

Effect of Thermal Discharge of Cool Water Outfall from Liquefied Natural Gas (LNG) Plant into Sea Using CORMIX

Shivangi Nigam^{1*}, B. Padma S. Rao¹, A. Srivastava²

¹National Environmental Engineering Research Institute (NEERI), Nagpur, India; ²National Environmental Engineering Research Institute (NEERI), Mumbai Zonal Lab, Mumbai, India.

Email: *s_nigam@neeri.res.in

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ABSTRACT

The numerical modeling for the cool water outfall discharge from the LNG Plant is undertaken using CORMIX to evaluate the design of diffuser for discharge. The hydrodynamic data tide and currents are used inputs to the model. It is then calibrated using monitored data. The software has been run to calculate the mixing zone and dilution patterns for various flow conditions. Model result shows that ambient condition is achieved within 64 m from the proposed outfall locations. From the results of the modeling studies it can be concluded that the proposed diffuser design and outfall locations are suitable for all tide conditions. It also shows that there is no significant impact on the marine life due to the proposed cool water discharge, beyond the small area around the discharge location, as the parameters are attaining near ambient water quality within the acceptable space and time.

Keywords: CORMIX; Mixing Zone; Outfall; LNG Plant; Hydrodynamic Model

1. Introduction

The Gulf region in the earth contains the largest man-made islands in the world. The Gulf is one of the most highly impacted regions in the world and the greatest threats facing are the Gulf's marine communities [1]. The development which has occurred at unprecedented rate and scales, poses numerous environmental challenges. In India the Gulf of Kutch is characterised by high tidal ranges. Tidal range increases from mouth to head [2]. The Government of Gujarat has declared part of the Gulf of Kutch as the marine national park of India to protect the marine biota of the area and create long range interest of conservation [3]. Rapid economic development and population growth have brought widespread prosperity to this region. Coastal development and associated pollution can potentially alter or damage important shore habitats nearby, disrupt vital ecological pathways and cause permanent loss of nursery grounds for commercial shellfish and fish species. Nowadays they are facing lots of environmental issues like loss of productive natural

coastal habitat and associated marine life. Without good planning and careful consideration for existing coastal features, hydrodynamics and offshore bathymetric conditions, the consequences of such development can be severe and long lasting. Gulf countries need to take urgent action to prepare for the potential impacts of climate change on coastal areas and resources [4].

In this work, modeling of cool water outfall from LNG plant into sea port in Gulf of Kutch of India has been studied. In this LNG plant once through sea water is used for heating the LNG which turns cool by 3°C - 5°C. The cool sea water is discharged as outfall in to the sea which further gets dispersed by the tidal current. The CORMIX (Cornell Mixing Zone Expert System) system has been used for designing of diffuser as per the mixing zone. It is a comprehensive software system for the analysis, prediction of outfall mixing zones resulting from discharge and designing of diffuser. It contains mathematical models of point source discharge mixing within an intelligent computer-aided-design (CAD) interface [5, 6]. It mainly focuses on environmental impact assessment and regulatory management. The basic aspects for consideration of

*Corresponding author.

discharge in flowing surface waters are:

- 1) Defining **mixing zone** following the guidelines or regulations present in the current scenario [7].
- 2) The physical components of **hydrodynamic mixing processes** determining cool water outfall fate and distribution.

1.1. Software Availability

Name of software: CORMIX.
 Developer and contact address: USEPA, Centre for Exposure Assessment Modelling
 Year first available: 1991.
 Hardware required: Microcomputer (MS-DOS).
 Software required: MS-DOS or equivalent.
 Program language: FORTRAN and VP-Expert.
 Program size: 1.63 MB (downloadable distribution file).
 Availability and cost: free at
 (<http://www.mixzon.com>.)

1.2. Study Area

The study area coordinates as longitudes of 71°06' E and 72°54'E and the latitudes of 19°57'N and 22°3'N is selected for carrying out analysis and predicting the impacts due to discharge (**Figure 1**).

2. Hydrodynamic Data

The hydrodynamic data at the site of the discharge (water level and currents) has been taken from literature [8]. The discharge dispersion in coastal and marine waters depends on turbulence and currents. The coastal currents originate due to geophysical and meteorological conditions, responsible for mixing of pollutants. The input parameters have been tabled in **Table 1** for simulation to software.

2.1. Currents & Waves

Design current velocity of 0.5 m/s has been considered for the design of the berths. Direction of currents away from the coast also favours greater dispersion of pollutants from wastewater (**Figure 2**). Tide current velocity is 1.4 m/s and current direction in the port is counter-clockwise.

2.2. Winds

During the month of June, mean annual wind speed and maximum mean wind speed was observed 8.9 km/h and of 13.5 km/h respectively. During the month of January, lowest wind speed was observed to be 6.9 km/h. During the month of May to August Very high mean wind speed was observed in the range of 11.0 to 13.5 km/h.

