which can lead to an increased incidence of respiratory disease. Educational programs would include disease prevention measures for respiratory diseases (tuberculosis, colds, flu) which are associated with close living quarters and congested environments such as marketplaces and public transportation. Limited and directed funding would be provided to address treatment of respiratory diseases (if deemed appropriate), and people found to have respiratory diseases during the initial employee medical screening process will benefit from this program.

8.7.3 Vector-Related Diseases

Impact: Increased incidence of vector-related diseases such as malaria, schistosomiasis, filariasis, and onchocerciasis

Significance: Significant but mitigable

Mitigation: Implement measures in the areas of project housing, transportation, water and sanitation regarding the prevention of vector-borne diseases

Monitoring: Monitoring would be conducted prior to construction and occupancy of housing units to ensure that proper design measures aimed at minimizing water accumulation have been incorporated into the construction design.

Measures that address vector control and housing standards would be incorporated in the Request for Proposal (RFP) process for construction, operation, and maintenance of temporary and permanent housing. Health screenings and malaria surveillance programs would be implemented through the project occupational health program. Employee orientation sessions would be provided regarding the types of work activities which extend breeding areas for mosquitos due to temporary water accumulation. Measures that prevent water pooling along construction routes, near water sources, drains, sewers, housing areas, and waste management areas would be implemented. The existing project malaria control program will cover all workers.

Temporary and permanent housing conditions directly affect the incidence of mosquito-borne/vector diseases, such as drainage, surface collection of water, periodic flooding, uneven gradients and poor ditching of village areas, distance maintenance from swamps, pools, sink holes, or other surface collections of water and would therefore be an area of focus of the COP. Other areas of focus would include: water sanitation, pit latrines, laundry and bathing, refuse disposal, insect and rodent control.

8.7.4 Sexually Transmitted Diseases

Impact: Increase in the incidence of STDs/HIV

Significance: Significant but mitigable

Mitigation: The following would be implemented for the project work force and the Republic of Chad would implement the same strategies for the community surrounding the project area directed toward the prevention of STDs/HIV:

- Coordination with government national AIDS program, particularly programs directed toward female commercial sex workers and other vulnerable women
- Surveillance and treatment of STDs, particularly genital ulcers

- Information, education and communication (IEC)
- Aggressive distribution of condoms
- Surveillance activities to monitor HIV prevalence rates

Monitoring: Monitoring would be conducted during construction and operations to ensure that all new project workers attend IEC programs addressing the prevention of STDs. Monitoring would be conducted prior to construction and periodically thereafter.

During employee orientation, IEC sessions would be conducted for all workers addressing the prevention of STDs, including HIV. Condoms and signage regarding STD prevention would be available. The project occupational health program would provide medications for STDs found in workers which are curable, thereby reducing the number of active treatable STD cases in the population. Active STD prevention is associated with a significant (up to 40 percent) decrease in AIDS case rates. Project contractors, including trucking/transportation contractors, will be required to implement STD IEC programs aimed at reducing the transmission of STDs/HIV. Distribution and availability of condoms will be aggressively promoted.

The Government of Chad will be responsible for implementing its existing programs and policies with the continued support of the World Bank and other donors currently involved in Chad's STD/HIV initiatives. These efforts will be concentrated in the project area during project construction. The role of the government in the overall approach to the problem of STDs is critical since the movement and activity of high risk commercial sex workers is an issue that cannot be controlled by the project. Ongoing monitoring and surveillance of AIDS/HIV rates for the community will be the responsibility of the government using existing policies, procedures, protocols, and strategies as stated in the government's AIDS activities plan (listed in public health appendix). Any monitoring of the work force or other activities for STD/HIV will be consistent and compatible with the overall Chadian strategies for AIDS/HIV.

The outreach program includes support of educational programs targeting the prevention of STDs/HIV, including members of the debrouillardes community and other at-risk female population. It would include signage addressing STD prevention, activities such as social marketing of condoms, developing world IEC strategies (empowerment programs) to positively reinforce condom use behavior, and specific education programs directed toward commercial sex workers. Limited and directed funding to NGO programs that address STD prevention, through IEC, will be provided.

8.7.5 Water and Food-Related Illnesses

Impact: Increases in incidence of water and food-related illness

Significance: Significant but mitigable

Mitigation: Implement measures in project housing, transportation, water and sanitation directed toward water and food sanitation and hygiene

Monitoring: Monitoring would be conducted during construction and installation of construction camps and project housing to ensure that proper sanitation guidelines have been incorporated. Mitigation monitoring would also be conducted regularly during operations to verify that sanitation guidelines related to food and water supplies are being implemented.

Sanitation requirements would be provided in the contracts for companies who are responsible for the construction and operation of temporary housing, mobile construction camps, and permanent housing. These guidelines would address toilet facilities, potable water, sewage disposal facilities, laundry, hand washing, and bathing facilities. Stewardship measures that include timely audits and evaluations will be implemented. Sanitation and hygiene training would be incorporated into new employee orientation programs.

Specifications would be in place for food and water supply maintenance to prevent depletion of local food and water sources. Food sanitation standards would be provided for contractors who provide food service for temporary and permanent housing units. These standards would include: 1) food protection; 2) food storage; 3) food preparation; 4) food display; 5) food transportation; 6) food handlers' health, personal cleanliness, clothing, and practices; 7) equipment and utensil cleaning and sanitization and storage; 8) potable water supply, plumbing, and toilet facilities; 9) insect and rodent control; 10) construction and maintenance of physical food service facilities; 11) bacterial testing; and 12) work practice evaluations. Work practice evaluations are an essential component of an effective program since the prevention of enteric (diarrheal) diseases by their nature, involve behavioral change. Food handlers would participate in health screening programs on a regular basis through the project occupational health service. The implementation of an effective food sanitation program will create both short-term improvements and widespread sustained improvements over the long-term life of the project.

Local entrepreneurs would have the opportunity to contract as food supply sources for the project. They would be provided information on project requirements such as: 1) food protection; 2) food storage; 3) food preparation; 4) food transportation; 5) food handlers' health, personal cleanliness, clothing, and practices; 6) equipment and utensil cleaning and sanitization and storage; 7) water supply and pit latrines; and 8) insect and rodent control. After meeting measures for the protection of food, these local contractors would be equipped with the knowledge and skills to provide safe food products at local marketplaces, thereby positively impacting local food sources.

Waterborne disease prevention community programs would focus on educational programs aimed at water source protection and safety including water-related disease transmission methodology and prevention. Specific program targets would include: water supply, pit latrines, laundry and bathing, refuse disposal, insect and rodent control. Wells which are not needed for project operations could be donated to the local community, if feasible, which would improve the overall community water supply. Education programs would include simple water testing methodologies and effective water supply management. If internal project use disrupts local water supplies, alternative supplies would be provided to the affected community.

8.7.6 Accidents and Injuries

Impact: Increases in accidents and injuries, security incidents

Significance: Significant but mitigable

Mitigation: Implement measures in the areas of project housing, transportation, water and sanitation, and telecommunications targeting the prevention of accidents and injuries

Monitoring: Monitoring would occur prior to construction to verify that specific safety measures including provision of new worker orientation, medical emergency response plans, and accident investigation have been implemented. Mitigation monitoring would also be conducted during construction and operations to ensure that project workers adhere to safety guidelines established for the project and that adequate safety signage has been posted.

Specific measures will be in place to maintain a safe work environment and prevent accidents. Site specific medical emergency response plans will be in place for all work locations. Should an incident occur, specific investigation procedures would be in place to determine the cause and prevent future occurrences. During orientation, on-site safety training for all project personnel and driver safety training for all drivers will be provided. Project workers will be required to use appropriate safety equipment and follow site safety practices.

Road safety signage would be installed along all newly constructed and existing roadways utilized for the project. Pictorial construction safety signage around all construction sites would be provided. Access to construction areas will be limited. The project work force, including drivers would participate in a drug and alcohol program.

Cross-cultural training which relays information regarding the variety of cultures represented during the construction phase of the project would be provided during employee orientation. An understanding of cultural behavioral differences can reduce risks for workplace violence. Specific security measures would be in place to address violence at the work site and security problems. Project contractors would be responsible for developing and implementing an accident/injury prevention plan(s) to address worker safety.

The project would provide educational programs geared toward adults and children focusing on construction safety, particularly in areas of excavations, temporary storage of construction/excavation debris, and erosion mudslides. Child safety would also be presented.

Education efforts would be enhanced with construction safety signage utilized along all areas of construction. Non-essential personnel would not be permitted in construction areas. Input would be obtained regarding community perceptions of road construction routes and planned local uses. Signage addressing new routes would be provided in all villages.

8.7.7 Chemical Exposure - Environmental Diseases

Impact: Increase in chemical exposures and environmental diseases

Significance: Significant but mitigable

Mitigation: Implement measures in the areas of project housing, transportation, water and sanitation, and telecommunications targeting the prevention of chemical exposures and environmental diseases

Monitoring: Monitoring would be conducted prior to the construction period to verify that waste management plans and an occupational health program have been developed and implemented. Monitoring would also be conducted throughout construction and operations to ensure that project workers adhere to the subject plans and associated procedures established for the project and that adequate training has been provided.

Standard waste management practices and waste management plans would be incorporated into the project design. Appropriate waste inventory and segregation plans would be implemented along with an effective waste management plan and emergency response plan. An occupational health program which would include both medical and industrial hygiene components would be implemented . Contingency plans would be in place for the provision of supplemental water during waterborne disease epidemics. Medical waste would be appropriately separated and managed to prevent the spread of blood-borne pathogens.

