3

HABITAT CHARACTERISATION

GENERAL

The present day environment of the Meda creek has been analysed for its physical and chemical components to prepare a baseline dataset on the characteristics of the study area as a present day habitat so that can be compared with the past record. The geomorphology, geology as a substrate, creek water chemistry, creek bottom sedimentology and clay mineralogy were analysed along with the micro palaeontology. The present chapter deals with the details on the geomorphology and physicochemical conditions of the Meda creek.

GEOMORPHOLOGY

Geomophologically, the Meda creek display a mosaic of landforms formed by present day natural processes and human induced activities superimposed on local geology. Several local geomorphic units like beach/mouth bar complex, tidal channels, tidal flats, ancient tidal flats, shore platform, coastal cliffs, spit, backshore dunes, pediments and coastal plains have been mapped in the study area. Submerged sand shoals occur near the creek mouth, which get periodically exposed during low tides. Near the high water line the intertidal zone is fringed by a very narrow strip of sandy beach that extends further landwards to form a zone of coastal dunes (Figure 3.1). The northwestward longshore currents redistribute the locally derived carbonate sand which is dominantly bioclastic in nature. The creek mouth characteristically shows a presence of about 2 km long spit that almost

blocks the creek mouth (Figure 3.2). The spit turns in to a mouth bar during peak summer in absence of the flushing current from the land, and many times local fishermen breach it to open a narrow channel for the navigation.

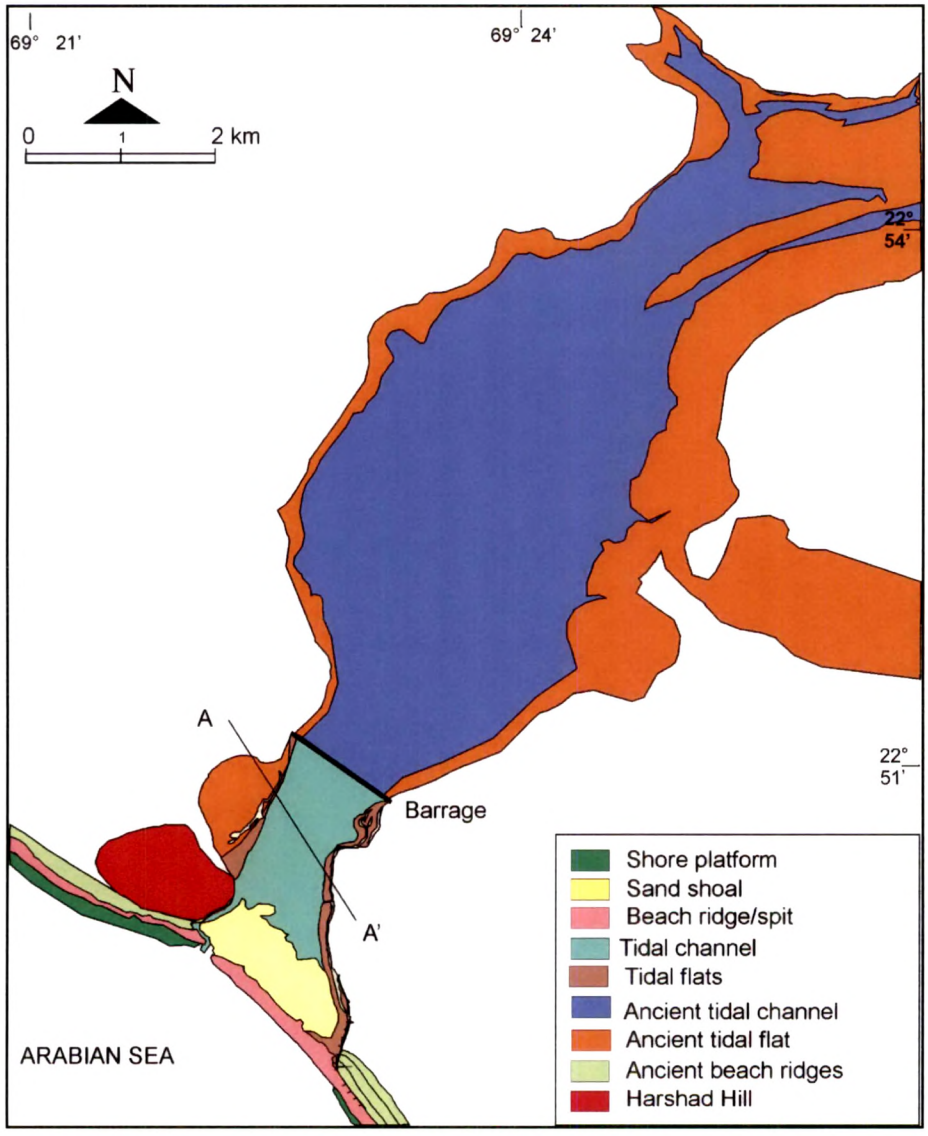

Figure 3.1 Geomorphology of the Mada creek and its adjoining area.

Figure 3.2 A view of the mouth of the Meda creek from the top of the Harshad hill.

Rocky cliffs shape out the southern coast near Miyani and extend further south behind the spit, having imprints of older shoreline features on it. A narrow linear depression that seasonally gets flooded separates the younger sand spit unit and the palaeo cliffs. The combination of spit-bar and associated sand shoal protects the Meda creek from the waves of the open sea. In general, the creek behaves more or less like a sheltered lagoon.

Meda creek tidal channel is a narrow linear depression which extends from the creek mouth towards a barrage, constructed 3 km upstream. The main channel profile along NW-SE shows that the main channel is close to the western bank of the depression (Figure 3.3). Another small channel is also formed on the eastern bank; however it does not reach to the sea, mouth bar and associated sand shoal creates a barrier on the eastern bank. This results in a shallow depression behind mouth bar and Miyani mainland.

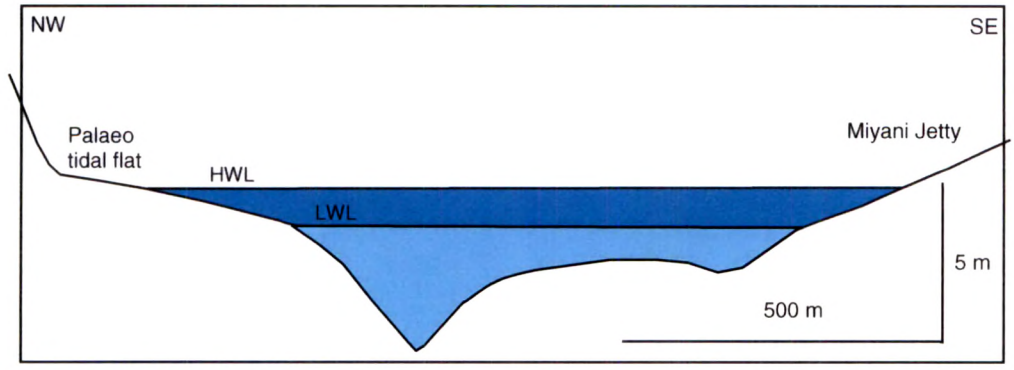

Figure3.3 Bathymetric profile of the Meda creek along A-A' shown in Fig 3.1

The creek is fringed by the active tidal flats that grade further in to palaeo tidal flats related to the relatively higher sea level in the past. The active tidal flats consist of mostly silty clay and get exposed during low tide and remain inundated during high tide. On the Western bank of the creek a small patch of stunted mangrove plants (mainly *Avicinia marina*) have been observed. As per the SOI

sheet of 1970, the tidal flats were existed up to 4 km landward with luxuriant growth of the mangroves, before the construction of barrage.

A large linear barren tract could be seen up to 8 km upstream of the barrage. This area is in general very flat that gets exposed during the summer when several embryonic dunes form due to interception of sands by small plants/herbaceous cover. However, after monsoon the region behaves as a shallow wetland due to the storage of rainwater behind the barrage. Palaeo tidal flats associated with palaeo tidal channels are exposed on both sides of the barren area, and could be distinctly identified by their flat nature and comparatively higher elevation to the present tidal flats.

Towards the open sea rocky intertidal forms a linear narrow zone, having a width of about 50 m, extending westwards from the high water line. The intertidal exhibits two distinct physiographic domains because of two distinct types of rocks exposed. Down the hill of Harshad, basaltic rocks of the Deccan Trap Formation are exposed in the intertidal. The zone shows a positive relief formed due to spheroidal weathering of the parent rocks. In contrast to this, in northwest side where shell limestone of the Chaya Formation are constituting the intertidal, highly dissected surface has formed due to typical cellular weathering defined by the varying size cup like structures with sharp edges. These two distinct nature of the intertidal seems to have an influence on the distribution of the benthic biota in this zone.

An attempt was made to understand relation between morphology and biota in this intertidal area.

INTERTIDAL MORPHOLOGY AND BENTHIC FAUNA DISTRIBUTION

A survey was carried out during the low tide, to study the control of this substrate morphology differences on the distribution and diversity of the intertidal benthic community along two shore-normal transects T1 along basalt and T2 along limestone (Figure 3.4).