2.3. Bathymetry

Bathymetry of study area has been presented in **Figure 3**. A maximum water depth of 6.0 m CD was recorded in the northwest 15 quadrant of the surveyed area at 252648.1E, 2332561.1N [9].

2.4. Discharge Data

The cool water is discharged into port with a flow rate of 6.17 m³/sec at temperature of 20°C. The seawater temperature varies between 23°C and 30°C. Density data is taken as per the temperature values of the fresh water body. The salinity is variable depending on the freshwater discharge into the area. This means that the density of ambient discharged water will vary by a few kg/m³ but the density contrast between ambient water and discharge will remain at about 1.5 kg/m³.

2.5. Thermal Characteristics of Discharge and Sea

Temperature near intake pipe in sea is 30°C and is assumed as the ambient temperature. Delta T across the Vaporizer is 5°C.

2.6. Criteria for Discharge

- 1) Limit of -5°C temperature between discharge and ambient sea at point of discharge.
- 2) Limit of -0.5°C temperature contrast between the discharges at 50 m from the point of discharge.

3. Output Parameters

The NFR is the zone of strong initial mixing. However, this information may be useful for the discharge designer because the mixing in the NFR is usually sensitive to the discharge design conditions (**Figure 4**). The model output parameters have been shown in **Table 2**.

4. Results & Discussion

The design of diffuser in Case I appears to be satisfactory for initial dilution of the cool water discharge because deeper water offers a greater opportunity for dilution of the cool water. Case II design leads to a significant increase in head loss of the discharge system. As a consequence there is a risk of flooding at the upstream end of the discharge system. Recirculation is expected to be low because of tidal mixing and gravity-driven flows. The study also evaluates that case I discharging at the inside edge is expected to give dilution up to 0.5°C above ambient within about 100 - 150 m of the discharge point and below 0.5°C at the exit from the harbour into the outside environment. The second case discharging at the outside

