Environmental Assessment Report

Summary Initial Environmental Examination
Project Number: 39921
July 2006

India: Dahej Liquefied Natural Gas Terminal Expansion Project

Prepared by Petronet LNG Limited for the Asian Development Bank (ADB).

ABBREVIATIONS

ADB	−	Asian Development Bank
BOD	−	biological oxygen demand
COD	−	chemical oxygen demand
EIA	−	environmental impact assessment
EPA	−	Environmental Protection Agency (US)
EPC	−	engineering, procurement, and construction
GAIL	−	Gas Authority of India Limited
GPCB	−	Gujarat Pollution Control Board
HSE	−	health, safety, and environment
LNG	−	liquefied natural gas
MOEF	−	Ministry of Environment and Forest
NAAQS	−	National Ambient Air Quality Standard
NOx	−	nitrogen oxides
OHSAS	−	Occupational Health & Safety Management System
OISD	−	Oil Industry Safety Directorate
PLL	−	Petronet LNG Limited
SIEE	−	summary initial environmental examination
SO_2	−	sulfur dioxide

WEIGHTS AND MEASURES

^oC	−	degree Celsius
dBA	−	decibel acoustic
ha	−	hectare
km	−	kilometer
m	−	meter
m^3	−	cubic meter
mg/l	−	milligram per liter
mg/m^3	−	milligram per cubic meter
MMPTA	−	million metric tons per annum
NTU	−	nephelometric turbidity units
ppm	−	parts per million
$\mu g/m^3$	−	microgram per cubic meter

GLOSSARY

Ambient	–	Referring to existing or predominate conditions
Benthic	–	That portion of the marine environment inhabited by marine organisms that live permanently in or on the bottom
Benthos	–	The forms of marine life that live on the ocean bottom
Biochemical oxygen demand	–	The amount of dissolved oxygen needed to decompose organic matter in wastewater
Chemical oxygen demand	–	The amount of dissolved oxygen needed to oxidize organic matter in wastewater, under acidic conditions
Hazardous waste	–	Any industrial by-product, especially from the manufacture of chemicals, which is destructive to the environment or dangerous to the health of people or animals
Phytoplankton	–	Photosynthetic plankton
Pig	–	Typically a small device that is forcibly moved through a pipe to inspect it and/or to remove buildup resulting from biological growth or chemical processes
Plankton	–	Passively drifting or weakly swimming organisms in marine and fresh waters; members of this group range in size from microscopic plants to jellyfish measuring up to 2 meters across the bell, and include the eggs and larval stages of the nekton and benthos
Salinity	–	The amount of dissolved material (salt) in seawater
Zooplankton	–	The animal forms of plankton

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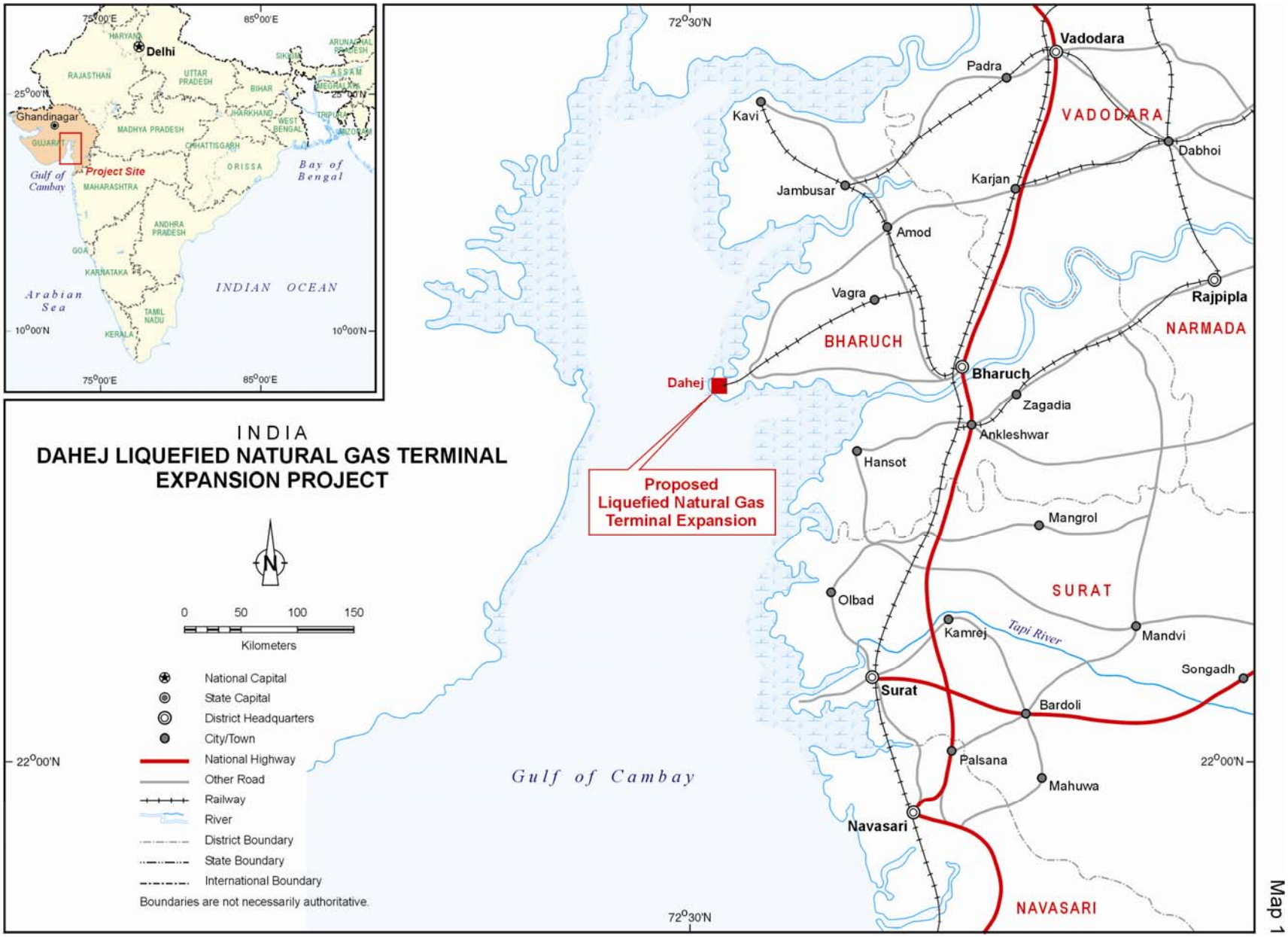

Map 1

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I. INTRODUCTION

1. Petronet LNG Ltd. (PLL) owns and operates the liquefied natural gas (LNG) terminal, which began commercial operation on 9 April 2004. PLL will double the capacity of the terminal from 5 million metric tons per annum (MMTPA) to 10 MMTPA. The second phase development of the Dahej LNG terminal in Dahej, Gujarat, will be carried out under the proposed Dahej LNG Terminal Expansion Project (the Project). The Gujarat Pollution Control Board (GPCB) provided a no objection certificate for the LNG terminal based on the environmental impact assessment (EIA) reports prepared during 1999–2000, which also cover the second phase development. However, the Ministry of Environment and Forest (MOEF) granted environmental clearance only for the first phase development. For the proposed expansion, MOEF advised PLL to update the EIA documents to reflect changes in the baseline environmental condition over the 5 years since the original reports were prepared. Consequently, PLL commissioned the Engineers India Limited to update the EIA for the Project, and the National Institute of Oceanography to update the EIA for the marine facilities. In April 2005, PLL submitted the two updated EIA reports to MOEF, which granted environmental clearance for the Project on 23 November 2005.

2. This summary initial environmental examination (SIEE) has been prepared for the Asian Development Bank (ADB) in line with its environmental and social safeguard policies, and information disclosure requirements for environmental category B projects.[1] The SIEE is based on the original EIA documents, as well as the two updated EIA reports. These documents are available for public review at PLL and ADB on request.

II. DESCRIPTION OF THE PROJECT

3. The capacity of the Dahej LNG terminal needs to be increased sooner than expected, as economic growth has raised energy demand. Natural gas plays an increasingly important role under the Government of India's policy to diversify the country's energy base and reduce air pollution, which results mainly from the use of oil and coal. As such, the Government plans to have natural gas meet 20–30% of the country's energy demand by 2025, meaning natural gas consumption will increase on average by about 2 MMTPA. The Project, therefore, will help meet this projected demand.

4. The Dahej LNG terminal occupies about 48 hectares (ha) in the Gujarat Industrial Estate on the coast of the Gulf of Khambhat in western India. The terminal is about 45 kilometers (km) from Bharuch town, Bharuch District, Gujarat State (Map 1). The industrial estate has several large chemical and petrochemical industries, all of which are in operation and have their own jetties.

5. The Project considered two alternatives: (i) a new terminal with 5 MMTPA capacity could be developed at a new site, or (ii) the LNG terminal at Dahej could be expanded. The second alternative is considered more appropriate, given the advantages of the existing site and the fewer environmental impacts that would be created compared to a new site. The advantages that will make the expansion alternative more economical and expeditious to implement include:

[1] A project is classified as Category B if its potential adverse environmental impacts on human populations or environmentally sensitive areas are less adverse than those of Category A projects.

(i) the ability to use the existing natural gas pipeline owned and operated by the Gas Authority of India Limited (GAIL), which presently serves the LNG terminal, to accommodate the additional supply of 5 MMTPA;
(ii) the existence of several major gas-consuming industries in Gujarat and along the gas pipeline;
(iii) proximity to the identified LNG supply source relative to other LNG sources in Asia Pacific;
(iv) natural draft of more than 12 meters (m), which facilitates berthing of large LNG tankers;
(v) sufficient water depth in the area, obviating the need for dredging and/or a navigation channel;
(vi) moderate wind and climate conditions favorable to unloading LNG from tankers;
(vii) land use exclusively for industrial development with no permanent structures close by that could be a potential safety hazard; and
(viii) existing infrastructure provided by the industrial estate.

6. The Project will add some new facilities within the existing LNG terminal complex: two new storage tanks, re-gasification facilities, and two new gas turbine generators. Table 1 summarizes the existing facilities and the new facilities to be constructed under the Project. Figure 1 shows an indicative layout of the new facilities to be added under the Project within the existing complex.

Table 1: LNG Terminal Facilities and New Project Facilities

Facilities	Existing Facilities (Phase I: 5 MMTPA Capacity)	Expansion Project (Phase II: 10 MMTPA Capacity
A. Marine Facilities		
Jetty	2.5 km long, trestle structure, designed to handle a capacity of 65,000 to 160,000 m^3.	No new facilities required.
	About 80 tankers expected per year.	About 160 tankers expected per year.
Other facilities	5 mooring dolphins; 4 breasting dolphins; unloading platforms; 1 gangway tower; and walkway bridges connecting the unloading platforms, mooring, and breasting dolphins.	No new facilities required.
B. Unloading Facilities		
LNG loading arms	3 loading arms of 16 inches diameter.	No new facilities required.
NG arm	1 NG arm of 16 inches diameter.	No new facilities required
Unloading line	2 unloading lines of 30 inches diameter.	No new facilities required.
Vapor return line	1 line of 10 inches diameter.	No new facilities required.
De-superheater	1 de-superheater for cooling the return vapors to ship.	No new facilities required.
Berthing time	20–22 hours.	Unchanged.
Unloading time	About 14 hours, average loading rate of about 10,000 m^3/hour.	Unchanged.
C. LNG Storage Tanks		
Number and capacity	2 tanks, each with 160,000 m^3 gross capacity.	2 new similar tanks.
Type	Full containment tank.	Full containment tank.

