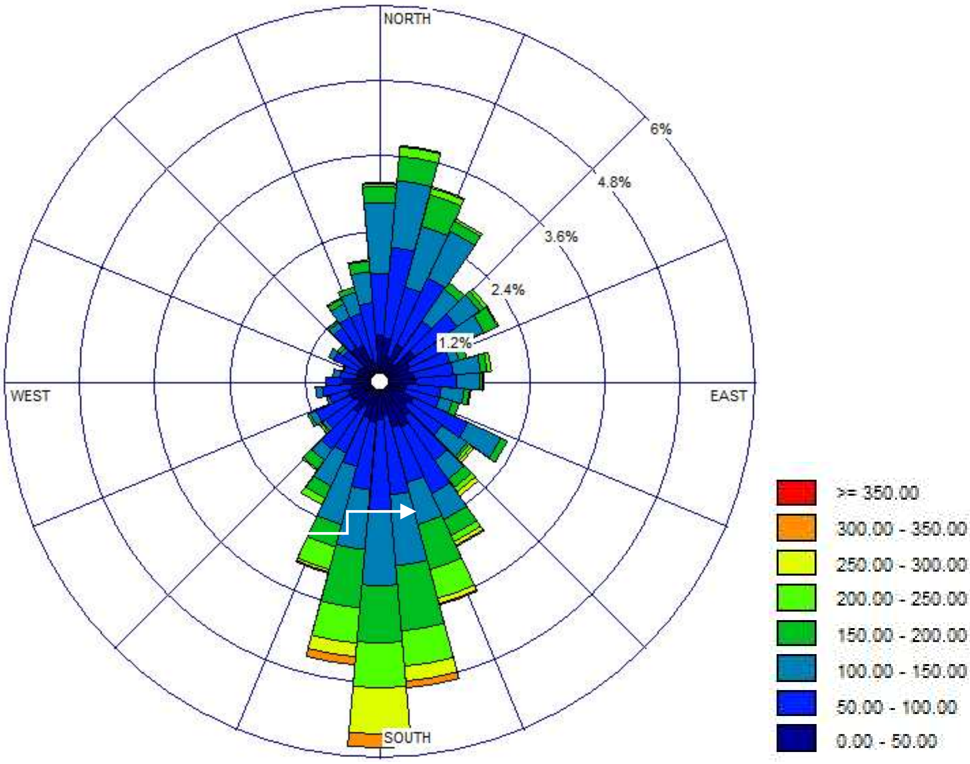


Figure 19– Rose plot -near surface current Vs direction (speed in mm/s)

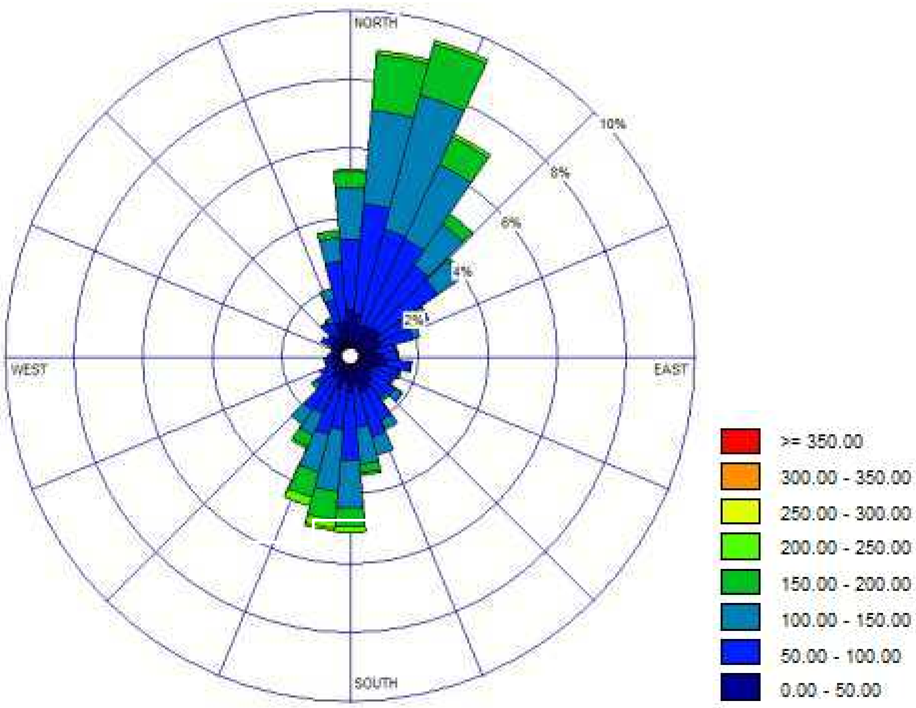


Figure 20 – Rose plot - mid-depth current Vs direction (speed in mm/s)

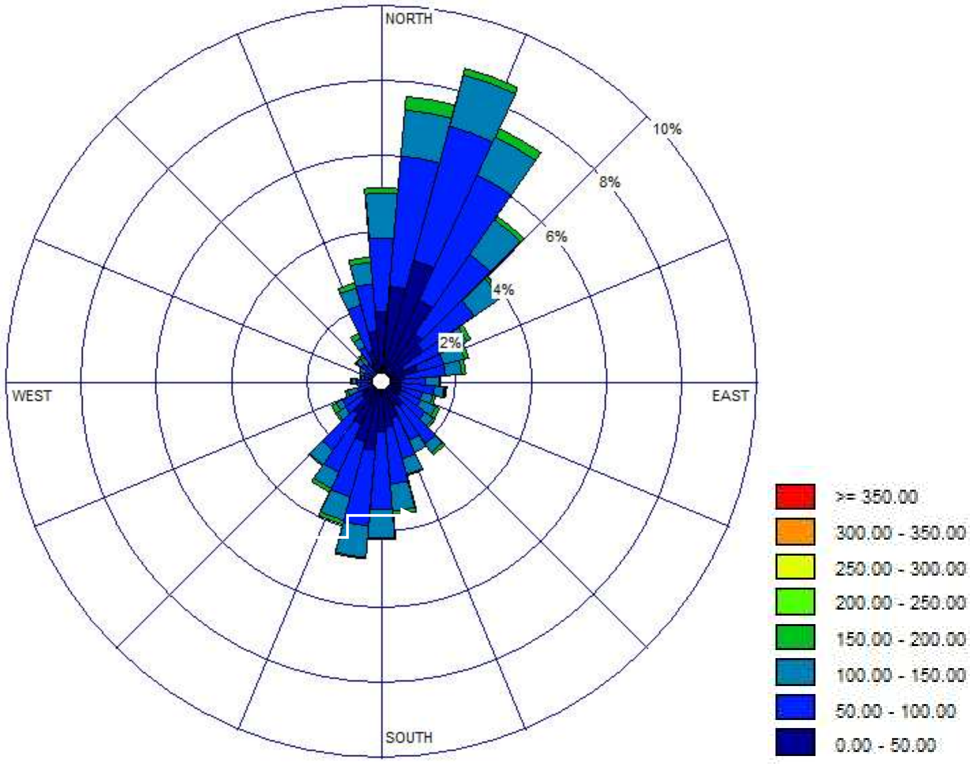
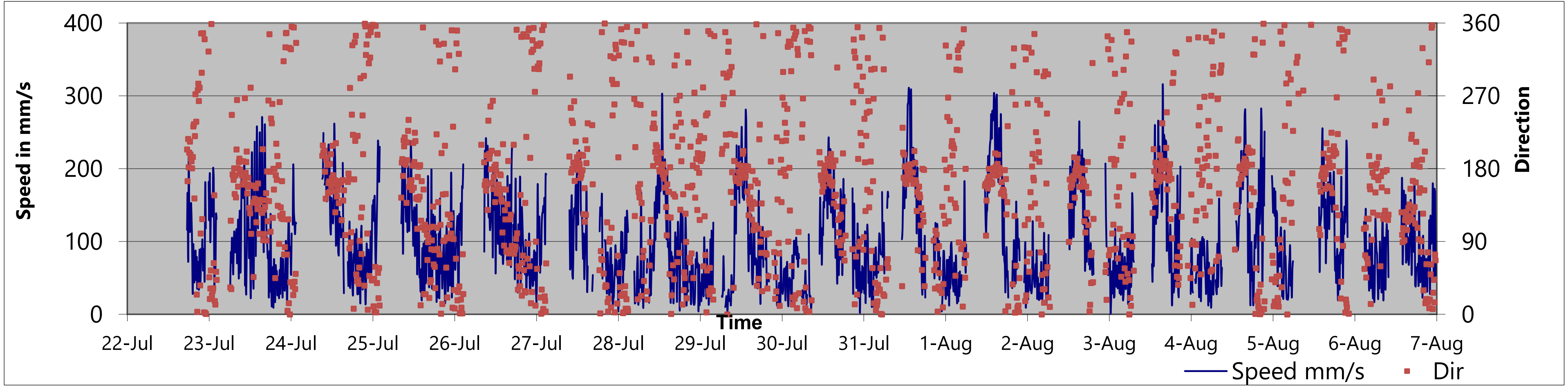


Figure 21 – Rose plot - near seabed current Vs direction (speed in mm/s)

The time series curves for the period, drawn for near surface, mid-depth and near seabed are represented in **Figure 22, Figure 23** and **Figure 24.** The surface currents were of the order of 300mm/s with a maximum of 366mm/s recorded on 10th August 2018 at 0940 hrs. The mid depth currents were of the order of 200mm/s. The near seabed currents were less compared to the surface currents.



