

Interim Progress Report

Environmental Impact Assessment (EIA) Study on Pollution Due to Oil Spill and Other Hazardous Substances



for



Maharashtra Pollution Control Board (MPCB)

Submitted By



National Environmental Engineering Research Institute (NEERI)

[This report is an interim progress report and many areas of data collection and interpretation are still underway]

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1.0 Background

The Mumbai oil spill occurred after the Panamian ships *MSC Chitra* (IMO: 7814838) and *MV Khalijia 3* (IMO: 8128690) collided off the coast of India near Mumbai on Saturday, 7 August 2010 at around 9:50 a.m. local time. *MSC Chitra*, which was outbound from South Mumbai's Nava Sheva port, collided with the inbound *MV Khalijia-3*. The geographical position of the collision is 18°51'51.8" N and 072°49'12.0" E. The impact of collision was so severe that *MSC Chitra* tilted to about 80 degrees soon after the collision, spilling an estimated 400 tonnes of oil in initial few hours. The ship was loaded with an estimated 2,600 tonnes of oil at the time of the accident. During the accident, there was a spillage of about 879 tonnes of oil which traveled long distances to the various coast line of the Mumbai Metropolitan region (MMR) and near by areas.

MSC Chitra was also carrying 31 containers of the pesticide like pyrethrins and the organophosphates. The crude oil moved to different coastline of the Mumbai, Thane and Raigad district due to the tidal movement. The shoreline of most of these areas here shown signs of oil from the very next day of the collision. The coastal sediment affected along the shoreline can be classified as bedrock, sand, boulders etc. The mangrove stretch along shore can be also seen affected. The degree of impact of the oil spill varies with locations.



The Ships: Kalijia 3 and MSC Chitra

The fallen containers were swept away in different coastal parts. Some of these are still in the offshore region, and can be seen at low tide. Materials of damaged containers have moved in

different directions. Much of these have been retrieved, however large chunks are still lying around in multiple directions and locations.

The present report focuses on the oil spill impact on the mangrove with respect to the percent cover, affected species, affect on the fruiting and flowering etc. Along with the impact on the mangrove study, study of the oil spill impact on the sediment with respect to type of sediment, area cover, age etc. has also been undertaken. The study also addresses the impact of the spill on the associated marine biota and the animals, using multiple tools. Socioeconomic impacts are also a part of the study for assessment of direct and indirect impacts on livelihood.

2.0 Objectives

The study components of NEERI include multifaced objectives. Given below are the overall components and their finer attributes.

1. Impact mapping of the region to assess the level of damages, which will include:
 - a. Area of water with high concentrations of oil and other hazardous material
 - b. Levels of contamination and its spatial and temporal mapping.
 - i. Locations and its effective region.
 - ii. Concentration gradient at multiple locations.
2. Contaminants profile for whole region
 - a. Types of contaminants and their levels shall be plotted for iso-contours
 - b. Prediction of their movement
 - c. Fate analysis of the contamination based on weather, place and clean ups, if any
3. Contamination regions of all types shall be identified through the data given by NIO and any other agencies such as BARC, other Govt agencies, Godrej Foundations, NGOs, villagers etc
 - a. NEERI will carry out some ground truthing of all data obtained using its own team
 - b. It shall also use Remote Sensing Satellite data with ground truth data
 - c. It will need to use the Coastal Zone Management map (available with GOM) and map these values on the same.
4. Response assessment and evaluation of cleanup
 - a. Physical survey and assessment of secondary information and primary data over a period (Short term and long term)

- b. Chemical and biological quality assessment based on secondary and primary information [limited primary data] (short and long term)
 - c. As there are many agencies carrying out assessment at varying time interval and extent of work, it is important to integrate and use the same for interpretation by collating the same with MPCB.
 - d. Clean up of efficiencies of various efforts and documentation
- 5. Response assessment and evaluation of cleanup
 - a. Damage assessment
 - b. Water quality related
 - c. Aquatic Bio-diversity: fish, planktons etc
 - d. Terrestrial system: mangrove and other plants/shrubs
 - e. Sediment system: physical and biological
 - f. Fisheries and other resources (other source of data and information to be obtained through MPCB/GOM efforts to get necessary secondary information)
- 6. Response assessment and evaluation of cleanup
 - a. Assessment of total directly affected population within the impacted area
 - i. Affected population due to oil spill impacting their daily earning
 - ii. Affected population due to soil spill impacting tourism and related activities
 - iii. Aesthetic damages
 - iv. These damages will be computed using direct techniques and other techniques for assessment of intangibles
 - b. Losses and other damages over a period of active phase of the oil spill and other material spillage
 - c. Secondary level assessment of population with types affected due to long term effect of the spill
- 7. Recommendation and Deliverables
 - a. The whole mapping of the region shall be divided into various aspects of damages and costs of the restoration
 - b. The damage costs shall include direct costs (where direct clean up is possible by human efforts) and indirect damage (where natural attenuation is the only way)
 - c. The report shall include:

- i. Total areas of affected and their extent of damage [short term and long term]
- ii. Damage types: water, sediment, rocks, beaches, mudflats, mangroves, other vegetation, aquatic and terrestrial ecosystem
- iii. Damages with regard to human population: directly affected population (fishermen, small businesses, tourists, etc) and indirectly affected (loss of tourists traffic, aesthetic damages etc)
- iv. Direct costs of oil spill and indirect costs including intangibles in short term
- v. Long term costs can be attempted, however the same will depend upon the availability of data

8. Recommendation and Deliverables

9. Support and Data Needs

- a. MPCB/GOM shall assist in getting all the necessary data and information from other agencies such as NIO, CMFRI, CZMA, DGCA, and any other agencies
- b. Data from NIO shall be the starting point for the coastal water, sediment and mangrove damage assessment
- c. Necessary permissions to visit and perform survey in all the affected regions

3.0 Methodology

The methodologies used for different attributes of environment affected by the oil spill have been summarized herewith. An attempt has been made to fully appreciate the methods, however after visiting the actual site conditions; suitable modifications in the methodologies have been made.

3.1 Shoreline Sediment Monitoring and Assessment

This component includes three major categories.

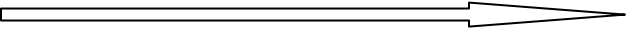
- ⇒ Collection and arrangement of shoreline maps for background information
- ⇒ Determination and marking of the affected areas to fix the survey area
- ⇒ Determination of substrate type

The Coastline substrate can be divided into following types

- **Bedrock or Rock:** Porous/non-porous, Broken/not broken
- **Boulder:** Porous/non-porous, Broken/not broken
- **Cobble:** Porous (e.g. coral, pumice)/non-porous.
- **Pebble:** Or “shingle” if flattened.
- **Granules/ Gravel:** Rounded/flat. • Compacted/loose.
- **Sand:** Fine to coarse
- **Mud/Silt/ Clay:** Consolidated/loose. Dry (e.g. mud cliffs).
- **Earth/ Soil:** applicable to cliffs and seawalls.
- **Ice:** In the Antarctic territories.
- **Shellgrit:** Wet/dry. Usually with sand.
- **Coral:** Rubble/Boulder/Cobble.
- **Concrete:** Rubble.
- **Wood:** Debris/logs; pilings. Debris can overlay other substrates.
- **Metal:** Pilings, sheeting. Usually artificial structures.

Shoreline Form – Gradient Width Height etc. can be interlinked with the level of energy used or destroyed depending upon the locations specifically gradient and substrate. Figure delineates the energy from that is common in coastal regions.

Substrate, Gradient, Form, Shoreline Energy:

Energy	<div> <div>Low</div> <div>  </div> <div>High</div> </div>						
Substrate	Mud	Sand	Grits	Pebble	Cobble	Boulder	Bedrock
Forms	Swamps		Flats		Beach		Reefs Cliffs
Gradient/ Slope	Gentle slope			Steep slope		Vertical	

3.1.1 Monitoring Methods for Shoreline Oil

Ground Surveys

Ground surveys are usually required for identification and marking of oil impact area. In particular to measure or estimate the thickness of oily bands, and describe the character of the oil. Ground surveys are also required to determine whether subsurface oil is present, usually from percolation of oil into interstitial spaces, or by burial by mobile sediments. Subsurface oil

adds significantly to the cleanup efforts required and may also have significant implications for waste management.

3.1.2 Assessment of Oiled Shorelines: Surface Oil

Methodology

- Divide shoreline into Sectors and Segments for the easy detail study.
- The documentation should be made for Length, Width, Energy, Substrate, Form etc.
- For each Segment, draw a sketch map showing the approximate location of the oil.
- Record the length, width and the percent cover (visually)
- Oil thickness can be assessed by dividing into Pooled oil, Cover, Coat, Stain. Film

3.1.3 Assessment of Oiled Shorelines: Sub-Surface Oil

- Divide shoreline into Sectors and Segments for the easy detail study.
- The documentation should be made for Length, Width, Energy, Substrate, Form etc.
- Dig trenches or pits to detect subsurface oil. Narrow trenches are more suitable for sandy substrates. Pits are more suitable for cobbles or small boulder substrates. The depth required will depend on substrate type and, for sand – pebbles, on sediment mobility (wave energy).
- For each pit, or location along a transect trench, following details are recorded
- Minimum depth of oil, distance from the beach surface to the top of the buried layer.
- Substrate type at various depths or in the oily bands as required.
- Description of the oil in the oily layer in terms of Fluid Oil, Viscous Oil, Mousse/Emulsified and Tar.

