preserve the biological diversity of Trinidad and Tobago. The leatherback turtle is symbolic of endangered species in Trinidad and Tobago. Conservation of biological diversity is a matter of international concern, because its benefits accrue not only to the local population but to people the world over.

23-8 Benefits versus Costs

Benefits can only be expressed qualitatively, while costs are quantifiable. Benefits and costs cannot be compared in equal terms. The present conditions of petroleum pollution are not tolerable by any standard, given the fact that waste water discharged from the production facilities is an oil-in-water emulsion that can contain oil in thousands of ppm, and the emulsion mixes uniformly with river water and sea water, affecting the entire body of water from the surface to the bottom. Survival of the onshore petroleum industry should be considered to hinge upon elimination of such oil-in-water emulsion and achievement of the 50 ppm target, to say nothing of further expansion of the petroleum sector. If the choice is to be between termination of onshore petroleum production and implementation of the proposed program, the former option to save 4,769 thousand U.S. Dollars per year, corresponding only to 0.58 percent of the export earnings of crude oil and petroleum products, and corresponding to about three percent of the economic value generation in Bernstein Main Storage, would be unreasonable.

23-9 Alternative Case Study

23-9-1 Barometric Condenser versus Surface Condenser

During the third field survey the study team recommended that the barometric condensers of the vacuum distillation units be replaced by surface condensers to reduce the large amount of oily water that is being discharged by them. Petrotrin, being concerned about the cost of replacement, said that the barometric condensers should remain and the water effluent from them can be treated by No. 4 API Separator which will have enough capacity for treating the effluent after oily water streams and non-oily water streams are separated. It was agreed that the project scheme stipulates replacement of the barometric condensers as base case but the case in which barometric condensers remain would be studied as a sensitivity case. This case is called Case-1 here.

The effluent water from the barometric condensers is vigorously agitated with condensing oil vapor and becomes oily; therefore, treatment with CPI and DAF would be needed. The required additional capacity is assumed to be 262 tons per hour.

Table 23-11 shows the input figures and Table 23-12 calculates the cost of Case-1. In Case-1 the plant cost is reduced for not replacing the barometric condensers by surface condensers; however, much of the reduction is offset by the incremental cost for the additional train of the CPI/DAF.

Table 23-12 shows that the annual cost increases from 885 to 1,251 thousand U.S. Dollars and from 0.04 to 0.06 U.S. Dollars per barrel.

The substantial increase in the treating cost is attributable to the additional CPI/DAF train. One may argue that this new CPI/DAF train is not needed, by saying that the oil particles entrained in the effluent stream from the barometric condensers can separate in a traditional gravity-induced API separator and guard basin, and the effluent stream can meet the 50 ppm target. This could be so. It must be remembered, however, the first step toward better waste water management is to reduce the amount of foul water. The amount of effluent water from the barometric condenser is substantial; the amount of oily water could be double or even more if the barometric condensers remain. If the effluent water from the refinery meets the 50 ppm target, the water still contains oil and dissolved substances, at a maximum of 50 ppm. Given that the cost for Pointe-a-Pierre Refinery accounts for only 17 percent of the total cost, an attempt to make a marginal reduction of that cost at the expense of the effect of the system does not make sense.

Table 23-11 Cost Comparison with/without Barometric Condensers Replacement

(Unit: thousand U.S. Dollars)

	Base Case	Case 1
Economic plant cost	2,723	2,723
Barometric condensers		-612
DAF		+348
CPI		+54
Pipe (assumed at 10 percent of the total)		-30
Pump (assumed at 10 percent of the total)		-18
Total	2,723	2,525
Pre-operation cost	20	20
Working capital	72	144 1)
Variable operation cost	263	526 1)
Fixed operation cost	230	330 2)
Overhead	50	70 3)

Source: Study team

Note: 1) Working capital and variable operation cost are doubled.
2) MIT is reduced by the ratio of plant cost and labor and salary is doubled.
3) Overhead is increased by 40 percent because of the additional CPI/DAF train.