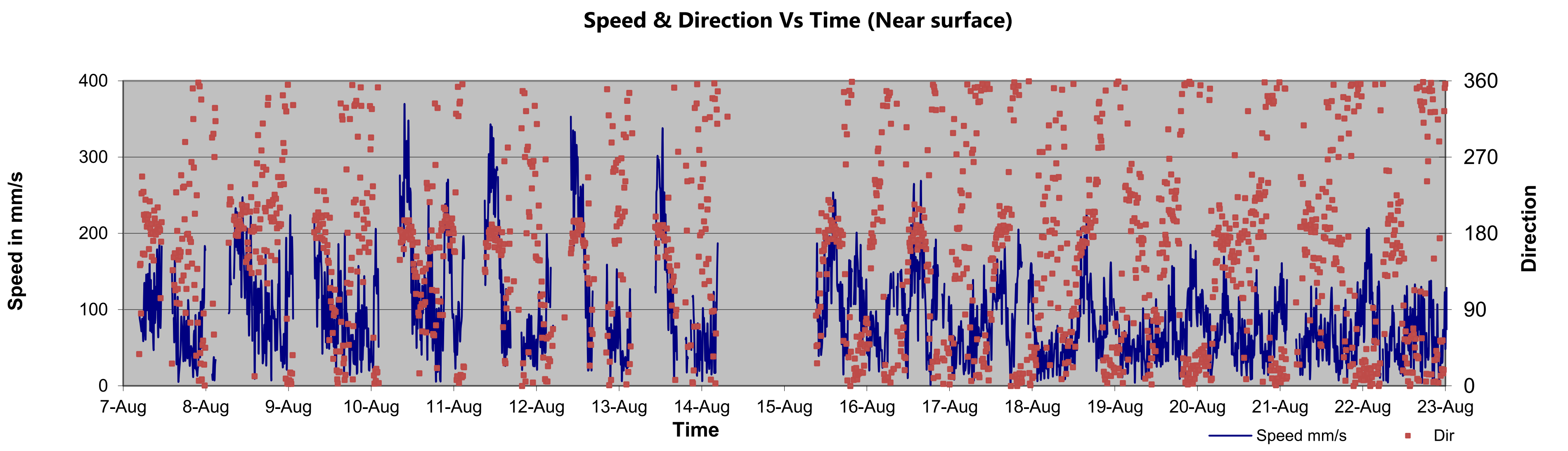


Figure 22 – Near Surface time series curves

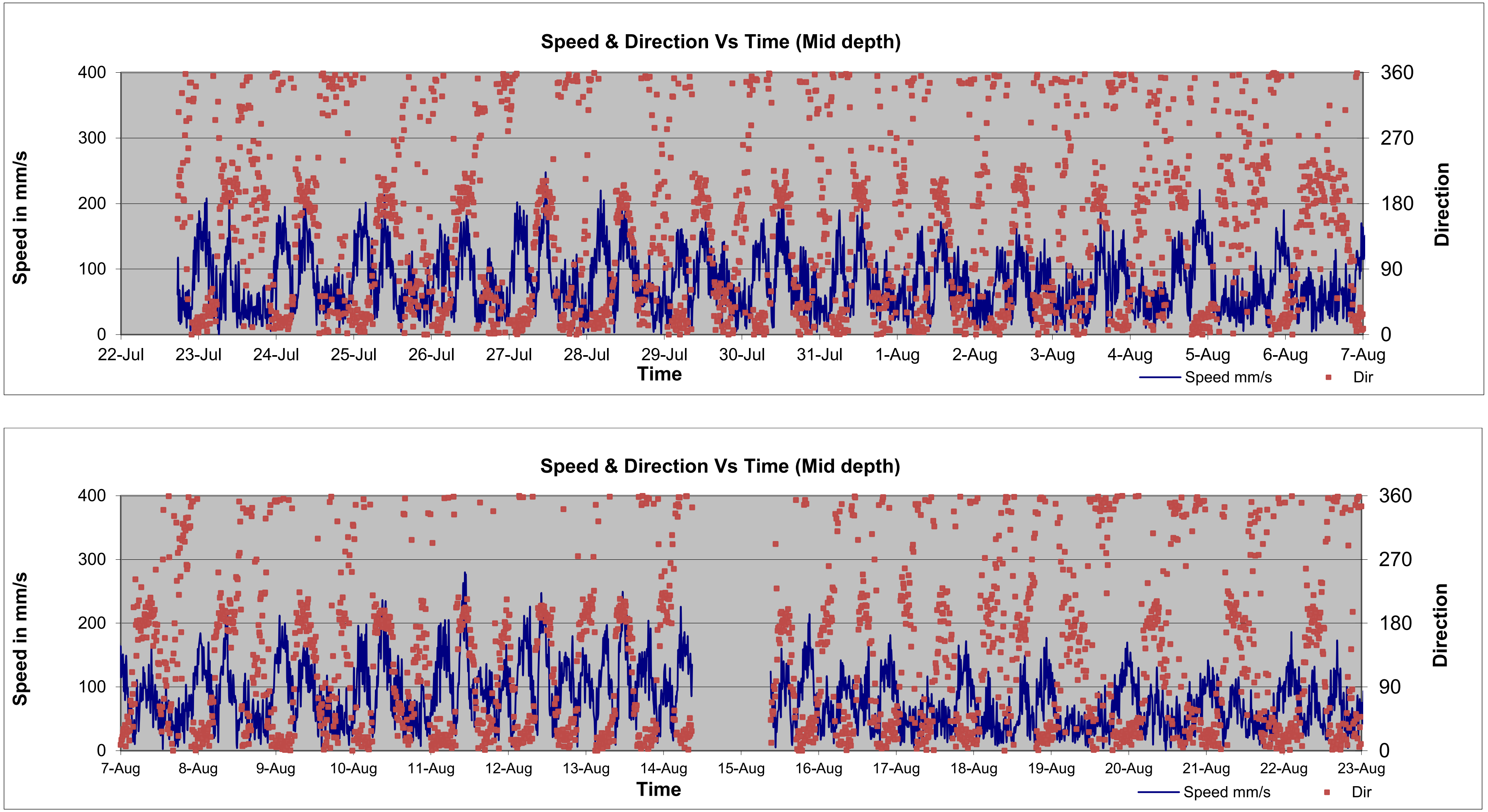
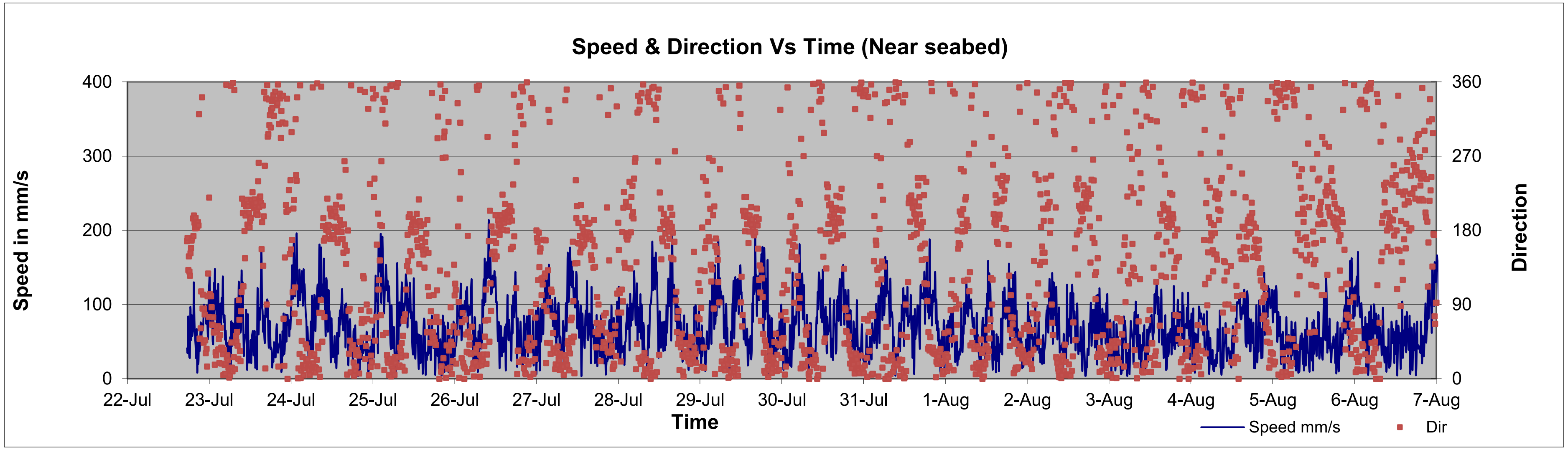


Figure 23 – Mid-depth time series curves



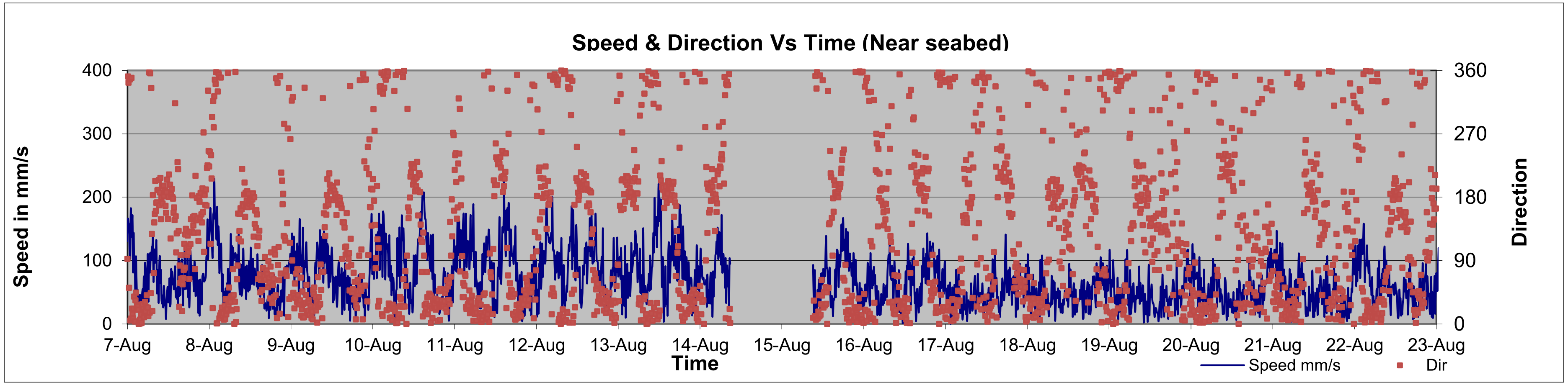


Figure 24 – Near-seabed time series curves

6.5.1.3. Wave measurements

The data from ADCP was processed in format 12 of WavesMon - the software provided by Teledyne RD Instruments. The wave data was collected at an hourly interval. The wave direction was predominantly from the west north-west direction as can be seen from the rose plots provided below:

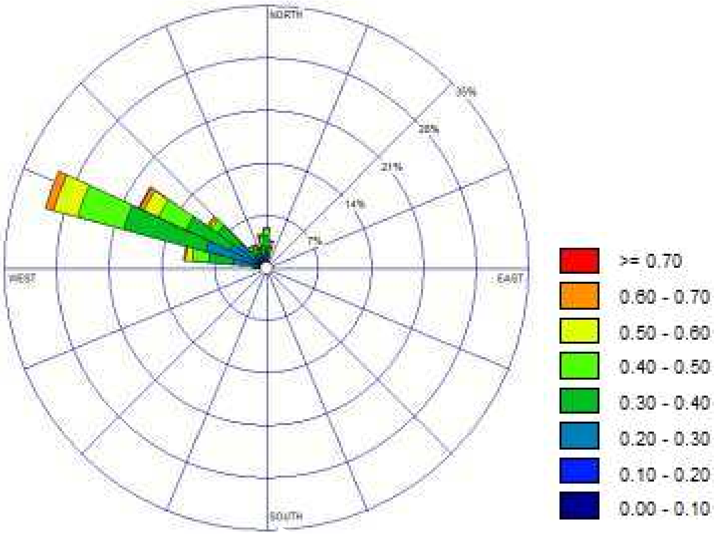


Figure 25– Rose plot - Hs Vs direction (Hs in metres)

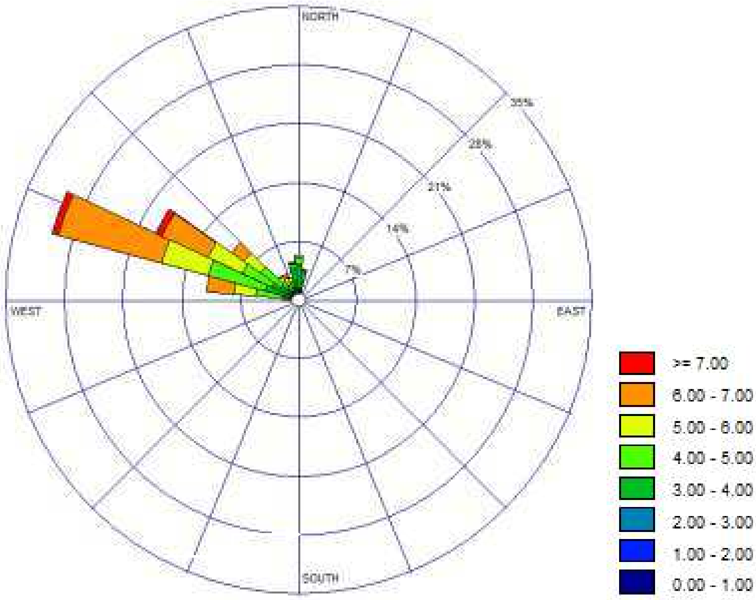
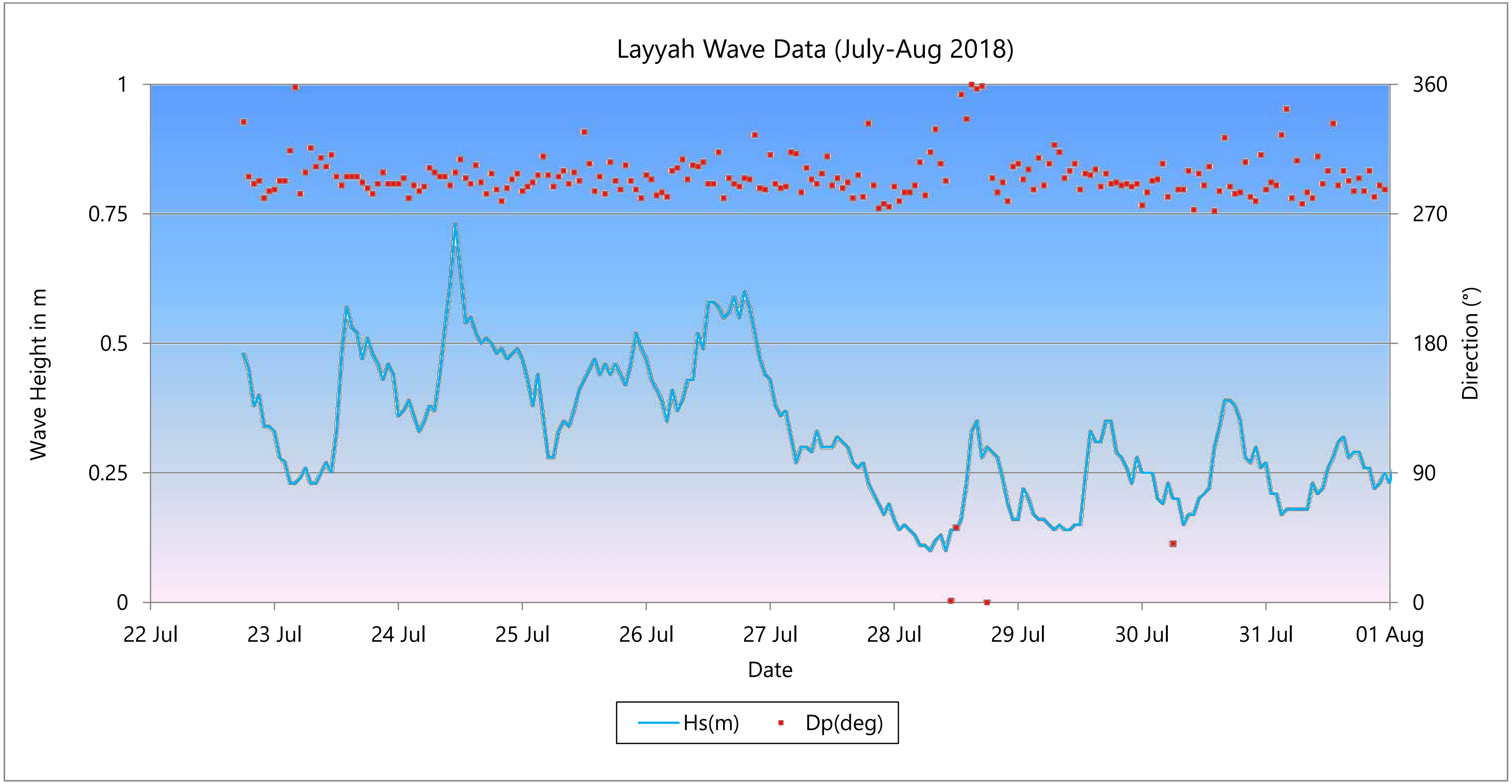
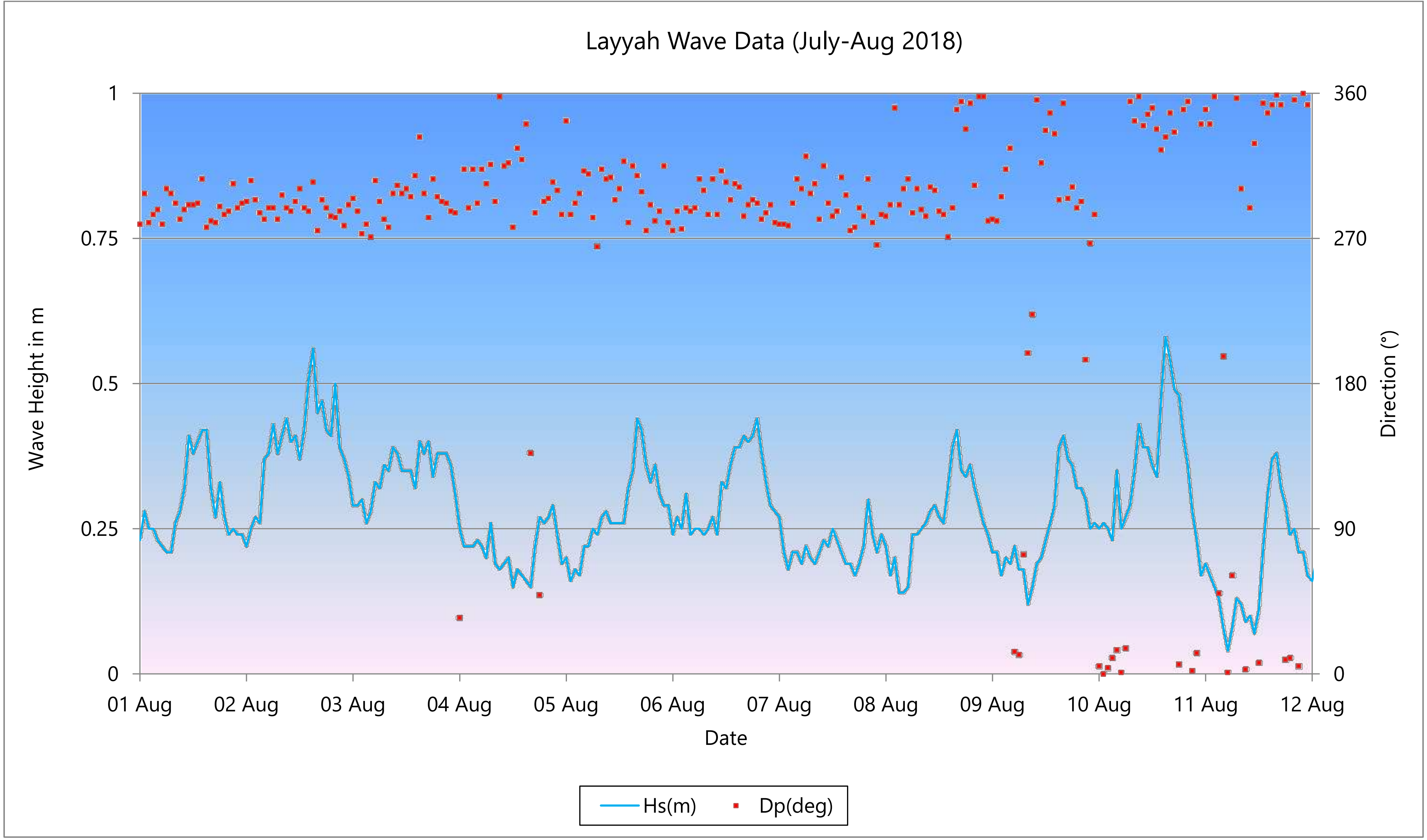