Covered parking facilities, if added to the design (currently not included) for motor vehicles would be designed with adequate ventilation measures to prevent accumulation of exhaust gases. Vehicular maintenance procedures would be implemented for equipment utilized for construction. Project workers would receive training regarding the safe handling of hazardous materials and safety around aircraft. Project design measures would include aviation plans to control frequency and duration of air traffic.

8.8 SOLID, LIQUID, AND HAZARDOUS WASTES

Impacts associated with generation, treatment, and disposal of project wastes were described in Section 7.8. No significant impacts were identified as a result of construction and operation of the proposed project, therefore no mitigation is needed or proposed. This is due to the incorporation of waste management facilities in the project, implementation of practices identified below, and facility-specific plans that would be developed during final engineering design.

Solid, liquid, and hazardous wastes generated by the project would be effectively managed through the use of facility-specific waste management plans. Facility-specific waste management plans would be prepared prior to commencing each major construction and operation activity. These plans would contain waste characteristics and final engineering design of waste treatment and disposal facilities for specific locations. The adoption and implementation of these facility-specific plans in project design and operations would result in the effective prevention and control of waste-related impacts to the environment and public health.

In addition to the facility-specific waste management plans, the following waste management practices would be implemented into project design and operations:

- Dispose or manage wastes and secondary materials in authorized locations only. Unauthorized disposal or management would be prohibited.
- Reduce waste generation whenever practicable. This is known as "waste minimization" or "pollution prevention." For example, the following actions often minimize the amount or toxicity of wastes produced:
  - Purchase the quantity of materials that can realistically be used within a reasonable period of time so that inventory does not spoil and become waste.
  - Use a "first in, first out" inventory method to minimize spoiled inventory.
  - Purchase materials in bulk or in reusable/returnable containers to minimize packaging waste or empty waste containers.
- Take steps to avoid or minimize leaks and spills. Leaks and spills generate waste, which takes time and money to manage, and spills could create unsafe conditions or damage the environment.
- Use nonhazardous material alternatives. For example, substitute aqueous degreasers and cleaners for petroleum-based or chlorinated solvents.

- Reuse or recycle materials whenever practicable. This not only lowers consumption of raw materials, it eliminates the need for waste disposal.

- Treat wastes to reduce their volume or toxicity whenever practicable. Where wastes cannot be reduced or eliminated through source reduction or beneficially reused or recycled, their volume, toxicity, or physical hazards should be reduced to the extent required for safe and efficient management. In some cases, volume, toxicity, and hazards may also be reduced before recycling or reuse. Sometimes this can be done "in process" by the generator using an extra cleanup step.

- Avoid commingling wastes of different classifications. Subsequent segregation might be unsafe or impractical. An optimal management method for a particular waste might not be possible because of the presence of another waste. For example, a mixture of a restricted waste and an inert waste might increase the volume of material that must be managed as a restricted waste at higher cost.

- Maintain good housekeeping practices. Project workers should maintain neat, clean work areas to reduce the need for equipment washdowns and the chance of accidental spills.

- Properly store wastes, especially restricted, nonrestricted, and medical wastes, to avoid releases to soil, water, or air until they can be appropriately managed. Usually, this means they should be put into leak-tight containers, with tight fitting lids if necessary.

- Clearly identify waste containers. Use a label or other means to clearly identify the contents of containers of reactive, nonreactive, and inert wastes. This will communicate to others any potential hazards and help ensure that only appropriate wastes are deposited in them. Use only dedicated containers for hazardous waste and medical waste.

- Document quantities of restricted waste using a waste manifest. Waste tracking can be essential in helping to manage costs.

8.8.1 Waste Management Operations

Operations at project waste management facilities would be accomplished through a hierarchical application of practices of source reduction, reuse, recycling/recovery, treatment, and environmentally responsible disposal. Figure 8.8-1 displays how these waste management practices would be applied. A description of the waste management facilities, treatment, and other general features is provided below.

8.8.1.1 Landfill

The landfill located in the vicinity of the OC would be specifically designed and constructed to accommodate the types and volumes of wastes identified in Section 3.2.12. Wastes would not contain any free oil or liquids. Design of the landfill would include features to provide long-term containment for both nonhazardous and hazardous wastes, including an impermeable lining to contain landfill contents and an additional liner for hazardous waste cells. Liners could be constructed with clay, compacted laterite, synthetic clay-like materials, or plastic. Groundwater monitoring would also be included to monitor the effectiveness of the liner for the hazardous waste cell. Monitoring frequency and locations would be decided based on location of the landfill determined during final engineering design. A leachate collection and treatment system would also be included. Wastes would be managed according to the hierarchy presented in Figure 8.8-1. Fencing for security would be included to prevent unauthorized access. Netting may also be included if it is determined that the landfill is attractive to wildlife. Final engineering design would provide details on closure design, capping, revegetation, and protection.

8.8.1.2 Incinerator

The incinerator would be located close to the landfill to minimize handling and transportation of ash to the landfill. The incinerator would include process heaters and may be a dual chamber, fixed hearth, or rotary kiln type. Ash would be periodically monitored for composition and volume prior to landfilling. If leachable metals are indicated, solidification of ash would be conducted prior to landfilling. Potential air quality mitigation would be consistent with that described in Section 8.6.

8.8.1.3 Wastewater Treatment

Package wastewater treatment facilities or septic systems would be used for the treatment of domestic wastewater during construction and operations. Design requirements would include treatment of biological, physical, and chemical constituents, including oil and grease, pathogens, dissolved solids, metals, etc. Treated wastewater would be discharged to surface waters or natural drainages or to septic systems. Effluents would meet World Bank Guidelines for Onshore Oil and Gas Development (see Appendix A) for wastewater, domestic sewage, and contaminated storm water prior to discharge to surface waters or natural drainages. If septic systems would be utilized during operation, the systems would be designed and located based on knowledge of local hydrological conditions. Regular maintenance and periodic monitoring would be conducted to keep systems operating as planned. Refer to Section 8.4 for further details on wastewater treatment.

8.8.1.4 Produced Water

Disposal wells would be constructed to reinject produced water and other treated fluids back into the producing zone for disposal. Produced water, a byproduct of the reservoir, is one of the principal wastes arising from oil production operations. It contains residual oil and sediments from the reservoir and possibly some chemicals from well treatment operations. Produced water would be treated physically to remove the oil and solids prior to reinjection.

This physical treatment of produced water would be conducted separately from the domestic wastewater treatment facilities. Produced water would be monitored periodically.

With the described treatment of produced water, reinjection to the producing zone would not significantly degrade the quality of the water in the aquifer.

8.8.2 Facility-Specific Waste Management Plans

A Waste Management Plan addressing each major construction and operation activity would be prepared. This plan would contain detailed waste characteristics and final engineering and design of waste treatment and disposal facilities. The plan is intended to meet applicable World Bank guidelines (World Bank, 1995c) and international environmental standards for waste management practices. The implementation of this Waste Management Plan would result in environmentally responsible waste handling and disposal for the project.

Impact: Generation, treatment, and disposal of various types and volumes of solid, liquid, petroleum-based, and hazardous wastes

Significance: Less than significant with project design measure

Project Design: Incorporation of standard waste management practices in the project would include an overall project waste management plan and facility-specific waste management plans.

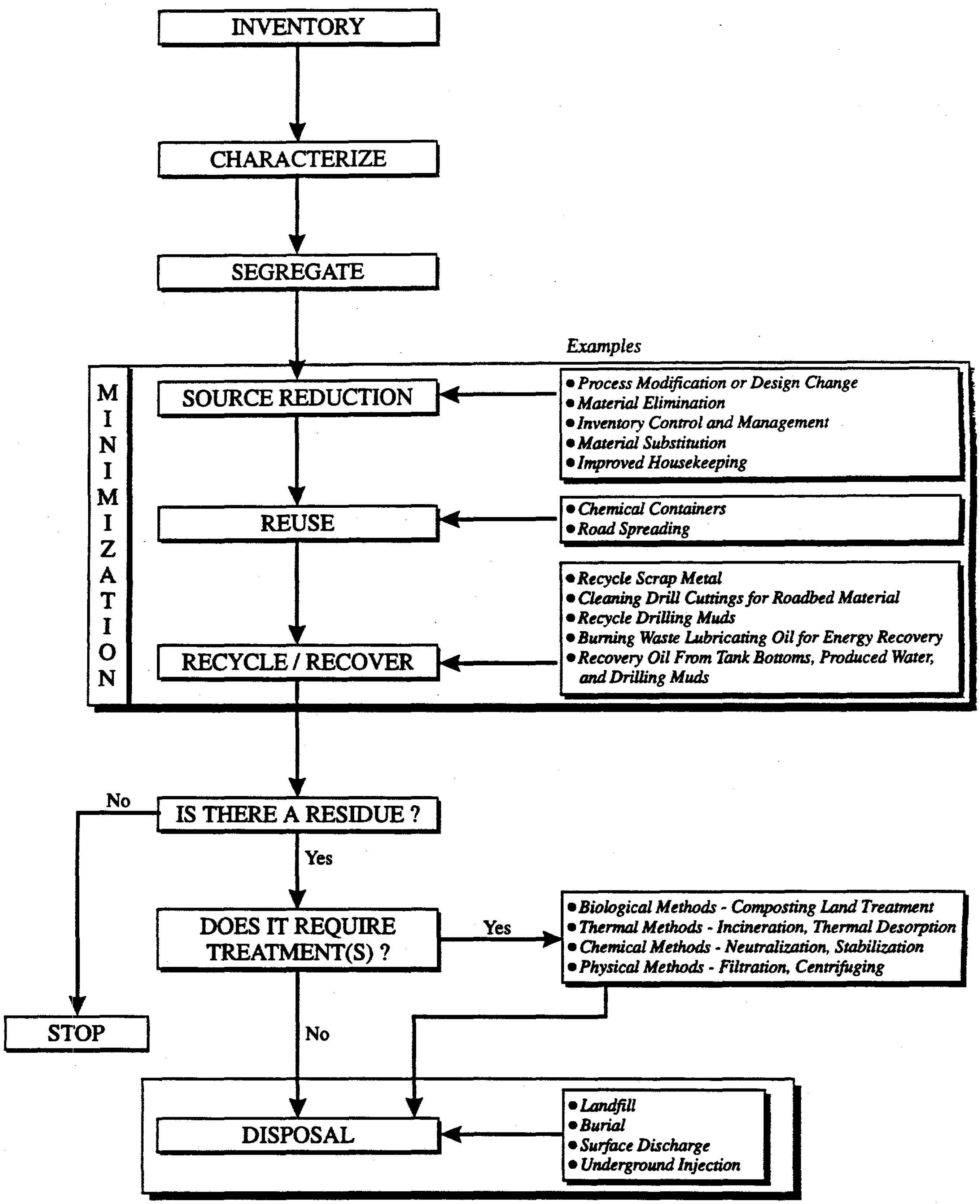
Monitoring: Monitoring would be conducted prior to construction to verify that waste management plans have been developed and implemented. Monitoring would also be conducted during construction and operations to ensure that project activities adhere to the subject plans and associated procedures established for waste management.

