Final Report

DISASTER & RISK MANAGEMENT AND COST BENEFIT ANALYSIS FOR MUMBAI SEWAGE DISPOSAL PROJECT

Sponsor

Municipal Corporation of Greater Mumbai

CSIR-National Environmental Engineering Research Institute (NEERI)

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Chapter 1
Introduction

Mumbai, the most populous city in India, is the capital city of state of Maharashtra. It is the fourth most populous city in the World, with a total population of approximately over 12.5 million (Census of India, 2011).The floating population from the neighbouring urban areas, including Navi Mumbai and Thane, also travel daily to Mumbai for trade and commerce adding to tremendous demand on multiple services.

Municipal Corporation of Greater Mumbai (MCGM) has extended infrastructure facilities such as, water supply, wastewater collection and treatment, solid waste management etc. in order to cover the basic civic needs of the ever-increasing urban population. However, the expectations of the population at large are not totally fulfilled thereby creating a gap between required and provided infrastructural facilities. Due to such inadequacy, there is always a risk of catastrophe to occur.

1.1 Mumbai Sewage Disposal Project (MSDP)

1.1.1 Background

The domestic wastewater collection and treatment and disposal facilities were provided since 1880's and were extended from time to time with growth of the city. The City of Mumbai overcome the problems with less organized facilities, the first sewerage master plan came up in 1979 and the wastewater collection and treatment facilities were further developed. This has established an infrastructure development strategy that included a system of seven zones each operating independently of one another. At present sewerage infrastructure consists of 1,469 km of sewers, 51 pumping stations, preliminary treatment facilities, marine outfalls at three locations, three stage lagoons at one place and single stage lagoons at two places. The decision for the treatment to be adopted in the seventh service was under review and modification.

With the approval of Ministry of Environment & Forest (MoEF), Govt. of India, the implementation of MSDP-I's components under World Bank assisted first sewerage master plan has been completed in 2003 as the expansion of Mumbai Sewage Disposal Project-I called MSDP-I. The construction works under MSDP-I were carried out with Environmental Impact Mitigation and Monitoring Action Plan, based on the clearance issued by MoEF. The activities included plantation of mangroves, appointment of Citizens Advisory Committee (CAC) and monitoring of air and noise quality at construction sites. The World Bank had supervised the project including the mitigation measures by deputing Supervision Missions once in every six months.

The implementation of MSDP-I had helped MCGM in improving the health and environmental conditions in Mumbai by way of disposal of sewage in environmentally accepted manner, reduction in pollution in Thane and Mahim Creek, the protection of ecology etc. The near shore water had improved from aesthetic point of view. The local fishermen had reported increase in the fish yield thereby improving their financial status.

In 1979 MSDP Stage II plan had served the Mumbai well, which was updated by MCGM in 2002 by carrying out Feasibility study of the Master Plan. The second phase of development of wastewater conveyance, treatment and disposal facilities to meet projected flow, wastewater discharge standards and environmental conditions in the year 2025, are considered under the Municipal Sewage Disposal Project (MSDP Stage II) and will be implemented by MCGM in stages.

The rationale of the Mumbai Sewage Disposal Project, Stage II is to provide a healthier and improved environment for people living in city of Mumbai, while minimising the impact of wastewater on the natural environment achieved by increasing the quality and reliability of wastewater collection, treatment and disposal. To achieve this, the Mumbai Sewage Master Plan, Stage II (2002) layed down attainable goals and quantified the expected outcomes for the year 2025. Phase I and Phase II of the 2002 Stage II Master Plan were deemed as “Priority Works”.

1.2 Objective and Scope of MSDP EIA Studies

The overall objective of the project is to bring out the improvements in the collection of non-point discharges and to expand the sewage network that will lead to increased wastewater collection and discharge as point sources. Another objective is to finalize the scheme for Malad Zone to improve the water quality in Malad creek as the effluent from Malad zones of Mumbai will be discharged into the Arabian Sea via outfall at Erangal.

The key features of MSDP Stage II includes Provision of sanitation facilities to entire slum population, improvement of sewerage conveyance system, rehabilitation of sewers, upsizing of sewer and laying new trunks sewers, placing/expansion/ refurbishment of pumping stations and transfer of flows, new sewage pumping stations, rehabilitation/ extension and new wastewater treatment works, disposal of treated effluent through outfalls including recycling, provision of new/ upsize sewer lines, rehabilitation of manholes and transfer schemes i.e. transfer of sewage in pipeline.

Objectives of the MSDP- Stage II Project

The objectives of the Mumbai Sewage Disposal Project Stage-II are:

- To provide a healthier and improved environment for people living in the Mumbai city, while minimizing the impact of wastewater on the natural environmental achieved by increasing the quality and reliability of wastewater collection, treatment and disposal.
- To bring out improvements about health and environment by collection of non-point pollution sources.
- To bring out progressive improvements in the water quality at discharge points with enhanced levels treatment by 2031.
- To expand the sewerage network and collection efficiency that will lead to the gradual increase of flows at influent pumping stations for proper disposal to receiving water bodies and increased volumes of wastewater discharges as point sources.
- To improve the water quality in Malad Creek as the effluent from Versova and Malad zones of Mumbai will be discharged into the Arabian sea via proposed long sea outfall at Erangal after effective collection and treatment.
- With the implementation of MSDP Stage II, there will be new additions/augmentations of sewerage facilities and MCGM will be able to comply prescribed discharge standards by 2025 in all seven zones.
- To carry out mitigation measures to reduce the environmental impacts during construction and operation.
- To assist the success of the Master Plan implementation with Environmental Capacity Building and improve the environment of Mumbai.
- To comply with the state and central pollution control boards norms and other stakeholders for achieving the effluent and receiving water quality standards through the project implementation for both industrial and municipal wastewaters.
- To improve public awareness of the environmental benefits from implementation of project works.

1.3 Scope of the Work

Priority Works -MSDP: Stage II

The proposed MSDP Stage II is to be implemented in elaborate phases (up to year 2031) of which phases 1 and 2 are Priority Stage II works. MCGM intends to undertake MSDP Stage II Priority works for implementation for improvement of environment in and around Mumbai city. The priority works for implementation of various pumping stations, rising mains and modification in wastewater treatment facilities (WWTF) to be undertaken are:

Phase I

1. Expansion of Versova Pumping Station and rising mean to Versova WWTF
2. Versova Effluent Pumping Station (Versova EPS)
3. Transfer from Versova EPS to Erangal Outfall shaft works
4. Malad Pumping Station expansion/upsizing
5. Malad Effluent Pumping Station and transfer to shaft works
6. Modification of Versova lagoons

Phase II

7. Increase the preliminary treatment capacity at Malad WWTF
8. Extension of primary treatment at Colaba WWTF
9. Upgradation of Colaba WWTF to secondary treatment (Phase IV Work)
10. Extension of primary treatment at Worli (Lovegrove) WWTF
11. Upgradation of Bhandup WWTF
12. Upgradation of Ghatkopar WWTF
13. Upgradation of Bandra WWTF
14. Two stage lagoons at Malad
15. Erangal shaft works and outfall
16. Recycle/reuse of treated sewage

1.4 Disaster and Risk Management Study

As a part of EIA study, disaster and risk assessment is an essential component to be evaluated for the proposed activities. The main objective of Disaster and Risk Management for the Mumbai Sewage Disposal project -Stage II is to build MCGM's competency to manage disaster risks and improve legal, institutional arrangements and better coordination to facilitate information exchange among institutions involved in disaster risk management.

The various components of this large system pose different types of potential threats of failure due to natural and manmade disasters. The components include gravity and pressure pipelines, pumping stations, treatment plants and marine sewage outfalls.

The proposed study envisages the details analysis of failure of components at each location due to various threats delineates feasible and cost effective management strategies. The work will encompass study of these systems based on the details provided by the Municipal Corporation.

Causes of potential failure and threats perception, pollutant dispersion in water through mathematical modelling, development of impact scenarios etc. will be evaluated followed by the delineation of disaster and risk management options.

A. Risk of contamination of land/water from releases of pollutants into the ground or sewers, coastal waters or the sea
    a. Assessment of risk due to handling, storage or use of material
    b. Discharge of effluent and related failure of system
    c. Deposition of sediments and its impact due to project design failure and operational failure
    d. Emission in air and risk
    e. Long term risks of the operation
B. Risk of accidents leading to impact on human health or environment
    a. Risk due to explosion, spillage, fires etc.
    b. Any other causes such as flooding etc.
    c. Risk due to natural disasters, earth quake, flood, landslide, and cloudburst.
C. Disaster Management Plan for all the above risk and mitigation plan for undertaking remedial measures which shall include:
    a. Onsite plan
    b. Offsite plan

Chapter 2

Baseline Status on Marine Environmental Water Quality

2.1 Water and Wastewater Scenario

In order to cover the basic civic needs and improve environmental conditions of Mumbai city, Municipal Corporation of Greater Mumbai (MCGM) had implemented MSDP. The detailed EIA was conducted and report as per MoEF format was submitted in 2011. The observations made in three seasonal surveys on the water environment for the coastal zone around Mumbai are summarised below:

- MCGM caters to about 3400 mld water supply from the four major sources, viz. Tansa; at Vaitarna Modak Sagar; Upper Vaitarna and Bhatsa multipurpose schemes. The water quality supplied through organized water distribution scheme is very good.
- Groundwater sources located in the vicinity of the project area were analyzed to study the possible impact of seepage from nearby sewage treatment plants and pumping stations. Total Dissolved Solids (TDS) was higher than desirable limit but well within permissible limit of drinking water standards. Total coliform (TC) and fecal coliform (FC) counts were observed in all the groundwater samples indicating poor microbial quality. These sources are not used for drinking purposes.
- Influents and effluents from the WWTFs were analyzed for physico-chemical, bacteriological and trace metals. Dissolved oxygen (DO) was absent in all the raw and treated wastewater samples. Biochemical oxygen demand (BOD) of influents from the all the 7 WWTFs was in the range 170 to 312 mg/l. Chemical oxygen demand (COD) to BOD ratio indicated good biodegradability of the wastewater. TC and FC were in the range $10^7$to 10^8CFU/100ml at all the WWTFs during all the three seasons. Trace metals concentration in wastewater was within the guidelines stipulated by MPCB and CPCB as general effluent discharge standards.
- Wastewater quality evaluation of drains/nallas draining into west coast and Thane creek indicate the discharge of significant pollutants it terms of organic matter. The samples collected from all selected sources were characterized by turbidity, BOD, COD, ammonical nitrogen (NH_3-N) and total kjeldahl nitrogen (TKN). DO was absent at almost all places in all seasons. Microbial pollution was observed with FC counts in the range $10^3$to 10^8 CFU/100ml. Trace metals in nalla waters joining west coast and Thane creek indicated concentration of Mn and Cr indicating inputs of industrial waste.

2.2 Marine Environment

- Coastal water quality was monitored at 18 identified locations along north-south (12 sections) and east-west directions (at 1, 3, 5 and 7 km sea ward distance), impact zone of marine outfalls during low and high tides. Water quality was evaluated with SW-II standards for pH, Turbidity, BOD, DO and FC. Considering designated best use of coastal water in the study region as bathing, contact water sports, commercial fishing, pH is favourable for all activities.
- Turbidity was exceeded the limit (30 NTU) in limited samples, mostly at 1 and 3 km distance during post monsoon and winter seasons in the impact zone of Malad, Marve and Vasai (Bassin) creeks.
- DO was more than 4 mg/l (SW-II standard) in 99 % samples indicating favourable conditions for commercial fishing and protection of aquatic life. Observations of BOD in coastal water in the zone of Worli and Bandra outfalls and discharge from Malad, Marve and Vasai creeks, indicated marginal pollution during low and high tide in all the three seasons. BOD values more than 3 mg/l were observed more frequently beyond Bandra impact zone upto Vasai creek. Coastal waters were analyzed for important trace metals and no indication of inputs of industrial pollution through co-disposal with the wastewater discharges.
- Microbial quality of coastal water in terms of FC showed non-compliance of SW-II standards at all sampling locations in all the seasons during low and high tide conditions with count 10^{3} to 10^{5}CFU/100ml.
- Water quality at existing outfalls at Bandra, Worli and Colaba and proposed outfall location at Erangal were satisfying SW-II standards for DO and BOD in post monsoon and winter season. BOD exceeded the standard at Bandra, Worli and proposed Erangal outfalls during pre-monsoon. High FC count was observed at all outfalls in three seasons which indicate no improvement in microbial quality.
- Thane creek of Mumbai receives huge quantum of wastes through multiple point and non point discharges. It was observed that pH was within limits of SW-II standards while turbidity exceeded in almost all samples during post-monsoon in both tides and during low tide in pre-monsoon period. DO was less than 4 mg/l up to middle portion of the creek. BOD during low tide indicated non compliance with improvement during high tide. Pre-monsoon water quality was comparatively good among all seasons. Trace metal analysis showed presence of Mn, Fe, Cr and Zn in varying concentrations and indicated inputs of industrial pollution. The creek was heavily polluted with high bacterial densities ranging 104to 105CFU/100ml in the upper narrow region. The outer region with adequate dilution showed some improvement. None of the samples in the Thane creek met the SW-II standard for FC.

- Marve (Manori) creek has number of beaches, amusement parks, Navy Settlement, tourist hotels and small villages inhabited by fishermen. Marve creek receives lateral inflow of waste at multiple locations from residential areas, jetty activities etc. DO was low at all the locations except near the mouth of creek. BOD exceeded SW-II standards in all seasons during high and low tides. Microbial water quality was very poor with FC count in the range of $10^3$to 10^6 CFU/100ml. The metals like Cu, Ni, Pb, Cd and Zn were below detectable limit indicating absence of industrial pollution.
- Malad creek is environmentally worst affected area as the wastewater from Malad and Versova WWTFs and non-point sources through creeklets and nallas. The creek is very shallow and narrow along its whole length. BOD exceeded SW-II standards in all seasons during low and high tides. DO was found to be practically zero during low tide and improves during high tide upto middle portion. Upper narrow portion of the creek still exhibit high BOD and low DO. Microbial water quality was also very poor with FC count in the range of 10^3to10^6 CFU/100ml. Water quality warrants urgent action to improve the ecosystem of the creek.
- Mithi river originates as a confluence of fresh water discharges from Powai and Vihar lakes and flowing through residential and industrial complexes and meets Arabian sea at Mahim creek. Discharges of raw sewage, industrial wastes and garbage are showing sign of threat to marine life. Non compliance of DO, BOD and FC was observed at all locations in all seasons. There is an urgent need to take stringent measures to improve the status of Mithi river for pollution abatement and proper drainage for water carried through storm water drains.
- Beach and seafront water quality was seasonally evaluated on the basis of SW-II standards to find out the impact of unorganized wastewater/sewage releases. Turbidity was high in most of the samples against compliance level (30 NTU). Except Mahim beach, DO on all beaches waters was always more that 4 mg/l. Water quality in terms of BOD was not complying the standards at Breach Candy, Girgaon, Dadar, Mahim and Khar beaches. None of the beaches met standards for FC ranged between $10^2$to 10^6CFU/100ml.
- Sediments provide habitat for many benthic and epibenthic organisms and are the important component of aquatic ecosystems. Trace metals in sediments of west coast and Thane creek were found to be below marine sediment quality standards of Washington State Department of Ecology. The total nitrogen and total phosphorus in west coast samples were in the range of 1400 - 3500 mg/kg and 860 - 1543 mg/kg, respectively. Sediment analysis of Thane creek showed the total nitrogen in the range of 1500 – 5040 mg/kg and total phosphorus in the range of 820-1540 mg/kg.

2.3 Biological Environment

- The aquatic ecosystem of west coast and Thane creek constitutes of phytoplankton, zooplankton, benthos and fishes. The diversity of individuals in the community and overall population is mathematically expressed as SWI. Phytoplankton comprised of 5 groups and 42 genera in west coast and 4 groups and 38 genera in Thane creek in three season analysis. In coastal water, bacillariophyceae and chlorophyceae were represented maximum percent followed by euglenophyceae, dinophyceae and cyanophyceae with SWI ranges 0.81 to 3.74. While in Thane creek, chloryphyceae was the dominant group followed by bacillariophyceae, uglenophyceae, and cyanophyceae with SWI ranges 0.53 to 3.14. SWI indicated low to moderate diversity. Zooplankton comprised of 15 groups of 34 genera in west coast and 11 groups and 25 genera in Thane creek in three season analysis. In coastal water, Copepoda was found to be the dominant group of zooplankton followed by Pisces and Ciliata with SWI ranges 0.1 to 3.18. While in Thane creek, Copepoda was predominant group among eight groups of zooplankton with SWI ranges nil to 2.34. Polychaeta an indicator species of pollution was observed at all sampling locations indicating moderate to heavy pollution by sewage at all the points in Thane creek.
- Benthos represents an important secondary consumer and decomposers of the marine environment. Total 62 species belongs to 11 groups were observed in west coast and 22 species belongs to 10 groups were observed in Thane creek. Benthos belongs to groups foraminifera under micro benthos, while porifera, coelenterate and rotifera of meiobenthos and trbellaria, polychaeta, gastropoda, pelecypoda, amphipoda and pisces from macrobenthos were observed in the sediments.
- Many commercial important fish species were observed namely Elasmobranchas, Eels, Chirocentrus, Sardines, Harpodon, Nehereus (Bombay duck), Pomfrets, Mackerel, Seer fish, Anchoviella, many shell-fishes like Prawn, Shrims, Lobsters and Molluks.

2.4 Socio Economic Environment

- Socio economic survey was carried out at all the project sites based on general information, water supply, wastewater, sanitation and health and project awareness. The project directly or indirectly will have an influence on sea water quality and its impact on fishing business. Therefore, the opinion and views of the fishermen from Versova, Bhandup, Erangal, Colaba and Worli were recorded. Mixed opinion from the locals and residents near Malad, Versova and Erangal area for the implementation of proposed Erangal outfall were received.

Chapter 3
Approach to Risk Assessment

3.1 Introduction

Risk assessment is a tool for analyzing the risk of system failure in a rational way, which allows for the prioritization of resources in reducing said risks consciously and pro-actively. While risk assessment has been commonly used in a wide variety of process / technical industries in recent years, it has yet to find its way into the sewage sector, despite these methods appearing well suited to operational and planning type goals.

Safely drainage of sewage treatment works and storm water through storm water drains is one of the major tasks of sewerage system. Inherited sewer and wastewater systems suffer from insufficient capacity due to continuous urbanization, construction flaws and pipe deterioration. Consequences are structural failures, local floods, surface erosion, and hydraulic and chemical stress.

3.2 Study Area and Components of WWTF Under Consideration

The study area consists of 7 zones viz. Colaba, Bandra, Worli, Versova, Malad, Bhandup and Ghatkopar. There are 51 pumping stations in these seven zones. The study involves risk assessment scenarios for the pumping stations and treatment works for the process and operational risk.

Description of components for Sewerage System:

Pumping Stations: The sewage pumping station consists of screens, dry well and wet well, pumps, piping main fitted with discharge valves and lines.

Screens: The sewage from the various zones is collected by gravity at the respective pumping station through sewer lines. It is received at the inlet chamber or wet well prior to the bar screen which provide quiescent condition before its entry. The screen chambers with a mechanically raked screen are provided to remove large solid materials and plastics from sewage before pumping to protect blockage or damage of the pumps from solid materials, plastics and fabric.

Dry and Wet Well: The wet well is divided into two compartments to allow maintenance without total shutdown. An isolation gate is provided in the partition wall between two wet wells to allow flexibility of operation.

Pumps: Wastewater pumps are designed to handle solids below 100 mm diameter without clogging. Sewage then shall be pumped by submersible pumps into a common outlet channel which joins to WWTF through under gravity pipeline. Adequate gates shall be provided to isolate any of the screen chambers or/and wet wells. In some of the pumping stations, pumps will start and stop automatically based on level in the wet well.

Knife Gate Valve and Check Valves: All the valves on suction and discharge lines shall be of knife gate type and installed with a flange adaptor for ease of installation and removal for maintenance. The valve is operated by electric actuator. Check valves installed on the delivery pipe between the pump and gate valve reduce the possibility of water hammer throughout the system by controlling valve opening and closing speeds so the operation does not cause pressure surges in either direction. The operation of check valve is independent of flows.