Facilities	Existing Facilities (Phase I: 5 MMTPA Capacity)	Expansion Project (Phase II: 10 MMTPA Capacity
D. Boil-off-Gas Recovery System		
Cryogenic compressors	3 units, each with 12,000 kg/hour capacity with 1 common suction knockout drum.	No new facilities required.
Suction gas de-superheater	1 common unit.	No new facilities required.
Recondenser	1 unit.	No new facilities required.
E. Send Out Facilities		
Capacity	1,550 m^3 per hour.	3,100 m^3 per hour
Low pressure in-tank pumps	7 units.	Additional 7 units for the 2 new tanks.
High pressure in-tank pumps	5 units.	Additional 5 units for the 2 new tanks.
Shell and tube vaporizers	7 units.	Additional 7 units for the 2 new tanks. Additional 1 unit for using the heat of flue gases from the gas turbine.
Submerged combustion vaporizers	2 units.	Additional 2 units for the 2 new tanks.
F. Auxiliary Facilities		
Gas turbine generators	3 units, each with 7.6 MW capacity.	2 new additional units required.
Transmission line	220 kVA transmission line from the grid of Gujarat Electricity Board as a power supply backup.	Unchanged.

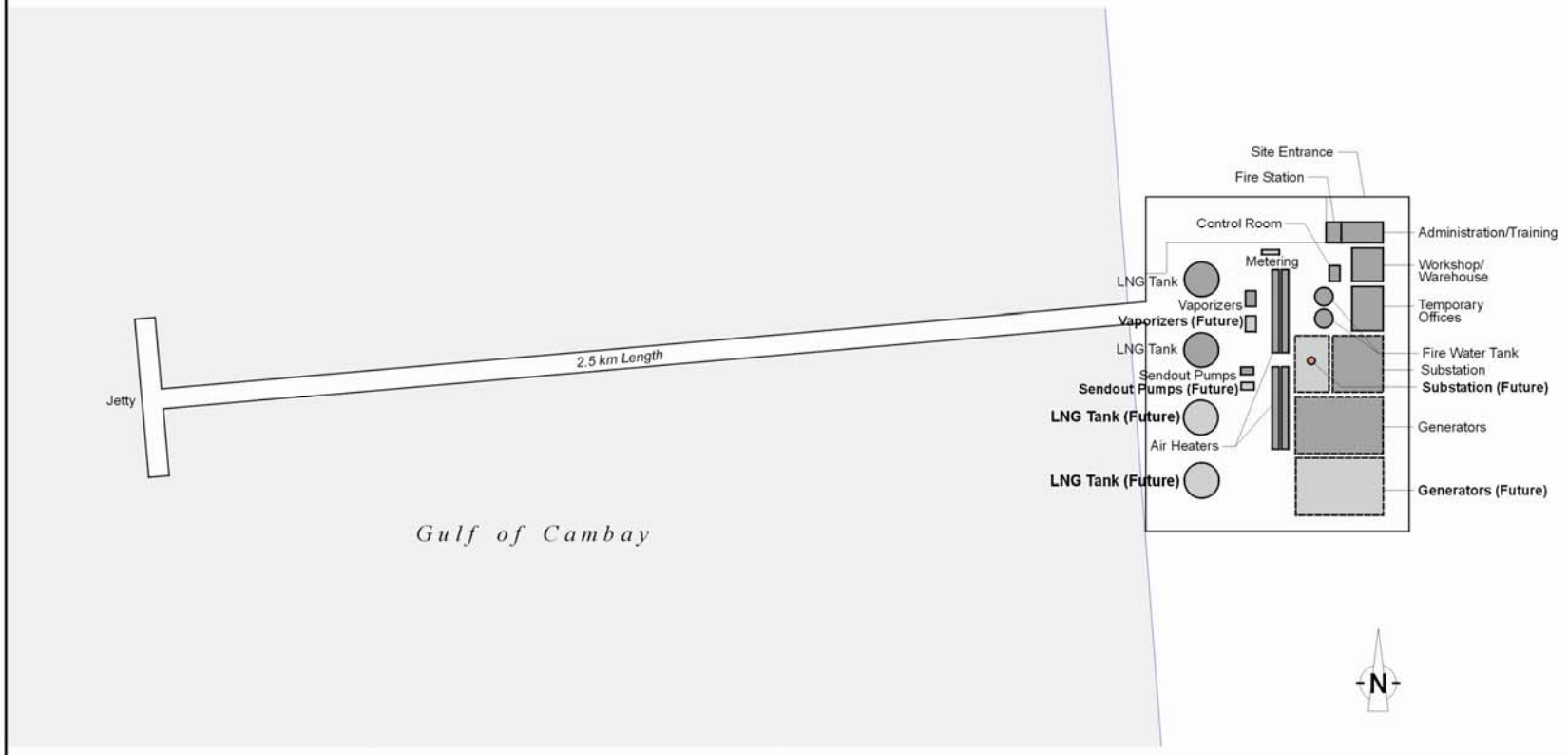
kg/hour = kilogram per hour, kVA = kilo-volt ampere, LNG = liquefied natural gas, m^3 = cubic meter, m^3/hr = cubic meter per hour, NG = natural gas, MMTPA = million metric tons per annum, MW = megawatt.
Source: Petronet LNG Limited.

7. The Project will be implemented under an engineering, procurement, and construction (EPC) contract, combining detailed design, construction, supply and installation of equipment, and commissioning. The EPC contract for the first tank was awarded to Ishikawajima-Harima Heavy Industry Co. Ltd. on 9 December 2005. The contract for the second tank was awarded to the consortium of Ishikawajima-Harima Heavy Industry Co. Ltd, Toyo Engineering Corporation, Toyo Engineering India Limited, Itochu Corporation, and Mitsui & Co., Ltd[2] on 23 January 2006. Construction is expected to be completed within 3 years.

8. The expansion of the LNG terminal will not change its operations. Figure 2 shows the process flow diagram of the existing operation. The new facilities will be integrated into the existing facilities, as shown in the process flow diagram of the terminal after the expansion (Figure 3).

[2] This is the same consortium that constructed the existing terminal.

Figure 1
DAHEJ LIQUEFIED NATURAL GAS TERMINAL EXPANSION PROJECT
Project Layout



LNG : Liquefied Natural Gas

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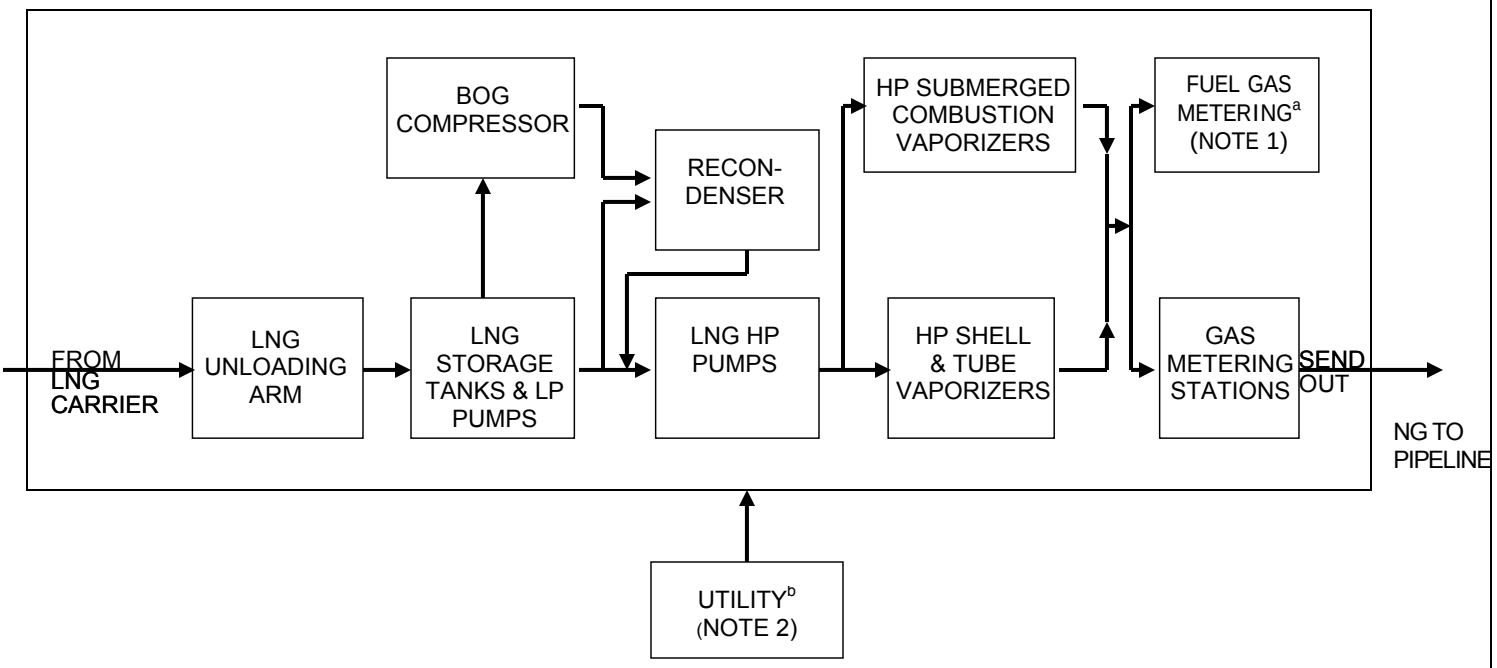
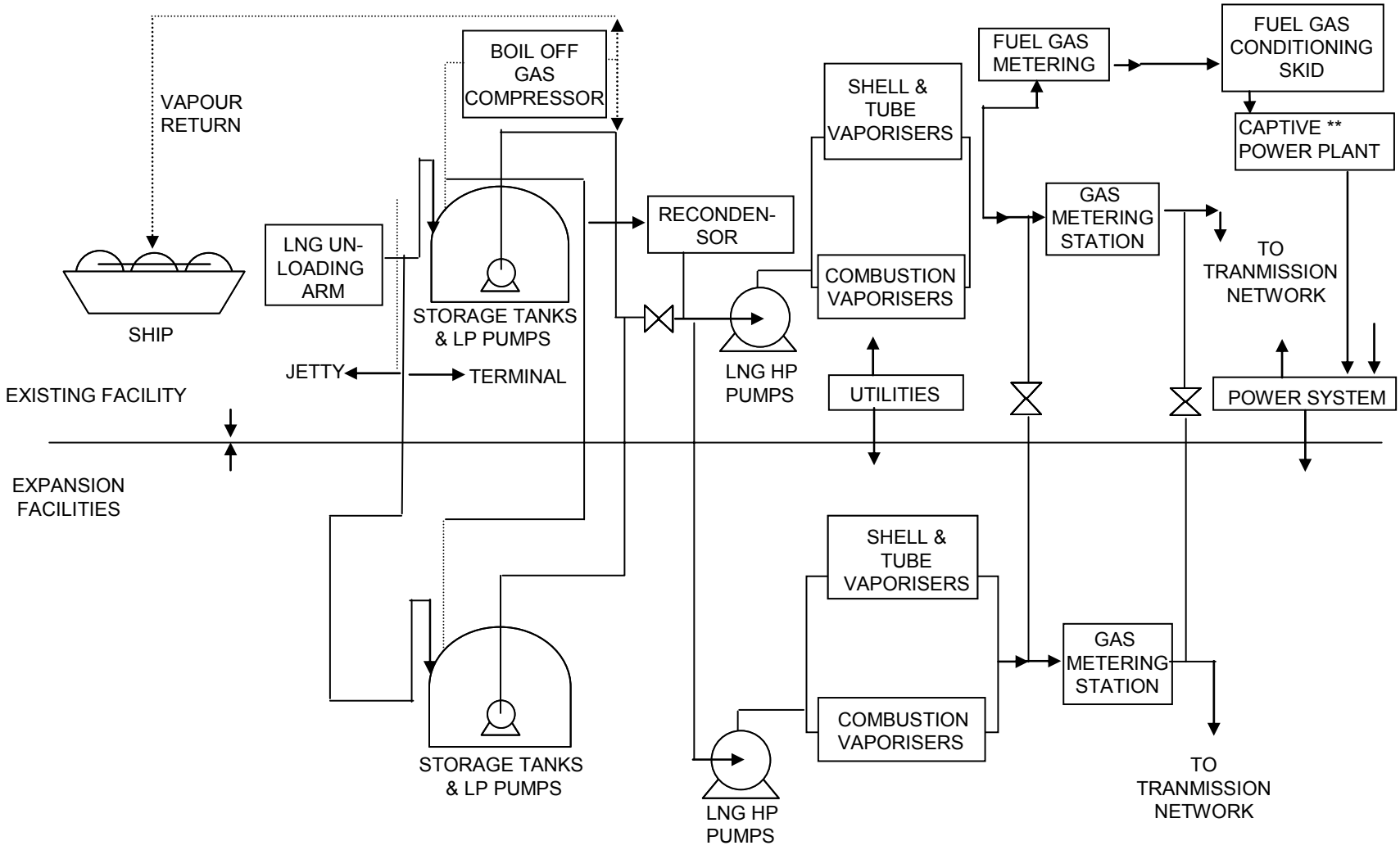
Figure 2: Process Flow Diagram of Existing LNG Terminal