Figure 26 – Rose plot - Hs Vs direction (Hs in metres)

The wave period indicates short period waves less than 10 seconds throughout the observation period. A maximum period of 9.8 seconds was observed on 8th August 2018 at 1600 hrs. The observed wave in the area revealed calm conditions during the observation. A maximum significant wave of 0.73m was recorded on 24th July 2018 at 1100 hrs. The time series curves for the period are provided below:


Layyah Wave Data (July-Aug 2018)
Wave Height in m
Direction (°)
1
0.75
0.5
0.25
0
360
270
180
90
0
22 Jul
23 Jul
24 Jul
25 Jul
26 Jul
27 Jul
28 Jul
29 Jul
30 Jul
31 Jul
01 Aug
Date
Hs(m)
Dp(deg)


Layyah Wave Data (July-Aug 2018)
Wave Height in m
Direction (°)
1
0.75
0.5
0.25
0
360
270
180
90
0
01 Aug
02 Aug
03 Aug
04 Aug
05 Aug
06 Aug
07 Aug
08 Aug
09 Aug
10 Aug
11 Aug
12 Aug
Date
Hs(m)
Dp(deg)

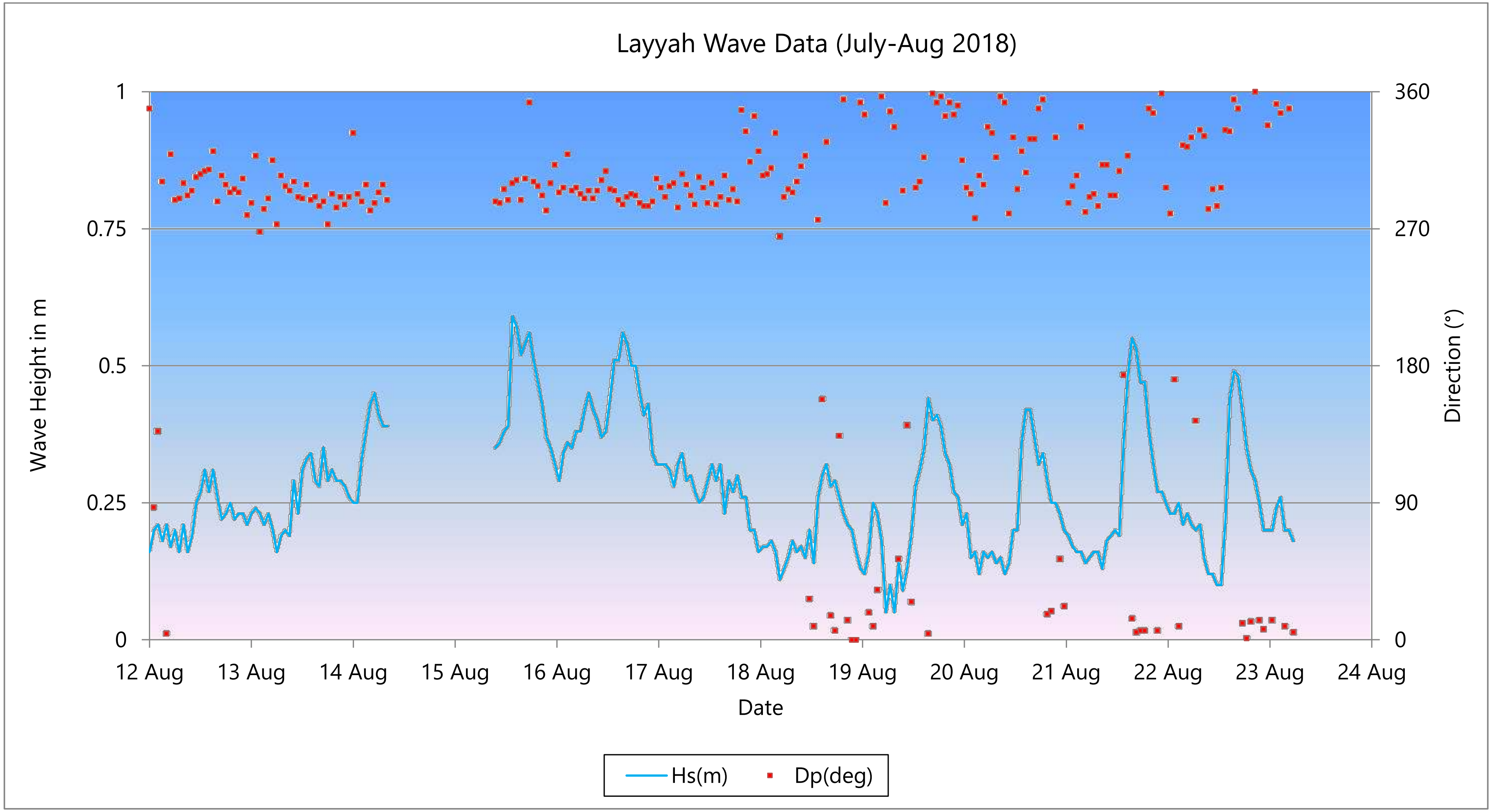
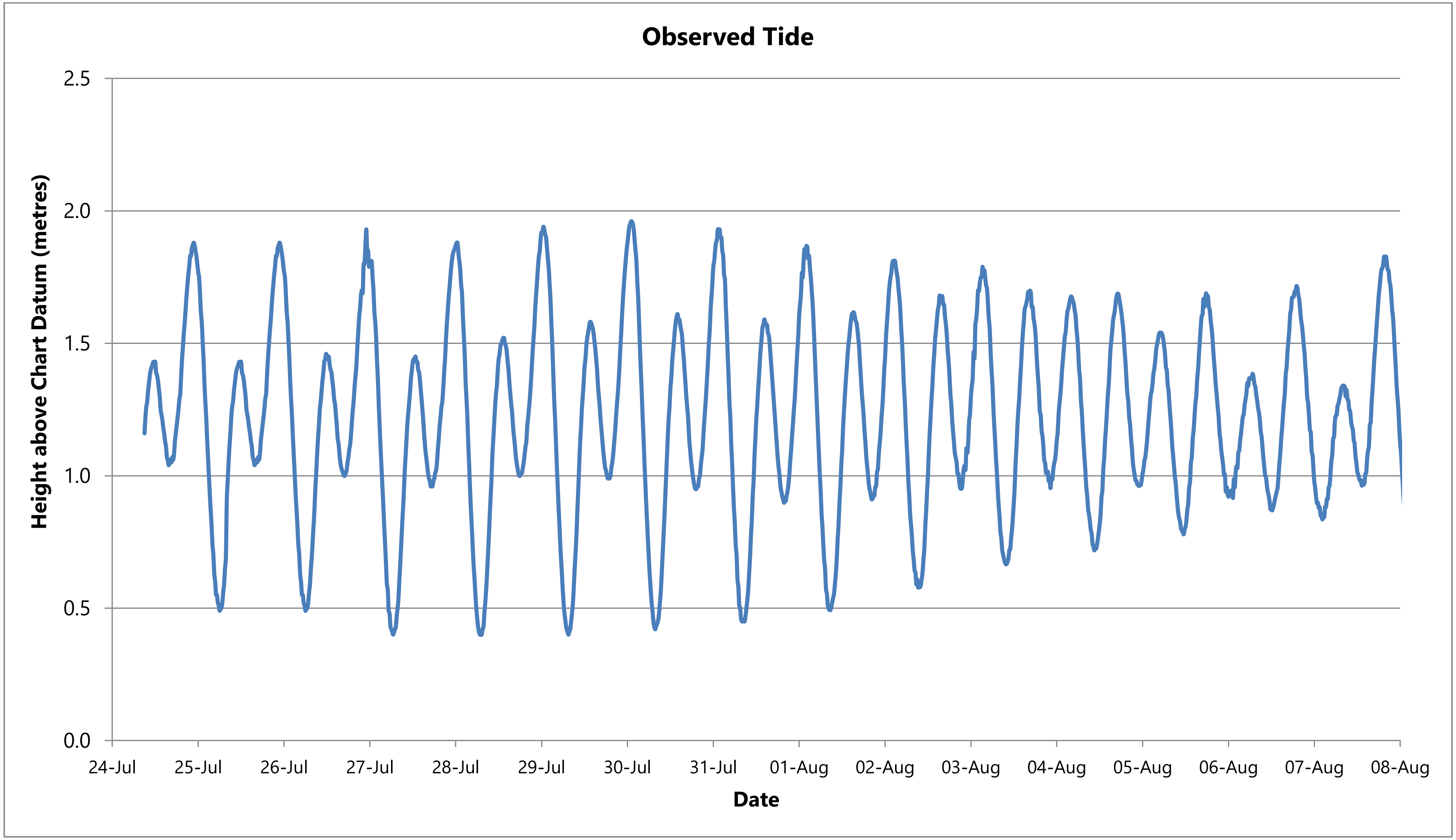


Figure 27 – Time series curves of wave parameters

The wave data revealed cam conditions with a maximum significant wave height of 0.73m. The wave period was less than 10 seconds, indicating short period waves prevailing in the area. The wave direction was predominantly from west northwest direction.

6.5.1.4. Tide Measurements

The data from Valeport ATG was downloaded and after applying corrections to level the data to the chart datum. The observed tides are semi-diurnal. The maximum tides were observed during the spring tide. The range of tide was about 1.2m during neap tide and 2m during spring tides.


Observed Tide
Height above Chart Datum (metres)
2.5
2.0
1.5
1.0
0.5
0.0
24-Jul
25-Jul
26-Jul
27-Jul
28-Jul
29-Jul
30-Jul
31-Jul
01-Aug
02-Aug
03-Aug
04-Aug
05-Aug
06-Aug
07-Aug
08-Aug
Date