Pipelines: Suction and discharge pipes are normally ductile iron (DI). Each discharge line starting from the pump and connecting to the main channel is DI double flange type. The velocity through the discharge pipe shall not exceed 3 m/sec. The type, diameter and length of the pump discharge and force main piping are predetermined while designing. Pump stations generally include all piping through the last valve connected to the pump station end of the force main. Common pipe materials are stainless steel, ductile and PVC.

Liquid Level Sensors: One or more liquid level sensors suspended in the wet well report the fluid level. This data is used by the pump station controller to turn pumps on or off and, in the event of a problem, to turn on alarms and transmit alarm data. The type of sensors used is determined by customer preference or by the controller chosen for the pump station.

Flow Calculating & Metering : An easy and inexpensive way to accomplish Flow Calculating & Metering to measure the volume of fluid being pumped is by calculating the flow by multiplying the volume of water pumped with each pump start by the number of pump starts. An electromagnetic flow meter can be located in the force main. Transmission of flow data to a remote computer is also available.

Control Panel & Electrical Power : Typically, the electrical controls of the pump station are located in a control panel within a weatherproof enclosure. Various devices supply power to the pumps, control the pumps, receive operational and fault data from sensors within the pumps and the wet well, report elapsed operational time for each pump and report operational status and alarm conditions both locally and to remote sites through telephone circuits, radio transmissions and other means.

Components of WWTF: The treatment facilities for domestic waste water provided at Mumbai are preliminary treatment which includes bar screens and grit removal, and then either marine outfall system or aerated lagoons. The details are presented in the **Table 3.1**.

Table 3.1: WWTF in Mumbai

Service Zone	Organised Waste Water Flow (MLD)*	Method of Disposal
Colaba	35	1.1 km Marine Outfall
Worli	393	3.2 km Marine Outfall
Bandra	473	3.2 km Marine Outfall
Ghatkopar	120	Aerated Lagoon
Bhandup	121	Aerated Lagoon
Versova	190	Aerated Lagoon
Malad	101	Marine outfall (Proposed)

** October 2006 Source CEIA MSDP Stage II, Vol I, page 1.10*

- Marine outfall system consists of effluent pumping stations, tunnel and diffusers with multiple risers and ports. Once the marine outfall is operational, it is cumbersome to find its functional and operational behavior in coastal region. Any breakage of diffuser will make compulsory closure of the system and by pass of the preliminary treated WW in the near shore region has to be adopted which will result in non compliance of sea water quality standards.
- Aerated lagoon consists of the constructed tank either single cell or three cell, which receives preliminary treated waste water after grit chamber. Mechanical surface aerators are provided for effective aeration. The outlet of the Aerated lagoon joins the receiving water body. Other than aerators there is no mechanical part in the aerated lagoon system. Adequate stand-by aerators are provided in case of the failure of some and hence there will not be any significant risk in operation of the system.

  Under proposed modification scheme of outfalls, activated sludge process and advance chemical treatment is being incorporated to partial flow to improve the effluent water quality in the coastal region.

3.3 Methodology of Risk Assessment

A risk assessment study helps to determine the appropriate conditions to mitigate environmental risk in case of the failure of the system. At pumping stations, such conditions could set requirements for overall pump capacity, stand-by pumps, back-up generators, on-site storage capacity, alarm systems and telemetry. A risk assessment should be undertaken to determine whether the site is an appropriate existing location and for the proposed development and to set appropriate conditions to mitigate the risk to the environment. There will be fewer options available for mitigating risk with existing pump stations, especially those servicing low-lying or flood-prone areas.

A sewage pumping station (or lift station) is a facility in the sewerage system that mechanically lifts sewage to a higher level to assist the flow of the sewage from its origin to the sewage treatment plant. A large sewage pumping station poses a significant risk to the environment where a system failure or blockage of the flow results in sewage being released. These overflows can occur under both dry and wet weather conditions due to a wide variety of causes. Dry weather overflows create a lower risk to the receiving environment than wet weather overflows because of the diluting effects of flood or storm water.

Historically, development permit conditions for the discharge to the environment of untreated sewage from pump stations and overflow structures may have been explicitly authorized under defined circumstances such as:

- excessive rainfall
- power failure
- accidental damage to the pump station and/or additional equipment
- Other emergency.

The administering authority recognizes that managing complex and large sewerage systems presents substantial challenges. In many cases the sewerage assets vary in performance according to age, quality of materials and the design standards of the time.

3.4 Risk Due to Spillage and Overflow Incidents

In managing sewage pumping stations and other overflow structures in sewage transfer networks, the administering authority should evaluate the likely essential elements for investigating incidents that result in environmental harm. Due to the diversity in size, scale and location of operations, it is not possible to provide a 'one size fits all' solution to the management of overflows for operators. The hazards identified in the wet well operations are shown in **Table 3.2**.

Table 3.2: Expected Hazards and Its Consequences in the Wet Well Operations at Pumping Stations

Source	Key Hazard	Contributing Factors	Consequences
Wet well, Treatment system and disposal area	Release of contaminants due to 'failure' of Onsite wastewater treatment system	1. Soil 2. Environmental Sensitivity 3. Flooding 4. Topography 5. Loading rates 6. Operation and maintenance practices	1. Soil contamination. 2. Surface water logging. 3. Surface water contamination. 4. Machinery damages. 5. Electrical damage. 6. Property damage.
Surrounding Soil	Inability to renovate effluent and prevent contaminants from reaching groundwater and/or surface water	1. Soil Type 2. Depth of soil horizons 3. Physical characteristics 4. Chemical characteristics 5. Water table depth	1. Deposit of harmful chemicals in bottom sediment causing degradation of vegetation and soil. 2. Higher concentration of toxic metals penetrating and making the soil unfit for crop cultivation.
Public Health	Contamination of water/surrounding environment such that a considerable health risk is evident due to the release of contaminant (namely pathogens) which have an impact on human health	1. Surface exposure 2. Water supply (ground/surface) 3. Aerosols 4. Pests (mosquitoes etc.)	1. Contaminated water causing spread of disease. 2. Flooding cause injuries such as Sprains, strains, etc. 3. Microbial pathogens introduced into groundwater can threaten public health. 4. Sewage can introduce pesticides, other chemicals, into fresh water.
Environmental	Release of contaminants into receiving ground/surface waters causing environmental degradation (such as eutrophication) causing unsuitable environment	1. Surface runoff 2. Ground water discharge 3. Flooding 4. Water table	1. Affect river ecosystems. 2. Economic damage. 3. Rise of certain bacteria causing short/long term illness. 4. Too warm/cool sewage temperatures can disturb the aquatic life. 5. Significant odour problems.

3.5 Risk Due to Failure of Pumps

The consequences occurred in the event of hydraulic failure of pumps at sewage pumping stations are reported in **Table 3.3** below.

Table 3.3: Failure Scenarios Related to Sewage Pumps

Failure Scenario	Consequences
Hydraulic Failure of pumps	• Sewage ponding on ground surface near subsurface system or leakage on slopes • Sewage pipe blockage and backup into pipes and fixtures
Groundwater and surface water contamination with chemical pollutants	• Elevated nitrate levels in drinking water sources; taste or odour problems in drinking water caused by untreated, poorly treated, or partially treated wastewater; presence of toxic substances (e.g., solvents, cleaners) in water source • Algal blooms, high aquatic plant productivity, low dissolved oxygen concentrations in nearby freshwater and marine water bodies.
Microbial contamination of ground and surface water	• Shellfish bed bacterial contamination; recreational areas contaminated due to high bacterial levels; contamination of down gradient drinking water wells with fecal bacteria or viruses.

3.6 Risk due to Flooding/ Overflow/Spillage

The risk due to flooding in the area nearby pumping stations has severe impact on the pumping stations. The risk due to flooding has effect on environment as well health. The risk of water contamination due to flooding is shown in **Table 3.4**.

Table 3.4: Flooding Risk - Concentrations Threshold Values used for Risk Assessment

Issue	Parameter	Response	Guideline values# (thresholds)
Environmental	NO_3-N	General fresh Water Quality	10 mg/L
		Eutrophication*	≤ 40 µg/L- Freshwater Rivers ≤ 15 µg/L- Estuaries
	PO_4^{3} –P	General Water Quality	No Guidelines
		Eutrophication*	≤ 50 µg/L- Freshwater Rivers ≤ 30 µg/L- Estuaries
Public Health	E. *coli*	Drinking water	0 cfu/100 mL
		Primary Contact (recreation, swimming)	≤ 150 cfu/100 mL
		Secondary Contact Irrigation, boating	≤ 1000 cfu/mL
	F.coli	For Bathing, Contact Water Sports and Commercial Fishing	100/100 ml (MPN)@
	NO_3-N	Drinking (ingestion)	10mg/L

* Indicated values are general guidelines for river WQ standards by CPCB and MPCB
#as per BIS 10500 -2012 for drinking, @SW II standards for marine environment

3.7 Risk Rating Analysis at Pumping Stations

Table 3.5 shows the risk rating analysis at the pumping station. The risk analysis potential of each activity at the pumping station is analyzed for the potential risk, its consequences in terms of potential injury, person at risk and preventive action to avoid the incidents. Based on the severity of the risk the rating of risk is categorized in the three categories 'High, Medium and Low'.

Table 3.5: Risk Assessment of Pumping Stations

Sr. No.	Activity	Potential Injury Hazard	Persons at Risk	Risk Rating	Action
1	Operations at Bar screen	Engulfment manual handling of screens, weight of screens	Operators Adjacent personnel	Medium	Preventing engulfment, Restricted areas, Correctly fitted (particularly moving guards), Guarding of screen
2	Operations in Dry well	Falling of worker into well, short circuit of electric cables	Operators	High	Proper guards, fire fighting equipment's in the each level of well
3	Operations at wet well	Sewage Overflow	Operators	High	Proper safety arrangements
4	Delivery of equipment	Vehicle reversing	Adjacent personnel	Medium	Ensure vehicles reverse under supervision
5	Off-loading of equipment	Failure of lifting equipment. Failure of lifting lugs or straps. Overhead power lines.	Operator Adjacent personnel	Medium	Ensure only qualified personnel use equipment. Check lifting equipment. Ensure lifting unit does not operate over any area where personnel are present. Prevent unauthorized personnel from entering the risk area.
6	Working in confined space (where applicable)	Asphyxiation	Installation personnel	High	Ensure personnel are trained for confined space working. Ensure gas detector is present and operational at all times.

Low Risk: Very unlikely, consequences minor, normal precautions.
Medium Risk: Likely if extra precautions are not employed, consequences possibly serious, take special action.
High Risk: High probability if extra precautions are not taken, consequences possibly very serious, take special action.

Table 3.5 (Contd..) : Risk Assessment of Pumping Stations

Sr. No.	Activity	Potential Injury Hazard	Persons at Risk	Risk Rating	Action
7	Installation of mechanical & electrical equipment	Failure of lifting equipment. Trailing power supply cables.	Installation personnel. Adjacent personnel.	Medium	Check lifting equipment. Ensure PPE is worn. Ensure power supply cables are routed in a safe manner. Prevent unauthorized personnel from entering the risk area.
8	Working over open tanks.	Falling	Installation personnel. Adjacent personnel.	High	Ensure open holes are cordoned off. Do not carry out any work unaccompanied.
9	Installation of electrical cables. Installation of earth bonding	Exposure to live electrical equipment.	Installation personnel	Low	Ensure power supply is disconnected. Prevent unauthorized personnel from entering the risk area.
10	Inspection & testing of: • Electrical controls. • Electrical operation. • Safety devices • Integrity of earth.	Exposure to live electrical equipment	Test personnel	Medium	Ensure only trained personnel carry out this work. Ensure RCCD safety devices are working properly. Take precaution when testing live circuits.
11	Commissioning (foul water pump stations only)	Sewage spillage	Commissioning personnel Adjacent personnel	High	Ensure any special medical treatment is available. Prevent unauthorized personnel from entering the risk area.

Low Risk: Very unlikely, consequences minor, normal precautions.
Medium Risk: Likely if extra precautions are not employed, consequences possibly serious, take special action.
High Risk: High probability if extra precautions are not taken, consequences possibly very serious, take special action.

3.8 Risks at WWTF

The basic risk in a WWTF with marine outfalls and aerated lagoons will incorporate the failure of mechanical parts essentially the pumping systems for influent and effluents which ultimately will lead to flooding, spillage of the liquid waste with lots of microorganisms causing diseases, generating odour due to presence of organic matter. The major issues are already covered in risk assessment and management for pumping stations. The spread of major contaminants and its impacts are elaborated in the **Table 3.6**.

Table 3.6 : Major Contaminants of Municipal Sewage, Their Impact on the Environment and the Gross Parameter to Quantify the Degree of Contamination

(Adopted from : Veenstra, 2000)

Contaminant	Impact on the Environment	Gross Parameter
Suspended Solids	Suspended Solids increase the turbidity of water, reducing the available light for light dependent organisms like seaweeds, sea grasses and corals. After sedimentation suspended solids can cover the benthic species.	TSS (Total suspended particles
Biodegradable organics	Increased biochemical oxygen demand (BOD) can result in anaerobic conditions which lead to fish kills and bad smell (H_2S,NH_3)	BOD(Biochemical oxygen demand)
Nutrients	Although essential for primary production, an excess of nutrients will result in eutrophication. Eutrophication will stimulate the growth of algae, resulting in strong oxygen production daytime. Respiration during the night and degradation of dead algae will lead to anaerobic conditions (fish kills). Eutrophication also stimulates the growth of nuisance and toxic algae (cyanobacteria red tides). Eutrophication triggers the dieback of coral reefs and sea grasses	N (Kjeldahl Nitrogen) and P (Total phosphorous)
Toxic compounds	Can concentrate in shell fish and fish tissues, resulting in unacceptable high concentrations for consumers (e.g. mercury pollution) Can interfere with microbiological processes in sewage treatment plants.	Activity tests of indicator organisms
Pathogens	Water related diseases (e.g. gastro intestinal, typhoid, shigellosis, hepatitis, and cholera) are among the main health concerns in the world. Can directly affect humans by causing illness and possible death. Often contamination through contact with water or via food (e.g. via irrigated agriculture, or via fish /shellfish)	Bacteria (Fecal coliforms), viruses and worm eggs

Source: Improving Municipal Wastewater Management in Coastal Cities: Training Manual. UNEP 2004

3.9 Spillage Scenario for Pumping Station

The spillage scenario at the pumping station during spillage or flooding events is worked out based on the levels contours at the various pumping stations. The indicative pumping station one out of seven different zones have been marked with three concentric circles around it at a distance of 50 m, 100 m and 200 m which shows the elevation level marked to the direction of east, west, north and south on each circle respectively. The direction of water flow in the event of disaster occurs in pumping station is indicated with arrow.

3.9.1 Colaba Pumping Station (Zone 1)

At the time of disaster the water will spill out in South-East direction as the elevation level is declining towered South-East in contrast to other directions **(Figure 3.1)**

3.9.2 Lovegrove Pumping Station (Zone 2)

At the time of disaster the water will spill out in South-West direction as the elevation level is declining towered South-West in contrast to other directions **(Figure 3.2)**.

3.9.3 Bandra Pumping Station (Zone 3)

At the time of disaster the water will spill out in South-West direction as the elevation level is declining towered South-West in contrast to other directions **(Figure 3.3)**.

3.9.4 Versova Pumping Station (Zone 4)

At the time of disaster the water will spill out in North-West direction as the elevation level is declining towered North-West in contrast to other directions **(Figure 3.4)**.

3.9.5 Malad Pumping Station (Zone 5)

At the time of disaster the water will spill out in North-West direction as the elevation level is declining towered North-West in contrast to other directions **(Figure 3.5)**.

3.9.6 Bhandup Pumping Station (Zone 6)

At the time of disaster the water will spill out in West direction as the elevation level is declining towered West in contrast to other directions **(Figure 3.6)**.

3.9.7 Ghatkopar Pumping Station (Zone 7)

At the time of disaster the water will spill out in North direction as the elevation level is declining towered North direction in contrast to other directions **(Figure 3.7)**.