BOG = boil-off-gas, HP = high pressure, LNG = liquefied natural gas, NG = natural gas,
[a] For captive power plant.
[b] Power, industrial water, DM water, and ethylene glycol (other utilities requirements are met by captive generation).
Source: Petronet LNG Limited.

Figure 3: Process Flow Diagram of the LNG Terminal After Expansion



HP = high pressure, LNG = liquefied natural gas, LP = low pressure, NG = natural gas.
Source = Petronet LNG Limited.

9. Although its gas pipeline is adequate for the additional volume, GAIL plans to construct a new 421 km pipeline from Dahej to Uran to serve new clients in Gujarat and Maharashtra states. The new Dahej–Uran pipeline is part of the Dahej–Hazira–Uran–Dabhol gas pipeline project that GAIL is implementing. This new gas pipeline system consists of (i) 569 km of 30-inch diameter trunk line from Dahej to Hazira (101 km), to Panvel (285.5 km), and to Dabhol (182.5 km); (ii) 473.5 km of spur lines of smaller diameter pipes branching out from the trunk line at various locations; and (iii) 87 km of loop lines of smaller diameter pipes. The 34.3 km Panvel–Uran spur line has 12-inch diameter pipes. In July 2004, MOEF granted the new gas pipeline project environmental clearance. Construction has started and is expected to be completed by the end of 2006.

10. This new gas pipeline is not part of the Project, and is not the responsibility of PLL. However, it is considered associated project facilities. The EIA of the gas pipeline, conducted in 2002, did not find any significant environmental impacts, as the pipeline corridor would not traverse ecologically sensitive areas. For the Dahej–Hazira–Panvel–Uran route, only about 5.4 km of the Panvel–Hazira section will pass through degraded forest with less than 10% canopy cover. Basic transient environmental disturbances normally associated with pipe trenching will not have significant impacts, as the pipeline corridor is in a rural setting. Each short section will be built over a short period, and then construction will move on to the next section. Nevertheless, such environmental problems as soil erosion, noise, exhaust emissions, and construction wastes will be minimized using established mitigation measures and good construction practices. In addition, GAIL will undertake a compensatory afforestation program.

III. DESCRIPTION OF THE ENVIRONMENT

A. Physical Environment

1. Overview of the Project Site

11. The project site is the LNG terminal complex in the vast Gujarat industrial estate. The LNG terminal complex covers about 48 ha, excluding the jetty area (about 800 m by 615 m). The site extends from the shoreline inland, with a 2.5 km jetty for unloading LNG. The site is surrounded by vacant land with neighboring industries at a distance: Birla Copper about 2.1 km to the north, Indian Petrochemicals Ltd about 1.3 km to the east, BASF Styrene Ltd about 2.8 km to the northeast, and Gujarat Alkali and Chemicals Ltd about 6.0 km also to the northeast. Map 2 shows land use within a 10 km radius of the site.

12. The Gujarat industrial estate occupies an area of 22,954 ha, including 14,272 ha that have been developed and 10,265 ha that have been leased. It has 166 operating industries and 91 industries in various stages of development. The estate does not have any environmentally sensitive areas. Largely unoccupied, the Gujarat industrial estate is used exclusively for industrial development. It has adequate infrastructure, such as roads, water supply, and electricity supply. The Project will not require new off-site infrastructure.

2. Climate

13. The coastal region of Gujarat has four distinct seasons: winter (December–March), summer (April–June), rainy season (July–September), and monsoon season (October–November). Air temperatures range from an average daily maximum around 40 C, normally recorded in April and May, to an average daily minimum around 13 C in the winter. Relative

humidity is quite high, exceeding 70% during rainy season. The sky is mostly cloudy during the rainy season and less cloudy in the post–monsoon months, with clear sky during the other months of the year. Wind speeds are generally low, though they accelerate during the latter part of summer and early southwest monsoons. Wind speeds range from calm to more than 24 km per hour.

3. Air Quality

14. The updated EIA includes the results of ambient air quality monitoring at five stations within a 10 km radius of the LNG terminal (Appendix 1). The EIA concludes that all air quality was within the limits prescribed by the National Ambient Air Quality Standards (NAAQS) (Appendix 6, Table A6.5). However, some parameters, such as sulfur dioxide (SO_2), nitrogen oxides (NOx), hydrocarbon, and carbon monoxide, appeared to be increasing from the levels recorded during the first EIA in 1999–2000. This could be attributed to increased industrial activities and traffic within the industrial estate.

4. Noise

15. Noise levels were measured at 20 locations: 5 in the noise-sensitive areas,[3] 6 in commercial areas, 5 in residential areas, and 4 in industrial areas. The results are summarized and compared with national noise standards (Appendix 2). The baseline noise levels recorded ranged from a minimum of 37.2 decibel acoustic (dBA) to a maximum of 60.7 dBA. Only the noise levels during the day in the noise-sensitive areas exceeded the prescribed limits. At night, the noise levels were within the prescribed limits. The noise model indicated that the Project would have negligible impact, which is less than 1 dBA, on the baseline noise level. The impact on noise level, therefore, is considered insignificant.

5. Water Quality

16. Groundwater samples were taken from six locations. Surface water samples were taken from the Narmada River, a pond in Luhara village, the sea around the PLL jetty, and a pond in Lakhigram village. The water samples were analyzed for their key physical, chemical, and biological qualities. The results indicated that industries had not polluted the groundwater or surface water (Appendix 3). The surface water samples showed some pollution from domestic sources. Seawater intrusion appeared to have affected the quality of groundwater. The general standards for inland surface water and drinking water are in Appendix 6 (Tables A6.8 and A6.9).

B. Coastal Environment

1. Physical Conditions

17. The jetty for the LNG terminal site is on the coast of the Gulf of Khambat, which receives discharges from several major rivers. Water movement in the gulf is influenced by a mixed semidiurnal tide, with a large diurnal inequality and varying amplitude decreasing from north to south along the coast. The sea from the shoreline is shallow up to about 2 km before the sea bed rapidly drops, forming a coastal shelf. At the jetty site, the tidal range averages 8 m. During low tides, the water line recedes from the shoreline as far as about 2 km, which explains the

[3] A noise-sensitive area is an area where excessive noise could have significant impacts compared with other areas. The five noise sensitive areas include four schools and one primary health care center.

need for a jetty that is 2.5 km long. However, the water depth at the end of the jetty is adequate for the operations of LNG tankers without regular dredging.

18. Wind and wave conditions in the gulf are favorable for LNG tanker operations. Wind speeds are generally low, though gusty winds are experienced occasionally during the monsoon season. The coastal water is relatively calm most of the time, with waves 0.2–0.5 m in height. Choppy conditions are experienced occasionally in the monsoon season. The unloading operations have established procedures to cope with varying wind and wave conditions.

2. Water Quality

19. The Gulf of Khambat is well mixed, as indicated by the absence of significant salinity stratification even during the discharge of flood waters from the Narmada River and other rivers. The dynamic tidal regime associated with strong currents accounts for the well-mixed condition, which makes water quality uniform throughout the depth.

20. As several rivers with heavy silt loads from agricultural areas drain into the gulf, the coastal waters could be expected to be turbid and high in nutrients. The water quality data confirmed high turbidity, as indicated by the levels of suspended solids. The suspended solids observed at Dahej ranged from 211.6 to 1,174 milligrams per liter (mg/l) during ebb tides and 205.6 to 1,929 mg/l during flood tides. The concentrations of nitrogen compounds and phosphorus compounds were relatively high and varied with the seasons. The concentrations of nitrite nitrogen and ammonia nitrogen were low in the near shore, as well as in the open shore, suggesting good oxidizing conditions.

21. Although the gulf is the waste sink for river discharges from the hinterland, its water still has relatively high levels of dissolved oxygen, varying from 5.83 to 6.8 mg/l; and relatively low levels of biochemical oxygen demand (BOD), ranging from 1.03 to 4.89 mg/l. This indicates a low organic pollution load relative to the waste assimilative capacity of the gulf.

3. Marine Resources

22. As the water in the gulf is turbid, productivity could be expected to be low. The overall biological characteristics off Dahej–Jogeshwar indicate low production potential of the gulf. The levels of phytoplankton pigments are markedly low compared with normal coastal waters. However, cell counts are moderate with low generic diversity. Considering the quantitative and qualitative nature of zooplankton, the area can be rated as moderate to poor in secondary productions. The region supports very poor subtidal benthic stock in terms of population and biomass. However, standing stock of intertidal fauna is comparatively higher than that of subtidal macro benthos. The experimental trawling and other relevant information confirm that the area is not a viable fishing ground for commercial fishery even during the peak fishing season. Consequently, the gulf has no active commercial fishing except for limited subsistent shore-based fishing using common bag nets or hand nets.

C. Economic Development

23. The Gujarat industrial estate in the core industrial development area of Gujarat state was created to serve large chemical industries. The estate is in a rural area. The industries in the estate would not create direct forward or backward links with the rural economy, apart from providing some employment. In this regard, the Project would not have a significant economic

link with the economy of the surrounding rural areas, although it would provide employment to about 400–600 local people during construction.

