

Tapping into a new frontier oil province

The first foreign oil companies entered Chad in search of oil more than three decades ago, leading to several oil discoveries in the 1970s. Civil war, tribal infighting and a war with Libya have plagued the country throughout most of its independence and stalled efforts to explore and develop its oil reserves.



Parker service rig on the Komé field

At present, however, a consortium comprising Exxon's wholly-owned affiliate, Esso Exploration and Production Chad (40%), Société Shell Tchadienne de Recherche et d'Exploitation (40%) and Elf Hydrocarbures Tchad (20%) is spearheading development of the Doba Basin in Southern Chad, where commercial oil reserves of roughly 1bn barrels have been discovered. Total project costs for the development of the project's three fields and a 1,050-km export pipeline through Cameroon will be around \$3bn.

The Chad export project could be set into motion by the end of 1998, if the World Bank, as expected, approves loans for the Chad and Cameroon governments; equity in the pipeline project. With the start of the three-field development and construction of the export pipeline, crude oil from the Doba Basin could reach world markets by late 2001.

Net exporter for decades

Peak oil production is expected to reach 225,000 barrels a day (b/d). The 30-year project lifetime, combined with the potential for further discoveries in this new frontier, could ensure that Chad remains a net oil exporter for many decades to come.

The Esso-operated project would be beneficial to both Chad and Cameroon. Chad could earn almost \$5bn in revenues during the project lifetime – a significant amount for a country with a per capita gross national product of less than \$200. Cameroon also could reap \$500m through transit fees and its equity in pipeline and marine terminal operation.

The Esso-led consortium is close to beginning field development and construction of the export pipeline to a proposed off-shore terminal near, Kribi, Cameroon.

Because of Chad's unique and difficult geology and its land-locked location, Esso's project will entail overcoming a number of technical challenges, including production of heavy, viscous oil from multiple pay zones, high volumes of water production and re-injection, and the construction of the export pipeline through environmentally sensitive areas in Cameroon.

Early exploration

With its acquisition of the Chad Permit H concession in 1969, Conoco became the first foreign oil company to undertake significant oil exploration in Chad. This 26m-acre tract encompassed all of the country's prime exploration acreage, including the Doba, Doseo, Salamat, Bongor and Lake Chad basins. A series of farm-ins during the 1970s eventually led to the creation of multinational consortium comprising Conoco (12.5% and operator), Shell (37.5%), Exxon (25%) and Chevron (25%). Between 1973 and 1975, oil was discovered in varying amounts in the Doba, Doseo, and Lake Chad basins. In the Doba Basin, the relatively prolific Miandoum 1-wildcat, which had flows of 1,650 b/d of 25°API gravity crude from late cretaceous sandstone, paved the way for further wells and the identification of the Miandoum and Komé fields in 1975 and 1977, respectively. In 1975, the Sedigi 1-wildcat, located north of Lake Chad, resulted in production of 150-3,000 b/d from several horizons. The subsequent Kanem and Kumia wells, however, confirmed the existence of only small oil reserves in the Lake Chad Basin.

After a lengthy suspension of work due to the civil war that broke out in 1979, Conoco withdrew from Chad in 1981, providing Esso with the opportunity to acquire operatorship of the consortium. By 1986, the Esso consortium had acquired 22,000 km of seismic data and drilled 29 exploration wells, 10 of which tested positive for hydrocarbons. The subsequent collapse of world oil prices slowed exploration activity until 1988, at which time the Permit H concession was re-negotiated. Between 1988 and 1996, Esso focused its efforts on the Doba Basin and, with Western Geophysical, conducted 2-D and 3-D seismic work and drilled 14 more wells, 11 of which resulted in oil shows. In 1989, the Bolobo field was discovered near the Miandoum and Komé fields. In 1993, Elf purchased Chevron's 20% stake in the consortium, which has retained its composition since that time. Under its current Permit H concession contract, the Esso consortium will relinquish 20% of its acreage in 1999.

