Mitigating the Health, Safety and Environmental Risks of an Enhanced Oil Recovery Project in a Tropical Forest

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ABSTRACT

The Petroleum Company of Trinidad and Tobago (Petrotrin) has initiated an Enhanced Oil Recovery (EOR) project that will involve steam flooding in the Upper Morne L'Enfer (UMLE) Sands of the Forest Reserve Oilfield, Trinidad. This project involves the conversion of recently drilled wells to injectors, relocation and retrofit of a 30 year- old steam generator from an adjacent oilfield, construction of a gathering station, installation of gas, water, steam, and crude oil pipelines with associated tie-ins. These facilities will be operational for a 20 to 50 year period.

During the project-planning phase, an Environmental Impact Statement and a Hazard Operability (HAZOP) Study were conducted to acquire Environmental Management Authority and Ministry of Energy and Energy Industry approvals and address potential safety and environmental risks associated with the project. Baseline data was extracted from an Environmental Impact Assessment that was recently conducted for drilling sixty wells in the same area.

Integrating the environmental baseline into the HAZOP study served to identify and rank both potential environmental and safety hazards, which in turn permitted Petrotrin to prioritize risk mitigation strategies. All parties involved in the risk assessments agreed that the team approach used in the HAZOP study permitted a more efficient and effective forum to identify and mitigate both safety and environmental risks as compared to combining results from individual assessments.

This paper describes how the UMLE Steam Flood Project's potential safety and environmental risks were assessed and mitigated. The success in minimizing the risk associated with these hazards serves to demonstrate that oil and gas operations can coexist with sensitive environments.

INTRODUCTION

Petrotrin's Forest Reserve oilfield is located within the Morne L' Enfer Forest Reserve in the southwest peninsula of Trinidad (See Figures 1 and 2). Trinidad Leaseholds Limited (TLL) drilled the discovery well for this field in 1914. Since then, over 1650 wells and supporting production infrastructure were developed in this small field of only 12 Km^2 by Petrotrin and its predecessor companies including Texaco (1956- 1985) and the Trinidad and Tobago Oil Company (TRINTOC, 1985-1993). Other production infrastructure include (some decommissioned) eight gathering stations, two tank farms, several steam generators, field offices with workshops, three compressor stations, hundreds of miles of pipelines, a power station and water treatment plant.

Since the 1920's, the private main oilfield road traversing Forest Reserve was gated off from the general public and the dense tropical evergreen forest also provided a natural barrier to outsiders. This gated community became known to locals simply as 'Forest Reserve'. The Forest Reserve residential community under Texaco in the 1970's and early 1980's was completely self-contained with its own electrical and water supply, housing, medical center, churches, primary schools, post office, club house with sporting facilities, rifle range and convenience store.

Several other Petrotrin oilfields including the North Palo Seco, Grande Ravine, Fyzabad and Central Los Bajos fields surround Forest Reserve. These fields are located within similar physical, biological and socioeconomic environments, but were developed by different predecessor companies.

Much of Forest Reserve's operations and support services infrastructure were downsized as a result of the downturn of the industry in the 1980's and the centralization of Petrotrin's Exploration and Production operations in Santa Flora in the 1990's. Production from the Forest Reserve field peaked at an average of 22 000 barrels of oil per day (bopd) in 1959 and has been on a steady decline since (1). Present production averages 3200 bopd per day from 334 oil wells. In 1999, a reservoir characterization study of the Forest Reserve field identified the Upper Morne L'Enfer (UMLE) sands as a prime candidate for drilling. The UMLE steam-flooding project will improve production of the high gravity crudes from stranded reserves.

This is the first EOR project being implemented in Trinidad since the passing of the Certificate of Environmental Clearance (CEC) Rules in 2001. This legislation mandates that any new project that can have significant environmental impacts, such as the UMLE EOR project, will require a CEC from the Environmental Management Authority (EMA).

The Ministry of Energy and Energy Industries (MEEI), who assists the EMA in reviewing CEC applications, requested that a Hazard Operability (HAZOP) Study be conducted to support the CEC application. The HAZOP Study process is based on the principle that a team approach to hazard analysis will identify more problems than when individuals work separately and then combine results. The study served to identify and rank both potential environmental and safety hazards that permitted Petrotrin to prioritize risk mitigation strategies. An Environmental Impact Assessment (EIA) was conducted for the 2003-2004 drilling program in Forest Reserve and the baseline data gathered was used in the HAZOP study to assess risk specific to the Forest Reserve physical, biological and socioeconomic environment.

The recommendations from the HAZOP study were used to develop the Health, Safety and Environment (HSE) risk mitigation management plan.

UMLE EOR PROJECT

The UMLE project site, nicknamed the 'Sahara' due to the sandy soils in the area, is located within the southeastern quarter of the 1999 Reservoir Characterization Study Area (See Figure 2). Petrotrin drilled eight (8) wells into the UMLE sands from 2000-2001. Five (5) wells were later added in 2003-2004 drilling program within the same acreage.