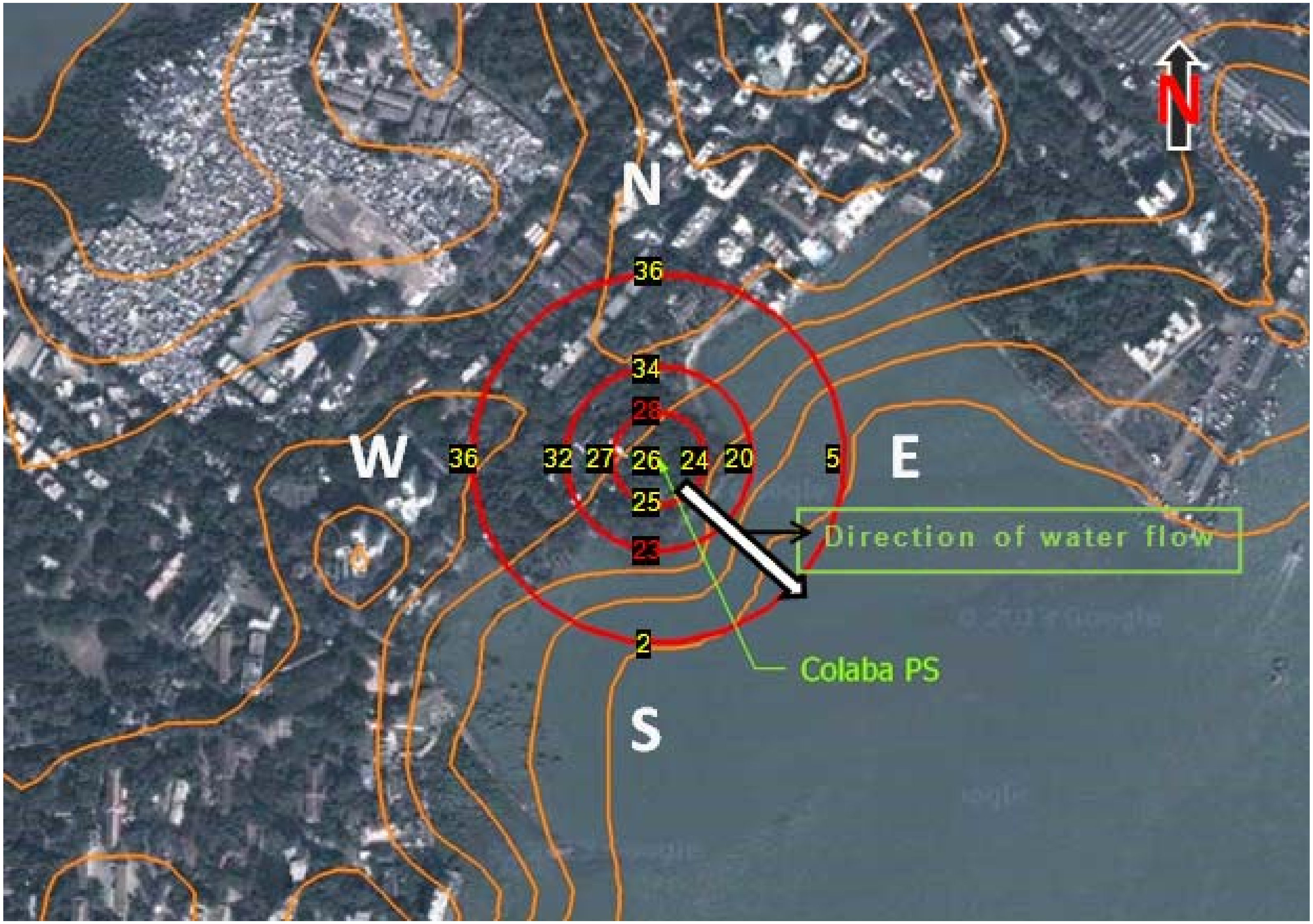

Figure 3.1 : Direction of Spillage at Colaba Pumping Station

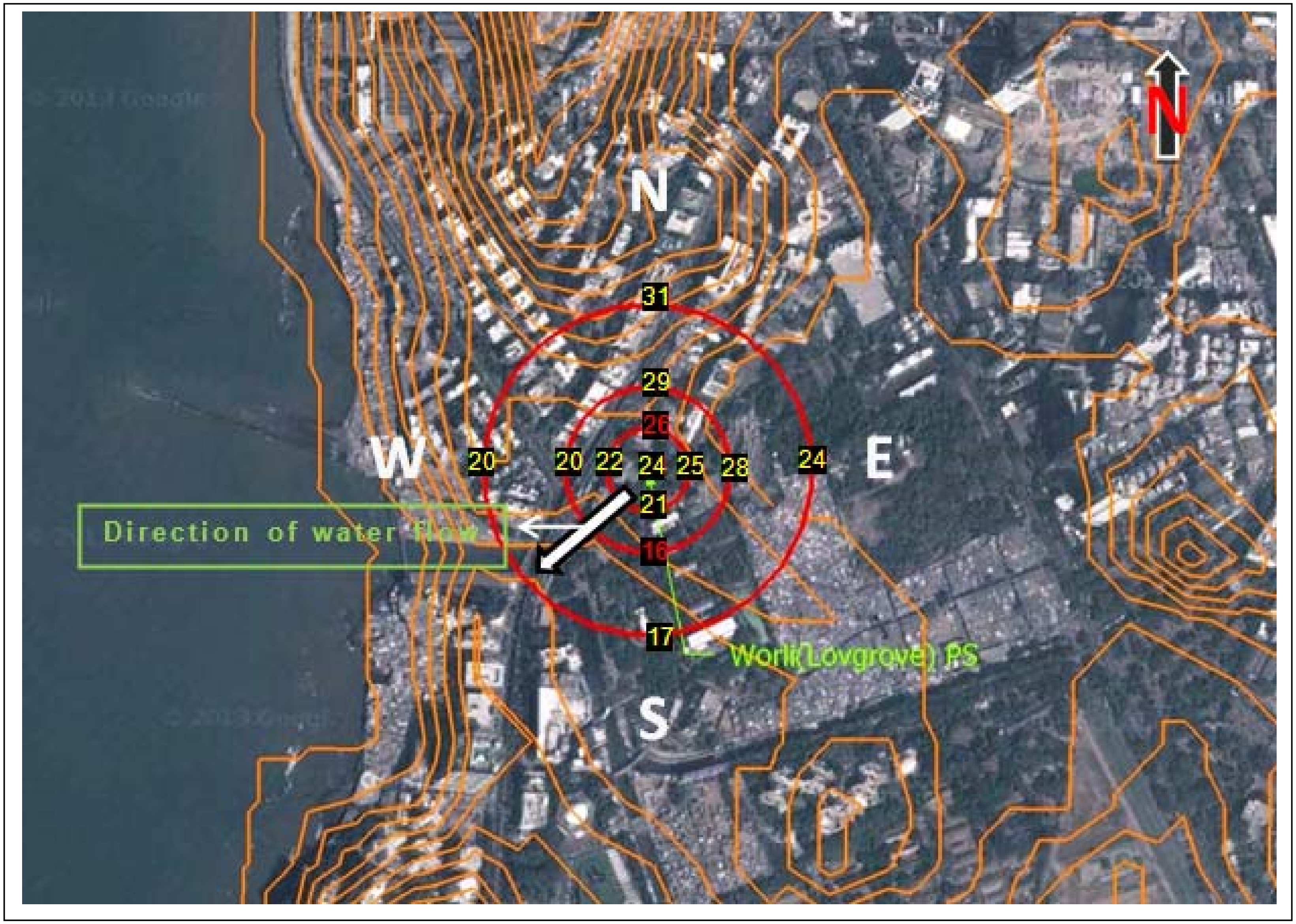

Figure 3.2 : Direction of Spillage at Lovegrove Pumping Station

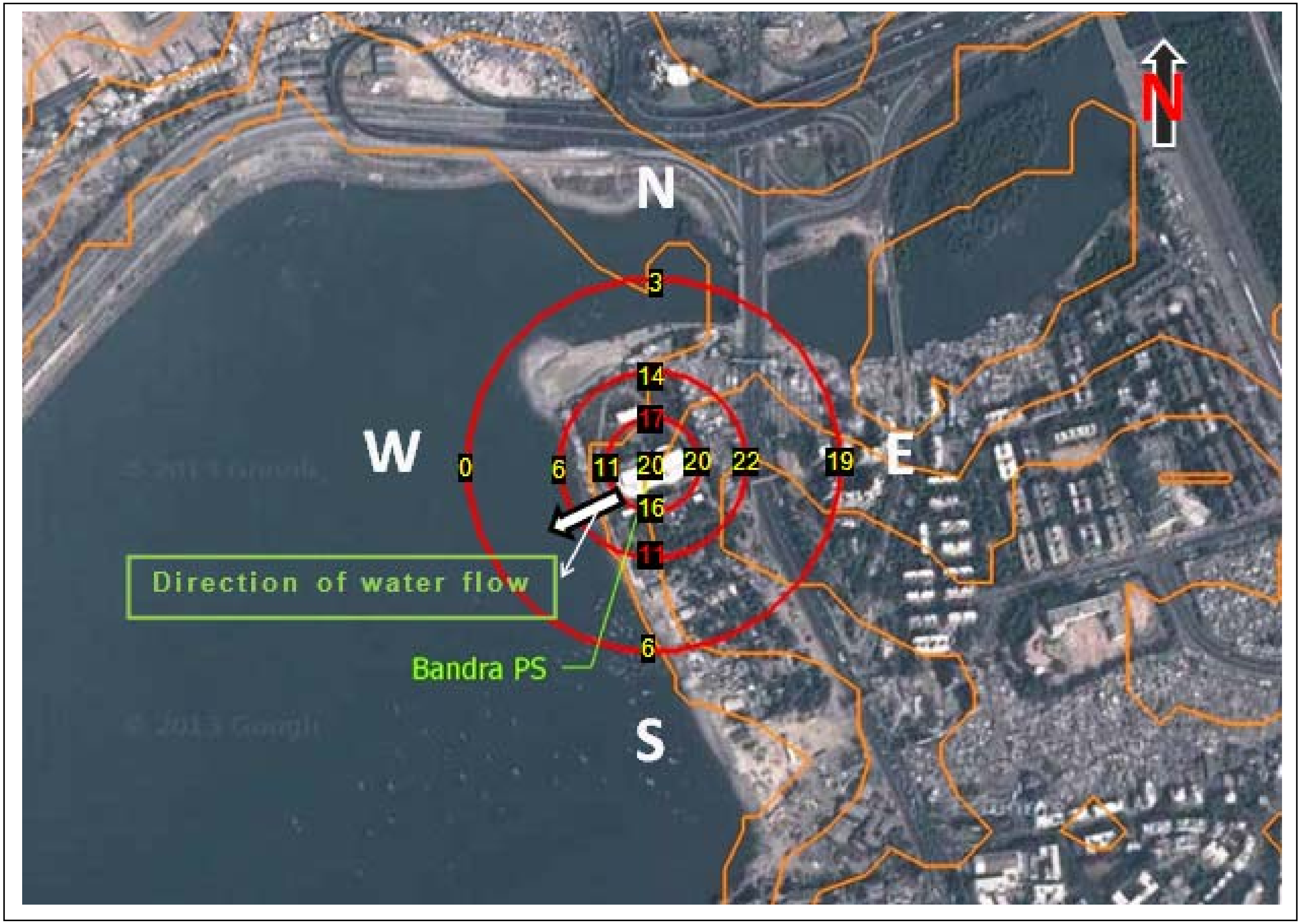

Figure 3.3 : Direction of Spillage at Bandra Pumping Station

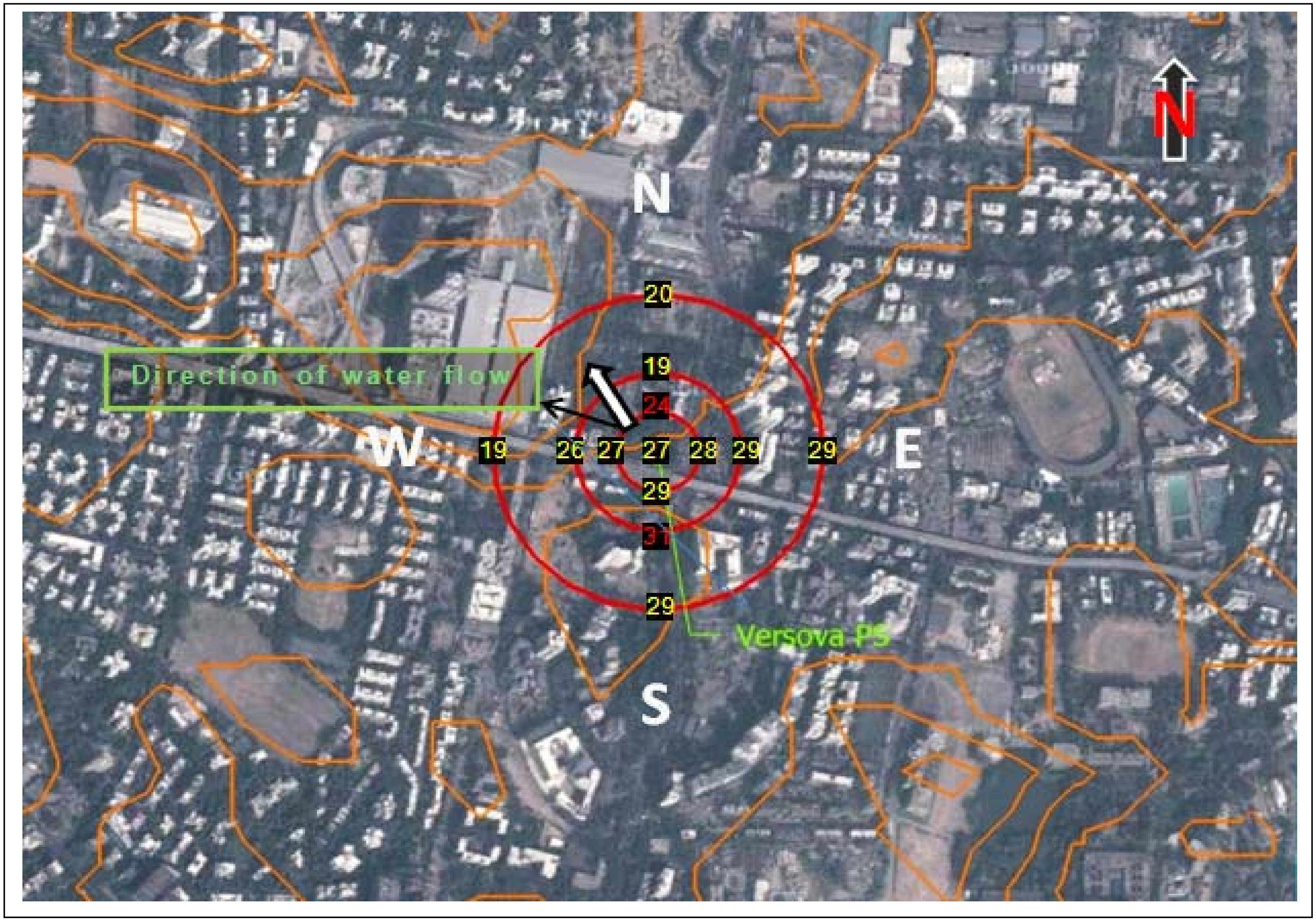

Figure 3.4 : Direction of Spillage at Versova Pumping Station

Figure 3.5 : Direction of Spillage at Malad Pumping Station

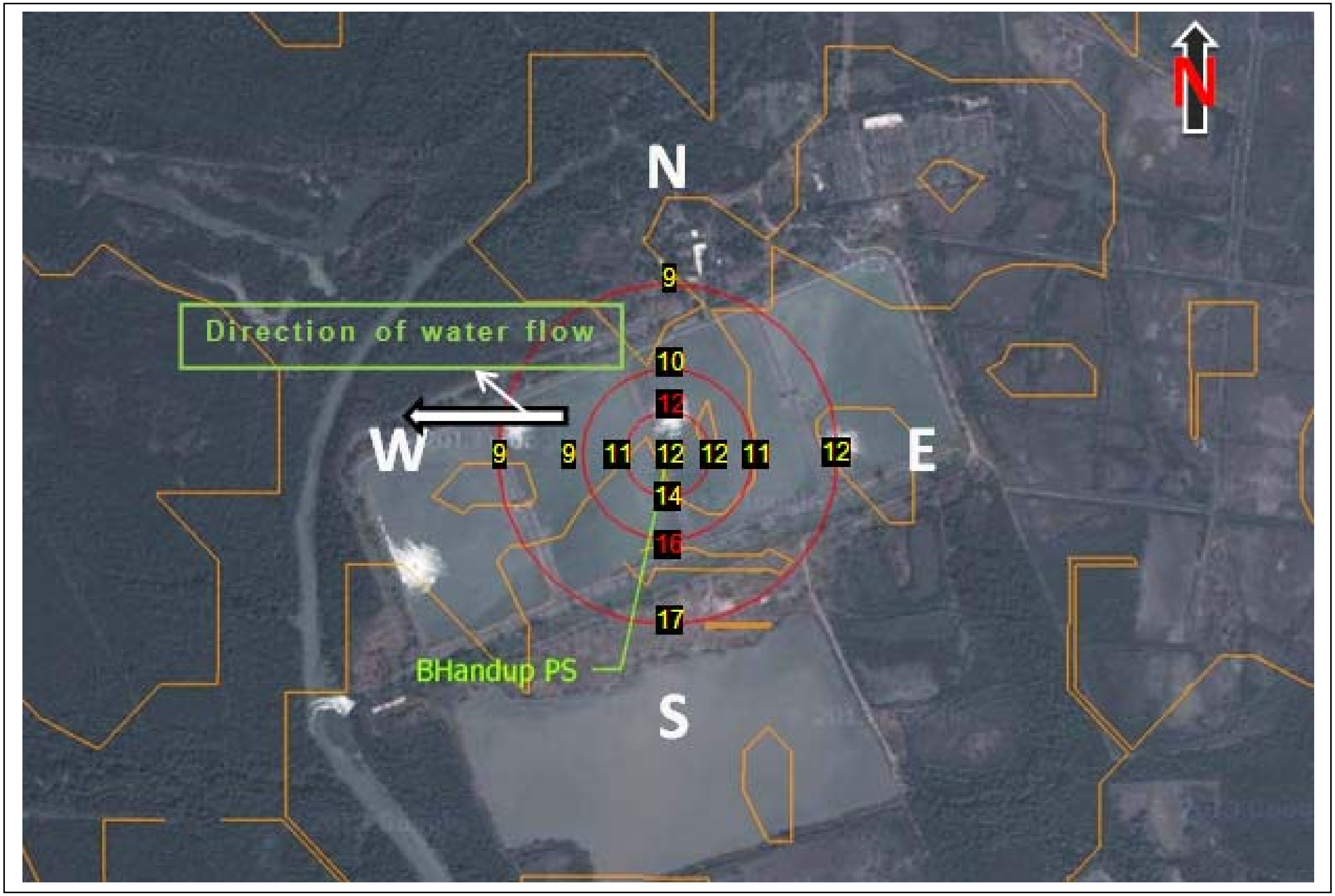

Figure 3.6 : Direction of Spillage at Bhandup Pumping Station

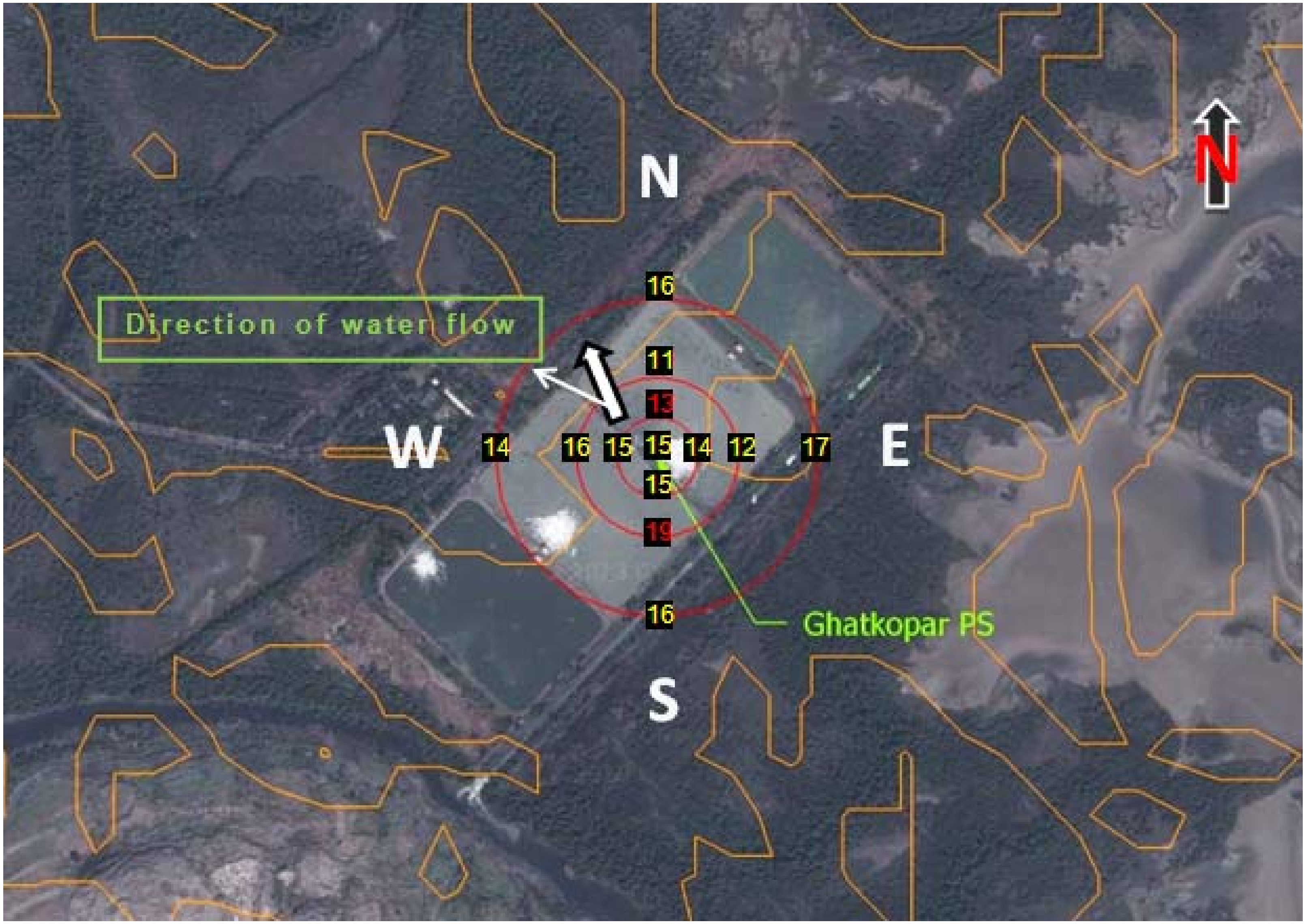

Figure 3.7 : Direction of Spillage at Ghatkopar Pumping Station

Chapter 4

Proposed Mumbai Sewage Disposal Scheme in Seven Service Areas

The extension and up-gradation of treatment plants at various locations are designed based on flow prediction for 2031. Biological process such as lagoon, activated sludge process etc. are designed for Average Dry Weather Flow (ADWF) and physical (preliminary and primary) processes such as screening, grit removal and primary sedimentation are designed for Past Forward Flow (PFF). Effluent quality of the treated wastewater from the WWTFs is based on Central Pollution Control Board (CPCB) and Maharashtra Pollution Control Board (MPCB) discharge standards. In MSDP Stage II priority works, the various treatment processes, design flows and effluent quality at various treatment works are presented in **Table 4.1**.

Table 4.1: Proposed Design Flows, Effluent Quality and Treatment at Different Treatment works.

Treatment Works	Zone	ADWF mld	PFF mld	PFF/ADWF	Effluent Quality BOD/SS	Process
Colaba	1	37	101	2.73	20/30	ASP
Lovegrove	2	493	981	1.99	100/100	ASP
Bandra	3	728	591	1.95	100/100	CEPT
Versova	4	325	750	2.31	100/100	3SL
Malad	5	847	1726	2.04	100/100	ASP
Bhandup	6	323	693	2.15	100/100	ASP
Ghatkopar	7	506	1048	2.07	20/30	ASP

Source: CEIA for MSDP Stage II Vol-I page 2.13

4.1 Colaba

At present preliminary wastewater treatment plant is commissioned at Colaba. It consists of two fine screens and two aerated grit chambers with a rated peak flow capacity of 101 mld. Treated effluent is discharged into a head chamber of marine outfall extending 1.1 km east towards Oyster Rock Battery in Mumbai Harbour.

