

# Marine Ecological Assessment for LNG Terminal at Port Qasim

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## ABSTRACT

Multinational companies intend to develop a Liquefied Natural Gas (LNG) terminal with floating storage and regasification arrangement (FSRA) in the jurisdiction of Port Qasim. Approximately 500 MMSCFD or 3.5 million tons per annum of LNG would be transferred through a mooring arrangement, which would require marine works/structures such as a berth for docking and mooring of LNG Carriers and Floating Ship Regasification Arrangement (FSRA) i.e., unloading, storage and vapor recovery and return unit and pipelines to the delivery point for transport to off-takers. The FSRA will deliver the re-gasified liquefied natural gas (RLNG) via jetty and onshore associated facilities to the gas network operated by the in-country transmission pipeline providers SSGCL and SNGPL. The approach channel of Port Qasim is associated with Gharo Phitti Creek System consists of three creeks: Gharo Creek, Kadiro Creek and Phitti Creek has tidal creeks and are with associated mangrove and mudflats ecosystems that are linked with a network of creeks in the Indus Delta. Dredging will be required to create the berthing and the turning basin of diameter 400 to 700 m with a depth of -13.5 m below chart datum (CD). Approximate dredged material would be upto 5.5 Million cubic meters. The dredged material will be utilized for the reclamation and to construct shore protection structure. Land Area of 75-100 acres with water front of 1000 m has been allocated in the PQA for this project. This would be the first time that LNG terminals are being set up in PQA.

## 1. INTRODUCTION

The approach channel of Port Qasim is associated with that consists of three creeks: Gharo Creek, Kadiro Creek and Phitti Creek. These are tidal creeks with associated mangrove and mudflats ecosystems. The Gharo Phitti Creek System is linked with a network of creeks in the Indus Delta. The environmental ecological assessment study was conducted in the Port Muhammad Bin Qasim area during 2010 South West Monsoon period. The overall objective of the study was to establish an environmental baseline, at the proposed port sites designated for construction and operation of LNG terminal, which would include, docking and mooring of LNG

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Carriers, Floating Ship Regasification Arrangement (FSRA) i.e., unloading, storage, vapor recovery and delivery point for transport to off-takers. The FSRA will deliver the re-gasified liquefied natural gas (RLNG) via jetty and onshore associated facilities to the gas network operated by SSGCL and SNGPL. A baseline ecological impact assessment has been conducted to assess impacts on mangrove plantation, marine benthic invertebrates, and fisheries was carried out within an area in close proximity to the proposed LNG site in PQA. The proposed sites at Port Qasim in the Gharo - Phitti creek system are dedicated areas for Oil and Gas development that promote local energy supply system. This is the first time that LNG projects are being set up in the PQA area. LNG operations includes constructing and operating a Liquefied Natural Gas (LNG) terminal in Port Qasim, inclusive of ship berthing and import facilities, floating storage tanks and regasification equipment.

The environmental baseline programme focuses on mangrove ecosystem marine organisms, their habitats, water quality, productivity, The baseline also takes into consideration the probability of the ecosystem being affected by port development, and evaluates unique ecosystems, key linkages, habitat loss for any endangered organisms found in the Mangrove Ecosystem, marine flora and fauna of the Mudflats that may require special management during LNG jetty development and accidental spillage of LNG during regassification and unloading operation. The purpose of this paper is to assess marine ecological impact of setting up of LNG terminal in the Port Qasim area.

