THE STUDY
ON
POLLUTION PREVENTION AND CONTROL WITHIN PETROLEUM SECTOR
IN
THE REPUBLIC OF TRINIDAD AND TOBAGO
PRELIMINARY STUDY REPORT

FEBRUARY 1993

JAPAN INTERNATIONAL COOPERATION AGENCY

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CONTENT

1. PREFACE

In response to a request from the Government of the Republic of Trinidad and Tobago, the Government of Japan decided to conduct a preliminary study on Pollution Prevention and Control within the Petroleum Sector in the Republic of Trinidad and Tobago and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Trinidad and Tobago a preliminary study team, headed by Mr. Hiromi Chihara, from Sep. 11 to Oct. 1 in 1992.

The team held discussions with the officials concerned of the Government of Trinidad and Tobago, and conducted field studies. After the team returned to Japan, further studies were made and the present preliminary study report was prepared. The report was prepared to outline and define the scope of work and methodology for clear understanding in subsequent cooperation.

2. PETROLEUM INDUSTRIES IN TRINIDAD AND TOBAGO

2－1 Outlines of Trinidad and Tobago

The Republic of Trinidad and Tobago is located off the delta of the Orinoco River that flows from west to east in the Republic of Venezuela, and on the continental shelf of the South American Continent. The Republic has a population of a little less than 1.3 million. The GNP per capita is US$3, 610 and Trinidad and Tobago ranks as a mid UpperMiddleIncome Economic Country. Major industries are dependent on petroleum and natural gas derivatives. Basic indicators for the country are shown in Table 21, and further economic indicators per capita are summarized in Table 22 in comparison with the following three countries.

a) Gabonese Republic : GNP per capita is equivalent to Trinidad and Tobago, petroleum producing state and a major export is petroleum with a population of 1.1 million.

b) Republic of Singapore : Island country hosting export oriented refineries (EXOR). Population is 3.0 million and GNP per capita is US$11, 160, ranking as Lower HighIncome Economic Country.

c) Japan : Highly developed country with a population of 123.5 millions and one of the largest importing country of petroleum with highly advanced technologies and management for petroleum refining.

From the information in Table 22, specific characteristics of Trinidad and Tobago might be surmised as follows:

a) GNP per capita of Trinidad and Tobago performed zero growth over the last 25 years, which illustrates petroleum dependent structure has been established prior to the period. Comparison of the trends of petroleum production, GDP shares of agriculture and industry of Trinidad and Tobago and Gabon are as follows;

	Trinidad and Tobago				Gabon			
Petroleum Production, MBPD								
	1960	1970	1980	1990	1960	1970	1980	1990
	115.7	139.8	211.0	144.4	16.1	108.8	180.0	269.0
GDP Share, %	1965	1990			1965	1990		
Agriculture	8	3			26	9		
Industry	48	48			34	49		

Growth by exodus from agriculture through petroleum production increase was realized over the last 25 years in Gabon, while the share of agriculture was not so high at the outset in Trinidad and Tobago, and the economic aspect of the Republic is considered the direct reflection of world petroleum status.

b) Singapore is a smaller island country than Trinidad and Tobago but has EXOR and high value added manufacturing industries based on a larger Asian marketing hinterland. Trade balance is however deficit and made progress to reach its economies with developed financing and services. The share of services in GDP is higher than Japan.

c) Trinidad and Tobago has high potential for natural gas development. Natural gas development and utilization is ranked as one of the most important national economic development targets. Already natural gas is effectively utilized at the three thermal electric power generation stations as well as for vehicle fuel use as compressed natural gas (CNG). The central issue of future economic growth in the Republic is judged the beneficial utilization of natural gas.

Table 2-1: MAJOR INDICES OF TRINIDAD AND TOBAGO

Area:	5,124km²
Population:	1.27MM(Estimate for 1990)
Population Density:	248/km²
Age Distribution:	
0-14	32.9%
15-49	58.7%
60+	8.4%
Ethnic Groups (1980):	
Africans	40.8%
East Indians	40.7%
Whites	0.9%
Chinese	0.5%
Others	0.8%
Mixed	16.3%
Official Language: English	
Religions:	
Roman Catholic	32%
Anglican	15%
Presbyterian	4%
Hindu	25%
Moslem	6%
Major Cities and Population:	
Port-of-Spain(Capital)	0.30MM
San Fernando	0.05MM
Government Type: Parliamentary Democracy	
Labor Force:	
Agriculture	9%
Mines	8%
Industry	30%
Services	53%

Land Use:

	Share of Total Land Area (1989)	Average Annual Growth (1965-89)
Agriculture	23%	1.0%
Permanent Pasture	2%	1.0%
Forest and Woodland	43%	(-)0.4%
Other	31%	(-)0.1%

Sources: 1)World Almanac 1992
2)ATLASECO 1990
3)World Bank: World Development Report, 1992
4)J.Taylor: Trinidad and Tobago, 1991

Table 2-2 : BASIC INDICATORS FOR COUNTRY COMPARISON PER CAPITA

Items	Unit	Gabonese Republic	Republic of Trinidad and Tobago	Republic of Singapore	Japan
1. GNP/Capita, 1990	US$	3,330	3,610	11,160	25,430
-GNP/Capita Ascending Order among 184 Economy	—	115	116	132	152
-AAGR, 1965-1990	%	0.9	0.0	6.5	4.1
2. Population, 1990	MM	1.1	1.2	3.0	123.5
-Estimate, 2025		3.0	2.0	4.0	128.0
-AAGR, 1989-2000	%	2.8	1.0	1.2	0.3
3. GDP/Capita, 1990	US$	4,291	3,958	11,533	23,929
-GDP Deflator, 1980-1990	%	2.3	(-)4.7	6.4	4.1
-GDP Share, 1990	%				
-Agriculture		9	3	0	3
-Industry		49	48	37	42
-(Manufacturing)		(7)	(13)	(29)	(29)
-Services		42	49	63	56
4. Per Capita Value Added, 1990	US$				
-Agriculture		392	103	32	600
-Manufacturing		234	450	2,821	6,714
5. Per Capita Merchandize Trade, 1990	US$				
-Export		2,246	1,733	17,542	2,322
-Import		691	1,052	20,216	1,872
-Balance		1,555	681	(-)2,674	450
6. Per Capita External Debt, 1990	US$	3,315	1,923	na	na
-External Debt/Export, 1990	%	138	99	na	na
-External Debt/GNP, 1990		86	51	na	na
7. Per Capita Daily Calorie Supply, 1989	Calorie	2,383	2,853	3,198	2,956
8. Per Capita Commercial Energy Consumption, Oil Ton, 1990	Ton	0.50	4.80*	3.88	2.90
-Solid		0.00	0.00	0.01	0.65
-Liquid		0.37	0.78	3.87	1.67
-Gas		0.08	4.02*	0.00	0.37
-Electricity		0.05	0.00	0.00	0.21
9. Per Capita Petroleum, 1991	BBL				
-Proven Crude Reserve		663.64	449.17	0.00	0.48
-Annual Crude Production		97.79	43.19	0.00	0.05
-Annual Refining Rated Capacity		7.96	74.83	108.65	13.63
-Annual Products Consumption		3.09	5.51	22.79	9.43
-Crude Reserve/Crude Production	Year	6.79	10.40	na	9.60
10. Per Capita Natural Gas, 1991	MMSCF				
-Proven Reserve		0.410	74.17	0.00	0.008
-Annual Production		0.003	0.17	0.00	0.001
-Reserve/Production	Year	136.0	436.29	na	8.00

Notes : * Gas consumption in Trinidad and Tobago is misleading, because 75% of its production is exported as gas derivatives such as ammonia, urea and methanol. Similar data is referable for Brunei with its per capita consumption of 10.46 Ton of which approximately 80% is LNG and exported mostly to Japan.

Sources : 1) Energy Statistics Year Book, 1990, UN
2) Energy Statistics, 1988-1989, IEA, OECD
3) *World Development Report, 1992, World Bank*

2－2 Development and Utilization of Petroleum and Natural Gas

The production of petroleum and natural gas is undertaken at present by six(6) *major corporations and twelve(12) lease/farmouts at onshore as well as offshore* production fields in Trinidad and Tobago :

(1) Amoco Trinidad Oil Co., Ltd. (ATOC): Largest producer of petroleum and natural gas, foreign private corporation of the USA.

(2) Trinidad and Tobago Oil Co., Ltd. (TRINTOC): State owned corporation and has two petroleum refineries.

(3) Trinidad and Tobago Petroleum Co.,Ltd. (TRINTOPEC): State owned corporation.

(4) Trinidad Northern Area Ltd. (TRINMAR) : Joint venture of three corporations each with equal one third share; TRINTOC, TRINTOPEC and Texaco Trinid Inc.

(5) Trinidad and Tobago Marine Petroleum Co.,Ltd. (TRINTOMAR): State owned joint venture of TRINTOC, TRINTOPEC and National Gas Corp.

(6) Premier Consolidated Oilfields Ltd. (PCOL): Foreign corporate of the UK.

(7) Lease/Farmout: There are twelve (12) domestic and private corporation including Lease Operators Ltd.(LOL), Oil Contractors Ltd.(OCL) and Krishna Persad and Associates Ltd.

It should be noted that the Government of Trinidad and Tobago is implementing a policy of merging TRINTOC and TRINTOPEC in 1993.

Major petroleum and natural gas fields are, as shown in Fig. 2－1, concentrated in the southern region of Trinidad and distributed from eastern offshore, crossing southern onshore of Trinidad and extended to western offshore up to the state boundary with Venezuela. Proven reserve of petroleum is 536 MMBBL which is equivalent to 0.077% of global proven reserve. Natural gas reserves are distributed eastern off shore as well as in the northern region of Trinidad and offshore in the Gulf of Paria. Proven reserve of natural gas is 8.9 TCF which is equivalent to 0.25% of global reserves. Production at eastern offshore fields is undertaken by ATOC, TRINTOMAR and TRINTOPEC, western offshore by TRINTOMAR and onshore by TRINTOC, TRINTOPEC and others.

Trinidad and Tobago commenced production of petroleum in 1866 and is therefore one of the oldest petroleum producing country in the world. Large scale commercial petroleum production started at the beginning of the 1900s and supplied two thirds of the petroleum demand of the British Empire by 1946. Later in 1954 the western offshore petroleum fields were developed and then the eastern offshore. Petroleum production reached a historical high of 211 MBPD in 1980 and then declined up to 1990 to record production of petroleum, condensate and natural gas of 144 MBPD, 3.7 MBPD and 780 MMCFD, respectively. Therefore, ratio of (Proven Reserve)/(Production) is calculated to be 10.2 years for petroleum and 31.3 years for natural gas. However, the ultimate reserves of petroleum is 3,300 MMBBL and natural gas is 20 TCF and recalculated (Ultimate Reserve)/(Production) is 62.8 years for petroleum and 70.2 years for natural gas.

In Trinidad and Tobago, petroleum refineries were constructed at Point Fortin in 1912 and Pointe–a–Pierre in 1916. Nameplate capacity in 1950s were 100MBPD at Point Fortin and 365 MBPD at Pointe–a–Pierre. The share of petroleum and products exports among total exports were 80% in 1943. Present commodity export and import in terms of values are summarized in Table 2－3. Export share of petroleum and its products is 65% in values and over 80% for the products including natural gas derivatives such as ammonia, methanol and urea. Eventually current trade structure of the state is almost identical with that of 50 years ago. Present nameplate refinery capacity is 85 MBPD at Point Fortin and 155 MBPD at PointeaPierre. However, present throughput is lower due to various technoeconomic constraints.

Table 2－4 summarizes petroleum and natural gas production, import, export and domestic consumption by corporation. Approximately 50% of domestic petroleum is directly exported. Although some amount of petroleum and products is imported, domestic consumption of petroleum products is approximately 10% of domestic production. Approximately 25% of natural gas production is consumed for domestic electric power generation, and over 95% of natural gas derivatives such as ammonia, methanol and urea are exported. It might be appropriate to state that petroleum and natural gas industries in Trinidad and Tobago are of export oriented nature, and the refineries are typically export oriented (EXOR).

Trinidad and Tobago has been implementing natural gas utilization projects to phase out excess dependence on petroleum and started large scale ammonia plant in 1977 and methanol as well as urea plants in 1984 after the petroleum price hike in 1973. Lately, compressed natural gas (CNG) sale at major gasoline stations for vehicle fuel use in Trinidad and Tobago has started.

Export and import balance of commodities of the Republic is summarized in Table 2－3. Export share of petroleum and natural gas products is, as mentioned in the preceding paragraph, over 80%, commoditywise trade balance, except petroleum and natural gas industries, are limited. The only surplus is in the beverage and tobacco sectors, other commodity sectors are in deficit. This trend will prevail for some time to come. It will be optimal to enhance economic growth by modernizing and increasing value added in the petroleum industries. Natural gas utilization industries should be simultaneously promoted to protect against the reduced operating profit of petroleum industries because of the expected petroleum production cost increase from the use of enhanced oil recovery techniques as well as the reduction in and eventual exhaustion of petroleum and exhaustion of petroleum production in the mid－term future.

It should be noted that environmental protection and conservation of unspoiled tropical natural resources for potential sightseeing and tourism industries development should be enhanced and promoted for Trinidad and Tobago.

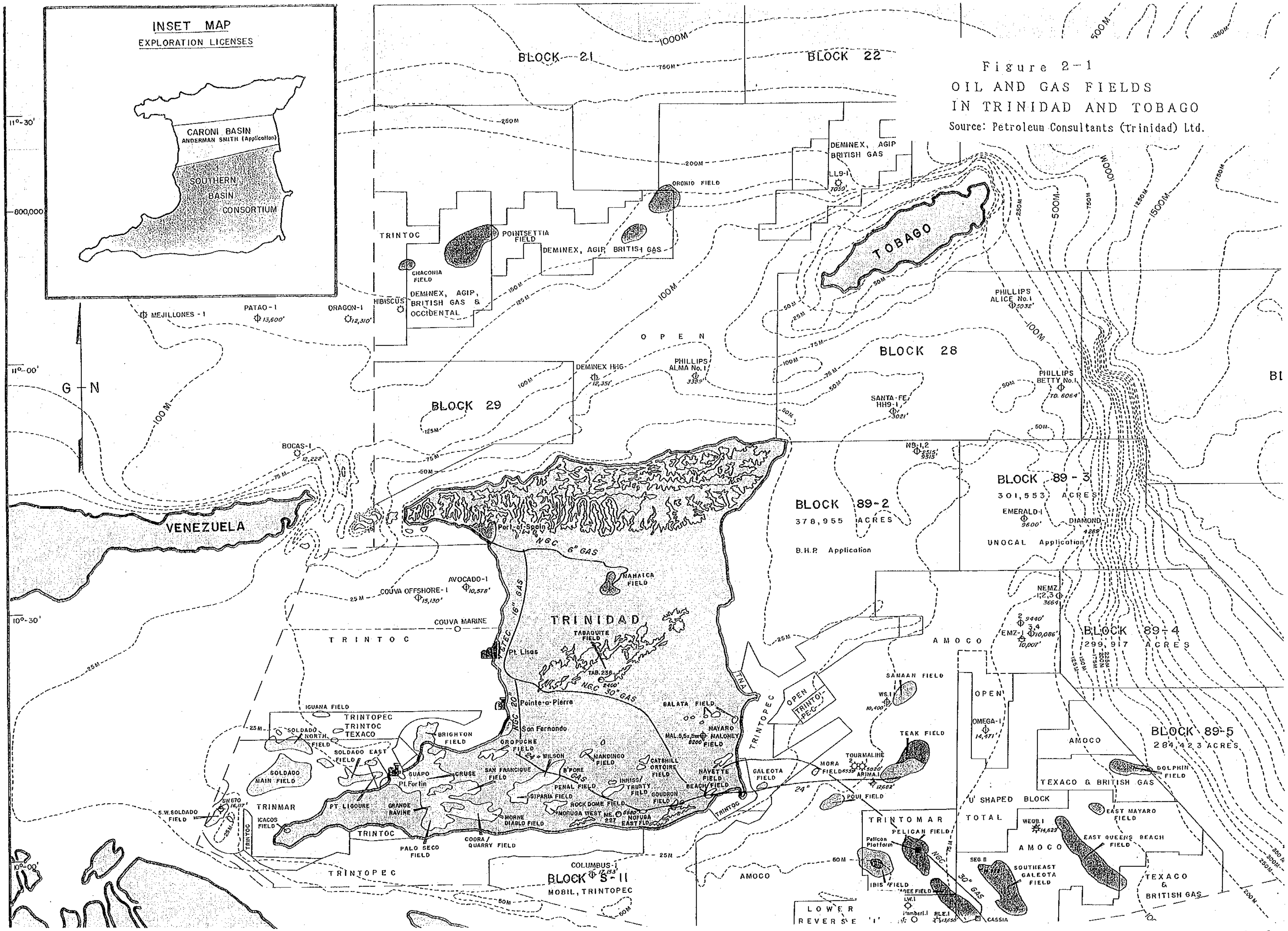


Figure 2-1
OIL AND GAS FIELDS
IN TRINIDAD AND TOBAGO
Source: Petroleum Consultants (Trinidad) Ltd.

Table 2-3 : IMPORT, EXPORT AND BALANCE OF VISIBLE TRADE OF TRINIDAD AND TOBAGO

(Unit : TT$, Million)

Commodities	Trade Value			Major Commodities and Values	
	Export, FOB	Import, CIF	Balance	Export	Import
0. Food and Live Animal	378	895	(-)517	Sugar and Molasses: 137	Milk and Cream :115 Soya Beans :122 Vegetables :138
1. Beverage and Tobacco	100	41	59	—	—
2. Crude Materials Inedible except Fuel	11	444	(-)433	—	Iron Ore :155
3. Mineral Fuel and Lube	5,506	1,039	4,467	Crude Oil :2,591 Petroleum Products:2,794	Crude Oil :911 Petroleum Products:106
4. Animal and Vegetable, Oils and Fats	14	35	(-)21	—	—
5. Chemicals	1,421	892	529	Methanol : 261 Ammonia : 770 Urea : 285	Medicine :139
6. Manufactured Goods and Materials	781	1,360	(-)579	—	Paper :182 Pipe and Tube :166
7. Machinery and Transport Equipment	42	1,841	(-)1,799	—	Motor Car :180 Pumps :113 Other Machinery :125 Instrument :123
8. Miscellaneous Manufacatured Articles	87	490	(-)403	—	—
9. Others	2	47	(-)45	—	—
Total	8,342	7,084	1,258	6,833	2,462

Notes : 1) Major commodities are selected among values of more than TT$ 100 Millions.

2) Major export destination countries are : USA; 48.6%, Barbados; 3.3%, Neth. Antilles; 3.3%, Venezuela; 2.8%, Frech Guiana; 2.7% and UK; 2.2%.

3) Major import origin countries are : USA; 38.9%, Venezuela; 14.0%, UK; 7.4%, Japan; 5.6%, Canada; 4.9% and Brazil; 3.8%.

4) Export share of crude oil and products is 64.5%, while crude oil, natural gas and their products is 80.3%.

Sources : Overseas Trade, 1991, Central Statistical Office, Republic of Trinidad and Tobago.

Table 2-4 : PETROLEUM AND NATURAL GAS BALANCE

1. Crude Oil and Products (Unit : MBPD, 1990)

Items	Production	Import	Consumption	Export
Crude Oil				
ATOC	70.0			70.0
TRINMAR	33.8			
TRINTOPEC	17.8			
TRINTOC	17.1	18.0+	91.0+	
TRINTOMAR	3.9			7.0
PCOL	0.8			
Lease/Farmout	0.9			
Sub-Total	144.4	18.0+	91.0+	77.0
Products				
TRINTOC	84.0+			70.0+
NP		3.0	17.0	
Total	84.0+	3.0	17.0	70.0+

2. Natural Gas and Derivatives (Unit : MMCFD, 1990)

Item	Production	Captive Consumption	Net Sales	
Natural Gas				
ATOC	625	123	502	
TRINMAR	71	71	0	
TRINTOPEC	20	20	0	
TRINTOC	50	49	1	
TRINTOMAR	15	0	15	
Sub-Total	781	263	518	(Pipeline Capacity: 1,000)

Derivatives	Production, TPD	Export, TPD	Natural Gas Consumption, MMCFD	
Ammonia				
Hydro-Agri	750		34	
TRINGEN	2,650		105	
FERTIN	2,100		94	
Sub-Total	5,500	4,050		
Methanol				
T&T Methanol Co Ltd	1,380	1,350	43	
Urea				
T&T Urea Co Ltd	1,620	1,550	11	
T&TEC(Electricity)	578MW		145	(Capacity : 1,200MW)
Phoenix Park(LPG)	10MBPD	7MBPD	23	
ISCOTT(Iron)	2,610		30	(Sponge Iron)

Sources : East-West Center, 1991, Oil and Gas Journal, July 6, 1992, Financial and Petroleum News, Jan/Feb, 1992.

2−3 Geographical Environmental Conditions

(1) Marine Conditions

Ocean streams around Trinidad and Tobago are developed, as shown in Fig. 2−2, 2−3, by merging of the Guyana Current from the northbound South Equatorial Current alongside the South American continent with the flow of the Orinoco River. The Guyana Current is divided into two streams at the south−east corner of Trinidad. One flows alongside with eastern shore of Trinidad and Tobago bound north with a current speed of 0.5 to 1.0 m/sec, while the other flows through the Columbus Channel and Serpent's Mouth to reach the Gulf of Paria and make a clock wise circulation in the Gulf. It then flows out from the Dragon's Mouths to the Caribbean Sea in warm currents with 1.0 to 1.5 m/sec flow rate. The Gulf of Paria is a semi−enclosed body of water between Trinidad and Venezuela.

(2) Climatic Conditions

Trinidad is located in tropical zone between North Latitude 10° and 11° and West Longitude 61° to 62°, and climate is rather mild as it is surrounded by sea. Average annual atmospheric temperature is 27°C with monthly average of (±) 2°C. Annual rainfall is 1,524 mm in north−west and 3,048 mm in north−east with May to December of rainy season and January to April of dry season. Trade winds are dominant in this region and prevail north−east to east from November to February and east in April to July. Wind direction is unstable during August to October.