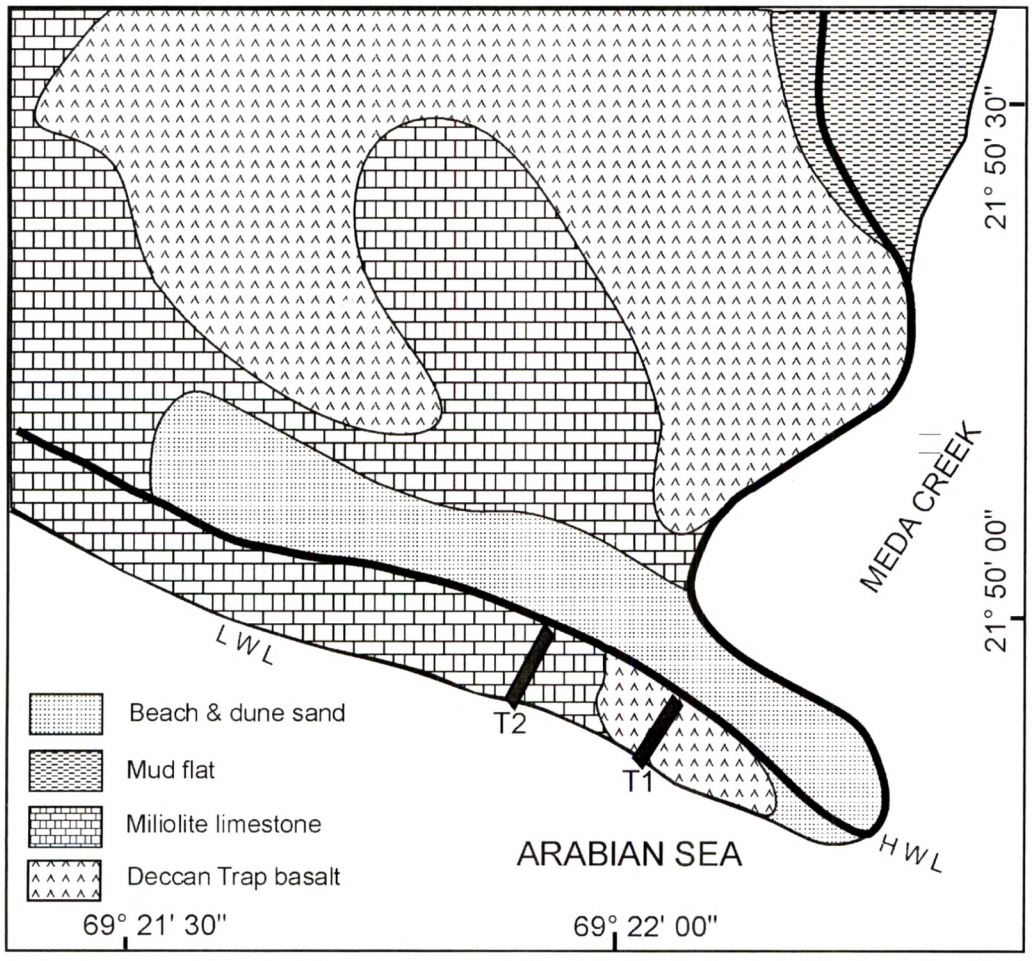

Figure 3.4 Location of transects T1 and T2 in the rocky intertidal for the study of diversity of the benthic fauna diversity

Intertidal fauna were studied on an exposed coast during the low tide period. Quantitative assessments were made for the dominant species using Transect Quadrate Methods (TQM) in two shore-normal transects T1 along basalt and T2 along limestone (Figure 3.4). Representative samples were hand picked and kept in glass bottle containing 5 to 10% neutralised sea water formalin solution. Standard

catalogues and references were used for the identification of species (Pillai and Patel 1988, Wye 1991, Allen and Steene 1999, Fernando and Fernando 2002).

The species diversity (H') of benthic fauna was calculated according to the Shannon–Weiner formula,

$H' = \Sigma\ Pi \log_e Pi$

where Pi is the proportion of the i^{th} species in the collection and H' is the diversity of a theoretically infinite population.

The species richness (d) was calculated using the following formula (Mergalef 1968).

$$d = S/\sqrt{N}$$

Where, S = number of species.
N = number of individuals.

Dominance index (c) was calculated using the formula (Simpson 1949).

$c = \Sigma\ (ni/N)^2$

Where, ni = biomass of each species
N = total of importance values.

The macro-benthic faunal species, biomass and species diversity at both the stations of rocky intertidal at Harshad coast is listed in Table 3.1. Altogether 19 species of macro-benthic fauna belonging to 9 groups were recorded. The number of species were observe along T-1 were 13, whereas they were 15 along T-2. 9 species were present in both transects, 6 species that were found in transect 2 were absence in transect one were as 4 species of transect 1 were not found in transect 2. Total individuals were more in transect 2 (2308) compared to that of 2 (1840).

Table 3.1 Diversity of macro-benthic fauna along transect T1 and T2

Dist. from LWL in meter	Species	Transect 1		Species	Transect 2		Species
		number	biomass	Diversity	number	biomass	Diversity
0	*Balanus amphitrite* (Barnacle)	40	80				
	Thias tisssoti	4	24				
	Porites sp. (Coral)				400	400	
	Petella vulgata (Common limpet)				4	20	
	Zoanthids sp				200	100	
	Cerithidea cingulata				8	8	
	Total	44	104	0.439	612	528	1.058
5	*Thias tisssoti*	8	48				
	Balanus amphitrite	20	40		20	40	
	Thias rudolphi				4	28	
	Zoanthids sp				80	40	
	Turbo canaliculatus				4	4	
	Total	28	88	0.863	108	112	1 123
10	*Balanus amphitrite*	800	1600		20	40	
	Chiton tuberculatus (sea cradles)	4	20		8	40	
	Terebra palustris	4	40				
	Trochus radiatus	8	40		8	40	
	Zoanthids sp.				40	600	
	Total	816	1700	0.169	76	720	1.538

Table 3 1 contd. .

Dist. from LWL in meter	Species	Transect 1 number	Transect 1 biomass	Species Diversity	Transect 2 number	Transect 2 biomass	Species Diversity
15	*Megabalanus tintinnabulum tintinnabulum* (Barnacle)	12	84				
	Cerithidea cingulata	20	20		8	8	
	Trochus radiatus	8	40		4	20	
	Heteractis crispa (sea anemone)	4	8				
	Paetella vulgata	4	20				
	Terebra palustris	4	20				
	Turbo brunneus				8	8	
	Porites sp.				200	200	
	Total	52	192	2 288	220	236	0.7872
20	*Thias tissoti*	4	24				
	Balanus amphitrite	40	80				
	Trochus radiatus	8	40		16	80	
	Polychete tube	4	12				
	Cerithidea cingulata				16	16	
	Turbo brunneus				4	4	
	Crab				4	40	
	Zoanthids sp.				100	40	
	Total	56	156	1.292	140	180	1 3551
25	*Megabalanus tintinnabulum tintinnablulum*	20	144				
	Polychete tube	4	12				
	Turbo canaliculatus	4			4	4	
	Zoanthids sp.				80	40	
	Crab				8	40	
	Total	28	160	1.15	92	84	0.678

Table 3 1 contd...

Dist. from LWL in meter	Species	Transect 1 number	Transect 1 biomass	Species Diversity	Transect 2 number	Transect 2 biomass	Species Diversity
30	*Nerita albicilla*	4	16		4	16	
	Cerithidea cingulata	600	600		60	60	
	Turbo canaliculatus	4	4		4	4	
	Patella vulgata	4	20				
	Dasychalina cyathina (sponge)				4	12	
	Polychete tube				4	12	
	Balanus amphitrite				100	200	
	Thias rudolphi				*8*	*56*	
	Total	612	640	0.17	184	360	1.682
35	*Turbo canaliculatus*	4	4		20	20	
	Trochus radiatus	4	20				
	Polychete tubes	4	12				
	Balanus amphitrite	100	200				
	Thias rudolphi	4	4		8	8	
	Nerita albicilla	4	16		4	16	
	Porites sp.				400	400	
	Cerithidea cingulata				400	400	
	Total	120	256	1.04	832	844	1.247
40	*Cerithidea cingulata*	8	8				
	Turbo canaliculatus	8	8		8		
	Nerita albicilla	60	240		20		
	Patella vulgata	8	40				
	Balanus amphitrite				12	4	
	Cypraea arabica				4	8	
	Total	84	296	1.32	44	12	1.790
	Average	204	399	0.97	256	342	1 25

The diversity wise most dominating group was Gastropods, having 10 species belong to 8 genuses. Population wise *Balanus amphitrite* (barnacle) was the most dominating species in T-1, other dominating species was *Cerithidia cingulata*. *Porites* sp. (coral) is dominating in T-2 followed by Zooanthids, *Cerithidia cingulata* and *Balanus aphitrite*.

A total of 9 algal species were recorded from the area, of which two were recorded from T-1 and 8 species were recorded from T-2 (Table 3.2).

Diversity of benthic fauna along T-2 is 1.25, which is higher than that of T-1 (0.97). Species richness along T-2 is 0.624, which is also higher than that of T-1 (0.606).

Table 3 2 Algal species present in the rocky intertidal

Species	Transect 1	Transect 2
Ulva sp	p	p
Amphiroa anceps	p	p
Caulerpa racemosa	-	p
Padina pavonia	-	p
Sargassum sp	-	p
Codium elongatum	-	p
Grateloupia indica	-	p
Caulerpa scalpelliformis	-	p
Total	2	8

The substrate along T-1 is of basalt and its toughness makes the rock to withstand against wave action. The typical spheroidal weathering style results in to a positive relief with convex upward nature (Figure 3.5). Therefore, the region gets quickly exposed with low tides, which makes difficult for many organisms to survive in water stress conditions. This is reflected in the comparatively less faunal density and diversity along T-1. Barnacle (*Balanus amphitrite*) is a dominating species in this transect with very high dominating index of 0.56. Barnacles, because of their sealable test, are more tolerant to adverse conditions like desiccation, reduced

feeding time and higher temperature, faced during the low tide (Levintson 2005). These conditions reduce the competition otherwise created by the other species (Burrows and Lodge 1950, Hartnoll and Hawkins 1985) and hence, Barnacles dominate the intertidal region. In addition, the basalt provides uniform surface that helps Barnacles to attach firmly to the rock.