## **2. PHYSIOGRAPHY OF MAJOR CREEKS IN PQA**

The present delta covers an area of about 600,000 hectares and is characterized by 16 major creeks and innumerable minor creeks, (figure 1), dominated by mud flats, and fringing mangroves. The coastal morphology is characterized by a network of tidal creeks and a number of small islands with sparse mangrove vegetation, mud banks, swamps, and lagoons formed because of changes in river courses. The Gharo Phitti Creek System consists of three creeks: Gharo Creek, Kadiro Creek and Phitti Creek. All three are connected in a series starting from Gharo Creek at the north-eastern end to the Phitti Creek at the south-western end and located at 22.3 km from Karachi. This creek system is about 28 km long and its width ranges from 250 to 2,500 m. The Korangi Creek, and Kadiro Creeks are connected with it at the north-eastern end while it acts as main waterway connected with the open sea at the south-western end. The main channel of Port Bin Qasim lies in this creek system, which has been dredged to maintain a navigable depth of -11.3 metres.

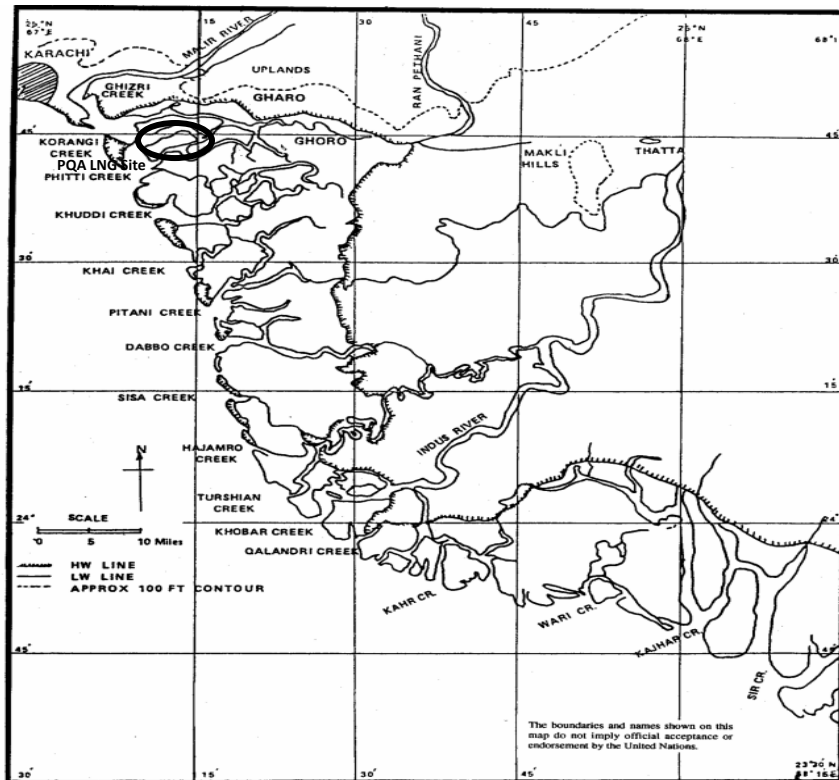


Figure 1. The Indus Delta and the numerous creeks in the deltaic region. Encircled area is PQA LNG site

The inner section of the creek is sheltered from the onslaught of high energy waves during the south west monsoons (June, July and August). Strong tidal currents have been observed during spring and neap tides. Seawater flows in the creek with velocities as high as 2-3 m/sec during the flood and ebb tides. The sediments are subjected to coastal dynamic processes, such as, tides, winds, waves, and currents. This leads to accretion and erosion of the Indus deltaic coast. The daily ebb and flow of water entering and leaving the creek have an erosional effect on the sediment movement in the creek.

### 3. THE MANGROVE ECOSYSTEM

In the Indus Delta mangrove ecosystem, there are eight species of mangroves. The dominant mangrove species are *Avicenia marina*. The other mangrove species in the deltaic region such as the *Ceriops tagal* occur in localized patches and there are a few plants of *Rhizophora mucronata*. All other species are rare and have disappeared from most part of the Delta due to adverse environmental conditions.

The Ghoro Phitti Creek System and its environs support a large mangrove ecosystem in the PQA coastal environments. The mangrove trees grow within the 200-300 m breath of PQA coastal belt of the creeks that are flushed by seawater in the land ward direction show an overall decline in

the height of the mangrove plantations. The density of mangrove vegetation was randomly evaluated in an area of 100 m<sup>2</sup> in the PQA creeks.