(3) Hydrometric Conditions

Major river system of Trinidad is illustrated in Fig. 2−4. Most of these rivers flow through petroleum onshore fields and discharge into the Gulf of Paria.

(4) Natural Environment

Trinidad and Tobago is gifted with attractive natural environment with of typical tropical features which are considered some of the best sightseeing and tourism resources.

Presently the principal industry in the Republic is the petroleum sector. Therefore co-protection of development of petroleum industry and natural environmental conservation is an extremely important policy option in the state. More specifically, these basic features should be observed for the development of the petroleum industry as well as of natural environmental protection:

1) Protection of Mangrove

Mangrove will be critically damaged and killed by suffocation through petroleum covering of its expiration roots system above sea surface level. Suffocation damage of mangrove was reported at Guayaguayare Bay in the south-east region of Trinidad and at Point Ligoure near Point Fortin. However, the situation is improving as waste water discharge in the petroleum fields is now being directed to eliminate waste water pollution in the regions. Also, protection of a bird sanctuary in the Caroni Swamp, south of Port of Spain, the natural habitat of several tropical birds including the national bird (Scarlet Ibis), is an important issue.

2) Coral Reef Protection at Tobago

Coral is also sensitive to petroleum pollution and suffocation of coral should be minimized in Tobago.

3) Protection of Natural Sand Shore of Atlantic Ocean of Trinidad and Tobago

The breeding and spawning of leatherback turtle on the Atlantic Coast should be protected to maintain natural resources.

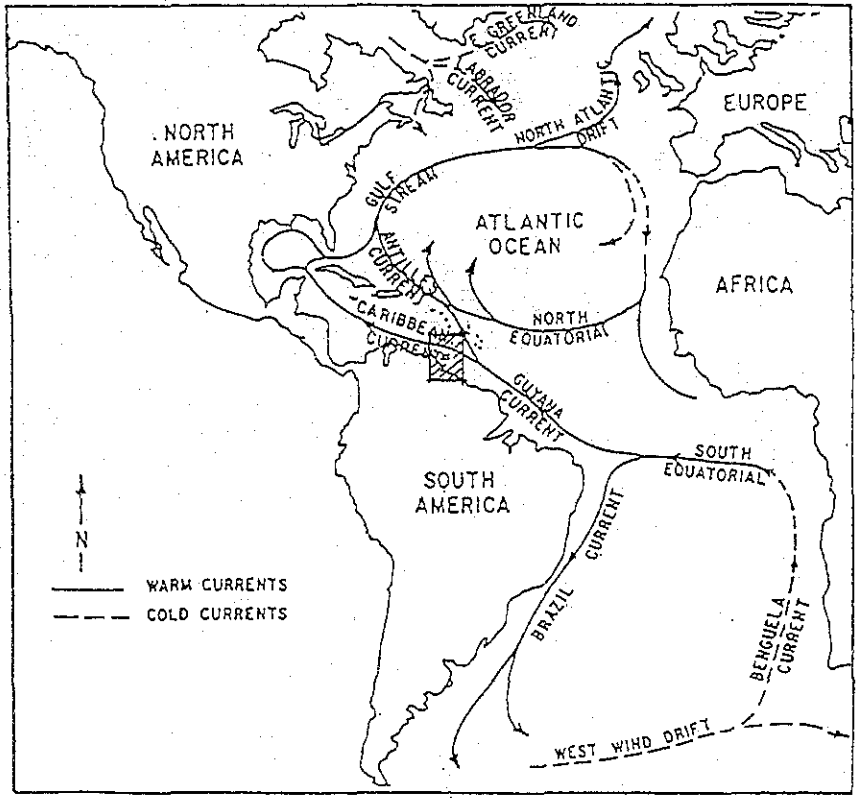


Figure 2 − 2
CURRENT PATTERNS OF
THE ATLANTIC

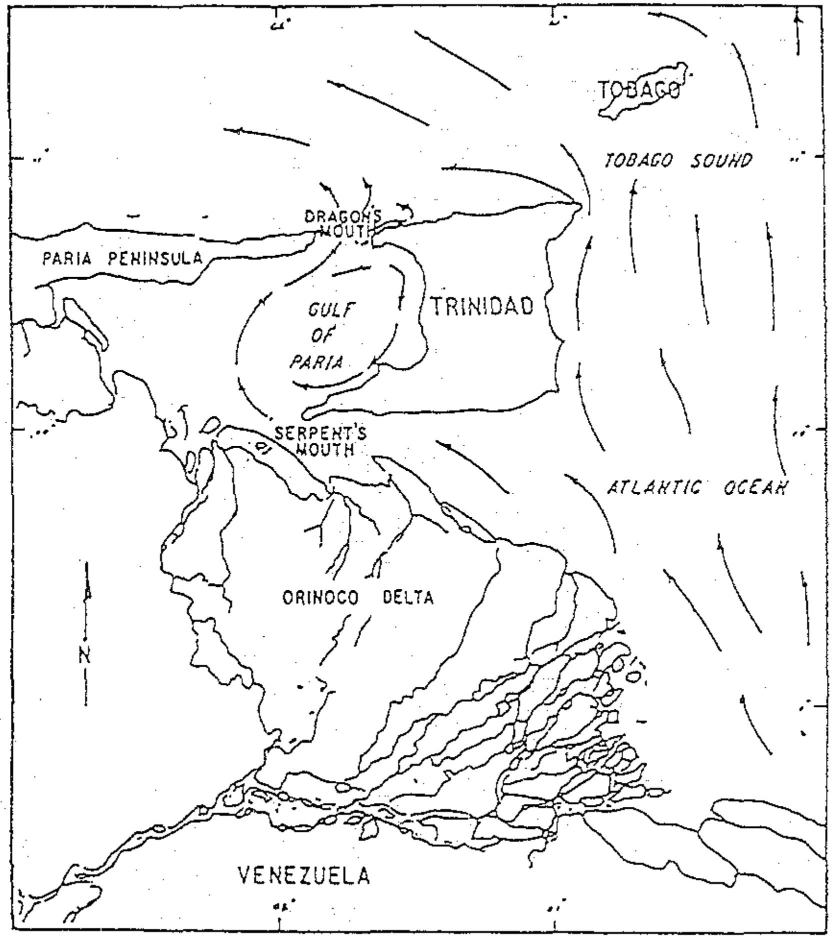
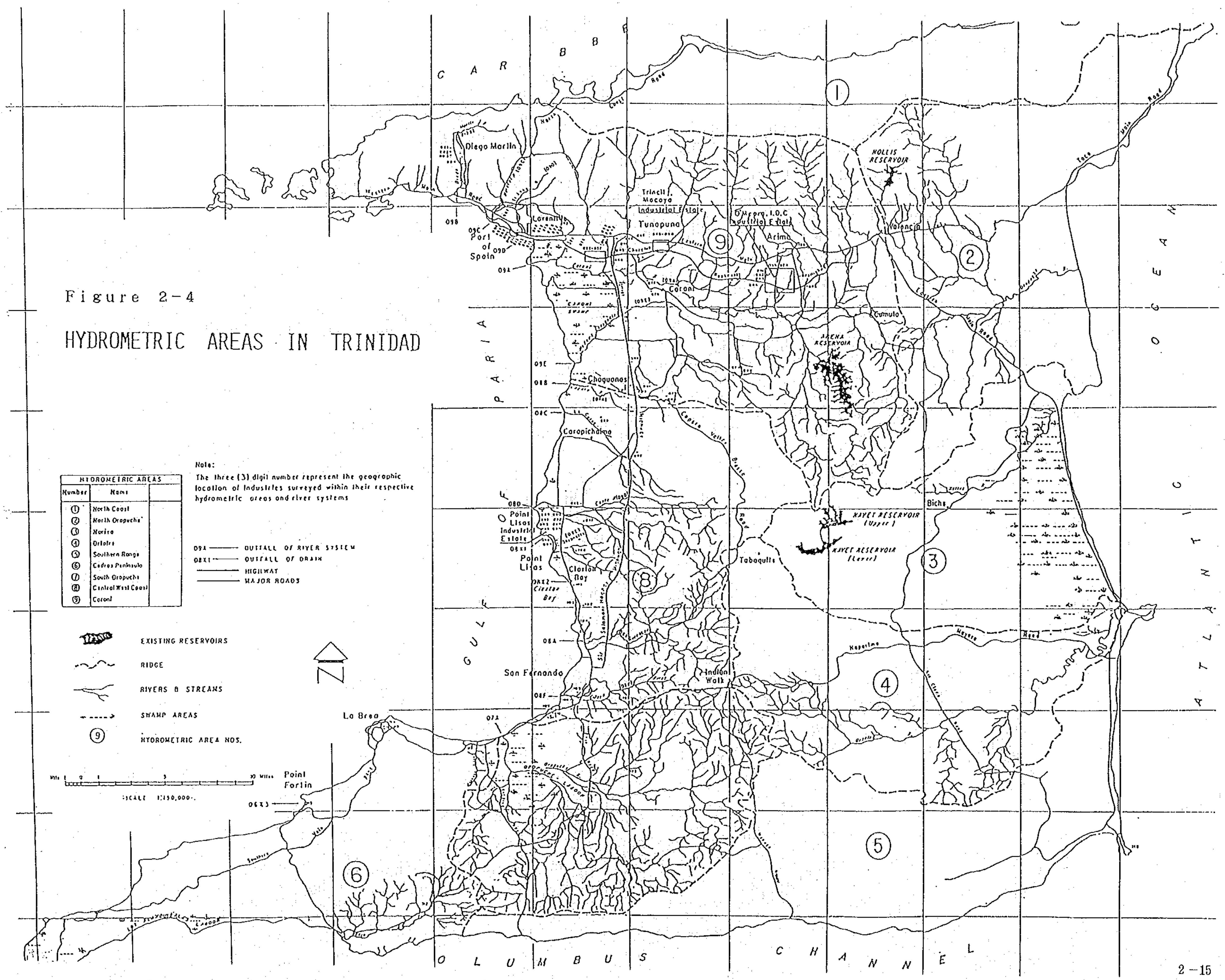


Figure 2 − 3
CURRENT PATTERNS AROUND
TRINIDAD AND TOBAGO

Figure 2-4

HYDROMETRIC AREAS IN TRINIDAD



2－4 Environmental Pollution by Petroleum and Conservation Countermeasures

(1) Pollution and Monitoring

In Caribbean Sea and neighboring Gulf of Mexico, petroleum pollution has been discussed for many years, as many petroleum oil fields and petroleum refineries are situated there and tanker vessels carrying crude oil have been busy. Since 1979, The Intergovernmental Oceanographic Commission's Regional Subcommission for the Caribbean and Adjacent Regions (IOCARIBE) was organized by 14 gulf countries and started to collect environmental monitoring data in collaboration with and with assistance of The United Nation's Environment Programme (UNEP) and Food and Agriculture Organization (FOA).

Three basic data has been collected:

a) Quantity of tar stranded on beaches

b) Quantity of drifting tar

c) Quantity of dissolved/dispersed hydrocarbons

In Trinidad and Tobago, measurement of stranded tar on the beach was carried out by Institute of Marine Affairs (IMA). In these data tar is defined as an intermediate stage of degradation of oil at sea influenced by temperature, rain, winds and waves.

IMA measured and recorded stranded tar quantity in gr/m of beach length from October, 1980 to September 1981 as shown in Table 2－5 and Fig. 2－5.

Generally beach tar is detected by naked human feet at 10 gr/m and it is considered not appropriate for sea water bathing or sightseeing for tourists at 100 gr/m, therefore the measurements in 1980/81 indicates considerable pollution at the eastern beach of Trinidad. It was considered however, that the origin of the tar was mainly from disposal from tanker vessels or seepage of natural petroleum offshore. The amount of tar from petroleum oil fields in the south－east offshore of Trinidad is minor.

Meanwhile, CARIPOL is reporting that the high concentration of tar detected on the eastern beaches of Curacao, Cayman Islands and Bonaire originated half from tar in the ocean beached by ocean current and trade winds and half from ballast and cleaning of tanker vessels. It is estimated that disposal from tanker vessels has since been reduced due to the reinforcement of international agreements. The considerable pollution reported on the eastern beaches of Trinidad was greatly improved when the preliminary study mission visited in September 1992. No problems for sea bathing tourists were recognized.

Needless to mention, an adequate management system is essential to prevent petroleum leaks and spills from offshore petroleum wells as well as onshore petroleum tank facilities at the south-east region of Trinidad. When a large quantity of tar on the eastern beaches was observed in April 1986, it was concluded that the origin was the onshore south-eastern petroleum terminal, by using several analytical procedures. Thereafter, IMA has been establishing a data base of gas chromato graphy, infrared spectra, ultra-violet fluorescent spectra and atomic absorption of the crude oil produced by each oil field for finger-printing identification of the origin of beach tar and accidentally spilled oil.

The pollution characteristics of the Gulf or Paria are a little different. Analytical data for petroleum hydrocarbons floating in the sea water in the Gulf is shown in Fig. 2-6. It is clear that the pollution is concentrated in the southern portion of the Gulf because:

a) The gulf is the destination of rivers flowing in the onshore petroleum oil fields.

b) The gulf is the location of loading and discharging port facilities for crude oil as well as products.

c) Refineries are located near the beaches.

d) Petroleum seeps from offshore seabed faults in the Gulf.

There is a report mentioning that pollution is worse in the Gulf of Paria than in the Middle East petroleum oil fields (Table 26).

(2) Environmental Protection Countermeasures

The central issues for Trinidad and Tobago are the development of petroleum industries, modernization and capacity increases of refineries as well as promotion of enhanced oil recovery (EOR). Work on these issues by utilizing loans from international financing institutions (IDB and World Bank) has just started. It is clear that if waste water treating facilities at petroleum oil fields as well as at refineries are kept as they are, petroleum waste water pollution might be increased, because increased oil production inevitably results in the increase of waste water, which further overloads the waste water treatment facilities.

The historical development of legal pollution control countermeasures in petroleum industries in Trinidad and Tobago are summarized in Table 2－7. The initial Petroleum Regulation was documented in 1970. However, embodiment of a control standard was shown in the Draft Guideline of 1990. As the Ministry of Energy and Energy Industries has been designated as the administrative authority, the Ministry has urged petroleum industries to observe the oil and grease target. This specifies a monthly average of 50 ppm with 75 ppm of daily maximum level for the waste discharges from petroleum oil fields and petroleum refineries (100 ppm of monthly average and 150 ppm of daily maximum are applied at offshore petroleum facilities over 20km from the shore). In this respect petroleum industries environmental countermeasures have only lately been initiated in Trinidad and Tobago.

The standard of 50 ppm oil and grease in discharges that had been proposed by the Ministry was confirmed with the assistance of USEPA with reference to the standards of neighboring countries. However, as shown in Fig. 2－7, the discharged water quality in the public rivers are considerably higher than the standard at present. Further extensive and intensive administrative efforts will be required to achieve the national standards in Trinidad and Tobago.

Further, it might be necessary to examine if the standard is appropriate. The Environmental Guidelines of the World Bank, one of international environmental guidelines specifies maximum allowable pollutants dischargeable, as shown in Table 2−8, per 1,000 m^3 of petroleum crude oil throughput at refinery. At Pointe−a−Pierre Refinery, daily discharge of processed waste water is over 80,000 TPD and upon the completion of the upgrading project to increase throughput to 175 MBPD while maintaining the current rate of production waste water, the environmental status at Pointe−a−Pierre will not meet the World Bank Guidelines even if the oil and grease concentration is reduced to 50ppm.
Japanese present status is quoted as reference. There are 46 refineries in Japan with 4.13 MMBPD total nameplate capacity in 1989 with total processed water discharge of 254,000 TPD and complying with the national standard of 5.0 ppm for oil and gas concentration. The details will be discussed in section 6.

Further, it is recommended that the amount of oil that should be permissible to discharge from petroleum oil fields and refineries into the semi−closed water system of the Gulf of Paria should be verified and justified.
It should be noted that for pollution control in general, the environmental protection consciousness of operators should be enhanced along with the improvement and reinforcement of the environmental control equipment and machinery.

Proper maintenance to keep pollution prevention facilities functioning normally is essential. Daily cleaning of API separators and oil catches to recover retained oil should be performed. The pollution of public rivers and ocean water could then be minimized even when heavy storm water has flooded these environmental protection facilities.

Table 2-5 : TAR CONCENTRATION AT TRINIDAD

(Unit : Wt. Av. gr/m of Beach Length)

Surveyed	Pilot Survey 1980			Main Survey 1980/1981												
Coasts	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	Average
North	0.1	0.1	0.1	0.1	Trace	2.4	Trace	Trace	0.5	Trace	0.0	0.0	0.2	Trace	Trace	0.3
East	121.3	456.6	74.6	46.1	61.1	92.8	34.0	27.3	69.0	91.3	72.8	82.3	34.2	34.4	5.0	54.0
South	0.5	5.6	3.6	0.5	1.0	4.1	3.3	5.7	0.5	0.7	0.5	0.1	0.1	0.6	0.4	1.5
West	5.0	0.4	1.4	6.5	13.0	6.2	2.7	0.8	16.5	15.6	0.7	2.8	5.9	0.0	15.7	7.1
Average	34.2	16.0	19.9	13.1	18.1	25.9	10.0	8.5	21.6	28.2	18.5	21.3	10.1	8.3	5.3	15.7