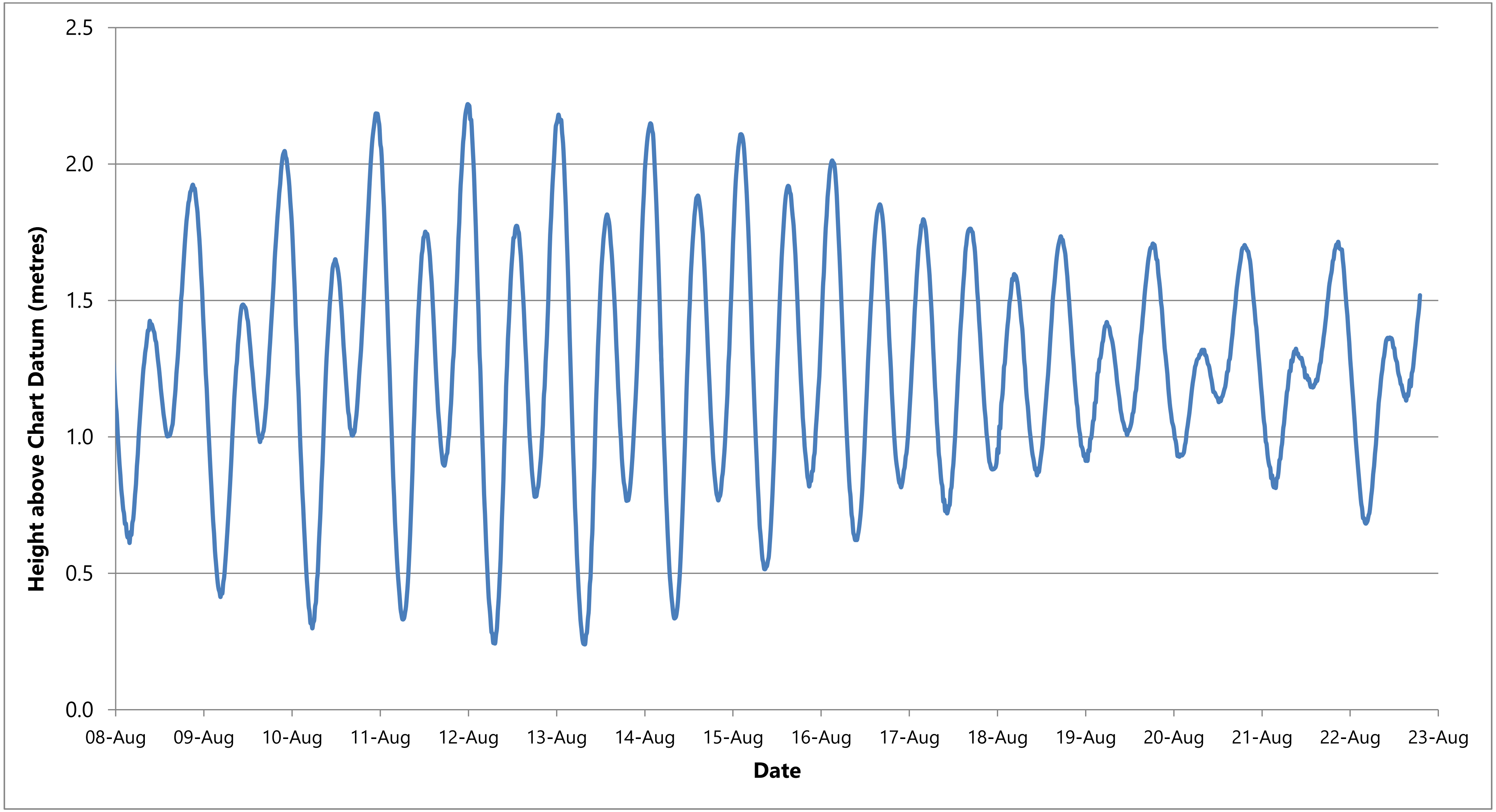


Figure 28 – Tide curves

6.5.2. SEA WATER QUALITY

6.5.2.1. Sampling and Analysis

Sea water quality samples were collected in at surface (-0.5m below) using a Niskin water sampler. Water samples were collected in Amber Glass and High Density Polyethylene plastic bottles of 1L capacity, preserved in ice box and sent to a ENAS accredited laboratory for analysis. The analyses are performed at ENAS accredited laboratory using standard methods determined by APHA (2017) - 23rd Edition.

6.5.2.2. Results and Discussion

In-situ analysis of sea water samples collected in the Arabian Gulf is presented in **Table 55.** The results obtained for quality analysis of the seawater samples collected from Arabian Gulf and lagoon area are summarized in **Table 56** and **Table 57.**

Table 55 - Results of Seawater Quality (In-situ analysis)

Station No	Sampling Time	Temp (°C)	pH	Turbidity (NTU)	Salinity %	DO (mg/l)
SW1	12.45	38.3	8.24	<1.0	43.6	5.19
SW2	8.37	33.8	8.23	<1.0	41.1	5.27
SW3	11.03	34.7	8.19	<1.0	41.4	5.20
SW4	9.16	34.3	8.14	<1.0	41.7	4.84
SW5	11.34	34.2	8.18	<1.0	41.0	5.71
SW6	8.04	33.7	8.18	<1.0	41.1	5.33
SW7	7.25	33.7	8.14	<1.0	41.0	5.39
SW8	12.10	34.0	8.18	<1.0	41.1	5.64
SW9	6.46	33.8	8.15	<1.0	41.0	5.45
SW10	13.12	38.3	8.19	<1.0	43.6	5.19
SW11	9.46	35.0	8.15	<1.0	41.2	4.84
SW12	1.23	35.2	8.26	4.36	42.3	5.52

Table 56 - Results of Seawater Quality

S. No	Parameters	Units	Harbour Area SW – 1	*Arabian Gulf*						*DM-EPSS Marine Water Quality Objectives*
				SW-2	*SW-3*	*SW-4 (Creek Entry)*	*SW-5*	*SW-6*	*SW-7*	
1)	pH	--	8.02	8.03	8.08	8.07	7.98	8.10	8.05	**--**
2)	Dissolved Oxygen (DO)	mg/L	6.0	6.0	5.9	5.5	5.8	5.9	5.9	**5.0**
3)	Turbidity	NTU	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**75**
4)	Temperature	°C	38.3	33.8	34.7	34.7	34.2	33.7	33.7	**--**
5)	Chlorine (Residual)	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	**0.01**
6)	Chlorides	mg/L	27,296	25,186	25,243	25,201	25,186	25,170	25,201	**--**
7)	Fluorides	mg/L	0.95	0.59	1.1	1.0	0.80	0.62	0.47	**--**
8)	Nitrogen - Ammonia	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**0.1**
9)	Nitrogen - Nitrite	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**--**
10)	Nitrogen - Nitrate	mg/L	0.04	0.06	0.03	0.05	0.03	0.04	0.02	**0.5**
11)	Sulphate (SO_4^{2})	mg/L	3,435	3,124	3,144	3,177	3,118	3,105	3,155	**--**
12)	Total Hardness	mg/L	9,400	8,350	8,300	7,750	7,950	7,600	7,750	
13)	Total Dissolved Solids (TDS)	mg/L	44,300	43,400	43,200	42,800	41,800	42,100	42,600	**--**
14)	Total Suspended Solids (TSS)	mg/L	<10	<10	<10	<10	<10	<10	<10	**25**
15)	Biochemical Oxygen Demand (BOD)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	**20**
16)	Chemical Oxygen Demand (BOD)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**--**
17)	Oil and Grease	mg/L	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	**--**

S. No	Parameters	Units	Harbour Area SW – 1	Arabian Gulf						DM-EPSS Marine Water Quality Objectives
				SW-2	SW-3	SW-4 (Creek Entry)	SW-5	SW-6	SW-7	
18)	Phenols	mg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	--
19)	Surfactants	µg/L	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	**20**
20)	Carbonates	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	--
21)	Phosphates	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	--
22)	Total Nitrogen	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**2.0**
23)	Chlorophyll a	mg/m^3	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	--
24)	*Total Coliforms*	CFU/100 ml	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	--
25)	*E. coli*	CFU/100 ml	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**200**
26)	Aluminum (Al)	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	**0.2**
27)	Arsenic (As)	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**0.01**
28)	Cadmium (Cd)	mg/L	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	**0.003**
29)	Calcium (Ca)	mg/L	628	546	507	457	467	443	453	--
30)	Chromium (Cr)	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**0.01**
31)	Cobalt (Co)	mg/L	<0.066	<0.066	<0.066	<0.066	<0.066	<0.066	<0.066	--
32)	Copper (Cu)	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	**0.005**
33)	Iron (Fe)	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	**0.2**
34)	Lead (Pb)	mg/L	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	--
35)	Potassium (K)	mg/L	554	517	536	527	542	521	542	--
36)	Sodium (Na)	mg/L	14,510	13,940	14,310	14,240	14,200	14,010	14,440	--
37)	Zinc (Zn)	mg/L	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	**0.02**
38)	Nickel (Ni)	mg/L	<0.063	<0.063	<0.063	<0.063	<0.063	<0.063	<0.063	--

S. No	Parameters	Units	Harbour Area SW – 1	*Arabian Gulf*						*DM-EPSS Marine Water Quality Objectives*
				SW-2	*SW-3*	*SW-4 (Creek Entry)*	*SW-5*	*SW-6*	*SW-7*	
39)	Magnesium (Mg)	mg/L	1,902	1,701	1,717	1,613	1,645	1,574	1,611	--
40)	Mercury (Hg)	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	**0.001**
41)	Gasoline Range Organics (C6 – C9)	mg/L	<0.119	<0.119	<0.119	<0.119	<0.119	<0.119	<0.119	--
42)	Diesel Range Organics (C10 – C30)	mg/L	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080	--
43)	Heavy Fractions (>C30)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	--

Table 57 - Results of Seawater Quality (Continued…)

S. No	Parameters	Units	*Arabian Gulf*		*Al Khan Lagoon*	*Sharjah Creek*	*Khalid Lagoon*	*DM-EPSS Marine Water Quality Objectives*
			SW-8	*SW-9*	*SW-10*	*SW-11*	*SW-12*	
1)	pH	--	8.11	8.08	8.02	8.09	8.02	--
2)	Dissolved Oxygen (DO)	mg/L	6.1	5.9	5.8	5.9	5.9	**5.0**
3)	Turbidity	NTU	<1.0	<1.0	<1.0	<1.0	<1.0	**75**
4)	Temperature	°C	34.0	33.8	34.7	34.3	35.2	--
5)	Chlorine (Residual)	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	**0.01**
6)	Chlorides	mg/L	25,219	24,638	25,116	25,398	25,019	--

S. No	**Parameters**	**Units**	***Arabian Gulf***		***Al Khan Lagoon***	***Sharjah Creek***	***Khalid Lagoon***	***DM-EPSS Marine Water Quality Objectives***
			SW-8	***SW-9***	***SW-10***	***SW-11***	***SW-12***	
7)	Fluorides	mg/L	1.10	0.56	0.76	0.84	0.65	**--**
8)	Nitrogen - Ammonia	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	**0.1**
9)	Nitrogen - Nitrite	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	**--**
10)	Nitrogen - Nitrate	mg/L	0.02	0.13	0.03	0.02	0.02	**0.5**
11)	Sulphate (SO_4^{2})	mg/L	3,163	2,764	3,129	3,253	3,090	**--**
12)	Total Hardness	mg/L	7,700	8,100	7,300	7,800	7,550	
13)	Total Dissolved Solids (TDS)	mg/L	42,100	42,500	41,900	41,500	42,200	**--**
14)	Total Suspended Solids (TSS)	mg/L	<10	<10	<10	<10	<10	**25**
15)	Biochemical Oxygen Demand (BOD)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	**20**
16)	Chemical Oxygen Demand (BOD)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	**--**
17)	Oil and Grease	mg/L	<1.3	<1.3	<1.3	<1.3	<1.3	**--**
18)	Phenols	mg/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	**--**
19)	Surfactants	μg/L	<10.0	<10.0	<10.0	<10.0	<10.0	**20**
20)	Carbonates	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	**--**
21)	Phosphates	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	**--**
22)	Total Nitrogen	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	**2.0**
23)	Chlorophyll a	mg/m^3	<1.0	<1.0	<1.0	<1.0	<1.0	**--**
24)	*Total Coliforms*	CFU/100 ml	<1.0	<1.0	<1.0	<1.0	<1.0	**--**

S. No	Parameters	Units	Arabian Gulf		Al Khan Lagoon	Sharjah Creek	Khalid Lagoon	DM-EPSS Marine Water Quality Objectives
			SW-8	SW-9	SW-10	SW-11	SW-12	
25)	*E. coli*	CFU/100 ml	<1.0	<1.0	<1.0	<1.0	<1.0	**200**
26)	Aluminum (Al)	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	**0.2**
27)	Arsenic (As)	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	**0.01**
28)	Cadmium (Cd)	mg/L	<0.003	<0.003	<0.003	<0.003	<0.003	**0.003**
29)	Calcium (Ca)	mg/L	446	492	411	465	449	**--**
30)	Chromium (Cr)	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	**0.01**
31)	Cobalt (Co)	mg/L	<0.066	<0.066	<0.066	<0.066	<0.066	**--**
32)	Copper (Cu)	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	**0.005**
33)	Iron (Fe)	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	**0.2**
34)	Lead (Pb)	mg/L	<0.08	<0.08	<0.08	<0.08	<0.08	**--**
35)	Potassium (K)	mg/L	531	541	542	534	527	**--**
36)	Sodium (Na)	mg/L	14,330	14,290	14,680	14,580	14,360	**--**
37)	Zinc (Zn)	mg/L	<0.012	<0.012	<0.012	<0.012	<0.012	**0.02**
38)	Nickel (Ni)	mg/L	<0.063	<0.063	<0.063	<0.063	<0.063	**--**
39)	Magnesium (Mg)	mg/L	1,596	1,680	1,527	1,616	1,559	**--**
40)	Mercury (Hg)	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	**0.001**
41)	Gasoline Range Organics (C6 – C9)	mg/L	<0.119	<0.119	<0.119	<0.119	<0.119	**--**
42)	Diesel Range Organics (C10 – C30)	mg/L	<0.080	<0.080	<0.080	<0.080	<0.080	**--**
43)	Heavy Fractions (>C30)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	**--**

Owing to the sampling being carried out during the peak summer months, the surface temperature ranged from 34.0 – 38.34 °C. Sampling station SW1 was observed to have recorded the highest temperature. In general, the turbidity was low at most of the locations except at SW12 (Khalid lagoon). The salinity was invariably high ranging from 41.0 – 43.6 ppt. Dissolved oxygen concentration ranged between 4.84 and 5.71 mg/L. Overall, DO was higher in the open waters than at the closed locations at the creek. The pH values ranged from 8.14 to 8.26 without showing any trend from near shore to far shore.

The results of seawater analysis compared with marine water quality objectives of Dubai Municipality. The perusal of the results indicates that all criteria pollutants are complying with the marine water quality objectives.

The outfall effluent being discharged to sea was collected from the outfall channel and it was analyzed for physic-chemical analysis. The results are compared with Sharjah Municipality sea discharge limits and IFC effluent guidelines. The results comply with Sharjah municipality sea discharge limits and IFC effluent guidelines.