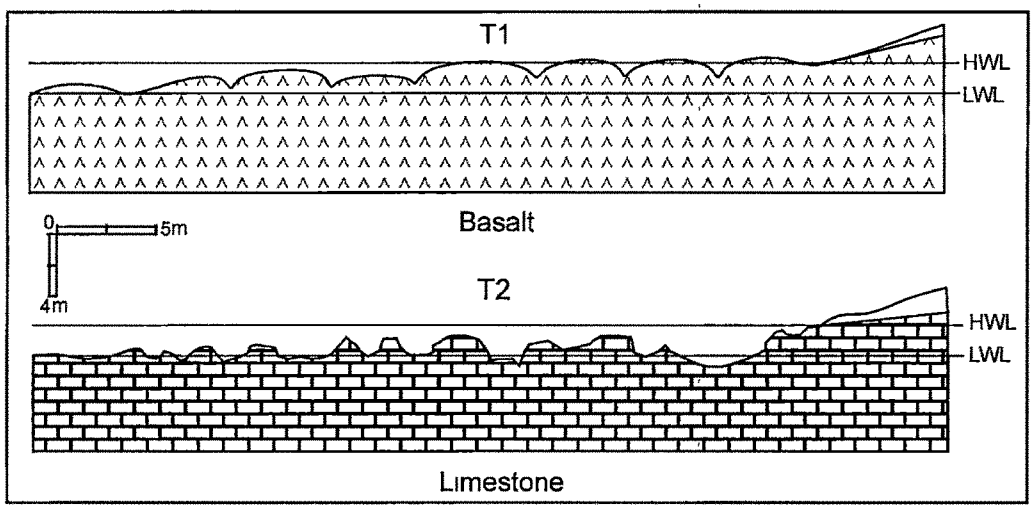

Figure 3 5 Schematic section depicting profiles of transect T1 and T2

The miliolite limestone substrate along T-2 is a porous rock that retains water for longer period, reducing desiccation stress. Due to erosion by the wave action and solution action of water, the limestone forms a typical cellular intertidal containing several pit-holes and solution rills of different shapes and dimension (Figure 3.5). These pits were observed at various places right from the upper to lower intertidal of the transect-2. The shallow water of the pits promoted the growth of macro algae which is well represented along T-2 (Table 3.2). The algae provide a variety of resources for associated benthic fauna, like they increase the amount of space available for attachment, they provide shelter from wave action, desiccation and heat, at the same time they are an important food source. These factors have a positive influence on biodiversity (Hawkins *et al* 1992, Hill *et al* 1998) as observed along T-2.

Observation of a coral species, *Porites* sp. (Figure 3.6) from transect, T-2 is also worth mentioning, as it was dominating (dominating index 0.38) faunal species. Presence of coral is mainly attributed to the solution rills and pits carved in the miliolite limestone. During low tides too, the water remains in the pits and provides a suitable habitat for the coral polyp to establish and grow. Another factor supported the growth of *Porites* sp. is its massive and robust structure unlike the delicate *Acropora* sp, it is resistant to the wave damage (Allen and Steene 1999).

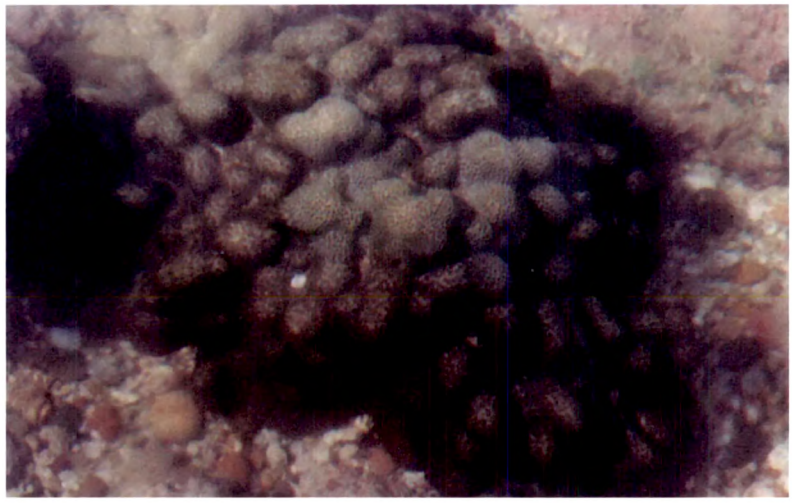

Figure 3.6 Coral, *Porites* sp. in a water pool in the intertidal area along T2.

Recently, corals have also been reported from other places of Saurashtra coast like Dwarka, Veraval, Diu and Mahuva (Raghunathan *et al* 2004). However, this is the first time any species of coral has been noticed in the intertidal region of Harshad. *Porites* sp. is extensively present in the Gulf of Kachchh (Pillai and Patel 1988, SenGupta *et al* 2003), which might have acted as source of coral polyp to the coral sights along the Saurashtra coast (GES 2005), as well as this region. Here, though the occurrence of coral is patchy and does not make any prominent reef, it is still capable of supporting good biodiversity (Raghunathan *et al* 2004, Veron 2004).

It can be concluded that limestone with its complex topography and ability to

support algae and corals formed a better habitat for benthic fauna, whereas due to its positive relief and less water retention the Daccan Trap basalt has supported less diversity of benthic fauna.

PHYSICOCHEMICAL ENVIRONMENT OF THE MEDA CREEK

A multi seasonal behaviour mainly dominated by sea water quality, but with substantially lower energy conditions than the open sea, forms Meda creek a unique habitat. To evaluate the primary habitat conditions in the Meda creek, several proxies pertains to the creek water and creek bottom sediments were studied. The following paragraphs give a details on methodology adopted and results obtained.

Methodology

Sampling

In the year 2003 water sampling was carried out for the three seasons viz., pre-monsoon (April), monsoon (June) and post monsoon (September), from following locations (Table 3.3).

Table 3.3 Locations of sediment and water samples from the Meda creek

No.	Station name	N Latitude & E Longitude
1	Miyani Jetty	21° 50.14' & 69° 22.45'
2	Centre of Creek	21° 50.16' & 69° 22.29'
3	Near Harshad temple	21° 50.15'& 69° 22.16'
4	Down the bridge	21° 50.42' & 69° 22.41'
5	Creek mouth	21° 50 03' & 69° 22.17'

Near bottom water samples were collected from these five locations (Figure 3.7) using *Niskin water sampler.* In July 2004 sediment samples were also collected at these five stations and analysed for sedimentology and micropalaeontology which are discussed in detail in the forthcoming chapters.

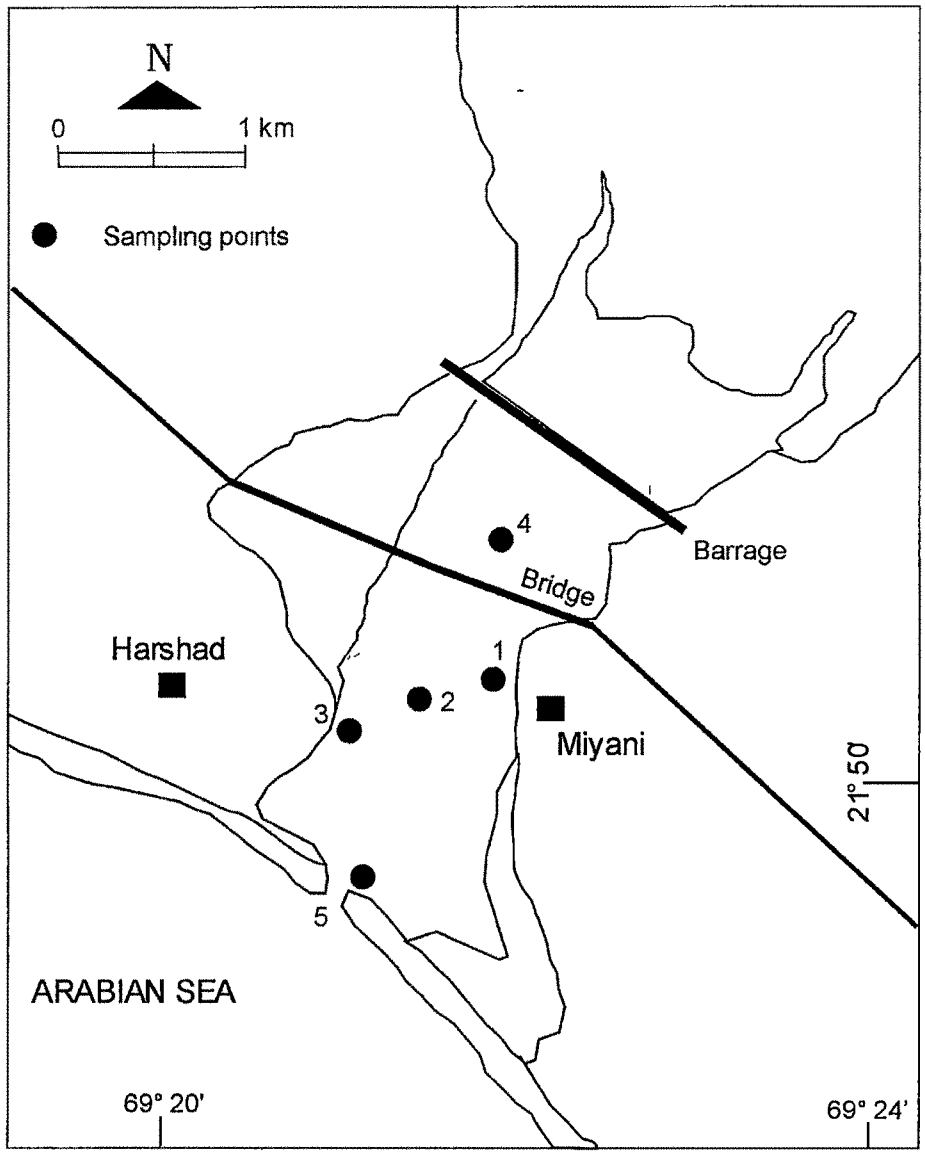

Figure 3.7 Map showing sampling locations in the Meda creek

The water samples were analyzed for its pH, salinity, nutrients and DO properties, following the standard methods (Grasshoff *et al* 1983).

pH

Principle: The pH of solution is measured using a glass electrode, which is sensitive to Hydrogen ion concentration, and a reference electrode ($Hg\text{-}HgCl_2$ or Ag-AgCl electrode).