D. Social and Cultural Environment

24. As the LNG terminal is within the industrial estate, no communities are near the site. Only five villages are within 5 km of the project site. Table 2 summarizes the data on population, number of households, and literacy rates. Although based on the official census carried out in 2001, most data would still remain largely valid considering the slow socioeconomic changes in most villages.

Table 2: Information on Villages Within 5 Kilometers of the Project Site

Settlement	Distance from LNG Terminal	No. of House-holds	Population			Literacy Rate (%)
			Total	Male	Female	Total
Dahej	5.0 km	279	1,614	844	770	897
Lakhigram Village	1.3 km	319	1,877	985	892	1,086
Luvara Village	1.2 km	103	538	276	262	305
Jogeshwar Village	3.0 km	447	2,103	1,122	981	1,172
Ambheta Village	4.9 km	173	1,062	543	519	573
Total		**1,321**	**7,194**	**3,770**	**3,424**	**4,033**

km = kilometer.
Source: Petronet LNG Limited.

25. The five villages have basic social and physical infrastructure, including primary school, primary health subcenters, maternity facilities (except Dahej Village), piped water supply, post office, public telephones, and electricity. Two of these villages have secondary schools. Dahej Village also has a veterinary hospital, although it does not have maternity facilities.

E. Environmental Impact of the Existing Facilities

26. The latest information on environmental quality discussed above indicates that the existing LNG terminal has no significant impacts on the natural environment. GPCB confirmed that the facilities have met the national environmental standards on air emission, water discharge, waste management, and noise; and that no public complaints have been registered.

IV. FORECASTING ENVIRONMENTAL IMPACTS AND MITIGATING MEASURES

A. Impacts During Construction

27. The Project will entail the construction of two LNG storage tanks. The construction activities would create some environmental disturbances normally associated with major construction works, such as dust, noise, and exhaust emissions of heavy construction equipment and vehicles. As the construction will be confined within the existing LNG terminal, which does not have any communities nearby, the impacts of such environmental disturbances

will be insignificant. Nevertheless, the Project will adopt good environmental management practices during construction to minimize environmental disturbances.

28. During the peak of the construction phase, about 400–600 laborers would be employed. The EPC contractor is expected to employ as many local people as possible. However, the construction activities also would generate significant employment in ancillary activities, attracting some outsiders. Therefore, adequate basic sanitation infrastructure and amenities will have to be provided to prevent localized pollution and unhygienic conditions. The sewage generated by the workers (about 60 m^3 per day), as well as solid wastes (less than 1 ton per day), will be treated in septic tanks that meet the relevant standards. Sludge removed from septic tanks will be sent to a treatment plant approved by GPCB,[4] and the treated water will be used for greenbelt development. In addition, education and strategies for minimizing HIV risk will be required. These mitigation measures are included in the EPC contracts to ensure all environmental problems associated with construction workers will be addressed effectively.

B. Impacts During Operations

1. Tanker Collision or Grounding

29. In case of tanker collision or grounding, LNG might spill into the sea. Upon reaching water, the spilled LNG will vaporize rapidly due to the high water temperature relative to the low boiling point of LNG. As LNG is very buoyant, with a density of 0.45 gram per milliliter, LNG that leaks below the water will surface and vaporize rapidly. Consequently, LNG spilled into the water will not have a significant impact on the environment.

30. A tanker collision or grounding also could result in an oil spill. However, as LNG tankers run on natural gas, the amount of oil spilled would be small compared with ships running on diesel oil or oil tankers. The LNG terminal has a comprehensive oil spill contingency plan and equipment for containing oil spill. The plan details actions to be taken and the coordination required to deal with the problem.

31. Since the volume of any oil spill likely would to be small and the gulf is not biologically rich, the ecological impact would not be significant.

2. Environmental Pollution of Unloading Operation

32. After the expansion, the number of LNG tankers will increase to about 160 per year. Only one tanker will be at the jetty at a time. Unloading each tanker takes about 14 hours.

33. The tankers will not be allowed to discharge wastes into the gulf. As the tankers use natural gas as fuel, the potential for an accidental oil spill from the tankers is virtually eliminated.

3. Environmental Pollution of Terminal Operation

34. The main sources of air pollutants are gas turbine generators running on natural gas. As natural gas is extremely low in sulfur and particulates, NOx is the only major air pollutant. The three existing gas turbine generators are equipped with "lean-burn" technology to control NOx emissions. This technology enables the gas turbine generators to produce only 0.85 grams of

[4] Since the amount of sludge is small, the first treatment is expected to be in 2007–2008. The nearest sewage treatment plant is about 50 km from the project site.

NOx per brake horse power per hour, and negligible amounts of hydrocarbons, carbon monoxide, and particulates. The monitoring of stack emissions from April 2005 to February 2006 showed NOx levels consistently below 15 parts per million (ppm), compared with the GPCB's prescribed limit of 50 ppm. Considering the effectiveness of lean-burn technology, the two new gas turbine generators also will be equipped with this technology.

35. Although the submerged combustion vaporizers for LNG gasification also operate on natural gas, they are used only occasionally during winter when the ambient air temperature is too low to meet the thermal energy requirement of the shell and tube vaporizers. Therefore, the contribution of the submerged combustion vaporizers to NOx emissions is minor compared with the NOx emissions of the gas turbine generators, and can be disregarded.

36. The impact of the two additional gas turbine generators on ground-level concentrations of NOx in ambient air was predicted using the United States Environmental Protection Agency (EPA) SCREEN3 model[5]. Only the impacts of the two additional gas turbine generators were considered in the modeling, as the impacts of the three existing gas turbine generators were reflected in the baseline air quality data. NOx levels were forecast based on the worst meteorological conditions, i.e., high atmospheric stability and low wind speed. The maximum ground-level concentration of NOx was predicted to be 1.2 microgram per cubic meter (μg/m^3) at a distance of 4 km from the Project. Considering the maximum ambient NOx level in the area is 16–24 ug/m^3, the resultant ground-level concentration after the Project will be 17.2–25.2 ug/m^3. This range is well within the limits prescribed under NAAQS (Appendix 6, Table A6.5).

37. Other environmental problems, such as noise and domestic wastewater, will be minimal and contained within the LNG terminal complex. The number of employees during operations will increase from 145 to about 204, generating about 30 m^3 of wastewater per day. The LNG terminal operation does not produce any wastewater and hazardous wastes, except for a small volume of spent oil. Storm runoff is not contaminated by chemicals and can be discharged safely into the sea. At present, PLL contracts out the disposal of waste oil to a hazardous waste disposal contractor accredited by GPCB.

C. Risk Management

1. Overview

38. An LNG terminal is considered hazardous. Events that constitute risk[6] to the LNG terminal under the Project are (i) the collision of LNG tankers with other ships, or LNG tankers running aground; (ii) an LNG leak during unloading; (iii) an LNG leak from safety valves at the top of the storage tanks; and (iv) major earthquakes. The likelihood of these events must be minimized through strict application of rigorous standards in the design and operations of the terminal. If these events occur, their adverse consequences must be minimized through proper site of the facilities, and by institutionalizing a standard emergency response plan (ERP) and a disaster management plan (DMP). The Project will adopt these risk-management measures.

[5] SCREEN3 model is a mathematical model developed by the EPA for prediction of NOx levels in ambient air resulted from emissions from stationary sources such as power plant.

[6] Risk is related to an undesirable event that could happen, generating adverse consequences for the environment, people's lives, properties, and financial performance and reputation of a business. Risk, therefore, is related to the likelihood of the event, and the magnitude of adverse consequences.

2. Design of Project Facilities

39. The technology and design standards for LNG terminal facilities are well established. The national design codes are the Oil Industry Safety Directorate's OISD–194. The design standards are the internationally adopted European EN–1473, US National Fire Protection Association's NFPA–59A, and British BS7777. These design standards, which were adopted by the existing facilities, will be applied to the new facilities with some non-safety-related modifications tailored to the site. One of the modifications was the selection of indirect LNG re-gasification using a glycol water-air heating system, instead of the conventional open rack vaporizers. The air heating system has been environmental friendly, producing a significant volume of clean water from condensation of humidity in the air.

40. The two existing LNG storage tanks are full containment tanks, which are safer than single or double containment tanks. However, full containment tanks cost more than single and double containment tanks. In addition to being safer, full containment tanks have several other advantages over single and double containment tanks: (i) higher operating pressure, which reduces boil-off gas during unloading; (ii) loads of piping structure and accessories not transferred to the primary container; (iii) no risk of leaks from tank; and (iv) a secondary container to withstand external impacts without collapse, and to hold LNG in case of leaks from the primary container. For these reasons, the two new storage tanks under the Project will be full containment tanks.

41. Several safety measures that were adopted in the design of the existing LNG terminal will be incorporated into the design of the new facilities. Some examples are (i) locating the isolation valve of the pig launcher station closer to the plant boundary to provide additional protection against backflow from the transmission network, which could feed fires that could damage the tank; (ii) providing a pressure sensor on the glycol side of the shell and tube vaporizers to trigger LNG shutdown should a leak occur; (iii) installing a rupture disk on the glycol side (shell) for overpressure protection; and (iv) providing blast-proof construction in accordance with local regulations. The control room, administration building, and other inhabited buildings are constructed with few or no windows towards the process area, and their overall window area is kept to a minimum. Water tanks and pumps to fight fires are located as far from the process areas as possible.

42. The project site is in a region classified as seismic zone 3[7]. Therefore, the existing terminal facilities' design assumed an earthquake-induced lateral movement once in 1,000 years. The project facilities also will adopt this design criterion.

3. Unloading Operations

43. Wind speeds and wave heights in the vicinity of the jetty are monitored continuously, and the data are transmitted to a central unloading control room at the jetty. Emergency responses to various wind and wave conditions, as well as to LNG leaks, are prescribed. Procedures are established and ready to be implemented. The jetty terminal is fully equipped with firefighting equipment. The water around the jetty also is patrolled regularly to ensure security. These safety operations are outsourced to a qualified port operator. The Gujarat Maritime Board regulates and regularly inspects the emergency and safety measures.

[7] India has been divided into five seismic zones with respect to severity of earthquakes. Of these, zone 5 is the seismically most active region where earthquakes of magnitude 8 or more could occur. Zone 1 is the seismically least active region.

4. Terminal Operations

44. Terminal operations are centrally controlled by computer. A data control system continuously measures and monitors all process parameters, such as pressure, temperature, flow rate, and mass. The real-time data are processed and interpreted by computer to ensure efficient process control and safety. The data control system system allows immediate identification and location of leaks in the terminal system. Emergency signals and alarms are sent out automatically to ensure immediate response.

5. Likelihood of Tanker Collisions

45. The traffic of deep-sea vessels in the gulf is confined to the 72 km navigational channel from the mouth of the gulf to the entrance to the terminal jetty. Therefore, the probability of a tanker collision for 480 transits per year in the gulf would be once in 2,000 years. The probability of tankers running aground based on 160 transits per year would be once in 20,800 years.

46. A traffic control scheme, such as segregation of lanes with adequate separation distances and constant monitoring physically or through remotely operated devices, is evolved to minimize the risk of tanker encounters. Further, adequate navigational aids are installed to indicate channels, as well as separation distances. Their positions should be marked clearly on the charts. Proper policing is enforced to prevent vessels from discharging bilge, tanker washings, oily slop, etc. into the marine waters, as a part of the environmental management strategy.