The trees were characterized (visual observations) according to the arbitrary height of the plants and results expressed as percentages. (Figure 2 and 3)

- Mangrove sapling were characterized as having a height between 0.5 -1.0 m (5%)
- Short mangroves trees were characterized as having 1-2 m height.
- Medium height mangroves trees had were characterized as having 2-3 m height. (30)
- High mangroves trees had were characterized as having >3 m height. (60%)

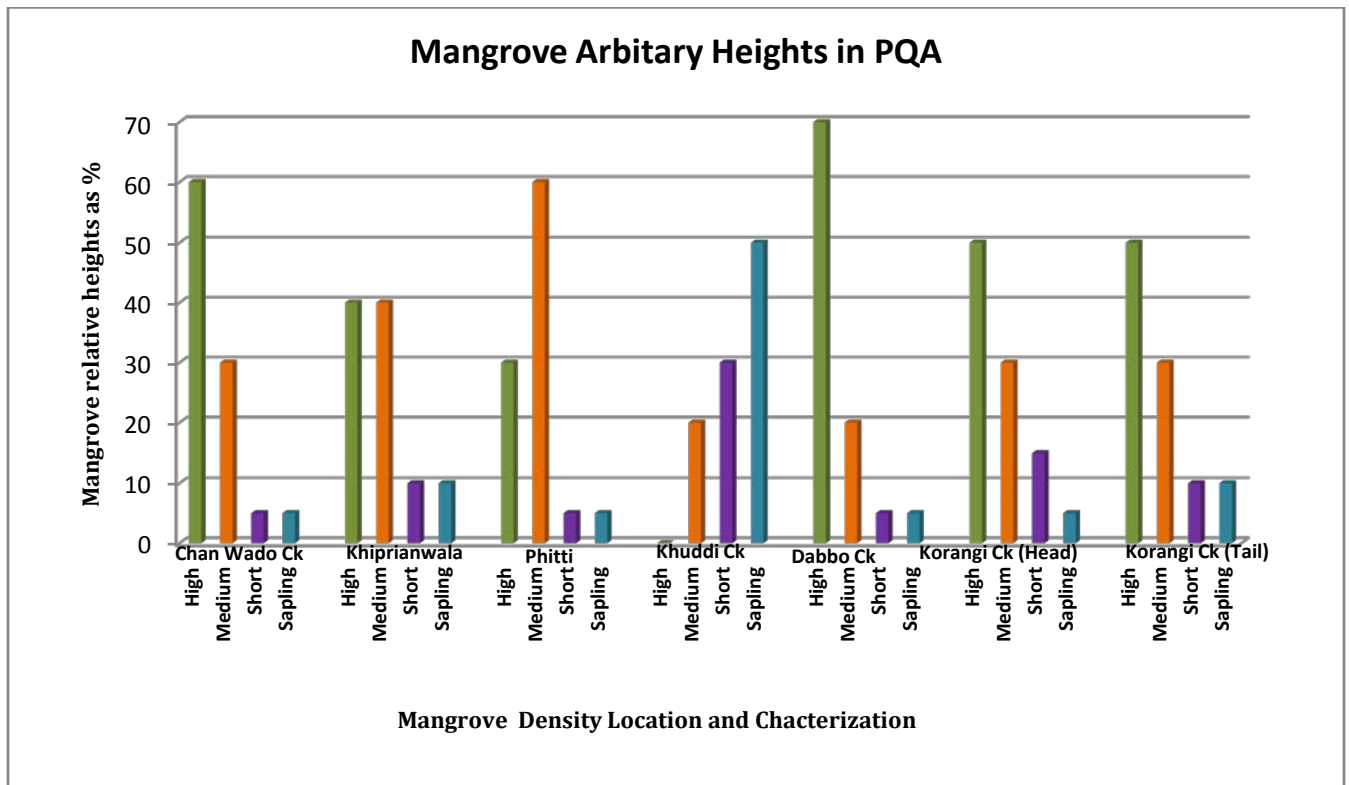


Figure 2. Arbitrary mangrove heights (high/medium/short/sapling) at different locations in PQA