Field development plans

In November 1996, the Esso-consortium and the Chadian government signed a memorandum of understanding (MOU) concerning development terms for the Doba Basins fields. This MOU followed the conclusion of a bilateral treaty between Chad and Cameroon that provided the basis for construction and operation of the accompanying export pipeline to an offshore terminal near Kribi.

The upstream development will cost slightly less than half of the project's total cost (\$3bn) and will entail drilling about 300 production and 20 re-injection wells in the Komé, Bolobo and Miandoum fields. Only two or three rigs will be active in the Komé region, even at the height of drilling activities, because, on average, each well will be drilled in less than a week. Esso currently leases its Komé base camp from Parker Drilling, which is hopeful that it will win the project's drilling contract. At present, Kellogg, Bouygues and GEC Alsthom have signed letters of intent to construct field facilities at the Komé fields.



**The Export Pipeline
Route to Market
(55k JPG)**

Wells generally will be placed on separate pads. In certain cases, though, multiple wells may be located on a single pad in order to tap stacked pay zones. Vertical and horizontal wells will be drilled at the fields, allowing for improved extraction rates from low-permeability or slim pay zones. In order to counteract the effects of the heavier crudes, electric submersible pumps will be employed at each production well. Due to the crude oil and reservoir qualities, large draw-downs are likely to lead to high levels of sand production, especially from unconsolidated sedimentary layers. Therefore, gravel packing will be used to limit sand production.

Initial oil production is planned for late 2001. During the 30-year life of the project, Esso hopes to recover about 900m barrels of oil. Esso's production plans will result in significant volumes of water production and correspondingly large draw-downs at each well. Production profiles for the three fields are expected to exhibit a skewed log-normal curve: peak production 225,000 b/d is expected as soon as the year after start-up, but output will decline to about 150,000 b/d by the project's sixth year and less than 100,000 b/d between the tenth

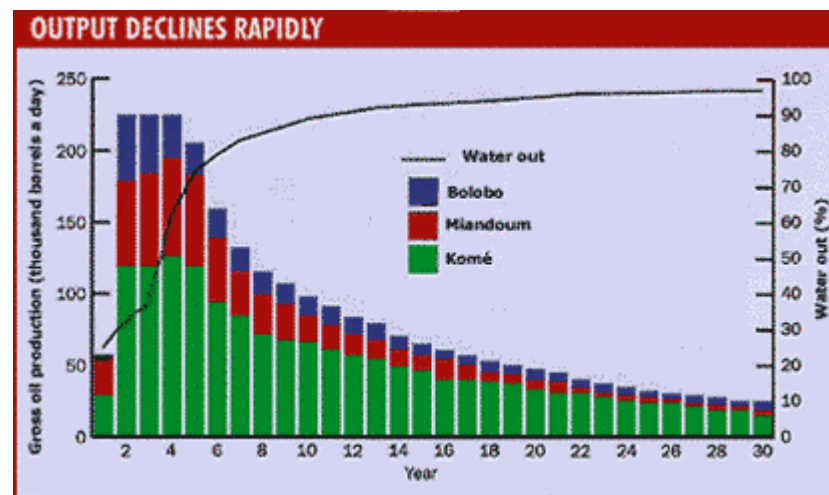
and thirtieth years of the project.

Cumulative water projection is estimated at 7.5bn barrels, with water production averaging 900,000 b/d after about the first 10 years of the project. Re-injection wells will have a design capacity of 25,000 b/d. Water-cut will rise sharply during the first several years after start-up, with initial water-cuts of 25% rising to about 60% by the fourth year, 80% by the sixth year, and approaching 95% during the rest of production life. Gas lift may also be employed for extraction of smaller volumes of lighter crudes in the early cretaceous pay zones.

Production from the Komé, Bolobo and Miandoum fields will include oil, water, and small amounts of emulsified natural gas. None of the fields contains a gas cap. After oil production from various wells is channeled to field manifolds, buried gathering lines will be used to transport oil to gathering stations at each of the three fields. The Komé field will have 10 manifolds and two field pumping stations, which will be used to pump liquids production to the field's gathering station. The Bolobo and Miandoum fields will each contain three manifolds and one gathering station, but will not have any pump stations.

