CHAPTER VIII

B A T H Y M E T R I C S T U D I E S

VIII.1 INTRODUCTION

It is observed that the navigability of the Gulf coast, is controlled by a number of factors like coastal geomorphology, geohydrographic features, tidal currents and climatic factors. The study comprises a critical evaluation of the creeks and 'nars', islands, coral reefs, currents, waves, wind velocity, directions of wind, cyclones, storms etc., in relation to the problems of navigation.

The Gulf of Kutch has a funnel shape, opening up westward into the Arabian sea, and tapering to the east and merging into the Little Rann. It lies between Lat. $20^{\circ}17'$ N to $22^{\circ}55'$ N and Long $69^{\circ}5'$ E to 70° $15'$ E. Length of the Gulf is about 140 km, and the total area occupied is approximately 5675 sq km giving a shore-line of about 340 km length. The width of its mouth is about 42 km, N 20°E of Okha. The width and depth progressively reduce eastward to merge into the Little Rann of Kutch.

VIII.2 SHORELINE

The Gulf is bounded by two shore lines - the northern forming the Kutch boundary and the southern comprising the Saurashtra boundary.

1) Northern Shoreline

The northern shoreline is smooth, crescent-shaped dissected by a number of streams. Its total length between Jakhau to Kandla being about 190 km. Kandla is the main port of this shoreline while Mandvi and Mundra are the other two minor ports. Kandla creek extends parallel to Long. $70^{\circ}14'$ E with 6 m. depth and 1 km width. Western part of this shore

has almost no mud zone, and the land gradually slopes to form the Gulf bottom. On the other hand, the eastern half from Mandvi has 0.05 to 5 km wide mud zone with abundant mangroves.

Absence of coral reefs along this shore line is a characteristic and striking feature. Corals are always obstalces for navigation. These are not there, but other obstacles i.e. a number of shoals, are typical of this coast line. The shoals are both rocky and sandy. The important shoals are 1) Ranwara shoal south of Mandvi, 2) Sonar Durree shoal south-east of Kotdi Creek, 3) Kala Dara shoal, 4) Kapoor shoal and 5) Baptista shoal south of Kandla Creek. The latter three shoals are sandy and muddy while the former two are rocky. Except Baptista shoal, the rest remain under water even at low tide.

2) Southern Shoreline

The southern shoreline forms the boundary of Saurashtra. It is highly irregular and concave in shape and consists of several characteristic features like islands, coral reefs, submerged stream channels and wide mud flats with mangroves.

The shoreline being highly irregular and dissected by stream channels, has given rise to a number of islands or bets. Some of these islands are above the water line (Table VIII.1) while others remain submerged even during the low tide. The surface of these islands is covered by muds and mangroves.

Table VIII.1

I. Islands that remain above the waterline during high tide:

1)	Bet Shankhodhar	2)	Nara Island
3)	Bhaidar Island	4)	Chank Island
5)	Ajad Island	6)	Panero Island
7)	Gandiya Kado Island	8)	Dhani Island
9)	Karumbhar Island	10)	Norara Bet
11)	Munde ka Bet & Dide Ka Bet	12)	Bains Bid
13)	Chhad & Jindra Bet	14)	Pirothan Island

II. Islands that remain submerged during high tide only :

1)	Dona	2)	Boria	3)	Manguda
4)	Savaj	5)	Pashu	6)	Guga
7)	Dhani	8)	Vudda	9)	Kudda
10)	Goos	11)	Kalvan Island	12)	Paga

III. Islands that remain always submerged :

1) Ranson Shoal (north of Jamnagar),

2) Bobby Shoal,

3) Marian Shoal (west of Okha)

4) Gurur Shoal (north-west of Okha)