8.9 ENVIRONMENTAL MANAGEMENT PLAN (EMP)

It is the objective of the EMP to describe measures and actions that are planned to be undertaken during the design, construction, operation and decommissioning of the Chad portion of the project to eliminate or reduce key identified biophysical, socioeconomic, and health issues/impacts to acceptable levels. In order to accomplish this goal and function as an implementation plan for the project's environmental management actions, the EMP will:

- Denote the project's key biophysical, socioeconomic, and health topics and their associated issues/impacts
- Provide summaries of specific biophysical, socioeconomic, and health-related issues/impacts mitigation and monitoring actions planned for the Chad portion of the project
- Define and discuss the roles and responsibilities of the key project participants (i.e., the Consortium's designated Operator, Esso; TOTCO; and the Government of Chad)
- Outline project and government oversight organizations as they relate to environmental matters
- Summarize the costs associated with these environmental oversight organizations
- Provide a milestone schedule that features important environmentally-related milestone linkages to project execution
- Introduce environmental management tools that are envisioned for the project and key activities/studies that will assist in the crafting of these tools.

The EMP will contain those measures which Esso, as the Consortium Operator, and TOTCO and the Republic of Chad are committed to undertake.



ESSO Exploration and Production Chad Inc.

WASTE MANAGEMENT HIERARCHY

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

FIGURE 8.8-1

9.0 CONSULTATION WITH AFFECTED GROUPS, NONGOVERNMENTAL ORGANIZATIONS, AND GOVERNMENT AGENCIES

9.1 OVERVIEW

Consultation has been performed during the preliminary engineering phase of the project, and through EA development. Consultation will continue as the EA (and other key project documents including the EMP) are publicly reviewed, and will be an integral part of project development and operations throughout the life of the project.

Consultation with the local population has been underway since early 1995, and has been performed in local languages and in a format with which the local participants are familiar and comfortable, almost always at the village level. The following communities have been consulted in this manner:

- Mbikou, canton Mbikou
- Gomon, canton Mbikou
- Madena, canton Mbikou
- Mbikou Mbairabetole, canton Mbikou
- Bolobo, canton Komé
- Bela, canton Komé
- Kayaraal, canton Komé
- Beto, canton Komé
- Bebe, canton Komé
- Mayongo, canton Komé
- Naikam, canton Komé
- Bernou/Mouarom, canton Komé
- Kome Ndolebe, canton Komé
- Begada, canton Komé
- Madana Natphor, canton Komé
- Mainanai, canton Komé
- Bongbeti, canton Komé
- Mako, canton Komé
- Madjo, canton Bero
- Mbanga, canton Bero
- Bero I, canton Bero
- Bero II, canton Bero
- Miarom, canton Bero
- Dildo, canton Bero
- Missamadji/Moundanromkagiti, canton Bero
- Sananga, canton Bero
- Takouti, canton Bero
- Bendjeri, canton Bero
- Dangdin, canton Bebedjia
- Begadoua, canton Bebedjia
- Donara, canton Bebedjia
- Bebedjia, canton Bebedjia
- Bedaninga, canton Bebedjia
- Miandoum, canton Miandoum
- Manboy, canton Miandoum
- Mainkeri, canton Miandoum
- Bendoh, canton Miandoum
- Ngalaba, canton Miandoum
- Mekab, canton Miandoum
- Ouao, canton Timberi
- Benarbe, canton Gadjibian
- Ngara, canton Gadjibian
- Madog I, canton Bessao
- Bedoli, canton Bessao
- Betabar I, canton Bessao
- Lima/Diba, canton Mont de Lam
- Bingo, canton Mbaissaye
- Doba Urbain, canton Doba
- Boro, canton Doba
- Bedouada, canton Bodo
- Dungabo, canton Beboni
- Moundou Urbain, canton Moundou

Consultation has also been conducted with various nongovernmental organizations (NGOs), and NGO coordinating and oversight bodies, including the following organizations in Chad, many of which have been consulted on more than one occasion:

NGOs

- UNAD
- INADES Formation
- APICA
- World Vision International
- CARE
- AFRICARE
- ASSAILD
- ORT
- VITA
- OXFAM
- BELACD
- CEPRIC
- IRED
- Doctors Without Borders
- FONGT

NGO Coordinating and Oversight Bodies

- COLONG
- CILONG
- SPONG

NGO meetings held internationally have involved the following organizations:

- VITA
- WWF
- ORT
- CARE
- OXFAM
- AFDI
- IUCN
- AFRICARE
- IRED
- Carter Foundation

Consultations in Chad with other organizations have involved:

- USAID
- The Peace Corps
- UNDP
- The World Bank

The consultation process for the Chad Export Project is viewed as a long-term undertaking that will be in place for the life of the project. The consultations referred to above (on which more detail is presented in the remainder of Section 9.0) provide the foundation for future consultations with these and other organizations.

As a result of the consultation process to date, the following issues have been identified as being of most importance to the local population and interested organizations (these issues have been addressed in the EA and were considered during the preliminary design process):

- Land use, particularly compensation and resettlement (see Sections 7.2 and 8.2 for further details)
- Potential impacts on water resources, including the potential for pollution and the risk of oil spills (see Sections 7.4 and 8.4 for more details)
- Consultation with the potentially affected population (see the remainder of Section 9.0 for more details)

- Project timing (see Section 3.0 for more details)
- Employment and business opportunities for Chadians (see Sections 7.2 and 8.2 for more details).

9.2 INTRODUCTION

A program has been established for the proposed project to coordinate and consult with affected groups, nongovernmental organizations, and government agencies. This program has been developed to meet the project's objectives for consultation, and in compliance with the requirements of the World Bank *Environmental Assessment Source Book* (World Bank, 1991–1995 [1991a; 1993; 1994b]), World Bank Operational Directives 4.01 and 14.70 (World Bank, 1991b and 1989), and International Finance Corporation (IFC) *Environmental Analysis and Review of Projects* (IFC, 1993).

Consultation and interaction with affected groups, local interested parties, local and international NGOs, and government agencies is viewed as a critical component of project development and EA preparation. This consultation assists with identification of possible project impacts, reconciliation of opposing views about the project, promotion of understanding of the nature and extent of any social or environmental impacts, and the acceptability of proposed mitigation measures to affected groups. This program is recognized as a continuing process that will evolve throughout project development and progress beyond finalization of the EA.

9.3 PURPOSE OF CONSULTATION WITH AFFECTED GROUPS, NGOs, AND GOVERNMENT AGENCIES

Consultation with affected groups is essential to gain a proper understanding of the nature and extent of social and environmental impacts that may result from development of the project and to seek inputs from those communities in the development and implementation of appropriate mitigation measures.

Local and locally represented international NGOs are primarily focused on rural development and health-related issues in Chad. NGOs have experience in these areas and may, therefore, play a role in the execution of mitigation measures for resettled people (such as intensive agriculture projects) and also in maximizing benefits to local economies of providing goods and services to the project. Consultation with these organizations is important to assess their capabilities to determine whether these capabilities meet project needs.

Consultation and coordination with government agencies at national, regional, and local levels is necessary because of the broad range of responsibilities of such agencies in social and environmentally related matters such as water, land use, biological resource conservation, and health. In the case of the proposed project, such consultation also reflects the position of the Government of Chad as a participant in the project.

9.4 APPROACH

A consultation program has been implemented and refined since the early stages of the project cycle and will continue to evolve through project implementation.

To effect consultation, coordination, and interaction with affected groups, NGOs, and government agencies from the early stages of the project cycle through project design, a consultation methodology was established based on in-country fact-finding meetings. Fact-finding meetings became the basis around which consultation and data gathering from affected groups, NGOs resident and active within Chad, and government agencies were undertaken.