Removing water

The Komé gathering station will employ both unheated free-water knockout tanks to separate water that is not emulsified with oil, as well as heater-treaters to reduce the levels of emulsified water and gas in the oil. As produced oil is sent through both processes, water-cut will be reduced to 40% and 20%, respectively. Because the Bolobo and Miandoum fields will produce lower-viscosity crude, water-cuts of 20% may be obtained with only the use of free-water knockout tanks at these locations. Water treatment also will occur at the gathering centres, as would the de-sanding operations. Remaining oil-water emulsions from the Bolobo and Miandoum fields will be carried to the central treating facility (CTF) located at the Komé field.



The CTF and operations centre, as well as a power plant, a crude topping unit, an airfield, and all of the administrative and support buildings will be located at the Komé field. The CTF will dehydrate the oil-water emulsions from 20% to less than 1% and handle oil and gas production for use in both the power plant and its own power system. In addition, the CTF will perform the important function of blending the oil output from the three fields in order to produce an optimal, sales quality, export crude.

Esso is planning to build a 100-MW power plant, which will be both oil- and gas-fired, to provide power for the field development site. Gas separated from liquids production at the gathering stations will supply about one-third of the fuel needs for the power plant. About 70% of the power plant's generating capacity will be needed to power the electric submersible pumps, especially during the project's early production phase. A 1,000 b/d crude oil topping unit will be used to produce about 100 b/d of diesel for use in field operations. At the height of field construction activities, about 1,000 expatriates and 2,000 Chadian nationals will be employed in the Komé region.

Pipeline to Cameroon

Blended crude from the Komé, Bolobo and Miandoum fields will be exported via a 30-inch, 250,000 b/d capacity pipeline that will run from the project area in southwestern Chad to an offshore terminal near Kribi, Cameroon. The 1,050-km pipeline will run 170 km in Chad and 800 km in Cameroon. A 12-km offshore pipeline will then connect the onshore facilities at Kribi with a floating marine terminal.

Total downstream project costs will be slightly more than \$1.5bn. The pipeline through Chad and Cameroon will be built and owned by two separate companies. Tchad Oil Transportation Company (TOTCO) will build and operate the Chad pipeline segment and the first pumping station at the Komé field. TOTCO, which was formally incorporated in July 1998, comprises Exxon (34% and operator), Shell (34%), Elf (17%) and the Chad government (15%). The Cameroon Oil Transport Company (COTCO) will build and operate the Cameroon pipeline link as well as two more pumping stations and the offshore loading facilities. COTCO was officially formed in August 1997 and comprises Exxon (34.6% and operator), Shell (34.6%), Elf (17.3%), the Cameroon government (8.5%) and the Chad government (5%). Both TOTCO and COTCO will use service contracts to obtain the technical assistance required for pipeline design, construction, operation and maintenance. In 1998, US-based Wilbros and Spie Batignolles signed letters of intent to lay the pipeline in Cameroon.

Several options

The proposed pipeline will run from the Doba Basin fields across the Mbere River just south of Touboro, Cameroon. After running north of the Mbere Rift Valley, it will then head southwest through Dompla and Belabo before passing just north of Yaounde. After Yaounde, it will head south and west towards Kribi. This proposed pipeline route was one of several options considered by the Esso-consortium. It was chosen after a comprehensive study of the physical, environmental, biological and socio-economic aspects of each proposed route.

Assuming the approval of financing is obtained as planned, pipeline construction could start as early as late 1999 and could be completed within 20-24 months. Typical construction times along any given area are expected to be three to six months, which would be about as long as one growing season. The pipeline will be buried three feet along most of the route, although increased depth of soil coverage and heavy-wall pipeline may be used when crossing streams, rivers, and roads. During construction, a temporary right-of-way of 30 metres or more will be needed, although the permanent right-of-way along the entire route will average only 10-15 metres. Pipeline construction activities will involve only two fully operational spreads at a given time – each with one movable base camp that would cover a 65-80 km stretch of the route. At peak, pipeline camps will employ more than 1,500 Chadian and Cameroonian nationals and expatriate staff.