VIII.3 CORAL REEFS OF THE SOUTHERN COAST

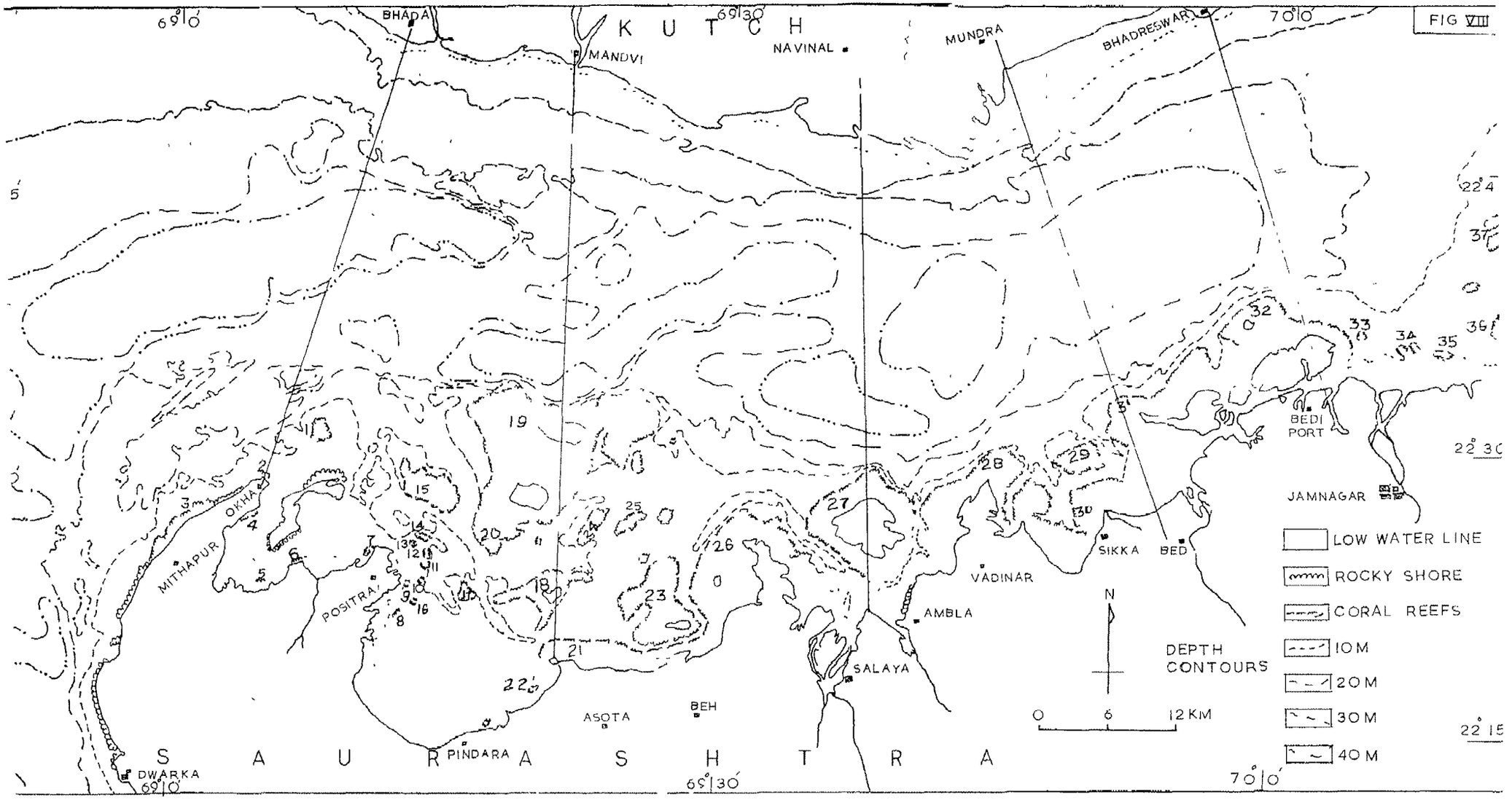
Along the southern coast, the growth of corals along the islands and adjacent mainland is a common feature. Except Narara island, all the reefs comprise living forms forming barrier reefs, fringing reefs and at places atolls. Their growth is vertical but because of exposure to sunlight or sedimentation on top they grow laterally or inclined also. Uptil now 37-40 island and mainland coral reefs have been investigated by Marine Biological Research Station, Okha Port. The details of the coral reef are given in the map (Fig. VIII.1) and the table No. VIII.2.