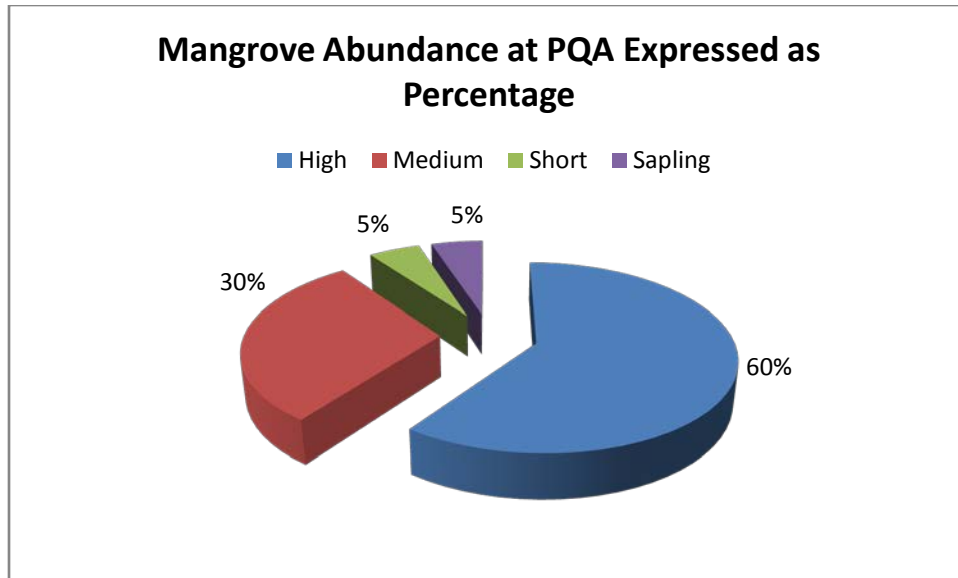


Figure 3. Accumulative abundance of mangroves trees in PQA expressed as percentages

#### 4. COASTAL MUDFLAT HABITATS.

Coastal areas and the intertidal region is a complex area where the division between land and sea is unclear. Coastal intertidal areas have a diverse range of communities including sandy shores, mudflats, and mangrove forests. The Gharo Phitti Creek System has faunal communities characteristic of very fine sediments from muddy to clayey. The communities included in the mud flats were dominated by faunal assemblages representing the soft sediments having a high percentage of silt and clay. The sediment substrate were generally found to be high in organic content and with black mud just below the substrate (anaerobic sediments with  $H_2S$ ). Most of the area surveyed constitutes of mangrove and the fauna associated with mangrove communities.

#### 5. BENTHIC SPECIES DISTRIBUTION PATTERN

The Marine Benthic Invertebrates (MBI) plays an important role in mixing the organically enriched bottom sediments. The MBI are a key linkage in transferring the energy from lower trophic level to the next higher trophic level in the food chain. The species distribution pattern of benthic invertebrates in the PQA area of interest are randomly distributed, while a few species aggregate. (Table 1) The distribution of invertebrates is dependent on the surface current that redistributes the planktonic larval form to locations away from where they were spawned they are hence random in their population densities. Aggregation is also a function of reproduction, where the benthic organisms tend to colonies together. The substrate sediment samples taken from the creeks, Nematodes, Annelid Polychaete worms, bivalve mollusk, Pinnotherid crabs, and species of Tanaidacean were by far the most dominant benthic species in the benthic sediment samples collected from the PQA region.