6. Exclusion Zones

47. If LNG leaks from the unloading arms, storage tanks, or pipelines, it might form a liquid pool. If ignited, the flammable vapor resulting from the evaporation of the liquid will travel back to the spill, resulting in a pool fire.

48. The safety of the LNG terminal site is checked conventionally using two parameters—a thermal exclusion zone and a vapor dispersion zone. An LNG pool fire would radiate heat, which would diminish with the distance from the pool fire. EN–1473 recommends a thermal exclusion zone based on the maximum thermal radiation of 5 kilowatt per square meter (kW/m^2). For the vapor dispersion zone, EN–1473 recommends 5% of methane in air as the lower flammability limit. The vapor dispersion zone covers the distance from the LNG pool to the 5% concentration contour.

49. The thermal exclusion zone and the vapor dispersion zone were calculated for the following probable scenarios:

(i) rupture of one of the unloading arms during discharge of LNG from the tankers, and
(ii) release of LNG from the three relief valves on top of one of the tanks.

50. The thermal exclusion zone and the vapor dispersion zone were calculated using the models recommended in EN–1473 for the storage tank leak, and the models recommended by the EPA for the unloading arm leak. The findings are summarized in Table 3, while a summary of the calculations is in Appendix 4. The exclusion zones for the storage tanks are within the boundaries of the terminal complex. For the unloading arms, the exclusion zones are between the jetty and the complex.

Table 3: Summary of the Consequence Analysis

Exclusion Zone	Rupture of Unloading Arms	Leak From the Storage Tank
Thermal	700 m	77 m
Vapor Dispersion	250 m	57 m

m = meter.
Source: Petronet LNG Limited.

51. In compliance with an MOEF condition for environmental clearance, PLL will review the risk analysis and submit reports to MOEF and the relevant authorities every 6 months.

7. Emergency and Disaster Preparedness

52. PLL has prepared and institutionalized an ERP and a DMP. The ERP prescribes actions and procedures to deal with major releases, non-ignited releases, and fire and explosion emergencies. The ERP is supported through (i) gas detection, (ii) safety shutdown and fire protection systems, (iii) safety and security zones, (iv) ship and facility emergency response plan, (v) coordination with the Gujarat Maritime Board and coast guard, and (vi) evacuation plans and procedures. The ERP will be revised to cover the expanded operations.

53. Prepared by PLL, the DMP is effective in preventing and managing incidents or accidents in and around the terminal complex, the jetty, and the waterfront. For prompt application of the DMP procedures at any time, PLL has (i) established and maintained suitable systems, (ii) employed or contracted skilled and trained personnel, and (iii) installed efficient communication equipment and all other necessary equipment and facilities. PLL organizes periodic exercises and simulations with the port operator and the LNG tanker crew in accordance with simulated accident scenarios. PLL will revise the DMP as appropriate to cover the expanded operations in line with MOEF's conditions for environmental clearance.

54. For jetty operations, PLL has engaged an experienced port operator to provide services, including hazard prevention, as well as health, safety, and environment (HSE) operations. The HSE unit is involved in prevention activities on the waterfront with the assistance of the port operator. PLL personnel have been trained extensively in firefighting at LNG terminals in France and Qatar. The port operator also has deployed trained personnel for managing waterfront activities. The waste management plan complies with International Convention for the Prevention of Pollution of Ships, or MARPOL, standards.

55. A mutual aid system also is in place with the companies operating in the industrial estate. If a major incident occurs, the management can call upon other companies in the area for assistance within their resource, and make them available as required. This collaboration will pool resources of the participants. Appendix 5 shows the list of companies operating in Dahej and their resources**.**

V. INSTITUTIONAL REQUIREMENT AND ENVIRONMENTAL MONITORING PLAN

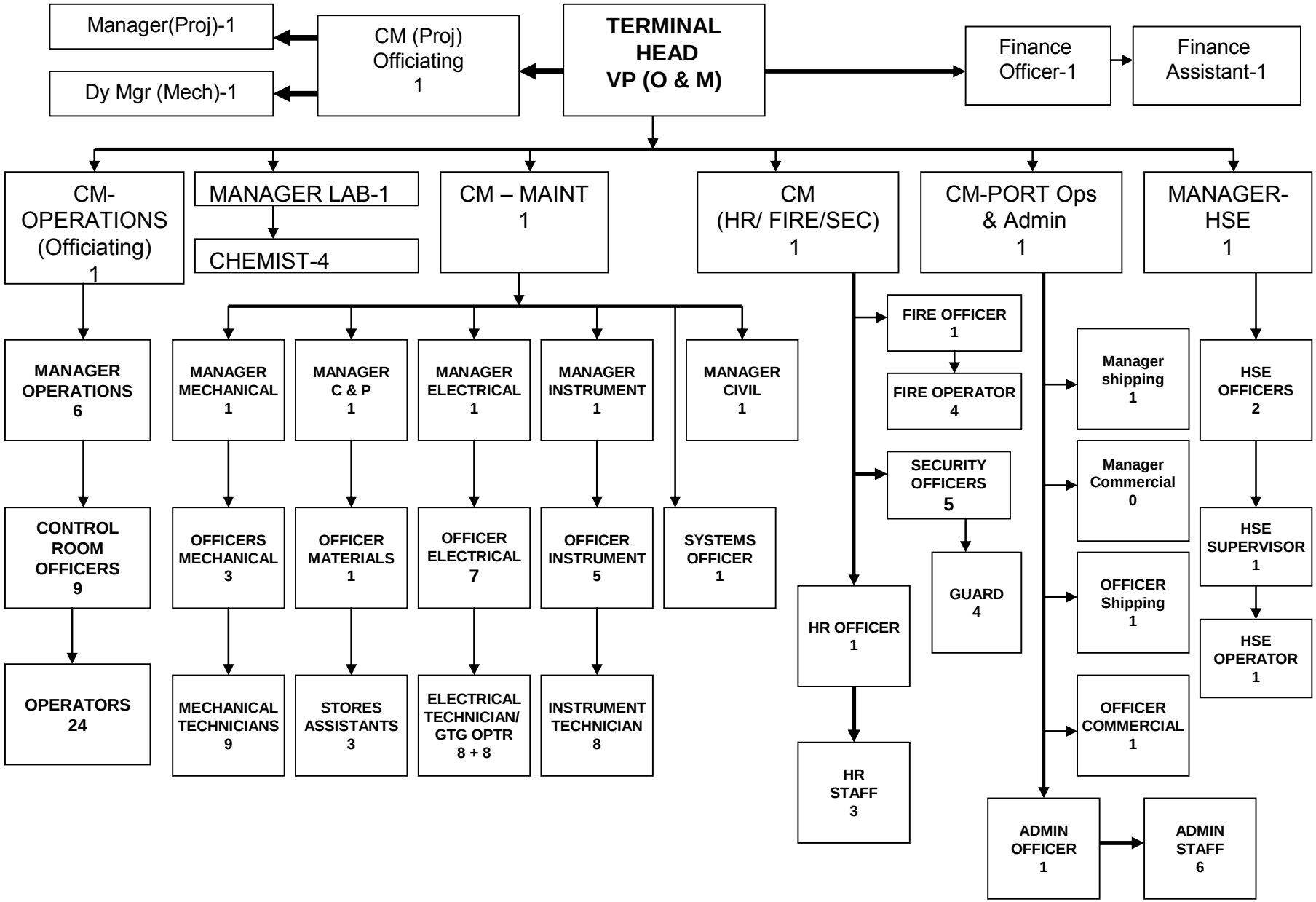
56. PLL has been accredited with ISO 9001, Occupational Health & Safety Management System (OHSAS) 18001, and ISO 14001 environmental management system. PLL has a corporate policy on HSE, which it has been implementing from inception. Over the past 20 months of operations, the LNG terminal has not had any major incidents related to the environment, safety, or occupational health.

57. PLL has established an HSE unit to implement its HSE policy. It has five staff and a well-equipped laboratory for analysis of environmental samples. Figure 4 shows the organizational chart of PLL Dahej LNG Terminal, including the HSE unit. The unit is monitoring the environmental performance of the existing LNG terminal, as required by GPCB and MOEF. In addition to activities of the HSE unit, environmental management tasks are integrated with the terminal's process control and management tasks. The terminal operation staff include specialists responsible for specific aspects of environmental management and monitoring. Training in environmental management is provided regularly to the terminal operations staff.

58. During project construction, the HSE unit will monitor the EPC contractor's compliance with the requirements of GPCB and MOEF regarding air emission, water effluent, receiving water, and noise standards. During operations, PLL will enlarge the scope of the monitoring program to cover the expanded operations. Appendix 6 summarizes environmental mitigation measures, as well as the monitoring program for the construction and operation phases of the Project. PLL must follow the conditions imposed under the clearance granted by GPCB and MOEF, including the reporting requirements of these authorities.

59. PLL will pay close attention to environmental mitigation and safety operations in all stages of the Project. It will monitor and control the environmental performance of the Project, and consult regularly with responsible authorities and nearby communities. PLL will join local environmental monitoring committee. The budget for environmental management and monitoring is about Rs5 million per year, while the budget for environmental mitigation is about Rs2.4 million per year. These budgets do not include safety and health management, which would be included in the operational expenses of the terminal.

Figure 4. Petronet LNG Limited, Dahej Terminal Organization Chart



Asst = assistant, CM=Chief Manager, C&P= Contract and Purchase, Dy=deputy, GTG Optr=gas turbine generator operator, Maint=maintenance, O&M=operations and maintenance, Elec=electrical, HR=human resource, HSE=health, safety, and environment, Mech=mechanical, Mgr=Manager, Ops=operations, Proj=project, SEC=security, Sr. Sup=senior supervisor.
Source: Petronet LNG Limited.

60. For safety operations, PLL has institutionalized the ERP and DMP (paras. 52–55). A number of agencies, such as National Safety Council, Gaz de France, and DNV.NET, monitor and regulate the safety of the LNG terminal operations.

VI. PUBLIC CONSULTATION AND DISCLOSURE

61. During the preparation of the previous EIA, formal public consultations were carried out through public meetings, newspaper announcements, and advertisements. The aim was to inform the public about the Project and solicit their comments, particularly on environmental, social, and safety aspects.

62. For the Project, public consultation was more limited since the public consultation during the original EIA covered the full-scale development. On 22 September 2005, the Expert Committee for Infrastructure Development and Misc. Project under MOEF reviewed the Project. The committee consisted of 12 members with assorted disciplines from various institutions. MOEF granted the Project environmental clearance on 23 November 2005. Subsequently, PLL published the project information, as well as MOEF's environmental clearance paper, on 30 November 2005 in two local newspapers (the Western Times and Gujarat & Gujarat Mitra), and on MOEF's Web site. These public information activities should adequately serve the purpose of public consultation for the Project. No public concerns were received after the publication of the Project, mainly due to the location of the terminal within the exclusive industrial estate.

VII. FINDINGS AND RECOMMENDATIONS

63. The Project will have no significant environmental impacts during construction and operations due to the nature of the Project and its site. The emission of NOx is the only environmental issue. The Project will adopt lean-burn technology to minimize the NOx emitted by the gas turbine generators. Despite the emission of NOx from the two additional gas turbine generators, the level of NOx in the ambient air will remain well below the prescribed limits.