Table VIII.2

I : Island Coral reefs
M : Mainland Coral reefs

1) Chindri I	2) Samiani I
3) Aramda - West M	4) Aramada NE M

Contd...



GULF OF KUTCH SHOWING DEPTH CONTOURS, CORAL REEFS, ROCKY SHORES AND LOCATIONS OF CROSS PROFILE

Table VIII.2 (Contd.)

5) Rajpura Bandar M	6) Kyu I
7) Positra Port M	8) Dabdaba I
9) Lefa I	10) Merodi and Langa Merodi I
11) Dona I	12) Boria I
13) Mongunda I	14) Savaj I
14) Paga I	16) Manmarudi I
17) Pashu I	18) Ajad I
19) Bural or Chank reef	20) Chusna Bety I
21) Kimra khat I	22) San Belia I
23) Gunjao Kudda I	24) Vudda I
25) Kudda I	26) Dhani M
27) Karumbhar I	28) Narara M
29) Goos reef I	30) Sikka reef M
31) Munde M	32) Pirothan I
33) Kalvan I	34) Rosy M
35) Sachana I	36) Sachana M
37) Balachadi I	

On the basis of the relative abundance of corals (Chhaya & Patel, 1977) have divided the shoreline into three zones :

1) Shoreward zone 2) Middle zone

3) Seaward zone

1) Shoreward Zone (0 to 25 m)

Almost devoid of corals. The reefs of Laku point and Adatra are made up of sharp-edged rocks holding small pools of water wherein stray specimens of coral (average size 10 to 60 cm) are encountered.

2) Middle Zone (26 to 875 m)

Owing to rugged topography and overpassing currents, coral establishments are quite rich. The Narara reef zone is rather plain made up of dead coral boulders and pebbles covered with mud.

3) Seaward Zone (876 to 1000 m)

Concentration of corals is rather high, much higher than the previous zone.

VIII.4 CREEKS

The southern shoreline of the Gulf of Kutch is full of islands, shoals, coral reefs etc. because of which free navigation is difficult. For this, some creeks [illegible] were carefully studied and possible deep water lines were marked. Situated

near the mouth of the Gulf, in between Okha and Bet Shankodhar, is a commercial port, where good depths of water are available for berthing 40,000 D.W.T. ships, with a suitable turning circle.

The north-eastern side of the Bet Shankhodhar has a rocky shore with a very close deep water zone. Rock cliffs of 2 m height extend under water to a depth of 5 m and then to 10 m forming a sharp break in profile. This site also leaves sufficient space for turning big ships. Tidal currents have less effect on this side being in Pindara Bay. Bet Shankhodhar being on western side, the site is protected from the fury of SW monsoon wind, which blows with a great speed during monsoon.

A deep water channel is extending due SE from the east of Bet Shankhodhar upto Khimra Khat reef, where there is a water depth of 5 m right upto the reef at the eastern border of Pindara Bay. This bay is protected from both wind and currents, lying in between the mainland on SW side and Bhaidar and Ajad Islands on NE side. This channel is bordered by reefs at places on either side.

The area between Salaya Harbour and Patra Van Creek is full of creeks and sub-creeks with good depth of water, and providing sites with good shelter from wind, tidal currents and waves.

Karumbhar Island, north of Salaya, has formed two big and important creeks in the mainland 1) Salaya creek and 2) Pathfinder inlet.

Salaya creek is situated north of Salaya extending in a NW-SE direction between Dhani Island and Karumbhar Island with a water depth of 5 m or more upto north of Sykes Point. Creek sides are almost vertical and bordered by corals. Length of creek is about 12.0 km with an average width of 1.00 km. With a progressive shrinking, the creek is joined with the Pathfinder inlet by Blunt channel. Blunt channel is devoid of corals and its southern border near H.W.L. is rocky (N of Mota Ambla).