Table 23-12 Economic Cost of Waste Water Treatment, Pointe-a-Pierre Refinery, Alternative Method, Case-1

Pollution Prevention and Control within the Petroleum Sector in the Republic of Trinidad and Tobago

Unit: 1,000 US Dollars

Economic Analysis, Pointe-a-Pierre Refinery																					
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Plant Cost		2,525																			
Pre-operation Cost		10																			
Interest during Const.		63																			
Consultancy Fee	60																				
Interest on Cons. Fee	2	3																			
Repayment Statement																					
Outstanding Debt		2,601	2,341	2,081	1,821	1,561	1,301	1,040	780	520	260	0	0	0	0	0	0	0	0	0	0
Repayment		0	260	260	260	260	260	260	260	260	260	260	0	0	0	0	0	0	0	0	0
Interest Payment		0	130	117	104	91	78	65	52	39	26	13	0	0	0	0	0	0	0	0	0
Working Capital		144																			-144
Operation Cost																					
Variable Cost			526	526	526	526	526	526	526	526	526	526	526	526	526	526	526	526	526	526	526
Fixed Cost			330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330
Overhead			70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Compensation			1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251
Cash Flow	-60	-2,679	325	325	325	325	325	325	325	325	325	325	325	325	325	325	325	325	325	325	469
NPV at 10 percent		-2																			
Throughput, BPSD		60,000																			
Cost, US$/Bbl		0.06																			

23-9-2 Effects of Inefficient Oil Wells

As was said before, the first step toward better waste water management is to reduce the amount of foul water. This principle can also apply to Bernstein Main Storage. The average design water rate is two tons of water per ton of oil, or per 6.3 barrels of oil. Crude oil come from a large number of wells, which differ greatly in the rate of water production. Figure 23-1 simulates the water/oil production pattern at the completion of the program, developed from combining the actual data on water/oil production of all major fields sending crude oil to Bernstein Main Storage and Los Bajos Main Storage.

Figure 23-1 shows forecast cumulative water production versus cumulative crude oil production, starting from the oil wells of the lowest water producing ratio to the wells of the highest water producing ratio, but covers almost all wells. It is seen from this figure that the tail-end one-sixth high-water producing crude oil contributes to three-quarters of water production. This figure may not exactly represent annual production pattern, because the figure was developed on one set of data. Though not shown on this report, the figures developed on the same method for other fields -- Fyzabad Thermal, Fyzabad Primary, Forest Reserve Thermal, Forest Reserve Others, Gran Ravine, North Palo Seco Thermal, Central Los Bajos Thermal, Apex/Quarry Thermal, Bennett Village Thermal, HGOR, North Palo Seco, South Palo Seco, McKenzie Non-thermal, Central Los Bajos Non-thermal, Apex/Quarry Non-thermal, Coora Non-thermal, Quarry Non-thermal, Erin Non-thermal -- all show similar patterns.

Now, a question emerges whether the operation of inefficient wells, or wells of high water producing ratios, should be suspended to drastically reduce the amount of foul water, thereby reducing the cost of waste water treatment.

A case study is done to answer this question on the following premises.

1. Treating cost per unit volume of water of the waste water treating system at Bernstein Main Storage varies in proportion to 0.8 powers of the capacity of the system.