Table 58 - Results of Outfall Effluent Quality

S. No.	Parameters	Units	Outfall Channel -01	Outfall Channel - 02	***Sharjah Municipality Discharge Limits - Sea***	***IFC Effluent Guidelines***
21)	pH	--	8.04	8.09	**6 - 9**	**6 - 9**
22)	Dissolved Oxygen (DO)	mg/L	5.9	5.9	**--**	**--**
23)	Turbidity	NTU	<1.0	<1.0	**75**	**--**
24)	Temperature	°C	40.9	41.6	**--**	**--**
25)	Chlorine (Residual)	mg/L	<0.005	<0.005	**--**	**0.2**
26)	Chlorides	mg/L	27,536	25,036	**--**	**--**
27)	Fluorides	mg/L	0.77	0.57	**--**	**--**
28)	Nitrogen - Ammonia	mg/L	<0.01	<0.01	**5.0**	**--**
29)	Nitrogen - Nitrite	mg/L	<0.05	<0.05	**--**	**--**
30)	Nitrogen - Nitrate	mg/L	0.03	0.02	**--**	**--**
31)	Sulphate (SO_4^{2})	mg/L	3,551	3,095	**--**	**--**
32)	Total Hardness	mg/L	9,000	7,800	**--**	**--**
33)	Total Dissolved Solids (TDS)	mg/L	44,800	42,000	**--**	**--**
34)	Total Suspended Solids (TSS)	mg/L	<10	<10	**30**	**50**
35)	Biochemical Oxygen Demand	mg/L	<2.0	<2.0	**30**	**--**

S. No.	Parameters	Units	Outfall Channel -01	Outfall Channel - 02	*Sharjah Municipality Discharge Limits - Sea*	*IFC Effluent Guidelines*
	(BOD)					
36)	Chemical Oxygen Demand (BOD)	mg/L	<1.0	<1.0	**150**	--
37)	Oil and Grease	mg/L	<1.3	<1.3	**10**	**10**
38)	Phenols	mg/L	< 0.1	< 0.1	**0.5**	--
39)	Surfactants	µg/L	<10.0	<10.0	--	--
40)	Carbonates	mg/L	<1.0	<1.0	--	--
41)	Phosphates	mg/L	<0.03	<0.03	--	--
42)	Total Nitrogen	mg/L	<1.0	<1.0	--	--
43)	Chlorophyll a	mg/m^3	<1.0	<1.0	--	--
44)	*Total Coliforms*	CFU/100 ml	<1.0	<1.0	**100**	--
45)	*E. coli*	CFU/100 ml	<1.0	<1.0	--	--
46)	Aluminum (Al)	mg/L	<0.2	<0.2	--	--
47)	Arsenic (As)	mg/L	<0.01	<0.01	**0.05**	**0.5**
48)	Cadmium (Cd)	mg/L	<0.003	<0.003	**0.05**	**0.1**
49)	Calcium (Ca)	mg/L	585	499	--	
50)	Chromium (Cr)	mg/L	<0.01	<0.01	**0.5**	**0.5**
51)	Cobalt (Co)	mg/L	<0.066	<0.066	**0.5**	**0.5**
52)	Copper (Cu)	mg/L	<0.005	<0.005	**0.5**	
53)	Iron (Fe)	mg/L	<0.2	<0.2	**2.0**	**1.0**
54)	Lead (Pb)	mg/L	<0.08	<0.08	**0.1**	**0.5**
55)	Potassium (K)	mg/L	566	525	--	
56)	Sodium (Na)	mg/L	15,130	13,760	--	
57)	Zinc (Zn)	mg/L	<0.012	<0.012	**0.1**	**1.0**
58)	Nickel (Ni)	mg/L	<0.063	<0.063	**0.1**	
59)	Magnesium (Mg)	mg/L	1,832	1,590	--	
60)	Mercury (Hg)	mg/L	<0.0005	<0.0005	**0.001**	**0.005**
61)	Gasoline Range Organics (C6 – C9)	mg/L	<0.119	<0.119	--	--
62)	Diesel Range Organics (C10 – C30)	mg/L	<0.080	<0.080	--	--
63)	Heavy Fractions (>C30)	mg/L	<1.0	<1.0	--	--

6.5.3. MARINE SEDIMENT QUALITY

6.5.3.1. Sampling and Analysis

Stainless steel Van Veen grab sampler was used to obtain bottom sediments from 10 selected sampling stations which are represented in **Figure 14** and details of the sampling locations are given in Table 53**.** The samples collected were analyzed for benthos analysis as well as the chemical analysis. Of the 10 sediments samples, five samples had either silty sand (MS 2), fine sand (MS 4) or coarse sand (MS 5 and MS 8). Other samples were mostly made of gravels, boulder and/or broken shells.

Owing to the hard substrate sediment samples using a grab sampler could not be collected at four (MS1, MS4, MS6, MS7) of the identified locations. Accordingly, the sediment samples from the remaining six locations (MS2, MS3, MS5, MS8, MS9 and MS10) were analyzed for chemical parameters. The photos of sediment samples collected are presented in **Figure 29**.


Sediment Sample collected at sampling station (MS-1)

Pebbles - One with Encrustation at MS-1

Sediment sample at MS-2

Sediment sample at MS-2

A larger coralline boulder with epiphytic alga & shells at MS-2


Sediment Sample collected at sampling station (MS-3) - Fine Silty Clay

Figure 29 – Photos of sediment samples collected in Arabian Gulf


Sediment Sample collected at sampling station (MS-4)

Sediment Sample collected at sampling station (MS-4) - Broken shells, largely of bivalves

Sediment sample at MS5 - Coarse sand with broken shells

Sediment sample at MS-6

Sediment Sample at MS 6 - Pearl oyster shells with an unidentified red alga

Photos of sediment samples collected in Arabian Gulf

Sediment Sample at MS 7 - Broken shells – Pearl Oysters

Sediment Sample at MS 8 - Coarse sand with broken shells

Sediment Sample at MS 9 - Silty sand plus shells

Sediment Sample at MS 10 -Fine sand; broken shells

Photos of sediment samples collected in Arabian Gulf

The sediment samples were collected in pre-cleaned glass containers of 1Kg capacity and sent to ENAS accredited laboratory for analysis under strict chain of custody with QA/QC procedures. Sediment samples were dried in an electric oven and powdered in agate mortar. The sediments were analyzed for the chemical parameters.

The results of sediment analysis are compared with Canadian marine sediment quality guidelines. Canadian interim sediment quality guidelines (ISQGs) and probable effect levels (PELs) can be used to evaluate the degree to which adverse biological effects are likely to occur as a result of exposure to particular toxic contaminant in sediments. The ISQGs and PELs are valuable tools for assessing the eco-toxicological relevance of concentrations in sediments. The perusal of the results, toxic contaminants in the sediment samples are well within the Canadian marine sediment quality guidelines.

Table 59 - Results of marine sediment analysis in the project study area

S. No	Parameters	Units	*Arabian Gulf*					*Canadian Sediment Quality Guidelines*[10]	
			MS – 1	*MS-2*	*MS-3*	*MS-4*	*MS-5*	*ISQG**	*PEL*[#]
1)	Total Organic Carbon	Wt. %	Rocky Bottom – No sediment is collected	<0.5	1.01	Rocky Bottom – No sediment is collected	0.58	--	
2)	Total Phosphate	mg/kg		<1.0	<1.0		<1.0	--	
3)	Nitrates	mg/kg		14	23		40.0	--	
4)	Nitrogen - Ammonia	mg/kg		<5.0	<5.0		8.4	--	
5)	Total Nitrogen	mg/kg		3.2	5.3		17.0	--	
6)	Sulphates	mg/kg		208.0	604.0		1798.0	--	
7)	Aluminum (Al)	mg/kg		244.0	63.0		1202.0	--	
8)	Arsenic (As)	mg/kg		<1.2	<1.2		<1.2	**7.24**	**41.6**
9)	Cadmium (Cd)	mg/kg		<2.2	<2.2		<2.2	**0.7**	**4.2**
10)	Chromium (Cr)	mg/kg		1.0	<0.95		19.0	**52.3**	**160.0**
11)	Copper (Cu)	mg/kg		<1.4	1.5		42.0	**18.7**	**108.0**
12)	Iron (Fe)	mg/kg		616.0	323.0		1820.0	--	--
13)	Lead (Pb)	mg/kg		<1.8	<1.8		<1.8	**30.2**	**112.0**
14)	Nickel (Ni)	mg/kg		<0.5	<0.5		12.0	--	--
15)	Zinc (Zn)	mg/kg		3.0	4.4		68.0	**124.0**	**271.0**
16)	Mercury (Hg)	mg/kg		<0.025	<0.025		<0.025	**0.13**	**0.70**

Canadian Council of Ministers of the Environment. 2001. Canadian sediment quality guidelines for the protection of aquatic life: Summary of Tables Updated. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Table 60 - Results of marine sediment analysis in the project study area (Continued....)

S. No	Parameters	Units	Arabian Gulf					Canadian Sediment Quality Guidelines	
			MS – 6	MS-7	MS-8	MS-9	MS-10	ISQG*	PEL#
1)	Total Organic Carbon	Wt. %	Rocky Bottom – No sediment is collected		<0.5	<0.5	0.5	--	
2)	Total Phosphate	mg/kg			<1.0	<1.0	<1.0	--	
3)	Nitrates	mg/kg			39.0	33.0	41.0	--	
4)	Nitrogen - Ammonia	mg/kg			<5.0	9.1	9.0	--	
5)	Total Nitrogen	mg/kg			8.8	17.0	18.0	--	
6)	Sulphates	mg/kg			597.0	559.0	730.0	--	
7)	Aluminum (Al)	mg/kg			57.0	864.0	852.0	--	
8)	Arsenic (As)	mg/kg			<1.2	<1.2	<1.2	**7.24**	**41.6**
9)	Cadmium (Cd)	mg/kg			<2.2	<2.2	<2.2	**0.7**	**4.2**
10)	Chromium (Cr)	mg/kg			<0.95	7.4	6.1	**52.3**	**160.0**
11)	Copper (Cu)	mg/kg			<1.4	2.8	1.9	**18.7**	**108.0**
12)	Iron (Fe)	mg/kg			226.0	154.1	1504.0	--	--
13)	Lead (Pb)	mg/kg			<1.8	<1.8	<1.8	**30.2**	**112.0**
14)	Nickel (Ni)	mg/kg			<0.5	7.8	5.1	--	--
15)	Zinc (Zn)	mg/kg			<0.23	7.9	4.8	**124.0**	**271.0**
16)	Mercury (Hg)	mg/kg			<0.025	<0.025	<0.025	**0.13**	**0.70**

***** *Interim Marine Sediment Quality Guidelines prescribed by Canadian Sediment Quality Guidelines for the protection of aquatic life*
#Probable Effect Levels prescribed by Canadian Sediment Quality Guidelines for the protection of aquatic life

6.5.4. MARINE ECOLOGY

6.5.4.1. Survey Methodology

Marine Ecology survey was carried out underwater, by qualified divers (marine ecologist – **Dr. Shahid Mustafa**) in the study area. The observations were also documented using media tools such as videography and photographs. Qualitative and semi quantitative rapid assessment baseline surveys was performed on by underwater Drop down Camera at each site to record the bottom type, visible benthic flora and fauna where observed.

6.5.4.1.1. Survey Methodology – Epibenthic Ecology

Ten stations were selected to be representative of the shallow, open aspect, subtidal marine habitats within the study area. Two to five minute videos were taken at each station and all epibenthic characteristics encountered were counted. At each site either diver or drop-down camera was used to conducted a 25 m video transect to characterize photo-quadrats (0.25 m^2) for estimating of percentage cover of dominant substrates (Figure 3). All notable macro-invertebrate fauna and macroalgae encountered at each station were recorded. Photo-quadrats were taken at 5 m intervals (0 m, 5 m, 10 m, 15 m, 20 m & 25 m). At the stations where photo-quadrats were collected the images were subsequently analysed using Coral Point Count with Excel extensions (CPCe) *(Kohler and Gill, 2006*[11]*)* to assess percentage cover of sea grasses, macro algae, corals, macro invertebrate fauna and substrate type at each station. Percentage covers were also visually assessed at stations, not supporting significant populations of corals, where photo-qudrats were not taken.

6.5.4.1.2. Survey Methodology – Plankton community

A total of 10 samples of phytoplankton were collected and preserved in Lugol's iodine solution from the project area. The phytoplankton samples were allowed to settle and the supernatant solution was decanted, leaving a concentrated plankton volume of 50ml. A 1ml sample of settled plankton was then transferred to a Sedgwick-Rafter slide (1ml capacity) using a glass dropper. Initially the sample was examined for qualitative analysis, and then the taxa were counted. The same procedure was repeated three or four times. The number of individuals, in each taxon of phytoplankton, present per 1L of sample, was calculated.

[11] *Kohler, K.E. and Gill, S., 2006. Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. Computer & Geosciences, 32(9):1259-1269*

6.5.4.1.3. Survey Methodology – Epibenthic Ecology

A total of 10 samples of zooplankton were collected from the project area. Oblique hauls with plankton net, mesh size 200 μm, were used to sample zooplankton at all sampling stations. Porosity, or mesh transparency (= ratio of mesh aperture area to total mesh area), should be 55%. The samples were preserved in 5% formaldehyde (analytical grade) solution. Sub-samples were taken (50-100% depending upon population) using either Folsom splitter or Stemple pipette for the major groups. Before sub-sampling by Stemple pipette, samples were diluted to a known volume with filtered sea water and then mixed gently so that organisms were randomly distributed in the container. The population was calculated using following equation:

$$V = \prod r^2 d$$

Where,

V= Volume of water filtered;
r = radius of plankton net mouth; and
d = distance through which the plankton net is towed.