The existing Colaba WWTF will be upgraded to Activated Sludge Process (ASP) as secondary treatment with the addition of primary settling tanks, aeration tanks with fine pore aeration, and secondary settling tanks to provide effluent quality of 20 mg/l BOD and30 mg/l TSS. Existing preliminary treatment has sufficient capacity for proposed upgraded options. The technical details as provided by MCGM are presented in **Table 4.2**. Sludge handing and treatment will include centrifuge, dewatering and alkaline stabilization to produce bio-solids acceptable for land utilization or disposal in sanitary landfill. Effluent disposal will continue from the existing outfall system.

4.2 Lovegrove (Worli)

At present Treated effluent is disposed through the Lovegrove effluent pumping station into west coast by a head chamber and outfall diffuser system located at 3.2 km into sea.

The existing Lovegrove WWTF will be upgraded to ASP to provide effluent quality of 100 mg/l BOD and TSS with the addition of primary settling tanks, aeration tanks with fine pore aeration, and secondary settling tanks. After treatment of all flows, 50% of flow would receive secondary treatment and will be blended with remaining effluent of primary treatment to achieve effluent standards. The design details are presented **Table 4.3** Effluent disposal will continue from the existing effluent pumping station and outfall system.

4.3 Bandra

At present Bandra SPS discharges flow into preliminary treatment plant. Treated effluent pumps through a new Bandra EPS into a head chamber and ocean outfall at 3.5 km on the west coast.

The Bandra WWTF will be upgraded in the future to provide effluent quality to a 100 mg/l standard each for TSS and BOD with the addition of chemically-enhanced primary treatment (CEPT). Existing preliminary treatment has sufficient capacity for the proposed flow. Sludge handling and treatment will include centrifuge dewatering and alkaline stabilization to produce bio-solids acceptable for land utilization or disposal in sanitary landfill. Effluent disposal will continue through the effluent pumping station and outfall system. The design details are presented in **Table 4.4**.

4.4 Versova

A preliminary treatment plant at Versova was commissioned in 1998. It consists of three fine screens and three aerated grit chambers with rated peak flow capacity of 295 mld. Secondary treatment consists of two parallel trains of three – stage, aerated/aerobic/facultative lagoons with a rated capacity of 90 mld average flow and average hydraulic retention time of about four days. Treated effluent is discharged to a short channel that is tributary to Malad Creek.

The existing Versova WWTF will be modified into three stage lagoon to provide effluent quality to a 100 mg/l of BOD and TSS, by reconfiguring the existing waste stabilization pond. The existing ponds will be converted to high-rate, three stage ponds with 2.47 days hydraulic retention time, from the existing three-stage 4.3 day detention time ponds that achieves the effluent quality equivalent to secondary treatment. Reconfiguring the ponds by constructing three additional cells adjacent to existing will result in an increase in treatment capacity to 325 mld. Other requirements will be expansion of preliminary treatment using mechanically-cleaned screens and vortex grit chambers, to 750 mld capacity. The design details are presented in **Table 4.5.**

4.5 Malad

A preliminary treatment plant at Malad was commissioned in 1998. It consists of four fine screens and four aerated grit chambers (360 m3) with a rated peak flow capacity of 530mld. Treated effluent is discharged through a long effluent conduit into Malad Creek.

The existing preliminary treatment at Malad WWTF will be upgraded to ASP (424 mld) to provide effluent quality of 100 mg/l BOD and TSS with addition of primary settling tanks, aeration tanks, secondary tanks, anaerobic digesters, sludge holding tanks etc. All flows would receive primary treatment and 50% of flow would receive secondary treatment to provide a blended effluent that would achieve the effluent standards. The upgrading of the treatment works would require the demolition of old treatment facilities and office accommodation as well as the loss of areas of landscaping within the premises. The design details are presented in **Table 4.6**.

Effluent disposal will be through a new on-site effluent pumping station and combined effluent mains from Malad and Versova EPS to the outfall head works at Erangal. Prior to the construction of the Erangal outfall the effluent is discharged directly into Malad Creek.

4.6 Bhandup

A preliminary treatment plant at Bhandup was commissioned in early 2000. It consists of four fine screens and four aerated tanks (210 m3) with a rated peak flow capacity of 370 mld. Secondary treatment consist of four, single stage aerated lagoons

The existing preliminary treatment at Bhandup WWTF will be upgraded to ASP sludge process (323 mld) to provide effluent quality of 20 mg/l BOD and 30 mg/l TSS with addition of primary settling tanks, aeration tanks, secondary tanks, anaerobic digesters, sludge holding tanks etc. All flows would receive 100% primary treatment and secondary treatment to provide a blended effluent that would achieve the effluent standards. The upgrading of the treatment works would require the demolition of old treatment facilities and office accommodation as well as the loss of areas of landscaping within the premises. The design details are presented in **Table 4.7**. Sludge handing and treatment will include sludge blending tank, anaerobic digesters, sludge holding tanks, centrifuge, dewatering, gas scrubber etc to produce bio-solids acceptable for land utilization or disposal in sanitary landfill. Effluent disposal will be through the existing outlet channel to Thane Creek.

4.7 Ghatkopar

A preliminary treatment plant at Ghatkopar was commissioned in early 2000. It consists of four fine screens and four aerated grit chambers (520 m^3) with a rated peak flow capacity of 553 mld. Secondary treatment consists of four; single stage aerated lagoons with hydraulic retention time of about 1.5 days and rated capacity of 380 mld average flow. Treated effluent is discharged through creek outlet joining ultimately to Thane Creek.

The existing preliminary treatment at Ghatkopar WWTF will be upgraded to ASP (506 mld) to provide effluent quality of 20 mg/l BOD and 30 mg/l TSS with addition of primary settling tanks, aeration tanks, secondary tanks, anaerobic digesters, sludge holding tanks etc. All flows would receive 100% primary treatment and secondary treatment to provide a blended effluent that would achieve the effluent standards. The upgrading of the treatment works would require the demolition of old treatment facilities and office accommodation as well as the loss of areas of landscaping within the premises. The design details are presented in **Table 4.8**.

Table 4.2 : Design Details of Colaba WWTF (Existing and Proposed)

Unit Process	Design Criteria	Unit Size	Unit Dimension	No. of Units	Design Capacity (mld)
Screening	12 mm openings	N/A	1.2 m wide/ 1.6 m high	2	101
Grit Removal	Remove 95% > 0.02 mm	Vortex Grit Chamber Each for 51 MLD	4.3 m dia with suitable size inlet outlet channel	2	101
Primary Tanks	Peak SSR 120 m/d	484 m^2	22.0 m x 22 m x 4 SWD	2	101
Primary Sludge Pump	5-6% total solid intermittent pumping	20 L/S	5.6 kW open impeller, horizontal centrifugal	2 (1+1)	37
Aeration Tank	Average HRT=5.95 hr	361 m^2	19 x 19 x 6 m SWD	4	37
Process Air Blowers	1.0-1.1 kg O_2/ kg/BOD applied	92 kg/O_2/h	80 kW (connected) Rotary with twin Lobe	6 (4+2)	37
Secondary Tank	Peak SSR=45 m/d	1225 m^2	35.0 m x 35 m x 2.75 SWD	2	101
Return Sludge Pumps	50% of average flow	172 LPS	30 kW non-clog centrifugal	3 (2+1)	37
Sludge Feed Pumps	Continuous Operation	20 m^2/hr	Non-clog centrifugal	2 (1+1)	37
Anaerobic Digesters	TSS 8200 kg/day and VSS 72%	18 days digestion	18.3 m dia x 7 m LD	2	37
Digested Sludge Holding Tank	HRT = 24 @3.5-4%	49 m^2	7 m x 7 m x 5 m SWD 20 KW mixer		37
Centrifuge Feed Pumps	Continuous operation	10 m^2/hr	Non –clog centrifugal	2 (1+1)	37
Centrifuges	Continuous operation	400 kg/hr dry solids	15 kW, (Connected)	2 (1+1)	37
Polymer Dosing	2.0 kg/t dry solids (for thickening+ de-watering)	16.4 kg/d	6 m^2 each (0.1% solution) 2.2 kW mixer	2	37
Gas Scrubber, Bio gas Engine	1-1.1 m^3 gas /VSS removed	3000-3200 m^3 gas	0.26 Mwe		

Table 4.3 : Design Details of Lovegrove WWTF (Existing and Proposed)

Unit Process	Design Criteria	Unit Size	Unit Dimension	No. of Units	Design Capacity (mld)
Screening	15-20 mm openings	N/A	20 m openings	4 (existing)	1820
Grit Removal	Remove 95% > 0.02 mm	1240 m^3	34.5 x 7.0 x 5.1 SWD	4 (existing)	1820
Primary Tanks	Peak SSR =120 m/d	2116 m^3	50 m x 50 m x 4 SWD	4	981
Primary Sludge Pump	5-6% total solid intermittent pumping	± 150 m^3/hr	18.5 kW open impeller, horizontal centrifugal	4 (2+2)	493
Aeration Tank	Average HRT=5.5 hr	2520 m^2	71 x 35.5x 7.5 m SWD	3	247
Process Air Blowers	1.0-1.1 kg O_2/ kg/BOD applied	310 kg/O_2/h	Rotary with twin Lobe 250 kW	9 (6+3)	247
Secondary Tank	Peak SSR=39 m/d	2116 m^2	46 m x 46 m x 2.75 SWD	6	490.5
Return Sludge Pumps	50% of average flow	860 m^3/hr	40 kW non-clog centrifugal	9 (6+3)	247
Blended Sludge Holding Tanks	HRT = 12 @4-5%	850 m^3/hr	13.0 m x 13 m x 5 m. 50 kw mixer	1	493
Digested Feed Pumps	Continuous operation	18 m^3/hr	3.75 kW non-clog centrifugal	6 (4+2)	493
Anaerobic Digesters	TSS 91000 kg/day and VSS 72%	15 days digestion	30 m dia x 9 m LD	4	493
Digested Sludge Holding Tank	HRT = 12 @3.5-4.5%	720 m^3/day	13 m x 13 m x 4.5 m 30 kW mixer	1	493
Centrifuge Feed Pumps	Continuous operation	30 m^2/hr	Non –clog centrifugal	6 (4+2)	493
Centrifuges	Continuous operation	1200 kg/hr dry solids	30 Kw	6 (4+2)	493
Polymer Dosing	2.0 kg/t dry solids (for thickening+ de-watering)	156 kg/d	(0.1% solution) 3.8 kW mixer	6	493
Gas Scrubber, Bio gas Engine	1-1.1 m^3 gas /VSS removed	34000 m^3 gas	2.8 Mwe		

Table 4.4 : Design Details of Bandra WWTF (Existing and Proposed)

Unit Process	Design Criteria	Unit Size	Unit Dimension	No. of Units	Design Capacity (mld)
Screening	15-20 mm openings	N/A	20 m openings	4 (existing)	1910
Grit Removal	Remove 95% > 0.20	1230 m^3	34.5 x 6.9 x 5.2 SWD	4 (existing)	1910
Primary Tanks	Peak SSR =60 m/d nominal	2500 m^2	50 m x 3.5 SWD with 19 m dia. Flocculation chamber	4	591
Primary Sludge Pump	4% total solid intermittent pumping	± 150 m^3/hr	15 kW open impeller, centrifugal	4 (2+2)	303
Chemical Dosing	40 mg/L $FeCl_3$ at 20% solution	2500 l/hr	0-3000 L/h @ 22 kW	2 (1+1)	303
Chemical Storage	2 days	60,000 L	4.7 m x 3.5 m SWD, FRP	3	303
Sludge Holding Tanks	HRT=24 h @ 3-4.0%	625 m^3	140.0 m dia x 4.0 m (HWL-LWL), 10 kW mixer	2	303
Sludge Feed Pumps	Continuous operation	30 m^3/hrs	2.5 kW non-clog centrifugal	3 (2+1)	303
Centrifuges	Continuous operation	1200 kg/hr dry solids	30 kW (Connected)	3 (2+1)	303
Polymer Dosing	2.0 kg/t dry solids	136.5 kg/d	40 m^3 each (0.1% solution) 3.75 kW mixer	3 (2+1)	303
Alkanie Stabilization	pH > 12, 15 hrs operation	77.5 t/d dry solids including additives	Silos and conveyors systems suitable for 66 t/d	3 (2+1)	303

Table 4.5 : Design Details of Versova WWTF (Existing and Proposed)

Unit Process	Design Criteria	Unit Size	Unit Dimension	No. of Units	Design Capacity (mld)
Screening		1500 mm Wide and 2600 mm LD	6 mm	3	750
Grit Removal	Removal 95% > 0.03 mm	9.0 m Diameter	9.0 m Φ x 4.0 m SWD	2	750
2 nos. Streams of 3 lagoons in Series 1 no. New stream of same capacity as existing					
First Cells	HRT ≈ 0.8 days	Liquid Volume of 65000 m^3 each	156 m x 106 m x 4.0 SWD	2 existing 1 new	325
Second Cells	HRT ≈ 1.03 days	Liquid Volume of 84000 m^3 each	199 m x 106 m x 4.0 SWD	2 existing 1 new	325
Third Cells	HRT ≈ 1.03 days	Liquid Volume of 52000 m^3 each	128 m x 106 m x 4.0 SWD	2 existing 1 new	325
Surface Aerators	Floating Type	1.4 kg/ kg BOD removed			
First Cells	8.5 kW/ ML	15 units/ lagoon	38 kW each	15-existing 30 -new	325
Second Cells	2.68 kW/ ML	15 units/ lagoon	15 kW each	18-existing 27 -new	325
Third Cells	0.58 kW/ ML	2 units/ lagoon	15 kW each	4-existing 2 -new	325
Effluent Pumping Station	Peak Flow	2892 L/s @ 24.5 m	750 kW non-clog centrifugal 1200 x 1200 pumps	4 (including 33% standby)	750

Table 4.6 : Design Details of Malad WWTF (Existing and Proposed)

Unit Process	Design Criteria	Unit Size	Unit Dimension	No. of Units	Design Capacity (mld)
Screening		2200 mm wide and 1500 LD	6 mm openings	4	1726
Grit Removal	Remove 95% > 0.03 mm	9.0 m diameter	9.0 m Φ x 4.0 m SWD	4	1726
Primary Tanks	Peak SSR- 100 m/d	2209 m^2	47 m x 47 m x 4 m SWD	8	1726
Primary Sludge Pump	5-6% total solid, Intermittent pumping	± 200 m^3 /hr	18.5 kW open impeller horizontal centrifugal	4 (2+2)	847
Aeration Tank	Average HRT = 5.6 hr	2052 m^2	65 m x 32 m x 6 m SWD	8	424
Process Air Blowers	1.0 kg O_2/kg/ BOD applied	416 kg/O_2/hr/blower	Rotary twin lobe 315 SWD	12 (8+4)	424
Secondary Tanks	Peak SSR- 40 m/d	1849 m^2	43 m x 43 m x 3 m SWD	12	424
Return Sludge Pumps	50% of average flow	1470 m^3/hr	75 kW non clog centrifugal	8 (6+2)	424
Sludge Blending Tanks	HRT = 12 hr, 4-5%	1600 m^3	18 m x 18 m x 5 m 50 kW mixer	1	847
Digester Feed Pumps	Continuous Operations	63 m^3/hr	15 Kw non-clog centrifugal	3 (2+1)	847
Anaerobic Digesters	TSS 157800 kg/day and VSS 72%	15 days digestion	22 m dia x 20 m LD	6	847
Digested Sludge Holding Tank	HRT = 12@ 3-4%	1450 m^3/day	18 m x 18 m x 4.5 m. 50 kW mixer	1	847
Centrifuge Feed Pumps	Continuous operation	30 m^3/hr	Non –clog centrifugal	8(5+3)	847
Centrifuges	Continuous operation	1200 kg/hr dry solids	30 kW	8(5+3)	847
Polymer Dosing	2.0 kg/t solids (for thickening + dewatering)	270 kg/d	(0.1% Solution), 3.8 kW mixer	6	847
Gas Scrubber, Bio Gas Engine	1-1.1 m^3 gas /VSS removed	545000 m^3 gas	5 Mwe		

Table 4.7 : Design Details of Bhandup WWTF (Existing and Proposed)

Unit Process	Design Criteria	Unit Size	Unit Dimension	No. of Units	Design Capacity (mld)
Screening		1600 mm wide	6 mm opening	6	691
Vortex Grit Mechanisms	Removal 95% > 0.03 mm	2200 lps each	7.0 m Φ x 4.0 m SWD	4	691
Primary Tanks	Peak SSR=108 m/d	1385 m^2	42 m dia x 4 m SWD	4	323
Primary Sludge Pumps	5-6% total solid intermittent	100 m^3/hr	15 kW, non clog open impeller		
Aeration Tank	Average HRT= 5.5 hr	2178 m^2	66 m x 33 m x 5.6 m SWD	6	323
Process Air Blowers	1.0 kg O_2/kg/BOD applied	416 kg O_2/kg/blower	Rotary twin lobe 315 kW	9 including standby	323
Secondary Tanks	Peak SSR= 50 m/d	1849 m^2	51 m dia x 3.5 m SWD	8	323
Return Sludge Pumps	50% of average flow	1690 m^3/hr	75 kW non-clog centrifugal	8 including standby	323
Sludge Blending Tank	HRT = 8 @ 4%	450 m^3	10 m x 10 m x 5 m, 20 kW mixer	1	323
Anaerobic Digesters	TSS 59300 kg/day and VSS 72%	15 days digestion	16 m dia x 18 m LD	6	323
Digested Sludge Holding Tanks	HRT = 8 @ 4%	400 m^3	10 m x 10 m x 4 m, 50 Kw mixer	1	323
Centrifuge Feed Pumps	Continuous operation	30 m^3/hr	Non –clog centrifugal	4 (including standby)	847
Centrifuge	Continuous operation	1200 kg/hr dry solids	30 kW	4 (including standby)	323
Polymer Dosing	2.0 kg/t day solids (for thickening + dewatering)	135 kg/d	(0.1% solution). 3.8 kW mixer	3	323
Gas Scrubber, Bio Gas Engine with Housing	1-1.1 m^3 gas / VSS removed	24300 m^3 gas	2 Mwe		

Table 4.8 : Design Details of Ghatkopar WWTF (Existing and Proposed)

Unit Process	Design Criteria	Unit Size	Unit Dimension	No. of Units	Design Capacity (mld)
Screening		1600 mm wide	6 mm openings	6	1048
Vortex Grit Mechanisms	Removal 95% > 0.03 mm	3050 lps each	7.3 m Φ	4	1048
Primary Tanks	Peak SSR = 83 m/d	2123 m^2	52 m dia x 4 m SWD	6	1048
Aeration Tanks	Average HRT = 5.5 hr	2178 m^2	72 m x 36 m x 5.6 m SWD	6	506
Process Air Blowers	1.0 kg O_2/kg/BOD applied	370 kg O_2/kg/blower	Rotary twin lobe 331 kW	12 including standby	506
Secondary Tanks	Peak SSR < 50 mld	2123 m^2	52 m dia x 3.5 m SWD	12	506
Return Sludge Pumps	50% of average flow	1760 m^3	75 kW non-clog centrifugal	9 (including standby)	506
Sludge Blending Tanks	HRT = 8 h @ 4-5%	720 m^3	12 m x 12 m x 5 m LD 50 kW mixer	1	506
Anaerobic Digesters	TSS 113200 kg/day and VSS 72%	15 day digestion	20 m dia x 18 m LD	1	506
Digested Sludge Holding Tank	HRT = 8 @ 4%	600 m^3/day	12 m x 12 m x 4.5 m LD 50 kW mixer	1	506
Centrifuge	Continuous Operation	1200 kg/hr dry solids	30 kW	6 (including standby)	506
Polymer Dosing	2.0 kg/t dry solids (for thickening + dewatering)	220 kg/d	(0.1% solution), 3.8 kW mixer	4	506
Gas Scrubber, Bio Gas Engine with Housing	1-1.1 m^3 gas/ VSS removed	38500 m^3 gas	3.2 Mwe		

Chapter 5
Disasters in No Action Scenario

5.1 Effect on Fisheries

Fishery is the most important traditional activity in the city of Mumbai involving participation of large number of stakeholders forming organized groups through various fishery co-operatives. In the Greater Mumbai District there are 19 fish landing centers, 27 fishing villages with active fisher folk population. In addition to the active fishermen, large proportion of the community is involved in marketing of fish, making and repairing the net, in curing/processing activities, as labourers etc. Major fishing gears in the Greater Mumbai District are trawlers, gill netters, liners and other local variants like dugout canoes and plank built boats categorized into mechanized, motorized and non-motorized categories.