2. One barrel of crude oil has an economic value of 12.0 U.S. Dollars.

3. Water produced in association with crude oil comes from the injected steam.

4. One barrel of water consumes 0.08 barrel crude oil equivalent of fuel, or 0.96 U.S. Dollars.

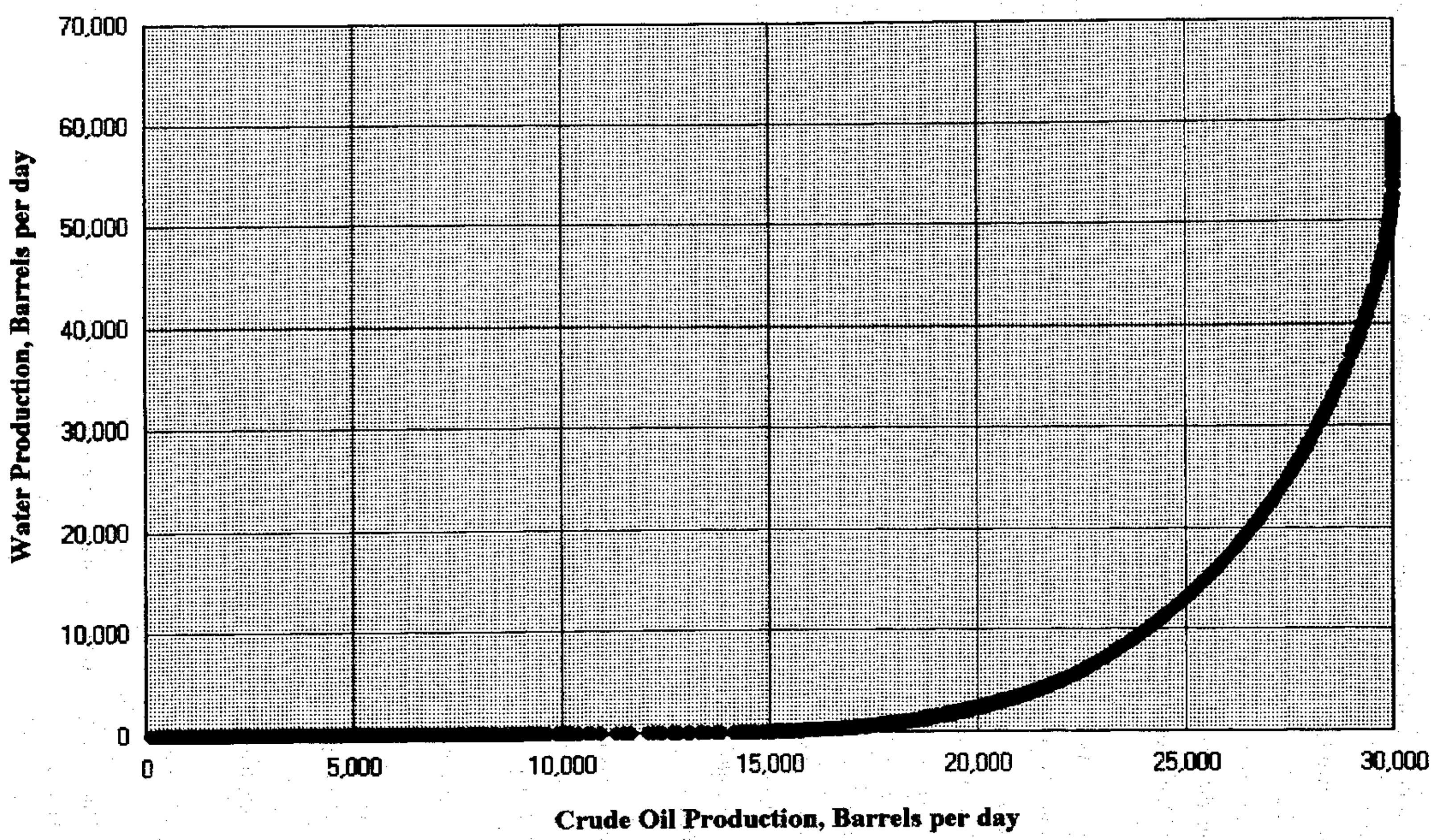

Figure 23-1 Water Production versus Crude Oil Production, Bernstein Main Storage

Table 23-13 compares economic value generation for 25,000, 27,500 and 30,000 barrel-per-day throughputs of crude oil at Bernstein Main Storage. Waste water to be treated for these three cases are 13,000, 24,000 and 60,000 barrels per day.

Table 23-13 Case Study of Economic Value Generation for Waste Water Treating Capacity at Bernstein Main Storage

(Unit: thousand U.S. Dollars per day)

	Crude oil throughput, barrels per day		
	25,000	27,500	30,000
Crude oil production, bpd	25,000	27,500	30,000
Waste water generation, bpd	13,000	24,000	60,000
Ratio	0.217	0.400	1.000
Ratio raised to 0.8 power	0.295	0.480	1.000
Economic value generation	300	330	360
Increment	0.000	30.000	30.000
Economic value consumption			
Waste water treating system	3.139	5.108	10.641*
Steam	12.480	23.040	57.600
Total	15.619	28.148	68.241
Increment	0.000	12.529	40.093
Net economic value	284	302	292