Note: Trace = 0.04gr/m or less

Source: IMA, Trinidad and Tobago

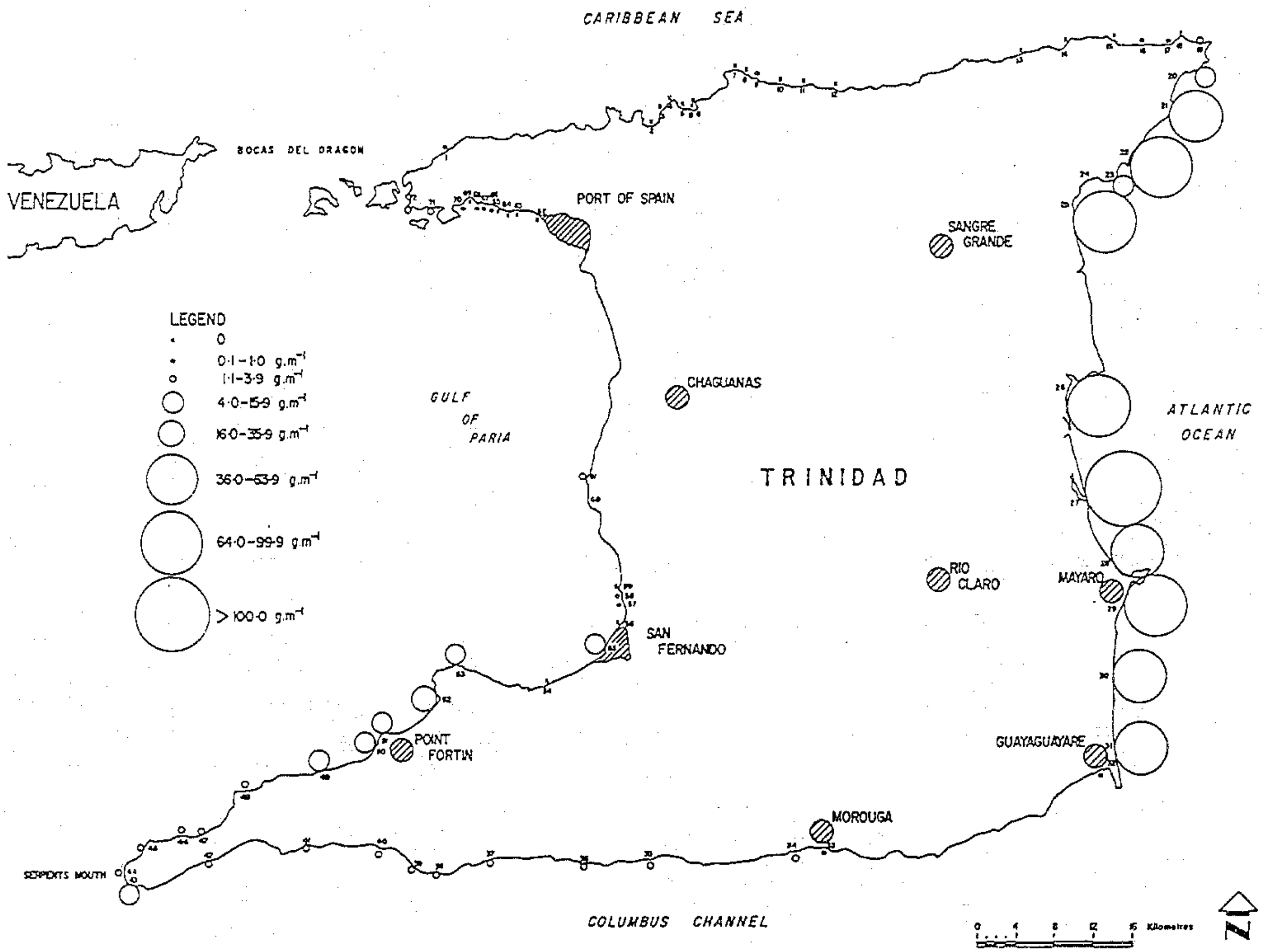


Figure 2 — 5 STRANDED TAR ON TRINIDAD BEACHES

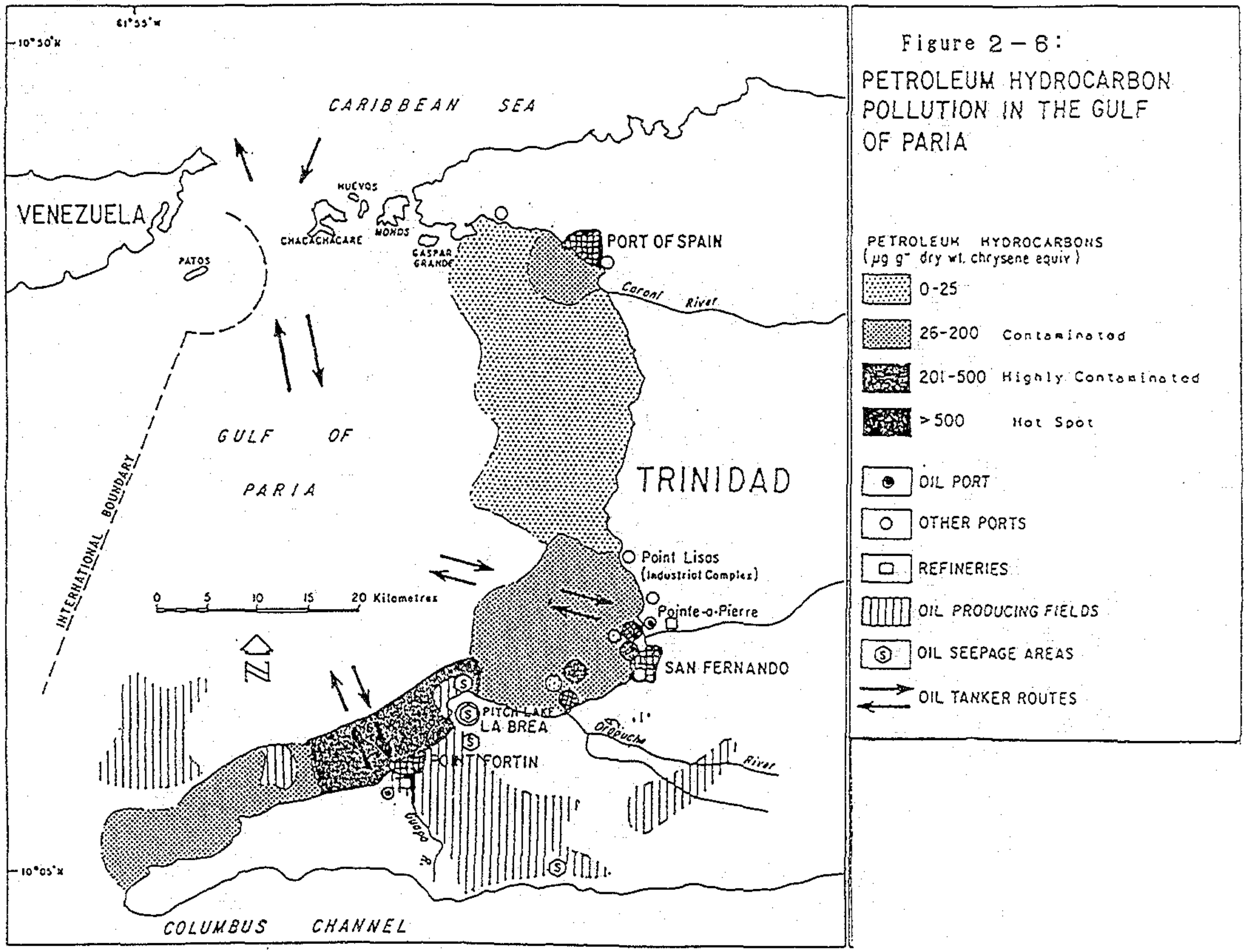


Figure 2 — 6:
PETROLEUM HYDROCARBON POLLUTION IN THE GULF OF PARIA

Table 2-6
COMPARISON OF TOTAL HYDROCARBONS IN SURFICIAL SEDIMENTS
AT DIFFERENT INTERNATIONAL LOCATIONS

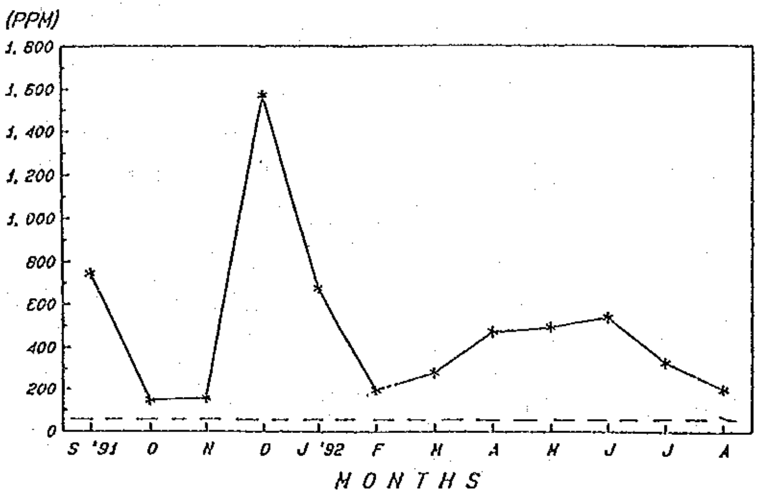
Location	Concentration Range (μg/g dry wt Kuwait Crude Oil Equivalents)	Comments	Reference
Coast of Oman	0.8-19.0		Burns et.al. (1982)
Shatt al-Arab River and North-West Arabian Gulf (Iraq)	0.4-44.0		Douabul et.al. (1984)
Kuwait	1.0-291.0	most concentrations in range 1.0-35.0 μg/g, only 5 higher	Zarba et.al. (1985)
Gulf of Paria	28.2-17,147.5	most concentrations in range 28.2-4,636.1 μg/g, only 3 higher	J.B.R.Agard et.al. (1988)

J.B.R.Agard et.al. "Petroleum Residues in Surficial Sediments from the Gulf of Paria, Trinidad" (1988)

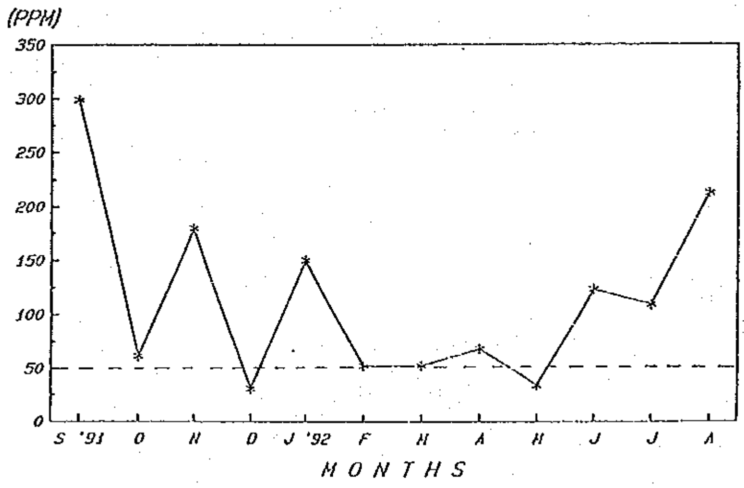
Table 2-7 : LAW AND REGULATION RELEVANT TO PETROLEUM POLLUTION IN TRINIDAD AND TOBAGO

Title	Issue Year Original	Issue Year Current	Major Contents	Pollution Aspects
1. Petroleum Act Chapter 62:01	1969	1980	Part 1: Petroleum Operation -Licences -Default and Dispute -Non-Resident Companies Part 2: Ancillary Rights Part 3: Miscellaneous and General Petroleum Regulations Price of Petroleum Products Order Protection against Fire Transport Regulation	 Fire Flash point, Capacity
2. Petroleum Taxes Act	1974	1981	Income Tax Supplemental Petroleum Tax - Land Operation : 35% - Marine Operation : 60% Marine Production Allowance : 10 to 30% Exploration Allowance : 150% Enhanced Recovery Allowance : 140% Supplemental Refining Tax :	
3. Petroleum Regulation	—	1970	Licences for Petroleum Operations - Exploration, - Pipe-Line - Exploration and Production - Refining , - Transportation - Requefaction of Natural Gas - Marketing, - Petrochemicals Assignment and Operation Rights General Obligations - Avoid Pollution (of sea, land, beach, river to ensure navigation, agriculture and fishing. Reseach and conservation of living resources and property) - Pay Compensation (for loss, damage or injury) Technical Obligations - Safety for Blow-out and Fire - Prevent Water and Air Pollution Work Obligations - Refinery Operation Duty	Pollution, General Pay Compensation Safety Pollution, Air and Water Refine locally over 50% of Crude
4. Draft Guidelines on Oil and Grease Limits of Chronic Oil Pollution by Ministry of Energy and Energy Industries ··· As Proposed Regulation under Petroleum Act, Chapter 62:01, 1980	1990	—	Average of 210 BPD of Oil and Grease Lost as Chronic Pollution in 1988 and Urgent Pollution Problems are cited at Point Ligoure Foreshore, and Guayaguayare Bay. Oil and Grease Discharge Monitoring. First Successful Well in 1860 Tarballs at Mayaro Beach and Guayaguayare Bay in 1905. Natural Seeps on the East and West Coasts of Trinidad NOSCP : National Oil Spill Contingency Plan, 1977 Continuous Monitering of Environment by CARIRI: Caribbean Industrial Research Institute and IMA : Institute of Marine Affairs Penalties	Oil/Grease — Monthly Av — Daily Max General — 50ppm — 75ppm Offshore, 20+km off — 100ppm — 150ppm Monitering Point Tarballs in 1905 Natural Seeps NOSCP, 1977 CARIRI and IMA Penalties/Fine - TT$ 0.010 MM/Case - TT$ 0.001 MM/Day

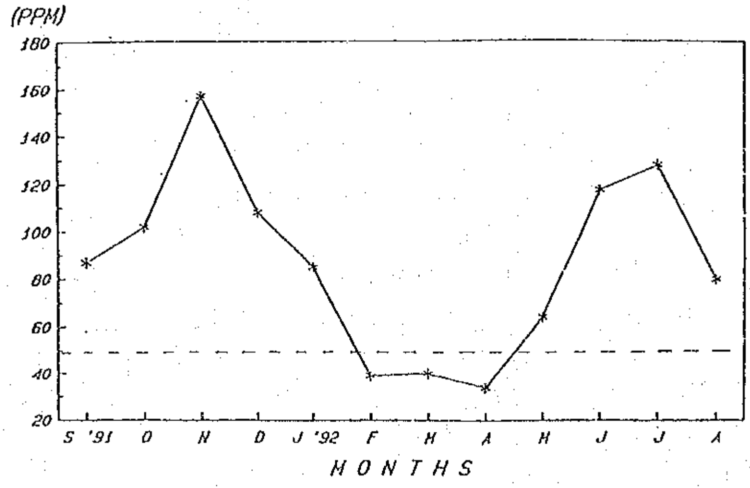
Figure 2-7 : OIL IN EFFLUENT
1991 SEPTEMBER ~ 1992 AUGUST



a) PENAL



b) BARRACKPORE



c) GUAYAGUAYARE

Table 2-8: LIQUID EFFLUENT LIMITATIONS FOR PETROLEUM REFINERY WATERS

World Bank: Environmental Guidelines (1988)

Process Category	Maximum Daily Discharge - Kg per 1000 m^3 of Feedstock a/ b/									
	BOD_5	COD	TOC	TSS	O/G	PHENOL	NH_3-N	SULFIDES	TOTAL Cr	Cr^{+6}
Topping	6.3	32	8.2	4.0	1.9	0.04	1.3	0.04	0.10	0.002
Cracking	8.7	61	11	5.8	2.6	0.06	8.6	0.05	0.14	0.002
Petrochemicals	12	69	15	7.7	3.5	0.08	11	0.06	0.19	0.003
Lube	18	126	24	12	5.6	0.12	11	0.10	0.31	0.005
Integrated	22	152	29	14	6.7	0.14	11	0.12	0.37	0.006
Runoff c/	0.03	0.19	0.03	0.02	0.01	—	—	—	—	—
Ballast d/	0.03	0.24	0.03	0.02	0.01	—	—	—	—	—

a/ Feedstock: Crude Oil and/or Natural Gas Liquids throghput.

b/ For all effluents: pH = 6 to 9.

c/ Applies only to process area runoff treated in main treatment system. All runoff from tank fields and non-process areas shall not exceed 35 mg/L of TOC or 15mg/L of O/G when discharged.

d/ Applies only to ballast waters treated at refinery.

BOD_5: 5-day Biological Oxygen Demand
COD : Chemical Oxygen Demand
TOC : Total Organic Carbon
TSS : Total Suspended Solids
O/G : Oils and Greases
NH_3-N: Ammoniacal Nitrogen

3. ENVIRONMENTAL POLLUTION BY PETROLEUM

3−1 Petroleum and Natural Gas

It has been said that the start of the petroleum industry in the Republic of Trinidad and Tobago was the use of natural pitch from the Pitch Lake in La Brea in the southwest region of Trinidad and Tobago, by British Sir Walter Raleigh in 1595 for caulking his ships. Even now the natural pitch of Pitch Lake is exported to various countries for pavement and other uses, and export in 1991 is recorded as 16,000 TPY. The pitch in the Lake is naturally resupplied from geological faults 100m below the Lake, according to off take of pitch and is considered the Largest petroleum seepage in the world with estimated reserves of 8.0 million tons.

The first oil field was developed at Brighton near the Pitch Lake in 1866 and the first commercial scale petroleum production was commenced in 1907 at Point Ligoure, south of the Pitch Lake. The oil and gas reserves are concentrated in the southern region of Trinidad. These start with the Soldado offshore petroleum field 25m below sea level, close to the boundary between Trinidad and Tobago and Venezuela, then cross the southern part of the onshore fields up to the Galeota peninsula and then expand to approximately 100 km offshore of the Atlantic Continent with offshore fields 250m below sea level. Commercial scale reserves of petroleum and natural gas have not been identified around Tobago, in the north-east region of the Republic.

As was explained in the preceding section, production of petroleum and natural gas is undertaken by six(6) major corporations and twelve(12) lease/farmouts in Trinidad and Tobago. In Table 3−1, available data on depth of well, number of wells, petroleum production, API gravity of crude oil, production method, associated water with crude oil and method of separation of crude oil and water are summarized. The figures in the table are preliminary and should be reviewed and elaborated for further detailed study and survey. The oiland gas fields distribution map is illustrated in Fig. 21 in preceding section.

Table 3-1 : CRUDE OIL WELLS AND PRODUCTION IN TRINIDAD AND TOBAGO

Company	Name of oil field, Discovery date	Depth Mft	No. of wells Producing	No. of wells Total	Production Average MBPD	Production Cumulative to Dec. 31, 1990 MMB	Reserves API Gravity	Reserves Recoverable Reserve MMB	Production Method Self Production	Production Method Pumping	Enhanced Oil Recovery Natural Gas	Enhanced Oil Recovery Water	Enhanced Oil Recovery Steam	Enhanced Oil Recovery CO_2	Water /Oil Ratio, B/B	Water Separation Platform and Water Separation Units	Water Separation Water in Processed Crude, %	Average Annual Growth Rate, %
Amoco Trinidad Oil Co Ltd (ATOC)	• Cassia, 1973	12.7	9	9	3.6	15.5	na/45.0								0.80	1		
	• Mora, 1982	8.5	2	2	0.3	0.8	na/na								2.10	1		
	• Poui, 1974	11.7	38	40	18.6	171.4	34.0/na								1.36	2		
	• Samaan, 1971	11.8	37	47	13.0	189.5	36.8/na								0.61	3		
	• Teak, 1969	15.2	60	71	39.6	265.7	29.3/30.0		x						0.13	5		(-)3.0%
			146	146	75.2	642.9	— /32.0										0.5	
Trinidad & Tobago Oil Co Ltd (TRINTOC)	Area IV and Guapo, 1963	na	85	192	na		25.5/na							x				
	Barrackpore, 1911	11.1	83	379	4.2		18.3/26.4											
	Brighton, 1903	7.5	59	620	0.5		20.8/31.8											
	Catshill, 1950	9.7	31	134	0.1		38.3/33.3											
	Forest Reserve, 1913	11.0	289	2,042	3.9		23.0/18.3											
	Grand Ravine, 1929	11.0	51	168	na		na-/33.5											
	Guayaguayare, 1902/59	10.8	115	699	1.8		3.7/na											
	Oropouche, 1944	9.1	29	128	0.2		na/32.0							x				
	Palo Seco, 1929	12.7	77	939	2.0		5.0/na											
	Parrylands 1-5, 1913	10.6	118	508	1.7		0.2/na											
	Penal, 1936	11.1	78	289	1.1		2.4/20.3					x		x				
	Point Fortin C & W, 1907	10.6	124	551	3.6		22.0/19.9											
	Trinity/Inniss, 1956	9.7	20	95	0.5		na/31.1											
	Bernstein/Point Ligoure, 1938	na	na	na	0.5		na/17.5						x					
			1,159	7,325	20.1	897.5	—								0.91	28	2.0	(-)3.0%
Trinidad Northern Areas Ltd. (TRINMAR)	• Fortin Offshore (FOS), 1954	na	12	35	0.2		24.8/na								na	na		
	• Soldado, 1955	11.0	371	673	37.5		na/20.0											
			na	767	33.8	513.2			x	x	x	x			0.21	4		(-)3.0%
Trinidad & Tobago Petroleum Co Ltd (TRINTOPEC)	Centarl Los Bajos, 1973		162	221	2.4		na/18.9											
	Coora/Quarry, 1936	14.0	151	736	3.4		23.8/na											
	Fyzabad/Apex/Quarry, 1920-38	11.0	300	1,042	2.8		21.5/19.2			x		x					1.0	
	Galeota, 1963	6.3	47	105	2.1		25.5/26.3											
	Palo Seco/Erin/Mckenzie, 1926	12.7	493	1,581	7.4		20.2/								0.97		2.0	(-)1.5%
	Guapo	na	196	923	2.7		na/13.1											
				5,101	20.8	507.9												
Premier Consolidated Oilfields Ltd (PCOL)	San Francique Barrackpore, Fyzabad	11.0	103	521	0.8	22.1	na/17.4			x			x		0.56		0.6	(-)1.5%
Trinidad and Tobago Marine Petroleum Co Ltd (TRINTOMAR)	• Pelican	—	—	6	3.9	2.2	na											
Lease/Farmout	Barrackpore	—	—	33	1.3	0.7	na											
	Total/Average	—	3,203	14,026	144.4	2,632	—	536										

Notes : 1) [•] Indicates Offshore Field

2) This Table is preliminary and should be eleborated for further study.

Sources : Oil and Gas Journal, International Petroleum Encyclopedia, 1992 and 1981, Oil and Grease Report 1988/9 Department of Energy and Energy Industries, Trinidad and Tobago, and Petroleum Encyclopedia of Trinidad and Tobago, 1993.

3-2 Outlines of Petroleum and Natural Gas Fields.

Generally the oil fields in Trinidad and Tobago are small in scale and superannuated. Crude density is also higher and enhanced oil recovery methods such as injection of natural gas, sea water, river water, steam and carbon dioxide are widely practiced. Further production of crude is associated with a large amount of produced water, injected water and steam condensate.

Crude petroleum forms emulsions with associated water in the form of normal emulsions as well as reverse emulsions when produced at petroleum fields. The number of producing wells is approximately 2,680 onshore and 520 offshore with a total of 3,200 wells. Simple average crude production per well is 54 BPD which indicate wells are characteristically small scale and superannuated in Trinidad and Tobago. Main features of individual fields are outlined below.

(1) Eastern Offshore Petroleum and Natural Gas Fields

Eastern offshore fields are the biggest in Trinidad and Tobago where approximately 75% of petroleum, 90% of natural gas and 100% of condensate are produced,

There are;

three(3) oil and natural gas fields of ATOC (Teak, Samaan and Cassia),
oil field of TRINTOPEC (Galeota), and
oil fields of TRINTOMAR (Pelican).

It is expected that further exploration and development in the region will increase production in future. API gravity of ATOC crude is 32.8 and sulfur content is 0.27%. TRINTOMAR and TRINTOPEC petroleum fields in the region coproduce condensate, and associated water is separated by the addition of demulsifier chemicals, treatment in setting tanks and then by conventional oil separators. The residual water in crude oil is reduced down to 0.5% and only minor chronic pollution is observed both offshore and onshore. All crude oil produced by ATOC and TRINTOPEC (API gravity of 27 with sea water injection enhanced oil recovery) is exported from Galeota. TRINTOPEC exports 90% of its production through its own export sales networks and 10% through ATOC exporting channels. Producing strata are of the Pliocene and Pleistocene periods and it is considered quite possible through geological investigation that there might be large petroleum reserves underneath the presently producing reserves.

(2) South Eastern Onshore Petroleum Fields

In the south eastern region of Trinidad, there are several petroleum oil fields such as Guayaguayare, Moruga East, Galeota Trend and Cathill. Petroleum production is mostly undertaken by TRINTOC. The produced petroleum is of medium gravity but the magnitude of production is smaller and total production of production is 8 MBPD at present.

(3) South Western Onshore Petroleum Fields

Oil fields are highly concentrated in the south western onshore fields and petroleum is produced by TRINTOC in the north, by TORINTOC in the south and by PCOL in the middle, with total production of 42 MBPD. Density of crude is getting heavier in the southern area and API gravity of the produced crude oil from some wells are less than 20 in that area. Generally, oil fields are smaller and superannuated, and enhanced oil recovery by steam injection is widely practiced. Therefore associated water quantity is higher and in some extreme cases it is cited that the ratio of (Associated Water) / (Crude Oil + Associated Water) is over 90% with an average ratio of 50%. Crude oil and associated water form emulsions and due to the insufficient separation of oil and water, oil and grease content in discharged water is observed over 1,000 ppm and floating crude oil itself is found on the surface of discharged water. Such crude oil is discharged into the Gulf of Paria through public rivers and streams. It was felt that solving technical problems in design of some oil separators, and of operation and maintenance of adequately designed oil separators are essential for the prevention of petroleum pollution at oil producing wells and crude oil tank farms onshore.

(4) Western Offshore Petroleum Fields

The Soldado petroleum fields of the south western region of the Gulf of Paria are made up of four oil fields: North, East, South West and Main fields, and petroleum crude oil is produced by TRINTOC, TRINTOPEC and TRINTOMAR. API gravity of crude is approximately 22 and production is associated with natural gas and water. Separated natural gas is recovered and reinfected for gaslight production of crude oil. A small scale seepage of natural gas near Soldado East offshore oil fields has been observed.