3.1.4 Sediment Sampling Methods

The oil reaches to the shoreline area by the natural tidal movement and gets deposited on the shoreline sediment. The impact of the oil spill on the shoreline depends on the shoreline energy, which depend on the type of substrate, from of the substrate and the gradient. The substrate types along the studied impact area mainly include bedrock, boulders, pebbles and the sandy type. Where as forms can be given as beach, swaps and flats. Most of the impacted sites have natural seaward gentle slope.

The impact and its persistence also depend on the texture of the sediment type as the rough surfaces; creviced surfaces hold more oil than that of smooth and fine textured surfaces. In this particular study, degree of impact on the shore line area varies greatly in the various areas.

Oil is only rarely incorporated into seabed sediments as a result of the weathering of surface slicks. However, oil can be incorporated into marine sediments as a result of the natural redistribution of oiled pebbles, sands, and silts due to wave or following remobilization by shoreline cleanup activities, particularly washing methods. If this accumulates to a significant extent then alternative cleanup strategies may be required. Monitoring of both natural and cleanup induced sand redistribution may be necessary to better determine the net environmental benefits of natural cleaning or intervention.

This monitoring method is usually suitable for shallow waters. Grab Samplers or Drop Corers are used. The sediment sampling methods are dependent on the basis of oil layer thickness and the type of the sediment affected.

Push Core Sampling A

This method of sampling involves pushing a clean plastic tube down into the substrate and extracting a column, or “core” of sediment. It is suitable for most sediment conditions, but particularly when:

- Oil is present on the surface as a thin layer (coat, stain, film).
- Oil penetrated to a fairly shallow depth (e.g. < 10 cm).
- Accurate measures of the amount of oil at various depths are not needed

Methodology

1. Push plastic tube into sediment. Generally the depth of sampling should not be more than two thirds of the length of the tube.
2. Seal the top of the tube and extract.
3. If the sediment is wet or loose, or does not stick to the inside of the tube when extracted, it may be necessary to dig down beside the tube and block the bottom opening before removing the tube from the sediment.
4. Alternately sealing the top of the tube with a bung can facilitate extraction of the core.
5. The core of sediment should be transferred immediately to a clean glass container.

Push Core Sampling B

This method is essentially the same as Method 1, but is used when it is necessary to differentiate between surface oil and subsurface oil. This may be needed if attempting to determine, for example:

- The amount of oil that could be removed by tidal action (i.e. surface oil) in low energy shores and oil likely to persist (i.e. subsurface oil).
- The rate of degradation of the oil. In this case the presence of relatively large amounts of surface oil could mask any observation of changes in subsurface oil (or visa versa).

Methodology

1. Scrape surface oil from a given area prior to pushing in the sampling tube.
2. Transfer this “surface sample” to a clean storage jar and record the area cleaned (square centimeters) and approximate depth of sediment removed (if possible).
3. Rest is same as method ‘Push Core Sampling A’.

3.1.5 Monitoring Damage to Invertebrate Beach Fauna

Species or communities should be observed or collected from both affected (oiled) and unaffected (unoiled) control areas. A number of affected and unaffected areas should be monitored. Determine species to be monitored or sampled.

Methodology

The parameters like number and position of the organism in transact or quadrat, oil cover impact, shell damage, mortality etc. should be part of the study. The photo documentation can use for this type of study. The mortality assessment must be considered seasonal and natural die-off and the control (unaffected area) mortality.

3.1.6 Monitoring Damage to Coastal Flora

Damage to coastal flora can occur as a result of oiling or response activities. Damage due to oiling plus response activities may need to be compared to the effects of oil alone to determine whether cleanup is having a net benefit or adverse effect. However, short-term effects should be evaluated against possible longer-term benefits. The persistence of the oil and likelihood of longer-term effects need to be evaluated.

Methodology

1. Determine monitoring locations for all affected and unaffected areas for monitored. A number of affected and unaffected areas should be monitored
2. Determine species to be monitored or sampled.
3. The parameter like number and distribution of plants, oil cover, mortality and other possible effect like leaf curling, chlorosis etc. can be considered.
4. The monitoring and assessment study can be carried out with transect or quadrat method or by aerial and ground survey.

3.1.7 General Methods for Assessment and Monitoring

The basic aim of a sampling design is to ensure field samples are representative of the area, habitat or community being investigated, and are collected efficiently and cost effectively. There are three basic approaches relevant to selecting sample locations:

Authoritative or Selective Sampling

This sampling is deliberately biased to specific areas, e.g. visibly oil-free and oil-impacted sites. It is ideal for Type I monitoring as it allows a smaller number of samples to be collected from the areas of most interest. However, it has a relatively high potential for error if variability is unknown.

Random Sampling

This is a more scientifically valid method but usually requires a large number of sample locations.

Systematic Sampling

This sampling area uses a grid or consistent pattern across the defined area. This approach is most suitable when looking for non-obvious contaminated locations, for most known areas of the present case, this method has been added.

Use of Quadrats and Transects

If the parameter being measured is based on area (e.g. animals per m²), small sampling perimeters or “quadrats” can be used. Quadrat size will depend on what is being sampled and the numbers to be counted. With large quadrats numbers can become unwieldy, if they are too small, sampling variability problems may arise. Generally, for shoreline work, an area of 0.2-

0.3 m² is sufficient (e.g. a 0.25m² area would be a 50cm x 50cm square quadrat or a circular quadrat with a diameter of about 56.4cm) for mangroves and large area, assessment quadrat size is much larger.

Transects are surveyed lines, usually passing from high to low tide, along which samples are taken. Like quadrats, transects can be positioned selectively, randomly or at regular intervals. Sampling points or quadrats can be distributed along transect continuously, selectively, randomly, or at regular intervals. In the last case this would effectively be the same as a grid pattern.

Photo-documentation

Photographic documentation can range from video or photo-surveys of coastlines or slicks at sea to detailed photographs of quadrats, transects, or individual impacted plant and wildlife. Photo documentation has the advantages that skilled interpretation of data can be done later, remotely and be consistently interpreted. This overcomes problems of shortage of skilled staff and the need to calibrate estimates by different field staff. More accurate calculations of percentage cover and numbers may also be possible.

3.2 Assessment and Sampling of Seabed Sediments

Oil can become incorporated into offshore sediments through natural processes or due to shoreline cleanup methods. If this accumulates to a significant extent then alternative cleanup strategies may be required. This monitoring method is usually only required in shallow waters. Grab Samplers or Drop Corers can be used. The former are suitable for the wider set of sediments and sea conditions. Sample handling is also easier. Sample volume should be consistent between sites and surveys to allow cross comparison.

Prerequisites

- Sampling vessels should be suited for expected weather, water depth and sea states.
- It should be equipped with communication tools, GPS and life preservation equipment with adequate deck place
- Sampling kits: sampling jars, sealing tape, gloves
- Sampling equipment (grab or corer): if biological samples are to be taken samples should be at least 10 cm depth and have a minimum surface area of at least 125 square centimeters.

3.2.1 Monitoring and Methodology

The sample number and the location can be determined by considering the following points:

- Amount of spillage
- Possible contamination area
- Current dynamics

Various grabs that can be used for the sampling:

3.3 Assessment and Monitoring of Mangroves

Level 1- Transect based survey recording mangrove locations, species zones, mangrove condition and identifying pressures. This is quick to do, and is a suitable exercise for capacity building with community groups.

Level 2- Vegetation plots in each zone recording community structure, height and diameter of trees, density of seedlings. Level 2 takes about a day per transect, and is better carried out by project staff, though can be done with community groups assisting.

Level 3- Sedimentation monitoring and litter productivity. These techniques take longer to carry out but can give good information on mangrove health and sedimentation trends.

Degree of Impact

In the centre of each mangrove zone, assess the degree of impact and type for each zone.

- Assess the degree of impact in an area with a 15 m radius around you.
- Impact is assessed on a scale from 0 to 5 where 0 is no impact and 5 is severely impacted as given in **Table 1**.
- It is done by looking up at the forest canopy and records the average height of trees, and assess how many are at that level.

An index of “impact pressure” is recorded within the area with a 15 m radius, or a rectangular section. The impact may be direct, indirect, or both. Records are made in accordance with any activities which are prevalent in the respective area.

Table 1: Recording method for short term impact of oil spill on mangrove ecosystems.

Impact	%Cover Canopy	Example
No Impact	0-10	No oil effects. No interference of oil on roots, leaves, & seeds, etc.
Slight Impact	11-30	Leaves are fairly black (influenced) due to Oil. Pneumatophores are also coated frequently. Some of them regenerate rapidly. It is not likely to produce any type of damage to the mangrove plant.
Moderate Impact	31-50	Leaves & roots become considerably black due to the oil coating. Leaves, trunk, branches, roots are coated with the oil layer. Oil layer becomes thick. Affected part could not recover over period of time.
Slightly High Impact	51-75	Tree parts are evenly black. Leaves, branches, roots, seeds, fruits also affected. Major portion of the mangrove appears to be destructed. It has affect to the productivity of plant.
High Impact	76-95	Only a few trees remain without being affected. Massive parts of mangroves have got affected. Extensive area could not survive. It will definitely affect productivity of mangrove.
Severe Impact	96-100	All mangrove trees have become black. There is no evidence of any greenery. Oil reached at the each and every part of the trees. Chance of survival is very less. Roots also affected.

3.4 Socio-economic Impacts

Methodology

Survey Design : This comprises a survey design dealing with the exact location and the area affected due to the oil spill spread. Congregation of information regarding specific services or products by important first hand information from the inhabitants and local stakeholders was the key to further interpretation. The overall area of oil spill impact is given in **Figure 1**.