Mumbai has the distinction of being most important city among the five coastal districts of Maharashtra where maximum number of fish mortality cases are seen when compared with the entire Indian coastline *(Chandra Prakashet al., 2002)*. During the month of October'2005, there were reports of dead fishes floating near Gateway of India and washed ashore at other locations along the coast of Mumbai. Recurring fish mortalities along the Mumbai coast have been reported earlier by various agencies and these mortalities are attributed to synergistic or combined effect of all the complex processes going on in the ecosystem due to sources of domestic and industrial pollution. Various uses of the Mumbai coast are in conflict between developmental work and exploitation of traditional fishery resources. A large and diverse population is directly impacted by the waste water discharged through anthropogenic activities *(Govt of India and CMFRI, 2006)*.

Earlier, provisions for treatment and disposal of the wastewater generated were not at par with the increase in water consumption. Hence, bulk of the wastewater received at the treatment plants was released untreated into the marine environment, which has deteriorated the water quality of the inshore waters to a considerable extent. The situation was supposed to be mitigated after commissioning of the sewage outfalls off Bandra and Worli on the west coast of Mumbai as these outfalls discharge sewage after partial treatment at a distance of 3 to 3.5 kms in the sea.

Water quality at Versova and Mahim showed severity of pollution. Departure from the normal standard values was pronounced at Versova and Mahim creeks, and these areas can be designated as hot spots. Recurring fish mortalities in the past have stressed the exigency for new strategies for conservation *(Singh & Raje, 1998)*.

5.1.1 Observations on Fish & Animal Tissue Analysis from the Impact and North of Impact Area

NEERI collaborated with CMFRI for the analysis of fish and animal tissue occurring in west coast of Mumbai for heavy metals. The most potentially dangerous heavy metals are Lead (Pb), Cadmium (Cd), Nickel (Ni), Copper (Cu) and Mercury (Hg), and the metalloids, i.e. Arsenic (As), Selenium (Se), and Tin (Sb).

Heavy metals have a great affinity for sulphur and attack sulphur bonds in enzymes of marine organisms and immobilize them. Fishes tend to accumulate chemicals and other metabolites in their body tissues when exposed to them. Marine organisms may accumulate contaminants like trace metals from water, sediment and food. Pelagic organisms may take up trace metals directly from the water column or benthic organisms may absorb these substances from contact with both the bottom sediments and the overlying water.

Chronic exposure of fish to chemicals results in modifications of adaptive and feeding behaviours, changes in population structure and dynamics. Thus, the process of bioaccumulation is carried through aquatic food webs and may accumulate in shellfishes and finishes. Measurement of bioaccumulation is used to estimate regional risks of consumption to predators, either wildlife or humans.

Finfishes such as Bombay duck, Oil sardine, Catfish and *Coilia* were collected from the outfall discharge area and north of the discharge area. Green mussel (*Pernaviridis*) was collected from their beds both from the outfall discharge area and north of the discharge area. After identification and cleaning of the specimen, the muscle, liver or pancreases portion of the animals were removed and dried in a hot air oven at 80°C until weight constancy was reached. The samples were then ground and acid digested for heavy metal analysis. Digested tissue samples were analysed for metals using AAS after following the standard procedure. The results were expressed as µg/g (ppm) dry tissue weight and presented in **Table 5.1**.

The permissible concentration of trace metals in fish and seafood from various countries are shown in **Table 5.2**.

Table 5.1 : Mean, Minimum (Min) and Maximum (Max) Concentrations of Trace Metals (µg/g dry tissue weight) in Fishes and Mussels Collected from the Outfall Area and North of the Impact Area in 2008

			Cd	Cu	Fe	Mn	Ni	Pb	Zn
Finfish	**Impact area**	**Mean**	BDL	BDL	827	BDL	30.46	125.75	8.00
		Min	BDL	BDL	22	BDL	BDL	6.56	BDL
		Max	BDL	BDL	4502	BDL	147.74	599.24	65.52
	North	**Mean**	4.23	5.47	578	3.84	17.29	330.22	44.76
		Min	BDL	BDL	88	BDL	BDL	26.83	0.00
		Max	39.18	15.17	2276	18.00	262.18	1710.06	123.40
Mussel	**Impact area**	**Mean**	BDL	53.00	659	BDL	BDL	118.97	BDL
		Min	BDL	50.20	535	BDL	BDL	109.20	BDL
		Max	BDL	55.79	784	BDL	BDL	128.73	BDL
	North	**Mean**	1.30	86.64	1538	31.48	2.65	320.22	20.77
		Min	BDL	BDL	44	BDL	BDL	28.02	BDL
		Max	23.56	339.31	23780	1779.30	83.13	12580.00	175.91

BDL= below the detection limit

Table 5.2 : Permissible Concentration of Trace Metals in Fish and Seafood from Various Countries

Metal	US FDA (mg/kg dry wt)	Australia (mg/kg wet wt)	New Zealand (mg/kg wet wt)	UK (mg/kg wet wt)	WHO (mg/kg wet wt)	WHO values recalculated on dry wt basis
As	76	2	-	4	4	17
Cd	3	2	1	3	2	9
Pb	1.5	2.5	2	3	2	9
Cu	-	70	30	20	30	130
Ni	80	-	-	-	2	9
Zn	-	10.3	40	50	50	217
Cr	12	-	-	-	2	9
Hg	1	0.5	0.5	0	0.5	21.2

In the last column WHO values are recalculated and expressed in dry weight basis for comparison with the present study. (For dry weight conversion wet weight values are divided by 0.23, based on ~77% moisture content in fish tissue).

Generally, metal concentrations in fish and mussel samples collected from Versova creek situated north of the impact area were high when compared to the values in fish and mussel samples collected from the impact area (**Table 5.1**). Concentrations of Pb were higher than the standard of 9 µg/g dry tissue weight in all most all the samples. Concentrations of other toxic metals like Cd, Cu and Ni were above the permissible limits in some of the fish samples.

Species Abundance

Effect of the diffusers on the species abundance of resident fish populations during 2006-07 has been compared, both qualitatively and quantitatively, with the baseline data collected during 2001-2002. An index of population density called abundance (unit weight or number of organisms per unit area/volume) measured per haul of fishing was taken for the comparison of pre-commissioning and post-commissioning periods. The abundance was estimated by undertaking trawling hauls in 10-20m depth area in the impact zone as well as in the control fishing areas situated North and South of the impacted area.

Synoptic fishing conducted during 2001-02 in 10-20 m depth off Worli yielded pelagic fishes at the rate of 9.55 kg/hr. There were 17 species which constituted the catch. Out of 17 *Coiliadussumieri* was the most dominant with the catch rate of 7.417 kg/hr. The other constituents were *Ilishafiligera* (0.378kg), *Anodontostomachakunda* (0.285kg), *Hilsatoli* (0.235kg), *Harpodonnehereus* (0.216kg), *Trichiurslepturus* (0.315kg) and *lepturacnathussavala* (0.319 kg). The fishing conducted during 2006-07 yielded 4.773 kg/hr. There were 13species contributing the catch. The major species was *Coiliadussumieri* at the catch rate of 2.763kg/hr. The other resources were *Sardinellalongiceps* (0.573 kg), *Decapterusrusselli* (0.528kg), *Lepturacnathussavala* (0.334 kg), *Trichiurslepturus* (0.191kg), *Eulpeurogammusmuticus* (0.028 kg) and *Harpodonnehereus* (0.17kg).

In the control areas which lies outside the impact zone the abundance of the resources are poor when compared to the impact area and the average catch was 2.756kg. The numbers of species recorded were 13 in this zone also. The major constituents were *Coiliadussumieri (1.179kg),Trichiurslepturus* (0.856kg), *Harpodonnehereus* (0.354kg), *Sardinellalongiceps* (0.126kg) and *Lepturacnathussavala* (0.021 kg) and *Decapterusrusselli* (0.107kg). The percentage composition indicated that *Coiliadussumieri* was the most dominant contributing 77.7% of the catch during 2001-2002 while it contributed 58.0% during 2006-07. Some of the species *viz. Dussumieriacuta*, *Nematolosanasus, A. chakunda, H. toli, Mugil*sp., *Lactariuslactarius and Bregmacerosmacclellandi* have disappeared from the catch in 2006-07 while *Sardinellafimbreata, E. thoracata*and *E. muticus*are the new entrants to the fishing grounds.

Excessive levels of ammonia can be harmful to aquatic life. Fish can suffer loss of equilibrium, hyper-excitability, increased respiratory activity and oxygen consumption, and faster cardiac rhythm. Different sub-lethal effects may occur: reduced hatching, reduced growth rates and morphological development, injuries to gills, liver and kidneys, and so forth. At extreme ammonia levels, they can suffer from convulsions followed by coma and death. The lethal concentration

(LC_{50} 96h) for ascertain number of fish species varies from 0.2 and 1.1 mg NH_3/L for Salmonidae and from 0.7 to 3.4mg NH_3/L for Cyprinidae *(Garric, 1987)*.

5.2 Effect on Biodiversity

a) Dissolved Oxygen

During monitoring it was observed that DO was more than 4 mg/l (SW-II standard) in 99% samples indicating favourable conditions for commercial fishing and protection of aquatic life.

Likely disaster in case no action is taken is lowering of DO levels in sea water. Dissolved oxygen is essential for a healthy aquatic ecosystem. Fish and aquatic animals need the oxygen dissolved in the water to survive. Depletion in DO can cause major shifts in the kind of aquatic organisms found in water bodies. Species that cannot tolerate low levels of DO - mayfly nymphs, stonefly nymphs, and beetle larvae - will be replaced by a few kinds of pollution-tolerant organisms, such as worms and fly larvae. Nuisance algae and anaerobic organisms (that live without oxygen) may also become abundant in waters with low levels of DO.

The decline in dissolved oxygen concentrations can also promote the formation of reduced compounds, such as hydrogen sulphide, resulting in higher adverse (toxic) effects on aquatic animals.

a) ***Phosphate***

Soluble phosphate concentration was in the range of BDL to 0.35 mg/l during all tidal conditions. PO_4-P was observed at most of the locations in winter and pre-monsoon. In alkaline range, soluble phosphate gets converted into insoluble form.

Nitrogen and phosphorous are the primary inorganic nutrients responsible for the eutrophication of marine water. The adverse effects on the marine environment, are losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters. Algal growth in marine waters is regulated by the level of nitrogen and phosphorous and to a lesser extent other inorganic compounds. Eutrophication leads to an increased algal growth (because the level of nutrients increases). It can lead to a shift in species composition to fast growing algae species (including toxic species) and a shift from long lived macroalgae to more nuisance species.

Algae can develop with phosphate concentrations as low as 0.05 mg/L. The case of pollution by phosphates generates disturbances in biochemical cycles resulting in an undesirable accumulation of sometimes toxic intermediaries in these cycles capable of generating ecological imbalances *(Kuenen and Robertson, 1988; Heathwaite, 1993)* that depend on their chemical form and concentration.

b) ***Ammoniacal Nitrogen***

Significant percent of samples at Dadar, Mahim and Versova showed NH_3-N in excess of 1 mg/l. Mahim and Dadar beaches remained heavily polluted with concentration of NH_3-N in the range of 2.3 to 7.8 mg/l. Water quality at Breach Candy, Worli and Bandra sea fronts in terms of NH_3-N showed improvement as compared to beaches at Dadar and Mahim. It may be attributed to shifting of wastewater discharges from shore to 3 km seaward through marine outfall at Bandra. Juhu beach showed lower values of ammonical nitrogen whereas Versova showed deterioration. The status of Madh remains same.

Elevated concentrations of NH_4^+, NO_2^- and NO_3^-, derived from human activities, can stimulate or enhance the development, maintenance and proliferation of primary producers (phytoplankton, benthic algae, macrophytes), contributing to the widespread phenomenon of the cultural (man-made) eutrophication of aquatic ecosystems *(Rabalais and Nixon, 2002; Turner, 2002; Smith, 2003)*. Eutrophication typically has adverse ecological and economic effects, for example through the creation of anoxic zones and toxic cyanobacteria blooms.

Among the different inorganic nitrogenous compounds (NH_4^+, NH_3, NO_2^-, HNO_2, NO_3^-) that aquatic animals can take up directly from the ambient water, unionized ammonia is the most toxic, while ammonium and nitrate ions are the least toxic. In general, seawater animals seem to be more tolerant to the toxicity of inorganic nitrogenous compounds than fresh water animals, probably because of the ameliorating effect of water salinity (sodium, chloride, calcium and other ions) on the tolerance of aquatic animals.

5.3 Aesthetics of Beaches

Water quality was monitored at 12 locations on the west coast of Mumbai during 2006-07.Monitoring was carried out at distances of 1, 3 and 5 km from the low tide water line. Water quality was monitored at 4 more locations each in Malad and Marve creek and 33 locations in Thane creek during the study by NEERI. Based on four parameters viz. pH, DO, BOD and FC, WQI was calculated. By this we can categorize each location into four categories viz. as good to excellent, Medium to good, Bad and bad to very bad. The method of calculation of WQI is described below.

Method for Calculation of Water Quality Index for Surface Water

An index is a mean device to reduce a large quantity of data down to a simplest form. The water quality indices help to evaluate the water quality profile and to identify the beaches where the gap between the desired and the existing water quality is significant enough to warrant urgent pollution control measures. In India the NSF WQI is being used by CPCB, with a slight modification in weights *(Abbasi, 2002, CPCB, 2001)*. The NSF WQI is expressed mathematically as:

$$NSFWQI = \sum_{i=1}^{p} W_i I_i,$$

where I_i = sub index for i^{th} water quality parameter
Wi = weight (in terms of importance) associated with water quality parameter
p = number of water quality parameters.

The modified weights (W_i) and the equation for the sub -indices (I_i) as per CPCB, are given in **Tables 5.3 and 5.4**, respectively. The range of the NSF WQI corresponding to various designated best use classification is given in **Table 5.5**.

Table 5.3: Original and Modified Weights for the Computation of NSF WQI based on DO, Fecal Coliforms, pH and BOD*

Water Quality Parameters	Original Weights from NSF WQI	Modified Weights by CPCB
DO	0.17	0.31
FC	0.15	0.28
pH	0.12	0.22
BOD	0.1	0.19
Total	0.54	1.00

** CPCB 2001*

Table 5.4: Sub –Index Equations for Water Quality Parameters (NSF WQI)*

Water Quality Parameters	Range Applicable	Equation
DO (Percent saturation)	0-40% saturation	IDO = 0.18+0.66 x (% Saturation DO)
	40-100% saturation	IDO = -13.55+1.17 x (% Saturation DO)
	100-140% saturation	IDO = 163.34-0.62 x (% Saturation DO)
B.O.D.(mg/l)	0-10	IBOD = 96.67-7 (BOD)
	10-30	IBOD = 38.9-1.23 (BOD)
	> 30	IBOD = 2
pH	2-5	IpH = 16.1+7.35 x (pH)
	5-7.3	IpH = -142.67+33.5 x (pH)
	7.3-10	IpH = 316.96-29.85 x (pH)
	10-12	IpH = 96.17-8.0 x(pH)
	<2 , >12	IpH=0
Fecal Coliform (counts/100ml)	$1\text{-}10^3$	IFC = 97.2-26.6 x log(FC)
	$10^3\text{-}10^5$	IFC = 42.33 -7.75 x log(FC)
	$>10^5$	IFC = 2

***** *Abbasi, 2002*

Table 5.5: NSF WQI for Various Designated Best Use*

Serial No	NSF WQI	Description of Quality (1978)	Class by CPCB	Remarks
1	63-100	Good to Excellent	A	Non polluted
2	50-63	Medium to Good	B	Non polluted
3	38-50	Bad	C	Polluted
4	38 & less	Bad to Very Bad	D, E	Heavily polluted

**CPCB, 2001*

The **Table 5.6** gives the water quality index calculated for 12 locations on west coast of Mumbai located 1 km from low tide line. We observe that at 1 km distance water quality are medium to good at all locations in all seasons in both high and low tide conditions except that in high tide, Post monsoon water quality was good to excellent at Girgaon and Bad at Khar.

Table 5.6 : Water Quality Index of Beaches on West Coast

Serial No.	Beaches	Low tide (Winter)	High Tide (Winter)	Low Tide (Post monsoon)	High Tide (Post monsoon)	Low tide (Pre Monsoon)	High tide (Pre monsoon)
1	Nariman Point	MG	MG	MG	MG	MG	MG
2	Breach Candy	MG	MG	MG	MG	MG	MG
3	Worli	MG	MG	MG	MG	MG	MG
4	Bandra	MG	MG	MG	MG	MG	MG
5	Colaba	MG	MG	MG	MG	MG	MG
6	Girgaon	MG	MG	MG	GE	MG	MG
7	Dadar	MG	MG	MG	MG	MG	MG
8	Mahim	MG	MG	MG	MG	MG	MG
9	Khar	MG	MG	MG	Bad	MG	MG
10	Juhu	MG	MG	MG	MG	MG	MG
11	Versova	MG	GE	MG	MG	MG	MG
12	Madh	MG	GE	MG	MG	MG	MG

The water quality indices of Malad creek given in **Table 5.7** were very bad during low tide in all seasons. During high tide, pre monsoon season, WQI improved to medium to good and at one location it was good to excellent.

Table 5.7: Water Quality Indices in Malad Creek

Sampling location	Low tide (Post monsoon)	High tide (Post monsoon)	Low tide (Winter)	High tide (Winter)	Low tide (Pre monsoon)	High tide (Pre monsoon)
Malad Creek Mouth	VB	Bad	VB	Bad	VB	MG
Malad Creek	VB	Bad	VB	Bad	VB	GE
Malad Creek	VB	Bad	VB	Bad	VB	MG
Malad Creek	VB	Bad	VB	Bad	VB	MG

The Water quality indices of Marve creek given in **Table 5.8** varied between bad to very bad in both low tide and high tide in all seasons except during high tide pre monsoon WQI was medium to good at two locations were very bad during low tide in all seasons. During high tide pre monsoon season, WQI improved to medium to good and at one location it was good to excellent.

Table 5.8: Water Quality Indices of Marve Creek

Sampling location	Low tide (Post monsoon)	High tide (Post monsoon)	Low tide (Winter)	High tide (Winter)	Low tide (Pre monsoon)	High tide (Pre monsoon)
Marve Creek Mouth	Bad	Bad	VB	Bad	Bad	MG
Marve creek	Bad	Bad	VB	Bad	Bad	MG
Marve creek	Bad	Bad	VB	Bad	Bad	Bad
Marve creek	Bad	VB	VB	VB	VB	Bad

Water Quality monitored at 33 locations in Thane creek given in **Table 5.9** showed that the water quality indices in inner creek from Kalwa Bridge up to Vashi Bridge were bad to very bad. Locations further south had improved water quality. Locations between Mankhurd to Nerul near Sagar dashing tower up to ONGC Jetty during high tide in post monsoon season had medium to good WQI. During low tide these locations had very bad WQI. Towards further south from ONGC Jetty to Uran, WQI were medium to excellent in all most all seasons and under both high and low tide conditions.