By adopting this fact-finding meeting approach, it has been possible, either directly or indirectly, to gather information and answer questions by allowing affected groups, NGO participants, or government agencies or entities to provide information or input of direct interest and concern to them. This open approach, based on conducting environmental and socioeconomic assessment at an early stage of project planning, encouraged participants to contribute freely because they were not being asked to comment on fixed ideas or defined plans.

The approach to consulting and coordinating with affected groups, NGOs, and government agencies has included:

- Conducting meetings in English or translated into French
- Developing a list of relevant government ministries and NGOs through discussions with the World Bank, literature/database research, review of bilateral donor agency documents, and EA project team knowledge before the initial in-country fact-finding meetings
- Prioritizing key issues for EA Terms of Reference (TOR) development and creation of a checklist of questions for in-country fact-finding meetings
- Conducting fact-finding meetings in N'Djamena and major towns near the pipeline route and project facilities to present a short but informative introduction to the project followed by a two-way question and answer approach to information exchange for TOR development

- Reviewing the draft EA TOR with the Chad government and presenting the EA work scope and issues for discussion
- Reviewing the draft EA TOR with World Bank Group
- Conducting consultation meetings during the EA development phase with individuals/small groups of affected communities, NGOs, and relevant ministries to discuss key issues related to the project
- Reviewing the draft EA with the Chad lead government ministry(ies) in advance of its formal submittal to the World Bank Group, along with a tour of the project area with members of the Interministerial Committee (IMC) responsible for EA liaison to discuss environmental and social issues. (The role of the IMC is discussed later in this section.)

Subsequent phases of the coordination and consultation process will continue to emphasize information sharing with government agencies, affected groups, and NGOs based on project data available at the time. This is intended to elicit reaction to project proposals of relevance to the groups and individuals with whom coordination and consultation is taking place, so that these proposals can be refined and developed in response to those reactions. Exchange of information and ideas throughout project development and beyond EA finalization is intended to maintain open lines of communication to facilitate the project construction and operations schedule and overall project objectives.

9.5 PUBLIC CONSULTATION AND DISCLOSURE PROCESS

A Consultation and Disclosure Plan was prepared in advance of the public availability of the EA and will be implemented immediately thereafter to inform the community, NGOs, and local public representatives about the project, identify and correct misconceptions, and answer questions. Local administrative and communication processes and infrastructure will be used where feasible. Presentation material will be presented in a culturally accepted manner. Below are key steps of the process:

- Issue the EA to the two Prefectures in the project area, local organizations such as NGOs and village associations
- Conduct meetings at selected locations and villages to discuss the EA; evaluation of meetings based on questions and responses will determine necessity for further meetings
- Place the EA in several public venues such as the Centre Culturel Francais, Centre d'Etudes et Formation pour le Developpement, and Centre National des Archives de Recherche and provide mechanisms to provide comments

- Place the EA in the World Bank Public Information Center.

9.6 SCOPE OF CONSULTATION WITH AFFECTED GROUPS, NGOs, AND GOVERNMENT AGENCIES

Objectives for the NGO consultation meetings were to identify and develop an understanding of key issues that should be addressed in the draft EA and communicate an understanding of the project and EA analysis process to meeting participants to support the public review process. Another objective for these meetings was to clarify misconceptions and expectations associated with the project and provide oil field and project-specific knowledge to NGO participants.

EA coordination and consultation with Chadian government agencies was initiated during in-country fact-finding meetings in November 1993. Objectives were to:

- Conduct fact-finding meetings in Chad as part of the development of the EA TOR
- Meet key government officials, NGOs, and other members of the interested or affected public to help identify the range of environmental and socioeconomic issues to be addressed in the TOR
- Gain a broad understanding of the environmental and socioeconomic context of the oil field development area and pipeline corridor in Chad
- Acquire contacts, information sources, and logistical information to facilitate future environmental and socioeconomic work on the project.

Key points generally introduced by project representatives to meeting attendees were:

- That project representatives were in Chad to conduct fact-finding meetings at an early stage of the project planning and development phase
- That fact-finding meetings were organized to facilitate early involvement in the project to identify environmental issues and aspects to be considered and resolved during engineering design
- Explanation of the TOR development and EA process with subject emphasis focused on the attendees' interests
- A brief description of the project including pictures/examples of other similar projects to facilitate understanding.

9.7 CONSULTATION MEETINGS

9.7.1 Affected Groups

A study of the human environment in those parts of Chad that may be affected by the project was begun in May 1995 and completed in mid-December, 1995 (Refer to Appendix B). Significant communication and consultation with affected communities and NGOs was carried out as part of the human environment field program (Refer to Section 6.2). The principal objectives of the study included collecting, collating, and analyzing basic data on the affected population by canvassing the population's views on the project. The in-country program consisted of:

- Meeting with representative samples of local residents in areas where project impacts may be significant and where existing data may be insufficient
- Meetings with active and appropriate NGOs (Refer to Section 9.7.2)
- Meetings with government and quasi-government agencies operating in areas of interest to the project (Refer to Section 9.7.3)
- Visits to relevant officials at various levels of national and local government.

The study was performed by a Ph.D. anthropologist, who has done extensive prior field work in Logone Oriental and speaks the local languages, and a Chadian assistant native to the area, who spent several months on anthropological research assessing the human environment of the project area and conducting a proactive grassroots socioeconomic survey. In all, 13 person-months of study were spent gathering data for this EA. A wide geographic area and the entire administrative region around the production facilities was surveyed. Table 9-1 provides a listing of the prefectures, cantons, and villages surveyed for the study.

To obtain reliable and representative data, a stratified sample was drawn to reflect:

- All ethnic groups found in the project area
- All subprefectural administrative areas in the project area
- All administrative cantons in which the facilities, fields, pipeline, and road would be located
- All cantons where impacts would be felt over the long term (rather than transient construction activities)

- All cantons which would feel immediate and long-term impact because villages or fields are likely to be located in the footprint of the project oil field facilities.

All strata were sampled; however, the lowest stratum, where most impacts may result, received the most attention. In this stratum a 5 percent sample of all geographically separate villages was drawn for a study of 5 percent of the total population of these villages. The people to be sampled were drawn from the tax lists of the villages, the most complete available listing of population, which includes all adult males and females, except the disabled, infirm, and mothers of more than five children.

The 5 percent sample were consulted, and questionnaires were administered to the group by literate villagers (Refer to Table 9-1). Topics included:

- Ethnic and geographic affiliations (in case resettlement is necessary)
- Family size, number of workers, relative importance of sources of livelihood, and resources at the families' disposal (in order to judge the number of people touched when various resources are reduced/removed from their environment)
- Sources of information available to the village and present knowledge and attitudes about the project (to evaluate present impact and future consultation and participation)
- Economic resources available to the subjects (to respond to opportunities created by the project).

Village meetings were convened in the 5 percent sample villages with traditional leaders, community and group representatives (male, female, and youth), and people who had lost land temporarily or permanently to previous oil exploration. A format similar to that shown in Table 9-2 was adopted for these meetings. Results of this program and issues identified by this survey are discussed in Sections 6.2 and 7.2. To address other target populations, informal discussions and questioning of merchants at local and town markets were undertaken to measure economic impacts and set a baseline. Because their presence changes the local situation as well as their own lives, the gendarmes charged with guarding oil facilities were also questioned. Local and non-local Chadian project workers' lives also have been changed by the project and their presence has an impact on the region; they joined in focus groups to discuss this impact.

The anthropologist who led the human environment field survey returned to Chad in November 1995 to undertake a second phase of the program. This included an attempt to fill data gaps and address issues identified during the initial field study and to advance the mitigation planning process. Consultation with residents in the project area and local NGOs, in the local languages, on issues related to housing, relocation, and compensation were addressed specifically.

9.7.2 Nongovernmental Organizations

Informal meetings were held with affected groups, communities, and NGOs during the November 1993 fact-finding mission in an effort to gather information and perspectives from the village level. Representatives met with the following organizations:

- USAID (U.S. Agency for International Development)
- UNAD (Union of Diocesan Associations for Development)
- INADES (Institute for Economic and Social Development)
- APICA (Association for Promotion of Africa's Community Initiatives)
- World Vision International – Moundou
- CARE-Chad
- AFRICARE
- ASSAILD (Support Association for Local Development Initiatives)

During these meetings, NGO representatives imparted valuable information to the EA preparation team and some of these organizations asked a variety of questions about the project. Items raised are presented in summary form below with related information as to how they have been addressed in preliminary design, pipeline routing, or in development of the EA.

U. S. Agency for International Development (USAID)

- *USAID is interested in how the project can help the local economies, particularly in identifying or developing new markets for local goods and services.*

  Goods, services, and some additional infrastructure would be required to support construction and operations personnel. A portion of these procurements can be purchased from local markets (Section 7.2).

- *Key concerns are 1) impacts on the local population, and 2) sustainability (would the positive impacts last?)*

  Potential short-term and long-term positive and negative impacts on the human environment are discussed in Section 7.2.

- *Seasonal fishing in Lake Chad and other lakes is very important. The project would need to address downstream water quality effects.*

  Aquatic impacts are addressed in Section 7.3, and hydrologic impacts associated with the project are discussed in Section 7.4.

Union of Diocesan Associations for Development (UNAD)

- *One major problem in the villages is the absence of a quantity of reliable, quality water. Reliance is on surface water because groundwater is often 80 m below ground surface and difficult for villagers to access.*

  Potential impacts on water resources are assessed in Section 7.4.