3-3 Present Conditions of Pollution at Petroleum and Natural Gas Fields

Generally speaking, petroleum pollution in Trinidad and Tobago are more or less identified at offshore oil and gas fields, onshore oil and gas fields, refineries and gasoline stations. During the preliminary study period, however it was felt that the degree of chronic pollution from offshore oil and gas fields is rather minor.

Separation of associated water and crude oil at Teak oil fields (API Degree of 32) in the eastern south offshore area is partially carried out at offshore platform by dissolved air flotation and separated water is discharged directly into ocean water after recovery of residual oil. No visible petroleum film on the surface of ocean water was detected.

Associated water produced at south western offshore Soldado East petroleum fields by TRINMAR is separated at onshore settling tanks. However, TRINMAR is implementing a waterflood project with environmental protection facilities including corrugated plate intercepter (CPI) as well as dissolved air flotation (DAF) equipment and it is expected that the pollution status after completion of the project will be improved to some extent.

Chronic petroleum pollution is notable in waste water primarily at onshore petroleum tank farm and refineries. The Ministry of Energy and Energy Industries estimated that the chronic pollution by petroleum in 1988 was 210 BPD. The distribution of the pollution is, however, not presented. During the preliminary study period, sampling and analysis of 18 samples of waste water from onshore tank farms and of public river water were made. (Waste water analysis at refineries is reported in section 5 and 6 in the report). The Government of Trinidad and Tobago points out 20 rivers in Trinidad are chronically polluted by petroleum. The major highly polluted rivers are shown in Table 32 in clock wise order starting with the south eastern rivers of Trinidad. Oil catches are installed at a fraction of the rivers floating petroleum, however there are several oil catches which are not functioning. Discharged crude oil covers the river banks or trees and grass of the river banks and is spoiling scenery. Petroleum, dispersed and emulsified in water, goes directly through the oil catch to the ocean as reverse emulsion.

Table 3−3 summarize the sampling and analytical study results of COD measured by simplified COD(Mn) method on typical conshore oil separator effluents as well as spot samples of the representative public waters, which were carried out during the preliminary study period in 1992. The analytical results indicate that there are many oil field effluent samples showing over 1,000 ppm of COD and public river waters with 25 to 50 ppm of COD. Generally, there is no defined correlation between COD value and oil and grease content, but both figures are considered equal in terms of order of importance. Hance, it is considered almost impossible to achieve the national standard of 50 ppm of oil and grease content at the discharge outlets of oil separators in oil field tank farms.

Petroleum pollution at onshore oil fields are attributed to mostly technical aspects of facility design, operation and maintenance, however the rainfalls and river stream volume in Trinidad and Tobago is also closely related to pollution. Annual rainfall is almost identical to Japan and is recorded at 1,800 mm. However, frequent shortterm heavy rain is observed there and it should be noted that countermeasures for petroleum pollution prevention should include control of flooding by storm water at petroleum recovery facilities. In Table 3−4 and Fig. 3−1, hydrometric basic data on major rivers in Trinidad and Tobago is presented. Daily flow rates of such rivers are available for heavily polluted small streams in Trinidad and Tobago. Also in Table 35 is presented hydrometric data of the Cipero River near the PointeaPierre Refinery. The data is cited only for reference. The Ciper River receives no effluent from any oil industry operations and is therefore irrelevant to oil pollution.

Table 3-2 : MAJOR PETROLEUM POLLUTED RIVER IN TRINIDAD AND TOBAGO

River Name	Tributary	Flow Rate Data (Oil Catch)	
1. Ortoire River	Balata, Poole, Mora, Teak	Yes:F4-1	
2. Bel Air River	Palmiste	No	
3. Tavia River	–	No	
4. Navette River	–	No	
5. Madame Francoise River	Lizard, Iguana	No	
6. Pilote River	Lawai, Eau Clarke, Petit Pilote	Yes:F5-2	
7. Moruga River	Petite Riviere, Stone, Grande Riviere	No	
8. Morrovite River	Little Moriquito, Cascas	No	
9. La Lune River	–	No	
10. La Marac River	–	No	
11. Grande Riviere River	–	No	
12. Erin River	Hope, Carapal, Quebrada Honda Arena, Ambard	No	(1)
13. Cap de Ville River(1)	Corova, Cemetiere	Yes:F6-3	
14. Guapo River(1)	Techier	Yes:F6-1	(2)
15. Cruse River	–	No	(1)
16. Vance River	–	No	(1)
17. Vessigny River	–	No	(1)
18. Silver Stream River	Morne L'Enfer, Manout, Timital	No	(1)
19. Tarouba River	–	No	
20. Oropuche River	Molai, Rio Negro, Curapo, John, Morocunapo, Coora, Morne Diablo	No	(2)
21. Godineau River	Papure, Oropuche, Cumuto, Curamata		
22. Guaracara River(2)	Moyo, Black Swamp	No	(1)

Notes: (1) Refinery of Point Fortin is located between Cap de Ville River and Guapo River. Waste water is discharged into Gulf of Paria. Point Fortin is taking 2,160 TPD of industrial water as well as sea water, both of which are discharged into Gulf of Paria. Waste water flow rate is estimated 47,000 TPD.

(2) Refinery of Pointe-a-Pierre is discharging 81,000 TPD of waste water to Gulf of Paria through Guaracara River.

(3) Climatic Conditions at Refineries are summarized as follows.

Item	Point-a-Pierre	Point Fortin
Rainfall, mm		
-Annual Average	1,877	1,877
-Annual Maximum	2,572	2,572
-Maximum/Day	120	120
Tidal Data, m		
-Highest Possible	1.6	1.6
-Spring High	1.3	1.3
-Normal High	1.0	1.0
-Mean Tide	0.6	0.6
-Normal Low	na	0.4
-Spring Low	0.3	0.0

Table 3-3: WASTE WATER DISCHARGE AT OIL FIELDS

Sample Number	Production Company, EOR	Field	Water Sampling Point	Approximate Width, m	Approximate Depth, m	Flow Rate m/sec	Flow, m^3/sec	COD, ppm	pH
1.	TRINTOC	Forest Reserved	Tank Farm Out	1.0	0.2	0.2	0.04	1,000	na
2.	TRINTOC	Bernstein	Tank Farm Out	0.5	0.5	0.2	0.05	1,000	na
3.	TRINTOC	Silver Stream River	Oil Catch Out	35.0	4.0	0.01	1.40	500	na
4.	TRINTOC	Arrow Head, Silver River	Dam Out	10.0	1.0	0.1	1.00	500	na
5.	PCOL/TRINTOC	Fazabad, Molai River	Oil Catch Out	1.0	0.3	0.1	0.03	1,250	na
6.	TRINTOPEC	Fazabad, John River	Oil Catch Out	5.0	3.0	0.05	0.75	750	na
7.	TRINTOPEC	Arrow Head, Silver River	4km down from Dam	5.0	1.0	0.1	0.50	1,250	na
8.	TRINTOC	Penal	Station - 7 Out	···	Pipeline Discharge···		0.10	1,250	7.3
9.	TRINTOC	Barrackpore	Oil Catch Out	3.0	1.0	0.2	0.60	25	7.6
10.	TRINTOC	Barrackpore	Oil Catch Out	5.0	0.5	0.1	0.25	25	7.5
11.	TRINTOC	Oropuche	Compressor Station Out	···	Pipeline Discharge···		0.10	50	8.2
12.	Public River	Galeota North	Small River	4.0	1.0	0.05	0.20	50	7.2
13.	TRINTOPEC	Guayaguayare	Tank Farm Out	—	—	—	na	1,000	7.0
14.	TRINTOPEC	Guayaguayare	Separator Out	—	—	—	na	1,000	7.6
15.	TRINTOPEC	Beach Field	Pump Station	0.8	0.2	0.1	0.02	1,000	7.6
16.	Public River	—	Pilote River	20.0	5.0	0.1	10.00	25	7.4
17.	Public River	—	Ortoire River	60.0	8.5	0.05	25.50	25	7.6
18.	TORINTOPEC	Los Bajos	Tank Out	na	na	na	na	na	7.0
	Total/Average	—	—	—	—	—	40.54	Wt. Av.87.35	Av. 7.5

Notes : 1) Samples were taken on September 22, 23 and 25, 1992 by members of JICA as well as officers of Ministry of Energy and Energy Industries, Trinidad and Tobago.

2) COD measurements were made by simplified COD(Mn) method.

Table 3-4 : HYDROLOGICAL SURFACE WATER DATA OF TRINIDAD AND TOBAGO

Hydrometric Area			Stream Gauging Stations			Streamflow, m³/second			Annual Rainfall	Annual River Run-off
Number	Name	Area km²	Number	Name	Area in km²	Peak	Average	Minimum	mm	mm (%)
①	North Coast	368	F1-1	Paria	23.6	48.7	0.58	0.14	1,884	772 (41)
			F1-2	Matelot	23.3	32.3	1.07	0.32	3,189	1,446 (45)
②	North Orupuche	606	F2-1	Cunapo	82.1	63.1	2.08	0.00	2,083	798 (38)
			F2-2	North Oropuche Toco Road	177.4	46.1	3.65	0.06	2,221	717 (32)
			F2-5	Matura	45.1	52.1	1.45	0.34	2,097	1,014 (48)
③	Nariva	461	F3-1	Navet	64.7	17.6	0.60	0.00	1,860	403 (21)
④	Ortoire	479	F4-1	Ortoire	146.1	39.4	1.44	0.01	1,789	308 (17)
⑤	Southern Range	526	F5-1	Moruga	77.7	36.4	1.08	0.00	1,731	435 (25)
			F5-2	Pilote	45.1	16.4	0.52	0.06	1,766	356 (20)
			F5-3	Inniss	86.5	44.3	1.02	0.00	1,563	368 (24)
⑥	Cedros Penninsula	420	F6-1	Guapo	41.7	30.7	0.65	0.00	1,691	490 (29)
			F6-2	Erin	45.1	* 19.6	* 1.43	* 0.01	* 1,759	* 1,008 (57)
			F6-3	Cap-de-Ville	14.4	19.9	0.22	0.00	1,743	439 (25)
⑦	South Oropuche	438	F7-1	South Oropuche	152.3	na	na	na	na	na (-)
⑧	Central West Coast	518	F8-1	Couva Caroni Ltd. Weir	62.9	55.7	0.45	0.00	984	227 (23)
			F8-3	Cipero	22.3	31.9	0.27	0.02	1,315	377 (29)
			F8-4	Caparo	58.0	17.9	0.63	0.01	1,531	339 (22)
⑨	Western Peninsula and Caroni	1,010	F9-1	Caroni Kelly	388.5	na	na	na	na	na (-)
			F9-2	St. Joseph	41.9	36.7	0.45	0.06	1,456	336 (23)
			F9-3	Diego Martin	31.6	45.4	0.17	0.01	1,587	166 (10)
			F9-4	El Mamo	16.6	31.0	0.35	0.00	1,731	663 (38)
			F9-5	Caura	23.8	6.5	0.48	0.10	1,920	633 (33)
			F9-6	Guanapo I	33.4	* 53.7	* 1.72	* 0.04	* 2,720	* 1,631 (60)
			F9-7	San Juan	53.9	50.0	0.76	0.21	1,612	442 (27)
			F9-10	St. Helena	384.1	154.8	8.71	2.33	1,806	717 (40)
			F9-11	Cuesa I	16.5	na	na	na	na	na (-)
			F9-12	Cunupia	38.8	17.0	0.46	0.00	1,426	371 (26)
			F9-14	Tacarigua	38.6	46.9	0.40	0.00	1,823	330 (18)
			F9-15	Cuesa II	21.4	na	na	na	na	na (-)
			F9-16	Guayamare	28.0	na	na	na	na	na (-)
			F9-17	Four Roads	36.8	na	na	na	na	na (-)
			F9-18	Guanapo II	41.5	108.6	1.23	0.15	1,544	933 (60)
	Total/Average	4,826	32	—	2,363.7	Av:43.2	Av:1.23	Av:0.15	Av:1,727	Av:605 (35)

Source ; Water Resources Agency, Government of Trinidad and Tobago, 1989 Edition and Supplemented by 1985 Edition (*)

Figure 3－1 : MAJOR RIVERS IN TRINIDAD AND TOBAGO

STREAM GAUGING STATIONS		DRAINAGE AREA IN km²
NUMBER	NAME	
F1-1	PARIA	23·6
F1-2	MATELOT	23·3
F2-1	CUNAPO	82·1
F2-2	NORTH OROPUCHE TOCO ROAD	177·4
F2-5	MATURA	45·1
F3-1	NAVET	64·7
F4-1	ORTOIRE	146·1
F5-1	MORUGA	77·7
F5-2	PILOTE	45·1
F5-3	INNISS	86·5
F6-1	GUAPO	41·7
F6-2	ERIN	45·1
F6-3	CAP - DE - VILLE	14·4
F7-1	SOUTH OROPUCHE	152·3
F8-1	COUVA CARONI LTD. WEIR	62·9
F8-3	CIPERO	22·3
F8-4	CAPARO	58·0
F9-1	CARONI KELLY	388·5
F9-2	ST. JOSEPH	41·9
F9-3	DIEGO MARTIN	31·6
F9-4	EL MAMO	16·6
F9-5	CAURA	23·8
F9-6	GUANAPO I	33·4
F9-7	SAN JUAN	53·9
F9-10	ST. HELENA	384·1
F9-11	CUESA I	16·5
F9-12	CUNUPIA	38·8
F9-14	TACARIGUA	38·6
F9-15	CUESA II	21·4
F9-16	GUAYAMARE	28·0
F9-17	FOUR ROADS	36·8
F9-18	GUANAPO II	41·5

HYDROMETRIC AREAS		AREA IN Km²
NUMBER	NAME	
①	NORTH COAST	368
②	NORTH OROPUCHE	606
③	NARIVA	461
④	ORTOIRE	479
⑤	SOUTHERN RANGE	526
⑥	CEDROS PENINSULA	420
⑦	SOUTH OROPUCHE	438
⑧	CENTRAL WEST COAST	518
⑨	WESTERN PENINSULA / CARONI	1010

LEGEND

BUILT-UP AREAS
STREAM GAUGING STATIONS
RIVERS & STREAMS
SWAMP AREAS
Refinery

5 0 5 10
Scale in Kilometres

WATER RESOURCES AGENCY
GOVERNMENT OF TRINIDAD AND TOBAGO

Table 3-5 : BRIEF DATA FOR CIPERO RIVER IN TRINIDAD AND TOBAGO

Items	Data in 1989
River Name	Cipero River (F8-3)
Location	South of San Fernando and Discharge into Gulf of Paria
Drainage Area, km²	22.3··· Heavy Clay Soil
Elevation and slope, m	5 to 69, channel slope=0.0056
Rainfall, mm	
Annual	1,315(100% in 1989)
Monthly Maximum	239 (18.1% in November)
Minimum	31 (2.4% in April)
River Run Off, mm	
Annual	377 (100% in 1989)
Monthly Maximum	90 (23.8% in November)
Minimum	7 (1.8% in April)
River Run Off/Rainfall, %	28.7
River Discharge Rate, m³/sec	
Instantaneous Peak	96.05 (Historical highest on July 21, 1985) 31.87 (1989)
Mean Discharg, m³/sec	
Annual	0.27 (1989)
Monthly Maximum	0.86 (September)
Minimum	0.06 (April)
Daily Maximum	8.40 (November 29)
Minimum	0.02 (July 02)

Notes : 1) The data is the latest available, however the recorded annual rainfall of 1,315 mm is considerably lower than the yearly average of 1,762 mm.

2) The hydrometric measuring was undertaken for Cipero River since 1978.

Sources : Surface Water Report, 1989, Water Resources Agency, Government of Trinidad and Tobago.

4. PETROLEUM STORAGE AND PIPELINE FACILITIES

4−1 Outlines of Petroleum Storage and Pipeline facilities

Crude oil produced at onshore wells is transferred to gathering station and then to tank farms, where crude oil is treated at wash tanks to separate oil and water. Associated water is discharged at the bottom of the tank while the upper layer of crude oil is sent to the Pointe−a−Pierre Refinery. Crude oil produced at offshore wells is transferred to the onshore base through submarine pipelines. The total volume of crude oil of ATOC and a portion of crude oil of TRINTOPEC are directly exported at the eastern south onshore base. The rest of TRINTOPEC's crude oil and TRINMAR's crude oil produced in the southwestern offshore area are sent through onshore pipeline to the Pointe−a− Pierre Refinery.

Submerged pipelines are coated with asphalt. Diameter of onshore pipelines are generally 2" from wells to gathering stations, 6" from gathering stations to tank farms and 8" from tank farms to Pointe−a−Pierre.

Natural gas is produced from associated gas in the southeastern oil fields and sent to the Industrial Estate of Point Lisas as well as to the electric power stations at Penal and Port of Spain.

Generally onshore pipelines are laid above ground, on racks approximately 50 cm high alongside public roads and when crossing public roads the pipeline is buried underground. In Table 4−1 outlines of major trunk pipelines are summarized.

Table 4-1: MAJOR TRUNK PIPELINES IN TRINIDAD AND TOBAGO

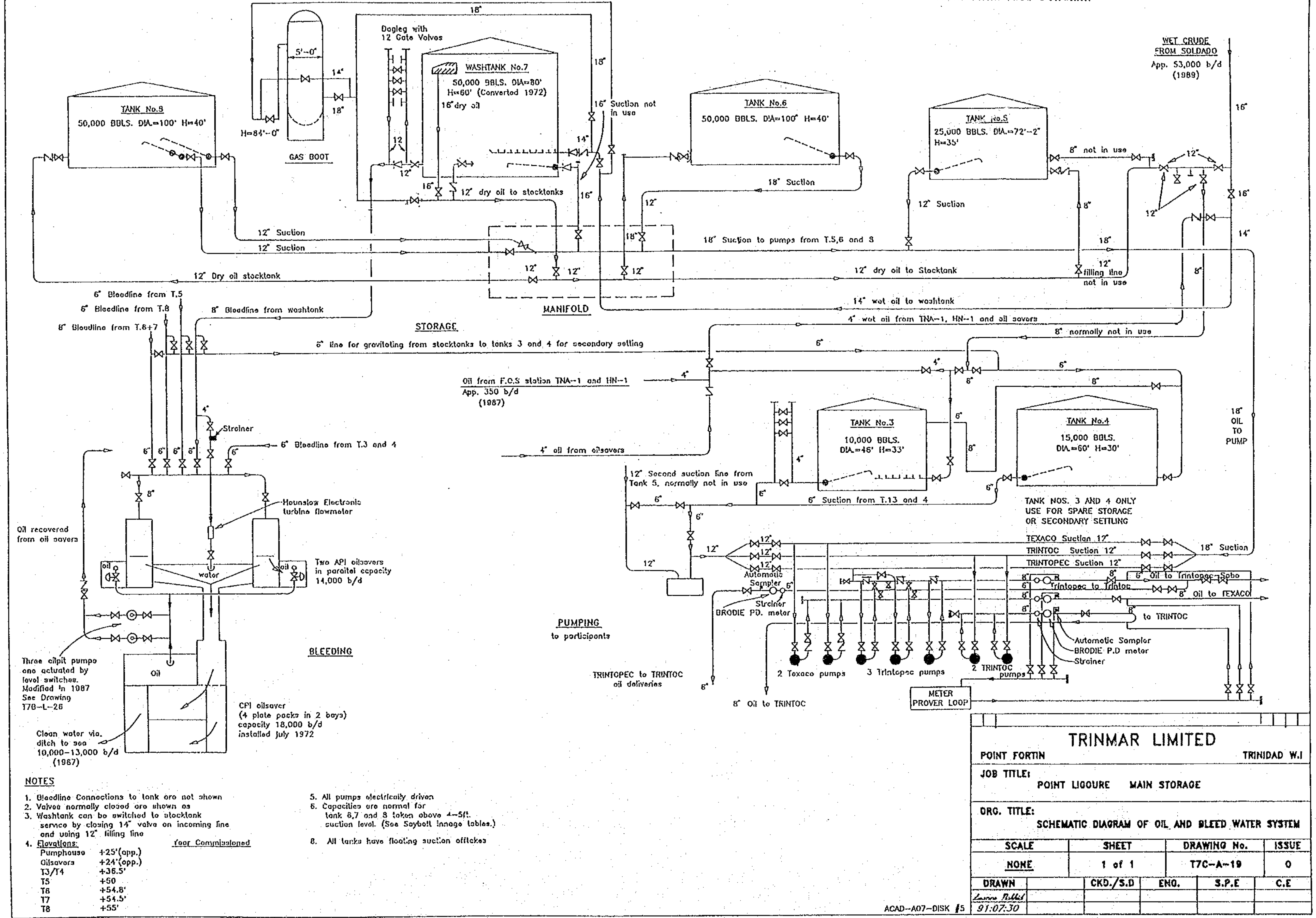
Pipeline Route			Diameter	Approximate	
From	To	Delivery	Feet, Inch	Distance, km	Remarks
Onshore					
Mayaro	Navatte Field	NG	5 - 1/2"	11	
Navatte Field	Beach Field	NG	1 - 6"	10	
		Crude	12"	10	
Balata East Field	Rochard Douglas Rd	Crude	1 - 6"	35	
Beach Field	Rochard Douglas Rd	Crude	1 -12"	40	
		Crude	1 - 8"	40	
Mandingo	Cottage Trace	Crude	1 - 3"	10	
			1 - 6"	10	
Polo Seco Field	Pointe-a-Pierre	Crude	1 -12"	30	
		NG	1 -16"	30	
		CO_2	10"	30	
Point Lisas	Pointe-a-Pierre	CO_2	1 - 8"	10	
		H_2	1 - 6"	10	
		NG	1 -12"	10	
Point Fortin	Pointe-a-Pierre	Product	1 - 6"	35	
Gelota Point	Point Lisas	NG	30"	60	
Pointe-a-Pierre	Port-of-Spain	NG	16"	30	
Mahaica Field	Port-of-Spain	NG	6"	30	
Offshore					
Cassia	Galeota Point	NG	30"	60	
	Teak A	Cond	8"	30	
Samaan	Teak B	Crude	16"	15	
Teak B	Poui	Crude/Cond	24"	20	
Teak A	Galeota Point	Cond	16"	40	
Poui	Galeota Point	Crude/Cond	24"	20	
Galeota D	Galeota Point	Crude	8"	10	
Saldado Main Field	Point Fortin	NG	8" + 10" + 12"	20	
		Crude	18"	20	
Brighton Marine-1	Point Fortin	Crude	6"	20	

Notes: NG=Natural Gas, Crude=Crude Oil, Cond=Condensate, CO_2=Carbon Dioxide for Enchanced Oil Recovery,
H_2=Hydrogen Gas for Refinery Uses. This table is preliminary and should be elaborated prior further study.
Sources: Location Map of Oil and Gas Pipelines, TRINTOC, June, 1985 and Others.