Note: * Treating cost at Bernstein Main Storage
Source: Study team

Note that net economic value generation decreases when the throughput increases from 27,500 to 30,000 barrels per day, because the incremental economic value generation is more than offset by the incremental economic cost of steam. The incremental 2,500 barrels per day of crude oil is produced by inefficient wells that need large amounts of steam. The incremental economic cost of the waste water treating system is marginal. Net economic value generation is almost the same for the above three cases. Under such a condition, suspension of the operation of the most inefficient wells is worth studying, because reduction of the amount of foul water has a number of advantages: reduction of the amounts of pollutants discharged to the environment, reduction in the size of waste water treating facility, reduction in the initial capital outlay.

If the economic cost of steam is disregarded as it is now on the ground that otherwise useless associated gas is burned to generate steam, it is natural that the consumption of steam, and generation of waste water as well, should not draw much attention. However, the associated gas should have legitimate uses and should have an economic value commensurate with its heating value. Also in the light of that, suspension of the operation of inefficient wells should be studied.

23-10 Life of Oil Field

All these studies are based on the assumption that the subject area will continue to produce oil for some 20 years. The study team did not conduct reservoir analysis of its own. The study team has been informed that Trinidad and Tobago is hopeful of the future oil-producing potential of this area and continues exploration and test drillings, and that there are untapped large reservoirs deeper in this area which enable this area to continue production for some tens of years.

Chapter 24 Conclusions and Recommendations

Chapter 24 Conclusions and Recommendations

24-1 Conclusions

The government of Trinidad and Tobago intends to diversify its economy, by reducing dependence on petroleum and encouraging other industries. However, the petroleum industry seems to be the only industry that can provide prompt return. Serious petroleum pollution is a factor which can impede further development of the petroleum industry. The government is very concerned about the seriousness of petroleum pollution. Recently, the government has set up the Environmental Management Agency (EMA), as a concrete step toward better environmental management. EMA will draft environmental standards and regulations. There is no legalized pollution standard for oil content in the effluent water from petroleum facilities. The only standard is the draft guideline that has been issued by the Ministry of Energy and Energy Industries specifying that oil and grease discharges from refineries and land based petroleum facilities shall not normally exceed 50 ppm on monthly average or 75 ppm on a daily maximum. This draft guideline is the target of this study.

Petroleum pollution in the study area, the southwestern oil-producing area of the Island of Trinidad, is serious and needs immediate remedial measures. Of air, water and soil pollution, water pollution is the most serious. Oil is being discharged with effluent waste water streams to rivers and sea from petroleum facilities. Water in the rivers and sea in this area shows very high oil content, sometimes as high as thousands of ppm. Oil is accumulated at dams and catches installed on the rivers in this area. The most serious petroleum pollution is caused by two types of emulsion.

First, water produced in association with crude oil is in the form of an oil-in-water emulsion. This water contains thoroughly dispersed oil particles ranging in diameter from less than one to a maximum of about 10 microns. The particles are so small that the emulsion is very stable and does not separate into oil and water by gravity-induced separators, the only type of separators installed in the study area. The oil content can be as high as tens of thousand ppm. This water resembles normal silt-containing brown-colored river water and is not visibly recognizable as containing oil. This water, oil-in-water emulsions, is discharged from producing facilities to the rivers in the study area and goes to the Gulf of Paria, mixed thoroughly with water, polluting the entire body of water from surface to bottom. Though not visible, pollution by this type of emulsion is very serious.

The other type of emulsion, water-in-oil emulsion, is very sticky and viscous like heavy oil. This type of emulsion is also very stable and hard to break into oil and water. It is seen floating on water in the separators. It is skimmed and returned to tanks. As it accumulates in the tanks and separators, it escapes to the environment and contaminates rivers, sea and soil. Unlike pollution by the former type of emulsion, pollution by this type of emulsion is visible.

Soil is contaminated with oil at places where oil has leaked from petroleum facilities, and where there are open earthen pits holding oil-containing wastes.

Technically, solution of these three pollution problems is the central objective of this study. Based largely on comprehensive experiments done by the study team, this report proposes solutions to these problems: dissolved air flotation with coagulation plus activated carbon adsorption for the oil-in-water emulsion, incineration for the water-in-oil emulsion, and abandonment of the practice of using earthen pits and bio-remediation undertaken by Petrotrin for oil-containing wastes.