Invertebrate Species	Variance	Mean	Chi-sq	d.f.	Probability	Aggregation
Brittle star (Amphiurid)	0.2381	0.2857	5	6	0.545356	Random
Annelida (Polychaeta)	2.9524	2.5714	6.8889	6	0.330937	Random
Mollusca (Gastropods)	3.9524	1.4286	16.6	6	0.010985	Aggregated
Ostracods	0.2857	0.4286	4	6	0.678836	Random
Crabs (pinnotherid)	4.8095	1.1429	25.25	6	0.000355	Aggregated
False Crabs	0.2857	0.4286	4	6	0.678836	Random
Hydrozoan	0.619	0.5714	6.5	6	0.369585	Random
Sea anemone	0.1429	0.1429	6	6	0.423695	Random
Amphipods	9.2381	3.7143	14.9231	6	0.020851	Aggregated
Nematoda	2	4	3	6	0.810439	Random
Tanaidacean	1.4762	0.8571	10.3333	6	0.11034	Random
Shrimp (Alpheus)	3.9048	1.2857	18.2222	6	0.005848	Aggregated

Table 1. Specie wise distribution of Marine Benthic Invertebrates and their distribution pattern in PQA benthic samples collected in Gharo - Phitti creek system

## 6. PELAGIC FISH AND BENTHIC FISH COMMUNITY

Pelagic fish community includes Juveniles of powerful swimmers, which are exclusively carnivore in nature like predaceous fishes, croakers, carangids, breams, and shrimps, and cephalopods. In the mangrove ecosystem the predaceous forms are often small in size and easily wander among the mangroves at high tide. A 15-20 minutes fish trawl was conducted at selected station in the major creeks of PQA viz -a- viz Korangi, Kadrio, Phitti and Chhan Waddo creeks. The pelagic fish generally show a random distribution pattern. With the exception of shrimps with showed to aggregate The fish and crustaceans species observed are given in table 2.

Fish /Crustaceans Species	Variance	Mean	Chi-sq	d.f.	Probability	Aggregation
Mulletts (Mugils)	1.5833	1.25	3.8	3	0.283189	Random
Sole fish (Cynoglossus sp)	1.3333	1	4	3	0.260453	Random
Carangoids	0.9167	1.75	1.5714	3	0.670141	Random
Pony fishes (Leiognathus sp)	2.9167	1.75	5	3	0.169987	Random
Shrimps (Metapenaeus sp)	8	2	12	3	0.007541	Aggregated
Swimming Crabs (Portunids)	1.5833	1.25	3.8	3	0.283189	Random

Table 2. Pelagic fish distribution pattern in major creeks of PQA

Benthic fish community includes detritus feeders, small and large herbivores, and small and large carnivores. In the mangrove ecosystem, the benthic community of the adjacent shallow water is a subject of interest. Here, the microbes decompose the plant litter into organic detritus-a

fundamental commodity of system energy. This detritus matter is picked up by the detritus feeders over the bottom, such as fishes, shrimps and shellfish, and then carried to the littoral zone by wave action, shared by the intertidal fauna such as crabs, shrimps, mudskippers, and other invertebrates. Grey mullets, gizzard shads, flat fishes, many skates and rays are some of the fish which prefer to live on soft bottom and feed on bottom detritus. At low tide, when a large part of muddy bottom is exposed, crabs, mudskippers and coastal birds (waders) are seen in large numbers picking up their food which includes worms and different animals left behind by the receding tide.