6.5.4.1.4. Survey methodology – Macrobenthos infauna community

Macro-benthic infauna samples were collected from 10 stations from the Project Area during October 2018 (Figure 3). At each sampling station, benthic samples were taken using a Van Veen grab, 10cm x 10cm opening ($0.01m^2$) and 10cm depth. Grab samples were taken at each location and sampling date and time were recorded. Grabs were retained only if the grab was full in order to standardize volume sampled. Immediately after collection, the samples were sieved through a 0.5 mm mesh screen, preserved in 10% buffered formalin with added Rose Bengal dye. Separation of animals from the remaining sediment was done under a dissecting microscope. All animals were identified to the lowest reliable taxonomic level, with random specimens verified by outside taxonomists. These procedures follow standard formats for benthic sampling outlined by the Environmental Protection Agency (EPA)-Environmental Monitoring and Assessment Program (*Hyland et al. 1991*[12]). Patterns of 174 infauna community composition were compared among stations for numerically common taxa (those comprising at least 1% or 3% of the total fauna collected at that station), for higher taxonomic groupings. Comparison of higher taxonomic groupings (polychaetes, amphipods, bivalves, oligochaetes) allows observation of overall patterns of distribution. The number of macro-benthic animals present in the sample was calculated using following formula:-

$$\text{no./m}^2 = \frac{\text{Number of animals present in the sample x 10,000}}{\text{Area sampled (cm}^2\text{)}}$$

[12] *Hyland, J., Baptiste, E., Campbell, J., Kennedy, J., Kropp, R. and Willliams, S. 1991. Macroinfauna communities of the Santa Maria Basin on the California outer continental shelf & slope: Mar Ecol Prog Ser 78 147-161.*

6.5.4.1.5. Univariate Analysis

The following univariate indices were selected:-

(a) Margalef Index (d):

The Margalef diversity index (d) is commonly used to characterize species diversity in a community using the following equation (Margalef 1968):

$$d = S\text{-}1/\text{Log}_e N$$

Where,

S is the number of species; and

N is the total number of individuals.

(b) Shannon-Wiener Diversity Index (H'):

The Shannon-Wiener diversity index (H') is another index that is very widely used for characterizing species diversity in a biological community (Shannon-Wiener 1949). The proportion of species i relative to the total number of species (p_i) is calculated, and then multiplied by the natural logarithm of this proportion (ln p_i). The resulting product is summed across species, and multiplied by -1:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where,

p_i is the proportion of individuals found in the species; and
ln is the natural logarithm.

(c) Pielou Evenness index (J):

The Pielou Evenness index is a measure of how evenly distributed abundance is among the species that exist in a community. The Pielou index is defined between 0 and 1, where 1 represents a community with perfect evenness, and decreases to zero as the relative abundances of the species diverge from evenness. Pielou Evenness index, J *(Pielou, 1966[13]):*

$$J' = \frac{H'}{H'_{max}}$$

Where H' = the Shannon-Wiener information function, H' (max.) = the theoretical maximum value for H' if all species in the sample were equally abundant.

[13] *Pielou, E. C., 1966. The measurement of diversity in different types of biological collections. J. Theor. Biol., 13: 131-144.*

6.5.4.2. Results and Discussion

6.5.4.2.1. Epibenthic Ecology

The ten (10) stations sampled varied in depth from 2-8 m. The estimated percentage cover of the dominant faunal and floral groups and the main substrate types are provided in **Table 61**

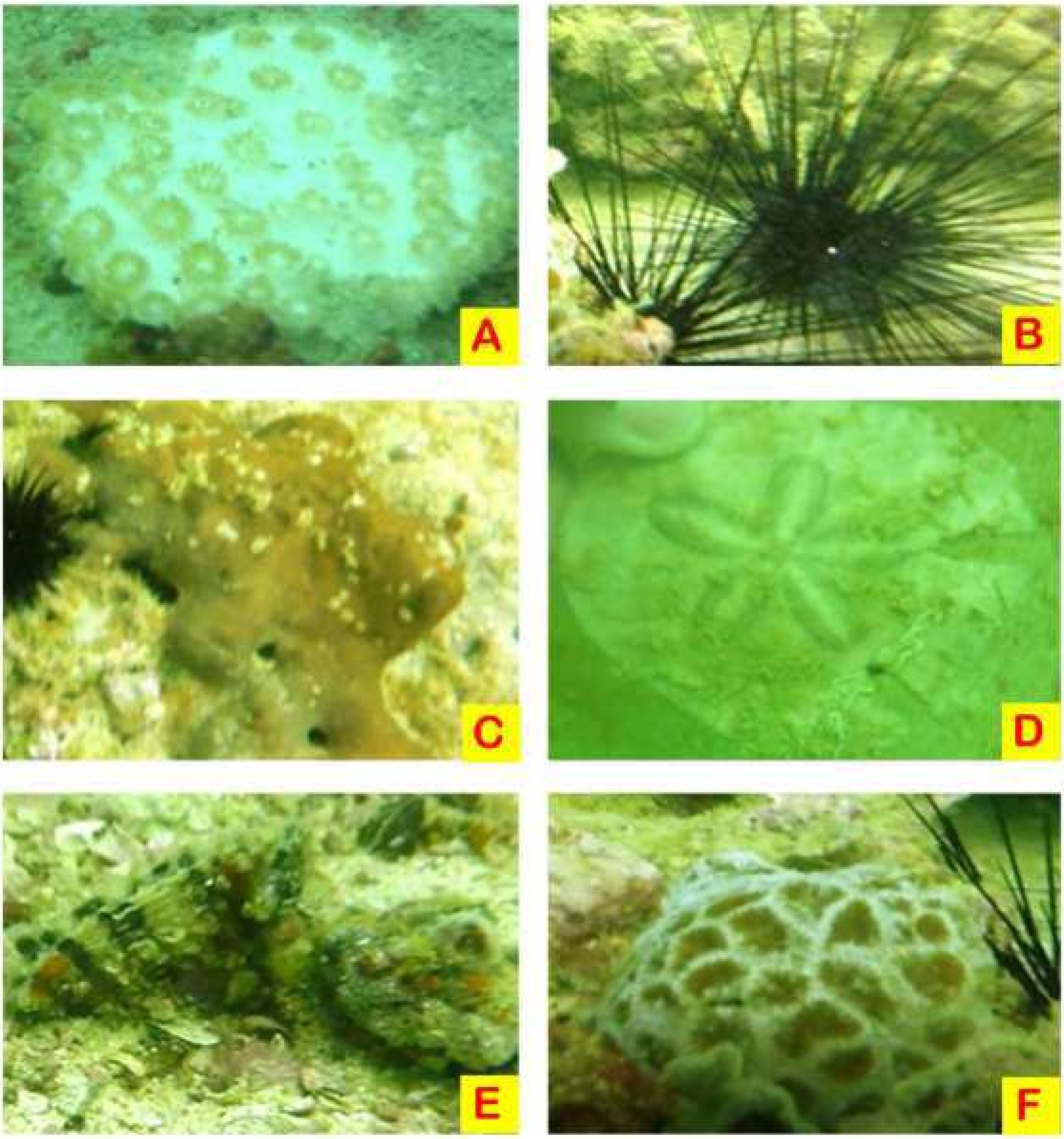


Figure 30 – *(A) Turbinaria peltata (B) Diadema setosum, (C) Porites sp, (D) Clypeaster humilis (E) Pearl oyster (Pinctada radiata)and (F) Favia sp. along stations ME-05 and* ME-08

Table 61 – Epi-benthic flora and fauna along project area

Biota (%)	**Sampling Stations**									
	ME-1	**ME-2**	**ME-3**	**ME-4**	**ME-5**	**ME-6**	**ME-7**	**ME-8**	**ME-9**	**ME-10**
Macro-Alage & Plants										
Epilithic algae		5			5	2.5	5	5		
Filamentous algae		5							5	
Turf Algae	2.5	1.5			5		5	2.5		
Hormophysa cuneiformis					5					
Porifera (Sponge)										
Actinarians sp.								10		
Callyspongia spp					2.5	1.5		1		
Ascidians sp.		25			5	5	1	2		
Cnidaria (Corals)										
Cyphastrea spp					2.5					
Siderastrea spp					1					
Favia palida					4					
Platygyra sp					1					
Favia sp					5			1		
Porites spp					5					
Turbinaria peltata					1			1		
Mollusca (%)										
Strombus sp.					0.5	1		0.5		
Hexaplex sp.					0.5	1	1	0.5		

Biota (%)	**Sampling Stations**									
	ME-1	**ME-2**	**ME-3**	**ME-4**	**ME-5**	**ME-6**	**ME-7**	**ME-8**	**ME-9**	**ME-10**
Cerithidea spp	10		2.5	2.5	0.5			4	5	2.5
Chama sp	1	1			1	1		1		
Spondylus marisrubri					1			1.5		
Pinctada radiata (Pearl oyster)		25			6.5	18	2	20		
Bivalves sp.	6.5	1.5	2.5	2.5	3	1		7.5		
Echinoderms & Sea Urchins										
Astropecten monacanthus						0.5				
Echinometra mathaei		5			5	5	1	2.5		
Diadema setosum		1			3	1				
Clypeaster humilis								5		
Chordate										
Phallusia nigra					2					
Substrate (%)										
Broken shell debris	10	10	5	5	10	22.5	30		5	7.5
Sand	70	20		90	25	40	55	35	85	40
Muddy-sand			90							50
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

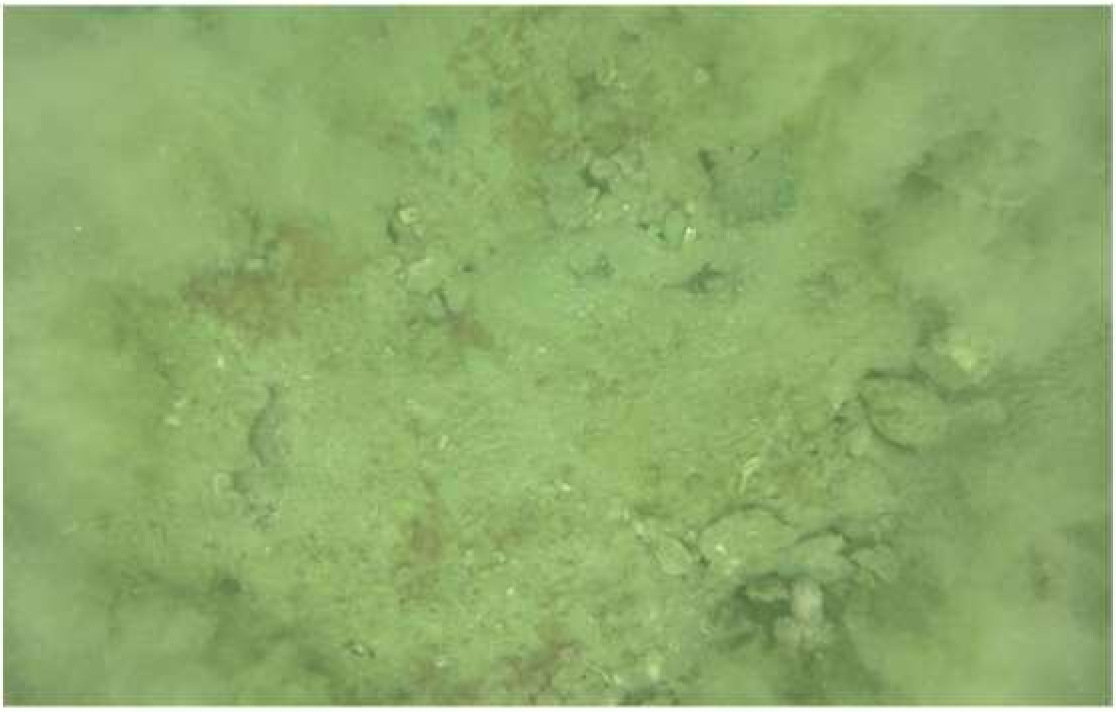
Habitat map of the study is presented in **Figure 31**. The epibenthic communities were dominated by oyster bed, corals, sandy and silty sand areas. The epi-benthic characteristics at following sites comprised of:

- Corals at station ME-5;
- Silty sand at Station ME3 and ME-10;
- Sandy Area at Station ME4, ME-7 and ME-9;
- Pearl Oyster and broken shells at Station ME-1, ME-2, ME-6 & ME-8.

Figure 31 – Habitat map along project area

The different characteristics of epibenthic community are shown in the **Figure 32** to **Figure 36**. Overall averages of all the stations show following percentage of the substratum.

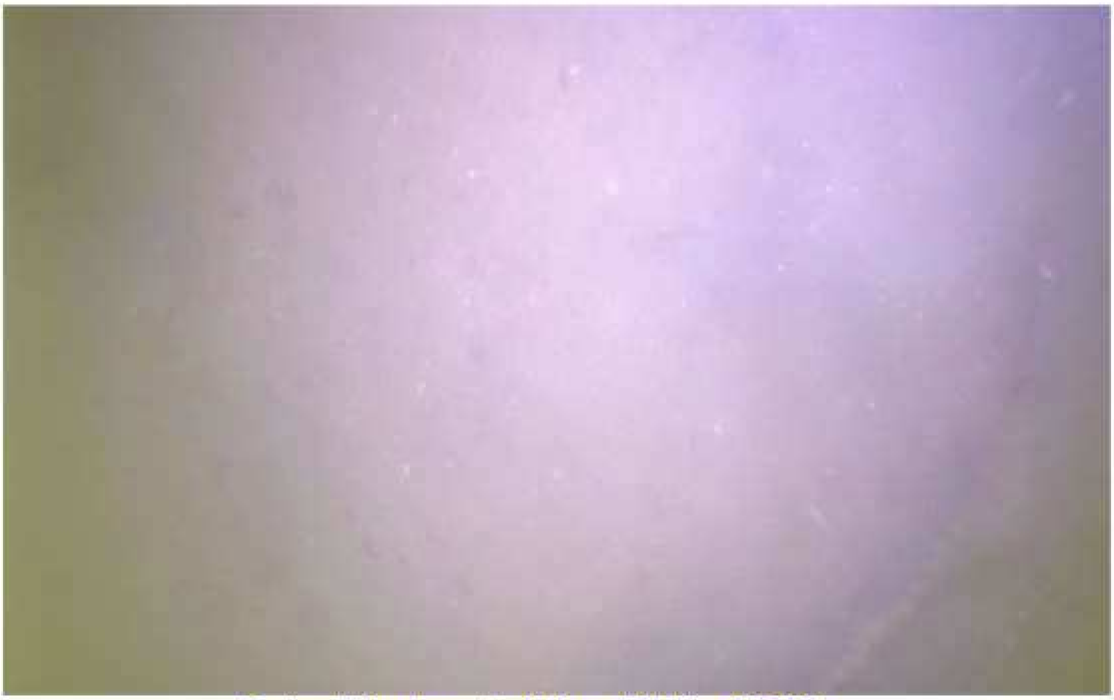
- Pearl oyster & Molluscs 13.6%
- Corals=2.2%
- Algae = 5.4%
- Actinarians (sponges)= 5.3%
- Echinodermates & Sea Urchins= 2.9%
- Chordates=0.2%
- Sand =46%
- Silty Sand=14%