The study team proposes installation of waste water treating systems at Pointe-a-Pierre Refinery and Bernstein Main Storage. Their cost is estimated at 3,377 and 16,300 thousand U.S. Dollars in 1994 Trinidad Tobago prices, respectively. The annual economic operation cost is estimated at 4,769 thousand U.S. Dollars, or 0.22 U.S. Dollars per barrel of crude oil. This report justifies this cost.

The major conclusions the study team has drawn from this study are as follows.

1. **Pollution Condition**

   Petroleum pollution in the study area is very serious. The most serious is water pollution, caused mainly by two types of emulsion: oil-in-water emulsion and water-in-oil emulsion. Oil content of water in the rivers and sea is very high. It can rise to thousands of ppm, a far cry from the 50 ppm target.

2. **Government Policy**

   The government regards the present pollution conditions as very serious and as a factor that can impede the social and economic development of the nation. Immediate remedial measures are desired. As a concrete step toward better environmental management, EMA has been set up to assume overall responsibility of environmental management.

3. **Dams and catches**

The climate of Trinidad and Tobago is divided into a dry season and a wet season; the former from January to May and the latter from June to December. During the wet season there are occasional heavy rains. In heavy rain, swollen river streams overflow the dams and catches installed on the rivers, washing down the oil and debris that have accumulated, polluting the downstream areas. The study team conducted hydrometeorological studies on these dams and catches and concluded that all these dams and catches are overloaded in heavy rain. However, the study team has concluded that expansion of these dams and catches would be useless and therefore is not recommended. Instead, the study team concludes that the waste water treating system should be designed not to be affected by climatic conditions rather than to absorb their fluctuations.

4. **Water Produced with Crude Oil, Oil-in-water Emulsion**

The study team has identified the water produced in association with crude oil as an oil-in-water emulsion under close observations under a microscope. The suspended minute oil globules give the water a brown color which makes the water resemble normal river water containing silt. It has also been confirmed by microscopic observations that the water essentially does not contain solid particles like those of silt. Size distribution was measured on several samples by the well-known Coulter counter method; the median globule diameter was found to be about 2.5 microns.

The globules are so small that the emulsion is very stable, and does not separate by gravity; therefore, it is not amenable to gravity-induced separators like API separators, CPI, or guard basins, the only type of separators installed in the study area. Economical and practical methods of breaking the emulsion into oil and water were sought. Effects of pH, temperature, emulsion breakers, extraction of oil globules by kerosene, and aqueous solutions of electrolytes were tested. Some of them were found to be partly effective in laboratory conditions; but none was found to be applicable in the field.

Finally, dissolved air flotation (DAF) using alum and a polymer as coagulant was found to be effective and applicable to the actual waste water streams. By this method, the treated water becomes crystal clean, indicating no trace of oil globules remaining in the treated water. In a DAF unit, flocs are generated in the waste water from alum and are coagulated by the polymer. The flocs float to the surface, catching oil globules. Finite air bubbles generated from the pre-pressurized water fed to the unit assist flotation of the flocs. Oil-containing flocs are removed by skimming, dewatered, and incinerated according to the proposed scheme.

5. **Water after treatment by DAF**

A number of samples of waste water, those from Bernstein Main Storage in particular, that were treated by dissolved air flotation with coagulation were found to contain higher than 50 ppm oil. Here the definition of 50 ppm becomes important. To be exact, 50 ppm is interpreted as 50 milligrams per liter of sample water that is recognizable as oil and grease by ASTM Test Method D-4281, the freon extraction method, the method officially employed in Trinidad and Tobago. In this test freon dissolves not only oil, or pure hydrocarbons, but also a variety of organic compounds. If only pure hydrocarbons from crude oil were involved, DAF alone would suffice to reduce the oil content to below 50 ppm; this is not the case with the subject water. If aromatic and naphthenic carboxylic acids are present in the crude oil, these substances tend to be dissolved in water, because of their high solubilities in water, and measured as oil by the ASTM D-4281 Method. This is what actually happens to the water produced with crude oil. By Gas-Chromatography/Mass-Spectrometry (GC/MS), these substances are indicated to be naphthenic acids. Two promising methods for eliminating these substances, biological treatment and activated carbon adsorption, have been tested; adsorption by activated carbon proved to be very effective while biological treatment showed a negative result. On the basis of such a result, adsorption by activated carbon (ACA) is proposed after the DAF unit for treating water produced with crude oil.