Reagents: Standard buffer solutions with pH 4.0 and 7.0 are used for the purpose.

These solutions were prepared by respective buffer tablets as per the direction printed on the tablets.

Apparatus: 1) Standard pH meter (Cyberscan 100 digital autometer); 2) glass electrode and reference electrode; 3) glass beaker for pH measurement and 4) thermometer (in measuring range of 0-50°C).

Procedure: Electrodes were connected to the pH meter. The electrodes were dipped in the beaker containing distilled water. The electrodes were wiped and dried with tissue paper and placed in a beaker containing standard buffer solution (pH 7.0). The knob was brought to the 'pH read' position and set the readout to pH 7.0 with 'calibration' knob. After this, the knob was set in 'standby' position. The electrodes were washed with distilled water and dried. Then the electrodes were dipped into the second buffer solution (pH 4.0) and the instrument was allowed to stabilize till a constant pH of about 4 was attained. The readout was adjusted to 4 with the help of knob. After washing, electrodes were placed in the sample and pH reading was noted.

Total Suspended Solids

Principle: Analysis of suspended solids estimates the total amount of suspended particulate matter in a water sample. A well-mixed sample was filtered through a weighted standard glass-fiber filter paper and the residue retained on the filter was dried to a constant weight at 103 to 105°C. The increase in weight of the filter paper represents the total suspended solids.

Apparatus: 1) Mettler AE 163 analytical balance (reading to 5 significant places), 2) Millipore polycarbonate membrane filters, (0.4 µm pore diam., 47 mm filter diam.), 3) forceps, 4) glass fiber filter paper, 4) oven with temperature 0- 110 °C.

Particulate matters were extracted by filtration upon a pre-weighed filter paper of nominal pore size. The weight difference between filter paper, before and after filtration and drying, was used to calculate the amount of suspended solid in the sample.

Salinity

Salinity was calculated by estimating chlorinity. Chloride was determined titrimetrically by adopting the method of Mohr-Knudsen wherein the samples were titrated against standard silver nitrate solution using potassium chromate as an indicator (Grasshoff *et al* 1983).

Principle Chlorides are determined in a natural or slightly alkaline solution by titration with standard silver nitrate, using potassium chromate as an indicator. At the end point all $AgCl_2$ gets precipitated and the excess silver ions react with chromate ions (indicator) to give red brown precipitates (Ag_2CrO_4).

Reagents: 1) 0.025 N Potassium Chromate (indicator); 2) 0.35 N Silver Nitrate; 3) Standard Sea Water (SSW) i.e, 1000 ml of 0.65 N NaCl solution which has $19.375X10^{-3}$ chlorinity .

Standardization of $AgNO_3$ The 10.0 ml of SSW was pipette out into a conical flask and about 25 ml distilled water and indicator, were added into it. $AgNO_3$ solution was slowly added from burette while stirring the titrant vigorously. Titration was continued till the colour of the solution changed from yellow to dirty orange. The standardization repeated thrice to get mean burette reading (cm). The standardization factor (F) was then calculated as:

$$F= N/cm$$

Where, N is chlorinity of the SSW.

Analysis of samples 10.0 ml sample was pipette out into a conical flask. Distilled water (about 25 ml) and indicator (6 drops) were added. Titration was done against the $AgNO_3$. The mean reading (Vc) of three titrations was recorded.

Calculations·

Normalized volume (V):

V= Vc X F

Obtaining the correlation factor (K) corresponding to 'V' from table, the chlorinity and salinity of sample can be calculated as:

Cl = V+ K

S = 1.8-655XCl.

Phosphate – Phosphorous

Phosphate-phosphorus content was estimated by the method of Murphy and Riley, as outlined in Grasshoff *et al* (1983).

Principle: The method is based on the reaction of the phosphate ions with acidified molybdate reagent to give phosphate–molybdate complex, which is then reduced to orthophosphate.

Reagents. 1) 9 N Sulphuric acid; 2) 50 ml of 1 N Ascorbic acid solution mixed with 50 ml 9 N H_2SO_4; 3) Mixed Reagent: 125 ml of 0.045 N Ammonium heptamolybdate tetrahydrate $[(NH_4)_6Mo_7O_{24}.4H_2O]$ mixed with 350 ml 9 N H_2SO_4 added to 20 ml of 0.08 N Potassium antimony tartrate $[K(SbO)C_4H_4O_6]$; 4) Phosphate standard stock solution: 1 ml of 9 N sulphuric acid added to 99 ml of 0.01 N potassium dihydrogen phosphate (KH_2PO_4) .

Apparatus: 1) Stopper glass tubes with 25 ml markings, 2) spectrophotometer and, 3) desiccator.

Calibration and determination of blank· 10 ml of stock solution diluted to 100 ml adding by distilled water so as to obtain 1 m mol stock solution of PO_4^{3-} -P / litre. 25 ml distilled water and 25 ml diluted phosphate standard solution was taken into 3 tubes and 0.5 ml ascorbic acid and 0.5 ml mixed reagent was added to each tube. Absorbances of blank and standards were measured at 880 nm wavelength on spectrophotometer. The factor (F) was calculated from formula:

$$F = \frac{1.0}{Ast - Ab}$$

Where Ast = Mean absorbance of standards
Ab = Mean absorbance of blanks.

Analysis of samples: 25 ml sample taken in a glass tube and 0.5 ml ascorbic acid and 0.5 ml mixed reagent was added to it. The absorbance (As) value was measured using spectrophotometer at 880 nm wavelength.

Calculations·

Calculate the amount of PO_4^{3-} -P in the sample from:

$$\text{m mol } PO_4^{3-}\text{-P / litre} = F \times (As - At - Ab)$$

Total Phosphorous

The measurement of Total Phosphorous was done as per Koroleff method (Grasshoff *et al* 1983).

Principle: Filtered water sample can be oxidised with the help of a strong oxidizing agent (potassium peroxodisulphate) by autoclaving in a closed condition. During the digestion, free chlorine gets liberated which has to be eliminated by adding ascorbic acid reagent.

Sampling and Storage· After collection the sample was preserved by adding 9 N sulphuric acid to (0.4 mg/100 ml) and preserved in cold storage.

Reagents : 1) 9 N Sulphuric acid; 2) Ascorbic acid solution: 50 ml of 1.1 N ascorbic acid $C_6H_8O_6$ mixed with 50 ml 9 N H_2SO_4 ; 3) Mixed Reagent: 125 ml of 0.045 N ammonium heptamolybdate tetrahydrate $[(NH_4)_6Mo_7O_{24}.4H_2O]$ mixed with 350 ml of 9 N H_2SO_4 and 20 ml of 0.08 N potassium antimony tartrate $[K(SbO)C_4H_4O_6]$ was added; 4) Phosphate standard stock solution: 1 ml of 9 N sulphuric acid added to 99 ml of 0.01 N Potassium dihydrogen phosphate (KH_2PO_4); 5) Potassium persulphate solution: 100 ml of 0.3 N potassium peroxidisulphate, ($K_2S_2O_8$) mixed with 5 ml of 9 N sulphuric acid

Apparatus: 1) Stopperd glass tubes, 2) UV spectrophotometer and 3) autoclave.

Calibration and determination of blank. 10 ml of stock solution diluted to 100 ml. 25 ml distilled water and 25 ml diluted phosphate standard solution was taken in 3 tubes. 4 ml peroxidisulphate solution, 0.2 ml 9 N sulphuric acid and 220 mg solid persulphate was added to each tube and dissolved by swirling. After closing the bottles were autoclaved for 30 min. After cooling, contents were transferred to a flask. 1 ml of ascorbic acid and 1 ml of mixed reagent was added to the flask. Absorbance of blank and standards was measured with UV spectrophotometer at 880 nm wavelengths. The factor (F) was calculated from:

$$F = \frac{1.0}{Ast - Ab}$$

Where Ast = Mean absorbance of standards
Ab = Mean absorbance of blanks.

Determination of blanks

(1) Cell-to-cell blank. This blank A_c, was measured as for phosphate.

(2) Reagent blank. The absorbance A_b in the calibration section includes the cell-to-cell blank, A_c, and the absorbance caused by phosphorus in the reagents provided that the redistilled water is free of phosphorus. The reagent blank

$A_{rd}=A_b-A_c$. Usually this blank is of the order 0.01 for a 10 cm cell.