The pipeline will include 35 main line block and check valves installed at roughly 35-km intervals. Seven of these valves will be located in Chad. All valves will be either manually, mechanically, or remotely operated in order to isolate sections of the pipeline in an emergency and to minimise the potential for environmental damage. The pipeline will be fitted with a SCADA system. The main pipeline control centre will be in Douala, with a back-up centre in either the US or Europe. The pipeline will have a corrosion-resistant external coating and a cathodic protection system.

The pipeline will include three pumping stations and a small pressure reduction station. The first pumping station will be located at the Komé operations centre in Chad. The second and third pumping stations will be situated at kilometres 215 and 570 in Cameroon, respectively. All three pumping stations will employ oil-burning heaters that will raise crude oil temperatures from reservoir temperatures of 31-33°C to 71°C in order to reduce viscosity and improve flow through the pipeline. Pumping stations will house about 50 personnel and will have their own power generation capability. An automated pressure reduction station will be located south of Kribi, about 2 km inland from the coast. This station will include crude storage capabilities. After reaching the pressure reduction station, the pipeline will run about 12 km offshore. The pipeline will be trenched until water depths of 7 metres are reached, after which it will lie on the seabed.

The floating storage and offloading (FSO) vessel will be a converted crude tanker with a minimum size of 320,000 dwt. This vessel will be connected to a single-point mooring system that would be able to accommodate tandem-berthed, 80,000-320,000 dwt export tankers. Typical loading times for larger tankers could be 20-40 hours.



Christmas tree at the Miandoum-1 discovery well

The Sedigi project

In addition to the Doba Basin development and related export pipeline project, Esso's MOU also includes a provision for development of the Sedigi field and construction of a pipeline link between the field and proposed new refinery in N'Djamena. As with plans in the 1970s, this proposed refinery's capacity is not likely to exceed 3,300 b/d. It would be operated by Société d'Etude et d'Exploitation de la Raffinerie du Tchad and would mainly produce fuel for transportation and electric power generation. The field development, pipeline and refinery are expected to cost about \$80m. The Sedigi field development will involve the tie-in of two existing wells and possibly one or two new wells, along with various surface producing facilities and gathering lines. This plan is similar to proposals in the late 1970s that were stalled because of civil war. Development of the Sedigi field and construction of the refinery would ease Chad's dependence on product imports. At present, Chad meets all of its 3,000-3,500 b/d of consumption needs through licit and smuggled imports from Cameroon and Nigeria. Problems with Nigeria's refineries have resulted in recent shortfalls of refinery products. In August 1998, Chad's Minister of Mines, Energy, and Oil Abdoulaye Lamana visited Yaounde to ask Cameroon to raise its shipment of products, which come mainly from the Limbe refinery, from roughly 2,300 to 2,800 b/d.

Regional activity

In the next few years, Chad, conceivably, could import crude oil from Niger. The first discovery in Niger's Termit Basin, which borders the Lake Chad Basin, was made in 1962. Four finds have been made to date, although the Agadi, Goumeri, Soko and Yogou discoveries are still unappraised. Esso (80%) and Elf (20%) are continuing to conduct exploration on the 9m-acre Agadem permit. In addition to recent seismic work, the two companies have drilled three new exploration wells in the concession, but with only limited success. Recent efforts to find oil in the nearby Bornu Basin, in northeastern Nigeria, also have proved difficult. In January 1998, Nigerian National Petroleum Corporation announced that it was ending 14 years of unsuccessful oil exploration in Nigeria's Lake Chad region after spending a total of \$150m.

Chad is hopeful that the large-scale investment in the Chad export project and the Sedigi field development will boost international interest in the country's upstream sector. The Ministry of Mines, Energy and Oil is revising upstream fiscal terms, allowing for production-sharing contracts and the full recovery of exploration costs. This is expected to spur new exploration in little-examined, but prospective, areas in central and northern Chad. The strong potential also exists for finding added commercial oil reserves in the Doba, Doseo and Salamat basins. If proved, oil from new fields in southern Chad could be exported via the Chad-Cameroon pipeline.