The UMLE sands are shallower than 200 feet, have a net oil sand thickness ranging from seventy (70) to one hundred (100) feet with high porosities and perm abilities. Average pumping production per well is between fifteen (15) to twenty five (25) barrels of oil per day (bopd). The crude is heavy oil with gravities ranging from 11.1^{o} to 15.3^{o} API and viscosities ranging from 200 to 5000 centipoises (cp). This viscous oil can only be assisted to surface by one method, steam assisted recovery.

Steamflooding was pioneered by Texaco Trinidad Ltd. in this field in the 1950's(1). The principle of thermal recovery is simple: increasing the oil's temperature dramatically reduces its viscosity, thereby improving its mobility. Recovery of this heavy crude by primary production in the pilot acreage is forecast to be 10% +/- of the oil in the reservoir. Recovery using stem flooding is forecast to be as high as 40 % of the oil in the reservoir.

The Petroleum Act mandates for drilling programs, the primary objective should maintain an inter-well distance of 300 feet. This requirement has been adhered to and there is no further space to drill wells within the pilot acreage without violating this clause. There are also no wells to be re-completed in this zone of interest in the pilot scheme.

Development of UMLE steam flooding infrastructure included:

1. Relocation of the #2 Steam Generator (SG) plant from neighbouring the Central Los Banjos field to the Forest Reserve Oilfield. The SG will be repaired to original condition and operated under normal parameters.

2. Installation of the following lines on existing Right of Ways (ROW's)

    - Water Lines. Installation of 1956 m of 4" Poly Vinyl Chloride (PVC) water line from the Forest Reserve water softening plant to the SG. 1500 barrels of water per day would be sourced from Petrotrin's Forest Reserve water wells.
    - Gas Lines. Installation of 1024 m of 3" schedule 40 double random welded gas line from the Forest Reserve Blue Basin gas manifold to the SG. These lines will be run above ground on pipe racks.
    - Steam Lines. Installation of a steam distribution manifold, 3 expansion loops, approximately 4500 feet of 3" and 2" steam injector line leading to injector wells. Much of these lines would be reclaimed from other fields and undergo integrity testing. All steam lines would be run above ground on supports placed 12' apart.

3. Moving the existing road (125m in length by 6m in width) twenty meters to the east for accommodation of the steam generator and gathering station.

4. Injection of steam into the Upper Morne L'Enfer (UMLE) sands via three (3) injector wells and producing oil and water through ten (10) off take wells. Production response is expected after one year. Over a ten year period, 1.2 million barrels of oil will be produced which responds to a recovery of 33 %.

5. Installation of a new Gathering Station to receive produced fluids from designated wells.

MITIGATING LEGAL RISK

Trinidad and Tobago's Environmental Management Act became law in 2000 and is regulated by the Environmental Management Authority (EMA). The Certificate of Environmental Clearance (CEC) Rules 2001 are the environmental permit regulations that fall under this Act, its purpose being to ensure environmental risks associated with new or significantly modified development activities are identified and a mitigation management plan developed to address potential hazards in the in the planning phase (2).

The Ministry of Energy and Energy Industries (MEEI) regulates the Petroleum Act (Chapter 62:01 of the 1980 Revised Laws of the Republic of Trinidad and Tobago) that contains broad HSE guidelines for the Petroleum sector. The MEEI will not grant approval for a project unless a CEC is granted from the EMA. The Forests Act Chapter 66:01 is administered by the Forestry Division of the Ministry of Agriculture, Land and Marine Resources. The Morne L'Enfer Forest was designated a Forest Reserve under this act. Before any vegetation is removed/altered in these reserves or any other state lands, approvals must be obtained from the Forestry Division. Petrotrin ensured that all permits from the Forestry Division were obtained prior to approaching the EMA and MEEI for approvals. The MEEI and Forestry Division assist the EMA in the review of EIA's that support CEC applications for energy based projects, so the EMA will not grant a CEC without a positive response from these agencies

The present Occupational Health and Safety legislation in Trinidad is outdated and only provides general guidelines in the Factories Ordinance Act 1948, Petroleum Act and Forests Act. The more recent Occupational Safety and Health (OSH) Act was passed by Parliament in 2004 but is yet to be proclaimed by the President. This legislation will regulate activities pertaining to the health and safety of workers in any workplace and will provide more directed legislation with stricter penalties. One of the key elements of this legislation is the provision of safer systems of work including risk assessments. Even though the OSH Act is not law, Petrotrin exercises voluntary compliance with this legislation.

For new projects such as UMLE, the CEC Rules have become a vehicle to enforce draft safety legislation as CEC's granted by the EMA can legally bind applicants to obligations under draft legislation including standards and codes. There are no monetary penalties if the CEC Rules are breached, however the EMA can shut down the activity and mandate the operator to pay compensation costs for any adverse impacts assessed by the EMA.