## 7. COMPARISON OF LNG HAZARDS WITH OTHER FUELS.

Risk of LNG hazards due to spill and leakages into the environment are considered to be less hazardous compared to other fossil fuels. LNG is considered a simple asphyxiant, but has low toxicity to humans (table 3). In a large-scale LNG release, the cryogenically cooled (-160<sup>0</sup> C) liquid LNG would begin to vaporize upon accidental release from the breach of an LNG cargo tank. If the vaporizing LNG does not ignite, the potential exists that the LNG vapor concentrations in the air might be high enough to present an asphyxiation hazard to the ship crew, pilot boat crews, emergency response personnel, or others that might be exposed to an expanding LNG vaporization plume. Although oxygen deficiency from vaporization of an LNG spill should be considered in evaluating potential consequences, this should not be a major issue because flammability limits and fire concerns will probably be the dominant effects in most locations.

Hazard	LNG	LPG	CNG	Petrol	Diesel
<b>Behavior, if spilled</b>	Evaporates, forming visible vapor cloud that disperses quickly	Evaporates, forming flammable vapor cloud that tends to accumulate	Evaporates, forming a visible vapor cloud that disperses quickly	Forms a flammable pool and flammable vapor cloud, environmental cleanup required	Forms a flammable vapor cloud, environmental clean up required
<b>Toxic</b>	No	No	No	yes	Yes
<b>Carcinogenic</b>	No	No	No	Yes	Yes
<b>Asphyxiant</b>	Yes in confined spaces	Yes same as LNG, but higher density encourages accumulation	Yes same as LNG	No	No
<b>Stored Pressure</b>	Ambient, except in small containers	Pressurized	Pressurized	Ambient	Ambient

<b>Autoignition Temperature °C</b>	540	455	540	257	315
<b>Other Health Hazards</b>	Low Temperature during transport (-160°C), Cryogenic Burns	May cause Nausea	May cause minor nasal irritation	Can cause Nausea, eye irritant, narcosis	Forms a flammable pool and flammable cloud vapor. Cleanup required.

Table 3, LNG Hazards Compared of to other fossil fuels Source: Based on Lewis, William W., James P. Lewis and Patricia Outtrim, PTL, "LNG Facilities – The Real Risk," American Institute of Chemical Engineers, New Orleans, April 2003,

## 8. POTENTIAL IMPACTS OF DREDGING ON PRODUCTIVITY

Continuous dredging in the creeks for safe operations of LNG would increase the sediment load, the suspended sediment load in the water column, may deteriorate the marine water quality and transparency for phytoplankton production, and it adversely affects fish and fish habitat. The overall Productivity of the mangrove areas has been reported to be high (365-780gC/M<sup>2</sup>/year), compared to coastal waters (50-200 gC/M<sup>2</sup>/Year),

High concentrations of resuspended sediment in the water during NE monsoon in side the shallow creek ranges between 25 to 178 ppm. Higher turbidity concentrations are detrimental to benthic organisms, (interstitial fauna) that include macro and meiofauna, fish ova and larval survival and productive capacity of a habitat. During the SW Monsoon period the suspended load levels are approximately 300 ppm. The Benthic fauna (Interstitial macro, meio and microfauna) although ubiquitous are restricted within the top 15-20 cms of the subsoil. The benthic fauna in silt/clay sediments below 20 cm of subsoil in the PQA channel is restricted to anaerobic micro organisms. The distribution of interstitial benthic fauna is restricted vertically due to compact silt clay nature of the sediments and low oxygen content within the sediments of PQA channel. Gray J.S and M. Elliott, (2009) have shown that benthic organisms have a well defined animal/sediment relationship. The benthic fauna has a short regeneration time. They quickly recolonize within 3-4 weeks of the disturbed sediment surface due to their reproductive potential. Phytoplankton and primary productivity will return to its original natural concentration of approximately 10 cells ul<sup>-1</sup> . Hence any disturbance of sediment suspension in the water column and within the microenvironment of PQA channel due to dredging activity would be temporary. Benthic organisms at the sediment disposal site may be buried and may not be able to migrate through the dumped sediment material. If the substrate is changed from what was previously present at the sediment dumping site, the organisms which recolonize the site may be different from those present prior to disposal. Increased suspended sediments may also interfere with production of macroinvertebrates and other aquatic fish food organisms.