Table 5.9 : Water Quality Indices of Thane Creek

Sampling location	Low tide (Post monsoon)	High tide (Post monsoon)	Low tide (Winter)	High tide (Winter)	Low tide (Pre monsoon)	High tide (Pre monsoon)
Kalwa Bridge	VB	Bad	VB	VB	VB	MG
Railway Central Bridge	Bad	Bad	VB	VB	VB	MG
Airoli Bridge	Bad	Bad	VB	VB	VB	MG
Discharge point of Bhandup C	VB	Bad	VB	VB	VB	Bad
Discharge point of Bhandup E	Bad	Bad	VB	Bad	Bad	Bad
Discharge point of Bhandup W	Bad	Bad	VB	Bad	VB	Bad
Godrej Mangrove Area C	Bad	Bad	VB	VB	Bad	Bad
Godrej Mangrove Area E	Bad	Bad	VB	VB	Bad	Bad
Godrej Mangrove Area W	Bad	Bad	VB	VB	Bad	Bad
In line of Ghatkopar TP C	VB	Bad	VB	Bad	VB	Bad
In line of Ghatkopar TP E	Bad	Bad	VB	Bad	VB	Bad
In line of Ghatkopar TP W	VB	Bad	VB	Bad	Bad	Bad
Vashi bridge C	Bad	MG	VB	Bad	Bad	Bad
Vashi bridge E	Bad	Bad	VB	VB	Bad	Bad
Vashi bridge W	Bad	Bad	VB	VB	VB	Bad
Mankhurd-Nerul Sagar Darshan Tower C	VB	MG	VB	Bad	Bad	MG
Mankhurd-Nerul Sagar Darshan Tower E	Bad	MG	VB	Bad	Bad	Bad
Mankhurd-Nerul Sagar Darshan Tower W	VB	MG	VB	Bad	MG	MG

Table 5.9 (Contd.): Water Quality index Thane Creek

Sampling location	Low tide (Post monsoon)	High tide (Post monsoon)	Low tide (Winter)	High tide (Winter)	Low tide (Pre monsoon)	High tide (Pre monsoon)
Belapurvillage-Nerul Indian Bridge Construction C	MG	MG	Bad	Bad	VB	Bad
Belapur village-Nerul Indian Bridge Construction E	MG	MG	Bad	Bad	Bad	Bad
Belapur village -Nerul Indian Bridge Construction W	MG	MG	Bad	Bad	Bad	VB
Chembur South Nava Sheva C	Bad	MG	Bad	Bad	MG	MG
Chembur South Nava Sheva E	MG	MG	Bad	Bad	MG	MG
Chembur South Nava Sheva W	Bad	MG	VB	Bad	MG	MG
Near Butcher Island C	MG	MG	Bad	MG	MG	MG
Near Butcher Island E			Bad	MG	MG	MG
Near Butcher Island W			Bad	Bad	MG	MG
ONGC Jetty C	MG	Bad	Bad	MG	MG	MG
ONGC Jetty E			MG	MG	Bad	MG
ONGC Jetty W			Bad	MG	MG	MG
Colaba to Uran C	MG	MG	MG	MG	GE	GE
Colaba to Uran E	MG	MG	GE	MG	GE	GE
Colaba to Uran W	MG	Bad	MG	MG	MG	GE

Chapter 6

Benefits through Improvement of Treatment Efficiencies

6.1 Present Scenario

Physico-chemical and bacteriological analysis of samples were carried out in the year 2006-07 for west coast and creeks including Manori, Malad, Mahim and Thane. Water quality in terms of FC was not complying the SW-II standards at all the sampling locations, even at existing outfalls at Lovegrove (Worli) and Bandra. Water quality of Malad creek was worse as compared to other creeks due to discharge of pollution load from open drains and preliminary treated effluent from Malad WWTF. Quality of treated sewage from Malad WWTFs was not as per discharge standards and wastewater discharges from drains / nallas were further deteriorating the water quality of creek. Water quality in terms of BOD, DO and FC was not satisfying the SW-II standards especially during low tide in the Malad creek. Even during high tide, upper portion near the tip of Malad creek was polluted due to heavy pollution load and narrow width of the creek. Same was the case with discharge zone of Bhandup and Ghatkopar WWTFs in Thane creek.

6.2 Alternative Options for West Coast

The following alternatives were considered and modelling was carried out.

6.2.1 Option 1- No Project Scenario

As per this scenario, there is no treatment up-gradation i.e. 100% preliminary treatment at Worli, Bandra, Malad and 100% preliminary treatment and 100% secondary treatment in 3 stage aerated lagoons at Versova. No pumping station overflows and no improvement in wastewater collection. If the proposed project is not implemented at all the wastewater from the open drains and existing level of treated effluent will continue to reach the creeks and coastal regions through the present system and cause heavy pollution. The details of no project scenario are described in **Table 6.1**.

Table 6.1 : Option 1 for West Coast
No project scenario : No Upgrade of Treatment,
No Improvement in Pumping Station Overflow or Collection Efficiency

Zone		Treated Effluent				Non Point Discharges			
Number	Area	Quantity (mld)	BOD (mg/l)	FC (CFU /100 ml)	Disposal	Quantity (mld)	BOD (mg/l)	FC (CFU /100 ml)	Disposal
2	Worli	345	228	5.23×10^7	Outfall	148	240	5.50×10^7	Foreshore /Creek
3	Bandra	437	228	5.23×10^7	Outfall	291	240	5.50×10^7	Foreshore /Creek
4 and 5	Malad Versova	534	182	3.36×10^7	Creek	638	254	5.50×10^7	Creek

Treatment Details : Worli : 100% Preliminary Treatment Bandra : 100% Preliminary Treatment
Versova : 100% Preliminary Treatment, 100% Secondary Treatment in 3 –stage Aerated Lagoons
Malad : 100% Preliminary Treatment

BOD during low tide was found to be above 10 mg/l at the upper region of Malad creek, whereas it varied in the range of 5-10 mg/l in middle and lower portion near the mouth of creek. During high tide, it was above 10 mg/l in upper and middle portions of creek due to the effect of effluents from Malad WWTF and in lower portion it varied between 3-10 mg/l. Similarly, BOD was above 10 mg/l at the upper region of Mahim creek while in middle portion it varied between 3 to 10 mg/l during both low and high tides. The effect of effluent discharges at Worli and Bandra outfalls can be observed during low and high tides.BOD plume at Bandra outfall disperses upto 2.6 km and concentration varied between 3 to10 mg/l, whereas at Worli outfall the plume travelled upto 3.3 km from the outfall and BOD varied between 3 to 5 mg/l during low tide. During high tide, BOD at Bandra outfall disperses upto 3.1 km while at Worli outfall it disperses upto 1.7 km and the concentration varied between 3 to10 mg/l. In case of DO, whole Marve, Malad and Mahim creeks (Mithi River) and nearby beaches exhibited DO below 4 mg/l during low tide. DO improved during high tide due to availability of tidal water for dilution, still some portion of Marve creek, whole Malad and Mahim creeks exhibited DO below 4 mg/l.

Simulation results of FC for no project scenario showed that west coast including creeks (Manori, Malad and Mahim) was highly contaminated. In upper regions of Malad and Mahim creeks, FC was found to be above $1x10^5$ CFU/100 ml, whereas in middle and lower portions it varied between $1x10^4$ to $1x10^5$ CFU/100 ml during low and high tides. The effect of discharges from drains into the Mahim creek can be visualised that the nearby beaches exhibited FC in the range of $1x10^2$ to $1x10^5$ CFU/100 ml. During high tide, FC reduced due to dilution effect of tidal water but not considerably due to high concentration of bacteria already existing in background environment and exceeded the standards. The existing coastal and creeks water quality exhibited bacterial pollution and high DO depletion in regions near the outlets of WWTF and significant BOD levels in creeks and moderate pollution in all along the coast.

6.2.2 Option 2 : Improvement in Treatment, Proposed outfall at Erangal and No improvement in Wastewater Collection

In this option, improvement in treatment ie. 100% preliminary and 100% primary treatment at Worli, 100% preliminary and 100% Chemically Enhanced Primary treatment at Bandra, 100% preliminary and Secondary treatment at Versova and 100% preliminary and 50% Secondary treatment at Malad. No improvement is considered in wastewater collection and effluents from Malad and Versova WWTFs diverted to proposed outfall at Erangal.

The details and predictions under this option are described in **Table 6.2**.There is improvement in water quality as compared to no project scenario due to improvement in treatment and diversion of effluents from Malad and Versova WWTFs to a proposed Erangal outfall.

Table 6.2 : Option 2 for West Coast Improvement of Treatment and Pumping (Overflows) and No Improvement in Collection

Zone		Treated Effluent				Non Point Discharges			
Number	Area	Quantity (mld)	BOD (mg/l)	FC (CFU /100 ml)	Disposal	Quantity (mld)	BOD (mg/l)	FC (CFU /100 ml)	Disposal
2	Worli	419	91	1.7×10^5	Outfall	74	240	5.50×10^7	Foreshore /Creek
3	Bandra	582	83	3.7×10^5	Outfall	146	240	5.50×10^7	Foreshore /Creek
4 and 5	Malad Versova	752	89	1.7×10^5	Proposed Outfall at Erangal	420	254	5.50×10^7	Creek

Treatment Details : Worli : 100% Preliminary Treatment, 100% Primary Treatment and 50% Secondary Treatment
Bandra : 100% Preliminary Treatment, 100% Chemical Enhanced Primary Treatment
Versova : 100% Preliminary Treatment, 100% Secondary Treatment in 3 –stage Aerated Lagoons
Malad : 100% Preliminary Treatment, 100% Primary Treatment and 50% Secondary Treatment

During low tide, BOD at the upper region of Malad creek was found to be above 10 mg/l, while in the middle portion it varied between 3 -10 mg/l and below 3 mg/l at the lower portion near the mouth. During high tide, the upper region of the Malad creek possessed high BOD i.e. above 10 mg/l. While, in the middle portion it varied between 3 to 10 mg/l, whereas in the lower portion it varied between 3 to 5 mg/l. Improvement in water quality of the Malad creek is due to diversion of treated wastewater from Malad and Versova WWTFs to Erangal outfall. The effect of diverted treated effluent is visualized at the proposed Erangal outfall location where BOD varied between 3 to 5 mg/l around the diffusers.

At the upper region of the Mithi River, BOD was found to be above 10 mg/l during low and high tides. The effect of unorganized discharges from drains/nallas is envisaged on the water quality of Mahim creek and also along the shoreline. There is slight improvement in BOD due to improvement in pumping stations (overflows) during low and high tides. The effect of discharges from Worli and Bandra outfalls is also seen near diffusers where BOD varied between 3 to 5 mg/l and 3 to 4 mg/l respectively during low tides. During high tide, this impact reduces slightly due to availability of tidal water for dilution. Due to improvement of treatment and pumping stations (overflow), simulation results indicate improvement in DO as compared to no project scenario (Option 1). Marve, Malad and Mahim creeks exhibited DO below 4 mg/l during low tide. There is improvement in DO during high tide upto middle portion, still upper region of creeks exhibit DO below 4 mg/l. Similarly, reduction in FC was seen from the distribution during low and high tides due to improvement in treatment as compared to no project scenario. Still, FC values exceeded the SW-II standards in west coast including creeks. There is slight improvement in Malad creek due to the diversion of effluent from Malad and Versova WWTFs to proposed Erangal outfall but creek exhibited high FC concentration (above $1x10^5$ CFU/100 ml). Even, FC values were high at shore due to no improvement in wastewater collection.

6.2.3 Option 3 : Improvement in Treatment, Proposed Outfall at Erangal and 50% Improvement in Wastewater Collection

In this option, improvement in treatment ie. 100% preliminary and 100% primary with 50% secondary treatment at Worli, 100% preliminary and 100% Chemically Enhanced Primary treatment at Bandra, 100% preliminary and Secondary treatment at Versova and 100% preliminary and 50% Secondary treatment at Malad was considered. Further 50%improvementin collection systems were considered.

The effluent from Malad and Versova WWTFs is diverted to proposed outfall at Erangal. The details of this option are described in **Table 6.3**.

Table 6.3 : Option 3 for West Coast Improvement of Treatment and Pumping (Overflows) and 50% Improvement in Collection

Zone Number	Area	Treated Effluent Quantity (mld)	Treated Effluent BOD (mg/l)	Treated Effluent FC (CFU /100 ml)	Treated Effluent Disposal	Non Point Discharges Quantity (mld)	Non Point Discharges BOD (mg/l)	Non Point Discharges FC (CFU /100 ml)	Non Point Discharges Disposal
2	Worli	444	91	1.7×10^5	Outfall	49	240	5.50×10^7	Foreshore /Creek
3	Bandra	655	83	3.7×10^5	Outfall	73	240	5.50×10^7	Foreshore /Creek
4 and 5	Malad Versova	970	90	1.7×10^5	Proposed Outfall at Erangal	202	255	5.50×10^7	Creek

Treatment Details : Worli : 100% Preliminary Treatment, 100% Primary Treatment and 50% Secondary Treatment
Bandra : 100% Preliminary Treatment, 100% Chemical Enhanced Primary Treatment
Versova : 100% Preliminary Treatment, 100% Secondary Treatment in 3 –stage Aerated Lagoons
Malad : 100% Preliminary Treatment, 100% Primary Treatment and 50% Secondary Treatment

It can be seen that there was significant improvement in BOD. It was found that BOD at the upper region of the Malad creek, near discharge points through drains/Nallas varied between 3 -10 mg/l, except these areas BOD was found below 3 mg/l during low and high tides. In the upper region of Mahim creek (Mithi river), BOD was found above 10 mg/l and near drains/nallas discharge points it was found in the range of 3 to 10 mg/l. Other than these areas, BOD was less than 3 mg/l. The effect of ocean outfall discharges was also visualized at all the three ocean outfall locations. There was no significant improvement in case of DO, as Marve, Malad and Mahim creeks (Mithi river) exhibit DO below 4 mg/l, except these areas DO was above 4 mg/l during low tide, DO improved during high tide and only the upper regions of Marve, Malad and Mahim creeks exhibited DO below 4 mg/l. In case of FC, there was reduction as compared to Option 1 and Option 2 but not upto significant level. FC ranged $1x10^3$ to $1x10^4$ CFU/100 ml at proposed Erangal and existing Worli and Bandra outfalls during low tide. Similarly, at the upper region Malad and Mahim creeks, it was found above $1x10^5$ CFU/100 ml and at the middle portion it varied between $1x10^3$ to $1x10^5$ CFU/100ml during low tide. FC improved during high tide but still it does not comply with the standards.

6.2.4 Option 4 : Change in Outfall Locations, Diffuser Lengths and Treatment Alternatives

Based on the above mentioned options, BOD improved from no project scenario (Option1) to improvement in treatment and proposed outfall at Erangal. Improvement in BOD can be observed in Malad creek under Options 2 and 3. Improvement due to treatment and wastewater collection can also be seen in creeks and impact zones of existing outfalls. Still, BOD predicted was in the range of 3 to 5 mg/l in the impact zone of outfalls. Even after 50% collection of wastewater, BOD was high at non- point discharges through drains and nallas in the creeks and coast. Similarly, DO improved from Option 1 to Option 3 however, during low tide it did not comply with the standards at Marve, Malad and Mahim creeks due to non-point discharge seven after 50% wastewater collection. FC improved but still it did not comply with the SW-II standards. Even in future scenario considering the treatment alternatives1 and 2 with 100% wastewater collection, predicted FC did not meet the standards. Therefore, Option 4 was formulated considering the changes in outfall locations and diffuser lengths (Option A: outfall length - 3.3km and diffuser length – 300m and Option B: outfall length – 3.5 km and diffuser length - 500m) with treatment alternatives 1 and 2 for water quality simulation.

Treatment Alternative 1: included 100% preliminary +100% primary +50% secondary treatment at Worli; 100% preliminary and 100% chemically enhanced primary treatment (CEPT) at Bandra WWTF; 100% preliminary and 100% secondary treatment (3-stage aerated lagoons) at Versova WWTF;100% preliminary, 100% primary and 50% secondary treatment.

Treatment Alternative 2: included 100% preliminary +100% primary +100% secondary treatment at Worli; 100% preliminary and 100% chemically enhanced primary treatment (CEPT) and 100% secondary at Bandra WWTF; 100% preliminary and 100% secondary treatment (3-stage aerated lagoons) at Versova WWTF; 100% preliminary, 100% primary and 100% secondary treatment

➢ **Outfall Location Option A with Treatment Alternative 1**

In this option, the diffuser location of proposed Erangal outfall was extended upto 3.3 km long with 300 m diffuser length and various treatment levels at WWTFs (Bandra, Worli, Malad and Versova). Treatment alternative 1 along with treated effluent quality and quantity is presented in **Table 6.4**.

Table 6.4 : Option 4 for West Coast
Change in Outfall Location, Diffuser Length and Treatment Alternatives with 100% Wastewater Collection Details in Proposed Erangal Outfall

Outfall Location Option	Position	Longitude	Latitude	Easting	Northing	Outfall Length in Km.	Diffuser Length (m)
A	Diffuser Start	72.758563	19.164139	264063.411	2120507.915	33	300
	Diffuser End	72.753712	19.104104	263763.411	2120507.915		
B	Diffuser Start	72.753712	19.104104	263763.411	2120507.915	35	500
	Diffuser End	72.748961	19.104045	263203.411	2120507.915		

Treatment Details and Levels

WWTF	Treatment Alternative 1	Treatment Alternative 2
Worli	100% Primary Treatment, 100% Primary Treatment and 50% Secondary Treatment	100% Primary Treatment, 100% Primary Treatment and 100% Secondary Treatment
Bandra	100% Primary Treatment, 100% Chemically Enhanced Primary Treatment	100% Primary Treatment, 100% Chemically Enhanced Primary Treatment, 100% Secondary Treatment
Versova	100% Primary Treatment, 100% Secondary Treatment in 3 -Stage Aerated Lagoons	100% Primary Treatment, 100% Secondary Treatment in 3 -Stage Aerated Lagoons
Malad	100% Primary Treatment, 100% Secondary Treatment and 50% Secondary Treatment	100% Primary Treatment, 100% Secondary Treatment and 100% Secondary Treatment

Zone		Alternative	Quantity (mld)	Treated Effluent		
Number	Area			BOD (mg/l)	FC (CFU /100 ml)	Disposal by
4 and 5	Malad	1	1172	100	4.6×10^5	Outfall
	Versova	2		20	1.86×10^4	
2	Worli	1	403	100	6.15×10^5	Outfall
		2		20	3.0×10^4	
3	Bandra	1	728	100	7.5×10^4	Outfall
		2		20	1.5×10^4	

As per simulation results, plume of BOD above SW-II standards at proposed Erangal outfall dispersed upto 3 km and upto 1.5 km at Bandra outfall during low tide whereas no effect was observed at Worli outfall due to deeper bathymetry. During high tide, plume travelled upto 2 km at proposed Erangal outfall, 1.5 km at Bandra outfall and 0.4 km at Worli outfall. While, concentration was more during low tide ranging 3-5 mg/l and 3-10 mg/l during high tide at proposed Erangal outfall due to smaller length of diffusers. Similarly, there was no change in the distribution of DO during both low and high tides as compared to future scenario with treatment alternative 1 and found above 4 mg/l in the modelling domain due to improvement in treatment and 100% waste water collection with concentration ranging between 1×10^2 and 1×10^4 CFC/100 ml. The combined effect of plume at Bandra and Worli outfalls travelled upto 17 km during low tide. Even pattern of the plume at proposed Erangal outfall was same as future scenario alternative 1 with concentration varying between 1×10^2 and 1×10^4 CFC/100 ml and travelled upto 8 km during low tide. The plume with higher FC concentration of 1×10^3 to 1×10^4 CFC/100ml was spread upto 4 km during low tide. There was reduction in FC concentration during high tide due to dilution effect of tidal water and plumes dispersed upto 2.7 km at proposed Erangal outfall, 3.4 km at Bandra outfall and less than 1 km at Worli outfall.

- **Outfall Location Option A with Treatment Alternative 2**

In this option, location and length of proposed Erangal outfall was same as Outfall Option A and change in treatment option as treatment alternative 2. The details of treated effluent quality and quantity are presented in **Table 6.4**. No BOD plumes were observed at proposed Erangal outfall and existing outfalls due to 100% secondary treatment and 100% collection of sewage/wastewater. BOD complied with the stipulated SW-II standards in west coast. Similarly, there was no change in the distribution of DO during both low and high tides as compared to future scenario alternative2 .The pattern of FC plumes at Bandra, Worli and proposed Erangal outfalls was same as future scenario alternative 2 with concentrations ranging between 1×10^2 to 1×10^3 CFC/100ml. The spread of the plume at proposed Erangal outfall was more in both low and high tides due to smaller length of diffuser as compared to future scenario. During low tide, plumes of FC dispersed in downward direction upto 4 km, 2.4 km and 1.2 km at Erangal (proposed), Worli and Bandra. During high tide, the plume at proposed Erangal outfall dispersed upto 1.2 km and less than 1 km at existing Bandra and Worli outfalls.