To acquire a CEC for energy projects such as the UMLE EOR project, the EMA will usually request a full scale Environmental Impact Assessment (EIA). On the onset of the project-planning phase, Petrotrin HSE personnel held several discussions with EMA and MEEI personnel to determine what HSE assessments were required. The EMA requested an Environmental Impact Statement (EIS), and the MEEI requested a HAZOP Study. Petrotrin HSE personnel used findings from the HAZOP Study to develop the mitigation management plan for the EIS.

Environmental Baseline Data was gathered in 2002- 2003 for an EIA to drill 60 wells in Forest Reserve. Because quality and current environmental baseline data was available, the EMA exempted Petrotrin from having to provide new baseline data for the UMLE EIS. This reduced the CEC procurement time frame by three months.

Most of the HAZOP Study sessions were conducted with MEEI personnel in attendance that permitted them to gain insight into the details of the project and lend recommendations to

Petrotrin that would permit the project to meet their approval. The findings and recommendations arising out of this study were presented to them in a formal report for their approval.

ENVIRONMENTAL BASELINE SURVEYS

The 2002-2003 Environmental Baseline Survey of the Forest Reserve Oilfield involved surveys of the Physical, Biological and Socioeconomic environment. The company contracted the expertise of top local biologists and sociologists to gather and interpret this data. The study area was the same as the area delineated in the 1999 Reservoir Characterization Study. Socioeconomic surveys however extended beyond this boundary to include communities that are directly impacted by activity in Forest Reserve.

Physical Environment

A description of the of the baseline physical environment included assessments of topography, geology and climate. Air, (ambient), soil, surface and groundwater quality was also measured. All but two of the twenty (20) water and soil samples measured were found to be within standards prescribed in draft environmental legislation. These samples were the pipe end discharge of the Bernstein Tank Farm into the Silver Steam River and 1km downstream of this tank farm. The first schedule of the Water Pollution Rules (Draft) contains standards detailing the condition or concentration at which a substance or parameter is defined as a pollutant. (See Table 1). At present there are no soil quality standards in Trinidad, therefore the Alberta Tier 1 standards were used to compare analytical results. The soils were slightly acidic to neutral, typical of soils in tropical forests experiencing a tropical marine climate.

Biological Environment

Assessments of the biological environment included floral and faunal surveys that were conducted by using vehicle and foot transects of the Study Area. Approximately seventy-five (75%) percent of the area is occupied by natural forest at various stages of degradation. The predominant vegetation formation identified is the Evergreen Seasonal Forest **(***Clathrotropis brachypetala-Attalea maripa* faciation**).** The vegetation along the roadsides and production facilities which amounts for less that 0.5 % of the total study area was mainly short herbaceous vegetation that is maintained by regular mowing or grazing. In total one hundred and fifty-one (151) species of plants were identified of which sixty-four (64) are upper canopy trees (3).

Field sampling of the aquatic fauna was carried out in the Silver Stream River and its tributaries. A total of 2 species of fish and 5 species of benthic macro invertebrate were collected from the three sites sampled. A total of 1 amphibian species was also recorded for the area. Avian species were observed and recorded over a five (5) day period using visualization and vocalization as a basis for identification. A total of thirty-four (34) avian families representing sixty-seven (67) species were recorded (3).

This level of floral and faunal biodiversity is on par with other Evergreen Seasonal Forests in Trinidad. Field personnel who were interviewed for this EIA noted that most floral and faunal degradation did not result from oilfield operations, but due to fires in the dry season started by careless motorists who use oilfield access roads open to the public. These fires spread rapidly in the dry season and burn for several days.

Socio-Economic Environment

A socio-economic survey of the project area was conducted using structured questionnaires for twenty (20) households, two (2) community leaders and two (2) business proprietors(3). This constituted 96% of households and 100 % of businesses in Forest Reserve. Two public consultations were held in Forest Reserve and concerns of the stakeholders were recorded. Unedited videotapes covering the entire consultations were submitted to the EMA .

Most of the concerns were more economic rather than HSE in nature. The majority of stakeholders interviewed were in support of oilfield development activity in Forest Reserve, once they would benefit directly from these activities. Residents had friends or relatives who worked or currently work in the Forest Reserve oilfield. They believed that the proposed E&P activity would bring social and economic benefits for the community. The Forest Reserve community has high levels of unemployment, especially amongst the youth.

HAZOP STUDY

A Hazard and Operability Study (HAZOP) was conducted by project personnel to assess risk, and develop recommendations to mitigate risk. This knowledge-sharing exercise brought together personnel with the relevant background and experience to identify and rank risks associated with this project at this location.

The HAZOP process is based on the principle that a team approach to hazard analysis will identify more problems than when individuals working separately combine results. The team included personnel from HSE, Utilities, Electrical, Projects, Production, Instruments, Field Equipment Maintenance, Gas Sales and Fire. The study was conducted in sessions and through brainstorming effort that stimulated creativity, new ideas and a thorough review of project parameters. Even though the study's main focus was hazard identification, it also consisted of identifying operability problems and determining whether additional safeguards and operational controls were required to ensure an appropriate level of safety for the project.