## **9. IMPACT ON MANGROVE ECOSYSTEM.**

Port development activity can have a major destabilization impact on Mangrove growth density and diversity if no mangrove rehabilitation management is made. However, the degradation of mangroves in the Indus Delta can be attributed to the progressive reduction in fresh water discharge over a period of many years. Historical records indicate that the distribution of mangroves in the Indus Delta has significantly changed during the past several hundred years with the shifting pattern of the river (Snedaker, 1984). Until recently the Indus River had a largely river-dominated estuary but increased utilization of the river for agriculture etc. has resulted in discharge to the Arabian Sea only during the summer southwest monsoon. During remaining nine to ten months the Indus River has no estuary due to elimination of the river discharge (Schubel, 1984). As a result, the mangrove ecosystem has been adversely affected. Some decades ago the area of mangrove cover in the active Indus Delta has been estimated at about 250,000 ha (Khan, 1966,). The mangroves are degrading rapidly caused by a number of factors such as cutting, browsing and by reduced silt laden river water. These forests which covered 263,000 ha in 1977 have recessed to about 160,000 ha in 1990 (Qureshi, 2005). This is probably the most serious problem focusing mangroves of Indus Delta; therefore the salinity value of 40 ppt or more is common in mangrove areas. Although there exist no previous records of salinity values in the area for past some decades, but it was appreciably lower since rice was once cultivated in Keti Bunder in the vicinity of mangrove stands (Saifullah, 1982). Due to hyper salinity and nutrient impoverishment decline in mangrove is now visible everywhere. Early dense and extensive forest has changed to stunted growth of trees and reduction in forest area.

## **10. IMPACTS OF DREDGING ON BENTHIC COMMUNITIES.**

The potential (negative) impacts of (conventional) dredging activities can impact benthic habitat and species. Recolonisation or recovery of disturbed areas may be possible; Alteration of sediment composition, i.e. of substrate characteristics in the surrounding of the dredging site, resulting in a change of the nature and diversity of benthic communities, e.g. decline of individual density, species abundances or biomass. Dredging generally causes to some extent an increase of turbidity that may be regarded as indicator for potential ecological impacts, as resuspension of sediments may give rise to various adverse effects on the environment. These include, spread of sediments and associated contaminants in the surroundings of the dredging site, leading to clogging of gills in fish, and smothering of benthic invertebrate community. Impact on pelagic and benthic organisms (e.g. decrease of primary production due to reduced transparency of the water column, smothering of benthic organisms may occur, but is less important at the dredging site than at the disposal site. Release of nutrients, would increase eutrophication; leading to decreased amount of dissolved oxygen in water column. turbidity

plumes and resuspension may change the physical/chemical equilibria, with a potential to release contaminants into the water phase (remobilisation), especially in suspensions of anoxic silty sediments, to enhance the bioavailability and ecotoxicological risk of the already present (background) contaminants (e.g. heavy metals), and to chemical or biochemical changes of contaminants and bioaccumulation of contaminants in tissues of benthic organisms, crabs and demersal fish. There is also a possibility of invasive species or the introduction of new species into the system through release of ballast water by LNG cargo tankers.