Pathfinder inlet extends in a NW direction parallel to Long $69^{\circ}40'$ E, for a length of about 6 km from the mouth to 5 m depth pt. in south. Width of channel is 300 to 400 m. This channel branches into two sub-channels of 5 m or more depth

on its eastern side extending in a NW-SE direction. Width of northern subchannel varies from 100 to 300 m, while the southern channel is hardly 100 m wide. Except near its mouth, the creek is free from corals and is muddy.

Sikka Creek extending NS for 4 km NW of Sikka. The creek is bordered by corals on its western and eastern sides. The creek has 4 off-shoots of 5 m depth and less. Offshoots vary in width from 100 m to 300 m. Sikka Creek is protected from the prevailing winds of SW and NE direction by Narara bet in the SW and partly by Goos reef on NE side.

Patra van creek is an important creek of this shore. It has maximum depth of 18 m with almost steep walls. Headward, the creek is terminating and has almost vertical walls and depth more than 10 m. It extends NW-SE for a length of 3 km with widths varying between 300 to 800 m. This creek is devoid of offshoots. It is, in fact the extension of the stream channel of Sasoi River.

The creeks and nars of the Jamnagar vicinity are very small, and useful during high tide time only.

VIII.5 GEOHYDROGRAPHIC FEATURES

1. General

Detailed geohydrographic studies were carried out by the Kandla Port Trust authorities in 1975 in connection with selection of site for the construction of a sheltered all-weather port. The observations were made especially between two minor ports Salaya and Sikka.

When the off-shore Oil Terminal Project was approved by the Government of India in 1974, the Indian Navy carried out a detailed hydrographic survey of the Gulf of Kutch including Pathfinder Creek and the Navigational Channel for very large crude carriers having capacity upto 3,00,000 tonnes which are expected to use the terminal. From the chart, it will be observed that very good depths are available in the Pathfinder Creek almost near the banks

The details given in the following pages were made available to the author by personal communication.

2. Tidal observations

In the vicinity of the Pathfinder Inlet tidal predictions for Salaya Lat. 22°22'0" N and Long. 69°37'0" E have been carried out by Survey of India, Geodetic & Research Branch,, Dehra Dun. The chart Datum is 3.21 m below the Indian Mean Sea Level and the values obtained for the year 1975 are shown below :

(i)	High water Spring	=	6.21 m on 5th Nov. '75
(ii)	High water Neap	=	4.06 m on 14th May '75
(iii)	Low water Spring	=	0.12 m on 6th Oct. '75
(iv)	Low water Neap	=	2.82 m on 3rd July '75
(v)	Spring tide range	=	5.48 m on 6th Oct. '75 (5.60 - 0.12)
(vi)	Neap tide range	=	1.66 m on 3rd July '75 (4.48 - 2.82)

3. Current observations

The Salaya and the Pathfinder Creeks are located on the western and the eastern sides of the Karumbhar Island respectively. Both the creeks meet in a channel on the southern side of the Island known as 'Blunt Channel'. In order to study the general tidal current, pattern of the creek system, simultaneous current observations with the

use of log ships in Salaya creek, Blunt Channel and Pathfinder Creek were carried out from 2.12.74 to 3.12.74 for one full cycle of spring tide. The important observations are as below :

(i)	Max. velocity during flood	0.69 m/sec (1.38 knots)
(ii)	Normal direction of current during flood	145°
(iii)	Max. velocity during ebb.	0.48 m/sec (0.96 knots)
(iv)	Normal direction of current during ebb	345°

It was also considered necessary to have further current observations near the proposed Berthing Jetty site and its approaches. The current observations were carried out with the help of log ships from 17.1.76 to 21.1.76 during one cycle of spring tide, and important observations are given below :

(i)	Maxm. velocity during flood	0.75 m/sec (1.5 knots)
(ii)	Normal direction of current	
(iii)	Max. velocity during ebb.	0.41 m/sec (0.83 knots)
(iv)	Normal directions of current during ebb.	298°
(v)	Singular peak velocity record	1.05 m/sec (2.10 knots)

4) Float observations

For ascertaining the surface velocity and to study the flow pattern of the water at different stages of tide in the vicinity of Berthing Jetty and approaches float observations were carried out from February to April, 1975