6. **Project scheme**

The following project schemes are proposed for Pointe-a-Pierre Refinery and Bernstein Main Storage.

	Bernstein Main Storage	Pointe-a-Pierre Refinery
Design conditions for DAF and ACA Units		
Flow rate, cubic meters per hour:	440/400	250
Oil content of water, mg/liter		
Inlet	1,000	400
DAF outlet, maximum		50
ACA outlet, maximum	50	

Waste treatment center, with incinerator		
Scums, tons per hour	32.0	2.0
Emulsion, barrels per day	75	33
Water/oil ratio of emulsion	35/65	35/65
Schedule, year		
Preparation	1	1
Construction	1	1

The waste water from Los Bajos Main Storage is sent to Bernstein Main Storage by installing an eight-inch pipeline over a distance of 12 kilometers along the road, with a pump and electric facilities. Auxiliary facilities are also installed.

Complete separation between oily-water streams and non-oily water streams is also an essential element of the project scheme.

7. Conceptual design and estimation of costs

Based on the project scheme, material balances, process modification and installation plans, process specifications of facilities, mechanical specifications of facilities, and layout plans were developed. These are detailed in Chapter 21, "Conceptual Design" of the Main Report. The installed plant costs were developed. The operation costs were also developed. These costs are 1994 Trinidad and Tobago Price expressed in U.S. Dollars. Inflation is not incorporated. The estimated costs are 3,377 and 16,300 thousand U.S. Dollars for Pointe-a-Pierre Refinery and Bernstein Main Storage, respectively.

	Bernstein Main Storage	Pointe-a-Pierre Refinery
Installed plant cost, U.S. thousand Dollars	16,300	3,377
Operation cost, U.S. thousand Dollars/year		
Variable operation cost	1,724	302
Fixed operation cost	915	269
Total operation cost	2,639	571

8. Evaluation

Cash flows were developed over a period of 21 years, two years for construction and 19 years for operation. Annual fixed amounts of compensation that make the proposed water treating facility economically viable at a discount rate of 10 percent per year were calculated; a compensation of 4,769 thousand U.S. Dollars per year, or 0.22 U.S. Dollars per barrel, has been obtained. This compensation has the following significance against the economic indicators.

0.13 percent of GDP; GDP is about 20,000 TT million dollars.

0.54 percent of petroleum sector's contribution to GDP; petroleum sector's contribution to GDP is about 25 percent.

0.45 percent of government revenue; government revenue is about 6,000 TT million dollars.

4.00 U.S. Dollars per capita per year; the population is 1.24 million. It is also 0.13 percent of GDP per capita, 3,043 U.S. Dollars.

0.38 percent of export earnings; export earnings are about 7,000 TT million dollars.

0.58 percent of export earnings of crude oil and petroleum products; export earnings by crude oil and petroleum products account for about 65 percent of total export earnings.

In view of the seriousness of the present petroleum pollution, onshore petroleum production cannot continue without satisfying the 50 ppm target. The question is how to sustain the cost or whether to terminate onshore petroleum production. With the small incremental economic burden, 0.22 U.S. Dollars per barrel, termination of the onshore petroleum production is out of the question. Export earnings of crude oil and petroleum products appear to be the most reasonable source of funds for the waste water treating cost. The percentage, 0.58, is not too large to be diverted to the cause of pollution prevention and control within its own sector. An incremental cost corresponding only to 0.58 percent of the earnings from petroleum export does not harm the competitiveness of Trinidad and Tobago in the international petroleum market.

The economic cost of waste water treating was compared with the economic value of crude oil produced in the subject area. The result of calculation shows that one barrel of crude oil still bears an economic value of eight U.S. Dollars after paying the economic costs of water treatment and crude oil production. Against all these, the cost of waste water treatment is justifiable.