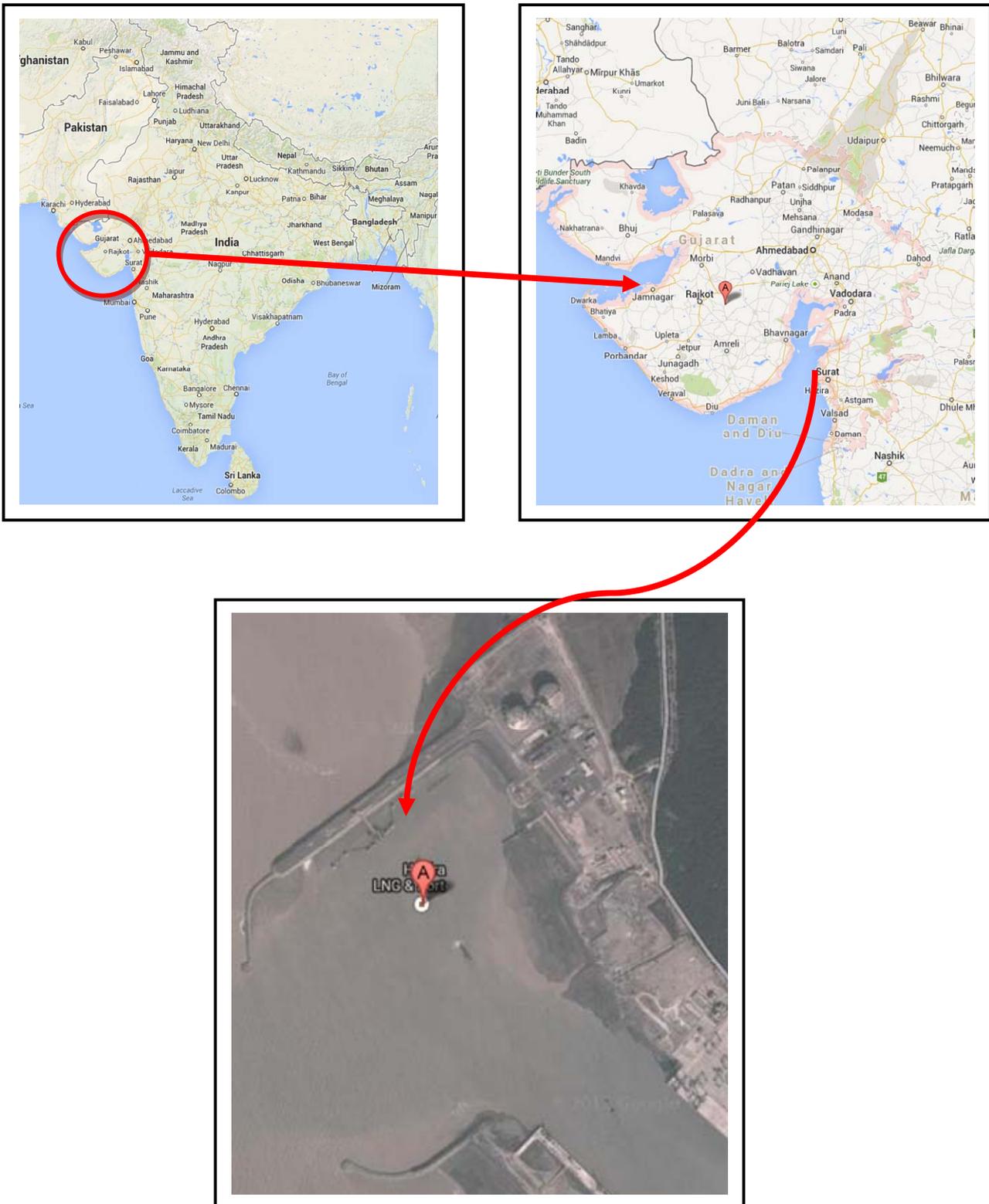


Figure 1. Location of Outfall Discharge of LNG Plant.

edge is expected to give adequate dilution of the discharge within 50 m, but would lead to losses in excess of the available head at high outside water levels. Hence

Case I with 4 nozzles is selected for designing which will give dilution within NFR region (64 m) with a travel time of 16 seconds and also protects the marine life via

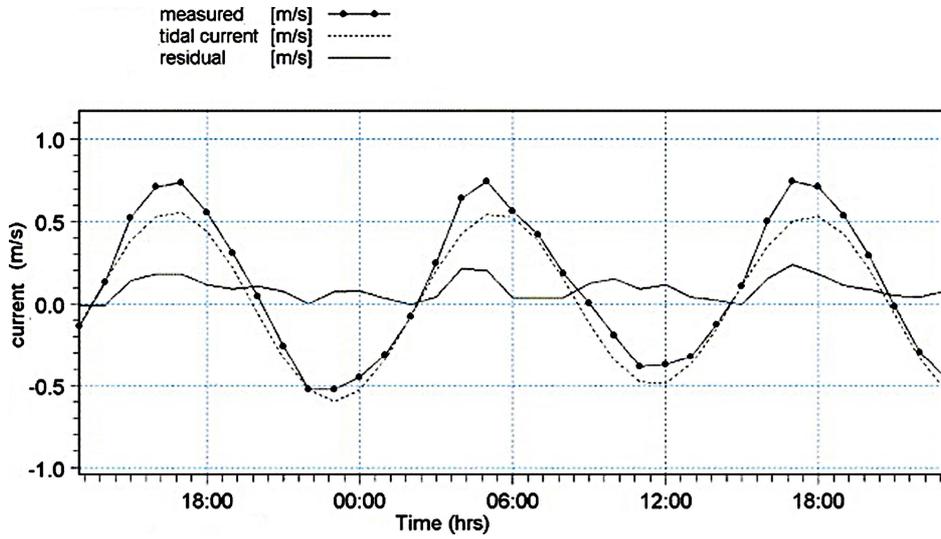


Figure 2. Current Variation with Time.

Table 1. Input Parameters for CORMIX Simulations.

Input Parameter	Baseline and sensitivity values
Bounded/unbounded	Unbounded
Nearest bank	Right
Channel width (m)	11% ± 1%
Depth at discharge (m)	10 ± 2.5
Ambient flow rate(m ³ /s)	6.17
Manning's N	0.02 - 0.05
Ambient temperature (°C)	35
Surface temperature (°C)	20 ± 10