The procedure consisted of the following elements:

1) Outlining the scope of the project ensuring individuals has a clear understanding of technical, environmental and legal issues and project objectives.
2) Identifying deviations from normal running operations and the associated causes. Reference was made to accident /incident records
3) Discussing the potential consequences to personnel safety, health, process operations, equipment or the environment (minimum level). Environmental baseline data specific to Forest Reserve and the UMLE project site was referenced when identifying potential consequences
4) Listing the existing HSE operational controls, emergency response plans and making a judgment as to their adequacy in mitigating the hazard
5) Developing recommendations where additional safeguards are required and assign responsibilities.

The team focused on specific portions of the process called "nodes". Risks from a broad spectrum of activities covering all nodes of the project were assessed. The sessions were recorded using a pre-formatted template to capture the discussion for each guideword and each node. The team lists the consequences, safeguards and any recommendations deemed appropriate.

The results were recorded in columnar format under the following headings :

What if..	Cause	Consequences	Safeguards	S	L	R	Recommendations	Action

Severity (S) was rated using a scale of 1 to 4 (Negligible to Disastrous) looking at potential impacts such as downtime, barrels spilled, fatalities, property damage, environmental concerns and public welfare.

Likelihood (L) was rated in terms of incidents per decade using a scale of zero (0) to three (3) incidents per decade as rare, and four (4) or more incidents per decade as frequent

Risk (R) was ranked by equating hazard severity and probability. When the level of risk identified got a ? or * ranking (See Table 2) risk reduction was recommended.

By nature the process was highly subjective as the HAZOP study teams evaluation are dependent upon personal judgment and experience, however the greater the participation level, the greater the accuracy in identifying hazards, ranking risk and developing appropriate recommendations to mitigate risk.

The six most significant HSE risks identified by a (?) or (*) risk rating (See Table 2) from the HAZOP study were from the following activities:

1. Discharge of produced water into adjacent watercourses.
2. Hydrocarbon spills from the Gathering Station
3. Emission of Hydrogen Sulphide (H_2S)
4. Disposal of Tank Bottoms
5. High Temperature High Pressure (HTHP) Operations.
6. Site preparation

Like any assessment of HSE aspects, there were also positive aspects associated with a project of this nature being implemented in an economically depressed. Baseline socioeconomic data used in the HAZOP indicated that HSE risk to fence-line communities would be negligible due to the remoteness of the project and that the project had more positive social impacts in terms of creation of temporary jobs and increased business activity within a socially depressed community.

HSE RISK MITIGATION STRATEGIES

For significant HSE aspects, risk mitigation strategies were recommended by the HAZOP team and were incorporated by HSE personnel into the HSE risk mitigation plan for the EIS (See Figure 4). The mitigation strategies for the most significant aspects listed above are as follows:

Contractor HSE Management

A review of accident and incident records from similar Petrotrin gathering stations and steam generators indicated that most occurred when contractors undertook regular maintenance activities. The implementation of an effective contractor HSE management system was therefore a priority in the mitigation management plan. All contractors who were registered to bid for

construction and maintenance contracts had to have an effective and documented HSE management system that identified, and controlled all risks associated with significant HSE aspects. Their HSE management system must include training of all personnel in the significant aspects of their activity, operational controls to reduce their risk and emergency response.

Project engineers (civil, electrical and mechanical), and operations personnel who have overall responsibility for construction the maintenance of the EOR infrastructure are responsible for ensuring contractors meet these requirements and perform work in accordance with company HSE policy. HSE personnel conduct regular facility and Environmental Management System (EMS) audits to ensure continual improvement.

Discharge of Produced Water into Adjacent Watercourses

All produced crude and water from the UMLE steamflood project will be sent to the Bernstein Tank Farm in Forest Reserve for processing and fiscalization. According to Petrotrin's Produced Water Effluent Monitoring Program which is done monthly on a voluntary basis, the main pollutants in effluent water discharge at the Bernstein tank farm that are not in compliance with the draft Water Pollution Rules effluent standards (Trinidad and Tobago Bureau of Standards - TTS 547: 1998 - Standard for Effluent Discharge From Industrial Processes) are Total Petroleum Hydrocarbons (TPH), Total Suspended Solids (TSS), Chlorides (Cl) and Sulphides (S) (See Table 1). The baseline surveys also indicated that produced water discharged from the Bernstein Tank Farm did not comply with this standard.

Much of this non- compliance with the TTS: 547 1998 standard results from existing steam flooding operations within Forest Reserve and surrounding fields (Forest Reserve Expansion and Parrylands Cruse-E EOR projects) that feed their production into the Bernstein Tank Farm. Steam combined with viscous and high gravity crudes facilitate the formation of stable emulsions that exhibit no sign of separation, even after quietly standing still for months. The most significant environmental impact from the petroleum industry in Trinidad and Tobago is the discharge of such emulsions to the environment without proper treatment to remove the oil. Sulphur reducing bacteria (SRB) also proliferate in thermal wells and increase the sulphide content of this "Thermal Produced Water".