Complex issues

The complexity of the environmental and social issues in Chad and Cameroon has prompted Esso to spend more than five years studying the potential impacts of the oilfield development and the pipeline project on indigenous populations in southern Chad and Cameroon. In addition to extensive scientific research and modelling of the environment along the proposed pipeline route, Esso has also held consultations with thousands of residents in Chad and Cameroon since 1993. These efforts have resulted in comprehensive environmental assessments, environmental management plans, and compensation and resettlement plans covering all aspects of the Chad export project. These documents, which are now under both World Bank and public review, outline pertinent issues and answers concerns raised by international observers about the environmental and social risks associated with the project.

Chad's complex ethnic and social make-up, which has in part led to the instability and tribal infighting of the past 20 years, will mean that careful political and economic management of this oil windfall will be required. The planning done to date by Esso and its consortium members, along with the World Bank's efforts to ensure a sound revenue management policy, will likely mean that the Doba Basin development and the export pipeline will be beneficial to Chad's development and stability.

Project financing and the World Bank's role

The Chad export project is expected to cost a little more than \$3bn. Esso, Shell and Elf are planning to finance about \$2.3bn, or 70% of the project's cost, through internal financing methods. Roughly 27% of the project cost, or about \$900m, will be obtained through loans from the International Finance Corporation (IFC), which is the World Bank's private-sector arm, as well as through export credit agencies, such as COFACE and the US Export-Import Bank, and a syndicate of commercial banks. Loans would be on a limited recourse basis. Financing would be obtained only to support TOTCO and COTCO in the downstream portions of the Chad export project.

The World Bank, through the International Bank for Reconstruction and Development (IBRD), will lend directly only about \$115m to the governments of Chad and Cameroon in order to allow those countries to obtain equity holdings in TOTCO and COTCO. These market-rate loans represent 3% of the project's total cost. Chad and Cameroon are seeking \$46m and \$69m, respectively. Despite its relatively small percentage of the total funding, the World Bank loans to the Chad and Cameroon governments are significant because the loan package will be made only after a number of pre-conditions have been met.

These conditions include developing and implementing a credible revenue management programme, promoting transparency and the participation of opposition parties, securing government commitments to target spending of oil revenues on infrastructure, health and education, implementing a satisfactory consultation programme with residents and other affected parties, and developing a resettlement programme for displaced individuals.

In July 1998, 86 non-governmental organizations (NGOs) signed an open letter to the World Bank, asking for it to delay of the project until environmental and human rights issues were resolved. Critics have also charged that the World Bank's participation in the project – through its lending to the Chadian and Cameroonian governments – constitutes "corporate welfare" by relieving the participating oil companies from some of the financial risks associated with the project. Others charge that scarce Bank resources spent on this project will divert financial assistance away from vital health and education projects. All of these charges are unfounded.

The World Bank's loans to Chad and Cameroon will support the Bank's other activities in these two countries, such as pursuing structural adjustment operations to support long-term public policy management and poverty reduction goals. It is also unlikely that funding for the Chad export project will impact adversely on other humanitarian aid programs in Chad and Cameroon. For the oil companies, the primary benefit of World Bank participation will be mitigation of the substantial political risks associated with the project. In response to the July letter from NGOs, the Bank stated that the Chad export project provides a "unique" opportunity to alleviate poverty and to foster sustainable growth in Chad and Cameroon and that the Bank will ensure that its conditions are met before proceeding with its loan packages.

Following an in-country review of the project in early 1998, the World Bank is reviewing Esso's environmental documentation and management plans. The Esso consortium is hopeful that the World Bank loans for the Chad and Cameroon governments can be secured by the end of 1998, allowing for subsequent award of construction and procurement contracts by early 1999.

Political stability and security in Chad

With a per capita income of \$180 in 1996, the World Bank ranks Chad as the fifth-poorest, and one of the least developed, countries in the world. Chad's extreme poverty has been compounded by religious, ethnic and social tensions.