Analysis of samples· 4 ml peroxodisulphate solution and 9 N sulphuric acid and 220 mg solid persulphate was added to 50 ml of sample and dissolved by swirling. The samples were then autoclaved for about 30 minutes, and cooled. 1 ml of ascorbic acid solution added to the samples and was thoroughly mixed. After 4 minutes, 1 ml mixed reagent was added to the sample. Absorbance (As) measured with spectrophotometer at 880 nm wavelength.

Calculations·

The amount of Total Phosphorous in the sample was calculated using:

$$\text{m mol T-PO}_4 \text{ / litre} = F \times (As - At - Ab)$$

$$\Sigma P, \text{ m mol/litre} = F\,[A_s - A_c\,(A_t) - A_b]$$

In near shore waters the determination of A_t may be necessary and is then made on a second portion of the sample, by omitting the reagents after the oxidation step.

Organic Phosphorous

Total phosphorous minus phosphate phosphorous gave organic phosphorus.

Dissolved Oxygen (DO)

Principle: The Winkler method, otherwise known as the iodometric technique. The dissolved oxygen (DO) in a measured volume of water sample is chemically bound by reacting with manganese (II) hydroxide in a strongly alkaline medium. The chemistry of this test is based on the addition of a manganese solution followed up by a strong alkali solution. The DO present rapidly forms hydroxide salts with the manganese.

Sampling and storage· The samples were collected in stoppered glass bottle of 100 ml capacity, 0.5 ml of the manganese reagent (Winkler A) and 1 ml of the

alkali-iodide solution (Winkler B) were added to it.

Reagents: 1) Winkler A: 100 ml of 1.9 N Manganese (II) chloride ($MnCl_2.5H_2O$); 2) Winkler B : 100 ml mixture of 0.06 N potassium iodide (KI) and 0.06 N sodium hydroxide (NaOH); 3) Hydrochloride acid (50 %); 4) 1000 ml of 0.01 N Sodium thiosulphate ($Na_2S_2O_3.5H_2O$) solution; 5) Starch indicator solution (1 gm in 1000 ml) and 6) Standard iodate solution: 1000 ml of 0.01 N KIO .

Apparatus: 1) Burette, 2) Conical flasks, 3) Magnetic stirrer, 4) pipettes and 5) BOD bottles.

Determination of reagent blank: 50 ml of distilled water taken in a conical flask added with 3 ml of 50 % HCl mix and 0.5 ml of Winkler B and Winkler A solutions. Finally 1 ml indicator solution was added to it. This was titrated against thiosulphate solution, the end point was marked by the appearance of blue colour, noted (b ml). This titration was repeated thrice to find the mean titrate value (bm ml).

Standardization of thiosulphate solution: 50 ml distilled water was taken in a conical flask in which 3ml of 50 % HCl, 0.5 ml of Winkler A and 0.5 ml of Winkler B solutions were added. Then 10 ml of, 0.01 N standard iodate solution added. The titration was done with thiosulphate solution in burette till solution turns pale yellow. 1 ml starch indicator solution was added and the titration was continued till the blue colour of the solution disappeared. End point was noted (V ml) from the burette. The titration was repeated three times and mean of three readings (Vm) was obtained.

$$\text{Normality of the thiosulphate (N)} = \frac{10.0 \times 0.01}{Vm - bm}$$

Analysis of samples: 3 ml of 50 % HCl was added to the sample bottle, closed

immediately and shook vigorously till all the precipitates dissolved. 50 ml of this solution was then taken in a conical flask and titrated against thiosulphate solution from the burette, till the solution turned pale yellow. Then after 1 ml of starch indicator was added and the titration was continued till the blue colour of the solution disappeared. The titrate value (S) from the burette was obtained.

Calculations:

The amount of dissolved oxygen in 1 litre of sample can be obtained as:

$$DO\ (ml/Litre) = 5.6 \times N \times (S - bm) \times \frac{V}{V-1} \times \frac{1000}{a}$$

Where N = *Normality of thiosulphate*
S = *Titrate value of sample*
bm = *Mean titrate value for blank*
V = *Volume of the sampling bottle*
a = *Volume of sample titrated (50 ml)*

Note: The factor V/V-1 needs to be corrected for the end volume of the reagents 1 ml added to the sample. Then worked out conversion factor is = (5.6 X 20 X N) X readings

Biological Oxygen Demand (BOD)

Seawater samples were collected in 125 ml glass bottles in duplicate and kept in a box to maintain the temperature close to the ambient till its transportation to the laboratory. The initial Dissolved Oxygen (DO) concentration was fixed in the field and later on measured in one of the bottle whereas other bottle was incubated in dark at 25 °C for three days. The DO concentration in the incubated sample was measured after 3 days by Winkler's method. The BOD_3 was calculated as the difference between the initial and final dissolved oxygen contents.

Nitrate Nitrogen and Nitrite Nitrogen

Nitrite was measured by the Bendschneider and Robinson method as outlined in

Grasshoff *et al* (1983).

Principle: Nitrate in seawater is quantitatively reduced to nitrite by heterogeneous reaction involving zinc-cadmium or copper-cadmium or copper-mercury amalgam in granules, dust or fillings.

The NO_2^- produced thus is determined by diazotizing with sulfanilamide and coupling with N-(1–naphthyl)-ethylenediamine dihydrochloride to form a highly colored azo dye that is measured calorimetrically.

When the sample is passed through the redutor column, nitrate is quantitatively reduced to nitrite while nitrite that is initially present in the sample passes unchanged. Hence, the measured absorbance is due to the initial nitrite in sample and nitrite obtained after the reduction of nitrate. Therefore, a correction has to be made for any nitrite initially present in the sample. During the reduction stage a buffering agent is added to the sample to maintain a stable pH.

Reagents: 1) Sulphanilamide solution: 1000 ml of 0.04 N sulphanilamide ($C_6H_8N_2SO_5$) containing 100 ml of conc. HCl; 2) N-(1-nephthyl)-ethylene diamine dihydrochloride solution (NEDD): 0.5 gm NEDD dissolved in 500 ml distilled water; 3) Buffer solution: 1000 ml of 2.4 N Ammonium chloride (NH_4Cl), having 8.5 pH; 4) Nitrite stock solution: 1000 ml of 0.01N Sodium nitrite ($NaNO_2$), having 10 m mol NO_2-N / ml; 5) Nitrate stock solution: 1000 ml of 0.01 N potassium nitrate (KNO_3), having 10 m mol NO_3-N / ml.

Apparatus: 1) Stopper glass tubes with 25 ml markings; 2) reductor column; 3) UV- visible spectrophotometer (Model Shimadzu UV-1700)

Calibration and determination of blank for nitrite analysis. The stock nitrite solution was diluted to contain 2 m mol NO_2-N / litre. 25 ml distilled water and 25

ml diluted standard solution were taken in triplicate for blank and standard preparation respectively. To each of the six tubes, 0.5 ml sulphanilamide solution was added that was followed by (after 4 min) 0.5 ml N-(1-nephthyl)-ethylene diamine dihydrochloride solution. The reaction was allowed to proceed for 10 minutes. The colour remains stable for 2 hrs. and the absorbance of blanks and standards can measure using UV spectrophotometer at 543 nm wavelength.

$$\text{Factor } FNO_2 = \frac{2.0}{\text{Ast, } NO_2 - \text{Ab, } NO_2}$$

Where Ast, NO_2 = Mean absorbance of the standards and
Ab, NO_2 = Mean absorbance of the blanks.

Calibration and determination of blank for nitrate + nitrite analysis: The reductor column was washed with using buffer solution mixed with distilled water (1 ml buffer solution to 50 ml distilled water). The stock nitrate solution diluted to 5 m mol NO_3-N / litre. 1 ml of buffer solution was added to 50 ml diluted standard solution. This solution was passed through the reductor column. 0.5 ml sulphanilamide solution was added to it was followed by an addition of 0.5 ml NEDD solutions. The reaction was allowed to proceed for 10 minutes. The absorbance of blanks and standards was measured with UV spectrophotometer at 543 nm wavelength. 50 ml of distilled water and 50 ml of diluted standard nitrate were taken in triplicate. 1 ml of buffer solution was added to each of these six tubes. The reductor column was washed using distilled water mixed buffer solution. The samples were then passed through the reductor column. The first 20 ml of sample was discarded and the next 25 ml of sample was collected for the subsequent analysis.

To all six tubes, 0.5 ml of sulphanilamide solution was added that was followed by (after 4 minutes) the addition of 0.5 ml NEDD solutions. The reaction was

allowed to proceed for 10 minutes. The absorbance of blanks and standard was measured at 543 nm wavelength on a spectrophotometer against distilled water as the reference.

$$\text{Factor } FNO_2 + NO_3 = \frac{50}{\text{Ast, } NO_2 + NO_3 - \text{Ab, } NO_2 + NO_3}$$

Where Ast, $NO_2 + NO_3$ = Mean absorbance of the standards and
Ab, $NO_2 + NO_3$ = Mean absorbance of the blanks.

Analysis of samples for nitrite: A 25 ml of sample taken in a glass tube was mixed with the, 0.5 ml sulphanilamide solution, and after 4 minutes 0.5 ml of NADD solution was added to it. The absorbance (as NO_2) was measured at 543 nm wavelength using spectrophotometer.