- **Outfall location option B with Treatment Alternative 1**

In this option, the outfall length was extended upto 3.5 km with 500 m diffuser length, change in location and various treatment levels at WWTFs (Bandra, Worli, Malad and Versova).Treatment alternative 1 along with treated effluent quality and quantity is presented in **Table 6.4**. As per simulation results of BOD, plume at proposed Erangal outfall dispersed upto 3 km and 1.5 km at

Bandra outfall during low tide whereas no effect was observed at Worli outfall due to deeper bathymetry. During high tide, plume travelled upto 1.6 km at proposed Erangal outfall, 1.5 km at Bandra outfall and 0.4 km at Worli outfall. The concentration of BOD at proposed Erangal outfall ranged between 3 to 5 mg/l, at Bandra outfall it was found between 3 to 4 mg/l during both low and high tides, whereas at Worli outfall BOD ranged between 3to4 mg/l during high tide. In case of DO, it was found above 4 mg/l in the modelling domain during low and high tides due to improvement in treatment and 100% wastewater collection. Simulation results of FC indicated its range between $1x10^2$ to $1x10^4$ CFU/100ml at proposed Erangal outfall and dispersed upto 8 km, whereas the combined effect of FC plume at Bandra and Worli outfall travelled upto 17 km downward during low tide. FC during high tide ranged between $1x10^2$ to $1x10^4$ CFU/100 ml and plumes travelled upto 2.7 km, 3.4 km and 1.6km at proposed Erangal, Bandra and Worli outfalls respectively. During high tide, plume travelled less distance due to tidal water dilution.

- **Outfall location option B with Treatment Alternative 2**

In this option, location and length of proposed Erangal outfall was same as Outfall Option Band change in treatment option as treatment alternative 2. The details of treated effluent quality and quantity are presented in **Table 6.4**. No plume of BOD more than 3 mg/l was observed under this scenario due to 100% secondary treatment and 100% collection of sewage/wastewater. Similarly, there was no change in the distribution of DO during both low and high tides as compared to future scenario treatment alternative 2. The pattern of FC plumes at Bandra, Worli and proposed outfalls was same as future scenario with alternative 2 with concentration ranging 1×10^2 to 1×10^3 CFC/100ml. The spread of plume at proposed Erangal outfall shifted to seaward side due to increased outfall length. During low tide, plumes of FC dispersed downward direction upto 2.8 km, 2.4 km and 1.2 km at Erangal (proposed), Worli and Bandra outfalls, respectively. During high tide, the plumes dispersed less than 1 km at proposed and existing outfalls.

6.2.5 Option 5 : Recycle and Reuse of Treated Effluent

Lovegrove (Worli), Bandra, Versova and Malad WWTFs are presently discharging their treated effluent in west coast through existing outfalls (Lovegrove and Worli) and existing outlets (Versova and Malad) in Malad creek. As per MSDP, Stage II priority works, various treatment levels are suggested for all the four WWTFs. Versova and Malad will treat these wage of quantity 1172 mld with effluent quality under treatment alternative 1 (BOD less 100 mg/l and FC 1.7x105 CFU/100ml) and alterative 2 (BOD less than 15 mg/l and $FC1.5x10^4$ CFU/100ml) with 100% wastewater collection. Similarly, Worli and Bandra will treat sewage quantity of 493 mld and 728 mld, respectively with same effluent quality. The present wastewater collection efficiency of the city is 50-55%. It will be difficult to achieve100% wastewater collection efficiency through sewerage system due to practical and feasible constraints. Considering the fact that huge quantity of treated effluent is proposed to be disposed in ocean through outfalls, particularly in water starved region like Mumbai, alternative option like recycle and reuse must also be explored and evaluated for various take holders after removal of bacteria. Also as per MoEF guidelines, it has been suggested and recommended that MCGM should treat the effluent to tertiary level as far as possible so that the water can be reused for industrial activities and for other horticulture/ landscaping. Even treated effluent may be used for flushing and dilution of existing polluted Malad creek.

6.3 Alternative Options for Thane Creek

Following sections describe the various alternative options considered for the betterment of the environmental protection and its impact on the water quality in Thane creek.

6.3.1 Option 1- No Project Scenario

As per this option, there is no improvement in upgradation of treatment, pumping station overflows and wastewater collection. If the proposed schemes are not implemented at Colaba, Bhandup and Ghatkopar WWTFs, wastewater from the open drains and existing level of treated effluent will continue to reach Thane creek through the present system and cause pollution. The details of no project scenario (do nothing option) are described in **Table 6.5**.

As per simulation result of BOD, the upper region near the tip of Thane creek exhibited BOD between 4 to 10 mg/l, whereas near discharge points of drains/nallas, Bhandup and Ghatkopar WWTFs outlets it was found above 10 mg/l and in nearby area varied between 3 to 10 mg/l during low tide. BOD improved during high tide but still the areas described above showed high concentration of BOD (3 to 10 mg/l). DO in the upper and middle portions of creek were found below 4 mg/l, while in lower portion near the mouth it varied between 4 to 7 mg/l during low tide. During high tide, upper region, east and west sides of the creek exhibited DO below 4 mg/l, whereas in middle and lower portions it varied between 4 to 7 mg/l. In upper and middle portions, FC was found above 1×10^5 CFU/100ml and at lower stretch it varied between 1×10^4CFU/100ml to 1×10^5 CFU/100ml during low tide. During high tide, FC improved but not upto compliance level of SW-II standards. Still, upper region exhibited FC above 1×10^5 CFU/100mland at the middle and lower portions it varied between 1×10^2 CFU/100ml and 1×10^5CFU/100ml.

Table 6.5 : Option 1 for Thane Creek
No Project Scenario: No Upgrade of Treatment, No Improvement in Pumping Station Overflows or Collection Efficiency

Zone Number	Area	Treated Effluent				Non Point Discharges			
		Quantity (mld)	BOD (mg/l)	FC (CFU /100 ml)	Disposal	Quantity (mld)	BOD (mg/l)	FC (CFU /100 ml)	Disposal
1	Colaba	35	238	5.2×10^7	Outfall	2	250	5.50×10^7	Foreshore /Creek
6	Bhandup	129	66	1.1×10^6	Creek	194	220	5.50×10^7	Creek
7	Ghatkopar	162	66	1.1×10^6	Creek	354	220	5.50×10^7	Creek

Treatment Details : Colaba : 100% Preliminary Treatment
Bhandup: 100% Preliminary Treatment, 100% Secondary Treatment in Single stage Aerated Lagoons
Ghatkopar : 100% Preliminary Treatment, 100% Secondary Treatment in Single stage Aerated Lagoons

6.3.2 Option 2 : Improvement in Treatment, Pumping Stations Overflows and No Improvement in Wastewater Collection

In this option, only improvement in treatment i.e. 100% preliminary + 100% primary and secondary treatment at Colaba Bhandup and Ghatkopar is considered. No improvement in wastewater collection is considered. The details of this option are described in **Table 6.6**. Improvement in water quality was observed as compared to no project scenario (option 1). At the upper region of the Thane creek, BOD varied between 3 to 5 mg/l and near discharge locations of Bhandup and Ghatkopar effluents, it varied between 5 to10 mg/l during low tide and above 10 mg/l at discharges of drains/ nallas. BOD improved during high tide but still the impact zones of effluent and drain discharges exhibits BOD 3 to 10 mg/l and upper portion of the creek exhibits BOD 3-4 mg/l. Simulation results of DO indicate that it is found below 4 mg/l at the upper and middle portions of the creek and 4-7 mg/l at lower portion during low tide. DO improves during high tide but still upper portion exhibits below 4 mg/l, whereas in middle and lower portions it varies between 4-7 mg/l.

Table 6.6 : Option 2 for Thane Creek
Improvement of Treatment & Pumping Stations (Overflows) and No Improvement in Wastewater Collection

Zone Number	Area	Treated Effluent				Non Point Discharges			
		Quantity (mld)	BOD (mg/l)	FC (CFU /100 ml)	Disposal	Quantity (mld)	BOD (mg/l)	FC (CFU /100 ml)	Disposal
1	Colaba	36	15	1.5×10^4	Outfall	1	250	5.50×10^7	Foreshore /Creek
6	Bhandup	194	13	1.5×10^4	Creek	129	220	5.50×10^7	Creek
7	Ghatkopar	304	13	1.5×10^4	Creek	202	220	5.50×10^7	Creek

Treatment Details : Colaba : 100% Preliminary Treatment, 100% Primary Treatment and 100% Secondary Treatment
Bhandup: 100% Preliminary Treatment, 100% Primary Treatment and 100% Secondary Treatment
Ghatkopar: 100% Preliminary Treatment, 100% Primary Treatment and 100% Secondary Treatment

As per simulation results of FC, there is reduction in FC concentration as compared to Option 1 but not upto considerable level. During low tide, FC varies from $1x10^4$ to 1×10^5 CFU/100ml and above1×10^5 CFU/100ml in middle and upper portions of the creek and in lower portion it varies between 1×10^2 to 1×10^5 CFU/100ml. During high tide, FC improves considerably in lower portion due to dilution and complied SW-II standards in the central zone (below $1x10^2$CFU/100ml). Improvement is also found in middle portion but not up to significant level and FC found in the range 1×10^3 to 1×10^5 CFU/100ml. Upper portion is highly contaminated with bacterial pollution due to high organic loading and less dilution. FC varies in the range of $1x10^4$ to 1×10^5 CFU/100ml and above 1×10^5 CFU/100ml in the upper region.

6.3.3 Option 3 : Improvement in Treatment, Pumping Stations Overflows and 50% Improvement in Wastewater Collection

In this option, improvement in treatment and pumping stations (overflow) and 50% improvement in wastewater collection systems are considered. The details of this option are described in **Table 6.7**.

Table 6.7 : Option 3 for Thane Creek
Improvement of Treatment & Pumping Stations (Overflows) and 50% Improvement in Wastewater Collection

Zone		Treated Effluent				Non Point Discharges			
Number	**Area**	**Quantity (mld)**	**BOD (mg/l)**	**FC (CFU /100 ml)**	**Disposal**	**Quantity (mld)**	**BOD (mg/l)**	**FC (CFU /100 ml)**	**Disposal**
1	Colaba	37	15	1.5×10^4	Outfall	0	250	5.50×10^7	Foreshore /Creek
6	Bhandup	258	13	1.5×10^4	Creek	65	220	5.50×10^7	Creek
7	Ghatkopar	405	13	1.5×10^4	Creek	101	220	5.50×10^7	Creek

Treatment Details :

Colaba : 100% Preliminary Treatment, 100% Primary Treatment and 100% Secondary Treatment
Bhandup: 100% Preliminary Treatment, 100% Primary Treatment and 100% Secondary Treatment
Ghatkopar: 100% Preliminary Treatment, 100% Primary Treatment and 100% Secondary Treatment

Improvement was observed in BOD as compared to Option 1 and Option 2 for Thane creek collection due to secondary treatment of sewage/wastewater and 50% improvement in wastewater. During low tide, BOD was found between 3 and 5 mg/l at the upper portion and impact zone of effluent discharges by Bhandup and Ghatkopar WWTFs. Similarly, during high tide BOD improved but still impact zones exhibit BOD between 3 and 10 mg/l. In case of DO, it is found below 4 mg/l in the upper region, nearby area of the drains/nallas, Bhandup and Ghatkopar effluent outlets during low tide. Other than these areas DO was found between 4 and 7 mg/l. During high tide, DO improved due to dilution effect of tidal water, still the upper stretch, influence area near Bhandup and Ghatkopar outlets exhibit DO below 4 mg/l. As per simulation results of FC during low tide, upper portion exhibit $1\times10^4$to $1x10^5$ CFU/100ml and above, whereas in middle and lower portions it varied between1×10^3 and 1×10^5 CFU/100ml. During high tide, FC improved considerably in lower portion due to dilution water and complied with SW-II standards in the central zone (below $1x10^2$CFU/100ml). Upper stretch exhibited FC above 1×10^5 CFU/100ml and in middle stretch it varied between 1×10^4 CFU/100ml to 1×10^5 CFU/100ml. Although, improvement is there in FC reduction in the middle stretch due to sewage treatment and 50% wastewater collection but did not comply with SW-II standards.

6.3.4 Option 4 – Recycle and Reuse of Treated Effluent

Colaba, Ghatkopar and Bhandup WWTFs are presently discharging their treated effluent in Thane creek through outfall (Colaba) and existing outlets (Bhandup and Ghatkopar). As per MSDP, Stage-II priority works, 100% wastewater collection and 100% secondary treatment of wastewater/sewage is suggested for all the three WWTFs. Ghatkopar and Bhandup WWTFs will treat the sewage of quantity 500 mld with effluent quality BOD less than 15 mg/l and FC $1.2x10^4$ CFU/100ml with 100% wastewater collection. It will be difficult to achieve 100% wastewater collection efficiency through sewerage system due to practical and feasible constraints. Considering the fact that huge quantity of treated effluent is proposed to be disposed in Thane creek, particularly in water starved region like Mumbai, alternative option like recycle and reuse must also be explored and evaluated for various stake holders after removal of bacterial contamination. Also as per MoEF guidelines, MCGM should treat the effluent to tertiary level as far as possible so that the water can be reused for industrial activities and for other horticulture/landscaping.

Chapter 7

Cost Benefit Analysis of Mumbai Sewage Disposal Project Including Five Pumping Stations

7.1 Approach

A cost-benefit analysis helps to answer the question "Is this project worth doing?" Alternate justification helps especially in Government welfare projects.

- Cost-Benefit Analysis is an information support tool that estimates and totals up the equivalent money value of benefits and costs to the community of projects to establish whether they are worthwhile or not. In the field of environmental management, it is applied to identify and measure the costs and benefits of pollution control options and resource management strategies.
- It provides inputs for decisions on how much capital investment is justified relative to the expected benefits. Benefit calculation is a complex task involving estimation of physical damage from pollution (effects on health, economic productivity, ecosystem quality, etc.) and assigning monetary values to that damage.
- Return on investment
- Improved performance e.g. lower operating costs; improved quality; better service
- higher speed or more flexibility
- Better customer service

Benefits can be tangible or intangible. A tangible benefit is something that can be directly measured and costed and an intangible benefit cannot be directly measured or costed. A typical tangible benefit would be increased higher sales resulting in increased income. A typical intangible benefit would be higher customer satisfaction rating: indirectly this might lead to long term branding, but it is not a direct relationship so cannot be easily "costed".

In order to define and assess benefits, one generally needs to know about current conditions (the baseline) and about what the benefit might achieve. This requires good information about the benefit area.

Information about benefits also contributes towards benefits realisation. It is not enough to define the benefits of the project going to deliver; but to also show how these are going to be assessed. For example, if benefit is around improved satisfaction, how will it be measured, and what results are expected? It is important to make sure that measures are directly related to the benefit.

There are various sources of information needed to think about the balance between the quality of the information (primary is usually better) versus the cost of getting it (secondary is usually cheaper).

The most typical limitation of cost benefit analysis is :

- The absence of technical information on the links between pollution, changes in environmental quality and the impacts on economic variables dependent on environmental quality.
- Environmental quality is known to affect economic variables at different levels.

There are two methods adopted for calculating cost –Benefit Analysis

- Direct production performance, such as changes in the production of goods and services for which there is a market (tourism, fisheries, etc.)
- Indirect opportunities available to society for enjoyment of the less tangible "services" of environment like landscape quality, open space for recreation, conservation of ecosystems.

In general, the information deals with the concept of "Willingness to Pay"

The methods adopted can be classified on the size of the projects. Commonly used techniques include:

- Payback
- Average rate of returns
- Net present value(NPV)
- Internal Rate of Return (IRR)
- Modified Internal Rate of Return (MIRR)

7.2 Environmental valuation

The rule of market economics is that the value of a commodity or service depends on its use. The concept of Total economic value [TEV] disaggregates the value of a resource or a site into various components, thus making the valuation problem becomes easier.

Environmental Valuation of Resources:

Total Economic Value (TEV) of a resource consists of:

- Use Value (UV), and
- Non-use Value (NUV)

Use Values may be broken down into

- Direct use value (DUV),
- Indirect use value (IUV), and
- Option value (OV)

Non-use value includes

- Existence Value (Biodiversity value).

Total economic value is therefore: **TEV= UV + NUV or, TEV = [DUV + IUV + OV] + NUV**

Categories of Values

- **Direct or Extractive Use Value**: This value is generally the easiest to measure by observable quantities and prices of products in a market context.

  For e.g., Extractive use value derives from goods which can be extracted from or built on coastal sites, such as the use value of timber extracted from coastal forests, fishing from the sea, sand extracted from the beach, etc.

- **Indirect or Non-Extractive Use Value**. Non-extractive (indirect) use value derives from the services provided by a coastal area. Measuring non-extractive use "aesthetic value" is often far more difficult than measuring extractive use value because the 'quantities' of the service provided are often hard to measure and market prices often do not exist.

  For e.g., wetlands filtering water, improving water quality for downstream users, national parks providing opportunities for recreation, etc. These services have value without any goods being extracted, produced or harvested. The value of non-extractive use services results from people visiting particular coastal area with particular quality characteristics.

- **Option Value:** Derives from maintaining the option of taking advantage of the direct and indirect benefits of a coastal site in the future. Option values are those that approximate an individual's willingness to pay (WTP) in order to ensure that the goods can be accessed at a later date. OVs are some sort of insurance values, in which people assign values to risk aversion in the face of uncertainty.

- **Non-Use (Existence or Biodiversity) Value:** Non-use value derives from the benefits which do not involve using the site in any way, the value that people derive from the knowledge that the site exists, even if they may never actually visit it. Non-use value is the most difficult type of value to estimate, since in most cases it is not, by definition, reflected in production or consumption behavior.

Categories of Value: The following diagram may offer an illustration of the classification of the different categories of services and benefits.

A. Use Services			**B. Non-use Services**
Direct use	**Indirect Use**	**Option**	**Existence**
Extraction and Building development	Recreation	Future use of Direct and Indirect services	Biodiversity and ecology
Timber Quarrying Fisheries Tourism accommodation Tourism services Marinas	Population visits to Coast Aesthetic enjoyment Habitat Marine Species Coastal protection Protection against erosion		Aesthetic Social wealth Natural history education National heritage

Cost Benefit Analysis (CBA) is a tool used to determine the worth of a project, programme or policy. It is used to assist in making judgments and appraising available options.

- CBA is a quantitative analytical tool to aid decision-makers in the efficient allocation of resources. It identifies and attempts to quantify the costs and benefits of a programme or activity and converts available data into manageable information.
- It provides inputs for decisions on how much capital investment is justified relative to the expected benefits.
- Benefit calculation is a complex task involving estimation of physical damage from pollution (effects on health, economic productivity, ecosystem quality, etc.) and assigning monetary values to that damage.
- The most typical limitation of cost benefit analysis is the absence of technical information on the links between pollution, changes in environmental quality and the impacts on economic variables dependent on environmental quality.
- Environmental quality is known to affect economic variables at two levels:
  - Direct production performance, such as changes in the production of goods and services for which there is a market (tourism, fisheries, etc.)
  - Indirect opportunities available to society for enjoyment of the less tangible “services” of the environment like landscape quality, open space for recreation, conservation of ecosystems.
- Production changes are easier to estimate through productivity changes in tourism or fisheries outputs, while indirect effects of pollution not reflected in market prices and quantities, have to

rely on estimates of people's valuation of the environment, in other words, the social demand for environmental quality.

- In principle, CBAs enable agencies to compare the relative merit of different (or alternative) programme or projects in terms of their returns on the use of public resources.
- It is often difficult to provide a clear ranking of alternative demands on public funds. This is perhaps the most controversial aspect of CBA. Environmental characteristics that are not normally bought and sold in the marketplace cannot readily be valued.

7.3 Application of Cost Benefit Analysis

Cost-benefit analysis introduces, among other things, environmental resource valuation necessary for :

- Estimating the social and economic value of environmental quality,
- Measuring the benefits accruing from protecting and enhancing that value and
- Helps justify environmental investment in terms of the benefits generated by environmental resource management.
- Help build up awareness of the economic importance of coastal ecology
- Environmental impacts on the quality of the coastal and marine environment translate into socio-economic losses due to resource productivity changes, loss of income, health effects and cumulative impacts on living conditions, poverty and economic development.
- Comparison of costs and benefits to show net value of the cost of investment, taking into account the conservation of resources achieved by that cost.
- Costs of proposed interventions to reduce pollution.