- *Displacement of agricultural people from the oil field area and the management of socioeconomic impacts on these people.*

  Land use and potential resettlement of affected households are discussed in Sections 7.2 and 8.2.

- *It would be necessary to study project impacts by talking to people directly to understand how they live and what is likely to affect them. The project may change their way of life.*

  A comprehensive, grassroots socioeconomic study of the human environment has been undertaken by a team of qualified experts (Sections 6.2, 9.0, and Appendix B).

Institute for Economic and Social Development (INADES)

- *Rural radio at special broadcast hours is a good way to disseminate information and could be used to spread public awareness of the project.*

- *Early communication and education is most effective, particularly for major works. Several days before commencing a phase of work in an area of villages there should be meetings to discuss the approaching work and to identify the issues.*

- *A number of trips should be made to increase familiarity and build local confidence in the project.*

  A program has been established for the proposed project to coordinate and consult with government agencies, affected groups and nongovernmental organizations. This consultation assists with identification of possible project impacts, reconciliation of opposing views about the project, promotion of understanding of the nature and extent of any social or environmental impacts, and the acceptability of proposed mitigation measures to affected groups. This program is recognized as a continuing process that will evolve throughout project development and progress beyond finalization of the EA (Section 9.0).

Association for Promotion of Africa's Community Initiatives (APICA)

- *Main concern was whether a sensitization program was planned and if so, who would do it*

Community relations with respect to construction and operations would be developed in greater detail as the project progresses. This is recognized as a continuing process that will evolve throughout project development and progress beyond finalization of the EA (Section 9.0).

World Vision International – Moundou

- *A concern was expressed regarding the project development bringing in its own health care infrastructure (hospital, clinic, etc.) which provides services to the community and would cause the people to stop participating in the development of local health care programs that can be sustained.*

  - The project cannot undertake to provide health care to the local population but would endeavor to ensure that the delivery of such services to its own project workers is performed in a manner consistent with other community-wide initiatives.

In early December 1995 project representatives visited N'Djamena and the project area to consult with a number of NGOs represented in Chad. Eight meetings were held with the following NGOs during the in-country trip:

- AFRICARE
- ORT (Organization for Rehabilitation through Training)
- Peace Corps
- VITA (Volunteers in Technical Assistance)
- OXFAM (Oxford Famine Relief)
- BELACD (Bureau for Studies and Liaison for Charitable and Development Activities)
- COLONG (in Moundou) (Concertation avec Les Organisations Non Gouvernmentales)
  - ASSAILD (Support Association for Local Development Initiatives)
  - VITA
  - BELACD
  - World Vision International
  - CEPRIC (Centre d'Etudes pour la Promotion et la Reutabilisation des Initiatives Communautaires)
- Doba NGOs
  - BELACD
  - World Vision International
  - AFDI (French Association of International Development).

Meetings with NGOs were conducted in both English and French, for the purposes listed below:

- To provide an overview of the project

- To describe the environmental assessment process and status (issues have been identified, mitigations are being developed) for the project

- To learn of any NGO issues or concerns relating to the project
- To learn of NGO capabilities that may be of interest to the project (recognizing that no commitment has been made to the involvement of NGOs in the project).

A broad description of the project was provided, and photographs illustrating example projects from other locations were shown. A summary of specific topics discussed at these meetings is set forth below.

AFRICARE

- *Timing of project*

  The earliest startup would occur in the year 2001; the project schedule is provided as Figure 3-13.

- *Number of personnel involved*

  Ranges of personnel requirements for the construction and operations phases are provided in Section 3.0.

- *Potential impacts of project on creating opportune situations for waterborne diseases*

  Waterborne disease impacts are addressed in Section 7.7.

Organization International de Récherche et de la Formation Technique (ORT)

No specific issues or concerns were raised with regard to the project.

Peace Corps

From local knowledge it was suggested by Peace Corps that two issues could be important:

- *Corrosive nature of regional groundwater*

  Project facilities would be designed and constructed to account for the known corrosive nature of regional groundwater (Section 7.4).

- *Uncertain nature of land tenure in rural Chad*

  The human environment sections of the EA address land tenure issues (Section 7.2).

Volunteers in Technical Assistance (VITA)

No specific issues with the project were raised; however, it was suggested that water could be an important issue in the project area.

Oxford Famine Relief (OXFAM)

- *What is the public involvement/public information process?*

  The process of consultation with government agencies, affected groups, and NGOs is discussed throughout this section.

- *Concerns regarding pollution potential*

  Pollution potential is addressed in Sections 3.2 and 7.8.

- *Concerns remain as to land tenure, compensation, etc.*

  Land tenure, resettlement, and compensation are discussed in Sections 7.2 and 8.2.

- *Will there be any purely social developments such as health care projects, water well development, etc., and if so, who will do them?*

  The government will receive royalties and taxes from the project and this income could be directed toward social development. This decision is entirely up to the government.

  The project will prioritize the benefits that it controls (jobs, local purchases, etc.) toward the impacted community.

  It was noted that the increase in disposable income that is expected to occur, particularly from those that are hired, should lead to improvements in health standards.

- *What are the implications of the known occurrence of rebel activity in the project area?*

  As has been the case during exploration activities, security will be the responsibility of the Government of Chad. The presence of the project and the economic benefits it will bring to the area are expected to enhance stability.

- *Transhumance is significant in the project area - have the herders been contacted (as well as the permanent residents of the project area)?*

  Transhumance issues were made a part of the Human Environment field study and are addressed in Sections 7.2 and 8.2.

- *It may be appropriate for continuing project liaison with NGOs to take place through an existing NGO coordinating committee that Oxfam participates in. (It would be helpful to establish an individual as a point of contact for all NGOs.)*

The most appropriate and effective means of liaison will be continuously reviewed as the project progresses.

- *How will impacts resulting from the introduction of the project work force to the area be managed?*

  The mitigation of these impacts is discussed in Section 8.2.

- *What is the project timetable?*

  Construction may commence as early as 1998; earliest start up would be in the year 2000. A schedule is provided as Figure 3-13.

- *What plans are being made for training Chadian personnel, and are there training scholarships?*

  Project personnel would receive training in safety measures and basic work practices. Plans would be tailored to each employee to meet project needs (Section 7.2).

Bureau for Studies and Liaison for Charitable and Development Activities (BELACD)

Issues raised at this meeting included:

- *Water pollution, especially since Lake Chad is a closed system*

  The potential for water pollution has been addressed in Section 7.4.

- *Project activities forcing pastoralists out of the project area and possibly into conflicts in new areas*

  Transhumant pastoralists in the project area are discussed in Section 7.2.

- *Land use, land ownership, indemnification, and compensation*

  Land tenure, resettlement, and compensation are discussed in Sections 7.2 and 8.2.

- *Acceleration of a current trend for people to move to the proposed project area and the resulting strains on the local community in areas such as sanitation, medical services, education, etc., and pressure on land*

  While the project cannot undertake to provide basic community infrastructure other than to its project workers, it will address direct impacts associated with the project (Section 7.0). Government revenues from the project provide one means of ensuring adequate infrastructure.

- *Mixing of different ethnic groups in the project area*

Mixing of different ethnic groups in the project area has been considered and addressed in Section 8.2.

- *Insecurity in the region*

As has been the case during exploration activities, security will be the responsibility of the Government of Chad. The presence of the project and the economic benefits it will bring to the area are expected to enhance stability.

Concertation avec Les Organisations Non Gouvermentales ([COLONG] - Coordination Committee for Liaison of NGOs)

- *Reinjection of produced water was seen to be an important issue.*

Reinjection of produced water is discussed in Sections 7.4 and 8.4.

- *Post-construction appearance and use of the land easement was questioned, and the prohibition of construction on the land easement was discussed, as was the desirability of revegetation for soil stabilization and erosion protection purposes. A suggestion was made that the land easement be used for a road since there are so few good roads in this area.*

The existing road would be upgraded for project activities and use of the land easement as a road would be discouraged (Section 3.2).

- *A question regarding the design life of the pipeline (or more specifically the time that will elapse before the pipeline fails) led to a discussion of design safeguards against leaks and spills (including corrosion protection, installation of block valves, etc.), and operational safeguards such as aerial surveillance of the land easement, leak detection systems, pipeline maintenance, etc.*

There is a slight potential for spills, although properly designed, constructed, operated, and maintained pipelines are acknowledged to be the most secure means of oil transportation (Section 3.2).

- The *question of land use and compensation was raised.*

The mechanisms for compensation are under consideration. Proposed compensation and mitigation measures are discussed in Section 8.2.

- *Seismic risk to the pipeline*

Data have been gathered on this subject, and it has been determined that no special safeguards are required, as the standard design methods would provide an adequate level of safety (Sections 6.5 and 7.5).

- *Potential for carrying out development projects or providing any health services to the local community*

  The increase in disposable income that is expected to occur, particularly from those that are hired, should lead to improvements in health standards (Health issues are discussed in Sections 7.2, 7.7, 8.2 and 8.7).

- *The question of training Chadians, especially the children of those directly affected by the project, was raised.*

  Prioritization of project benefits to those affected by the project and the project policy of nationalization of the work force are discussed in Section 7.2. Some expatriate workers would be required in the short term.

- *The question of long-term compensation was raised and circumstances in other countries where royalty payments benefit only a few powerful people, rather than the local population.*

  Government revenues are discussed in Section 7.2.4.