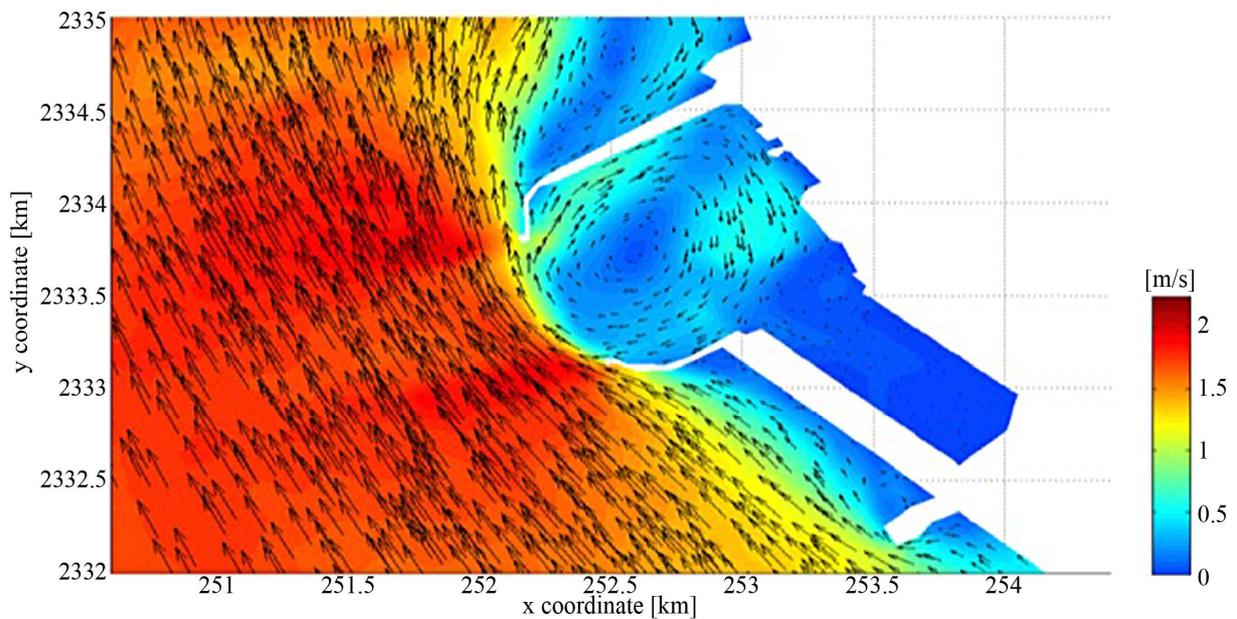


Figure 3. Bathymetry of the study area.

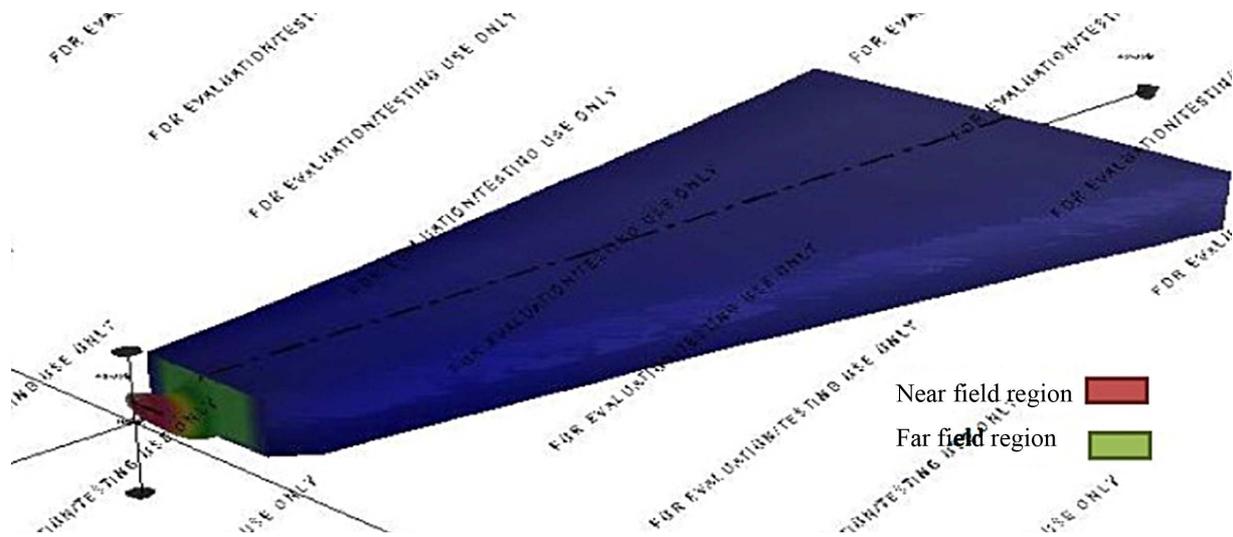


Figure 4. Generated 3-D View of Hydrodynamic Model Simulation Result for Multi-Port Diffuser.

Table 2. Model Output Parameters.

Sr. No.	Pollutant Concentration at NFR	Dilution at NFR	NFR Location (m) (Centerline Coordinates)	NFR Plume Dimension (m) Half Width(B_h), Thickness (B_v),	Travel Time (Sec)
Case1 (4 Nozzle 1.6 m diameter)	0.0360°C	138.7	x = 27.5 y = -0.06 z = 5.5	$b_h = 7.52$ $b_v = 5.5$	15.743
Case 2 (8 Nozzle 1.6 m diameter)	0.0616°C	81.2	x = 64.25 y = -0.10 z = 12.85	$b_h = 7.53$ $b_v = 12.85$	36.7143

phytoplankton and zooplankton of the port.

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