4－2 Flow Diagram of Petroleum Storage and Pipeline

A typical flow diagram of storage and pipeline of crude petroleum is shown in Fig. 4－1. The crude oil base at Point Ligoure is receiving 5 3 MBPD crude oil of Soldado offshore field of TRINMAR. Crude oil is further transmitted to TRINTOC Refinery through 6" and 8" pipelines.

Figure 4-1 : TANK FARM FLOW DIAGRAM



4 − 3 Connection, corrosion Prevention and Painting of Petroleum Storage and Pipeline

(1) Connection

Generally coupling connection are used for pipelines less than 4" in diameter and electric arc welding is used for 6" and larger pipelines.

(2) Corrosion Prevention and Painting

Corrosion preventive coatings are generally one layer of anti−rust coating and two layers of aluminum paint. The bottom plates of tanks are coated with two layers of coal tar. Finishing paints are mostly aluminum paint. In some cases, undercoatings of only one layer are also observed. Submarine pipelines are under−coated by mixture of gasoline and asphalt and then top−coated with asphalt − glass fiber − asphalt − glass fiber − asphalt multi−ply coated. Further cathodic protection by zinc plate is also practiced.

4－4 Present Condition of Environmental Pollution

Maintenance, leakage and spill checking of petroleum storage and pipelines system is practiced daily at Guayaguayare tank farm by two shifts of three men and major pipeline routes are patrolled by a team of two linewalkers once every week.

4－5 Pollution Status and Past Record of Spills and Leaks of Petroleum

One of the major sources of chronic pollution is that separation of associated water at separators is not considered to be adequately controlled and contaminated crude oil is discharged with waste water into public rivers. The waste water itself form emulsions (reverse emulsification), increasing pollution. Additionally spills of crude by poor operation, leakage from valves because of vandalism and corrosion of pipelines are recorded as the origin of pollution. The detailed data base of spills and leaks is not yet completed.

In Table 4－2, the petroleum spill and leak accident record of storage tanks and pipelines from January 1, 1989 up to August 31, 1992 is tabulated nationwide. The total number of accidents onshore is 185 and the number of cases of corrosion origin is 116 (62.7%).
Total spillage is 3.72 MB and that due to corrosion is 2.55 MB(68.5%). Recovery of spilled petroleum onshore is 47%, while there are 8 cases offshore spillage totaling 0.54 MB with no recovery.

Table 4-2: OIL LOSS FROM CRUDE OIL TANK AND PIPELINES

Location	Cause	Number of Incidents	Oil Spilled (MB)	Oil Recovered (MB)
On-Shore				
	Corrosion	116	2.55	1.02
	Non-Corrosion	69	1.17	0.72
Sub-Total		185	3.72	1.74
Off-Shore		8	0.54	0
TOTAL		193	4.31	1.74

Notes : Date is taken from January 1, 1989 to August 31, 1992
Source: Ministry od Energy and Energy Industries, 1992

5. REFINERIES

5-1 Process Operation at Refineries

(1) Operation System

Two(2) state-owned refineries are in operation under the management of TRINTOC, namely, PointeaPierre Refinery (175MBPD) and Point Fortin Refinery (80MBPD). Point Fortin Refinery is a hydroskimming one with atmospheric distillation, vacuum distillation, catalytic reforming, hydrogenation and asphalt production. PointeaPierre, on the other hand, is a socalled integrated refinery, consisting of atmospheric distillation, vacuum distillation, visbreaking, hydrogenation, catalytic reforming, catalytic cracking, alkylation, polymerization, lube oil production, sulfur recovery and petrochemicals such as Udex and normal paraffins.

Both refineries are operated in an integrated manner so that the highest efficiency is achieved; various feedstocks are transported reciprocally. Wide range naphtha (mixture of naphtha and kerosene) is shipped from PointeaPierre to Point Fortin to produce jet fuel at a high yield in the hydrotreating process, while excess amounts of atmospheric residue at Point Fortin is transferred to Pointe-a-Pierre through pipeline to feed fluid catalytic cracking via vacuum distillation.

Both of them make the best use of existing facilities to produce a wide range of petroleum products, including lube oils and petrochemicals. To achieve the best efficiency, not only indigenous crude but also imported crude oil from Venezuela is used. Integrated product yield is shown in Table 5-1.

(2) Major Facilities and Capacity

Major facilities and nameplate capacity of the refineries are tabulated in Table 5-2. Actual rate of operation during the first half of 1992 was as low as 41MBPD at Point Fortin and 88MBPD at PointeaPierre.

(3) Refining Process

Refining processes for the Point Fortin Refinery is shown in Figure 5 − 1 , and for Pointe−a−Pierre at present in Figure 5 − 2, and after the completion of scheduled upgrading (estimated) in Figure 5 − 3 .

Table 5-1

INTEGRATED SYSTEM PRODUCT YIELD

Liquefied Petroleum Gas	2.4 % Volume
Mogas	22.5
Kerosene	10.5
Gas Oil	15.5
Fuel Oil	47.1
Gas/Loss	2.0

Source : TRINTOC

Table 5-2

MAIN UNITS AND CAPACITIES

[BPD]

UNITS	Point Fortin Refinery		Pointe-a-Pierre Refinery	
	unit number	Capacity	unit number	Capacity
Crude Distillation	1	80,000	2	175,000
Vacuum Distillation	1	7,000	3	163,000
Visbreaking Unit			2	17,000
Hydrotreating Unit	1	21,000 (Naphtha, Kerosene)	2	128,000
Fluid Catalytic Cracking Unit			1	26,000
Catalytic Reforming	1	6,500	2	25,000
Kerosene Hydrogenation	1	4,500		
Udex Unit			1	9,500
Aromatics Fractionation Unit			1	2,500
Alkylation Unit			1	2,100
Catalytic Polymerization Unit			1	1,500
Lube Oil Plant				
Furfural			1	8,000
Methyl Ethyl Ketone			1	5,000
Hydrofining			1	3,000
Nonene Fractionation			1	400
Normal Paraffins			1	16,000
Sulphur Recovery			1	250 TPD
LPG Unit	1	2,700	1	1,500
Bitumen Blowing	1	1,600		

Source : TRINTOC

Figure 5-1 : SCHEMATIC DIAGRAM OF REFINERY PROCESSING POINT FORTIN

Unit: Capacity in MBPD
( ): Number of Units

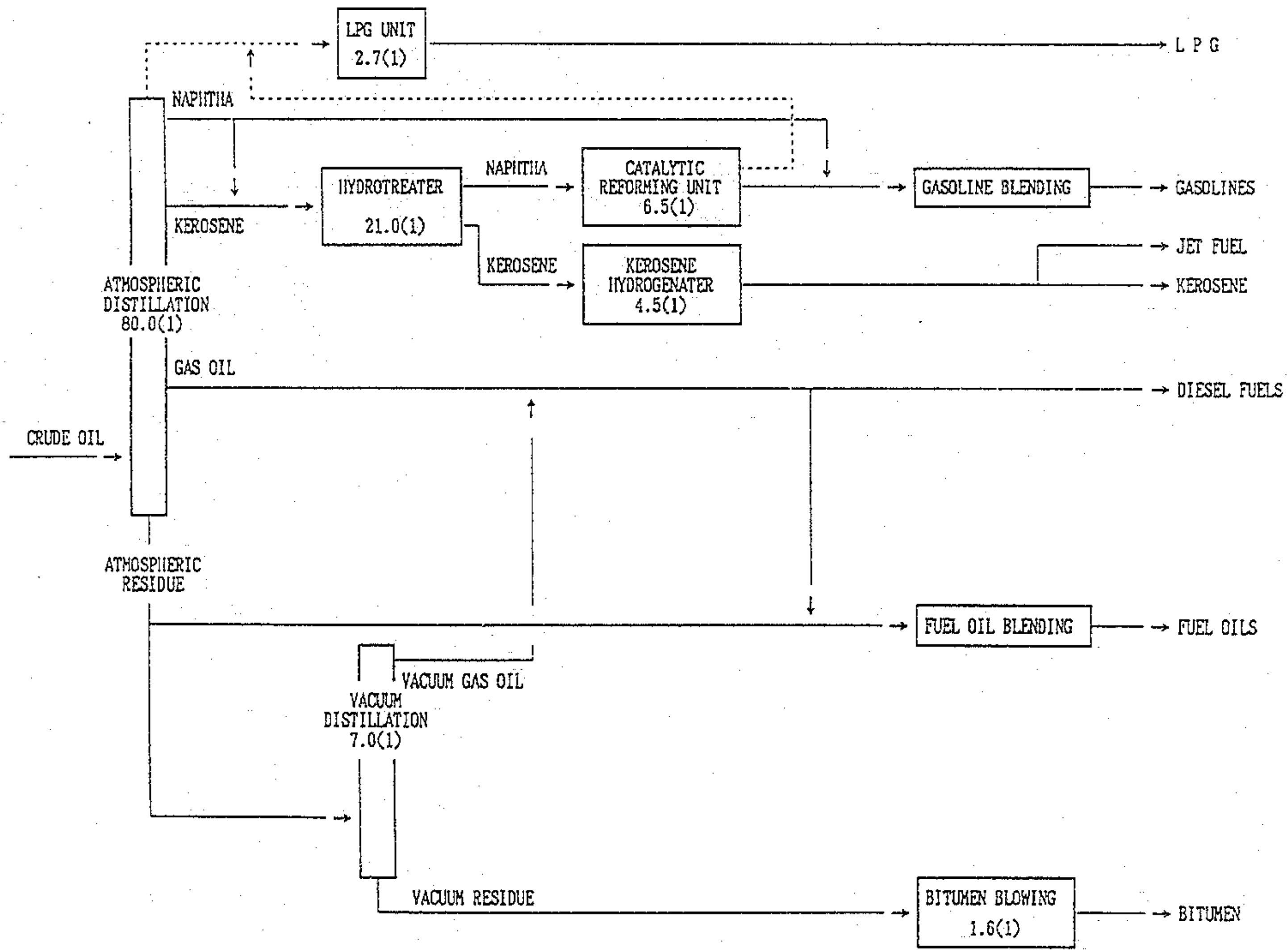


Figure 5-2 : SCHEMATIC DIAGRAM OF REFINERY PROCESSING
POINTE-A-PIERRE

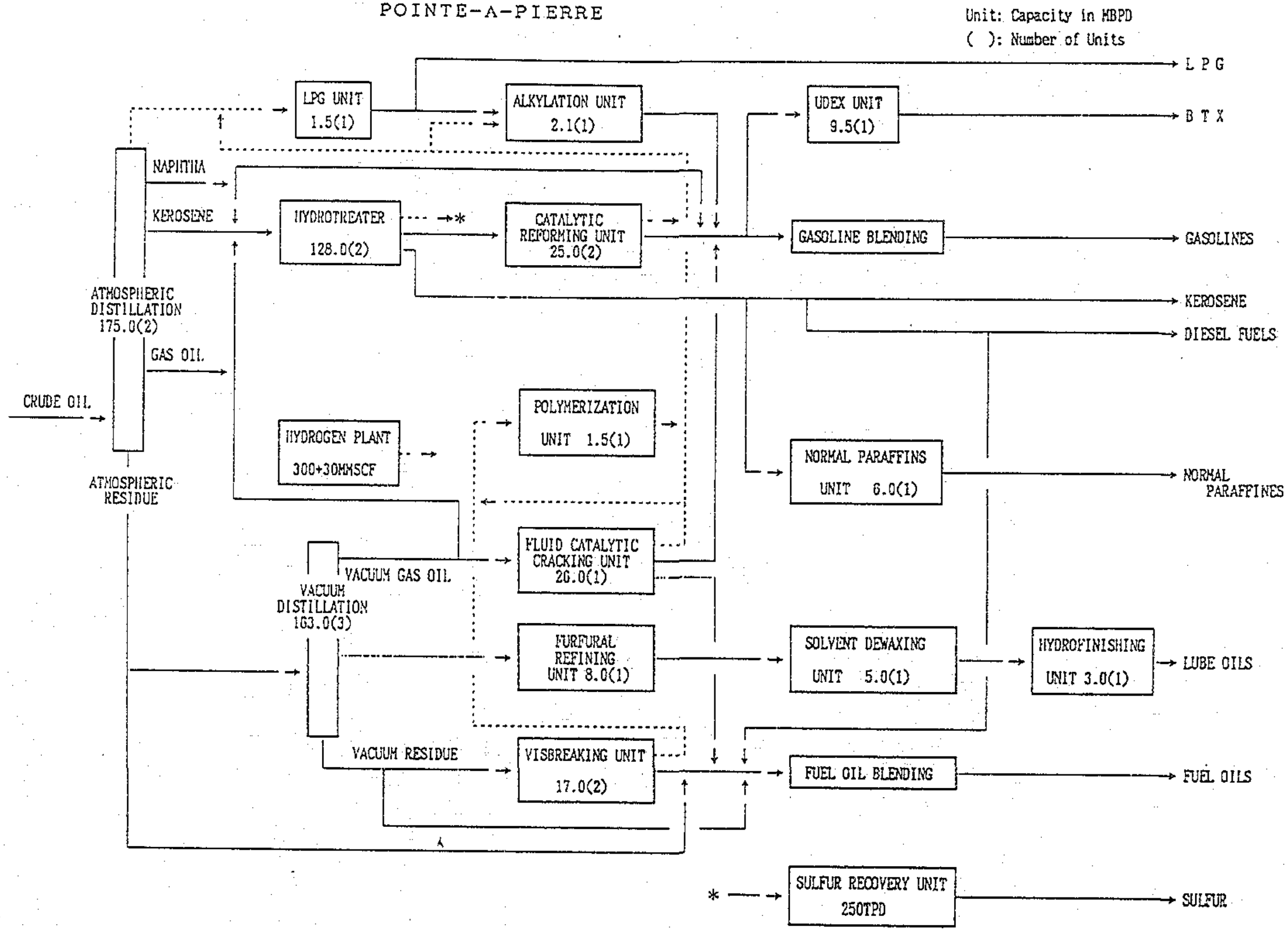
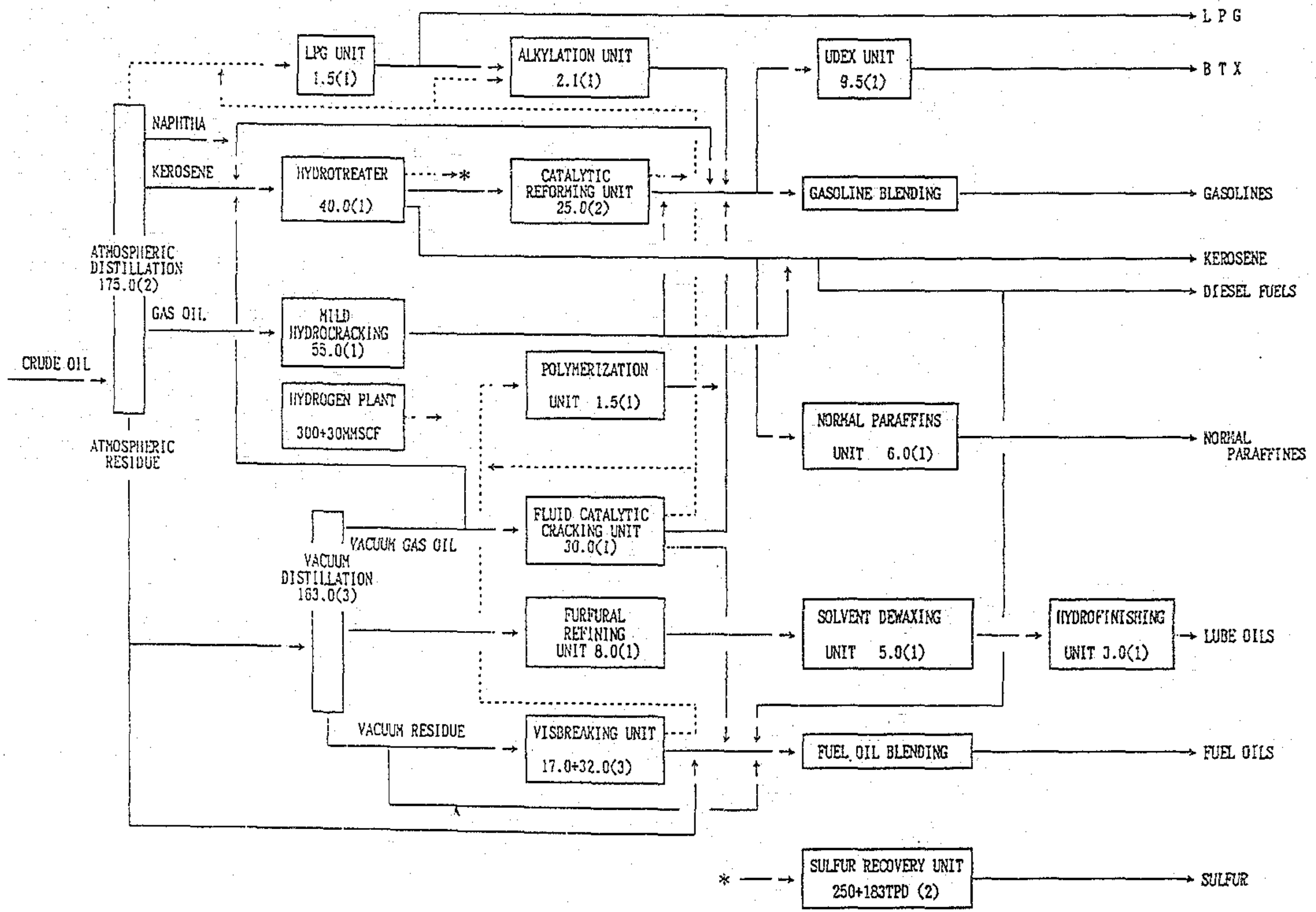


Figure 5-3 : SCHEMATIC DIAGRAM OF REFINERY PROCESSING
POINTE-A-PIERRE
After Upgrading Works Completed in 1995

Unit: Capacity in MBPD
( ): Number of Units



5−2 Present Status of Environmental Conservation at Refineries

(1) Emission Standards

1) Present Status

The Government of the Republic set the target of 50ppm as the monthly average oil and grease limit in the refinery effluent water on June 1, 1990. However, no other emission standards have been determined so far, with respect to water effluent and atmospheric emission.

While the establishment of standards other than oil and grease in water effluent was regarded as premature at the Workshop of the Ministry of Energy and Energy Industries in May 1992, TRINTOC proceeded to monitor the items listed in Table 5−3. Among these items, monitoring of pH, temperature, dissolved oxygen, oil and grease, dissolved solids, suspended solids, ammonia and sulfides were monitored at the outlets of API separators of both refineries in a six-week programme in 1992.

2) Movement in Future

The full monitoring programme listed for TRINTOC in Table 5−3 will be implemented in 1993 and is expected to continue till 1995. The data acquired will be used as the basis of design for the pollution protection facilities and also serve as a reference for the establishment of emission standards.

As to atmospheric emission, periodic continuous monitoring of SO_2 and H_2S concentrations at ground level is to be implemented early in 1993, as well as monitoring of CO, SO_2 and NO_x in the emission gas. Dust emission from the fluid catalytic cracking unit will be monitored after 1993. All these measurements will furnish reference data for the establishment of the emission standards. The guidelines of Latin American State Oil Reciprocal Assistance (ARPEL) have presented long term goal standards for various emissions. Noise emission stand ard will also be investigated. TRINTOC, a member of ARPEL, is making efforts to comply with the standards within 510 years.

(2) AntiPollution Facilities

1) Exhaust Gas

No stateoftheart equipment for antipollution is installed in either refinery. SOX in exhaust gas, however, is estimated to be at a low level, since clean natural gas is used as fuel, although no monitoring data is available.

2) Oily Effluent

Each refinery has four(4) API separators for the treatment of oily effluents from oil storage area and refinery facilities. Oily effluent treatment system at Point Fortin is shown in Figure 5-4. No.3 oil saver is followed by a CPI separator. Effluents from Nos.1, 2 and 3 oil savers pass through an effluent channel and flow into Gulf of Paria. At the mouth of the channel is installed an oil boom to catch spilled oil.

Figure 5-5 is a diagram of PointeaPierre effluent treatment System. No.2 API separator has an independent guard basin, while Nos.3 and 4 API separators have a common guard basin. Further, an oil boom is installed at the mouth of the Guaracara River into which both effluents flow. Besides, two(2) oil catchments for the effluents from pump house and four(4) oil catchments for those from tank farms are installed.

3) Sour Water

Sour water containing hydrogen sulfide is treated by a sour water stripper at each refinery.

(3) Effluent Flowrate and Analysis

No routine measurement of effluent flowrates is made for either refinery. Flowrate with analytical data of COD and O/G for Pointe-a-Pierre from April to July, 1992 is shown in Table 5-5. Table 5-4 gives an analytical data for Point Fortin on August 24, 1992 with design value of flowrate, since no actual data for the flowrate is available.

These data indicate 7 to 8 times higher effluent rate per barrel of throughput compared with that of Japanese refineries. Content of COD and O/G is also high, causing an environmental problem.