- *The likelihood that sacred sites will be encountered was raised, and the need for consultation was discussed.*

  Based on socioeconomic studies conducted in the study area, villagers usually are willing to relocate movable sacred objects as long as they are consulted in advance and compensated for any expense. Where feasible, sacred sites would be avoided, and where not, appropriate compensating measures would be negotiated (Sections 7.2 and 8.2).

- *The question of whether the project would be a source of electric power for the region was raised.*

  Power would be generated only for the project itself (Section 3.2.6.2).

Doba NGOs

- *Oil spills*

  There is a slight potential for spills, although properly designed, constructed, operated, and maintained pipelines are acknowledged to be the most secure means of oil transportation (Section 3.2).

- *Impacts on the human environment, particularly as they relate to land use and employment, and making sure that any improvements would be sustainable*

  Human environment impacts and associated mitigations are discussed in Sections 7.2 and 8.2.

- *The possibility of involving NGOs in the implementation of mitigations*

  NGOs would be considered for the implementation of some of the mitigation measures, when the NGO's expertise meets the project's needs and they are considered to be an effective organization (Section 8.0).

- *Any dangers from the oil extraction process, such as ground subsidence?*

  Subsidence would not be a significant issue (Section 7.4).

- *Timetable for construction*

  Construction would commence in early 1998 at the earliest; schedule provided as Figure 3-13.

- *The prospective draw of local people to oil-related employment, to the detriment of their subsequent ability to resume subsistence agriculture when employment is no longer available*

  Only a small proportion of the available local work force would be employed. A discussion on this topic is included in Section 8.2.

From mid-May to early July 1997 contact was initiated again when project representatives met the following NGOs at their international headquarters offices:

- AFRICARE
- VITA
- IRED (Development Innovations and Networks)
- WWF (World Wide Fund for Nature)
- OXFAM
- ORT
- CARE
- Doctors Without Borders.

Topics raised during these meetings are summarized below.

AFRICARE

No specific issues with the project were raised. AFRICARE is generally supportive of the project and its potential positive effects to the socioeconomic environment of the project area.

VITA

VITA is generally supportive of the project and sees the project positively influencing the development of local business opportunites. No specific issues with the project were raised.

IRED

IRED has a favorable impression of the recruitment and hiring plan proposed for the project. Comments received during the meeting reflected agreement with the project's compensation and resettlement plans. The proposed design measures were also found to be important and positive aspects of the project.

WWF

WWF raised a number of questions regarding the project and potential effects. Issues and questions relevant to the EA are provided below along with associated responses.

- *Profile of crude oil production*

  Figure 3-6 provides the estimated gross oil production by year.

- *Employment and training plan and use of nationals*

  Sections 8.2 and 3.2.12 provide details regarding recruitment and hiring plans and training plans, respectively.

- *Ground subsidence as a result of oil production*

  Potential geologic effects have been discussed in Sections 7.5 and 8.5 of the EA.

- *Beneficial impacts and indirect economic impacts*

  Potential socioeconomic impacts associated with the project are discussed in Sections 7.2 and 8.2 and also in the Environmental Economic Impact technical report prepared for the project.

- *Safety of facilities and security measures*

Safety and environmental protection measures are discussed in detail in Section 3.2.12 of the EA.

- *Width of land easement*

  Sections 3.2.7 and 3.2.10 describe in detail the characteristics and construction methods of the pipeline transportation system in Chad.

OXFAM

OXFAM raised a number of questions regarding the project and potential effects. Issues and questions relevant to the EA along with associated responses are provided below:

- *How will security issues and rebel activity in Chad be dealt with?*

  As has been the case during exploration activities, security will be the responsibility of the Government of Chad. The presence of the project and the economic benefits it will bring to the area are expected to enhance stability.

- *How will compensation issues for damages and dislocation be managed?*

  Section 8.2 provides the types of compensation measures for those people displaced by project activities.

- *Will the project provide sustainable benefits?*

  Human environment impacts and associated mitigations are discussed in Sections 7.2 and 8.2. Additionally, socioeconomic effects are discussed in detail in the Environmental Economic Impact technical report prepared for the project.

- *Does the project have a plan for gender equity?*

  The recruitment plan discussed in Section 8.2 would have provisions for employment opportunities for both men and women. Moreover, the consultation process has invited and encouraged both men and women to voice their concerns and questions regarding project opportunities.

The consultations outlined above are part of a continuing process that would extend throughout project development and operations. The precise form, nature, and timing of these further consultations should not be predetermined, but short-term plans include further familiarization with the project area for the Chad government IMC, governmental review of the EA, World Bank review of the EA, and public review of the EA in Chad.

9.7.3 Government Agencies

An initial meeting with various ministries in November 1993 was organized through the Chad government's Ministry of Mines, Energy, and Water Resources, Petroleum Division to conduct preliminary discussions about the project. Ministry representatives raised several issues and areas of concern in relation to the project, and these points have been considered in preliminary project design and addressed in the EA. An outline of these items and a brief summary of the approach to dealing with each is set forth below.

Ministry of Agriculture and Environment

- *Timbéri Forest Reserve, operated by village cooperatives and classified as a "collective forest," should be avoided or, if not possible, a tree nursery established for revegetation of damaged areas.*

  The Laramanay Reserve, north of Pandzangé and the pipeline corridor, contains habitat for elephants migrating between Cameroon and Chad. Reserve boundaries would be subject to a mission from the Ministry in December 1993.

  The pipeline transportation system has been routed to avoid impacts to the Timbéri Forest Reserve, the proposed Laramanay Reserve, and relatively undisturbed wooded savanna in the vicinity of the pipeline. Pipeline construction activities would occur 22 km from the Timbéri and 7 km from the Laramanay, far enough away to prevent disturbance to their biological resources (Section 7.3).

- *An important bamboo forest exists northeast of Bessao; although it is not currently an official reserve, it is also an elephant habitat and should be avoided.*

  The pipeline has been routed to avoid impacts to large stands of native bamboo (*Oxyantherva abyssinica*) around Bessao, though some small, isolated stands may be affected by pipeline or access road construction (Section 7.3).

- *Effects of wastes and waste oils on agriculture in the project area*

Adoption and implementation of site-specific waste management plans in project design and implementation would result in the effective prevention and control of waste impacts to the environment or public health (Section 7.8).

- *Origin of water for drilling and where produced water would be disposed*

  Project water supplies would be sourced from groundwater, and adverse impacts would be avoided or mitigated (Sections 7.4 and 8.4). Produced water would be treated and reinjected to the oil reservoir.

- *Impacts on secondary roads and trails should be considered when developing oil field infrastructure so as not to reduce access to markets for market gardeners.*

  Road upgrades associated with the project would ease transportation problems for local residents, help reduce transportation costs associated with imports and exports, and open up inaccessible foreign markets for cash crops (Section 7.2).

- *Risks to groundwater aquifers from oil exploration, exploitation, drilling, and storage of oil were questioned.*

  Measures implemented as part of project design including implementation of erosion and sedimentation control measures, waste management guidance, and an oil spill response plan would reduce most impacts to less-than-significant levels (Section 8.4).

- *No regulations concerning waste disposal currently exist in Chad, as the problem has not been posed previously.*

  Waste management facilities that would be designed and constructed as part of the project and the respective wastes that would be disposed of or treated during construction and operation of the project are presented on Table 3-6. These facilities for the project would be designed to meet applicable World Bank guidelines and international standards for waste management practices (Section 3.2.12).

- *There are trees and fish of fundamental importance for Chad within the project area, and locations of rare species should be identified.*

  Biological studies for the EA emphasized the mapping of habitats and vegetation types, description of plant community composition, vegetation associations and successional pathways, and the identification of sensitive species (Section 6.3).

Ministry of Water Resources and Meteorology

- *Inquiry about plans for setting up baseline monitoring programs to assess future impacts*

Baseline studies were commissioned only when necessary to support the EA. However, an Environmental Management Plan has been developed to manage and monitor project impacts (Sections 8.1 and 8.9).

Ministry of Mines, Energy, and Water Resources

- *Compensation for damages to peasants in and around construction area(s) where fields are crossed or trees cut*

  A detailed compensation plan would be developed including a resettlement plan to satisfy World Bank Operational Directive 4.30 requirements when final plans for project facilities are determined (Section 8.2).

- *Vegetation in forest reserves will have to be dealt with, as will consideration of utilization of forest resources and fauna by local people.*

  The pipeline transportation system has been routed to avoid impacts to the Timbéri Forest Reserve, the proposed Laramanay Reserve, and relatively undisturbed wooded savanna in the vicinity of the pipeline. Pipeline construction activities would occur 22 km from the Timbéri and 7 km from the Laramanay, far enough away to prevent disturbance to their biological resources. Impacts to elephant migration patterns from the Laramanay Reserve south across the pipeline corridor during construction would be considered less than significant (Section 7.3).

- *Potential alienation of mining reserves and prospective mineral deposits by pipeline development*

  The pipeline has been routed to avoid known mining reserves or mineral resources.

- *Soil transport is a major water quality issue and increasing levels of soil erosion, sedimentation, and the creation of blockages should be avoided.*

  Temporary erosion control procedures (e.g., sediment barriers, riprap) would be directed toward preventing soil erosion at the source and preventing silt and sediment from entering waterways and migrating downstream if soil erosion cannot be prevented. Permanent erosion control measures (e.g., trench plugs, diversion dikes, erosion control blanket) would be implemented to prevent sedimentation of the drainage system and to prevent erosion of the project area. A soil erosion control and sedimentation plan would be prepared during the final detailed design and engineering phase of the project (Section 3.2.12).