Domestic consumption of petroleum is very small compared with export. Under such a condition, it is not right to pass all the waste water treating cost on to domestic consumers.

If the economic burden of 4,769 thousand U.S. Dollars is charged to domestic consumers, it amounts to 0.033 TT Dollars per liter on average for all petroleum products. This is too much to add to the present average retail price of about 0.4 to 0.5 TT Dollars per liter.

The proposed program will bring about a variety of socio-economic benefits, though these benefits are not quantifiable in monetary terms. Damage to agriculture and fishery will be reduced. Health hazards stemming from petroleum pollution will be reduced. An environment favorable to expansion and development of the petroleum sector will be created. The program will bring about business opportunities to local businesses and introduce new technologies. It will raise public awareness of the importance of environmental conservation. It will help preserve the biological diversity of Trinidad and Tobago.

The proposed program calls for replacement of the barometric condensers of the vacuum distillation units of Pointe-a-Pierre Refinery with surface condensers to reduce the amount of foul water. An economic sensitivity study was done for the case of continuous use of the barometric condensers. It is assumed that the effluent water from the barometric condensers has to be treated by an additional train of CPI and DAF units. The cost increases from 0.04 to 0.06 U.S. Dollars per barrel.

Some inefficient wells produce disproportionately large amounts of water per barrel of oil. A set of data on oil production and water production from all onshore wells that send crude oil to Bernstein Main Storage directly or via Los Bajos Main Storage were arranged in increasing order of water/oil production ratio. An analysis of these data shows that 78 percent of water is produced with the tail-end 17 percent of oil production, 60 percent of water with the tail-end 8.3 percent. Net economic value generation is compared at three points of oil production; namely, full production, 8.3 percent reduction and 17 percent reduction. The net economic value generation virtually does not increase from the 17 percent reduction point, because the incremental value generation by increase in oil production is offset by the incremental costs of steam and waste water treatment. Under such a condition, suspension of operation of the most inefficient wells is worth considering, because reduction of the amount of foul water has a number of advantages: reduction of the amount of pollutants discharged to the environment, reduction in the size of the waste water treating facility, reduction in the initial capital outlay.

9. Operation and maintenance

Operation and maintenance of the petroleum facilities in the study area are generally good. The technical level of Petrotrin is high in these respects. Presumably because of insufficient availability of necessary funds, manpower and also because of accepted practice, operation and maintenance of the petroleum facility leave something to be desired. The following are important points from the viewpoints of pollution control.

(1) Non-oily water intrusion to waste water treating system

Oily waste water streams and non-oily waste water streams are not separated in most petroleum facilities. Intrusion of rain water in the waste oil treating systems in the rainy season overloads the systems and greatly decreases their efficiency. This occurs frequently during the rainy season.

(2) Lack of adequate water treating facilities

Pointe-a-Pierre Refinery, main storages, tank farms and gathering stations do not have waste water treating facilities suited to the types of waste water.

(3) Use of earthen pits

Earthen pits are used to hold oil-containing wastes. This causes pollution of soil and underground water.

(4) Oil and emulsion accumulation on the surface of separators

Oil and water-in-oil emulsions, which are supposed to be collected, accumulate on the surfaces of API separators, guard basins, dams and catches.

(5) Oil remaining not recovered at sites of past leaks

Oil is seen not recovered at sites of past leaks. The contamination can spread to the surroundings.

(6) Breakdown maintenance

Breakdown maintenance is still done on important facilities that can cause a major accidental pollution.

(7) Obsolete facilities

Some of the facilities are obsolete and deteriorated, flow lines and pipelines for example. They need frequent inspections to forestall spills.

10. **Legal and administrative measures**

Trinidad and Tobago does not have a legal framework that enables the administration to properly act to control pollution. Emission standards have yet to be established. Pollution conditions are not properly monitored.

24-2 Recommendations

This report presents two types of recommendation: recommendations which need to be implemented in order to achieve the 50 ppm target, and recommendations for good operational practices. These two types of recommendations are distinguished and presented separately.

24-2-1 Recommendations to Achieve the 50 ppm Target

The program presented in Chapter 20, "Project Scheme" and defined in more detail in Chapter 21, "Conceptual Design" should be implemented as quickly as possible. In implementing the recommended program, the following are also recommended.