(4) Sources of Oily Effluent

Sources of oily effluent are tabulated in the following tables;

Point Fortin: Tables 5−6 and 7

PointeaPierre: Tables 5−8, 9 and 10

Table 5-3

PARAMETERS FOR LIQUID EFFLUENT MONITORING

EXPLORATION AND PRODUCTION DIVISION	MANUFACTURING DIVISION
* pH	+ pH
* Temperature	+ Temperature
* Oil and Grease Content	+ Oil and Grease
* Total Dissolved Solids	+ Total Dissolved Solids
* Sulphides	* Sulphides
* Dissolved Oxygen	* Chemical Oxygen Demand
* Total Suspended Solids	+ Total Suspended Solids
╪ Heavy Metals	* Phenol
╪ Polyaromatic Hydrocarbons	* Cyanide
	* Heavy Metals
	╪ Polyaromatic Hydrocarbons
	╪ Chlorinated Hydrocarbons

+ - weekly monitoring

* - monthly monitoring

╪ - specific studies

Source : REPORT ON THE ESTABLISHMENT OF TRINTOC'S ENVIRONMENTAL UNIT AND AN ACTION PLAN FOR IMPLEMENTATION OF ENVIRONMENTAL PROGRAMMES

Figure 5-4 : POINT FORTIN REFINERY EFFLUENT TREATMENT

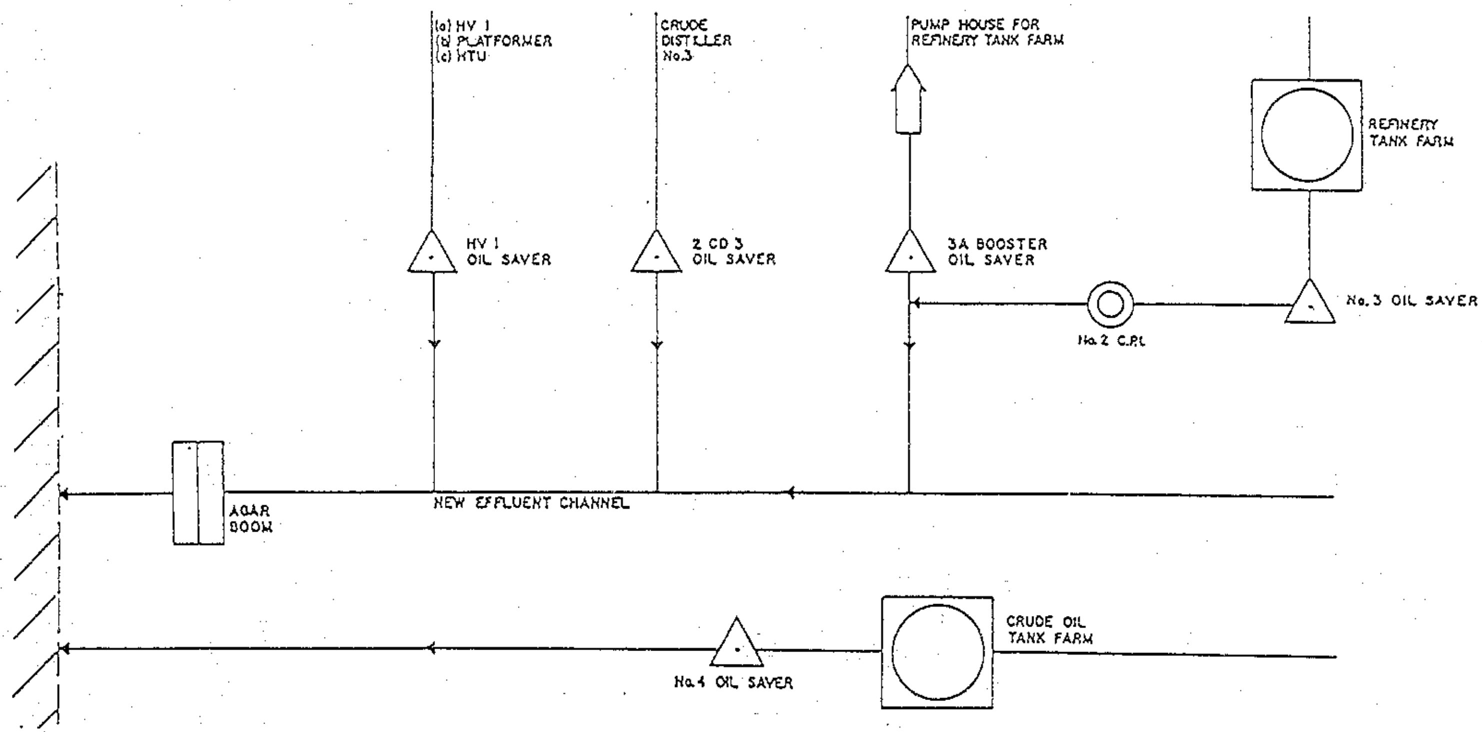


Figure 5-5 : POINTE-A-PIERRE EFFLUENT TREATMENT

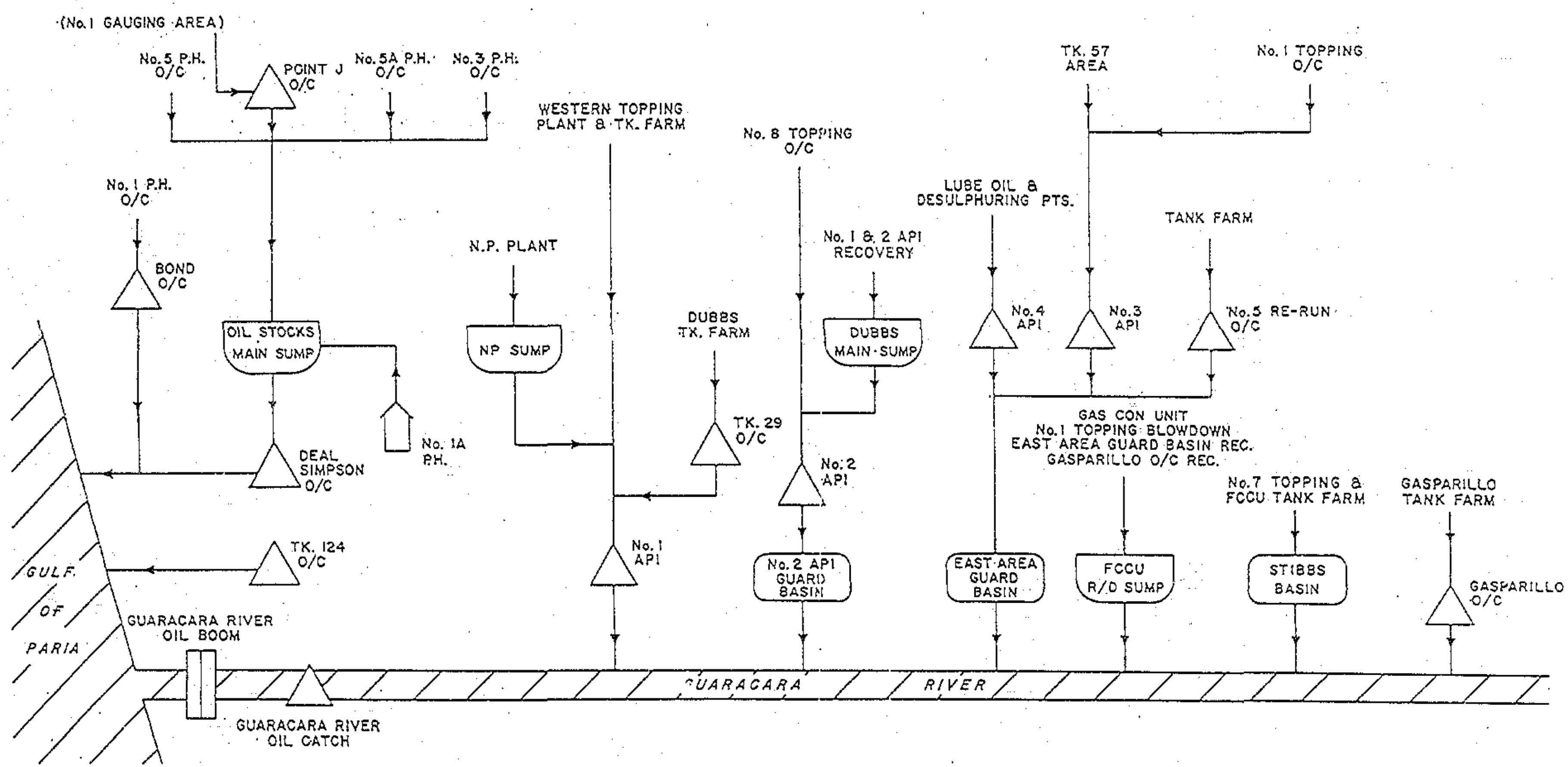


Table 5-4
POINT FORTIN EFFLUENT DATA

STATION	※1 FLOW RATE [m^3/hr]	※2 Oil & Grease [mg/]
#1 Oil Saver	379	88
#2 Oil Saver	117	25
#3 Booster and CPI Oil Saver	1,006	NA
#4 Oil Saver	452	45

※1 Design Figure Cited since no Actual Data Available.
※2 Analytical Data on August 24, 1992

Source : TRINTOC

Table 5-5
POINTE-A-PIERRE EFFLUENT DATA
(APRIL-JUNE 1992)

STATION	PARAMETER	FLOW RATE (m^3/s)	C.O.D. (mg/)	O. & G. (mg/)
#1 API	No. of samples	14	7	16
	Mean	0.041 148 m^3/hr	402	422
#2 API	No. of samples	15	7	16
	Mean	0.136 490 m^3/hr	291	406
#3 API	No. of samples	14	7	14
	Mean	0.041 50 m^3/hr	223	196
#4 API	No. of samples	14	7	16
	Mean	0.742 2,671 m^3/hr	229	176
#2 API Guard Basin	No. of samples	8	7	8
	Mean	0.150 540 m^3/hr	236	236
Total	3,899 m^3/hr			

Source : TRINTOC

Table 5 − 6: POINT FORTIN REFINERY FACILITIES (1)

REFINERY FACILITIES AT POINT FORTIN	RESPONSIBLE SUPERVISION	CHARGE IN	LIQUID WASTE TO OIL SAVER / OIL SKIMMER	OIL SAVER / OIL SKIMMER
CRUDE DISTILLATION III CD III	REFINERY OPERATIONS	Largo Treco Crude Oil / Indigenous Crude Oil	Kerosine, Gas Oil, Fuel Oil, Pump/gland leaks	# 2 OIL SAVER CD III
"	"	"	Salt Water	REFINERY EFFLUENT OIL SKIMMER
MEROX UNIT	REFINERY OPERATIONS	Light Tops from CD III, Platformer	Spent Caustic	REFINERY EFFLUENT OIL SKIMMER
UTILITIES	REFINERY OPERATIONS		Salt Water	REFINERY EFFLUENT OIL SKIMMER
HYDROTREATER UNIT HTU	REFINERY OPERATIONS	Heavy Kerosine/ Naphtha	Kerosine, Gasoiline, Pump/gland leaks pipelines	# 1 OIL SAVER COMPLEX / HV1 /NOR
"	"	"	Sour Water	TANKS R 23, R 22
PLATFORMER	REFINERY OPERATIONS	Gasoline	Gasoline, Platformate, pump/gland leaks	# 1 OIL SAVER COMPLEX / HV1 / NOR
HYDROGENERATOR HGU	REFINERY OPERATIONS	Light Avjet	Avjet, pump/gland leaks	# 1 OIL SAVER COMPLEX / HV1 / NOR
BITUMEN PLANT	REFINERY OPERATIONS	Fuel Oil	Fuel oil, Gas Oil, Bitumen, pump/gland leaks, Salt Water	# 1 OIL SAVER COMPLEX / HV1 / NOR
NAPHTHANIC OIL RESIDUE UNIT NOR	REFINERY OPERATIONS	Spent Caustic after treating gas oil	Sulphuric Acid, Spent Caustic, Salt Water	# 1 OIL SAVER COMPLEX / HV1 / NOR

Table 5 – 7: POINT FORTIN REFINERY FACILITIES (2)

TANK #	RESPONSIBLE SUPERVISION	LIQUID WASTE TO OIL SAVER/ PIT	OIL SAVER/ PIT
1 - 11	INSTALLATION & SHIPPING	Crude Oil & Slop Oil bleeds	# 4 CRUDE OIL SAVER
46	INSTALLATION & SHIPPING	Naphtha, Roof bleeds	# 4 CRUDE OIL SAVER
50, 52	INSTALLATION & SHIPPING	SR Naphtha	# 4 CRUDE OIL SAVER
54, R 159	INSTALLATION & SHIPPING	Mogas bleeds	MOGAS OIL SAVER
60, 61, 62, 65 53	INSTALLATION & SHIPPING	Kerosine bleeds	# 3 BOOSTER OIL SAVER
41, 42, 43	INSTALLATION & SHIPPING	Platformate bleeds	# 3 BOOSTER OIL SAVER
71, 72, 73	INSTALLATION & SHIPPING	Light Tops bleeds	# 3 BOOSTER OIL SAVER
21, 22, 23, 51	INSTALLATION & SHIPPING	Gas oil bleeds	# 3 BOOSTER OIL SAVER
24, 26	INSTALLATION & SHIPPING	Largo Treco crude oil bleeds	# 3 BOOSTER OIL SAVER
70	INSTALLATION & SHIPPING	Wide range Naptha bleeds	# 3 BOOSTER OIL SAVER
12, 13	INSTALLATION & SHIPPING	Largo Treco crude oil bleeds	SHORE-END PIT
27, 29, 30, 28	INSTALLATION & SHIPPING	Fuel oil bleeds	SHORE-END PIT
	INSTALLATION & SHIPPING	Kerosine, Gas oil, Gasoline, Fuel Oil, Platformate	JETTY HEAD PIT

Table 5 – 8: POINTE-A-PIERRE REFINERY FACILITIES (1)

REFINERY FACILITIES AT POINTE-A-PIERRE	RESPONSIBLE SUPERVISION	CHARGE IN	LIQUID WASTE TO API SEPARATOR	API SEPARATOR/ GUARD BASIN
# 8 CRUDE DISTILLATION UNIT - CDU	NORTH AREA	Holo Crude oil/ Largo Cinco Crude oil	de- oiled Water from #8 CDU Sump	# 2 API
"	"	"	Surface water	# 2 API
# 4 VACUUM DISTILLATION UNIT - VDU	NORTH AREA	Reduced Crude from Holo crude	Kerosine stripper Vapour, Gas Oil Tower condensate Vapour, Hot well Vapour, pump leaks -small, Sour water	# 4 API
"	"	"	Salt Water, traces of hydrocarbons due to leakages of overhead pipelines	RIVER KWAI
# 3 VACUUM DISTILLATION UNIT - VDU	NORTH AREA	Reduced crude from Largo Cinco	Salt water, light hydrocarbon vapour, steam, effluent from Hot well, pump bleeds	# 4 API
FURFURAL RECOVERY UNIT - FRU	NORTH AREA	Vacuum Gas oil	None - closed system, if any discharge however, pump bleeds	# 4 API
METHYL ETHYL KETONE UNIT - SDU	NORTH AREA	Refined oil	Closed system - if any discharge however, pump bleeds	# 4 API

Table 5 − 9: POINTE-A-PIERRE REFINERY FACILITIES (2)

REFINERY FACILITIES AT POINTE-A-PIERRE	RESPONSIBLE SUPERVISION	CHARGE IN	LIQUID WASTE TO API SEPARATOR	API SEPARATOR/ GUARD BASIN
# 1 CATALYTIC REFORMING UNIT - CRU	SOUTH AREA	Straight Run Gasoline, Naptha	Fresh water with traces of Gasoline, Naptha, Kerosine, Gas oil	# 2 API
# 1 HYDROTREATER HTU	SOUTH AREA	Atmospheric Gas Oil/ Kerosine	Fresh water with traces of Gas oil, Kerosine	# 2 API
# 2 GIRBOTOL	SOUTH AREA	Hydrogen Sulphide Rich Gas	De-amine, light hydrocarbon gas	# 2 API
CATALYTIC POLYMERISATION UNIT CPU	SOUTH AREA	Depropaniser tops	Caustic treated , amine	# 2 API
LOW PRESSURE GAS UNIT LPG	SOUTH AREA	Propane/ Butane/ Methane	Caustic treated light hydrocarbons	# 2 API
JP -4 TREATER	SOUTH AREA	Kerosine	Spent Caustic soda, Caustic in water	# 1 API
PETRECO	SOUTH AREA	Gas Oil	Caustic soda in water	# 1 API
# 1 VISBREAKER UNIT VBU	SOUTH AREA	Resid	Salt Water, Gas oil, Kerosine, Gasoline, Heavy crude material	# 1 API
# 1 VISBREAKER UNIT VBU	SOUTH AREA	"	Salt water	# 2 API
NAPTHALIC ACID PLANT NAP	SOUTH AREA	Soap Solution	Sulphuric Acid, Caustic Soda, traces of medium hydrocarbon, NOR traces	# 1 API

Table 5-10: POINTE-A-PIERRE REFINERY FACILITIES (3)

REFINERY FACILITIES AT POINTE-A-PIERRE	RESPONSIBLE SUPERVISION	CHARGE IN	LIQUID WASTE TO API SEPARATOR	API SEPARATOR/ GUARD BASIN
FLUID CATALYTIC CRACKING UNIT FCCU	EAST AREA	Vacuum Gas Oil	De-oiled water from FCCU Run Down Sump, Surface water from FCCU	East Area Guard Basin
GAS CONCENTRATION UNIT	EAST AREA	Compressed Gasoline, FCCU distillates, HP gases	Surface water, leakages from pumps, Caustic soda, Sour Water	East Area Guard Basin
D3 COLUMN	EAST AREA	Slop oil	pump glands leaks, acidic water	# 3 API
D4 COLUMN	EAST AREA	Phoenix Park Condensate	light hydrocarbons	# 3 API
ALKYLATION UNIT	EAST AREA	Butane, Butelyne	Alkylation bottoms, pump bleeds, caustic soda, sulphuric acid	# 4 API
ACID PLANT	EAST AREA	Hydrogen Sulphide	Amine, condensate, Hydrogen sulphide, weak sulphuric acid	PIT
# 1 CRUDE DISTILLATION UNIT - CDU	EAST AREA	Molo Crudè Oil	Medium hydrocarbons, pump leaks if any	# 4 API
# 1 VDU	EAST AREA	Reduced crude	Kerosine, Salt water, Light hydrocarbons	# 4 API

5－3 Present Status of Environmental Pollution at Refineries

(1) Oil Spill Incidents in the Past

Table 5－11 is a summary of oil spill incident statistics compiled by the Ministry of Energy. The table includes oil spills from onshore and offshore oil fields, crude oil tank terminals, pipelines and refineries, but does not include natural seepage.

Oil spill incidents from 1986 to 1988 are exceptionally high both in frequency and quantity. In 1986 Pointe－a－Pierre suffered two(2) oil spill incidents as outlined in the table. The worst one occurred on July 20 when ground subsidence caused a crack at the bottom of a storage tank. About 6.2MB of fuel oil spilled out to the sea damaging fisheries near Icacos peninsula.

Since 1989 the incidents reduced both in frequency and quantity, but still are at a high level considering the throughput of crude oil. Further, these data are only those reported to the Ministry; chronic oil spills through daily operation should be added to this record.
During this period no oil spills were reported from Point Fortin.

(2) Present Situation of Oil Pollution from the Refineries

No incidental oil spill has been reported from either refinery since 1987. Therefore, chronic oil spills from the refineries have been studied on the basis of daily operation and maintenance of the facilities as stated below;

1) Quantity of Oily Effluent from Refineries

Table 6－1 in the following section shows the calculated amount of oil and grease in the refinery effluent. Effluent from PointeaPierre contains 220.6ppm of oil and grease, equivalent to 126.5BPD of oil lost out of the refinery. That from Point Fortin is 56.3ppm, equivalent to 18.7BPD of oil lost.

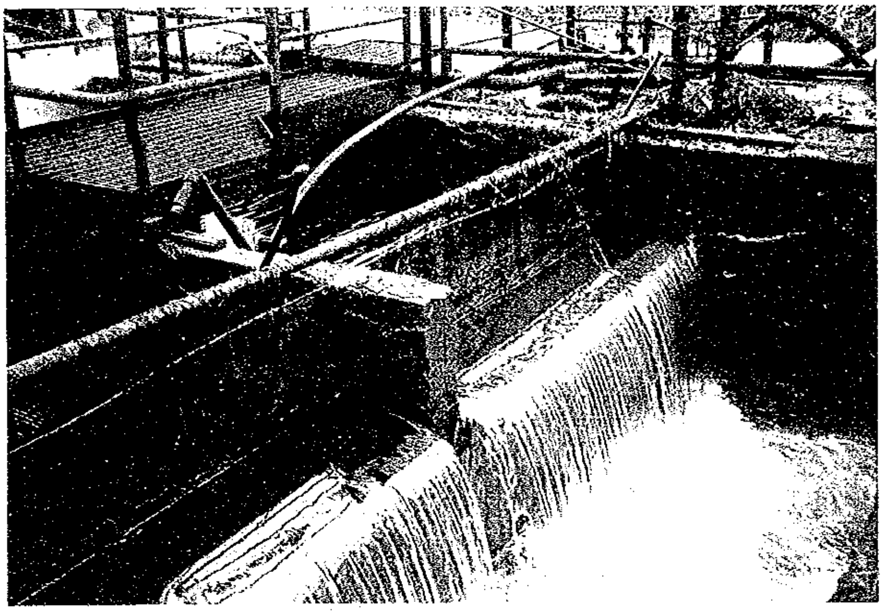
These figures are considerably higher than Japanese ones. In Japan, the National Regulation is 5 ppm maximum, average performance is 0.6ppm.