64. Project risks will be minimized through rigorous enforcement of international design and operational standards. LNG leaks from the rupture of one of the unloading arms or accidental release from the relief valves at the top of one of the storage tanks would result in a pool fire and vapor dispersion. As the thermal exclusion zone and the vapor dispersion zone will be within the site, the Project is relatively safe.

65. The environmental and safety aspects of the Project are straightforward and well understood. No further studies are required to elaborate these subjects. The IEE should be considered adequate.

VIII. CONCLUSIONS

66. The major conclusions are:

(i) The Project will have no significant environmental issues. The emission of NOx by the gas turbine generators can be controlled effectively, and air quality can be maintained within the prescribed standards.

(ii) The risk from an LNG leak is the only major issue of the LNG terminal operations. However, the likelihood of LNG leaks caused by tanker collision or grounding, rupture of unloading arms, or accidental discharge from the storage tanks is extremely low. Even if such a leak happens, the thermal exclusion zone and the vapor dispersion zone will be within the site.

(iii) The existing emergency response and disaster management systems are adequate to deal effectively with any accidents or disasters.

(iv) Considering the extremely low probability of an LNG leak, and the adequate protection measures, the Project could be justified in terms of its environmental and economic benefits.

(v) The Project's environmental aspect and risks are well understood, and can be mitigated effectively. Thus, further environmental investigation is unnecessary.

SUMMARY OF AMBIENT AIR QUALITY OF THE STUDY AREA

Parameter	No. of Samples		Location 1	2	3	4	5
SPM (µg/m^3)	6	Max.	301	310	374	288	262
		Min.	254	274	310	184	226
		98% tile	299.5	304	367.5	264.5	258
		Avg.	282.8	289.3	349.3	225.8	244.2
RPM (µg/m^3)	6	Max.	158	168	148	121	132
		Min.	101	132	126	110	104
		98% tile	150	162.5	141.5	120.5	129
		Avg.	125.2	147.6	133.2	117	117.2
SO_2 (µg/ m^3)	6	Max.	28	30	30	26	30
		Min.	22	20	22	18	21
		98% tile	27	30	30	26	30
		Avg.	24.6	24.6	27.6	23.5	27.6
NOx (µg/ m^3)	6	Max.	20	21	24	16	20
		Min.	11	14	14	12	10
		98% tile	19	20.5	22	15.5	19
		Avg.	16	18.2	18.8	14.3	15.7
Hydrocarbons (HC)-methane (ppm)	18	Max.	—	0.2	0.4	—	0.2
		Min.	—	0.1	0.2	—	0.1
		98% tile	—	0.19	0.37	—	0.19
		Avg.	—	0.15	0.29	—	0.16
Hydrocarbons (HC)-non-methane (ppm)	18	Max.	0.2	0.21	0.22	0.2	0.2
		Min.	0.1	0.18	0.18	0.1	0.16
		98% tile	0.19	0.2	0.21	0.19	0.19
		Avg.	0.15	0.18	0.19	0.14	0.17
CO (mg/m^3)	18	Max.	0.4	0.7	0.9	0.5	0.5
		Min.	0.1	0.21	0.6	0.2	0.2
		98% tile	0.37	0.56	0.85	0.45	0.45
		Avg.	0.27	0.37	0.71	0.33	0.31

Locations: 1 - Dahej; 2 - Petronet LNG; 3 - Village Lakhigram; 4 - Village Jageshwar; 5 - Near IPCL Gate.
— = data is not available or collected, µg/m^3 = microgram per cubic meter, Avg. = average, CO = carbon monoxide, max. = maximum, min. = minimum, mg/m^3 = milligram per cubic meter, NO_x = nitrogen oxides, ppm = parts per million, RPM = respirable particulate matter, SO_2 = sulfur dioxide, SPM = suspended particulate matter.
Note: Samplings were conducted 28 February–15 March 2005.
Source: Petronet LNG Limited.

SUMMARY OF AMBIENT NOISE LEVEL IN THE STUDY AREA

	Locations		Applicable Standard dBA	Noise Level dBA
1	Petronet LNG site	L_{day}	75.0	59.7
		L_{night}	70.0	41.6
2	Lakhababa temple	L_{day}	50.0	51.7
		L_{night}	40.0	37.4
3	GCPTCL front gate	L_{day}	75.0	60.2
		L_{night}	70.0	45.1
4	Lakhigram primary school	L_{day}	50.0	51.8
		L_{night}	40.0	37.5
5	Lakhigram market	L_{day}	65.0	52.7
		L_{night}	55.0	38.5
6	Lakhigram bus stop	L_{day}	65.0	53.3
		L_{night}	55.0	39.1
7	IPCL front gate	L_{day}	75.0	60.7
		L_{night}	70.0	45.6
8	IPCL back gate	L_{day}	75.0	57.7
		L_{night}	70.0	42.6
9	Luvara Panchayat house	L_{day}	55.0	51.5
		L_{night}	45.0	37.2
10	Luvara primary school	L_{day}	50.0	53.3
		L_{night}	40.0	38.2
11	Jageshwar primary school	L_{day}	50.0	53.9
		L_{night}	40.0	38.8
12	Jageshwar Panchayat house	L_{day}	55.0	52.8
		L_{night}	45.0	38.6
13	Jageshwar Ashram	L_{day}	50.0	53.1
		L_{night}	40.0	38.8
14	Krishnand Ashram	L_{day}	50.0	53.8
		L_{night}	40.0	39.6
15	Ambheta market	L_{day}	65.0	55.2
		L_{night}	55.0	40.1
16	IPCL diversion road	L_{day}	65.0	54.8
		L_{night}	55.0	40.6
17	Dahej primary health center	L_{day}	50.0	50.2
		L_{night}	40.0	38.4
18	Dahej high school	L_{day}	50.0	54.6
		L_{night}	40.0	39.5
19	Dahej market	L_{day}	65.0	52.0
		L_{night}	55.0	37.7
20	Dahej bus stop	L_{day}	65.0	53.7
		L_{night}	55.0	39.5

dBA = decibel acoustic, GCPTCL = Gujarat Chemical Ports and Terminals Ltd., IPCL = Indian Petrochemical Ltd., L_{day} = limit during day time, L_{night} = limit during night time.
Note: Samplings were conducted 28 February–15 March 2005.
Source: Petronet LNG Limited.

SUMMARY OF SURFACE AND GROUNDWATER QUALITY

Table A3.1: Surface Water Quality

	Location	River Narmada		Pond Water (Luhara)		Seawater (PLL Jetty)		Pond Water (Lakhigram Village)	
	Parameters	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	Turbidity, NTU	40	30	80	70	102	101	93	85
2	pH Value	7.8	7.6	7.2	7	7.4	7.2	8.1	7.9
3	Conductivity	39,100	16,000	775	773	49,300	48,100	745	743
4	Total Hardness (as $CaCO_3$) mg/l	5,020	2,008	340	338	6,442	6,054	394	392
5	Chlorides (as Cl), mg/l	14,296	5,772	132	130	18,300	16700	121	119
6	Dissolved Solids, mg/l	27,370	11,000	465	462	34,620	33,560	447	445
7	Heavy Solids	—	—	—	—	—	—	—	—
8	Total Coliforms/100 ml	120	118	80	80	51	51	80	80
9	BOD_5, 20 ^oC, mg/l	7	6	6	5.4	9	8	7	5
10	COD, mg/l	31	29	24	22	48	47	47.5	40
11	DO, mg/l	5.4	5.2	4.2	4.1	5.8	5.6	4.8	4.7
12	Temperature ^oC	20	20	20	20	20	20	20	20

— = data is not available or collected, ^oC = degree Celsius, BOD = biological oxygen demand, $CaCO_3$ = calcium carbonate, COD = chemical oxygen demand, DO = dissolved oxygen, Max. = maximum, Min. = minimum, mg/l = milligram per liter, ND = not detectable, NTU = nephelometric turbidity unit, pH = measure of acidity, PLL = Petronet LNG Limited.

Note: Samplings were conducted 28 February–15 March 2005.

Source: Petronet LNG Limited.

Table A3.2: Groundwater Quality

	Location	Petronet LNG Site (Sea Side)		Petronet LNG Site		Lakhigram		Ambeta		Luvara		Jageshwar	
	Parameters	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**
1	Turbidity, NTU	6.4	6.2	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
2	pH Value	8.3	8.1	8.4	8.2	8.1	7.9	7.8	7.6	7.2	7.0	7.9	7.7
3	Conductivity	8,000	7,908	4,000	3,908	8,016	7,938	3,534	3,508	2,231	2,215	2,134	2,130
4	Total Hardness (as $CaCO_3$) mg/l	2,600	2,560	860	850	2,560	2,500	960	940	598	590	400	394
5	Chlorides(as Cl), mg/l	2,280	2,240	440	436	1,820	1,800	540	490	320	310	312	306
6	Dissolved Solids, mg/l	5,200	5,140	2,600	2,540	5,200	5,160	2,310	2,280	1,450	1,440	1,387	1,385
7	Heavy Solids	—	—	—	—	—	—	—	—	—	—	—	—
8	Total Coliforms/100 ml.	—	—	—	—	—	—	—	—	—	—	—	—
9	BOD_5, 20 °C, mg/l	3	3	4	4	5	4	5	5	4	4	5	4
10	COD, mg/l	14	12	20	19	16	14	18	16	15	13	16	14
11	DO, mg/l	4.1	4.0	4.6	4.4	3.9	3.7	4.0	3.8	4.1	3.9	3.8	3.7
12	Temperature °C	18	18	19	19	19	19	19	19	19	19	19	19

— = data is not available or collected, °C = degree Celsius, BOD = biochemical oxygen demand, $CaCO_3$ = calcium carbonate, COD = chemical oxygen demand, DO = dissolved oxygen, LNG = liquefied natural gas, Max. = maximum, Min. = minimum, mg/l = milligram per liter, ml = milliliter, ND = not detectable, NTU = nephelometric turbidity unit, pH = measure of acidity.
Note: Samplings were conducted 28 February–15 March 2005.
Source: Petronet LNG Limited.

SUMMARY OF EXCLUSION ZONE ANALYSIS

A. Introduction

1. Although the probability of liquefied natural gas (LNG) leak in the unloading, storage, and re-gasification facilities is extremely low, the internationally adopted European and United States standards require a safety assessment. The assessment is based on two types of hazards: (i) pool fire; and (ii) formation of flammable vapor dispersion, which could lead to a vapor fire or explosion.

2. A risk analysis was carried out as part of the environmental impact assessment of the first phase project and this expansion project. The analysis determines the thermal exclusion zones and the vapor dispersion zones under various LNG leak scenarios. This appendix presents a summary of the major findings of the analysis.

B. Thermal and Vapor Dispersion Exclusion Zones

1. Thermal Exclusion Zone

3. If LNG spills near an ignition source, the evaporating gas in a combustible gas-air concentration will burn above the LNG pool. The resulting pool fire would spread as the LNG pool expanded away from its source and continued evaporating. A pool fire is intense, burning far more hotly and rapidly than oil or gasoline fires. The heat intensity, or thermal radiation flux, is highest at the center of the pool fire. The heat decreases with distance from the center, depending on wind speed and atmospheric stability. The distance from the pool fire to a point where the thermal radiation flux decreases to a certain level is referred to as the "thermal exclusion zone". The European EN–1473 recommends a thermal exclusion zone based on the maximum thermal radiation of 5 kilowatt per square meter ($kW/m^{2)}$. Table A4.1 presents limiting thermal radiation flux for buildings inside the LNG terminal. Table A4.2 presents limiting thermal flux radiation for areas outside the boundary.