Primary Information:

A walk-through survey of all areas and the entire study region is carried out. Primary information was gauged by the means of a detailed questionnaire to the local businessmen, governing body of the villages and other stakeholders. This detailed questionnaire comprised of enquiries regarding the reduction in customers or tourists as well as its impact on the daily

income. Critical questions which were posed when assessing the socioeconomic impact also considered the duration the impact, effects on local economy, support system of fishing and tourism. The other enquiries included the effect on their daily routine, vicinity, employment, population and aesthetics of the area of impact.

Secondary Information:

Secondary information obtained through the reviews of the experts relevant in the particular subject area, research journals, literature, latest released communications, newspapers and other publications in addition to the above.

3.5 Status of the Study

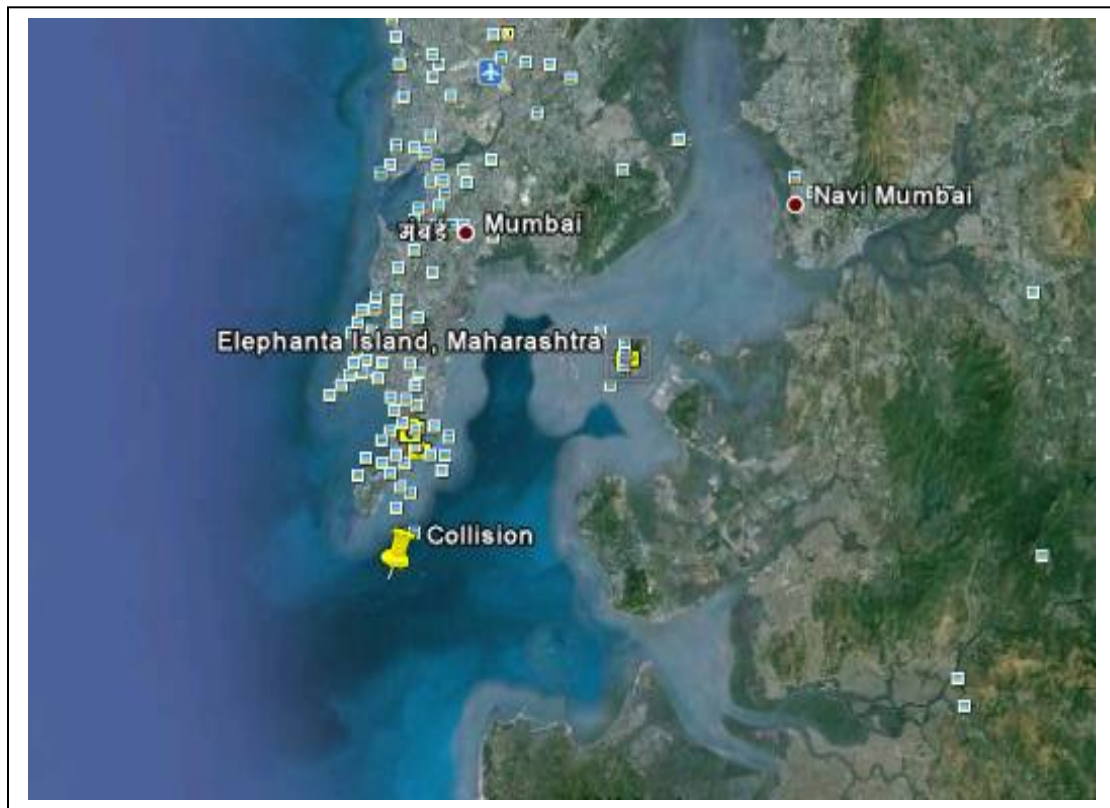


Figure 1 : Overall Area of Oil Spill Impact

The oil spill impact region comprises of coastlines of Mumbai, Thane and Alibag district. Coastlines of islands such as Elephanta and Bucher have also been included. Figure 1 presents the overall region, which has been impacted and mapped during the study.

Sediment Study: The spill impact study on the sediment can be divided into Physical, Chemical and biological impacts. Physical impact can be studied by the visual observation and photo documentation by dividing area into sectors and segments. The detail study of the physical impact can be done by using transect or quadrant method. The parameters like area cover, character of the oil, visual impact on the marine animals etc. can be included in the physical study.

Chemical study of the oil spill can be done by sediment sampling in the impacted area. The chemical impact includes concentration of the oil in the sediment, variation in the substrate type, characterization of the oil etc.

Biological impact of oil spill includes impact of oil on the small marine animals like crabs, mud creepers, bivalve etc. The biological study can be precomplished by visual observation, photo documentation by using different study techniques like transect or quadrant method. The biological impacts also comprise the effect of the oil on the mangroves, which is discussed in detail in separate section. The biological impact assessment needs more understanding in respective area like biodiversity, seasonal variation etc.

The shoreline of the Mumbai, Alibag and Thane district shows variation with respect to sediment type, form and gradient as it result in the difference in the shoreline energy.

Mangrove Study : The oil spill took place during the seeding season of Mangroves. The oil slick has been sighted ashore majorly in the mangroves of Elephanta Island, Vashi creek and some fringes of Mahul- Shewri. Signs of natural recovery were also observed with regeneration of new twigs. In most of the sites, canopy of mangroves is intact and mortality is not apparent. Mangroves are highly susceptible to oil exposure; oiling may kill them within a few weeks to several months. Lighter oils are more acutely toxic to mangroves than are heavier oils. Increased weathering generally lowers oil toxicity. Oil-impacted mangroves may suffer yellowed leaves, defoliation, and tree death. More subtle responses include branching of pneumatophores, germination failure, decreased canopy cover, increased rate of mutation, and increased sensitivity to other stresses. Response techniques that reduce oil contact with mangroves, such as chemical dispersants, reduce the resultant toxicity as well. Natural recovery is the most reliable strategy for mangroves. Tradeoffs include potential increased toxicity to adjacent communities, and increased penetration of dispersed oil to mangrove sediments.

The amount of oil reaching the mangroves and the length of time spilled oil remains near the mangroves are key variables in determining the severity of effect. Mangrove-associated invertebrates and plants recover more quickly from oiling than do the mangroves themselves, because of the longer time for mangroves to reach maturity. Physical mechanisms are the primary means by which oil has adversely affected mangroves. Comparing spill impacts at several mangrove sites indicated that variable effects are related to geomorphology and hydrologic kinetics of the mangrove ecosystem that, in turn, controls whether oil persists in the mangrove habitat. Oiled mangrove forests that are sheltered from wave and current exposure are likely to be more severely affected than well-exposed, “outer fringe” mangrove areas. Full extent of damage to mangroves is not apparent for many months or years after an incident as noted from many case studies. The oil spill impact status in different studied areas is given in following sections.

3.6 Elephanta Island

3.6.1 Sediment

The island is located at 18°57'45.59"N, 72°55'59.49"E and include three villages namely Shet Bandar, Mora Bandar and Raj Bandar having population of about 2000- 2500 (**Table 2**). Oil spill impact can be seen on the island near all three villages. The area at Raj Bandar is severally affected as compare to shoreline at other two villages. The sediment monitoring of the Elephanta Island reveals various shoreline types like sand, Bedrock, boulders, pebbles with slight seaward slope. The sediment is severely affected in the south, east and west direction of the island as compare to it northern site is lesser affected. Various agencies are engaged in the cleaning of different areas. Oil Spill response team (UK) is cleaning the Shet Bandar Jetty and surrounded area with hot water jet (80-90°C). The cleaning operations of the Oil spill response at various sites adding oil to the lower sediment. The private company “Seaworthy Shipping Services” also carrying out manual cleaning of the affected area nearby Raj Bandar jetty. The whole area of the Elephanta has been divided into 21 transects for the assessment of the area for oil spill.

Table 2: Location for Sediment at Elephanta Island

Transect	Geographical position	Type of sediment	% area affected
1	18° 57'30.2" N, 72° 55'35.0" E	Bed rock, sand	70
2	18° 57'32.5" N, 72° 55'33.4" E	Pebbles, Bed rock	60
3	18° 57'34.0" N, 72° 55'31.0" E	Boulders, pebbles	55
4	18° 57'32.7" N, 72° 55'31.9" E	Boulders, Bed rock	50
5	18° 57'33.6" N, 72° 55'31.1" E	Sand, Bed rock	70
6	18° 57'36.4" N, 72° 55'31.3" E	Sand, Pebbles	60
7	18° 57'43.7" N, 72° 55'32.0" E	Sand, Boulders	65
8	18° 57'59.6" N, 72° 55'44.9" E	Sand, Bed rock	60
9	18° 57'59.2" N, 72° 55'46.8" E	Sand, Bed rock	60
10	18° 58'00.6" N, 72° 55'43.2" E	Sand	50
11	18° 58'01.4" N, 72° 55'51.0" E	Sand	0
12	18° 58'01.8" N, 72° 55'51.8" E	Sand	0
13	18° 58'01.7" N, 72° 55'52.5" E	Sand	0
14	18° 58'00.6" N, 72° 55'43.2" E	Sand	20
15	18° 58'02.5" N, 72° 55'54.3" E	Sand, Bed rock	95
16	18° 57'19.7" N, 72° 55'47.6" E	Sand, Bed rock	100
17	18° 57'17.6" N, 72° 55'49.5" E	Sand, Bed rock	85
18	18° 57'15.7" N, 72° 55'52.8" E	Bed rock	80
19	18° 57'13.6" N, 72° 56'00.5" E	Sand, Pebbles	90
20	18° 57'08.6" N, 72° 56'03.7" E	Pebbles, Sand, Boulders	90
21	18° 57'16.2" N, 72° 55'56.1" E	Sand, Boulders	80
22	18° 57'32.8" N, 72° 56'13.4" E	Sandy pebbles	10
23	18° 57'49.0" N, 72° 56'24.2" E	Sandy	00