2) Current Situation of Effluent Treatment Facility

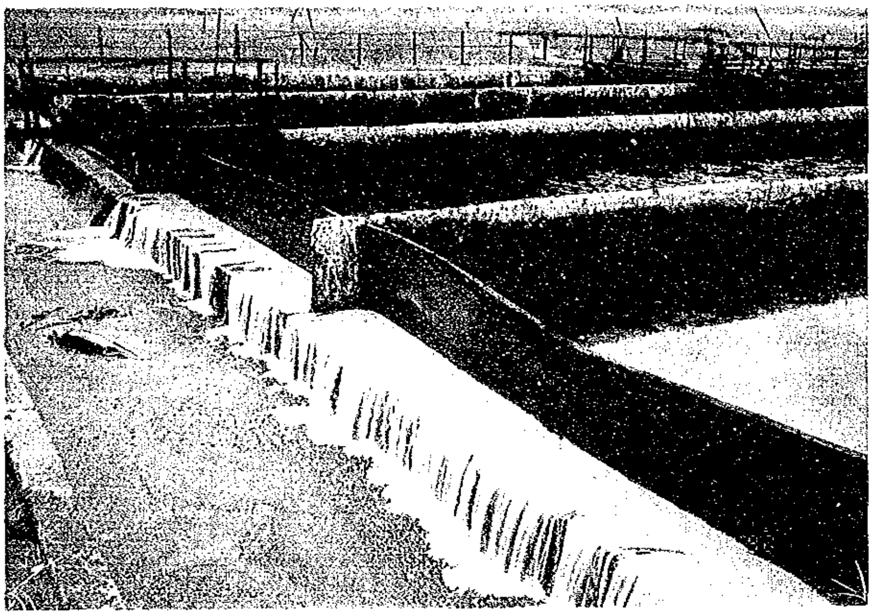
Main effluent treatment facilities in both refineries are API separators of gravity separation type with low separation efficiency. The following photos illustrate the performance of the separators;

a) Effluents from API separators of Pointe-a-Pierre are contaminated with floating oil mass as seen in the photos on the following pages.

Outlet stream from Nos. 3 and 4 API separators. The mark of black oil on the banks suggests incidental oil spills.

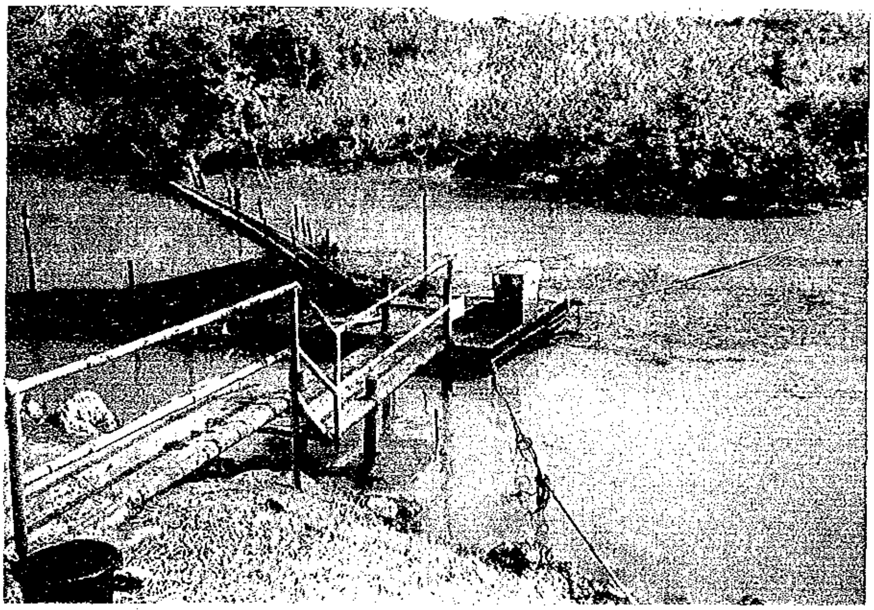


No. 2 API separator outlet. Oil is floating on the overflow weir.



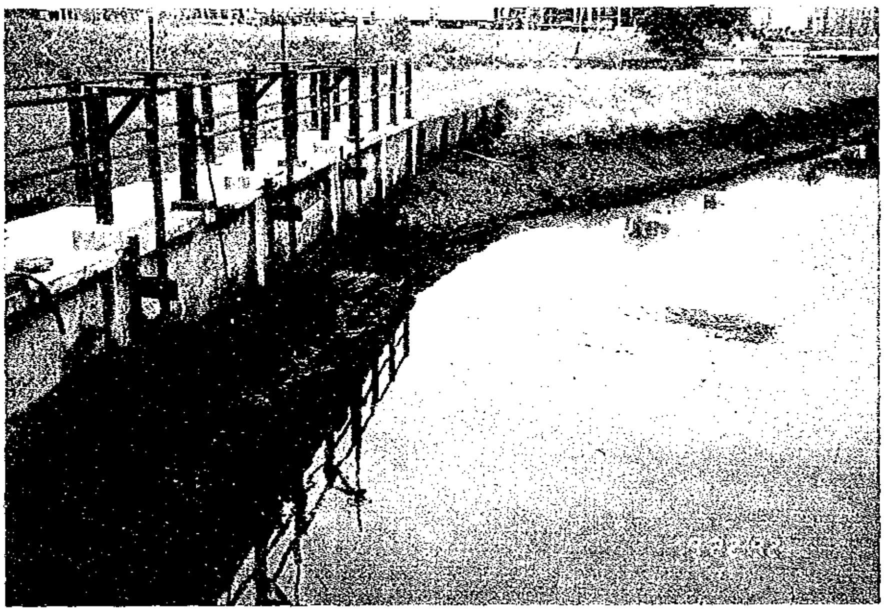
No. 1 API separator. Effluent is of milky, dark emulsion.
Also some floating oil.

b) The photo below is the oil boom at the outlets of Nos. 1,2 and 3 oil savers of Point Fortin. A mass of oil is trapped in the oil catch and a part of the oil passes through the boom and flows out to the sea.

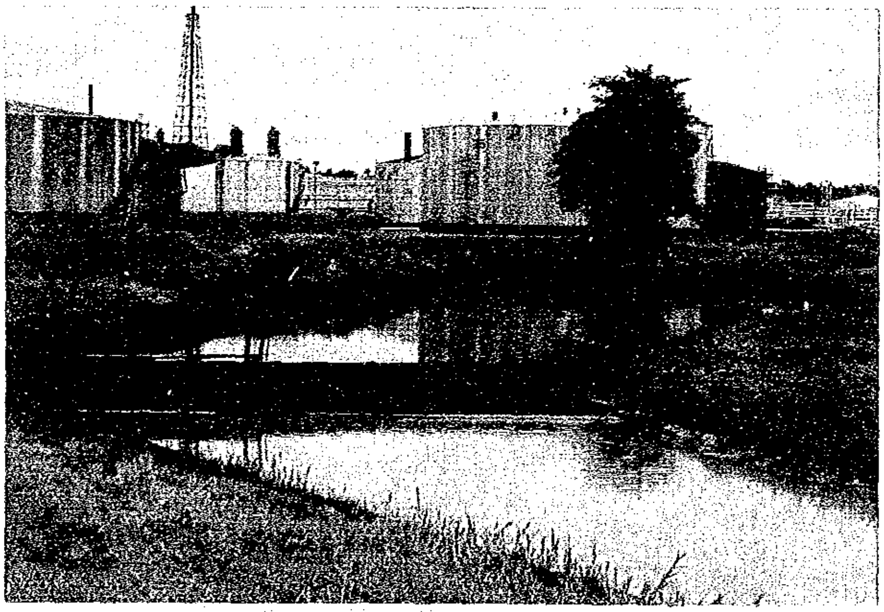


c) The black oil comes from crude/fuel oil storage, slop oil storage, crude distillation unit, desalter, vacuum distillation unit and visbreaker.

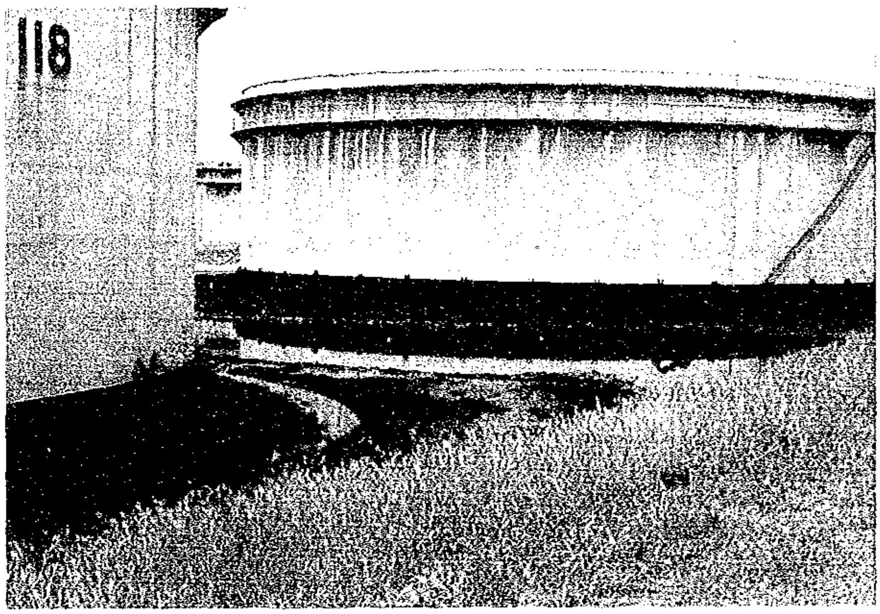
d) Guard basin is a unit where treated effluent and clean water are mixed and discharged out of the battery limit. However, as seen in the following photos, floating oil is observed at the outlet of the guard basins. Also, the oil mark on the bank indicates incidental oil spills.



East area guard basin at PointeaPierre



Guard basin for No. 2 API separator at PointeaPierre e) There are also oil spill marks on the banks of oily sludge pits and crude storage tank farms. Probably oil has spilled out during heavy rain. Also noticed is a quantity of oil puddled around some crude tanks, which was caused by a failure of sump pump. (photo below)



f) In summary, most of oil pollution from the refineries is due to insufficient effluent treatment, amplified by incidental oil spills.

3) Presumed Cause of Insufficient Effluent Treatment

Oil and grease content in the current effluent from both refineries does not meet the target value of 50ppm even under normal operation. In addition, oil pollution is further amplified by occasional incidents of oil spills.

The presumed causes of insufficient oil separation from effluent are as follows:

a) Insufficient separation of water from crude oil at oilfields;

Water content is as high as 2% in the crude oil from the oilfields where enhanced oil recovery (EOR) process is employed. This makes the

separation of water (bleeding operations) at the crude storage in the refinery difficult and it also overloads API separators.

b) The load of API separators is, additionally increased further by stormy rain.

c) Improper discharge operation of water out of the crude oil storage (excess oil may be associated with bleed water).

d) Improper desalter operation (oil was observed in the effluent during the visit by the study team).

e) Improper maintenance of API separators. (sediment or sludge, leakage, etc.)

f) Improper design of API separators and sewer system (introducing rain water into oily effluent system, improper geological level arrangement, etc.).

Table 5-11

OIL POLLUTION STATISTICS 1985~1992 AUG

Year	Spill Incidents	Oil Spilled in bbl	Oil Recovered		Oil lost to environment in bbl
			in bbl	%	
1985	90	13,700	12,400	90	1,300
1986 ~1988	609	65,615	47,240	72	18,375
Yearly Average	(304	32,808	23,620		9,188)
1989 ~1992Aug.	193	4,306	1,738	40	2,568
Yearly Average	(54	1,200	482		713)

DATE	REFINERY	SPILL INCIDENT	OIL SPILLED	SPILLED OIL IN BBL	RECOVERED OIL IN BBL
1986. 7.20	Pointe-a-Pierre	No.71 Fuel Oil Tank(22,600Kl) Leakage due to Crack of Bottom Corner	Fuel Oil	24,684	18,513
1986.11.19	Pointe-a-Pierre	Leakage from 10" Heavy Gas Oil Pipeline	Desulf. Heavy Gas Oil	1,170	1,140

Source : MINISTRY OF ENERGY

5－4 Environmental Conservation Direction at Refineries

Although further study is essential for the establishment of pollution preventive measures for the refineries, the following recommendations might be helpful to establish the concept of improvement. Integrated effects of the following items would lead to improved environmental conservation.

(1) Enhancement of Operator Training

Enhancement of operator training for proper operation and maintenance of the equipment is essential for minimizing pollution problems. Priority should be addressed for operators to be conscious of environment protection while performing their daily work.

(2) Establishing Operation/Maintenance Standards

Establishment of operation/maintenance standards is also important. Especially, establishing standards for crude tank bleeding operations or skimming operations and removal of sludge in API separators will minimize oil pollution.

(3) Detailed Study for Proper Selection of Emulsion Breaker

Proper selection of emulsion breaker, as well as determination of proper addition rate might reduce emulsion problems in bleed water from crude storage and effluent from the desalter.

(4) Modification of Equipment and Instrumentation

The following equipment should be examined for modification or new installation.

1) Slop oil tank

In case that satisfactory separation of oil is difficult in crude storage bleeding operations, installation of a slop oil tank may be of a help.

Drain water containing oil is first sent to the slop oil tank where emulsion breaker is added for better separation.

2) Depurator

Installation of a depurator will also be useful for better separation of oil from desalter effluent. Figure 5−6 is a flowsheet of a depurator.

The principle of the depurator is separating oily mud with air bubbles, which are generated by agitating effluent water containing oily mud with air. Oil and scum are skimmed and recovered from the effluent. Addition of chemicals may promote the separation efficiency.

3) Separation of Storm Water Drainage System from Oily Effluent System

4) Modification of existing API separators

Existing API separators should be examined carefully for treating capacities and a modification plan should be established based on the examination.

Generally speaking, API separators can recover oil droplets larger than 150 m. Oil droplets smaller than 150 m therefore pass through the API separators. In normal practice, API outlet concentration of oil and grease is approximately 30 ppm when inlet concentration is about 1, 000ppm. To meet the standard value of 50 ppm is possible with API separator alone if oil in the effluent exists in the form of large droplets and does not form emulsion.

If the effluent is in the form of reverse emulsion, it is necessary to break chemically or physically before it is introduced to API separators. Gravity separation processes like API separators are usually called primary treatment.

5) Dissolved Air Flotation Facility

Dissolved air flotation handles water after primary treatment (oil and grease 1030 ppm) to reduce the content to 25ppm. If it is proved difficult to meet the target of 50ppm with API separators alone, installation of a dissolved air flotation facility may be considered.

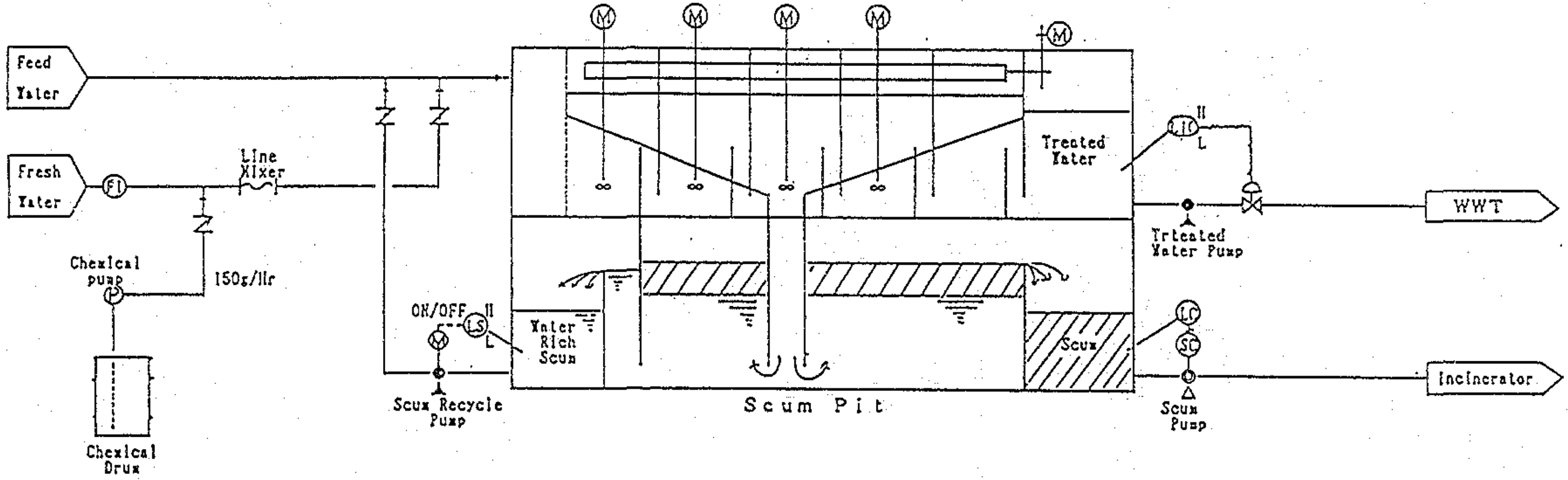
6) Modification of Instrumentation

Recent progress in instrument design permits improved detection of an oil/water interface, using an electrostatic probe rather than a conventional gravity sensor. Such a device might help better operation of desalters, etc.

In 1992 TRINTOC established an independent Environmental Section within the Safety, Environmental and Fire Services Department. Table 512 shows the action plan for the implementation of environmental programmes. The Workshop on Prevention of Chronic Oil Pollution recommended programmes for the improvement of environment by 1995 – 1996 when the upgrading project funded by IDB is completed. The outline of the programmes includes implementation of environmental monitoring (air and water), establishment of corporate standards (air, water and noise), separation of storm water and improvement of water treatment facilities.

It is recommended that improvement of facilities and enhancement of operation/ maintenance technology management be implemented taking the action plan into consideration.

Figure 5-6 : DEPURATOR FLOWSHEET



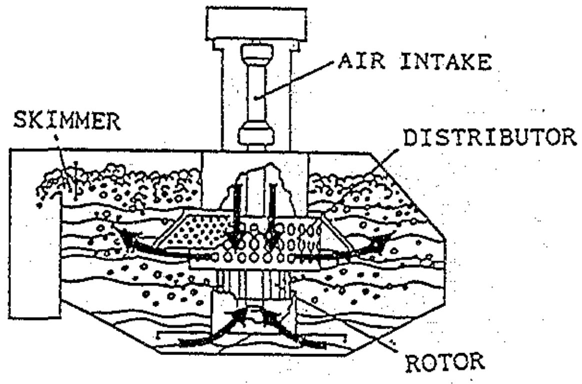


Table 5-12

ACTION PLAN FOR THE IMPLEMENTATION OF ENVIRONMENTAL PROGRAMMES AT TRINTOC

ACTIVITY	Targeted Completion/Implementation Date			
	1992	1993	1994	1995
1. Monitoring & Control Programmes				
a) Liquid effluent monitoring	Aug.			Dec.
b) Gaseous effluent monitoring				
(i) Ground Level Conc of H_2S/SO_2	Aug.			Dec.
(ii) Exhaust Gas Conc. of $CO/SO_2/NO_2$	Nov.			Dec.
(iii) Particulate Emissions		Mar. - Ongoing		
c) Control Programmes				
(i) Fugitive Emissions	Dec.			
(ii) Segregation of Stormwater flows from process flows			Dec.	
2. Solid Waste Management Programmes				
a) Quantification and characterization of oily solid wastes	Dec.			
b) Disposal of oily wastes				
(i) Establishment of landfarm site at Pointe-a-Pierre		Dec.		
(ii) Establishment of landfarm for E&P operations		June		
c) Management Plan for Pointe-a-Pierre Foreshore landfill and disposal of Solid Wastes		June		
d) Location of landfill site for disposal of solid wastes from Point Fortin		June		
3. Environmental Training Programme				
a) Training Environmental Unit Staff	Sept.			
b) Development of Training Packages	Oct.			
c) Training of line Managers and Operators	Oct.		Mar.	
4. Standard Limits for Liquid, Gaseous and Noise Contamination				
a) Development of Company Standards for				
(i) Oil & Grease (in conjunction with Ministry of Energy)	June			
(ii) Other Liquid Parameters (ARPEL Standards)	June			
(iii) Gaseous Effluents				June
(iv) Noise				June
b) Compliance with Standards for				
(i) Oil & Grease				June
(ii) Gaseous Emission				June
(iii) Noise				June
(iv) Other Contaminants in Liquid Wastes	five to ten year timeframe			
5. Procedures for the Prevention of Chronic Contamination				
a) Identification of Sources of Chronic Pollution	Oct.			
b) Development of Alternative Operation procedures in Pollution Control	Oct.	June		
c) Implementation of Procedures for the prevention of chronic contamination		June		
d) Implementation of Spill-Clean-up Standard		June		

Source: TRINTOC

6. WASTE WATER TREATMENTS

6-1 Waste Water Treatment at Petroleum Oil Field

Outlines of waste water treatments relevant to petroleum and natural gas production onshore and offshore in Trinidad and Tobago are described in preceding section. Generally oil fields are mature, aged and superannuated, and produced crude oil is of low gravity and associated with large quantities of water as enhanced oil recovery is practiced by injecting river water, sea water or steam. Crude oil forms reverse emulsions in water, and this forms a layer which is rather stable and difficult to break. Separated water is discharged containing reverse emulsion of high oil concentration as well as with floating crude oil itself on the surface of waste water. Thus petroleum is dispersed into the sea through public river water. Furthermore, in Trinidad and Tobago there are frequent tropical storm showers which disperse petroleum pollution by flooding oil separators as well as guard basins. Emulsion and floating crude oil is spread over large areas onshore, on beaches and on sea water itself.

Sources of petroleum pollution are distributed widely in the oil fields in the sout hern region of Trinidad. A portion of this pollution is extended to swampy land. Petroleum pollution starts with onshore oil fields, oil separators and guard basins, and then proceeds through small and medium scale rivers in turn to ocean. During the preliminary study in September, 1992, the study team took and measured COD (Mn) on a limited number of spot samples to make an estimate of the total volume of petroleum pollutants. The measurement data of oil and grease in waste water at Penal, Barrackpore and Guayaguayare of one sample in every month from September 1991 to August 1992 measured by the Government authority were available and are summarized in the preceding section. The data fluctuates widely with maximum of 2,600 ppm and minimum of 40 ppm. However, as the concentration data of oil and grease is not accompanied by estimated flow rates of the rivers, it is impossible to make any clear estimate of the total pollutant discharged from onshore petroleum producing fields. It was considered not appropriate to estimate at this stage the total pollutant discharged from oil fields onshore and offshore, or to discuss and predict the pollutant distribution of 210 BPD of oil, which is an estimate of total chronic petroleum pollution by the Government authority. However, it is clear that the pollution by petroleum offshore is minor compared to that of onshore.