Table A4.1: Maximum Thermal Radiation Flux Inside the Boundary

Buildings Inside the Boundary	Maximum Thermal Radiation Flux Excluding Solar Radiation (kW/m^2)
Concrete outer surface of adjacent storage tanks	32
Metal outer surface of adjacent storage tanks	15
Outer surface of adjacent pressure storage vessels and process facilities	15
Control room, maintenance workshops, laboratories, warehouses, etc.	8
Administrative buildings	5

kW/m^2 = kilowatt per square meter.
Source: Petronet LNG Limited.

Table A4.2: Maximum Thermal Radiation Flux Outside the Boundary

Areas Outside the Boundary	Maximum Thermal Radiation Flux Excluding Solar Radiation (kW/m^2)
Remote area visited infrequently by a few persons, such as moor land, farmland, desert	13.0
Urban area	5.0
Critical area—either an unshielded area of critical importance, where people without protective clothing can assemble at all times, including during emergencies; or a place difficult or dangerous to evacuate at short notice (e.g., sport stadium, playground, outdoor theater)	1.5

kW/m^2 = kilowatt per square meter.
Source: Petronet LNG Limited.

2. Vapor Dispersion Exclusion Zone

4. If a large quantity of LNG spills in the absence of an ignition source, the LNG would evaporate, forming a flammable vapor cloud. The vapor cloud would travel with the prevailing wind until it disperses below the flammable limits, or is ignited. A 5% average gas concentration is considered the lower flammability limit. The distance from the spill to the lower flammability limit is referred to as the "vapor dispersion exclusion zone". The distance depends on the wind speed, atmospheric stability, and surface roughness, as these three factors govern the dispersion and mixing between the vapor and air.

C. Risk Analysis: Unloading Arm Failure

5. The most likely scenario would be a rupture in the unloading arm, which would require emergency response and contingency planning.

6. The risk analysis was based on the manual for Risk Management Program Guidance for Offsite Consequence Analysis by the US Environmental Protection Agency. The following scenarios were analyzed:

(i) Worst-case scenario: 833 cubic meters (m^3) of LNG released from one of the unloading arms into the water, assuming a response time of 10 minutes.
(ii) Most credible loss scenario: 83 m^3 of LNG released from one of the unloading arms into the water, assuming a response time of 1 minute.

6. The results are summarized in Table A4.3.

Table A4.3: Results of Analysis for Unloading Arm Failure Case

Scenario	Time for Complete Evaporation (seconds)	Vapor Dispersion Zone (meters)	Thermal Exclusion Zone for Various Radiation Flux (kW/m^2) 37.5 meters	12.5 meters	5 meters
A. Worst-Case Scenario					
Wind speed = 1.5 m/sec	170	8,500	600	1,000	1,600
Wind speed = 3 m/sec	120	3,400	600	1,000	1,600
B. Most Credible Loss Scenario					
Wind speed = 3 m/sec	60	1,100	260	450	700

kW/m^2 = kilowatt per square meter, m/sec = meter per second.
Source: Petronet LNG Limited.

7. As the jetty is about 2.5 kilometers (km) from the LNG terminal, the thermal and vapor dispersion exclusion zones are within the sea areas. Therefore, an LNG leak due to the unloading arm failure would not pose a hazard to the LNG terminal.

D. Risk Analysis: Leaks From Storage Tank

8. Full containment tanks have an excellent safety record and very low probability of failing ($2x10^{-28}$), as shown in Table A4.4.

Table A4.4: Estimation of Probability for LNG Storage Tank on Fire

Event	Failure Rate
Failure of safety relief valve	8.76×10^{-4}
Failure of opening of vent valve	2.62×10^{-4}
Overfilling of tank	1×10^{-3}
High level cutoff switch fails to operate	8.76×10^{-4}
Failure of tank insulation	1×10^{-5}
Presence of a source of ignition due to human activities	1×10^{-2}
Failure of the re-liquefaction plant	1×10^{-3}
Operator fails to respond	1×10^{-3}
Probability	2×10^{-28}

LNG = liquefied natural gas.
Source: Petronet LNG Limited.

9. The storage tank is a full containment tank, consisting of a metal inner tank and a concrete outer tank. The inner tank contains LNG. The outer tank contains the tank insulation materials, and serves as a gas boundary during normal operation and as a secondary containment in case of an accidental release of LNG from the inner tank. Therefore, the tank will not have any direct leaks.

10. The risk analysis was based on an accidental release of LNG from the three relief valves on top of one of the tanks. Under this scenario, a flow rate is estimated at 35 m^3/sec based on the set pressure of the safety valves at 250 milli bar gauge. The flammable natural gas plume is

horizontal at the same elevation as the relief safety valves about 55 meters (m) due to the high initial speed of the jet plume. Thus, the flammable plume does not reach the ground.

11. The major findings are:

(i) At the safety valve elevation, the vapor dispersion exclusion zone was found to be 57 m.

(ii) The maximum radiation flux at the ground elevation is 2.2 kW/m^2.

12. Referring to Table A4.1 and Table A4.5, the safe distance between the safety relief valves of the tank and the adjacent storage tanks must be at least 25 m (32 kW/m^2). As the distance between two storage tanks is about 60 m, no unacceptable effect of this scenario on the adjacent tank is found.

Table A4.5: Estimation of Probability for LNG Storage Tank on Fire

Radiation Flux (kW/m^2)	Safe Distance From Relief Safety Valves at the Valves' Elevation (meters)
32	25
15	57
13	58
8	67
5	77

kW/m^2 = kilowatt per square meter.
Source: Petronet LNG Limited.

RESOURCES OF COMPANIES OPERATING IN DAHEJ

	Resources		
Company	**Firefighting**	**Medical**	**Marine Craft**
Indian Petrochemical Limited	4 fire tenders and complete fire team	Ambulance, dispensary, and doctor	2 tugs BP 20/15 tons, mooring launch, pilot boat
Gujarat Chemical Ports and Terminals Limited	3 fire tenders and complete fire team	Ambulance, dispensary, and senior nurse	Tug BP 42 tons, pilot boat
Dahej Harbour Infrastructure Limited (Birla Copper)	5 fire tenders and complete fire team	Ambulance, hospital, and doctor	2 tugs BP 42 *142* tons
Gujarat Alkalese Chemicals Ltd.	2 fire tenders and complete fire team	Ambulance, dispensary, and doctor	—
Well Spun Rhoern Steel Company	None available	Ambulance, dispensary, and senior nurse	—
BASF Styrenes		Dispensary	

— = data is not available, BP = Bollard Pull of Tug.
Source: Petronet LNG Limited.

MAJOR ENVIRONMENTAL IMPACTS, MITIGATION MEASURES, AND MONITORING PROGRAM

Table A6.1: Construction Phase—Impacts and Mitigation Measures

	Environmental Components	Potential Impacts	Impact Source	Mitigation Measures	Remarks
1.	Land	Construction waste, trenches and/or borrows	Construction activity	Sloping to be provided as per standard engineering practices	Short term and negative
2.	Surface Water	Increase in suspended solids and BOD public health problems, especially during monsoons	Construction activity	Construction of septic tanks and absorption trenches	Short term and negative
3.	Groundwater	No impact	No impact	No impact	No withdrawal
4.	Air quality	Marginal increase in SPM and RPM due to vehicular movement	Vehicular movement	Vehicles with PUC to be deployed, water spray, roads to be paved	Short term and negative
5.	Noise	Increased noise level	Construction activities and vehicles	Equipment selection	Short term and negative
6.	Socioeconomic Environment	Immigration of labor, population, increase in stress on the natural resource and infrastructure facilities	Construction activity	Deploy more local people in construction activities	Positive and long term; negative and short term.

BOD = biochemical oxygen demand, PUC = Pollution under Control certificate, RPM = respirable particulate matter, SPM = suspended particulate matter.
Note: PLL is responsible for implementing the mitigating measures.
Source: Petronet LNG Limited.

Table A6.2: Operation Phase—Impacts and Mitigation Measures

	Environmental Components	Potential Impacts	Source	Mitigation	Remarks
1	Water balance	GIDC to supply water which is generated in the LNG re-gasification process due to condensation of water vapor in air	—	No impact envisaged	—
2	Surface water	Disposal of accidental oil spill	Accidental spill	Physical removal of oil and disposal	None
3	Groundwater	None	None	None	Withdrawal
4	Ambient air quality	Marginal increase in Nox level in ambient air	Flaring unabsorbed or depressurized natural gas and captive power emergency generation	The dispersion model indicates occasional flaring will be dispersed quickly before reaching any human settlement. Generators will be maintained as per the emission standards	Negative and marginal impact Reduction in SPM and NOx levels in the industrial area due to switching over to NG for captive power generation by nearby industries Reduction in air pollution levels Long-term and positive impact
5	Noise	Increased noise level due to vehicular movement	Engine, compressor and human activity	Greenbelt as noise barrier	Negative and marginal impact
6	Land use	Industrial land to be developed. No acquisition of land		No impact	
7	Employment	An increase of about 59 PLL employees. In addition, the		Direct employment by PLL and additional	Long-term and positive impact

	Environmental Components	Potential Impacts	Source	Mitigation	Remarks
		Project will support expansion of activities of the end users of LNG, which will create additional employment		employment through the expansion of activities of the end users of LNG	
8	Population	An increase in the floating population and fixed population. Demand for houses and other things will increase the income of the villagers. However, laborers getting higher income due to employment might quit their regular jobs	Mechanization of labor-oriented jobs through cooperative societies	Project	Long-term and positive impact

— = not applicable, GIDC = Gujarat Industrial Development Corporation, LNG = liquefied natural gas, NG = natural gas, NOx = nitrogen oxide, PLL = Petronet LNG Limited, SPM = suspended particulate matter.
Note: PLL is responsible for implementing the mitigating measures.
Source: Petronet LNG Limited.

Table A6.3: Main Environmental Requirements
General Standards for Discharge of Environmental Pollutants Effluents

	Parameter (Units)	Standards Inland Surface Water	Land for Irrigation
1	Color and odor	Non-objectionable	Non-objectionable
2	Suspended solids (mg/l) max	100	200
3	Particulate size of suspended solids	Shall pass 850 micron IS Sieve	—
4	pH	5.5 to 9.0	5.5 to 9.0
5	Temperature max (˚C)	Shall not exceed 5˚C above the receiving water temperature	-
6	Oil and grease (mg/l) max	10	10
7	Total residual chlorine (mg/l) max	1.0	—
8	Ammonia nitrogen (as N)(mg/l) max	50	—
9	Total Kjeldahl nitrogen (as NH_3) (mg/l) max	100	—
10	Free ammonia (as NH_3) (mg/l) max	5.0	—
11	Biochemical oxygen demand (5 days at 20˚C (mg/l) max	30	—
12	Chemical oxygen demand (mg/l) max	250	—
13	Arsenic (as As) (mg/l) max	0.2	0.2
14	Mercury (as Hg) (mg/l) max	0.01	—

— = not applicable, ˚C = degree Celsius, IS = international standard, mg/l = milligram per liter, NH_3 = ammonia, pH = measure of acidity.
Source: Petronet LNG Limited.