Oil floating on the surface and on boulders at the main jetty at Shet bandar (16th day)



Affected sediment at sandy area along with the oil deposited compound wall (16th day)



Boulders of the jetty affected with the crude oil (16th day)



**Cleaning operation by oil spill response team UK:
on going cleaning and jetty divided into 10 m transect (40th day)**



Sediment affected with thin oil sheen and tar balls at boulders (40th day)



Cleaning at jetty and compound wall cleaned by oil spill response team (43rd day)



NEERI study: plotting of transect, sediment showing thin sheen of oil with melted tar balls (transect 1) 43rd day



Oil affected pebbles and boulders (transect 2) 43rd day



Transect 3 and 4 showing non affected bedrock and oil deposited boulders (43rd day)



Sediment sampling methods: core sampling and loose sediment sampling



Transect 5 and 6 affected bed rock and thin sheen of oil on the sandy shoreline (43rd day)



Transect 7 affected boulders (43rd day)



Transect 8 cleaning operation from oil spill response causes oil on the sediment and loose sampling method (44th day)



**Transect 9 unaffected bedrock with affected pebbles and
Transect 10 with affected and non affected sandy sediment (44th day)**



Transect 11 to 14 no visual oil impact seen, transact 14 shows thin sheen oil because of the cleaning activity (44th day)



Transect 15: Severely affected by the oil spill, oil deposited on the boulders, pebbles and thick melted, flowing oil can be seen at this site near raj bandar (48th day)



Transect 16 severely affected along with mangroves and grass (48th day)



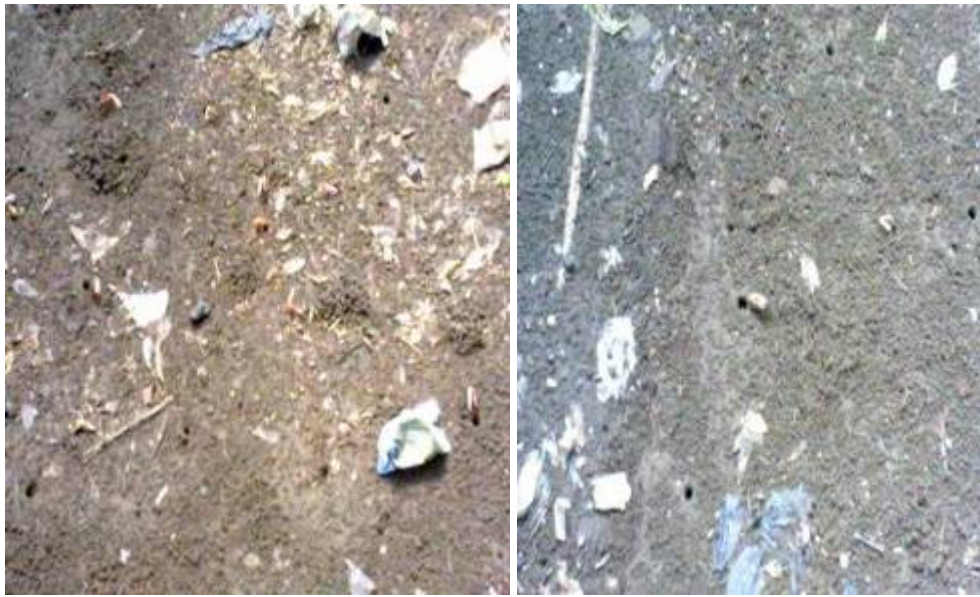
Transect 17 and 18 thin sheen on the sand and affected bedrock (48th day)



Transect 19 and 20 sand and pebbles affected with oil and cleaning activity by private company “seaworthy shipping services” (48th day)



Transect 21 Oil deposited pebbles, floating container and affected boulder with some tea packets (48th day)



Transect 22 and Transect 23: unaffected site at

3.6.2 Mangroves

Amongst all the sites, Elephanta Island mangroves are the most severely affected due to the oil slick. The tides are not strong enough to wash away all the oil. Ecologically sensitive mangrove fringes across the circumference of the island have been affected by oil. In some areas as shown in the pictures regeneration of new leaves has started. The sparse mangrove cover at Mora bandargoan, the north-east of the island is not affected by oil. The beach is also covered with packets of tablets, biscuits, tea bags and other material from the containers. The location of mangroves in different transect is given in **Table 3**.

Table 3 : Location Mangroves at Elephanta Island

Date	Site	Transect No	Latitude	Longitude	% affected
20/09/2010	Elephanta	1	18° 57'30.02 "N	72°55'35.00"E	84
		2	18° 57'30.02 "N	72°55'35.00"E	62
		3	18° 57'34.00 "N	72°55'31.00"E	44
		4	18°57'40.86 "N	72°55'29.53"E	33
		5	18°57'55.88 "N	72°55'30.72"E	37
		6	18°57'53.05 "N	72°55'35.33"E	60
		7	18°57'56.45 "N	72°55'38.32"E	63
21/09/2010	Elephanta	8	18°57'59.06 "N	72°55'44.09"E	70
		9	18°58'10.49 "N	72°55'48.35"E	95
		10	18°58'10.02 "N	72°55'46.54"E	0
25/09/2010	Elephanta	11	18° 58'19.00 "N	72°56'03.00"E	0
		12	18° 57'37.00 "N	72°56'14.00"E	82

Plates of Mangroves at Elephanta Island



Transect 1: Oil effects on mangroves at shetbandar on the 42nd day



Transect 2: Oil damaged debris seen reaching the roots of the inner frontiers of mangroves



Transects 3 and 4 A solitary mangrove species already existing in less density affected due to oil



Transect 6 and 7 Pneumatophores affected completely along with *Aveccinia* mangroves which are present in less density



Transect 8 a) Oil stressed pneumatophores around the base of a huge trunk of mangrove tree entangled with oil licked debris



Transect 8 b) Oil stressed pneumatophores around the base of a huge trunk of mangrove tree entangled with oil licked debris



Transect 9 Impact on various mangrove species due to oil as well as the accident debris coming in the way of circulation of sea water and contributing to further mechanical damages of oiling at the northern periphery of the elephant island





Transect 9 Pneumatophores of mangroves covered by thick oil layer. lenticels in the exposed portions of mangrove roots are highly susceptible to clogging by crude oil. These pictures highlight the pressures on the mangrove roots in the western periphery of the island at shetbandar.



Transect 12 Normal regeneration observed in oil affected mangroves at elephanta on



Quadrant 1 Mangroves affected by oil upto 5 ft at shetbandar



Transect 12 Monkeys scavenging and eating the oil licked biscuits and other debris accumulated at the base of the mangrove fringes at the south-west margins of the island

3.7 Butcher Island

3.7.1 Sediment: The Butcher island is located west of the Elephanta island, with geographic position $18^{\circ}57'35.60''\text{N}$, $72^{\circ}54'11.93''\text{E}$. The island is under control of Mumbai Port Trust and has multiple storage tanks of BPCL. The island has four jetties for the BPCL and other activities. This island is much smaller island as compared to Elephanta island, the location of sediment at different Transects is given in **Table 4**.

Table 4 : Location for Butcher Island Sediment

Transect	Geographical Position	Type of Sediment	Percent Area Affected
1	18°57'39.0" N, 72°54'13.0" E	Bed rock	70
2	18°57'23.0" N, 72°54'20.1" E	Bed rock	65
3	18°57'23.7" N, 72°54'17.6" E	Bed rock, Sand, Pebbles	20
4	18°57'41.0" N, 72°54'13.0" E	Bedrock, Sand	20

Plates of Sediment at Butcher Island



Transect 1 and 2 bedrock partially affected with the oil (48th day)



Transect 3 Melted tar balls on the bedrock and unaffected boulders inside the mangrove belt (48th day)



Transect 4: Bedrock showing algal growth along with melted tar ball (48th day)

3.7.2 Mangroves

Surviving fringe of mangroves at the oiled sites of Butcher Island had fewer and shorter prop roots. The slick has now settled due to the low tide and high tide interventions. Some of the dolphins were reported to be blackened by the officials of MBPT. The mangroves has present all around the island. There was some transects shows density of mangroves. Some of the locations which were studied is given in **Table 5**.

Table : Location Table for Butcher Island Mangroves

Date	Site	Transect no	Latitude	Longitude	% area impacted
25/09/2010	Butcher	13	18° 57'39.00"N	72°54'13.00"E	76
		14	18° 57'23.00"N	72°54'20.10"E	44
		15	18° 57'23.07"N	72°54'17.60"E	28
		16	18°57'48.59 "N	72°54'30.13"E	19

Photos of Butcher Island Mangroves



Transect 1 Right side of the main jetty of Butcher Island (Mumbai Port Trust) with oil affecting the mangrove roots in soft sediments



Transect 2 Container floating into the margins of mangroves that fronted the open sea at the left side of the main jetty of the butcher island



Transect 3 Inner side of dense cover of mangroves with the height of mangrove trees above 20 ft is affected. Few melted tar balls were spotted

3.8 Uran

The geographic position of this village is 18°52'42.45" N, 72°56'26.83"E. Uran has two jetties one is for public use (Mora jetty) and other is under control of navy. It is primarily a fishing village, which has developed into a special economy zone. It has ample industries, namely JNPT, P&O, GTI and other shipping companies. The monitoring and assessment covers area around Uran beach and area around Mora jetty. The overall assessment and monitoring inferred that the area is moderately affected due to oil.