Epibenthic characteristics at Station ME-01

Epibenthic characteristics at Station ME-02

Figure 32 – Epibenthic characteristics at sampling stations (ME-01 & ME-02)

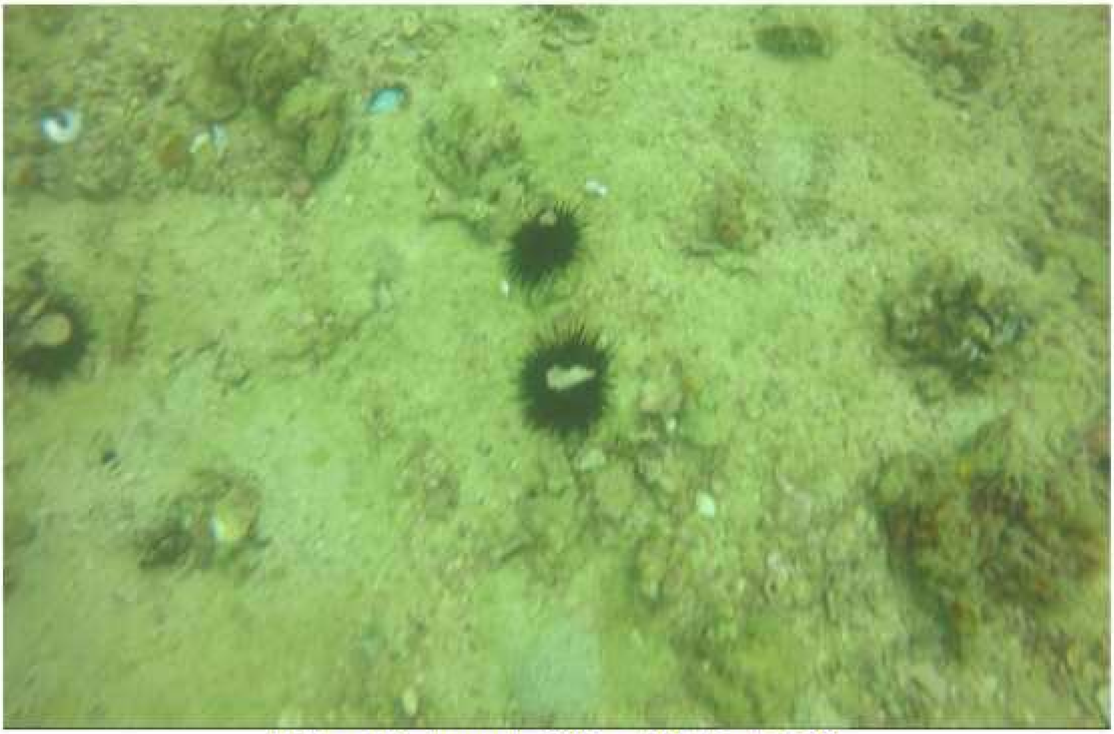


Epibenthic characteristics at Station ME-03

Epibenthic characteristics at Station ME-04

Figure 33 – Epibenthic characteristics at sampling stations (ME-03 & ME-04)

Epibenthic characteristics at Station ME-05



Epibenthic characteristics at Station ME-06

Figure 34 – Epibenthic characteristics at sampling stations (ME-05 & ME-06)

Epibenthic characteristics at Station ME-07

Epibenthic characteristics at Station ME-08

Figure 35 – Epibenthic characteristics at sampling stations (ME-07 & ME-08)

Epibenthic characteristics at Station ME-09

Epibenthic characteristics at Station ME-10

Figure 36 – Epibenthic characteristics at sampling stations (ME-09 & ME-10)

Moderately diverse coral communities have developed and more than 5 species have been recorded. Most of these corals develop at between 3 and 6 m depth. Above 3 m there is heavy grazing pressure from fishes and echinoderms on the rich algal turf that develops in shallow water, where the rocks are exposed to high sunlight intensity. It is likely that the high grazing pressure is largely responsible for the low colonisation of corals in shallow water in the UAE Arabian Gulf mainland. *Porites spp. and faviid corals* occurring in the Arabian Gulf are moderately tolerant of high temperatures and low siltation rates. The Area shows moderate diverse condition with potential importance of corals and oyster beds specially on station ME-5 and ME-8.

Multi-dimensional plot was developed, and presented in **Figure 37**. It shows the strong >60% resemblances in stations ME1, ME2 ME2, ME6, ME6, ME7 and ME8. These stations show pearl oyster sandy characteristics.

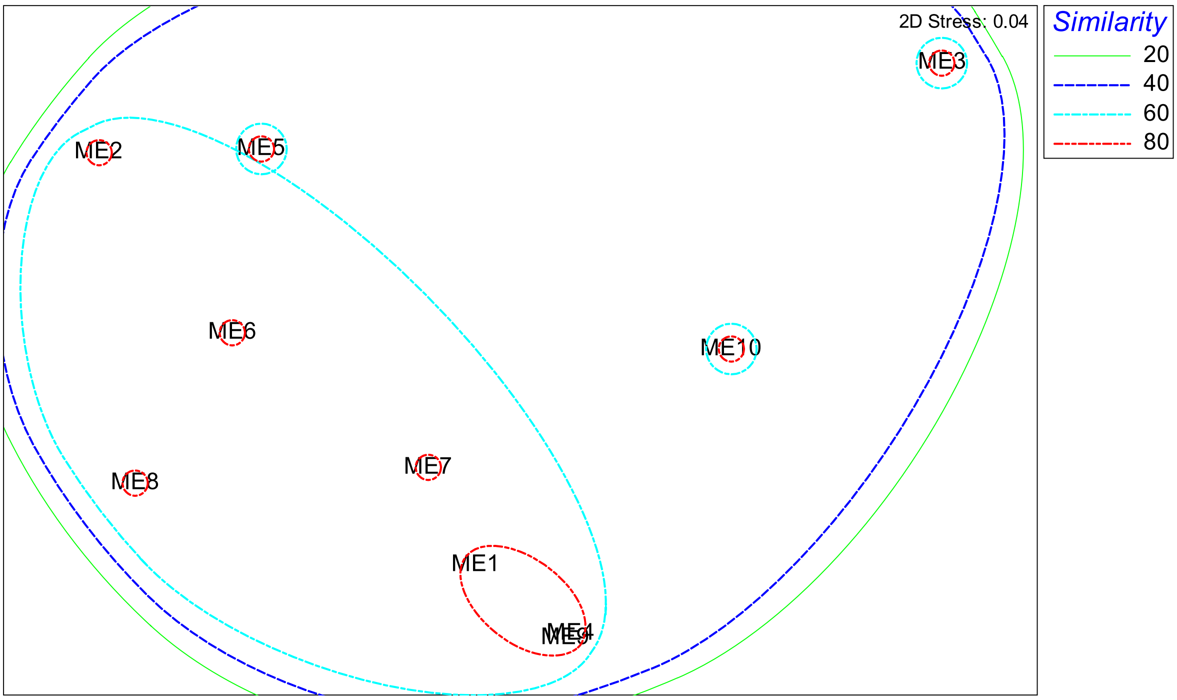


Figure 37 – Multi-Dimensional Scale plot of epibenthic community along the project area

6.5.4.2.2. Phytoplankton community

Results of the phytoplankton analysis are presented in **Table 62**. A wide variation was found within the population density of phytoplankton at the Project Area. Phytoplankton density in terms of cell counts varied from 22-83 No. $\times 10^3$/L with an overall average population density of 40.6 no. $\times$ 10^3/L.

Table 62 - Phytoplankton cell counts (no. x 10^3/L) at different sampling stations

Phytoplankton	Sampling Stations									
	ME-1	**ME-2**	**ME-3**	**ME-4**	**ME-5**	**ME-6**	**ME-7**	**ME-8**	**ME-9**	**ME-10**
Chaetoceros sp	2	3		4	2	3	2	3	2	2
Coscinodiscus radiatus		1	1			1			1	1
Proboscia alata	8	4	1	4	4	8	4	6	6	2
Rhizosolenia setigera	2	1	2	1		2		1		2
Thalassiosira eccentrica	1	1		1		1	1	2		1
Leptocylindrus minimus	2	1	2	1	2	2	2	1	2	
Pseudo-nitzschia sp.	2	3	4	3	2	1	2	1	2	4
Thalassionema bacillare	1	2	1	2	1	1	1	2	1	1
Ceratium furca	4	6		8	2	4	2	3	2	1
Prorocentrum micans	4	3	20	2	3	1	2	2	1	28
Protoperidinium sp.	12	14	4	4	8	12	6	8	12	8
Trichodesmium erythraeum			4							
Oscillatoria sp.	2		44							24
TOTAL	40	39	83	30	24	36	22	29	29	74

The dominant class of the phytoplankton was Dinophyceae (dinoflagellates) (45.8%) followed by Bacillariophyceae (Diatoms) (36%) and Cyanophyceae (Cyanobacteria) (18.2%). The most common species of phytoplankton from the Project Area were *Prtoperidinium sp* (21.7%), *Oscillatoria sp (17.2%), Prorocentrum gracile (16.3%), Proboscia alata (11.6%) and Ceratium furca (7.9%), Trichodesmium erythraeum (8.3%) and Thalassionema bacillare (5.9%).*

A total of 15 taxa of phytoplankton were recorded from the project area. Phytoplankton species, including 225 diatoms and 152 dinoflagellates have been recorded (*Dorgham and Mufatah, 1986*[14] and *Dorgham et al., 1987*[15]) in the Arabian Gulf despite possibilities of nutrient limitation (*Kimor, 1979*[16]). Planktonic organisms have been recognized as indicators of water masses and their movements (*Raymont, 1964*[17]). It has been reported that the coastal zone throughout the southern part of the Arabian Gulf is already exposed to major conflicts of resource utilization (MEPA 1992[18]). Population density was highest during the summer (*Azis, 1998*[19]) and phytoplankton blooms occurred during August and May. The present levels of phytoplankton indicate moderate population density along the Project Area. Harmful Algal blooms were absent in the phytoplankton samples.

6.5.4.2.3. Zooplankton community

Results of the zooplankton sample analysis are presented in **Table 63**. Zooplankton in the project area was comprised of 6 phyla (*Cinidaria, Chaetogantha, Annelida, Mollusca, Arthropoda and Chordata*). Arthropods represented the largest assemblage of zooplankton (64%) followed by Chordates (14%), Chaetoganth (12.2%), Molluscs (12.2%) and Cinidarians (1.2%).

An average of zooplankton density (172 no./m^3) and diversity (12 species) reflects moderate healthy conditions of zooplankton community along the project area. Fish eggs and fish larvae were not found in the samples collected.

[14] *Dorgham, M.M. and Muftah, A., 1986. Plankton studies in the Arabian Gulf. I. Preliminary list of Phytoplankton Species in Qatari Waters Arab Gulf J. Scient. Res., 4(2): 421-436.*

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Table 63 - Zooplankton density (No./m^3) at different stations from the project area

Group/Species	**Sampling stations**									
	ME-1	**ME-2**	**ME-3**	**ME-4**	**ME-5**	**ME-6**	**ME-7**	**ME-8**	**ME-9**	**ME-10**
CHAETOGNATHA										
Sagitta sp.	4	20	24	22	24	26	42	32	12	4
CNIDARIA										
Obelia sp.	2		4	4	2	2	4	1	2	
ANNELIDA										
Polychaete larvae	2		2	3	2		2	2	4	
MOLLUSCA										
Bivalve veliger larvae		6	4	6	6	14	4	7	6	
Gastropod veliger larvae		8	8	12	8	12	8	6	12	
ARTHROPODA										
Acartia fossae	42	12	48	52	62	48	36	42	24	18
Copepod nauplii	12	14	10	12	8	12	12	14	1	18
Copepod sp.	140	12	14	12	10	12	8	12	10	108
Oithona brevicornis	12		8	10	12	8	10	8	12	
Lucifer sp.	17	12	35	18	12	12	10	36	12	10
Mysis larvae		4		2	2		2		2	
CHORDATA										
Oikopleura larvae	35	52	22	17	22	13	14	24	18	24
Total	**266**	**140**	**179**	**170**	**170**	**159**	**152**	**184**	**115**	**182**

6.5.4.2.4. Macrobenthic infauna community

The number and distribution of subtidal benthic species in the project area recorded is summarized in **Table 64.** Diversity indices for macro-benthic infauna communities in the project area are provided in **Table 64**. The macro-benthic infauna at 10 sampling stations had population values ranging from 1200-3880 no./m^2 (average 2772 no./m^2).

Annelida (58.4%) and Mollusca (37.2%) constituted the community of macro-benthic infauna from the Project Area. *Polychaetes spp*.(33.1%), *Cerithiidae spp*.(10.9%), *Nereidae spp*. (9.3%), *Bivalve sp*.(5.7%), *Ophelina sp* (4.8%) and *Mitrella blanda* (4.4%) comprise major community structure of the macro-benthic infauna from the Project Area.

Polychaetes (Annelida), which include 80% population in the samples, are typically dependent on their diet such as microbial, meiobial and organic substances (*Shou et al., 2009*[20]), and formed an important component in the marine food chain especially by providing important source of food for demersal fish (*Parulekar et al., 1982*[21] and *Herman et al 2000*[22]). However, salinity and sediment particle are the two significant factors effecting benthic community of the Arabian Gulf (*Stephens and McCain, 1990*[23]). Infaunal abundance commonly increases with decreasing particle size and reduced of benthic organism by increasing salinity has been quantitatively observed in the gulf at salinities above 45‰ in the gulf of Swah and Abu Dhabi barrier island (*Clark and Keij 1973*[24], *Evans et al., 1973*[25]). The high population of macro-benthic infauna at between Stations M5-M8 could be associated with particle size in this Project Area.