5) Wind

The direction and velocity of wind prevailing in Gulf of Kutch vary from month to month. Observations of wind speed and direction near the proposed Berthing Jetty site carried out from June 1975 to October, 1975, are summarised as under :

June, 1975

(i) Max. wind velocity @ 11.20 hrs on 20.6.1975 — 63.60 km/hr

(ii) Direction — NW-W

July, 1975

(i) Max. wind velocity @ 02.30 hrs on 3.7.75 — 57.00 km/hr

(ii) Direction — SW-W

August, 1975

(i) Max. wind velocity @ 19.48 hrs on 7.8.1975 — 55.80 km/hr

(ii) Direction — N

September, 1975

(i) Max. wind velocity @ 24.00 hrs on 11.9.75 — 42.60 km/hr

(ii) Direction — SW-W

October, 1975

(i) Max. wind velocity @ 13.46 hrs on 20.10.1975 — 39.60 km/hr

(ii) Direction — NE-N

The normal direction and velocity of wind during the year are as below :

Period	Direction	Av. wind speed
(i) October to March	North-East	10 km ph
(ii) April to May	South-West	20 km ph
(iii) June to September	South-West North-East	60 km ph

It will seen from the above data that severe winds are from South-West direction in monsoon season from June to September.

6) Storms and Cyclones

It has been observed that occasional storms do occur in this region with a wind speed of

average 100 km ph. In the recent past an unprecedented cyclone swept the NW coast of Saurashtra on 22nd and 23rd October, 1975. The maximum velocity of wind as recorded in Jamnagar Air Force Meteorological Station was 180 km ph.

The severe cyclonic storm in east central Arabian Sea centred at 1730 hrs IST of 2nd June, 1976 near Lat. 19'.7° N and Long 71°.7' E moved NNE and crossed Saurashtra Coast between Mahuva and Bhavnagar at 8.30 hrs on 3.6.76. It further moved NE and emerged into the Gulf near Bhavnagar and again crossed south Gujarat coast near Cambay and weakened into a cyclonic storm centred at 8.30 hrs on 4th near Anand. It moved northward and weakened into a deep depression centred at 8.30 hrs on 5th about 70 km east of Ahmedabad. It further weakened and lay as a well marked low pressure area over extreme N. Gujarat region and S. Rajasthan on 6th morning. It further moved NE and lay as low pressure area over SE Rajasthan and N. Madhya Pradesh. Under its influence SW monsoon was established in South Gujarat shores and temporarily advanced in N. Gujarat state. During its passage, it gave heavy to very heavy rainfall in Gujarat

region and Bhavnagar District. Bhavnagar and Surat dist. reported exceptional heavy rainfall of 290 mm and 210 mm respectively on 6th June, '76.

More recently a severe cyclonic storm with a core of hurricane winds in east central Arabian sea moved NW till 9th November, 1978 and then started receding towards the Gujarat Coast. It crossed N. Gujarat coast near Kutch Mandvi on the midnight of 11th and weakened into a deep depression centred at 0830 HRS. IST on 12th November close to Kutch Mandvi. This deep depression moved Eastward and lay near Surendranagar as depression on 13th at 0830 HRS IST. The system further weakened into a well marked low pressure area over Saurashtra by 13th evening and became unimportant by 14th morning.

Under the influence of above weather conditions, rainfall was scattered in South Gujarat region on 10th isolated to scattered in Saurashtra during 11th to 14th, widespread in Kutch on 12th and 13th and scattered to fairly widespread in Gujarat region during 12th to 14th.

Night temperatures were generally appreciably to markedly above normal over the State during the week.

7) Waves

It is presumed that waves will be generated in the creek mainly due to wind blowing from north direction. However, the wave height in the creek is not of a big magnitude. During the Survey and Investigation period from October, 1974 to March 1975 it was experienced that wave action is not appreciable. The visual observations of wave height near the proposed berthing jetty site in Pathfinder Creek and its mouth in the Gulf of Kutch have been carried out from June 1975 to October, 1975.