With projected steam injection rates into the Morne L' Enfer Formation to be over 1500 barrels per day, most of this water will be returned to surface as produced water, so the volume of this non compliant effluent from the Bernstein Tank Farm is expected to increase. Production from steamflooding in Forest Reserve can contain as much as 70 to 85% water. The yields of crude oil at the Bernstein thermal wells are as low as 15 %.

When production enters the tank farm, it is stored in a ten thousand (10 000) barrel wash tank, which is bled for about two to three hours per day into two parallel API separators where the oil is skimmed off. With the increasing water production expected from this project, the retention time in these primary separation facilities will become increasingly inadequate.

Petrotrin has conducted detailed technical studies to mitigate the impacts of produced water pollutants from the Bernstein Tank Farm and has begun to implement the following strategies:

1. Reduction in TPH with enhanced primary physical separation facilities accompanied by site- specific reverse - emulsifier and flocculation treatments.

2. Construction of an additional 10 000 bbl wash tank at Bernstein to increase residence time is near completion. Technical studies have shown that this strategy alone will reduce TPH levels incompliance with draft water Pollution Rules 2001.
3. After primary treatments described in 1) and 2) above, the produced water would be piped via PVC line either south into the Columbus Channel, or west into the Gulf of Paria. Both water bodies have a high level of mixing due to tidal fluctuations. Environmental Impact Assessments to support a CEC application for the discharge of this water is carded for the dry season of 2005.

Hydrocarbon Spills from the Gathering Station

Oil spills at gathering stations usually occurs during tank cleanings, pipefitting work and infrequently- tank overflow. Though results from the baseline surveys indicate that oil spills in the Forest Reserve field appeared to have minimal impact to biological diversity and soil and water quality, Petrotrin has a zero tolerance to oil spills, and as such measures have been implemented to significantly reduce the risk of oil spills from the gathering station. These measures include:

1. Installation of tank level meters that activate transfer pumps and tank equalizing activation switches to prevent tank overflow
2. Integration of an alarm system into the Petrotrin Police radio communications network to notify field operations and maintenance personnel in the event of a power outage or any other incident.
3. Installation of a concrete bund wall to contain spillage in the event of failure of 1) or 2) above. The bunded area is designed to contain 125% the volume of the largest tank.
4. Utilizing a closed system so that there is no effluent discharge at the facility other than storm water runoff.
5. Regular table-top exercises of the Oil Spill Contingency Plan for Forest Reserve with necessary follow up action.

Hydrogen Sulphide (H_2S)

One of the hazards commonly associated with steam-flooding operations is the production of H_2S, especially when a steamflood matures. Even though ambient H_2S concentrations are expected to be negligible, and the wells and gathering station are greater than 1km and downwind from the nearest settlement, Petrotrin has ensured the risk of exposure to contractors and company personnel is significantly reduced. To mitigate any potential risks associated with H_2S emissions, the following controls have been implemented.

- H_2S Training for all employees and contractors who service EOR infrastructure.
- H_2S Scrubber installed after the gas-liquid separator at the Gathering Station.
- Installation of battery powered H_2S detection and alarm systems that are regularly serviced according to manufacturer specifications.

Disposal of Tank Bottoms

Oily basal sediments from all the gathering stations in Forest Reserve are stored in three large oily waste pits at the Bernstein Tank Farm. The contents of these pits will be excavated from the pit and land farmed on acreage adjacent the tank farm on a rotational basis using domestic produced fertilizers to stimulate microbe growth.

High Temperature High Pressure (HTHP) Operations

Operational controls and design modifications were implemented to ensure the risk associated with these aspects would be reduced to acceptable levels. The design and construction of facilities complied with international codes relating to structure (CUBiC), pipe laying/trenching (ASME), pipeline specification (API, ASME), fire protection (NFPA) and process safety (OSHA and PSM 1910.119)

Even though the steam generator was nearly 30 years old, there were many safety features that were engineered into the original design such as pressure relief valves, isolating valves and shutdown switches, especially for the gas supply and steam generator boiler tube. These design safety features significantly reduced most of the potential safety risks that may arise from HTHP infrastructure. The Gathering station on the other hand had several operational controls that were developed in the past 3 years to minimize the risk of oil spills.

Risk associated with vehicle use near HTHP infrastructure was also addressed. The project team ensured that as much of the piping was buried and where it was necessary to run them above ground, the Right of Way was further from the roadside with proper signage and barriers installed. The company has implemented a driver safety program for all employees who service field infrastructure.

For upset conditions in a HTHP environment, Petrotrin has six Emergency Response Plans that are regularly tested and updated. All registered contractors must attend orientation sessions to become aware of these plans and notification procedures. These emergency response plans include:

- Fire/ Explosion Emergency Response Plan
- Bomb Threat Emergency Response Plan
- Hurricane Emergency Response Plan

To date these facilities have been operational for over four months with no accidents or incidents.

Site Preparation

From the baseline surveys, it was determined that there were no endangered floral or faunal species in the area, but the project team still took measures to ensure the footprint was as small as possible. This was not only good environmental practice, but also reduced site preparation costs.