- *Prevention of oil pollution of the Logone, Lim, Mbéré, and Nya rivers is crucial to avoid polluting N'Djamena's water supply. Suitable monitoring points should be identified in water resources around oil field development areas to assess impacts.*

Prevention is the best response to an incident, followed by contingency planning. Hazardous operations and risk assessments were performed during the preliminary design phase to provide initial recommendations for prevention and contingency planning. During operations, risk assessments would be performed. Oil discharge and contingency planning for the project would provide the background information and response planning guidelines necessary to implement an effective oil spill response.

- *Query on use of surface or subsurface water by the project*

  Essentially all project water requirements would be met by groundwater resources, and impacts on other groundwater users would be avoided or mitigated (Sections 7.4 and 8.4).

- *Baseline data for transcontinental air pollution (dust and "chemical pollution") should be collected.*

  In the study area few air pollution sources exist other than agricultural activities, and baseline ambient air quality data were not required for impact assessment or project design purposes (Sections 6.6 and 7.6).

Ministry of Commerce, Industry, and Tourism

- *Measures to be taken to mitigate major socioeconomic changes causing upheaval in the area*

  Measures that have been developed to mitigate potentially significant adverse impacts identified in Section 7.2 are discussed in Section 8.2.

- *Discussed direct and indirect benefit(s) to people in the project area; there is uncertainty as to the number of people to be employed and at what level during operation and construction phases*

  The potential impacts on the existing human, biological, and physical environment resulting from the construction, operation, and decommissioning of the project are identified and described throughout Section 7.0. A specific discussion on employment during construction and operations phases also is included therein (Section 7.2).

- *The Logone Oriental prefecture, in which the project is situated, is underdeveloped, particularly in the areas of health, education, and transport; the project could effect changes with impacts on education, health, roads, transport, and food supply.*

  Each of these potential effects is dealt with in Section 8.2 of this EA.

Chef de Canton Bessao

- *There are seasonally high flows in the Logone, Lim, and Mbéré rivers which should be regarded in construction and operation of the pipeline.*

  Pipeline construction and operation design and implementation plans have taken seasonally high river flows into consideration, and pipeline installation at river crossings would not take place during periods of high river flow to the extent feasible (Sections 3.2, 7.4, and 7.5).

- *Many small swamps and "marigots" (low lying lands) may need to be crossed during pipeline construction.*

  The number of crossings of streams, rivers, and low-lying areas has been minimized, and appropriate techniques to minimize crossing impacts are addressed in the pipeline design (Section 3.2).

- *Population should be made properly aware of the project to avoid problems.*

  A program has been established for the project to coordinate and consult with government agencies, affected groups, and nongovernmental organizations. This consultation assists with identification of possible project impacts, reconciliation of opposing views about the project, promotion of understanding of the nature and extent of any social or environmental impacts, and the acceptability of proposed mitigation measures to affected groups. This program is recognized as a continuing process that will evolve throughout project development and progress beyond finalization of the EA (Section 9.0).

Prefecture of Logone Oriental — Doba

- *The proposed project is very important to the Doba subprefecture. The prefecture would like to make sure that benefits of the project also flow to the local population in Logone Oriental, who would have to face most of the impacts.*

  Plans are being developed to focus the benefits under the control of the project, such as employment and purchasing of goods and services, to groups and communities that would be adversely impacted by the project (Section 1.0).

- *Need to address toxics impacts on villages close to installations, and compensation may be necessary for any toxics problems caused by project development. Impacts to water, agriculture, trees, and fields near each site or installation may need to be identified.*

  The project has adopted World Bank guidelines for effluents and emissions. Impacts to the human, biological, and physical environments have been identified and, where appropriate, mitigations developed (Sections 3.0, 7.0 and 8.0).

- *Need to look at effects on people, more than just economic benefits of petroleum*

  The Human Environment sections of this document address the people potentially affected by the project (Sections 6.2, 7.2, 8.2).

- *Local operations management should be established in Doba, rather than Moundou, in order to maintain a close interaction with the prefecture and so that benefits are induced in Doba.*

  The Operations Center for the project has been sited based on operational and business needs (Figure 3-1).

- *Development of road infrastructure would be important during the construction phase, including streets in towns.*

  Upgrades to the road system in Chad are required for moving materials from the Cameroon border for the construction and operation of the pipeline, field facilities, and to support the drilling program (Figure 3-8).

Ministry of Agriculture and Environment (local representative who participated in Prefecture meeting)

- *Dense forest reserves in Logone Oriental should be protected from pipeline construction. Elephants and giraffes in Laramanay Reserve also should be protected.*

  The pipeline transportation system has been routed to avoid impacts to the Timbéri Forest Reserve, the proposed Laramanay Reserve, and relatively undisturbed wooded savanna in the vicinity of the pipeline. Pipeline construction activities would occur 22 km from the Timbéri Reserve and 7 km from Laramanay, far enough away to prevent disturbance to their biological resources. Elephant migration patterns from the Laramanay Reserve to Cameroon will not be impacted (Section 7.3).

- *Interested in village-level tree nursery projects to compensate for damages caused by the petroleum industry*

  Reclamation and natural revegetation of areas disturbed during construction are planned; therefore overall loss of trees would not be significant (Sections 7.3 and 8.3).

Ministry of Livestock

- *There are approximately 300,000 draft animals in the south and approximately 5 million head of cattle in herds in the north. About 80 percent of these migrate seasonally, and a minimum of 1 to 2 million head move through the south annually. Each family of herders manages a herd of 70 to 80 animals and often 20 families would move together resulting in a single, transhumant herd size of about 1,600* *cattle. The herds leave the north in October and arrive in the south between November and December. They usually follow natural or artificial "depressions" along the stream course floodplains, and cattle would naturally congregate in these areas as the dry season progresses and other sources of water disappear. There is a need to improve the use of such areas outside of rivers and streams.*

The potential effects to transhumant pastoralists are addressed in Sections 7.2 and 8.2. To minimize the disruption to transhumant pastoralists' herds, public announcements of construction locations and anticipated closures would be made.

Additional Chadian government or affiliated agencies contacted during this in-country trip included:

- ONDR (National Office of Rural Development)
- CNAR (National Center for Research Archives)
- CFPA (Center for Training and Promotion in Agriculture)

Building upon the 1993 fact-finding meetings, the following Chad government agencies were identified for participation in decision making and regular consultation during EA scoping, preparation, and review:

- Intergovernmental Environment Committee (IEC) (formation discussed in November 1993) (also referred to as the Chad Interministerial Committee [IMC])

- Petroleum Division, Ministry of Mines, Energy and Water Resources (MMEWR), as lead organization

- Ministry of Agriculture and Environment (MAE)

- Prefect of Doba.

The IMC was nominated by ministry representatives and the Chad government as the coordinating agency between the project and all national and local government agencies regarding EA preparation. The IMC also is recognized as the agency responsible for review, coordination, and approval of the TOR and the EA for subsequent submission to the World Bank.

Following the negotiation of a Framework Agreement for the proposed project with the Governments of Chad and Cameroon, formal contact was made again with government agencies in Chad, when project representatives presented the draft EA TOR to Chad government IMC representatives in N'Djamena in February 1995. Feedback was solicited on the draft TOR. The formal presentation was made in English and translated into French supported by French language view graphs. Questions and answers during the presentation also were translated.

A variety of questions were raised by the IMC during the presentation, in addition to written comments resulting from the trip. Questions and associated responses and/or approaches to resolution are outlined below:

Interministerial Committee (IMC)

- *Ultimate fate of produced water*

  Produced water would be treated and reinjected to the oil reservoir(Section 7.4).

- *Location of Central Treating Facility*

  The Central Treating Facility is situated in the Operations Center (OC) within the Komé-Miandoum-Bolobo Field Development Area (Figure 3-1).

- *Potential for oil pollution in streams*

  The potential for oil pollution has been addressed, and more detail is provided in Section 3.2.

- *Disposition of generated wastes*

  Generated wastes would be disposed of in accordance with the guidelines prescribed in area-specific waste management plans (Sections 7.8 and 8.8).

- *Proposed project power supply generation location(s)*

  These would be contained at the OC within the Komé-Miandoum-Bolobo Field Development Area.

- *Environmental effects from heating oil*

  A numerical modeling study has been conducted to evaluate soil temperatures and related environmental impacts resulting from installation of a heated oil pipeline. The modeling of different conservative ground conditions (soil, organic matter, surface heat flux) was used to determine pipeline design to minimize impacts (Section 7.6).

- *Possibility of building road(s) to cross over buried pipeline*

  Properly designed and constructed roads may cross over the buried pipelines.

- *Existence of road(s) along entire pipeline land easement during operations*

The use of land easements for nonmaintenance vehicular and pedestrian traffic would be discouraged.

- *How would floating storage operation (FSO) be sited?*

  This issue is addressed in the EA-Cameroon portion, produced as a separate document.

- *Necessity of relocating Bébédija and Doba*

  There would be no requirement for the relocation of any villages or towns due to direct project impacts.

- *World Bank requirements for the EA*

  World Bank EA requirements are outlined in Sections 1.0 and 5.0 and addressed overall throughout this document. (World Bank requirement documents were sent separately to the IMC following the meeting.)

- *Will river crossings be above or below the surface?*

  All river and stream crossings are planned to be below the bed of the river or stream (Section 3.2 and 7.4).