Sr. No.	Period	Maximum wave height in Pathfinder	Maximum wave height at mouth of creek
(i)	June, 1975	0.75 m	1.5 m
(ii)	July, 1975	0.88 m	1.65 m
(iii)	August, 1975	1.12 m	1.35 m
(iv)	September, 1975	1.00 m	1.5 m
(v)	October, 1975	0.60 m	1.5 m

8) Littoral drift

From the observations made so far no littoral drift is noticed along the coastline in this region.

VIII.6 OFFSHORE SUB-SOIL INVESTIGATIONS

The sub-soil investigations in the proposed alignment of rubbles around and in the vicinity of Berthing Jetty site have been carried out in the years 1974 and 1975 in order to facilitate foundation design of marine structures. Six bore holes were drilled for the purpose.

Three bore holes were drilled with hand boring equipment in the alignment of rubble mound. It is seen that the top strata comprises of sand with shells and corals followed by silty clay with corals. The rocky strata is available at a depth varying from 8 m (near the shoreline) to 8.5 m (towards the Pathfinder creek). In view of the availability of good sub-soil strata no appreciable settlement of mound is expected.

Bore hole Nos. 4 and 5 were drilled in the vicinity of Berthing Jetty with the help of mechanical rotary rig. With this rig undisturbed samples of sand, clay etc. could not be collected. Rock was met at RL-18.24 m (60.8 ft) at bore No. 4 and RL-17.4 m (58 ft) at bore No. 5.

Bore hole No. 6 was executed in 10 m contour water depth in the creek. The drilling operation was executed with the help of a steel dump barge anchored in the creek. As brought out earlier undisturbed samples of clay and sand could not be collected. Rock was encountered at 9 m (30 ft) depth below sea bed level i.e. at RL-18.9 m (-63.00ft).

VIII.7 SUNDRY DATA

1) Salinity of Sea water

The salinity of sea water in this area is normally between 10-11 on Beoums Degree with total dissolved solids to a tune of 44000 P.P.M.

2) Rainfall

The area is drought-prone. The rains occur in the period July-August. The average rainfall is about 200 mm. In 1975, the rainfall recorded at the proposed jetty site was 600 mm.

3) Temperature

The temperature drops from the month of December and heavy cold is experienced in the months of January and February. The minimum temperature in the region is $6^{o}C$. The temperature increases steadily from March onwards and in the months May and June it rises upto $36^{o}C$. Observations taken in the year 1975 indicate that maximum temperature was $36^{o}C$ in the month of May, and the minimum was $6^{o}C$ in January-February.

VIII.8 HYDRAULIC MODEL STUDIES

1) General

The basic prototype data such as a soundings in the creek, topographical survey of mud flats surrounding the creek system, observations on tides, currents, wind, waves, silt analysis from time to

time etc. carried out for a period of one year was supplied to the Central Water & Power Research Station, Pune for analysis. On the basis of prototype data a full scale hydraulic model of the entire creek system including the Pathfinder and Salaya creeks, Blunt channel and Karumbhar island was constructed at the Research Station. The analysis of data summarised by Research Station is as under :

2) Siltation

From the available survey data it is observed that no significant siltation has taken place in this area. Analysing the silt charge data it is felt that as the values are not large, the question of siltation should not pose a serious problem.

3) Current

The strength of the current is 1.05 m/sec (2.10 knots) in deeper portion (near the proposed jetty site) and in the shallow portion the current strength is low. The flood and ebb currents do not follow the same path but are divergent by about 20^{o}.

4) Wave observations

No data has been recorded by instrument but visual observations from June to October, 1975 have confirmed that wave height (near Berthing jetty) is in the order of 1.15 m only. Some waves approach from south-west direction generated by winds blowing over surrounding tidal flats when filled with water.

5) Tidal prediction

The tidal observations (at the jetty site) indicate that there is a strong diurnal inequality which reduces during the spring tide. It is seen that the tidal prediction for Salaya (Sykes Point) is more or less applicable to the Pathfinder Creek with minor variations.