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Table 64 - Abundance and diversity of macro-benthic infauna from the Project Area

Group/Genera/Species (No./m^2)	ME-01	ME-02	ME-03	ME-04	ME-05	ME-06	ME-07	ME-08	ME-09	ME-010
Annelida										
Cirratulus sp.						240		120		
Cossura sp.		120			120		360			
Glycera sp.	120	120			240	120	240	120		
Glycinde sp.					120		120			
Ophelina sp		240			240	120	240	120	360	
Nereidae spp.	240	360	240	360	360	240	120	240		360
Capitellidae spp.			640							240
Polychaetes spp.	1240	1040	240	1340	1240	840	1040	1200		840
Mollusca										
Ancilla sp.		120			120	80	120		120	
Bulla sp.		120					120		240	
Cerithiidae spp.	360	240	80	240	360	360	240	480	360	240
Loripes sp.					120		240			
Mitrella blanda	120	240			120	120	120	240	120	120
Tellina methoria	120	120			240	360	120	120	240	
Bivalve sp.	240	120		240	120	240	120	240	120	120
Gastropod sp.	240	120		240	240	120	120	240	240	120
Arthropoda										
Amplescia sp	120	120			120	120	80		40	
Amphiura sp.		120			120	120	120	120		
Total	2800	3200	1200	2420	3880	3080	3520	3240	1840	2040

Table 65 - Diversity Index of macro-benthic in-fauna from the Project Area

Stations	S	d	J'	H'(loge)
ME1	9	1.01	0.82	1.80
ME2	15	1.73	0.85	2.31
ME3	4	0.42	0.84	1.16
ME4	5	0.51	0.81	1.30
ME5	16	1.82	0.85	2.36
ME6	14	1.62	0.88	2.31
ME7	17	1.96	0.86	2.45
ME8	12	1.36	0.82	2.04
ME9	9	1.06	0.93	2.05
ME10	7	0.79	0.86	1.68

S – Number of species recorded; d – Margalef index; J' - Pielou Evenness index; H' - Shannon-Wiener Inmdex

Moderately high diversity index of Margalef (d) and Shannon-Wiener (H') at stations ME-01, ME-02, ME-04, ME-05, ME-06, ME-07, ME-08 & ME-09 shows moderate healthy statues of macro-benthic in-fauna in this project area.

Bray-Curtis similarity (**Figure 38**) and Multi-dimensional scaling (MDS) plots (**Figure 39**) of Primer 6 software graphically shows the relationship between stations (Station ME1-ME-10) along the project area. MDS plots use the similarities in community structure to graphically display the relationships between the stations. They are useful in representing the relative level of relationship between one or more stations. Bray- Curtis similarity in the present assessment show strong similarities (>80%) among Station ME1, ME2, ME4, ME5, ME6, ME7, ME8 & ME10. MDS plot also shows similarity >80% among ME1, ME2, ME4, ME5, ME6, ME7, ME8, ME9 & M10 stations (Figure 19).

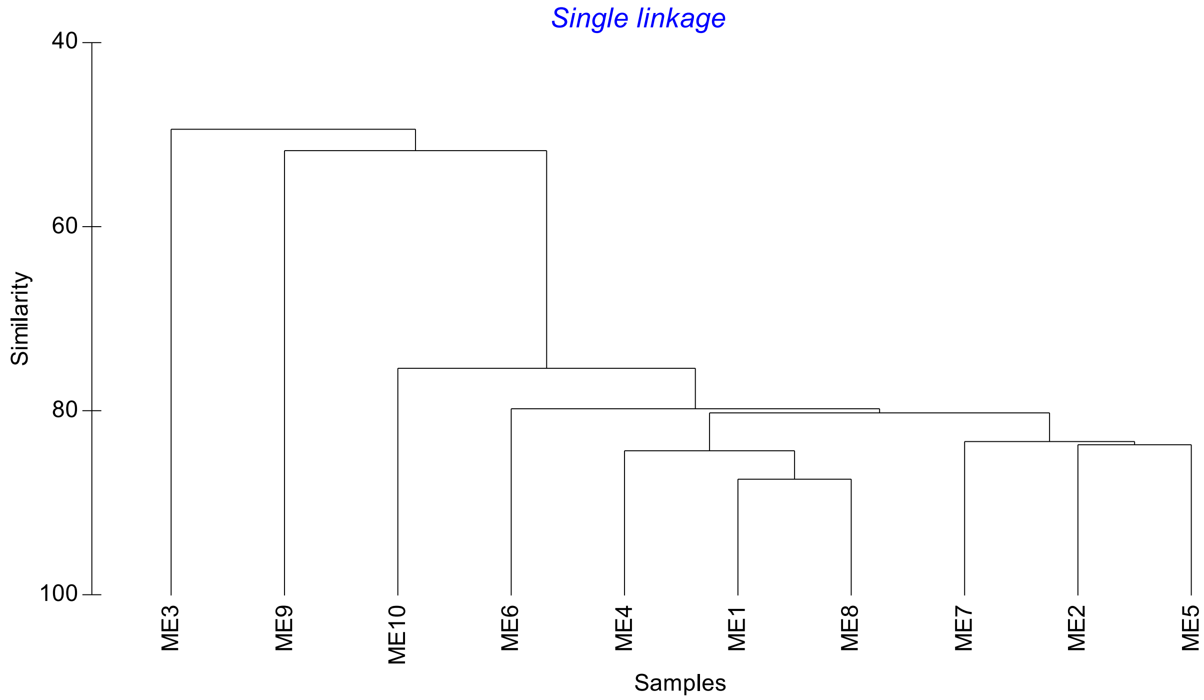

Figure 38 – Bray-Curtis similarity index of the macro-benthic infauna along the project area

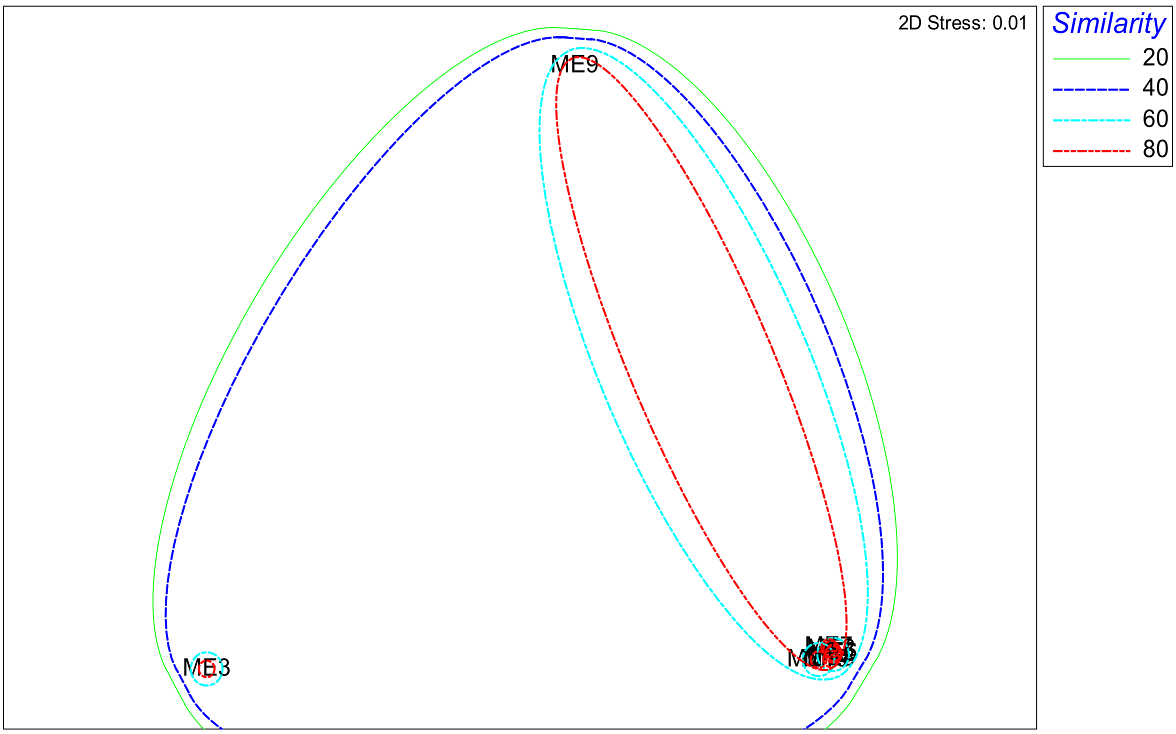

Figure 39 – Multi-Dimensional Scale (MDS) Plot of the macro-benthic infauna along the project area

6.6. SOCIO-ECONOMICS

Baseline of socio-economic presents the baseline characterization of the project area's socio-economic context prior to project implementation. The following aspects are discussed in this section:

- Land use
- Demography, including ethnicity
- Infrastructure and community access to services

6.6.1. LAND USE

The project is located in the Layyah in the Sharjah city of Sharjah Emirate, UAE. The information provided in this baseline reflects the primary area of influence by the proposed project and to the extent possible focuses on the population and communities neighboring the project.

The project site selected for proposed project is in Layyah Power Station where 900 MW power plant and 51 MIGD desalination plant are already in operation. The land allocated for the development is sandy without any vegetation and currently left barren which is used for temporary storage. The surrounding significant land use features of the project site covering 2km radius (primary impact area) are as follows:

- Power plant
- Sharjah container terminal
- Mina Khalid Port
- Arabian Gulf
- Creek and Lagoon
- Residential areas
- Hotel and Residency
- Graveyard
- Heritage area

6.6.1.1. Cultural Heritage

The following heritage receptors have been identified in the project area of influence:

- Sharjah Heritage Area (Heart of Sharjah): It is actually the epicentre and origin of Sharjah where the first families took up residence in their new stone-built homes.

Sharjah Fort, Heritage Museum are situated in the Sharjah Heritage Area. It is located 1km to the east of the project site.

- Sharjah Art Museum: The art museum is located 1.4km to the ENW of the project site.
- Sharjah Archaeological Museum: It is located 5.4 km to the east of the project site.

Cultural heritage structural or artefactual remains are not identified in the project site. The land is flat with barren land.

6.6.2. DEMOGRAPHY

Population growth in the United Arab Emirates is among the highest in world at a current 2.47% for the year of 2016. Immigration is the heaviest factor contributing to this growth. Expatriate workers in the UAE made up 90% of the country's workforce in 2013 and accounted for 7.8 million individuals out of a population of 9.2 million people. According to Federal Competitiveness and Statistics Authority (FCSA), UAE population for the year 2016 is 9,121,167 according to administrative records dated until 31 December 2016. The population administrative records also showed that 6,298,294 are male and 2,822,873 is female, making the gender split in the UAE 69% male and 31% female.

Sharjah is the third largest emirate in the United Arab Emirates, and is the only one to have land on both the Arabian Gulf and the Gulf of Oman. The emirate covers 2,590 km^2 (1,003 mi^2) which is equivalent to 3.3 per cent of the UAE's total area, excluding the islands.

6.6.2.1. Population

According to Sharjah Census 2015, total population in Emirate of Sharjah is 1,405,849. Sharjah is home to 175,432 Emirati nationals (local peoples), or 12 percent of the total population. Males and females account for 49 percent (86,325) and 51 percent (89,098) of the Emirati population respectively. Total foreign expatriates are counted at 1,230,417, making up 88 percent of the emirate’s population. Males account for more than two thirds of the expatriate population totaling 834,542, with females counted at 89,098.

Project site is located in the Sharjah city and the census found 1,274,749 people living in Sharjah city, accounting for 91 percent of the emirate’s total population. Sharjah’s east coast city of Khorfakkan was ranked second with 39,151 residents (2.8%), followed by the east coast city of Kalba with 37,545 (2.7%). Other notable urban areas covered by the 2015 census were: Al Dhaid city with a population of 20,165 (1.4%); Dibba Al Hisn city with 12,573 (0.9%); Al Madam city with 11,120 (0.8%); Mleiha city with 4,768 (0.3%); Al Bataeh city with 3,958 (0.3%); and Al Hamriyah city with 3,297 (0.2%).

6.6.2.2. Social and employment status

Of the Emirati population, 30,424 males (56%) and 29,728 females (51%) are married, while 44 percent of males and 49 percent of females are single, divorced, widowed or abandoned. Of the expatriate population, 454,597 males (63%) and 209,818 females (73%) are married, while 37 percent of males and 27 percent of females are single, divorced or widowed.

Data from the census shows that 76 percent of the 1.12 million residents over 15 years of age are employed, while 5 percent are full-time students and 6 percent are unemployed, retired, unable to work, self-supporting or carry out domestic work only. 95.1 percent of Sharjah's 855,709 working population are employees, 1.5 percent are self-employed and 2.1 percent are business owners. About 82 percent of Sharjah's working population (575,610) have occupations in the private sector, while the federal government employs 4 percent (29,673), the local government 6 percent (45,434) and semi-government bodies 3 percent (17,688). Domestic jobs account for a further 5 percent, while diplomatic and foreign sectors less than 1 percent. According to Sharjah Census 2015, there are 253,105 male and female students enrolled in educational institutions (aged four years and above), of which 22 percent are attending university.

6.7. INFRASTRUCTURE AND COMMUNITY ACCESS TO SERVICES

6.7.1. TRANSPORTATION

Sharjah Emirate has reasonably well developed transport infrastructure. Sharjah city has a problem with vehicular traffic congestion during rush hours especially the roads leading to and from the Emirate of Dubai. The role of the Sharjah Public Transport Corporation (SPTC) is to reinforce public transportation, setting its policies and find strategic solutions for smooth traffic, providing modern and professional transport services to the passengers, driving Sharjah Emirate or on the InterCity routes, between all emirates in UAE. There are two major series of highways in Sharjah, which are "E" and "S". E represents roads connecting other emirates and S for roads within the emirates. The major roads in the emirate of Sharjah include:

- E 11 - Al Ithihad Road - connecting Dubai, Ajman and RAK.
- E 311 - Sheik Mohammad Bin Zayed Road - connecting Dubai, Ajman and RAK.
- E 611 - Emirates Road - connecting Dubai, Ajman and RAK