1. **Favorable financing**

   If Trinidad and Tobago needs financing for funding this project, finances on favorable terms should be sought. The possibility of financing on favorable terms from the international financing organizations and from bilateral institutional financial systems of the OECD member nations should be studied.

2. **Lump-sum contract versus cost-plus-fee contract**

   It would be better for Trinidad and Tobago to execute the design and construction work under one lump-sum contract, with performance guarantee, with one contractor of demonstrated capability and credibility. In this way, the entire project can be understood in advance in a clear perspective. The owner of the project is assured of execution at a fixed price. The owner can hold one contractor fully responsible for the entire work, and needs not talk with a number of suppliers. Public competitive tender on equal conditions is possible with a lump-sum contract. Evaluation of the tender is easier with a lump-sum contract than a cost-plus-fee contract.

3. **Bleeding of water upstream of Bernstein Main Storage**

   It is a pre-requisite to the recommended program that any facility or operation upstream of Bernstein Main Storage should not bleed even a drop of water to rivers or the environment. If this is not faithfully observed, the effect of the entire water treating system will be reduced. Education and training of all those concerned with operation of facilities upstream of Bernstein Main Storage must be properly done in this respect.

4. **Study on effects of inefficient oil wells**

While preparation is being made for implementation, a study on the effects of inefficient oil wells such as that presented in 23-8-2 should be done in more detail, based on data periodically collected in a manner specifically designed for this purpose over a span of six months or so. Only by such studies can the proper EOR and the right amount of waste water be established. The study should incorporate all associated issues which include potential unemployment if operation of inefficient wells is suspended. Such a study can be done by no one but the government. Based on the findings of such studies, the benefits and costs of pollution control should be reviewed. The benefits will be further improved vis-a-vis the costs.

5. **Disposal of water-in-oil emulsions and scum**

If Trinidad Cement Limited (TCL) finds it possible to feed scum from DAF to, and burn slop oil, or water-in-oil emulsion, at their kilns, this will represent effective utilization of wastes. In such a case, these should be supplied to TCL and the sizes of the proposed waste treatment systems should be reduced.

6. **Effects of the dissolved substances**

It must be remembered that the effluent of the waste water treating systems contains water soluble hydrocarbon derivatives to a maximum of 50 ppm. Safety of such substances to aquatic organisms is not established. The government and Petrotrin should therefore monitor accumulation of such substances in the bodies of aquatic organisms that live in the contaminated areas and their effects, on a long-term basis.

24-2-2 Recommendations for Good Operational Practice

1. **Maintenance of facilities**

It is recommended that a number of recommendations enumerated in Chapter 17, "Maintenance" be gradually implemented to the extent the budget of Petrotrin permits.

2. **Use of earthen pits**

The practice of using earthen pits to hold oil-containing wastes should be abandoned.

Oil-containing wastes should be burned by the proposed waste treatment systems.

3. **Oil and emulsion accumulation on the surface of separators**

   Oil and water-in-oil emulsions accumulated on the surfaces of API separators, guard basins, dams and catches, should be recovered. Finding of oil on dams and catches should be regarded as emergencies, and emergency squads should be mobilized to recover the oil. The source should be identified and corrective measures must be immediately taken to prevent recurrence of such incidents.

4. **Oil remaining unrecovered at sites of past leaks**

   Oil remaining unrecovered at sites of past leaks should be recovered. The contaminated soil should be either re-mediated by the Petrotrin's planned bio-remediation project, or incinerated.

5. **Breakdown maintenance**

   Preventive maintenance should be done without exception on all facilities such as tanks and major pipelines that can cause major accidental pollution.

6. **Obsolete facilities**

   Some facilities are obsolete and deteriorated, flow lines and pipelines for example. They should be frequently inspected to prevent spills.

7. **Development of human resources for environmental control**

   Human resources needed for better environmental control should be developed. Human resources are needed in the administrative as well as technical fields. Trinidad and Tobago should identify qualified individuals and take every possible opportunity to develop their abilities.

8. **Environmental monitoring**

   Joint monitoring program by EMA, the Ministry of Energy and Energy Industry and Petrotrin should be promoted to monitor and accumulate data on petroleum pollution.