Analysis of samples for nitrite + nitrate: 50 ml of sample was taken in a glass tube and 1 ml of buffer solution was added to it. The sample has been taken then passed through the redactor column. 0.5 ml sulphanilamide solution added to the filtered sample, followed by (after 4 min) an addition of 0.5 ml NADD solution. The absorbance (as $NO_2 + NO_3$) was measured at 543 nm wavelength of spectrophotometer.

Calculations:

The amount of NO_2-N in sample was calculated from

$$\text{m mol } NO_2\text{-N / litre} = FNO_2 \times (As, NO_2 - Ab, NO_2) \quad \ldots..(1)$$

Calculate the amount of NO_2-N + NO_3-N in the sample from

m mol (NO_2-N + NO_3-N) / litre =

$$F(NO_2\text{-N} + NO_3\text{-N}) \times \{(As, (NO_2\text{-N} + NO_3\text{-N}) - Ab, (NO_2\text{-N} + NO_3\text{-N})\} \ldots..(2)$$

Calculate the amount of NO_3-N in the sample from

$$\text{m mol } NO_3\text{-N / litre} = (2) - (1)$$

Results

The water quality analyses of the Meda creek suggest a dominant influence of the seawater in comparison with the freshwater outflow by the river flow into it. Table 3.4 presents results of the aforesaid analyses carried out for the assessment of the creek water quality. The same are discussed further hereafter.

pH

pH varies in the range of 8.19 to 8.89 that indicates a sea domination on the water quality of the creek (Figure 3.8).

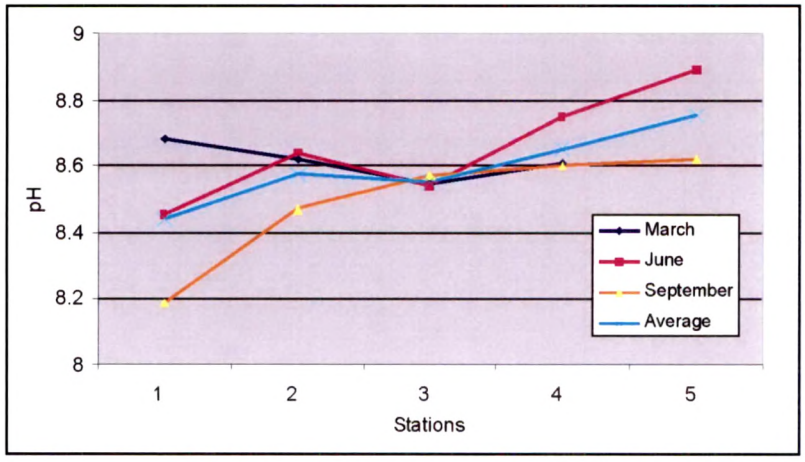

Figure 3.8 Spatial and temporal variations in pH values in the Meda creek water.

The lowest value of pH was recorded near the Miyani jetty; this marginal reduction could be due to release of fresh water as sewage of the village. Average pH remains lower at station 1 (8.44) and 3 (8.55) that could be due to acid germination by the decaying of the organic waste thrown by the adjacent settlements and tourism activities. The pH value is maximum at station 5 (8.76), close to the mouth, indicating high influence of the sea. Exceptionally higher pH at innermost station 4 (8.65) is due to regular isolation and evaporation of water leading to the concentration of carbonates. Nearby large colony of oysters must also be contributing to this elevated carbonates that can show increase in pH. The pH values have not shown much variation at station 3.

Table 3 4 Physicochemical parameters of water in the Meda creek

St. No.	St. Name	pH	TSS mg/l	Salinity ‰	NO2-N mg/l	NO3-N mg/l	PO4-P mg/l	TP mg/l	Org-P mg/l	DO mg/l	BOD mg/l
March											
1	Nr jetty	8 68	425.00	37.33	0.0029	0.074	0 024	0.030	0.006	4 25	1.25
2	Centre of creek	8.62	400.00	39.13	0.0022	0.077	0.016	0.023	0.007	4 37	1.20
3	Nr temple	8.55	292.00	40.94	0.0019	0.075	0 013	0.014	0.001	4 18	1.87
4	Down bridge	8.61	348.00	42.95	0.0028	0 075	0.026	0.028	0.002	4.05	1 35
	Average	8.62	366.25	40.09	0.0025	0.075	0.020	0.024	0 004	4 21	1 42
	Minimum	8 55	292.00	37.33	0.0019	0.074	0.013	0.014	0 001	4 05	1 20
	Maximum	8.68	425.00	42.95	0.0029	0.077	0.026	0.030	0.007	4 37	1.87

73

Table 3.4 cont ...

St. No.	St. Name	pH	TSS mg/l	Salinity ‰	NO2-N mg/l	NO3-N mg/l	PO4-P mg/l	TP mg/l	Org-P mg/l	DO mg/l	BOD mg/l
June											
1	Nr jetty	8.45	425.00	37 00	0.0017	0.215	0.026	0.027	0 001	4 15	1 09
2	Centre of creek	8.64	400.00	38.64	0 0022	0.097	0.028	0.029	0.001	3.75	0.54
3	Nr temple	8.54	292.00	40 33	0.0019	0 093	0.026	0.027	0.001	3 78	1.16
4	Down bridge	8.75	348 00	41.93	0 0022	0.094	0.030	0.032	0.003	3 30	0 41
5	Nr Mouth	8 89	161 00	43.94	0.0022	0.088	0 028	0 029	0 001	3 64	0 91
	Average	8.65	325.20	40.37	0.0021	0.117	0.028	0.029	0.001	3.72	0.82
	Minimum	8.45	161.00	37.00	0.0017	0.088	0.026	0 027	0.001	3 30	0 41
	Maximum	8.89	425.00	43.94	0 0022	0.215	0 030	0.032	0 003	4 15	1 16

Table 3.4 cont...

St. No.	St. Name	pH	TSS mg/l	Salinity ‰	NO2-N mg/l	NO3-N mg/l	PO4-P mg/l	TP mg/l	Org-P mg/l	DO mg/l	BOD mg/l
September											
1	Nr jetty	8.19	489 00	35.69	0.0025	0.143	0.025	0.029	0 004	4 37	1.09
2	Centre of creek	8.47	455 00	36.28	0 0044	0.117	0.030	0 036	0 007	4.39	1 18
3	Nr temple	8.57	372 00	39.51	0.0033	0.121	0.030	0.033	0.003	4 41	1 16
4	Down bridge	8.6	390.00	41.73	0.0043	0.109	0.037	0.045	0 008	4 12	0.62
5	Nr. Mouth	8 62	424.00	43.74	0.0038	0.096	0.025	0 035	0 010	4 45	2.33
	Average	8 49	426.00	39.39	0.0037	0.117	0 029	0.036	0.006	4.35	1.27
	Minimum	8.19	372.00	35.69	0.0025	0.096	0.025	0.029	0.003	4 12	0.62
	Maximum	8.62	489.00	43.74	0.0044	0.143	0.037	0.045	0.010	4.45	2 33

Except the station 1 and 3, other stations have higher pH in June compared to that of March. The effect of the monsoon (September) is observed as drop in pH. However there are minor variations of pH in the study area compared with the estuaries of south Gujarat having very high monsoon inflow as fresh water reduces pH substantially in the range of 6.5-7.6 (Zingde and Desai 1987).

Total Suspended Solids (TSS)

TSS represents both energy conditions and compositions of the sediments. TSS in Meda creek varies from nearly 300 mg/l to 490 mg/l with an exceptional low value of 161 mg/l near the creek mouth during June 2003. Average TSS (Figure 3.9) are maximum at station 1 and 2, indicating elevated energy conditions that must be bringing bottom sediments in to the suspension. TSS are minimum at station 4, where sand dominates the bottom sediments where the waves are not strong enough to take it into the suspension. The minimum TSS at 5 is due to its sheltered nature and minimum energy levels.

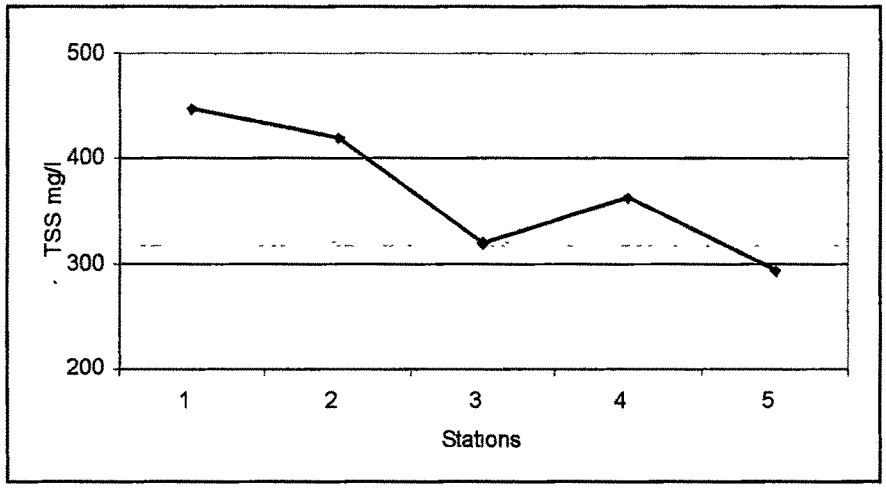

Figure 3 9 Season average TSS at various stations in the Meda creek.

Seasonal picture (Figure 3.10) shows the lowest energy level in pre monsoon (June) leading to low TSS and high TDS in September due to elevated energy conditions due to both, sea waves and fresh water currents.