3.8.1 Sediment: The sediment near Uran beach has been affected with lesser density of tarballs (**Table 6**). The sediment type of the area around Mora jetty is flat sandy and rocky (bed rock). This area is covered with mangrove of different species. The dried and melted tar balls were seen in this area. The sandy and rocky area near navy jetty is affected quite considerably along with the mangrove vegetation

Table 6 : Percent Sediment Affected Area at Uran

Transect	Geographical Position	Type of Sediment	% Area Affected
1	18°52'5.70"N, 72°55'17.40"E	Sand, Pebbles	5
2	18°52'14.03"N, 2°55'11.06"E	Sand, Pebbles, Bed rock	5
3	18°52'19.34"N, 72°55'6.47"E	Bed rock, Sand, Pebbles	5
4	18°52'57.79"N, 72°54'41.09"E	Bedrock, Pebbles, Sand	5

Plates of Mangroves Area at Uran



Container carried to the Uran beach, along with the material and tea packets spread all over the coast. (3rd day)



The area near Mora jetty, Uran bedrock is not much affected except the melted tar balls (50th day)



Unaffected area near old navy jetty, sandy and bedrock sediment (51st day)



Unaffected sediment, broken container, rag pickers collecting the plastic and other materials (51st day)

3.8.2 Mangroves

There are two regions specifically observed along Mora jetty and Uran beach. One of the biggest extents of wetland tracts and mangroves in this part of India lie in Uran. The Uran mangroves, about 60 km from Mumbai, is a vast stretch beginning from the northern end of Palm Beach Road in Navi Mumbai, up to Funde village, past the JNPT police Station (**Table 7**). Mangrove cover at Uran was observed to be sparse and visible contamination due to the oil spill was not apparent by the 50th day due to faster natural recovery in this area.

Table 7 : Location of Mangroves at Uran

Date	Site	Transect No	Latitude	Longitude	% area affected
27/09/2010	Uran	17	18°54'37.05"N	72°55'29.60"E	1-2
		18	18°54'37.01"N	72°55'26.30"E	1-2
		19	18°54'28.60"N	72°56'27.20"E	1-2
		20	18°54'10.33"N	72°56'10.24"E	1-2
28/09/2010		21	18°52'59.67"N	72°54'38.45"E	1-2
		22	18°53'02.98"N	72°54'36.97"E	1-2
		23	18°53'09.42"N	72°54'30.79"E	1-2
		24	18°53'15.37"N	72°54'29.34"E	1-2

Plates for Mangroves at Uran - (50th & 51st Day after Oil Spill)



Transect 17-20: The mangroves area near to Mora jetty. There was not seen oil impact on mangroves when surveyed. 50th day after oil spill



Transect 21-24 The mangrove fringes here are not affected by oil when surveyed on the 51st day

The survey results of 51st day indicated that there was little oil impact seen on mangroves. The mangrove area is considerably large, dominated by two species i.e. *Avicennia marina* and *Sonneratia alba*. Both species were found without coating of oil on the various parts of mangroves such as, leaves, pneumatophores, trunk, & fruits. Around some of the mangrove area some tar balls were observed. Many of the tar balls melted due to temperature. As such there was negligible impact seen in the entire area. Fauna was engaged in its daily activities. Birds were seen there such as the Egrets, Cormorants, Seagulls and Crows. Crustaceans like crabs were also found over rocks and sediments. Sparse presence of tar balls were seen around the region.

JNPT: The port is run by the **Jawaharlal Nehru Port Trust**, an organization entrusted with the operations of the large shipping port in Navi Mumbai, India and controlled by the Government of India. The geographic position of the port is 18°56'56.00"N, 72°56'57.32"E. The grab samples have been collected from the area nearby JNPT jetty. Floating containers have been observed near the jetty area.



Boulders near the grounded container at jnpt are unaffected; however, earlier oil layers were found. Most of there were got cleaned by natural action. (63rd day)

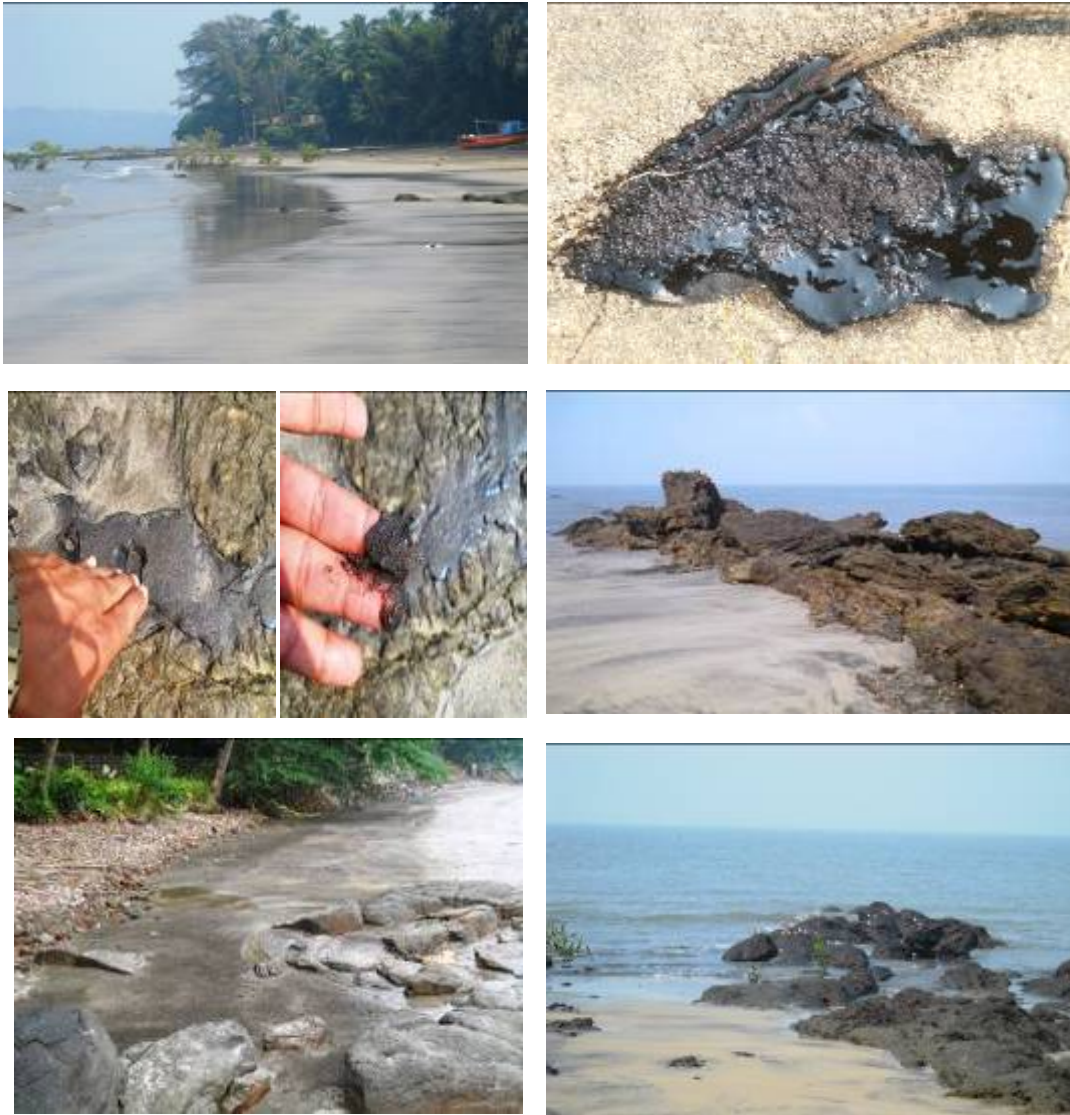
3.9 Mandva

It is a sandy and rocky beach having geographical 18°47'57.61"N, 72°55'56.42"E. It contains approximately 8-10 km coastline. There is a jetty, which is used for locals for transportation purposes. Around the jetty some stalls and shops are present. The area has a sandy beach with some rocky areas near the coasts.

3.9.1 Sediment

The sediment of the beach did not show significant traces of the oil except melted tar balls. Bed rock also had negligible oil cover on it. However, locals have reported that there was some oil layer in the beginning of the oil spill, which significantly receded by the 50th day. At the time of assessment, very few tar balls seen on the beach area.

Plates of Sediment at Mandwa Shoreline



Sandy beach of the mandva and melted tar ball, unaffected bedrocks and sandy sediments (50th day)

3.9.2 Mangroves

The locations were studied for oil impact upon the mangroves in the Mandwa region as given in **Table 8**. Oil impact on mangroves was insignificant. There are beaches on the side of the jetty, so maximum area has been covered by sand. Mangroves are in lesser density and have not been affected significantly.