Petrotrin's Survey Department produced a Geographic Information System (GIS) three-dimensional (3D) model for the UMLE area using Arcview GIS software to spatially reference all the variables on the project site that may be impacted upon by the construction and operation of the facility (See Figure 3). This model permitted a 3D analysis of several siting scenarios that achieved the following objectives:

- Minimize site clearing and earthworks
- Avoid fragmentation of forest habitats
- Minimize risk of erosion, slippage and subsidence of slopes and sedimentation of the Aripero river
- Maintain 150 ft buffer between existing wells
- Use of existing road as much as possible while providing safe access and egress to and from the UMLE area

- Create no collection 'basins' for any potential H_2S emissions
- Minimize distance to injectors to avoid temperature and pressure losses

OHSAS 18001 and ISO 14001 EMS Certification

The HSE Department is currently in the process of implementing a pilot Safety Management System (SMS) in accordance with the OHSAS 18001 Specification for the Operations Support Services (OSS) Group. The OSS Group includes most of the sections involved in the construction and maintenance of EOR infrastructure.

The company's Exploration and Production Operations Environmental Management System (EMS) has been ISO 14001 Certified since 2002. These operations are the largest in terms of manpower and acreage to be ISO 14001 certified in Trinidad. The environmental management programs for EOR operations were an integral component of the mitigation management plan. (See Figure 4).

For this EOR project, both of these HSE management systems play a significant role towards improving the effectiveness of the risk assessment and mitigation management process, and ensuring mechanisms are in place for continuous improvement in HSE performance.

CONCLUSION

For this EOR project in a tropical forest reserve, an integrated approach to assessing safety and environmental risk and developing mitigating strategies was adopted. Environmental Management Programs for EOR projects developed under the ISO 14001 EMS certification exercise for Petrotrin's E&P operations, and site- specific environmental baseline data of Forest Reserve was made available to a HAZOP Study team who comprised safety, environment and project personnel. This team risk assessment approach permitted a comprehensive assessment of both safety and environmental risks and the development of appropriate risk mitigation strategies for this ecologically and socially sensitive environment. The availability of this baseline data also reduced the environmental permit procurement time frame by three months.

Most of the significant HSE risks identified through the HAZOP Study, traditionally a safety risk assessment tool, were environmental in nature as adequate safety operational controls existed for construction and operation of the steam generator, gathering station and supporting EOR infrastructure. Of all aspects identified and assessed for this project, the discharge of produced water to the environment poses the greatest HSE risk. Implementation of new operational controls focused on the mitigation of environmental risks and those associated with contractor construction and maintenance activities.

HSE professionals who worked on the project agreed that it was more effective to mitigate safety and environmental hazards through a collaborative effort of environmental, safety, and engineering disciplines. It is the conclusion of the authors that acquiring HSE clearance for projects in ecologically sensitive areas will require multidisciplinary risk assessment teams and that HAZOP Studies can be a valuable and integral component of Environmental Impact Assessments.

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This paper is dedicated to Rudolph Ramjattan-Environmental Steward of Forest Reserve

TABLE 1

Tank Farm	BWPD	TPH mg/l	TSS mg/l	Chloride mg/l	Sulphide mg/l
TTS 547: 1998 Standard		<25	<50	< 250	< 1.0
Forest Reserve Bernstein	4200	48	85	7200	1.7

Averaged from June 2002- May 2003 data of samples taken and analysed in-house, monthly Source-(4).

TABLE 2

Risk Ranking Matrix for UMLE HAZOP Study

		LIKELIHOOD			
		1	2	3	4
SEVERITY	1	0	0	0	^
	2	0	0	^	*
	3	^	?	*	*
	4	?	?	*	*

LEGEND

0	Tolerable to the point where people can cope with it.
^	May be okay but uncertainties warrants that consideration be given to recommendations.
?	Definitely need to have some recommendations.
*	Not Acceptable/Reengineering required.