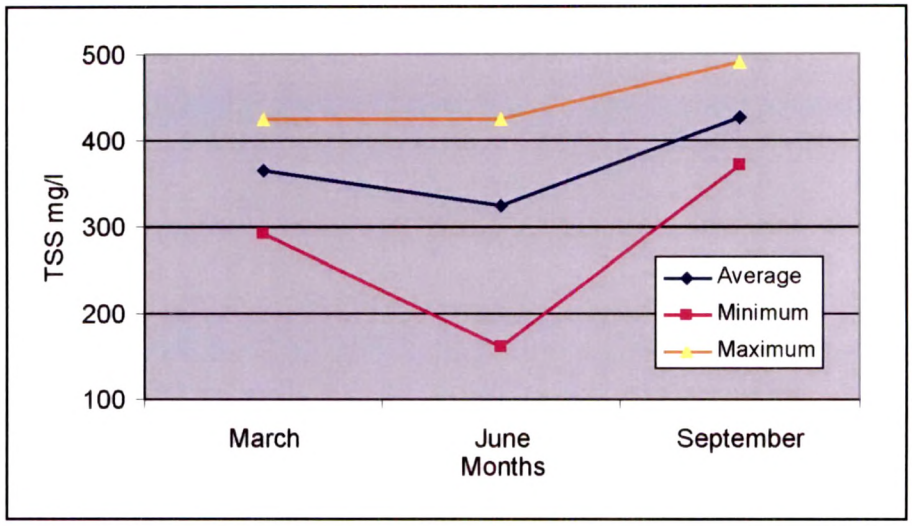

Figure 3.10 Seasonal variations of TSS in the Meda creek.

In general the average TSS value being 350 to 425 mg/l, represents a typical nature of the Meda creek similar to the other estuaries in Gujarat which are shallow bottom with bottom material composed of clay and fine sand, leading to a good amount of material under suspension (Zingde and Desai 1987).

Salinity

Salinity of the water samples varies from 35 to 44 ‰ indicating a higher salinity nature of the creek water. Salinity increases at almost constant rate from station 1 to 5 (Figure 3.11).

The average salinity being lowest at station 1 (36.6‰), reflects the discharge of fresh water from the near by fisherman village, Miyani. The station 2 being closer to station1 still shows lower salinity. Station 4 shows much higher salinity indicating its isolation and salt concentration due to evaporation. Lowered salinity is recorded during September, with average salinity going little below 40 ‰ that may be linked with fresh water input during monsoon.

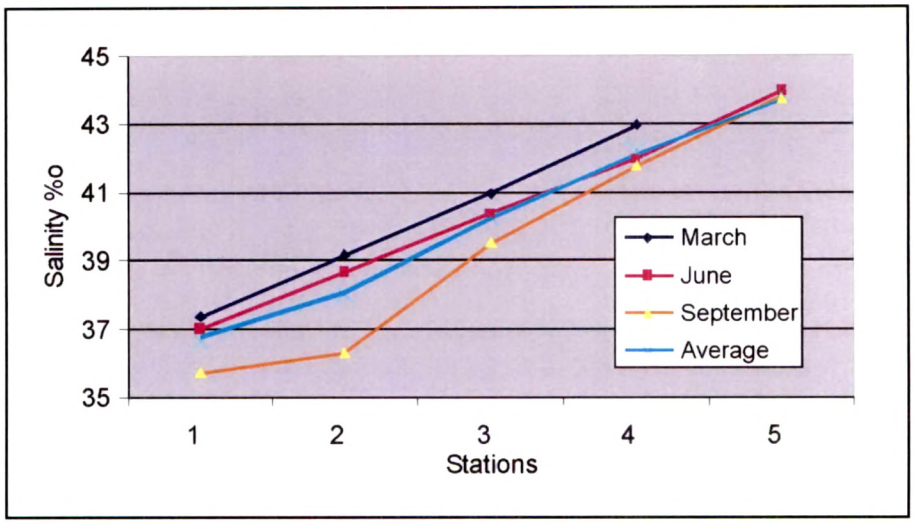

Figure 3.11 Showing increasing trend of salinity from station 1 to 5 in the Meda creek

Nitrite Nitrogen

Concentration of Nitrite nitrogen was found lower (0.024 mg/l) at stations 1 and 3 higher (around 0.03 mg/l) at other three stations (Figure 3.12). Nitrite nitrogen varied within a narrow range from 0.0013 to 0.0030 mg/l during pre-monsoon, which marginally increases to 0.0036 mg/l in post monsoon samples. This indicates its positive correlation the lower organic load and higher pH during summer.

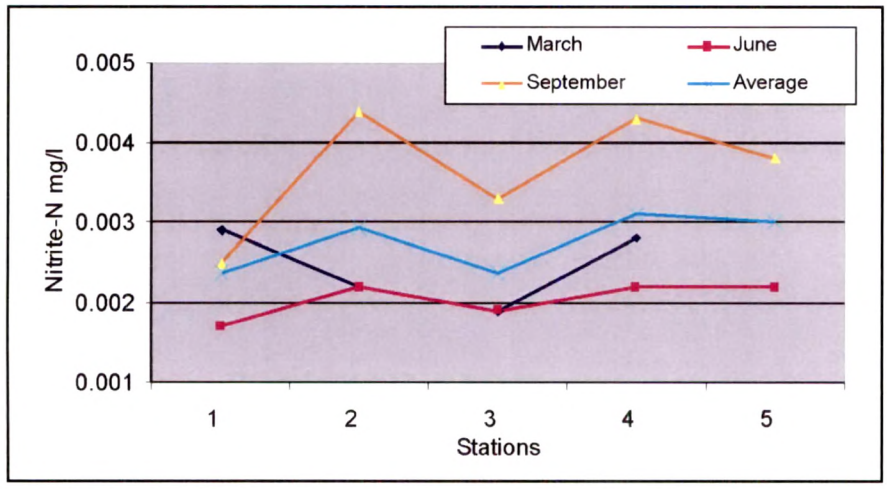

Figure 3.12 Variations of nitrite nitrogen values in the Meda creek water

Nitrate Nitrogen

The estuarine distribution of nitrate from the both, natural and pollutant sources is controlled by the physical processes like circulation of currents and tide pattern

operating in the estuaries. Though, nitrate concentration do not have direct relation with the lower salinity, fresh water inflow from the catchments and algal growth can always be considered as a major factor contributing to the Nitrates (Zinges and Dasai 1987). Nitrate nitrogen concentration varies from 0.074 to 0.215 mg/l (Figure 3.13).

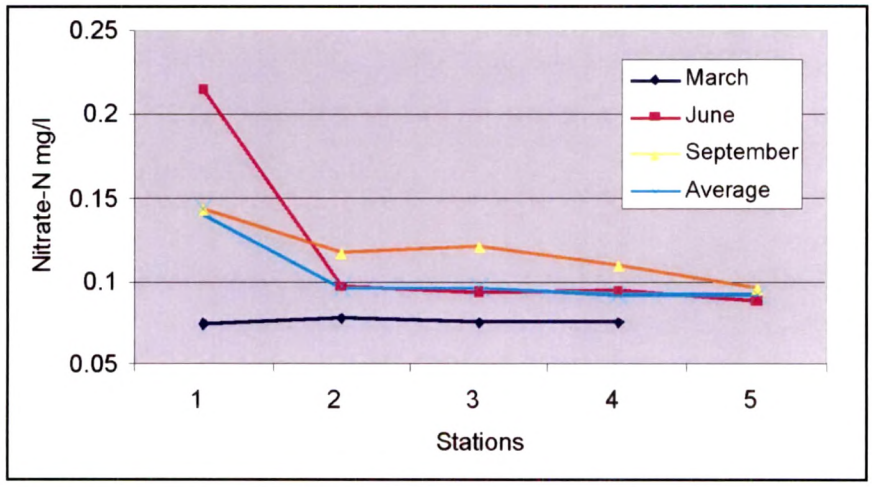

Figure 3.13 Nitrate nitrogen values in the Meda creek water.

Average nitrate nitrogen shows high concentration at station 1 (0.144 mg/l), this can be related to freshwater disposal and related algal growth on the bank of Miyani village. However, the concentration drastically reduces at stations 2 (0.097) and remains more or less constant at other stations. This also supports the inference that the high nitrate at station 1 is only a localized effect.

Nitrate concentration found elevated in the June and September samples, which is due to the increased algal growth in these seasons. Where as March data indicates low nitrate at all stations including station 1, which could be due to very low algal growth during this season.

Phosphate Phosphorous

The main source of phosphate in the costal environment is calcium phosphate minerals which are formed through the partial dissolution and reprecipitation of

skeletal and shell material. Phosphate concentration in the creek water remains in the range of 0.013 to 0.037 mg/l. Station 5, on the mouth and station 4 down the bridge showed higher averages (Figure 3.14).