Table 8 : Location of Mangroves Area at Mandwa

Date	Site	Transect No	Latitude	Longitude	% area affected
28/09/10	Mandva	25	18° 48'18.53"N	72°52'57.74"E	1-2
		26	18° 48'11.17"N	72°53'00.30"E	1-2
		27	18° 48'10.70"N	72°53'05.00"E	1-2
		28	18° 48'10.40"N	72°53'09.70"E	1-2
		29	18° 48'09.90"N	72°53'13.30"E	1-2
		30	18° 48'06.10"N	72°53'17.10"E	1-2
		31	18° 48'01.70"N	72°53'16.10"E	1-2
		32	18° 48'15.00"N	72°53'57.30"E	1-2

Plates of Mangroves at Mandwa After 50th Day Oil Spill



Amongst the 8 transects assessed at Mandva shoreline the moderate cover of mangroves was not significantly affected. tar balls were spotted.50th day after Oil

3.10 Revas

3.10.1 Sediment : The sandy shoreline is with abundance of mangrove vegetation. The area of study is near the jetty area, with the geographical position is 18°49'15.21"N, 72°56'47.58"E. The muddy and sandy sediment in this area did not show significant sign of oil on surface.

Table 9: Location of Mangroves and Sediment Identification at Revas

Date	Site	Transect No	Latitude	Longitude	% area affected
28/09/10	Revas	33	18° 49'16.80"N	72°56'47.60"E	1
		34	18° 47'25.60"N	72°54'38.30"E	1

3.10.2 Mangroves

Large swathes of mangrove stand along both sides of the Revas jetty and also in the creek- lets. The oil slick has not significantly affected the mangrove or mud flats.



Continuous stretches of mangroves are unaffected with intact mudflats and sandy muddy sediment at revas jetty

3.11 Alibaug

Alibaug is located about 15 nautical miles south of Mumbai, at 18°38'29"N 72°52'20"E. The Alibag shore line is mainly sandy in nature. There were few traces of oil on the sediment except back side of the Colaba Fort (Alibaug Fort). The percent affected and mangrove identification area is given in **Table 11 and 12**.

Table 11 : Sediment Percent Affected Area at Alibaug

Transect	Geographical position	Type of sediment	% Area Affected
1	18° 37'55.00"N 2°57'49.90"E	Bed rock, Sandy	20



Unaffected Alibag Beach (3rd Day)



Unaffected Sandy Sediment of the Alibag Beach (50th day)



Affected Sandy and Rocky Sediment: Back Side of the Alibag fort (50th day)

Table 12 : Location for Mangrove Identification at Alibaug

Date	Site	Transect No	Latitude	Longitude	% area affected
28/09/2010	Alibag	35	18°37'59.45"N	72°51'48.09"E	2-3



The mangrove cover at Alibag is not significantly affected by the oil. almost intact epiphytic algae as well as other epibiota are seen.

3.12 Vashi - Thane Creek

3.12.1 Sediment : Both sides of Thane creek have been assessed for the oil spill impact of the area of Bhandup, Kanjur, Vikroli and Airoli area. The muddy sediment in this area is showing very low visual signs of the oil by the 51st day. The creek-lets have abundance of birds like Cranes and Egrets. However, the sediments had shown oil traces during 5th -51st day .

Plates of Sediment Identification at Vashi - Thane Creek



**Thane creek: Bhandup creek, Kanjurmarg –moderately muddy sediment (51st day)
Densely populated habitant species harboring in the rookeries and mudflats**



Thane creek: near Airoli bridge- moderately affected muddy sediment

Thane Creek (Vashi area): The area comprises Vashi chowpatty (sector 8), the mangrove seen this particular area is 50-60 percent affected with oil and showing sign of regeneration by the 51st day of the study. The sandy and muddy sediment in this area has no sign of oil



Moderately affected sandy sediment and affected mangroves near Vashi sector 8 (51st day)

Palm Beach Road, Sarsole Village



Moderately affected bedrock and sandy sediment near Palm beach road (52nd day)

3.12.2 Mangroves

The fragile ecosystem of Vashi mangroves has been ravaged by the oil slick to a considerable extent along the eastern banks of the creek and Palm Beach road banks (**Table 13**). Vashi-Thane creek cover a stretch of dense canopy of mangroves strands with a dominance of *Aveccinia marina* species in the fore-front of eastern banks. Blackening of the mangroves has reduced by 51st day, as compared to the observations made in the first week immediately after the accident took place. Normal flocking of habitant bird species was apparent in the mangrove

rookeries. Mangroves towards the Navi Mumbai area are comparatively more affected than those in the direction of Thane creek. Regeneration of affected mangroves was not significant.

Table 13 : Location Identification for Mangroves at Vashi-Thane Creek

Date	Site	Transect no	Latitude	Longitude	% area affected
29/09/2010	Vashi	36	19°02'21.95"N	72°57'25.60"E	20
		37	19°07'80.60"N	72°58'04.40"E	20
		38	19°08'58.60"N	72°58'34.20"E	19
		39	19°10'00.00"N	72°58'51.00"E	20
		40	19°07'06.04"N	72°59'05.00"E	20
		41	19°06'00.00"N	72°58'51.00"E	30
		42	19°05'05.39"N	72°59'02.00"E	30
		43	19°05'10.87"N	72°59'10.33"E	30
		44	19°04'58.00"N	72°59'80.00"E	30
		45	19°03'48.00"N	72°58'45.00"E	30
		46	19°03'45.10"N	72°59'11.40"E	20
		47	19°03'45.00"N	72°58'48.30"E	30
30/09/2010	Palm beach	48	19°00'56.80"N	73°00'00.70"E	30
		49	19°01'07.70"N	73°00'07.80"E	25
		50	19°07'16.50"N	73°00'07.90"E	25
		51	19°01'16.92"N	73°09'87.00"E	25
		52	19°01'50.90"N	73°00'02.60"E	25
		53	19°02'20.70"N	72°59'54.30"E	25
		54	19°02'49.30"N	72°59'56.00"E	20

Plates of Mangroves at Vashi-Thane Creek Mangroves After 51st, 52nd Day of Oil Spill



Thane Creek : Bhandup Creek, Kanjur – Unaffected Mangroves Area (51st day)



Thane Creek Near Airoli Bridge- Unaffected Mangroves (51st day)



Affected mangroves near Vashi sector 8 (51st day)

Palm Beach Road, Sarsole village



Affected mangroves along area of the Palm Beach road. Near the Sarsole village there was a creek-let which shows the blackish water. There was so many boats which also polluted the region (52nd day)

3.13 Trombay, Mahul and Sewari Area:

It is a hook area of the Thane creek comprising of regions of Trombay, Mahul and Sewari. The seabed sediment samples were collected from this region by grab sampler



Grab sampling for seabed sediment (56th day)

3.13.1 Mangroves: About 15 acres mangroves area between Shewri and Trombay are the part of the study given in **Table 14**.

Table 14: Location for mangroves at Trombay-Shewri

Date	Site	Transect No	Latitude	Longitude	% area affected
04/10/2010	Trombay	55	19°02'51.00"N	72°57'44.00"E	10
		56	19°01'13.00"N	72°56'52.00"E	15
		57	19°00'44.00"N	72°56'11.00"E	10
	Shevari	58	18°59'37.00"N	72°53'80.00"E	20
		59	19°09'05.00"N	72°53'30.10"E	20
		60	19°00'27.00"N	72°53'00.00"E	20
		61	19°08'57.00"N	72°51'45.03"E	10
		62	18°59'48.31"N	72°51'39.31"E	15

Plate of mangroves at Trombay-Shewri After 56th day Oil Spill



A monotype culture of mangroves affected stands along the banks of Mahul – Shewri with birds harboring in the rookeries



Along the Mahul - Shewri area some oil coated seen on mangroves

3.14 Daramtar and Bhal Creek

This creek is situated in south of Uran shoreline and mainly divided into Dharmtar and Bhal creek (Table 16).



Floating container at Bhal creek (57th day)

Table 16: Location of mangroves at Dharamtar creek

Date	Site	Transect no	Latitude	Longitude	% area affected
05/10/2010	Dharamtar	D1	18°48'33.52"N	72°57'11.89"E	2
		D2	18°48'70.01"N	72°58'30.51"E	2
		D3	18°47'00.08"N	72°59'22.92"E	2
		D4	18°46'40.52"N	72°59'43.67"E	2
		D5	18°44'40.58"N	72°59'60.22"E	2
		D6	18°43'50.86"N	73°00'15.29"E	2
		D7	18°48'22.29"N	72°59'41.98"E	2
		D8	18°48'00.41"N	73°03'50.81"E	2
		D9	18°49'36.33"N	72°58'50.74"E	2
		D10	18°51'80.65"N	72°58'41.79"E	2

Plates of mangroves at Dharamtar after 57th Day of Oil Spill



A container barging into the large mudflats of the Dharamtar creek in the upper intertidal region. This region does not show significant oil spill impact by 57th day.

3.15 Nhava-Sheva

Nhava Sheva is the 6th largest port and largest container port in India. The geographical position of Nhava is at 18°57'28.5"N and 72°59'11.45"E and Sheva is at 18°56'05.34"N and 72°57'39.98"E (**Table 17**). Grab samples were collected from the shoreline for oil analysis. There was no visual oil impacted sediment at this site.

Table 17 : Location for Mangroves Identification at Nhava-Sheva

Date	Site	Transect No	Latitude	Longitude	% area affected
09/10/2010	Sheva	63	18°58'20.06"N	72°59'90.85"E	1-2
		64	18°57'47.30"N	72°58'50.20"E	1-2
		65	18°57'46.50"N	72°58'26.80"E	1-2
		66	18°57'52.00"N	72°58'20.50"E	1-2
	Nava	67	18°58'01.20"N	72°58'04.60"E	1-2

Plates of sediment at Nhava-Sheva After 61st days of Oil Spill



Sediment is showing insignificant oil impact (61st day)



3.16 Navy Nagar and Near by Area

The study area includes shoreline of INS Kunjali with geographical position 18°53'42.39"N and 72°48'35.07"E (**Table 18**). The shoreline of the INS Kunjali is mainly covered with bedrock, boulders and pebbles with few area covered with sandy sediment. Different levels of Oil cleaning operation have been carried out at the site.