7.4 Valuation Techniques

Resource valuation methods differ in terms of what they attempt to measure. The values of coastal resources can be measured directly, i.e. Market-based behavior is almost appropriate. For non-market values it is necessary to apply proxies to capture indirect and the non-use value. **Table 7.1** attempts to put together the categories of value outlined above with the corresponding menu of available valuation techniques.

Table 7.1: Choice of Valuation Technique

Category of Value	Resource	Valuation Technique	Measure of value
Direct Use Value Production entering the market Indirect Use Services and Option	Examples: • Tourism income • Fisheries • Timber • Sand quarrying	Market-based data Change-in-Productivity (Production quantities) Surrogate-proxy market data • Cost-based valuation • Contingent valuation (willingness-to pay)	Market prices If market Prices are unreliable, alternative cost approaches • Cost of replacement • Defensive expenditure
Existence Value	Biodiversity Habitat Recreation Aesthetic-amenity	Willingness to pay (or accept payment for loss) Contingent valuation Travel cost	Questionnaire data

Productivity or Market-price Methods: Direct benefits from the coastal environment can be measured using market information.

When market prices are not available or unreliable, proxy market techniques may be used such as replacement costs, defensive expenditure, opportunity cost, etc.

- **Replacement cost**. The cost of replacing beach facilities by swimming pools, the cost of reclaiming beaches, the cost of cleaning up a polluted beach etc., would indicate the minimum use value of the beach.
- **Protective expenditure cost**. The expenditure on engineering works to protect the coast against erosion and maintain a particular level of quality and productivity (preventive or protective investment) also serves to estimate the value of benefits from the use of the beach and its quality.
- **Indirect Valuation:** Valuation of indirect benefits from the services and quality of the coastal environment, such as habitat, recreation, amenity, as well as the biodiversity of the coastal environment, are not reflected in market transactions. It aims to assess people's preferences for biodiversity and the "demand" for conservation relative to development by applying Contingent Valuation Methods (CVM) and Concept of Willingness to Pay.

- **Contingent Valuation**: Contingent valuation relies on data derived through **questionnaire** survey by asking target population groups directly about their willingness-to-pay (WTP) to obtain or preserve a certain level of environmental quality. These are typically used to ascertain the value of **aesthetic benefits and the existence value of ecosystems.** CVM are also applied to value publicly or privately provided goods such as water supply and sewerage in areas without such services.
- **Methodology of Willingness to Pay:** The CVM involves the use of a survey questionnaire to elicit hypothetical willingness to pay (WTP). The common approach is to ask individuals (in a survey) how much they are willing to pay to obtain the change (or to avoid it). A benefit–cost analysis addresses this issue by converting the change of well-being into money, and compares it to the actual money that has been spent on providing the goods.

Steps:

a. Pre- test in a small focus group to determine the likely range that people will be Willing to Pay for the environmental goods or services.
b. This preliminary finding is used to make up a survey instrument, which must inform Respondents about the precise objectives of the interviews and setting up the hypothetical Market.
c. Estimating WTP
d. Follow up questions and reasons

- **Travel cost**: The travel cost method uses information on visitors' total expenditure to visit a site or a park to derive their "demand curve" for the site's services. The technique assumes that changes in total travel costs are equivalent to changes in admission fees, thus attempts to deduce value from observed behavior.
- **Hedonic method:** Hedonic Models have been widely used to examine the contribution of environmental quality to property prices. It is a preferred method for estimating value or demand.

The capital and operation-maintenance cost of the wastewater treatment facilities, and others are shown in **Table 7.2**.

Table 7.2 : Capital and Operation Maintenance Cost of the Wastewater Treatment Facilities

Treatment works	Existing peak flow Capacity in [MLD]	Existing Treatment method	Proposed Treatment method	Capital cost of upgradation [in crore]	Operation & maintenance cost of upgradation [in crore]
Colaba WWTF	101	Preliminary	Activated Sludge process	84.3	4.38
Worli WWTF	1820	Preliminary	Activated Sludge process	470.4	23.5
Versova WWTF	295	Preliminary	Three stage lagoon	331.7	16.58
Malad WWTF	530	Preliminary	Activated Sludge process	933.9	37.35
Bhandup WWTF	370	Preliminary	Activated Sludge process	506.4	31.10
Ghatkopar WWTF	553	Preliminary	Activated Sludge process	668.1	44.8
Bandra WWTF	1910	Preliminary	Chemically Enhanced Primary Treatment	134.1	6.35
Malad SPS		571	28		
Versova SPS & SPM to Versova WWTF		381	15		
New EPS at Malad & Construction of Effluent Transfer tunnel from Malad EPS to Erangal Outfall Shaft		244.9	10.0		
New EPS at Versova & Construction of Effluent Transfer tunnel from Versova EPS to Erangal Outfall Shaft		147.8	5		

Table 7.2 (Contd..) : Capital and Operation Maintenance Cost of the Wastewater Treatment Facilities

Treatment works	Existing peak flow Capacity in [MLD]	Existing Treatment method	Proposed Treatment method	Capital cost of upgradation [in crore]	Operation & maintenance cost of upgradation [in crore]
Erangal Outfall Shaft Works		677.40	2.0		
Afghan Church		8.22			
Harvey Road		5.78			
Nepean Sea Road		5.61			
Chimbai		4.06			
Vallabh Nagar		37.25			
Total costs		**5220.14**	**224.06**		

Source: MCGM, through correspondence, 2013

7.5 Environmental Attributes

7.5.1 Fish and Fisheries

India has a significant coastline of over 8,118 km, an exclusive economic zone (EEZ) of over 2 million sq km and continental shelf area of 0.452 million sq. km. Fisheries plays an important role in regional and national economy and this sector has been recognized as one of the powerful income and employment generators as it stimulates growth of a number of subsidiary industries. Fishery is the only sector that offers cheap and good animal protein to the people, particularly to the economically weaker sections of the society.

Figure 7.1 : Location Map of Fish Landing Centers in Mumbai Fishery District

Fishery Status of Mumbai District

There are 5 major fish landing zones at Mumbai district. Major fish landing centres in five zones of Mumbai district are shown in **Figure 7.1.**

Year-wise marine fish landings in Mumbai Fishing Zone for the last 10 years (2001-02 to 2011-12) is presented in **Table 7.3**.

Table 7.3 : Marine Fish Production from Mumbai Fishing Zone During the Years (2001 to 2011)

Fish catch	Marine Fish Production [MT]	In terms of value (INR lakhs)	Price per tonne in respective year (INR)	Price per kg (INR)
Year				
2001-02	180285	39979.65	22176	22
2002-03	162254	42471.09	26176	26
2003-04	165282	42878.77	25943	26
2004-05	169871	44828.25	26390	26
2005-06	160594	44916.25	27969	28
2006-07	181888	55773.91	30664	31
2007-08	184679	66251.93	35874	36
2008-09	162681	64598.71	39709	40
2009-10	159560	71873.45	45045	45
2010-2011	143157	68801.25	48060	48

(Source: EIA of Shivaji Memorial Report. NEERI, 2014)

7.5.2 Tourism

Mumbai is a wonderful tourist destination. This erstwhile insignificant port city has now developed to become one of the foremost metropolises of the world. Other than the charms of being in beautiful metropolis, Mumbai has monuments of historical importance. The Gateway of India is one such magnificent monument and prime tourist attraction in the city. The city also has wonderful beaches and these beaches have become wonderful leisure spots for people. The average expenditure for a domestic tourist ranges from Rs. 1000-Rs.3000 per person per night while for a foreign tourist may vary from Rs. 25000 upto Rs. 40000 for a high end tourists for a 10 day trip as per Ministry of tourism.

The Main tourist Destinations in Mumbai are:

Gateway of India	Prince of Wales Museum	Jahangir art Gallery
Hanging Garden	Mahalaxmi Temple	Haji Ali
Sidhivinayak	Elephanta Caves	Nehru Planetarium
GirgaonChowpatty	Marine Drive (NCPA)	

In Mumbai Suburban

Sanjay Gandhi National park	Kanheri Caves	Mahakali Caves
Girlbert Hill, Andheri	Juhu Chowpatty	Aksa Beach
Madh Island	Essel World	

The total number of visitors from April 2011 till March 2012 is presented in **Table 7.4.**

Table 7.4 : Month Wise Domestic and Foreign Visitors in Mumbai from April 2011 till March 2012

	11-Apr	11 May	11 Jun	11 July	11 Aug	11 Sep	11 Oct	11Nov	11 Dec	12 Jan	12 Feb	12 Mar	Total
Domestic Visitors													
Mumbai	2191458	2376863	2400511	2302108	2490833	2576564	2601439	2679896	2766002	2169404	2030979	2082530	28668587
Mumbai Sub Urban	356812	401574	398355	370521	355200	412690	425852	430518	455158	418975	469646	456455	4951756
Foreign Visitors													
Mumbai	138386	237874	137292	139978	140343	241112	141272	155237	155366	143917	136752	137487	1705016
Sub Urban	1055	1478	1063	783	2760	4390	6524	9025	9725	3882	6810	10330	56831
Total Visitors													
Mumbai	2329844	2524737	2537803	2442086	2631176	2717676	2742711	2835133	2921368	2313321	2267731	2220017	30373603
Sub Urban	357867	403052	399424	371304	356960	417080	432376	439543	464883	422857	476456	466785	5008587

Source: Ministry of Tourism, Annual Report 2012-13

7.5.3 Health

Health is the level of functional or metabolic efficiency of a living being. Environment contributes to the health of human being in positive and negative ways. Better nutrition and clean environment will help to increase to the life span whereas polluted environment will cause deterioration of Health. In Mumbai, MCGM largely takes care of the health care services. The state government, private organizations and private medical practitioners also contribute in providing the health care services. Birth rate in Mumbai was 14.30/1000 population and the death rate was 7.08/1000 population for the year 2012. Surveillance of monsoon related diseases such as hepatitis, malaria, gastroenteritis, Dengue etc. was carried out by the epidemiology cell. The malaria statistics for the year 2010-2012 are given in **Table 7.5.**

Table 7.5: Ward wise Comparison of Malaria Positive Cases in Mumbai : 2010-2012

Ward	2010	2011	2012
A	1670	1272	757
B	837	543	261
C	1713	574	273
D	3043	990	513
E	5617	2901	876
F/S	7287	2984	1048
F/N	3317	1558	729
G/S	8204	5847	1604
G/N	4261	1716	917
Total [City]	**35949**	**18385**	**6978**
H/E	2543	1269	631
H/W	2673	1192	404
K/E	4918	2761	1129
K/W	3704	1518	822
P/S	3003	1315	344
P/N	2294	1219	621
R/S	1424	811	356
R/C	1531	885	497
R/N	676	339	288
Total [WS]	**22766**	**11309**	**5092**
L	7229	3842	1256
M/E	1364	897	554
M/W	1899	1203	487
N	4274	1971	671
S	1989	1175	667
T	1285	1040	381
Total [ES]	**18040**	**10128**	**4016**
MUMBAI	**76755**	**39822**	**16086**

Source: ESR of Brihanmumbai 2012-2013

*S*ignificant decrease in cases of malaria can be attributed mainly to effective sanitation programme implemented and also good efforts of Malaria Control Department for Public Awareness. The figures have been shown in **Table 7.6**.

Table 7.6: Comparison of Malaria Positive Cases in Mumbai : 2010-2012

Data	**2010**	**2011**	**2012**
No. of Samples collected	1384538	1627912	1489525
No. of Positive cases	76755	39822	16086
No. of deaths	145	69	45

Source: ESR of Brihanmumbai 2012-2013.

Dengue cases have been increasing each year but have caused few deaths. **Table 7.7** shows the positive cases of Dengue observed:

Table 7.7: Comparison of Dengue Positive Cases in Mumbai : 2010-2012

Year	**Cases**	**Deaths**
2010	115	3
2011	416	3
2012	1008	5

Source: ESR of Brihanmumbai 2012-2013.

7.6 Environment Costs The Costs of Inaction

7.6.1 Direct Costs

a) Fisheries

The available data shows a steady production of fishes from 2002-03 upto 2005-06, after which there is an increase in the productivity for 2 years (2006-07 & 2007-08). From 2008-09 up to 2010-11 gradual drops in productivity per year is observed. Thus average fish production loss from 2008-09 up to 2010-11 has been considered for the study. The average fisheries production losses were calculated to be of 9762 MT from year 2008-09 up to 2010-11. In the report by *Glafkos Constantinides (2000)* half of the fish production has been considered due to pollution related impact. Reduction in the fish production has been considered as 20 and 30% as conservative figures based on the personal surveys with fishermen and their opinion that fish catch decline has been due to pollution **(Table 7.8)**.

Table 7.8 : Two Cases of Affected Scenario

Calculation	Description
Loss of productivity in 2008-09 to 2009-10	3121 MT fish
Loss of productivity in 2009-10 to 2010-11	16403 MT fish
Avg. loss in productivity in 3 yrs	19524/2 = 9762 MT fish
CASE I- ***20% of avg. loss of productivity*** 20% of 9762 Cost of pollution related fishery losses	 1952 MT fish 1952000kg × Rs.48/kg = Rs. 9.3715crores.
CASE II- ***30% of avg. loss of productivity*** 30% of 9762 Cost of pollution related fishery losses	2928.6 MT fish 2928600 kg × Rs. 48/kg = Rs. 14.0573crores

b) Tourism

The Mumbai city attracts about 30373603 visitors for the year 2012-13 including both foreign and domestic while the sub-urban Mumbai attracts about 5008587 visitors of both foreign and domestic kind for the same year. The average expenditure as per Ministry of Tourism for a domestic tourist is Rs. 2000 per person per night [Rs. 2000× 7 days = Rs. 14000 for a week] while for a foreign visitor is minimum Rs. 25000 for a week. It is difficult to estimate the impact on tourism however a socio economic survey carried out for 200 respondents indicate a pattern which has been used for arriving at round up. The total income due to tourism of the city will then be Rs. 51473 crores per year. We assume that at least 10% of tourism income that is Rs. 5147crores is at risk. The World Bank Report on Environmental Strategy in Middle East and North Africa, 1995, (Report No. 13601 – MNA) quotes estimates of between 11–22% of tourism reduction on account of environmental neglect as plausible. In the report by *Glafkos Constantinides (2000)* it is assumed that 10% of total tourism income is at risk and 50% of that is value added, which has been applied here **(Table 7.9)**.

Table 7.9 : Estimation of Tourism Related Monetary Risk

Calculation	Description
Total domestic visitors 2012-13	33620343
Total Foreign visitors 2012-13	1761847
Income from Domestic visitors	33620343 × Rs. 14000 per person per week = Rs. 47068.48 crores
Income from Foreign visitors	1761847 × Rs. 25000 = Rs. 4404.62 crores
Total income generated for year 2012-13	Rs. 51473.10 crores
10% of Total tourism income is at risk	Rs. 5147.31 crores
50% of that is value added	Rs. 2573.65 crores

c) Health

Data for the year 2012-13 shows that there were 17094 cases of malaria and dengue. Other diseases like Skin diseases, Typhoid, Cholera may be considered but limited availability of information limits this part of environmental cost. Partially treated wastewater when released causes problems like odor, attract mosquitoes which can cause Malaria, Dengue besides certain skin diseases may also affect the individuals when they come in direct contact with such water loaded with sewage. The lack of proper information limits this section. Various assumptions to evaluate the cost have been considered. Treatment cost per person per visit for this city has been assumed to be Rs. 300 which is a conservative figure and based on survey **(Table 7.10)**. For estimating the cost of health impacts only in cases of Malaria and Dengue have been considered which add to 17094 cases for year 2012-13. Two categories of costs are estimated: viz. the cost of treatment and the cost of income loss from loss of working days. The total number of deaths due to malaria and dengue is 50 during 2012 **(Table 7.11)**.

Table 7.10 : Morbidity Cost Due to Malaria and Dengue

Calculation	Description
Total no. of positive malarial cases for year 2012-2013	16086
Total no. of positive dengue cases for year 2012-2013	1008
Total No. of cases	17094
Treatment cost per person per visit is assumed to be	Rs. 300
Cost of treatment per year	=Total no of cases × Treatment cost =17094 × Rs. 300 = Rs. 0.513 crores
Avg. minimum wage rate of unskilled, semi-skilled, skilled and highly skilled for workers*	Rs. 360 per day
7 day income wages	Rs. 360 × 7 = Rs.2520
Loss of income days due to illness	7 days
Assuming 40% of total affected cases are considered to be working population, loss of income during illness.	40% of 17094 × Rs. 2520 = Rs. 1.723crores
Total cost	=1.723 crores + 0.51 crores = Rs. 2.233 crores

** Ministry of Labour, Govt of India, 2013*

Table 7.11 : Mortality Cost Due to Malaria and Dengue

Calculation	Description
No of deaths due to Malaria and Dengue	50
No of persons above 18 years (assuming 59% are above 18 years of age according to the Census data of 2011)	= 29.5
Loss of income due to death (assuming 60% of these people earn) in one year	= 29.5 x 360 Rs./day x 25days/month x 12 x 0.6 = Rs. 0.1912 crores
No of persons below 18 years of age (assuming 41% are below 18 years according to the Census data of 2011)	= 20.5
At an constant wage of 360 Rs /day and loss of 20.5 wage earners the annual loss of earning starting 10 years after death(assuming 60% of these people earn) in one year)	= 20.5* 360 Rs/day x 25 days/month x 12 = Rs. 0.1328 crores
The present value of this today	= Rs.0.0512 crores
Total loss of income due to death	= 0.191crores +0.0512 crores= Rs. 0.242 crores

7.6.2 Indirect Costs

7.6.2.1 Recreation

Recreation benefits concern the enjoyment of coastal areas of natural beauty by the national population. Tourism values have been considered above. There is no direct market for recreation in open access areas and valuation of such environmental services would need to be based on survey information revealing the social valuation that the local population place on recreation opportunities, known as "contingent valuation". Such valuation would reflect the indirect (non-production) benefit from the “services” of environmental quality. To estimate recreation benefits would ideally involve calculations of how much people would be **Willing to Pay** to have access to recreation areas of a certain level of quality, requiring a survey of social preferences. However, recreational benefits are as real and important as direct benefits and cannot simply be ignored. Often, proxy information is used referring to how many people visit coastal or marine parks for recreation in combination with indicative travel cost data and entrance fees costs to estimate the social valuation of access to protected or natural coastal areas. In the absence of information of this kind it is reasonable to classify this source of benefit as qualitative.

7.6.2.2 Biodiversity

The existence value of the environment is a very elusive parameter but one of potentially high value. Due to increased pollution level of water, serious effects are observed on the biodiversity of the marine flora and fauna. Reductions in the no. of fish species have a significant effect on income from fisheries. It refers to the value that people themselves place on the preservation of the ecosystem free of any use for productive activities. It is the social value of the ecosystem as part of the natural heritage. Economic valuation is constrained by the difficulty of establishing proxy values to make up for the lack of market prices and reveal the demand for coastal and marine diversity. Estimates are typically based on Contingent Valuation studies that attempt to utilize survey results which show the responses of people to questions referring to their **willingness to pay** for conservation of biodiversity of flora and fauna. Such data are rare in any case.

Assumptions used in Analysis:

- Fisheries: Average rate of fish/kg is considered as Rs. 48.
- Tourism: as per the Ministry of Tourism, average expenditure of a domestic tourist is considered to be Rs. 2000 per person per night while for foreigners Rs. 25000 for a trip of 7 days.
- Cost of Treatment per person per visit is Rs. 300.
- According to Ministry of Labour and Employment, Govt. of India, Avg. of Minimum wage rate of ‘A’ class city for un-skilled, semi-skilled, skilled and highly skilled worker employed in Construction or Maintenance of roads or runways or in building operations including laying down underground electric, wireless, radio, television, telephone, telegraph and overseas communication cables and similar other underground cabling work, electric lines, water supply line and sewerage pipe lines is Rs. 360.

7.7 Conclusions

The total capital cost of the project is estimated to be about Rs. 5220 crores and operation and maintenance cost is about Rs.224 crores. Based on the calculations the total benefit per year is about Rs. 2585.51crores. While calculating the total benefits, other benefits such as recreation, biodiversity, land pricing etc have not been quantified and hence not considered. The benefit from health effects has only malaria and dengue cases considered due to lack of information. Other diseases such as skin diseases etc have not been considered. It is important to note that direct cost benefits alone indicate the positive result which is expected due to this project implementation.

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