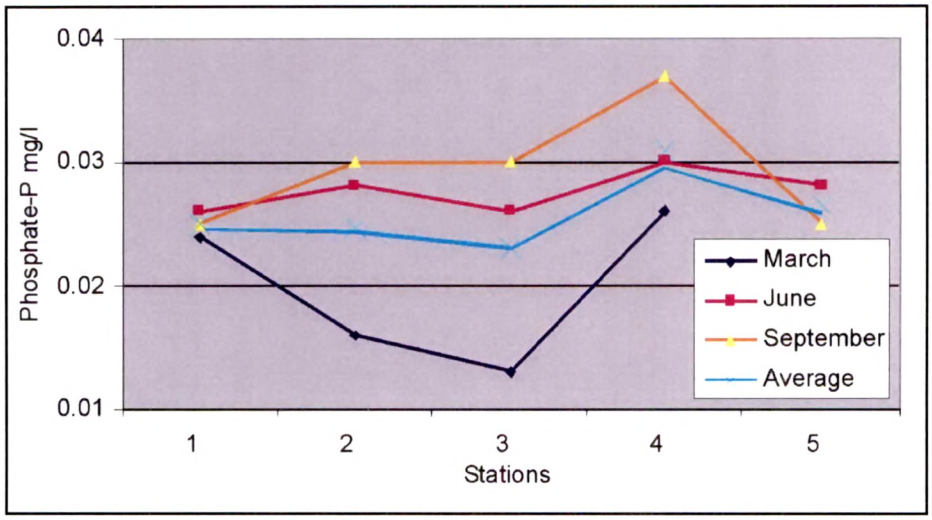

Figure 3.14 Variation of phosphate phosphorous concentrations in the Meda creek water

Distinctly higher concentration of phosphorus (around 0.25 mg/l) at station 1 could be due to constant low pH at that station. Increased biological activities and fresh water inflow leading dissolution of calcium phosphate can be seen in June in an increased phosphate value.

In general the phosphates contractions in the Meda creek were in agreements with that of the Arabian Sea.

Organic Phosphate

Organic phosphate has been recorded in the range of 0.001 to 0.01 mg/l (Figure 3.15). Very low concentration of organic phosphate recorded at station 3 (avg. 0.002 mg/l), indicates low biological activities on this bank, which could be due to a shallow hard rocky substrate, not much favored by a large number of biota.

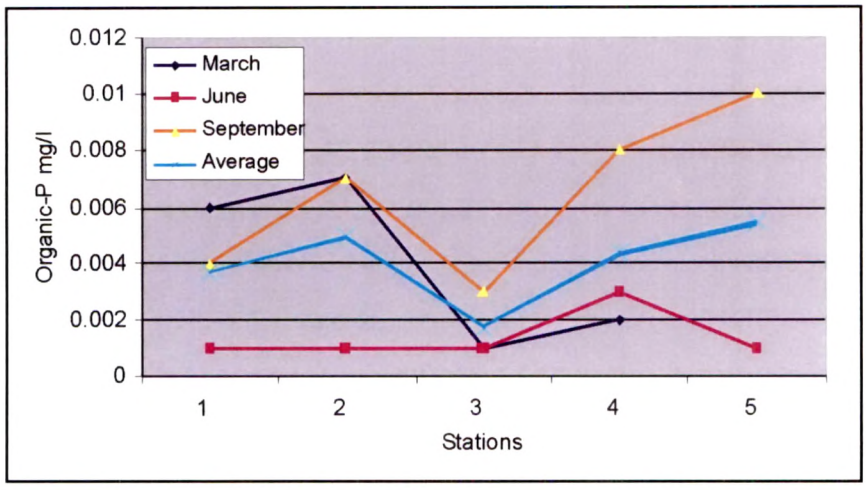

Figure 3.15 Organic phosphates concentration in the Meda creek water.

Organic phosphate concentration has been recorded maximum (0.01 mg/l) at station 5, mouth of the creek close to the calcareous sand, followed by station 4 (max. 0.008 mg/l) under the bridge. This indicates a presence of organic source at these locations. The average concentration declines from pre-monsoon (0.04 mg/l) to monsoon (0.01 mg/l), time and again increases in post monsoon period (0.06 mg/l). This has a relation with changing biological activities and dissolution of phosphates by fresh water.

Dissolved Oxygen (DO)

The DO content of water bodies is an important parameter to be determined, as the existence of aquatic life is intimately linked with the availability of oxygen for their survival. The quantum of DO is largely the net result of consumption for oxidation of organic matter and replenishment from the atmosphere and photosynthesis. DO in surface waters of the Arabian Sea are in the range of 4-5 mg/l, which is in agreement of the DO in the study area (Figure 3.16). However the closed nature of the creek has a reduced DO value below 4, at times. In general DO availability varies in the range of 3.30 mg/l to 4.45 mg/l

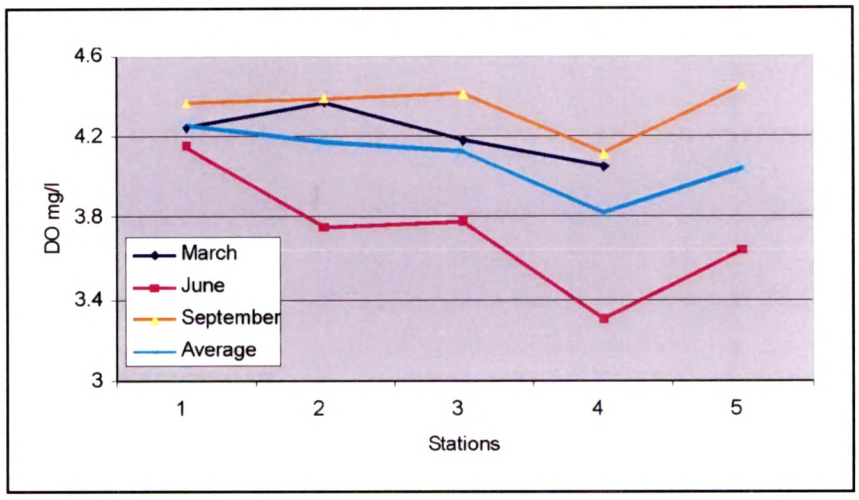

Figure 3.16 Dissolve oxygen values at various stations in the Meda creek water

Average DO reduces from March (4.21 mg/l) to June (3.72 mg/l) indicates increased biological activity as well as less frequent replenishment of DO by the Sea. Whereas September sea water as well as fresh water influx contributes to the increased DO (4.35 mg/l).

The average DO distribution in the Meda creek, regime shows clearly negative relationship with the average concentration of major nutrients (Nitrite nitrogen, Nitrates nitrogen, Organic phosphorous, Phosphate- phosphorous, Silicates) at various stations (Figure 3.17), which implies more nutrients leads to more biological activities and thus reduced availability of DO.

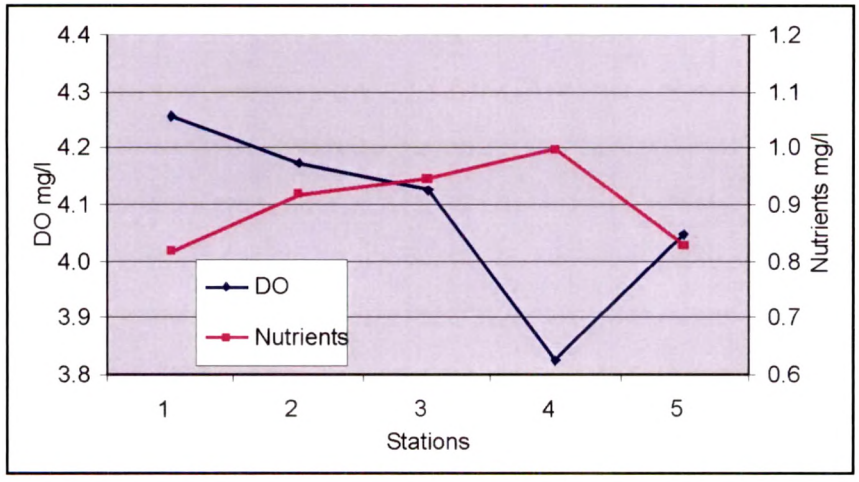

Figure 3.17 Relationship between DO and Nutrients at various stations in the Meda creek

Biochemical Oxygen Demand (BOD)

Through out the year BOD varies with in narrow range of 0.41 to 2, indicating a healthy habitat nature of Meda creek (Figure 3.18). Average BOD remains a bit higher during premonsoon, indicating a lesser rate of replenishment by the Sea tides; this is because during this season mouth bar almost detaches the creek from the open sea.

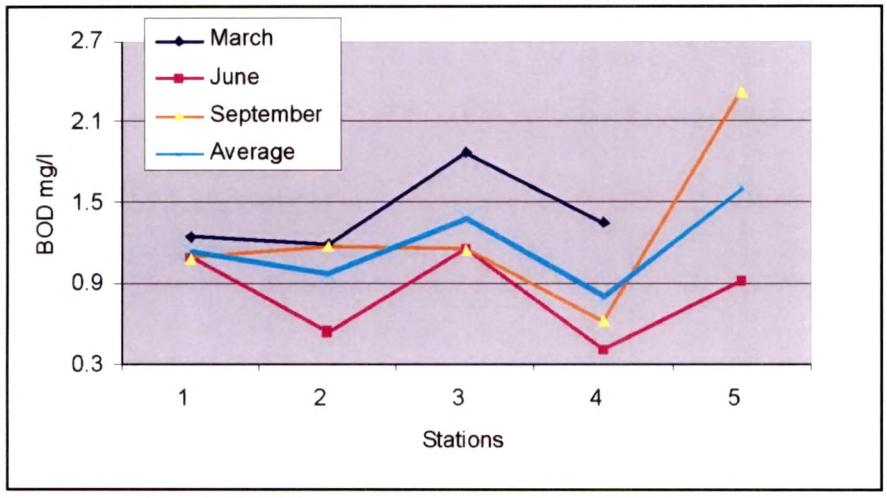

Figure 3.18 BOD recorded at various stations in the Meda creek

Average BOD has remained higher at station 1 and 3, contributed by the waste disposal by human on both the banks. An elevated BOD at station 5 near at mouth in post monsoon could be due to large dropping of large concentration of bird (seagull) population on near by sand shoal.