6－2 Waste Water Treatment at Refineries

In Trinidad and Tobago, two petroleum refineries are owned and operated by TRINTOC in Point Fortin and Pointe－a－Pierre. Operating throughput in 1992 averaged 41 MBPD at Point Fortin, cosuming mostly imported crude oil from Venezuela, and 88 MBPD at Pointe－a－Pierre, consuming mostly domestically produced crude oil.

Waste water treatment system at Point Fortin consists of 3 units of oil savers plus 1 unit of corrugated plate interceptor and final treatment is carried out at an oil catch at the mouth of the Refinery Channel where it enters the Gulf of Paria, while at Pointe－a－Pierre the system consists of 4 units of API separators and waste water is finally treated with an oil catch at the mouth of Guaracara River. The oil and grease concentrations in waste water at both refineries are higher as reverse emulsion and further floating heavy oil mass on the surface of the waste water goes through separators.

The analytical data of oil and grease in waste water at both refineries were determined at CARIRI during August, 1992 but the flow rates at Point Fortin are missing. Therefore petroleum pollutant volume is estimated by applying design flow rate of separators.

The basic data is summarized in Table 6－1 which shows the average analysis of oil and grease are 56.3 ppm at Point Fortin and 221 ppm at Pointe－a－Pierre. These figures are higher than 50 ppm which is the monthly average standard established by the Government.

Waste water is discharged into the Gulf of Paria (current direction in the Gulf is clock wise), polluting both sides of the mouths of rivers and the southern beaches of the Gulf as waste water goes through the oil catch in the Refinery Channel in Point Fortin and the Guaracara River in Pointe－a－Pierre.

Table 6-1: WASTE WATER FROM REFINERIES IN TRINIDAD AND TOBAGO

Items	Refineries in Trinidad and Tobago									
	Pointe-a-Pierre					Point Fortin				
1. Operating Rate, MBPD	88					41				
2. Oil Separator	No.1 API	No.2 API	No.3 API	No.4 API	Average, Total	No.1 Saver	No.2 Saver	No.3 Saver	No.4 Saver	Average, Total
3. Waste, Water, MTPD	3.54	11.75	1.21	64.11	80.61	9.10	2.81	24.14	10.85	46.90
4. COD, mg/l	402	291	223	229	246	na	na	na	na	na
5. Oil and Grease, mg/l	422	406	196	176	221	88	25	53	45	56.3
6. SS, mg/l	na	na	na	na	na	23	27	4	4	4.7
7. Discharge River	Guaracara River					Agaar River				
8. Final Discharge	Gulf of Paria					Gulf of Paria				

Sources : CARIRI, August 24, 1992

6−3 Petroleum Pollution at Refineries

It is not easy to access internationally objective data on the waste water treatment method at refinery and waste water qualities. In this study report, waste water environmental guidelines proposed by the World Bank and the national averages for waste water qualities of all refineries in Japan are referred to to make fair comparison with the present pollution status at the refineries in Trinidad and Tobago.

Basic environmental indices for Japanese refineries are summarized in Table 6−2. National waste water discharge standards for oil and grease in Japan is 5.0 ppm while past performance in 1989 recorded an annual average of 0.6 ppm and daily maximum of 0.76 ppm which is compared with 56.3 ppm at Point Fortin and 221 ppm at Pointe−a−Pierre in Trinidad and Tobago. Further it is noted that the ratio of oily waste water volume to refinery petroleum throughput is 0.078 TPB in Japan while 0.920 and 1.146 TPB in Trinidad and Tobago. Therefore the discharge of oil and grease per thousand barrels of refinery throughput averaged 0.34 B/MMB in Japan and 457 B/MMB at Point Fortin and 1,438 B/MMB at Pointe−a−Pierre in Trinidad and Tobago.

In Table 6−3, environmental guidelines of the World Bank, Japanese environmental load and the present status of Trinidad and Tobago are compared. The statistics indicate that not only is the oil and grease concentration higher in Trinidad and Tobago than in Japan, but also the volume of oily waste water per thousand barrels of crude oil throughput is higher. Therefore, the unit discharge of oil and grease is much higher in Trinidad and Tobago.
Total oil and grease pollution at refineries is 145.2 BPD which is fairly comparable to the chronic pollution of 210BPD estimated by the Government. Also, emission from petroleum fields must be added to the estimate.

Table 6-2 : ENVIRONMENTAL POLLUTANTS DISCHARGE FROM TOTAL REFINERIES IN JAPAN
(Statistics for 1989)

Number of Companies	Number of Refineries	Crude Oil Throughput, MMkℓPD	Discharge Water, MMTPD			Analysis, mg/liter of Oily			Notes
			Oily	Clean	Total	Oil and Grease	COD	SS	
1. Discharge Water									
9 (Normal)	45	0.51(3.19 MMBPD)	0.25	6.09	6.35	0.60	2.81	4.73	Annual Average
		Rated Capacity	0.40	6.59	7.45	0.76	5.97	9.73	Daily Maximum
8 (Special and Integrated)	32	=4.13MMBPD	na	na	0.31	na	25.0	na	Annual Average
			na	na	0.41	na	33.0	na	Daily Maximum
						5.0	120.0	150.0	National Regulation, Daily Average
						5.0	160.0	200.0	National Regulation, Maximum

2. Raw Water Supply and Consumption, MMTPD

9 28

Source	Process	Cooling	Boiler	Municipal	Others	Total
Municipal	0.001	0.001	0.000	0.011	0.001	0.014
Industrial	0.089	0.476	0.166	0.021	0.051	0.803
Recycled	0.014	5.666	0.029	-	0.007	5.717
Sea Water	0.001	5.501	0.000	-	0.005	5.501
	0.105	1.164	0.195	0.032	0.064	2.040

3. Flue Gases Exhaust

28 45

Discharge Flue Gas MMNm³/Day	Analysis SOx, ppm	NOx, ppm	Dust, mg/Nm³	Notes
23.65	198.4	106.0	22.0	Annual Average
38.99	272.5	154.0	43.0	Daily Maximum

* National Regulation is not applicable for exhaust gas analysis directly

4.Solid Wastes, MTPY

17 24

Oil	Sludge	Waste Catalyst	Furnase Dust	Fuel Ash	Waste Acid	Waste Alkaline	Metal Wastes	Construction Wastes	Total
15.2	3.2	6.9	74.5	1.9	18.5	22.8	4.8	26.2	174.0

5.Refinery Area, MMm²(%)

29 45

Green Area	Other Environmentals	Production	Total
3.96	0.42	35.27	43.5
(9.0)	(1.0)	(80.4)	(100.0)

Sources : Various Study Reports

Table 6-3 : POLLUTANTS IN REFINERY EFFLUEN.

Items	Unit	Trinidad and Tobago, 1992		Japan, 1989	World Bank Guidelines, 1988			
		TORINTOC	TRINTOC	Whole	Conventional Process		State-of-the-Art Process (1)	
		Pointe-a-Pierre	Point Fortin	Refinery	Simple (2)	Complex (3)	Simple (2)	Complex (3)
1. Crude Oil Throughput	MBPD	88	41	3,190	6.29	6.29	6.29	6.29
2. Oily Effluent	MTPD	81	47	250	0.093	0.235	na	na
3. Oily Effluent/Crude Throughput	TPB	0.920	1.146	0.078	0.015	0.037	na	na
4. Pollutant Concentration in Oily Effluent								
Oil and Grease	ppm	220.6	56.3	0.60	333.3	319.0	na	na
COD	ppm	245.5	na	2.81	233.0	1,400.0	na	na
SS	ppm	na	4.7	4.73	193.5	247.0	na	na
5. Pollutant Quantity								
Oil and Grease	TPD	17.87	2.65	0.15	0.031	0.075	0.003	0.007
(Oil and Grease)	(BPD)	(126.51)	(18.73)	(1.10)	(0.226)	(0.547)	(0.019)	(0.049)
COD	TPD	19.89	na	0.70	0.217	0.329	0.061	0.152
SS	TPD	na	0.22	1.18	0.018	0.058	0.006	0.007
6. Pollutan/Crude Oil Throughput								
Oil and Grease	grPB	203.1	64.6	0.05	4.93	11.93	0.41	1.07
Oil and Grease	(B/MMB)	(1,437.6)	(456.8)	(0.34)	(35.93)	(86.96)	(3.02)	(7.79)
COD	grPB	226.0	na	0.22	34.50	52.31	9.70	24.17
SS	grPB	na	5.4	0.37	2.86	9.22	0.92	2.23

Notes : Conversion factor for BPT is assumed 7.08 for Trinidad and Tobago, 7.29 for Japan and 7.30 for World Bank Guidelines.
(1) Cited as End-of-Pipe Control Technology with effective housekeeping measures.
(2) Cited as Topping plus Cracking Refinery.
(3) Cited as Integrated Refinery with Topping, Cracking, Petrochemicals plus Lube Processes.

Sources :(1) Data for Trinidad and Tobago is taken from various data provided by Ministry of Energy and Energy Industries as well as TORINTOC with minor modifications and adjustments.
(2) Date for Japan is taken from various study reports.
(3) Data for World Bank Guidelines is taken from Table 2.(Page 342) and Table 4.(Page 344) of Environmental Guidelines, Environment Department, The World Bank, September, 1988.

6－4 Environmental Conservation Direction at Waste Water Treatment

The largest source of petroleum pollution in Trinidad and Tobago is the formation of reverse emulsion of petroleum with associated water and floating oil mass at petroleum fields (especially onshore) flowing out of gravity separators to rivers, swamps and then dispersed in sea water. It is considered that the major reasons for pollution are large amounts of associated water produced with crude oil, insufficient demulsifier performance and the flooding of oil separator by tropical storm water.

At the refineries, indigenous crude oil received contains 2% of water in the form of normal emulsion and this results in excessive bleeding of crude oil with water at crude storage tanks, as well as in inadequate water separation at the desalter and gravity type oil separators causing them to pass through emulsion and floating heavy oil mass. The effluent volumes of oily waste water is excessive and inflow of storm, water creates flooding of oil separators and washes out the petroleum pollution into rivers and the sea.

The most effective countermeasure to reduce petroleum pollution is the improvement of waste water treatment facilities. The following approaches will in general promote prevention of petroleum pollution:

a) Reduction of the volumes of produced and inflow water, and increased recycling of waste water.
b) Effective use of demulsifiers to improve oil and water separation.
c) Formation of large sized droplets of petroleum in emulsions.
d) High temperature, longer retention at settling tank and bubble flotation for oil separation.
e) Addition of filtration and physical demulsification.
f) Biological treatment such as that using activated sludge.

g) Optimized designing of pollution prevention facilities as well as the enhancement of technology levels in operations and maintenance.

h) Improvement of geographical configuration of gravity type oil separator and prevention of inflow of storm, rain, cooling and miscellaneous waste water.

i) Reinjection of waste water.

j) The optimization and integration of waste water separation systems at onshore oil fields, tank farms and refinery storage tanks. High associated water content in crude at oil fields and high residual water content in crude at refinery are the major reason for petroleum pollution in Trinidad and Tobago. These two oil separations should be optimized and integrated.

In Table 6－4, factors relative to oil separation are summarized. Electrostatic charge, surface tension, temperature, salt concentration and other conditions of emulsion (normal and reverse) are essential factors for oil and water separation. It is expected that further detailed and elaborated study should be implemented to establish the most optimized and integrated pollution prevention system in Trinidad and Tobago.

Table 6-4 : DESIGN BASIS AND PERFORMANCE OF OIL SEPARATOR

Oil Separator Type	Applicable Oil Droplet Diameter in Micron[1]	Oil Content mg/l Out/In	Flow Speed m/min	Oil Droplet Rising Speec mm/sec	Notes
1. Gravity Separator					
- Settling Tank	200+	50-/1,000	—	—	—
- API: American Petroleum Institute	150+	30-/1,000	0.9	0.9	Rectangular
- PPI: Parallel Plate Interceptor	100+	10-/1,000	0.6	0.2	Parallel Plates
- CPI: Corrugated Plate Interceptor	60+	10-/1,000	0.3	0.2	Corrugated Plates
2. Heater - Treater					
- Vertical Heater - Treater					—
- Horizontal Heater - Treater					—
- Electrostatic Treater					Chemeletric, Electrochemical
3. Coalescer	15+				Fine Tubing
4. Flotation	15+				Contact Angel
- Pressurized Air Flotation					
- Vertical Type					
- Horizontal Type					
- Dispersed Air Flotation					
- Ion Flotation					Anionic Surfactants
- Precipitation Flotation					Cationic Surfactants
- Bentonite Method					
- Electrolytic Flotation					H_2 and O_2 gases
5. Clarifying Filtration	3+				
- Sand Filter					
- Anthracite					
- Granite					
- Pressure Filtration					
- Multilayer Filtration					
- Upflow Type Filter					
- Upflow/Downflow Type Filter					Anthracite/Sand/Graval
6. Bubble Flotation	1.5+				
7. Activated Carbon Adsorption	1.5-				
8. Demulsifier Addition					
- Multivalent Metal Coagulation	1.0-				
- Organic Chemicals	1.0-				
- Heating and pH Adjustment	1.0-				
9. Electrolysis	1.0-				Petrolite Oil Field Chems, Howe-Baker Engrs Inc. 40-150° C, 2.8 atg, 0.005 kWh/B
10. Activated Sludge Method	1.0-				
11. Concentration and Incineration	1.0-				

Notes : 1) Micron = μm = mm/10^3

7. PETROLEUM SOLID WASTES TREATMENT

7－1 Present Status of Solid Waste Treatment at Petroleum Oil Fields

Main solid wastes from oilfields are oily sludge. Sand and mud in the oil layer are pumped up to the surface accompanied by oil to form oily sludge, which settles at the bottom of gathering tanks and effluent treatment facilities as a sediment. Accordingly, solid wastes from oilfields are not of daily occurrence, but are discharged at the time of cleaning and maintenance. Other wastes include floating debris from oil catches in rivers, empty bottles and drums used for distribution and marketing of petroleum products.

At present these wastes are disposed or landfilled within the oilfield area. The place of landfill is naturally dirty, but since the location is limited within the area, environmental pollution problems are hardly recognized. However, it is not certain that the location of disposal or landfill has been checked for the possibility of secondary pollution, that is, contamination of underground water, overflow to the river or to the sea in case of heavy rain, etc.

7－2 Present Status of Solid Waste Treatment at Refineries

In the refineries, the main solid wastes are oily sludge consisting of polymer or residue, waste catalyst, floating debris from oil catches similar to ones from oilfields, empty bottles and drums.

Again, these wastes are discharged at the time of cleaning and maintenance of the equipment.

The method of disposing these wastes is by landfill, as in the oilfields.

7－3 Environmental Pollution by Petroleum Solid Wastes

(1) Oilfields and Refineries

As stated above, no significant pollution by petroleum solid wastes is recognized at present. However, due consideration should be paid to disposal or landfill operations to avoid secondary environmental pollution as stated in 71, especially for the refineries, which are located close to the sea.

(2) Waste Lube Oil

Waste lube oil is another waste related to the petroleum industry. Estimated amount of waste lube oil in Trinidad and Tobago is about 4 KL/D. The source of waste lube oil is gas stations where lube oil is changed in moter vehicles.
Gas stations are equipped with oil traps in the drains. But since the oil recovery system is not established, they do not recover oil from the trap and let it out to the public sewer system.

In Trinidad and Tobago fuels such as gasoline and lube oil are marketed solely by National Petroleum Marketing Co.(NPMC), Consequently, all gas stations in Trinidad and Tobago (about 220) are affiliated with NPMC.
NPMC is currently implementing a project in which waste lube oil is recovered from selected 22 gas stations and is recycled to the PointeaPierre Refinery as slop oil.

In general lube oil contains various additives, which may cause corrosion of equipment or poisoning of catalysts if fed back to a refinery process. The project, therefore, needs careful followup for detrimental effects to the refinery.

For information, lube oil consumption in Japan is 2.5MMKL/Y, spent lube oil is disposed in the following three(3) ways;

Incineration as industrial waste	18%
Heating of greenhouse, etc.	75%
Treatment for reuse	7%

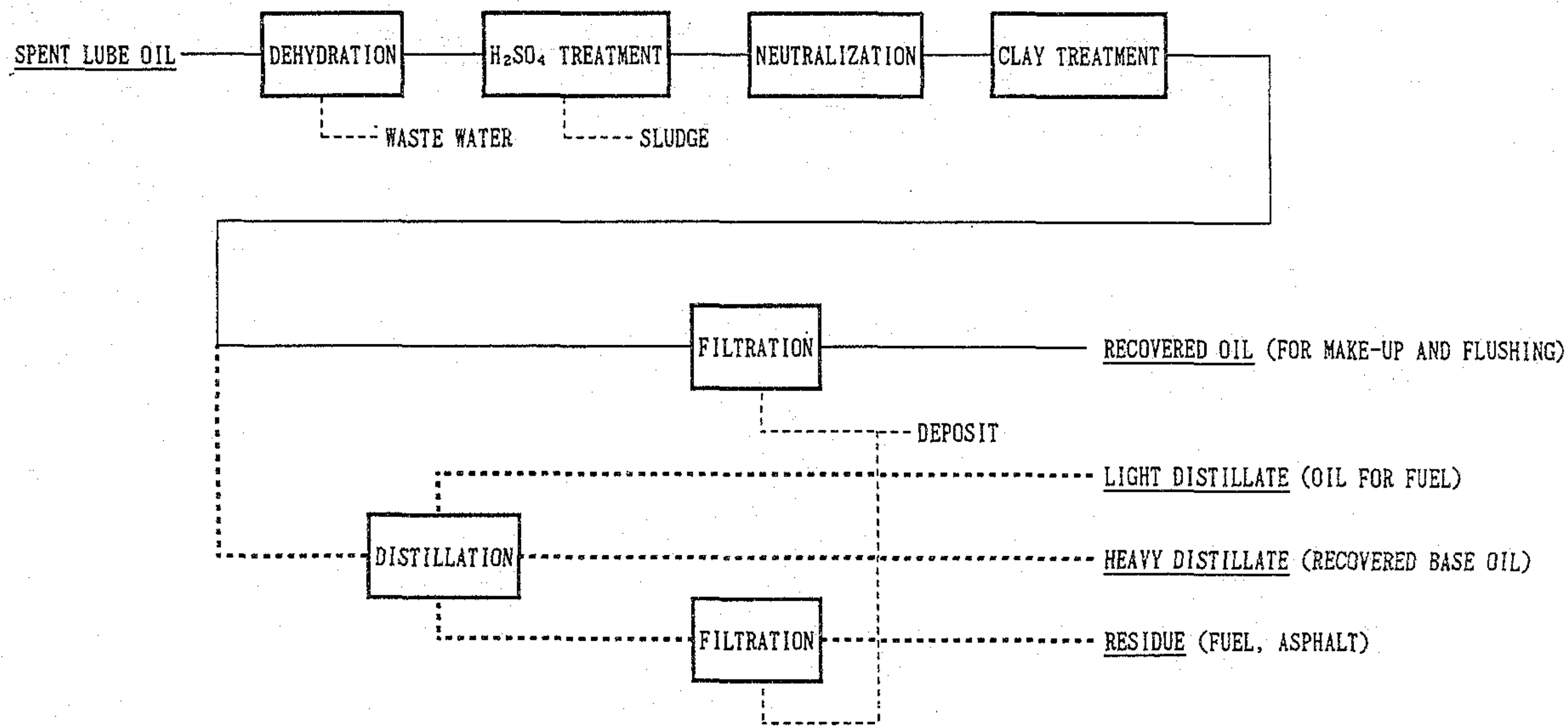
There are about fifty(50) small scale treatment plants in Japan, treating average amounts of 1,000KL of spent lube oil per plant annually. The technology of treatment for reuse has been established, but current price of petroleum products makes it unattractive to treat spent lube oil for reuse. In addition, secondary pollution such as waste clay and acidic sludge may be a problem.

Figure 7 − 1 illustrates basic flow diagram of spent lube oil recovery process. The spent oil is first treated mechanically to separate water, then washed with sulfuric acid to remove carbonized or oxidized impurities. In some cases a propane washing process is employed prior to sulfuric acid washing.
After washing, the oil is neutralized and purified by filtration. However, redistillation of the oil is required to recover it as suitable base oil.
In Japan, wastes containing oil must be incinerated and landfill is prohibited under "The Law on the Waste Disposal and Cleaning."

(3) Atmospheric Pollution

Atmospheric pollution from the petroleum industry might be another problem. During the visit of the study team, odors of SO_2 from the effluent of the sulfuric acid plant at the PointeaPierre Refinery and H_2S from a tank receiving steam flood crude oil were noticed. However, they were not noticed when the team visited again. Consequently the degree of pollution in terms of amount and frequency is not clear.
It is recommended that the height of the stack is checked for preventing pollution at the ground level: the calculation can be made if adequate information on the pollution source and meteorological data are available.

Figure 7-1: SPENT LUBE OIL RECOVERY PROCESS



8. CONCLUSION AND RECOMMENDATION

The preliminary study mission of JICA visited Trinidad and Tobago to find the present status of petroleum pollution and discuss the background and object of the request. Major findings and recommendations are itemized as follows:

8－1 Petroleum and natural gas industries are the backbone of Trinidad and Tobago.

8－2 In spite of plans for the diversification of industry in general, the petroleum and natural gas industries will continue to play a major role in the economic development of Trinidad and Tobago.

8－3 The petroleum and natural gas industries are characterized as export oriented industries. Domestic consumption is marginal.

8－4 Environmental pollution in petroleum industries at present is not adequately controlled. The administrative initiatives for pollution control and prevention are still in the cradle stage.

8－5 The most critical and chronic pollution is petroleum waste water pollution in onshore petroleum producing fields as well as at petroleum refining facilities. The Government has proposed environmental control standards for oil and grease at the outlets of all facilities. The other pollutants in petroleum waste water such as COD, SS and others have not been adequately studied to permit establishment of other standard for environmental protection.

8－6 The study on pollution prevention and control within petroleum sector in the Republic of Trinidad and Tobago will be beneficial for Trinidad and Tobago.
The study facilities and location should be selected in the prepatratory study.

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