Figure 1 – Location of Trinidad and Tobago

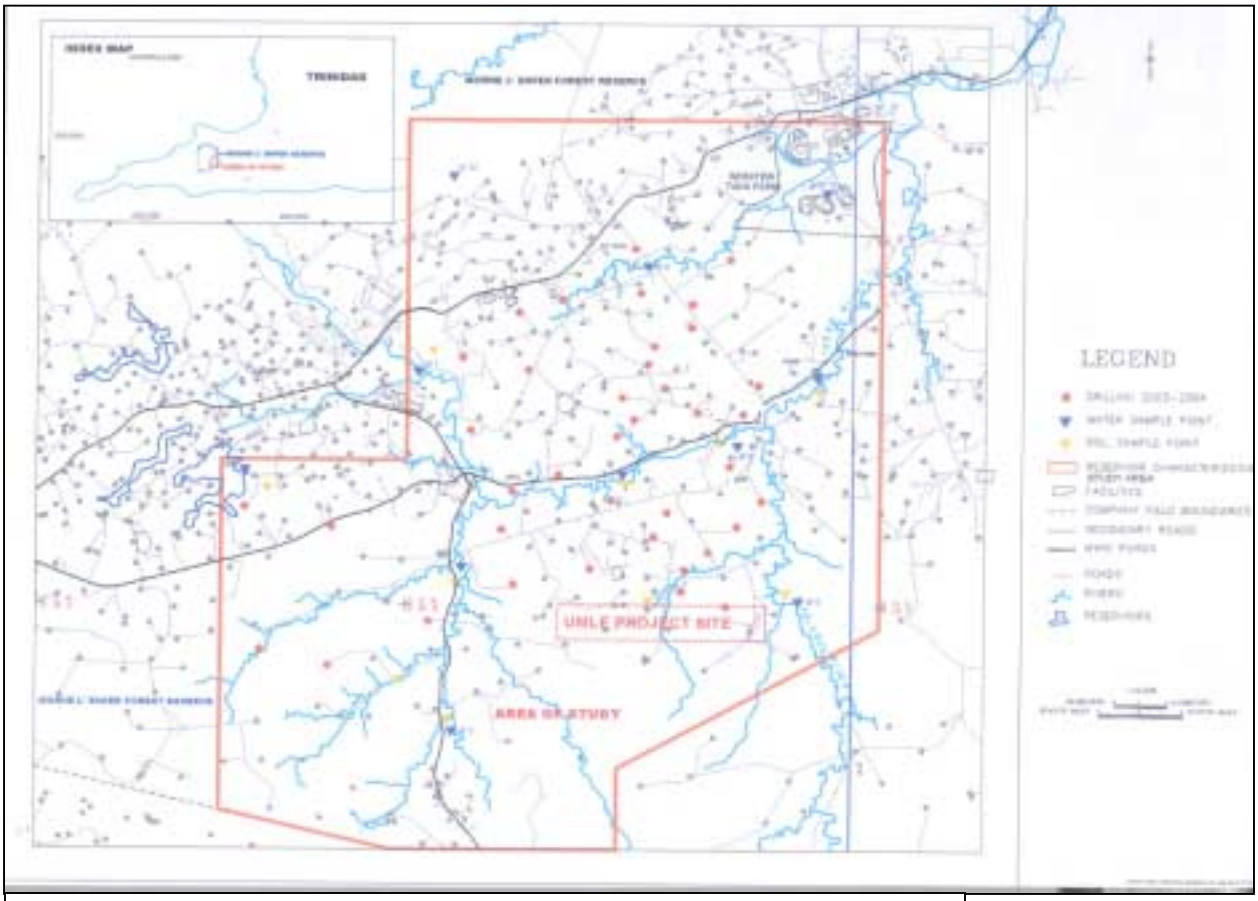

Figure 2 – Forest Reserve Facilities, Location of UMLE Project Site

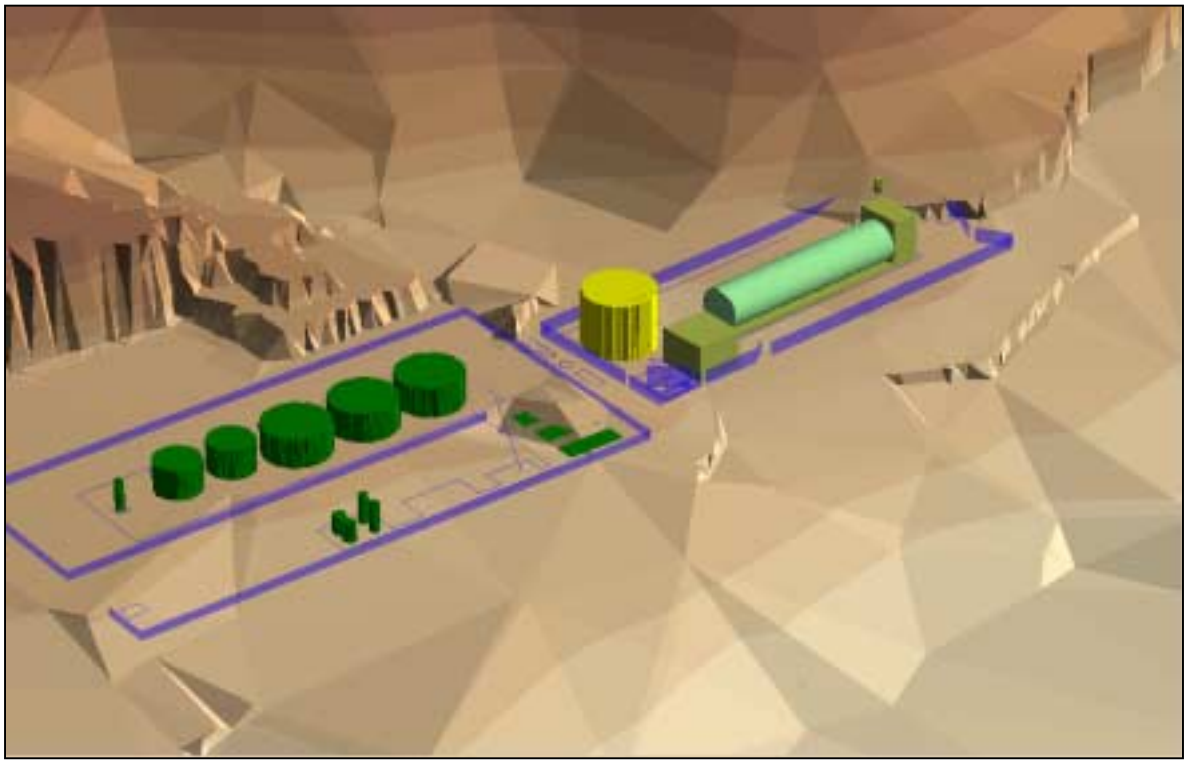