Since achieving independence in 1960, the country has been plagued by extended periods of civil war involving dozens of various tribal and ethnic factions, as well as two wars fought to counter Libyan aggression in the Aozou Strip, in the north of the country. Currently, Chad is experiencing its longest period of post-independence stability. This has been achieved under the leadership of President Idriss Deby, who swept to power in a coup in December 1990 and was re-elected in multi-party elections in June 1996. On balance, President Deby's tenure as president has brought political stability and increased economic activity to the country. Chad is currently undertaking an IMF-supported structural adjustment program that is expected to spur economic and social development. The World Bank estimates that more than 80% of Chad's 6.8 million citizens are employed in agriculture, which accounts for less than half of GDP. Chad's primary industry is cotton, exports of which earned revenues of about \$75m in 1996.

Islam is the dominant religion in Chad and perhaps 80% of N'Djamena's residents are Muslim. Most of the country's Christian and animist minorities live in southern Chad, which is the country's agricultural and economic base.

President Deby, who is a Muslim from the north, recently has made efforts to boost Chad's relations with Libya. After hosting Muammar Gaddafi in N'Djamena earlier in 1998, President Deby has flown twice to Tripoli, despite a UN ban on such travel.

In addition to several recent agreements designed to expand economic co-operation between the two countries, Chad and Libya agreed to set up three new oil companies in August 1998. According to the agreement, one of these companies will be responsible for upstream activities, such as exploration and production, while the two others will be active in products distribution and oilfield services.

The security situation in the oil development area in southern Chad is stable.

After the collapse of a peace accord in 1997, the Armed Forces for a Federal Republic (FARF) signed a similar deal with the Chad government in March 1998.

The truce has held, and FARF members have received amnesty and are currently integrating into the military. The primary security concern for the Chad export project is sporadic armed banditry along highways, especially at night.

At present, however, banditry alone does not represent a significant risk to the oilfield development or the export pipeline, which will be buried along most of the route.

Unique Geology leads to technical challenges

Chad contains a series of rift basins consisting primarily of early cretaceous lacustrine sandstone and shales. Chad's geology is non-marine in origin, thus setting it apart from that predominant in neighboring Nigeria. Reservoir rocks and producing intervals are primarily early and late cretaceous fluvial sandstones and siliclastic sediments. The Doba, Doseo, Salamat, Bongor and Lake Chad Basins are all marked by extensive folding and faulting. Rifting, as well as tectonic events, have resulted in numerous vertical faults that have divided each basin into two or more sub-basins.

Based on the roughly 30,000 km of seismic shot and 45 wells drilled to date in Chad, Esso places the country's recoverable reserves at slightly more than 900m barrels. Some industry experts, however, believe that possibly as much as several billion barrels may eventually be proved. The Doba Basin's Komé, Bolobo, and Miandoum fields hold almost all of the country's known oil reserves and provide the greatest production potential. The Sedigi field in the Lake Chad Basin holds smaller reserves, albeit of high quality crude, of perhaps 12m-20m barrels. Chad contains negligible known natural gas reserves, but a recent US Geological Survey study places the country's undiscovered gas resource base at around 2 trillion cubic feet.

Oil in the Doba Basin fields generally is trapped at two stratigraphic levels. More than 90% of proved oil reserves are located in high-quality, late cretaceous sandstones that hold heavy crude with 17°-24°API gravities, sulphur contents of less than 0.1%, and relatively high viscosities in the range of 30-800 centipoise. Pour points are usually below 10°C. Reservoir quality is good, with permeabilities of 1-5 darcies and porosities of up to 25%. Gas-oil ratios in late cretaceous crude are low, but the existence of an aquifer will enable an extensive water flooding programme to assist oil production efforts. Small amounts of 30°-50°API gravity crude is contained in discontinuous early cretaceous sediments, which have very low permeabilities of less than 100 millidarcies and typical porosities of 10% or less. Although this lighter crude has viscosities of less than 1 centipoise, pour points are around 50°C, making the crude difficult to transport after production. Average target depths for the two producing horizons are around 1,500 metres and 3,000 metres, respectively. Total oil recovery factors are projected at 10-35%, depending on the pay zone, and obtaining these factors will require an extensive water flooding programme early in field lives.