## **11. PROPOSED MITIGATION MEASURES**

The following mitigative measures will address the potential effects on the marine environment and marine organisms from increased suspended sediments. Vessels during the construction phase of the jetty should operate outside of biologically sensitive areas (close proximity to mangrove vegetation) and outside of periods of critical fish, shrimps life stages i.e. SW Monsoon season (June, July and August). The construction of the jetty should ideally be during the winter monsoonal months (NE Monsoon. i.e. November, December, January) timing. This period is best suited as it lies outside of biologically sensitive temperature ranges for fish gonadal maturation. Implement acoustic restrictions during construction phase, in biologically sensitive areas during breeding and spawning periods and critical fish life stages. Timing of dredging to avoid key biological processes (migration, spawning, etc.), and minimize sediment transport and mixing. Uprooted and dislocated mangrove trees during the construction phase must be replanted in location best suited for their growth. This should be done under the aegis of independent environmental monitoring organisation. Minimize use of lights during night. During Project operation, LNG carrier vessels may risk introduction of exotic species through bilge and ballast discharges into the marine environment. Arrival of international marine vessels in the PQA Channel potentially exposes native marine organisms to exotic/invasive species through ballast water exchange, hull fouling and direct transport. There is a possibility of invasive species or the introduction of new species into the system through release of ballast water by LNG cargo tankers. There is therefore a need to Implement ballast control measures, preferably away from the internal water; (beyond 200 m depth contour). Green House Gasses (GHS) levels in the PQA are within the permissible limits. The GHS ( $\text{NO}_x$ ,  $\text{SO}_x$ ) during the construction phase would not be an Issue. Levels of atmospheric  $\text{CO}_2$  levels may increase slightly during the construction activity mainly due to use of fossil fuels by construction machinery. These temporary increases in the  $\text{CO}_2$  level will not endanger the PQA environment. There is a need to develop a preparedness, prevention and hazardous materials spills protocol. An Environmental Protection Plan and an Emergency Response Plan for oil and LNG spill.

Treatment of the dredged material may be considered if this would facilitate beneficial use of the material. A variety of treatment processes are available to reduce contamination of the toxic components in the dredged material solids or slurries. Low-cost treatment alternatives include bioremediation. Bioremediation (use of bacteria, fungi, or enzymes to break down organic

contaminants), chemical treatment (e.g., oxidation, reduction, chelation, hydrolysis, detoxification, thermal (e.g., incineration) can use utilized.

## **12. UTILISATION OF DREDGED MATERIAL**

Use of dredged material as the substrate for habitat development is one of the most common and most important beneficial use. The use of dredged material for habitat development offers a disposal technique that is an attractive and feasible alternative to more conventional disposal options. Within various habitats, several distinct biological communities may occur. For example, the development of a dredged material, creation of an island or nourishment sediment to eroded creeks banks may initiate a wide variety of wetland, upland, island, and aquatic habitats. Potential developments include such communities as tidal flats, oyster beds, clam flats, fishing reefs, and aquatic plant and plantation of mangroves. The excavated dredged material can be used as the substrate for mangrove habitat development. Within various habitats, several distinct biological communities may occur. For example, the development of a dredged material can reinforce eroded banks by providing coastal nourishment. The sediments can be used for reclamation of Bundal Island can also be developed after initiating necessary coastal hydraulic studies. Potential developments could include encouraging faunal communities as tidal flats, oyster beds, clam flats, fishing reefs, and aquatic plant and replantation of mangroves

## **13. CONCLUSION**

To conclude extensive environmental surveys must be conducted on regular basis to have a better understanding of marine ecological impacts during construction and operational phases of LNG terminal at PQA. This should be a mandatory component of Environmental Monitoring Program (EMP). Ecological baseline information on PQA mangrove ecosystem in the Gharo-Phitti Creek System have been evaluated, that include mangroves, the mud flat fauna, Marine Benthic Invertebrates (MEI) habitats, pelagic and benthic fisheries along with the impacts of dredging and mitigation options have been taken onto consideration. PQA Gharo-Phitti creek ecosystem has key linkages, habitats and organisms associated within the mangrove ecosystem. Marine flora and fauna of PQA along with the mangroves and the mudflats may require special management during development of LNG jetties, dredging and LNG operation. A well formulated Environmental Management Plan (EMP) must be in place to effectively monitor the impact as per the national environmental quality standards (NEQS) and international environmental guidelines on a regular basis through independent environmental monitoring organizations. Any deviation from the basic ecological study must be highlighted followed by mitigation/remedial measures. Biological resources are renewable and can even increase with proper management.

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