Figure 3 - Forest Reserve UMLE Steamflood Project Gathering Station and Steam Generator Arcview 3D Image

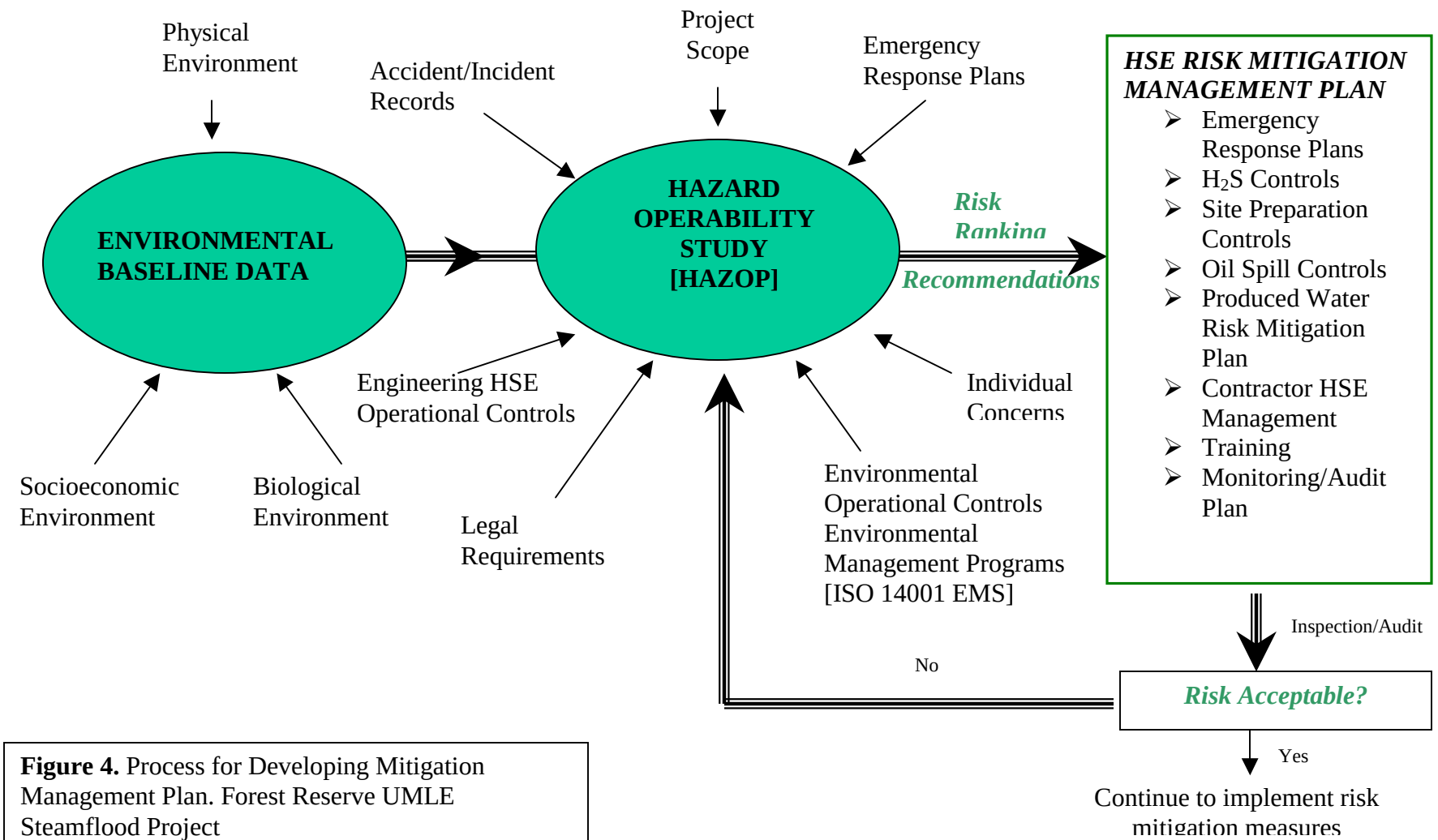

Figure 4. Process for Developing Mitigation Management Plan. Forest Reserve UMLE Steamflood Project