Oil covered with mud and marine algae (71st day)



Moderately sandy and pebbled shoreline and thin sheen on the sand (71st day)



Affected mangrove trunks along with the sandy sediment and oiled boulders (71st day)

3.16.1 Mangroves

Table 18: Location for mangroves identification near Navy Nagar area

Date	Site	Transect No	Latitude	Longitude	% Area affected
19/10/2010	Navy Nagar	68	18° 53'29.34"N	72°48'27.86"E	88
		69	18° 53'27.18"N	72°48'29.96"E	68
		70	18° 53'30.57"N	72°48'32.15"E	70
		71	18° 53'30.78"N	72°48'39.32"E	75
		72	18° 53'38.12"N	72°48'43.86"E	88

Plates of mangroves area near Navy Nagar



Effects of oil have reached the mangrove surfaces due to intertidal to shallow sub tidal levels at Navy Nagar.

Table 19: Degree of Impact on Mangrove Species at Elephanta

Date	Site	Transect No	Species	Height(ft)	Degree of impact (%)
20/09/2010	Elephanta	1	<i>Avicennia marina</i>	>5	100
				<5	80
		2	<i>Avicennia marina</i>	<20	25
				<15	50
				<10	70
				<5	90
		3	<i>Avicennia marina</i>	<5	100
		4	<i>Avicennia marina</i>	<40	20
				<20	30
				<10	--
20/09/2010	Elephanta	5	<i>No Mangrove</i>		
		6	<i>Avicennia marina</i>	<5	100
		7	<i>Avicennia marina</i>	<20	25
				<5	100
			<i>Sonneratia alba</i>	<15	50
				<10	80
21/09/2010	Elephanta	8	<i>Avicennia marina</i>	<10	70
		9	<i>Avicennia marina</i>	<5	100
			<i>Sonneratia alba</i>	<10	80
		10	<i>Avicennia marina</i>	<25	25
			<i>Sonneratia alba</i>	<25	25
25/09/2010	Elephanta	11	<i>Avicennia marina</i>		10
			<i>Sonneratia alba</i>		10
		12	<i>Avicennia marina</i>		70
			<i>Sonneratia alba</i>		30

(42nd, 43rd, 47th Day After Oil Spill Respectively)

Table 20: Degree of Impact on mangrove Species at Butcher

Date	Site	Transect No	Species	Height(ft)	Degree of impact (%)
25/09/2010	Butcher	13	<i>Avicennia marina</i>	<5	100
			<i>Sonneratia alba</i>	>5	30
		14	<i>Avicennia marina</i>	>20	30
		15	<i>Avicennia marina</i>	>20	10
		16	<i>Avicennia marina</i>	>20	10

(47th Day after Oil Spill)

Table 21: Degree of Impact on mangrove Species at Uran and JNPT

Date	Site	Transect No	Species	Height(ft)	Degree of impact (%)
27/09/2010	Uran	17	<i>Avicennia marina</i>	>20	0
			<i>Sonneratia alba</i>	>20	0
		18	<i>Avicennia marina</i>	>20	0
			<i>Sonneratia alba</i>	>20	0
	JNPT	19	<i>Sonneratia alba</i>		0
	Uran	20	<i>Avicennia marina</i>	>20	0

(49th Day after Oil Spill)**Table 22: Degree of Impact on mangrove Species at Mandva**

Date	Site	Transect No	Species	Height(ft)	Degree of impact (%)
27/09/2010	Mandva	21	<i>Avicennia marina</i>	<5	0
			<i>Sonneratia alba</i>	>5	0
		22	<i>Sonneratia alba</i>	>5	0
		23	<i>Avicennia marina</i>	>5	0
			<i>Sonneratia alba</i>	<5	0
		24	<i>Avicennia marina</i>	<5	0
		25	<i>Avicennia marina</i>	<5	0
		26	<i>Avicennia marina</i>	<5	0
			<i>Sonneratia alba</i>	>10	0
		27	<i>Avicennia marina</i>	>15	0
		28	No Mangroves		

(49th Day after Oil Spill)**Table 23: Degree of Impact on mangrove Species at Uran Beach**

Date	Site	Transect No	Species	Height(ft)	Degree of impact (%)
28/09/2010	Uran beach	29	<i>Avicennia marina</i>	<5	0
			<i>Sonretia alba</i>	<5	0
		30	<i>Avicennia marina</i>	<5	0
			<i>Sonretia alba</i>	<5	0
		31	<i>Avicennia marina</i>	<5	0
			<i>Sonretia alba</i>	<5	0
		32	<i>Avicennia marina</i>	<5	0
			<i>Sonretia alba</i>	<5	0

(50th Day after Oil Spill)

Table 24 : Degree of Impact on mangrove Species at Revas

Date	Site	Transect No	Species	Height(ft)	Degree of impact (%)
28/09/2010	Revas	33	<i>Avicennia marina</i>		0
			<i>Sonneratia alba</i>		0
		34	<i>Avicennia marina</i>	<5	0
			<i>Avicennia marina</i>	>5	0

(50th Days after Oil Spill)**Table 25 : Degree of Impact on mangrove Species at Alibag**

Date	Site	Transect No	Species	Height(ft)	Degree of impact (%)
28/09/2010	Alibag	35	<i>Avicennia marina</i>	>5	0

(50th Day after Oil Spill)**Table 26 : Degree of Impact on mangrove Species at Vashi**

Date	Site	Transect No	Species	Height(ft)	Degree of impact (%)
29/09/2010	Vashi	36	<i>Avicennia marina</i>	<25	0
		37	<i>Avicennia marina</i>	<25	0
		38	<i>Avicennia marina</i>	<25	0
		39	<i>No Mangroves</i>		
		40	<i>Avicennia marina</i>	>25	0
			<i>Sonneratia alba</i>	>20	0
		41	<i>Avicennia marina</i>	>20	10
			<i>Sonneratia alba</i>	>20	10
		42	<i>Avicennia marina</i>	>10	40
			<i>Avicennia marina</i>	<10	60
		43	<i>Avicennia marina</i>	>10	30
			<i>Sonneratia alba</i>	>10	30
		44	<i>Avicennia marina</i>	>10	30
			<i>Sonneratia alba</i>	>10	30
		45	<i>Avicennia marina</i>	<10	80
		46	<i>Avicennia marina</i>	>10	40
		47	<i>Avicennia marina</i>	<10	80

(51th Day after Oil Spill)

Table 27: Degree of Impact on mangrove Species at Palm Beach

Date	Site	Transect No	Species	Height(ft)	Degree of impact (%)
01/10/2010	Palm beach	48	<i>Avicennia marina</i>	>10	20
			<i>Avicennia marina</i>	<10	30
		49	<i>Avicennia marina</i>		
		50	<i>Avicennia marina</i>	>15	20
			<i>Sonneratia alba</i>	>10	30
		51	<i>Avicennia marina</i>	>15	40
			<i>Sonneratia alba</i>	>10	20
		52	<i>Avicennia marina</i>	>20	20
			<i>Sonneratia alba</i>	>10	30
		53	<i>Avicennia marina</i>	>15	30
			<i>Sonneratia alba</i>	>25	20
		54	<i>Avicennia marina</i>	>25	40
			<i>Sonneratia alba</i>	>20	50

(53rd Day after Oil Spill)**Table 28: Degree of Impact on mangrove Species at Trombay**

Date	Site	Transect No	Species	Height(ft)	Degree of impact (%)
04/10/2010	Trombay	55	<i>Avicennia marina</i>	>15	30
		56	<i>Avicennia marina</i>	>5	70
		57	<i>Avicennia marina</i>	>5	60
			<i>Sonneratia alba</i>	>5	40

(56th Day after Oil Spill)**Table 29: Degree of Impact on mangrove Species at Shewri**

Date	Site	Transect No	Species	Height(ft)	Degree of impact (%)
04/10/2010	Shevari	58	<i>Avicennia marina</i>	>5	20
		59	<i>Avicennia marina</i>	<5	50
				>10	30
		60	<i>Avicennia marina</i>	>5	40
			<i>Avicennia marina</i>	>10	30
				>10	30
		61	<i>Avicennia marina</i>	>10	30
				>10	30
		62	<i>Avicennia marina</i>	>10	10
				>10	10

(56th Day after Oil Spill)

Table 30 : Degree of Impact on mangrove Species at Sheva

Date	Site	Transect No	Species	Height(ft)	Degree of impact (%)
9/10/2010	Sheva	63	<i>Avicennia marina</i>		
			<i>Sonneratia alba</i>		
		64	<i>No Mangroves</i>		
		65	<i>Avicennia marina</i>		0
			<i>Sonneratia alba</i>		0
		66	<i>Avicennia marina</i>		0
			<i>Sonneratia alba</i>		0
	Nava	67	<i>Avicennia marina</i>		0
			<i>Sonneratia alba</i>		0

(61ST Day After Oil Spill)**Table 31 : Degree of Impact on mangrove Species at Navy Nagar**

Date	Site	Transect No	Species	Height(ft)	Degree of impact (%)
19/10/2010	Navy Nagar	68	<i>Avicennia marina</i>	<5	100
			<i>Avicennia marina</i>	>5	60
			<i>Sonneratia alba</i>	>10	20
		69	<i>Avicennia marina</i>	>5	50
			<i>Avicennia marina</i>	>10	30
		70	<i>Avicennia marina</i>	>5	100
			<i>Avicennia marina</i>	>10	60
			<i>Sonneratia alba</i>	>10	70
		71	<i>Avicennia marina</i>	>5	90
			<i>Avicennia marina</i>	>10	40
			<i>Sonneratia alba</i>	>10	30
		72	<i>Avicennia marina</i>	<5	100
			<i>Avicennia marina</i>	>5	60
			<i>Avicennia marina</i>	>10	40
			<i>Sonneratia alba</i>	>10	30

(71Th Day After Oil Spill)

Details of quadrat locations and assessment of the quadrat for identification of impact area is given in **Table 32** and **Table 33**.