- *Rationale for location of field facilities*

  The siting of the field facilities reflects a central location in the field development area, adequate distance from existing settlements, a suitable elevation with regard to potential flooding, utilization of existing infrastructure (e.g., roads), etc. The selection of well pad location would be a function of the subsurface reservoir location (Section 4.0).

- *Types of water analyses performed to date*

  A wide range of water analyses have been performed on representative samples of groundwater from the study area (Section 6.4).

- *Chadian involvement in biological survey(s) associated with route selection*

  The Chadian government ministries listed in Section 7.0 of the EA were consulted during routing surveys, and government agencies were consulted in a review of biological resources in the study area.

- *Process for identifying and quantifying indirect impacts*

  International consultants with expertise in relevant technical discipline(s) and oil field development projects were utilized to develop the impacts portion of this EA. Direct and indirect impacts and associated significance are discussed in Section 7.1.

- *Provisions to be made for leak detection and pipeline monitoring*

  The project includes a comprehensive system to provide for the transmission of information needed for the safe operation of the well fields, processing facilities, and export system, including leak detection and pipeline monitoring. The pipeline would be designed with high- and low-pressure sensor equipment and shutdown systems to shut in the pipeline and/or field facilities during upset conditions (Section 3.2.12).

- *Quantity of field facilities' power plant fuel supply that would be considered gas*

  While gas resources will be utilized for power plant fuel supply to the maximum extent feasible, gas will provide only a small proportion of the overall fuel needs.

Further consultations with the Ministry of Mines, Energy and Water Resources, Petroleum Division took place in May 1995. The project EA team introduced its plans to commence EA field work in Chad with two programs:

- Human environment data gathering and field work
- Project permitting plan/EA legislative review.

Information regarding the field work and data gathering conducted for the human environment is discussed in Section 9.7.1.

In early December 1995 contact was initiated again when project representatives visited N'Djamena and the project area to present to the Chad government's IMC the status and preliminary findings of the EA, discuss the Government of Chad's participation in the EA review process, and to conduct consultation with a number of NGOs represented in Chad.

The presentation to the IMC included a discussion of EA issues as they relate to potential impacts identified and associated significance levels. Highlights from the IMC meeting are summarized below.

- *The relatively low significance of the "loss of habitat" impact was queried on the basis that the alteration of land use will have widespread effects.*

  Land use is recognized as a significant issue in the discussion on the human environment (Sections 7.2 and 8.2).

- *A question was asked as to whether loss of vegetation was recognized as an impact.*

Loss of vegetation was recognized as a potential impact. These impacts are discussed in Section 7.3.

- *On the physical environment a question was asked regarding the potential for pollution to affect the taste (and presumably the potability) of water supplies.*

  Project process-type waste streams, such as produced water, would be treated and reinjected to the oil reservoir. Other wastes that would be generated (such as domestic-type trash, community and camp wastewater, etc.) would be managed appropriately and, therefore, adverse impacts on water supplies are not expected (Sections 7.4 and 7.8).

- *Questions on the overall issue of potential impacts on water, particularly with respect to potential leaks to groundwater from either production or reinjection wells arose.*

  Wells would be designed and constructed carefully to minimize risk. These concerns are by no means unique to the project and have been addressed successfully in many oil field developments (Section 7.4).

- *It was suggested that the potential for pollution of the Logone be addressed in the EA.*

  The potential for oil pollution has been addressed, and more detail is provided in Section 3.2.

- *As to the human environment, a query was raised on resettlement.*

  On the order of 100 households may be resettled involuntarily, with more being impacted but not requiring involuntary resettlement (Section 7.2).

- *On prospective health and sanitation issues, a question was asked on the potential for the influx of workers to overload facilities in towns near the project. Similarly, inquiry was made as to whether the EA only deals with the area in the immediate vicinity of the oil fields, as there could be pollution problems generated in towns such as Doba and Moundou resulting from project-induced population growth.*

  The housing of project personnel in both the construction and operation phases is discussed in Section 3.2. Appropriate mitigations would be developed for direct impacts to towns or communities that the project may generate. The EA deals with a project area encompassing both Doba and Moundou.

- *Would resettlement be required from both the pipeline land easement and in the field facilities area, and as a result of both short-term and long-term impacts?*

  No resettlement is envisaged as a result of either short-term impacts or from pipeline land easement activities (Section 7.2).

9.8 SUMMARY

Consultation with affected groups, NGOs, and governmental agencies has provided valuable insight into the nature and extent of potential social and environmental impacts associated with or resulting from the proposed project.

Coordinating with affected groups, NGOs, and government agencies is an activity evolving throughout EA preparation, environmental management and mitigation planning, monitoring planning, and ultimate project development. This process will continue beyond finalization of the EA and mature with project development and implementation. The coordination and consultation process is a critically important component of the project to integrate public opinion and to promote understanding of potential impacts and proposed mitigation measures associated with the project.

TABLE 9-1
PUBLIC CONSULTATION SUMMARY

PREFECTURE	CANTON	VILLAGE	# QUESTIONNAIRES	TOTAL POPULATION
Logone Occidental	Moundou	Moundou Urbain	17	*
		Town Subtotal	**17**	
Logone Oriental - Doba Town and surrounding cantons				
	Doba	Doba Urbain	14	*
	Doba	Boro	6	235
	Bodo	Bedouada	5	*
	Beboni	Dungabo	7	765
		Canton Subtotal	**32**	**1,000**
Logone Oriental - Cantons in Oil Field Area				
	Mbikou	Mbikou	4	3,640
		Gomon	14	299
		Madena	10	174
		Mbikou Mbairabetole **- Control Village**	6	54
		Canton Subtotal	**34**	**4,167**
	Komé	Bolobo	36	370
		Bela	12	309
		Kayaraal	10	193
		Beto	5	116
		Bebe	5	114
		Mayongo	12	241
		Naikam	5	56
		Bemou/Mouarom	12	240
		Komé Ndolebe	19	388
		Begada	11	598
		Madana Natphor	11	52
		Mainanai	12	226
		Bongbeti	7	81
		Mako **- Control Village**	9	
		Canton Subtotal	**166**	**2,984**
	Bero			
		Madjo	17	342
		Mbanga	26	543
		Bero I	25	513
		Bero II	40	816
		Miarom	3	38
		Dildo	29	633
		Missamadji/Moundanromkagiti	13	244
		Sananga	6	128
		Takouti	3	25
		Bendjeri **- Control Village**	17	356
		Canton Subtotal	**179**	**3,638**
	Bebedjia	Dangdin	20	
		Bengadoua	33	909
		Donara	12	251

TABLE 9-1
PUBLIC CONSULTATION SUMMARY
(CONTINUED)

PREFECTURE	CANTON	VILLAGE	# QUESTIONNAIRES	TOTAL POPULATION
		Bebedjia I	16	2,037
		Bedaninga - **Control Village**	4	821
		Canton Subtotal	**85**	**4,018**
	Miandoum	Miandoum	10	1,786
		Manboy	22	426
		Mainkeri	22	483
		Bendoh	12	238
		Ngalaba	40	834
		Mekab II - **Control Village**	1	19
		Canton Subtotal	**107**	**3,786**
Logone Oriental - Improved Road and Pipeline Area				
	Timberi	Ouao		173
	Gadjibian	Benarbe		146
		Ngara		276
	Bessao	Madog I		95
		Bedoli		362
		Betabar I		148
	Mont de Lam	Lima/Diba		609
	Mbaissaye	Bingo		160
		Road and Pipeline Subtotal		**1,969**
	Gendarmes at Komé Base Camp		25	
		TOTAL	**645**	**21,562**

TABLE 9-2
SAMPLE VILLAGE MEETING FORMAT

VILLAGE MEETING DEVELOPMENT
An appointment with the village will have been made, so everyone in the village will have the opportunity to be present for the meeting. Representatives of all village organizations will have been requested to attend.
A. Brief presentation of the team and of the objectives of the meeting • Team represents neither Esso nor government and is in village to hear what villagers have to say • Objective is to explore the relation between the project and the village
B. Explanation of how village was chosen by random sample
C. Main themes to be addressed (the following order of presentation is not intended to be strictly adhered to, but rather to represent items for discussion at some stage of the meeting) • History of the village (how long located there, main events, extent and size, etc.) • Main activities of the people: 1. Agriculture: crops (including cash crops), area under cultivation, yields, cropping pattern (fallow), timing, links with extensionists, use of inputs (mineral fertilizers, manure, seed, etc.), animal mechanization, pressure on land, economic problems with subsistence and cash crop farming 2. Livestock: cattle, goats and sheep, importance, management, pasture, inputs, health problems, veterinary facilities 3. Fishing and hunting, who, when, importance, etc. 4. Artisans: masons, carpenter, blacksmith, etc. 5. Shopkeepers 6. Laborers 7. Migrant workers (who, when, why) • Markets: where, when, problems with marketing produce • Credit • Schools: where, how many children (boys and girls), teacher, buildings, payment of teachers, etc. • Health facilities • Water supply • Traditional groups, associations, co-operatives • NGOs working in the village, their projects, etc. • Relationship with other villages • Main problems of the village • Religious aspects: sacred woods, initiation rites, etc. • Relations between ethnic groups such as transhumants • Traditional leadership • Modern leadership
D. Discussion of the project a) Description on the basis of materials approved b) Discuss the population's understanding of project and concerns about project c) Discuss how to deal with impacts of the project: • Affected land • Employment • Roads/infrastructure upgrades • Needs for agricultural products for the project workers (construction and operations) • Other impacts villagers envisage.

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10.1 TECHNICAL CONSULTANTS

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