Table A6.4: General Emission Standards

Parameters	Standards
Concentration-Based Standard	
Particulate Matter	150 mg/mm^3
Equipment-Based Standards	
Sulfur dioxide	60 mg/scm
Power generation capacity	
500 MW and more	275 m
200/210 MW and above to less than 500 MW	200 m
less than 200/210 MW	$H = 14 (Q)^{0.3}$

H = physical height of the stack in meters, m = meter, mg/mm^3 = milligram per cubic meter, mg/scm = milligram per standard cubic meter, MW = megawatt, Q = emission of SO_2 in kilogram per hour.
Source: Ministry of Environment and Forest. 1986. *Environment (Protection) Rules*. India.

Table A6.5: National Ambient Air Quality Standards

	Pollutant	Average (Time Weighted)	Concentration in Ambient Air ($\mu g/m^3$) Industrial	Residential	Sensitive	Method
1	SO_2	Annual[a]	80	60	15	Improved west and Gaeke Ultraviolet Fluorescence
		24 hours	120	80	30	
2	NO_2	Annual	80	60	15	Jacob and Hochheiser (NA Arsenite Gas Phase
		24 hours	120	80	30	chemilumine scence)
3	SPM	Annual	360	140	70	High volume Sampler (HSV) Avg > 1.1 m^3/min. Same as
		24 hours	500	200	100	annual
4	RPM (size < 10 μm)	Annual	120	60	50	RPM sample
		24 hours	150	100	75	Same as annual
5	Lead (Pb)	Annual	1.0	0.75	0.50	HVS using EPM 200 or equivalent filter paper
		24 hours	1.5	1.00	0.75	Same as annual
6	Carbon Monoxide	8 hours[b]	5.0	2.0	1.0	NDIR spectroscopy
	(CO)	1 hour	10.0	4.0	2.0	Same as 8 hours

μm = micrometer, μgm^3 = microgram per cubic meter, Avg = average, HVS = high volume sampler, m^3/min = cubic meter per minute, NDIR = non-dispersive infrared, NO_2 = nitrogen dioxide, RPM = respirable particulate matter, SPM = suspended particulate matter SO_2 = sulfur dioxide.

[a] Annual Arithmetic mean of min. 104 measurement in a year taken twice a week hourly at uniform interval

[b] 24 hourly / 8 hourly values should be met 98% of the time in year. However, 2% of the time it may exceed but not on two consecutive days.

Source : Gujarat Pollution Control Board, Gazette Notification dtd. 11/4/94, Part II : Sec 3 (ii).

Table A6.6: Ambient Noise Standards

Area Code	Category of Area	Limits in dBA	
		Daytime	Nighttime
(A)	Industrial area	75	70
(B)	Commercial area	65	55
(C)	Residential area	55	45
(D)	Silence zone	50	40

dBA = decibel acoustic.

Notes: (i) Daytime is defined as 6 a.m. to 9 p.m.
(ii) Nighttime is defined as 9 p.m. to 6 a.m.
(iii) Silence zone is defined as an area up to 100 meters around premises such as hospitals, educational institutions, and courts. The silence zones are to be declared by a competent authority. Use of vehicular horns, loudspeakers, and bursting of crackers shall be banned in these zones.
(iv) Mixed categories of area should be declared as one of the four main categories by the competent authority, and the corresponding standards shall apply.
(v) Noise monitoring will be carried out at different locations inside and outside the plant using portable noise measurement equipment.

Source: Ministry of Environment and Forest, *Environment (Protection) Rules* 1986.

Table A6.7: Environment Monitoring

	Nature of Analysis	Frequency of Analysis	Number of Samples	Analysis Results	GPCB Limits
1.	Stack monitoring for three GTG stacks	Monthly	3	SPM : < 10 mg/Nm^3 SOx : 0 ppm NOx: < 15 ppm	SPM: 150 mg/Nm^3 SOx: 100 ppm NOx: 50 ppm
2	Analysis of groundwater, as per GPCB parameters	Once in 6 months	3	To be carried out	—
3.	Collection and analysis of sanitary water, as per GPCB parameters	Once a month	1	BOD : < 10 mg/l SS: < 10 mg/l Residual Cl2: min. 0.5 ppm	BOD : 20 mg/l SS: 30 mg/l Residual Cl2: min. 0.5 ppm
4	Collection of ambient air quality samples within and outside company premises, as per GPCB guidelines	Once a month	4	SPM : < 170 μg/m^3 SOx: < 30 μg/m^3 NOx: < 30 μg/m^3 Hydrocarbon: < 55 μg/m^3	SPM : 500 μg/m^3 SOx: 120 μg/m^3 NOx: 120 μg/m^3 Hydrocarbon: 160 μg/m^3

— = data is not available, BOD = biochemical oxygen demand, Cl2 = chemical formula for chlorine, GPCB = Gujarat Pollution Control Board, GTG = gas turbine generator, mg/Nm^3 = milligram per normal cubic meter, μg/m^3 = microgram per cubic meter, NOx = nitrogen oxide, ppm = parts per million, SPM = suspended particulate matter, SO_x = sulfur oxide, SS = suspended solids.
Source: Petronet LNG Limited.

Table A6.8: Inland Surface Water Categories

	Characteristics	Tolerance Limits for Inland Surface Waters				
		Class A	Class B	Class C	Class D	Class E
1	pH	6.5−8.5	6.5−8.5	6.5−8.5	6.5−8.5	6.0-8.5
2	Dissolved Oxygen, mg/l	6	5	4	4	
3	BOD 5	2	3	3		
4	Total Coliform MPN/100 ml	50	500	5,000		
5	Color hazen units, Max.	10	300	300		
6	Odor	Unobjectionable				
7	Taste	Tasteless				
8	Electrical Conductance at 25˚C, mho				$100x10^{-6}$	$2.25x10^{-6}$
9	Sodium Absorption Ratio					26
10	Total Dissolved Solids, mg/l	500		1,500		2,100
11	Total Hardness (as $CaCo_3$), mg/l	300				
12	Calcium Hardness (as $CaCO_3$), mg/l	200				
13	Free Ammonia (as N), mg/l				1.2	
14	Free Carbon Dioxide (as CO_2), mg/l				6	
15	Oil and Grease, mg/l				0.1	
16	Magnesium (as Mg), mg/l	100				
17	Copper (as Cu), mg/l	1.5		1.5		
18	Iron (Fe), mg/l	0.3		50		
19	Manganese (as Mn), mg/l	0.5				
20	Chlorides (as Cl), mg/l	250		600		600
21	Sulphates (as SO_4), mg/l	400		400		1,000
22	Nitrate (as NO_3), mg/l	20				
23	Fluorides (as F), mg/l	1.5	1.5	1.5		
24	Phenolic Compound (as C_6H_5OH), mg/l	0.002	0.005	0.005		
25	Mercury (as Hg), mg/l	0.001				
26	Cadmium (as Cd), mg/l	0.01		0.01		
27	Selenium (as Se), mg/l	0.01		0.05		
28	Arsenic (as As), mg/l	0.05	0.2	0.2		
29	Cyanides (as CN), mg/l	0.05	0.05	0.05		
30	Lead (as Pb), mg/l	0.1		0.1		
31	Zinc (as Zn), mg/l	15				
32	Chromium (as Cr^{+6}), mg/l	0.05	0.05	0.05		
33	Anionic Detergents (as MBAS), mg/l	0.2	1			
34	Polynuclear Aromatic Hydrocarbon (PAH), mg/l	0.2				
35	Mineral Oil, mg/l	0.01				
36	Barium (as Ba), mg/l	1				
37	Boron (as B), mg/l					2
38	Percent Sodium, Max.					60
39	Silver (as Ag), mg/l	0.05				
40	Pesticides	Absent				

	Characteristics	Tolerance Limits for Inland Surface Waters				
		Class A	Class B	Class C	Class D	Class E
41	Alpha Emitters, µc/ml	10^{-9}	10^{-9}		10^{-9}	10^{-9}
42	Beta Emitters, µc/ml	10^{-8}	10^{-8}		10^{-8}	10^{-8}

^{o}C = degree Celsius, µc/ml = microgram per milliliter, BOD = biochemical oxygen demand, $CaCO_3$ = calcium carbonate, MBAS = methylene-blue active substances, mg/l = milligram per liter, mho = unit of conductance, ml = milliliter, MPN = maximum possible number, pH = measure of acidity.

Notes: Class A – drinking water source without conventional treatment but after disinfection; Class B – outdoor bathing; Class C – drinking water source with conventional treatment followed by disinfection; Class D – fish culture and wildlife propagation; Class E – irrigation, industrial cooling, or controlled waste disposal.

Source: Petronet LNG Limited.

Table A6.9: Drinking Water Specification

	Substance or Characteristics	Desirable Limit	Permissible Limit in Absence of Other Source
A.	**Essential Characteristics**		
1.	Color, Hazen units	5	25
2.	Odor	Unobjectionable	—
3.	Taste	Agreeable	—
4.	Turbidity, NTU	5	10
5.	pH value	6.5−8.5	No relaxation
6.	Total Hardness (as $CaCO_3$), mg/l	300	600
7.	Iron (as Fe), mg/l	0.3	1.0
8.	Chlorides (as Cl), mg/l	250	1,000
9.	Residual Free Chlorine, mg/l	0.2	—
B.	**Desirable Characteristics**		
1.	Dissolved Solids, mg/l	500	2,000
2.	Calcium (as Ca), mg/l	75	200
3.	Magnesium (as Mg), mg/l	30	100
4.	Copper (as Cu), mg/l	0.05	1.50
5.	Manganese, mg/l	0.1	0.3
6.	Sulphate (as SO_4), mg/l	200	400
7.	Nitrate (as NO_3), mg/l	45	100
8.	Fluoride (as F), mg/l	1.0	1.5
9.	Phenolic Compound (as C_6H_5OH), mg/l	0.001	0.002
10.	Mercury (as Hg), mg/l	0.001	No relaxation
11.	Cadmium (as Cd), mg/l	0.01	No
12.	Selenium (as Se), mg/l	0.01	No
13.	Arsenic (as As), mg/l	0.05	No relaxation
14.	Cyanide (as CN), mg/l	0.05	No relaxation
15.	Lead (as Pb), mg/l	0.05	No relaxation
16.	Zinc (as Zn), mg/l	5	15
17.	Anionic Detergents (as MBAS), mg/l	0.2	1.0
18.	Chromium (as Cr^{6+}), mg/l	0.05	No relaxation
19.	Polynuclear Aromatic Hydrocarbons (as PAH)	—	—
20.	Mineral Oil, mg/l	0.01	0.03
21.	Pesticides, mg/l	Absent	0.001
22.	Radioactive Materials:		
	a. Alpha Emitters	—	—
	b. Beta Emitters	—	—
23.	Alkalinity, mg/l	200	600
24.	Aluminum (as Al), mg/l	0.03	0.2
25.	Boron (as B), mg/l	1	5

— = data is not available, $CaCO_3$ = calcium carbonate, mg/l = milligram per liter, NTU = nephelometric turbidity unit, pH = measure of acidity.
Source: Petronet LNG Limited.