Table 32 : Details of Quadrat Locations

Quadrat No	Location	Latitude	Longitude	Length (meter)	Width (meter)
QD 1	Elephanta	18° 57'59.60"N	72°55'47.30"E	5	5
QD2	Elephanta	18° 57'58.90"N	72°55'48.50"E	5	5

Table 33 : Assessment of the Quadrates

Quadrat No	Species	Height (ft)	Degree of Impact (%)	No of Sp.
QD 1	<i>Avicennia marina</i>	<5	100	70
	<i>Sonneratia alba</i>	>5	80	4
QD2	<i>Avicennia marina</i>	<5	100	48
	<i>Sonneratia alba</i>	>5	80	7

During the survey at different transect the percent impact of oil spill and the number of species affected of *A. marina* and *S. alba* have been estimated. The total number of affected species in different region is given in **Table 34**.

Table 34 : Trees affected of *A. marina* and *S. alba* at Different Locations

Location	Total No. of <i>A. marina</i> Plants	Total No. of Affected <i>A. marina</i> Plants Trees	% of Affected <i>A. marina</i> sps
Elephanta	337613	66655	20
Butcher	75159	21928	29
Vashi	1930360	427126	22
Trombay	643668	99206	15
Navy Nagar	17021	12202	72

Location	Total No. of <i>S. alba</i> Plants	Total No. of Affected <i>S. alba</i> Plants Trees	% of Affected <i>S. alba</i> sps
Elephanta	9723	2296	24
Butcher	34163	10838	32
Vashi	965365	213604	22
Trombay	20107	3099	15
Navy Nagar	349	235	67

3.17 Fixed Transect Analysis of Oil Spill Impact on Elephanta Island

After oil spill there will always be changes due to the mechanically stressed pressures, tidal currents and weathering of the spilled oil. There has been movement of the thick oil layer and blackening of the shoreline buffers after the oil spillage accident. This oil movement involves processes like dispersion, spreading, evaporation, dissolution emulsification, oxidation and biodegradation. Due to the higher relative density of oil i.e. crude oil, that has been deposited upon the marine substrate such as rocks, sediment etc. and other biota that includes the mangroves, marine animals, fishes, crustaceans, mollusks etc. have been affected to a considerable extent.

To enhance the impact assessment NEERI has carried out a fixed transect analysis of the Elephanta Island site as it has been the worst hit areas by the oil spillage. The analysis of this particular transect would be a simulation for assessment of the overall impacted area. The fixed transect analysis was monitored from over the period of 77 days after the accident near the Mumbai coastline as shown in **Figure 3**. Detailed observations were recorded of visible oiling and blackening of mangroves, sediment, living creatures and other epibiotic assemblages. Photo documentation of the fixed transect reveals the gradients of impact and natural recovery of the mangroves, sediments and rocks over the time period of the study. As can be seen from figure 3, the impact of oil has been reducing at a rapid pace for mangrove affected by the oil spill.

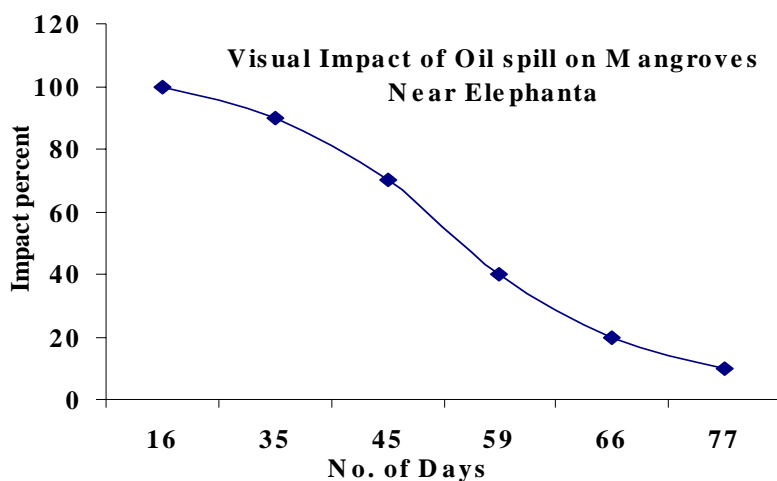


Figure 2 : Fixed Transect Analysis Near Elephanta



(16th day after oil spill)- 23-08-10

The above photograph illustrates the oil impact on the mangroves within 15 days after the accident took place. Blackening of almost the entire mangrove transect can be conspicuously seen. Marine flora and fauna in the transect area as well as its vicinity are worst impacted due to the oil spillage.



The transect plotted for the fixed transect analysis was on the western periphery of the island. (Latitude 18° 57'59.06"N and Longitude 72°55'44.09"E).



Documented during the high tide to compare the changes or physical stresses caused due to the tidal levels and hydrological patterns.



(35th day after oil spill) -13-09-2010



Sheen of oil covering the sediment is seen in some patches of the transect at Shetbandargaon even on the 35th day.



The blackening reducing by the 35th day due to natural recovery.



The mangroves showing aerial breathing root, trunk, leaves affected due to the oil coating. Other epibiota like crabs inspite of being oil licked are thriving in the sediments and crevices of crocks.



(45th day after oil spill) - 23-09-2010

The photograph highlights a dense patch of pneumatophores under a solitary trunk covered with oil on the 45th day though the thick layer subsides.



Lighter gradients of oil seen in the stretch of mangrove as compared to the 35th day.



The sheen of oil in the sediment and bed rock recovering slowly.



(59th day after oil spill) - 7-10-2010

On the 59th day observations distinctly reveal the natural recovery taking place by the reduction in blackening of oil impacted mangroves. Though the oil layer covering on the pneumatophores persists their growth is not highly shunted, new growth is seen to be extending as depicted in this densely networked pneumatophores.



Other epibiotic assemblages like crustaceans, mollusks living with normal movements in the transect area and its vicinity.



(66th day after oil spill) - 14-10-10

The blackening of thick oil layer on the bed rock observed to have reduced on the 66th day. Also oil stressed crabs surviving in these bed rocks were spotted.



Algae observed to be growing after 66th day on the affected transect area indicating the direction towards recovery after undergoing direct and indirect stresses of oil spill



Mortality of mangroves below 2 ft tampered due to oil layers



Degradation of micro and macro habitats in sediments has taken place but existence of burrows of fiddler crabs is apparent.



Over a period of 66 days, the above photographs show further recovery of the mangrove spread. The oil affected mangroves and mud flats getting slowly vegetated with the respective species.



(77th day after oil spill) -25-10-2010

The transect along the western periphery of the island clearly highlights the recovery in process of the stretch of mangrove fringes after 77 days. Mortality of stunted *Aveccinia marina* in a small patch of the transect is spotted.



Stray cattle feeding on the recovered assemblages in the soft sediments were spotted onsite



Distinct epibiotic assemblage and sessile invertebrates on open coast and bed rock are observed after oil stress of 77 days.



Oil in sediments and mudflats has affected percolation and surface run offs, silt loads and stream flows but attachment and activities of epibiota is observed to be taking place due to the recovery process.



Reduction in surface area for attachment of epibiota is observed but foliose algae have been observed in small patches.



After a period of 77 days, regeneration of various mangrove species is conspicuously observed over the oil coated branches. The earlier period shows a thick oil layer on the mangrove leaves which hindered the light reaching the surfaces for essential plant physiological process like photosynthesis and metabolism. The fresh mangrove leaves shall help in recovering from the changes and disturbances in the amount of light reaching the mangrove surfaces. Also post spill, the oil covered significantly less space on the prop roots.

3.18 Work in Progress

The assessment work presented in this report is limited to first interim assessment based on data and information. During the study, many samples have been collected which are being analyzed. Socio-economic and other data sets are also being analyzed for interpretation after complete documentation. The work under progress is given here under which shall be submitted in subsequent reports.

1. Impact mapping of the region

- a. Remote Sensing Satellite data is being analyzed with the ground truth data.
- b. Data representation the map with details of area.
- c. Long term impact assessment
- d. Chemical quality assessment is under progress.
- e. As there are many agencies carrying out assessment at varying time interval and extent of work, it is important to integrate and use the same for interpretation by collating the same with MPCB.
- f. After all the data of other agencies including that of NIO is obtained, these will be overlaid for further analysis.

2. Damage assessment

- a. Water quality related
- b. Fisheries and other resources (other source of data and information to be obtained through MPCB/GOM efforts to get necessary secondary information)

3. Recommendation and Deliverables

- a. The whole mapping of the region shall be divided into various aspects of damages and costs of the restoration. This work shall be submitted in subsequent reports.
- b. The damage costs shall include direct costs (where direct clean up is possible by human efforts) and indirect damage (where natural attenuation is the only way)
 - i. Direct costs of oil spill and indirect costs including intangibles in short term
 - ii. Long term costs can be attempted, however the same will depend upon the availability of data

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