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Measurement and Prediction of tides for Gopalpur Port, Orissa

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SYNOPSIS

Gopalpur Port is a fair weather port in Orissa, situated on the east coast of India. The predicted tide levels reported in the Indian Tide Table do not include the tides for the Gopalpur Port, it was felt necessary to study the tidal characteristics at Gopalpur. The hourly tidal heights measured from 8 January 1993 to 10 April 1993 have been used for the analysis. The measured tide levels indicated that the tides at Gopalpur is about 0.26m lower than the tides at Paradip and about 0.13m higher than at Visakhapatnam. The tides at Gopalpur has a time lag of 11 min behind Paradip and 15 min behind Visakhapatnam. The tides predicted for Gopalpur based on the limited data collected during the present study is found to agree very well with the measured tides.

INTRODUCTION

The Gopalpur Port is situated on the east coast of India at lat. $19^{\circ} 45'$ N and long. $84^{\circ} 58'$ E (Fig. 1). The port is presently under operation during October to March and development is under progress to convert the port as an all weather port. Various oceanographic studies have been planned to evaluate the engineering design parameters for the development of the port. The tide in this region is predominantly semidiurnal. The average spring tidal range is about 2.39 m and neap tidal range is 0.85 m. As the predicted tide levels reported in the Indian Tide Table published by the Surveyor General of India do not include the tides at the Gopalpur port, it was felt necessary to study the tidal characteristics at Gopalpur Port. Accordingly, the variation of tides were measured at Gopalpur Port, using computer based self recording tide gauge from 8 January 1993 to 10 April 1993.

METHOD OF STUDY

Data collection

An Inter Ocean (USA) self recording tide gauge (WTGS4) was deployed at the entrance channel, close to the dredger pedestal (Fig. 1). The instrument was programmed to record the tides internally at hourly interval. It is a rugged self-contained instrument, featuring micro processor control for ease of adapting to user requirements, self contained CMOS solid state memory, and dual pressure sensors for optimum performance of wave and tide measurements. The pressure transducer output is amplified and then manipulated by an on board microprocessor to obtain tide data. With the aid of an S110 Interface Unit, communication with the WTGS4 is handled through a serial RS223 link.

Data analysis

The procedure and methods adopted in the present analysis were followed from Foreman, 1984. The amplitudes and phase lags were calculated using the method of least square fits coupled with nodal modulation for the possible harmonic tidal constituents. Considering the standard 69 constituents, the possible constituents that can be resolved from the length of the present record were calculated. The astronomical tidal variables required by the tidal analysis programme were used from Doodson (1921) in his development of the tidal potential.

The values of the astronomical variables in the constituent data were calculated from power series expansions formulae in the Explanatory Supplement to the Astronomical Ephemeris, American Ephemeris and nautical Almanac. The frequencies specified for all constituents have been calculated from the rates of change of the astronomical variables and the respective Doodson numbers. The Rayleigh comparison constituent is used for deciding whether a specific constituent should be included in the analysis.

The tidal records were analyzed using the least squares fit for constituent amplitude and phase. If σ_j for $j=1, M$ are the frequencies of the other tidal constituents chosen for inclusion in the analysis by the Rayleigh criterion, then to find the amplitudes A_j and phases ϕ_j of the function,

$$C_o + \sum_{j=1}^M A_j \cos ((2\eta(\sigma_j t_j - \phi_j))$$

that best fit the series of observations, $y(t_i)$, $i=1, N$. The most common optimization criterion used is the least squares technique. There were no gaps in the recorded data. More details of the analysis are presented in Godin

(1972) and Foreman (1984). The summation expressions arrived in the least squares fit were simplified using matrix solutions. The result of the least square analysis gives the constituent with frequency σ_j , the optimal amplitude A_j and phase ϕ_j value for the tidal signal $A_j \cos [2\eta(\sigma_j t - \phi_j)]$.

RESULTS AND DISCUSSION

Variation of tides at Gopalpur

The typical variation of measured tides at Gopalpur in March 1993 is shown in Fig. 2. The tides are semi diurnal with little inequality with the occurrence of two high and two low tides in a day. The spring and neap tidal ranges recorded during the measurement period from 8.1.93 to 10.4.93 are presented in Table 1. The spring tidal range varied from 1.57m to 2.08 m and the neap tidal range varied from 0.46 to 0.87 m.

Comparison of measured tides with Paradip and Visakhapatnam

The measured tides at Gopalpur were compared with the predicted tides at Paradip published in the Indian Tide Table, 1993 (Surveyor General of India) (Fig.2). The tidal ranges at Gopalpur are approximately 0.26 m less than those occurring at Paradip. The tide at Gopalpur has a time lag of about 11 min as compared to the tide at Paradip.

The measured tides at Gopalpur were compared with the predicted tides of Visakhapatnam in March 1993 and is shown in Fig. 3. The tidal ranges at Gopalpur is approximately 0.13 m higher than those occurring at Visakhapatnam. The tide at Gopalpur has a time lag of 15 min as compared to the tide at Visakhapatnam.

Prediction of tides for Gopalpur

Based on the analysis of the measured tides, the 39 tidal constituents derived are presented with amplitude and phase lag in Table 2. Using these 39 tidal constituents, the tidal prediction is made for the Gopalpur Port. The predicted tides for Gopalpur Port for March is compared with measured tides of the same month (Fig. 4). It is seen that the predicted tide levels and time of tidal occurrence agree well with the measured tide. Still closer agreement could be achieved, if the tidal measurement is carried out for a longer duration in order to derive additional tidal constituents. Using the same procedure the tide levels at Gopalpur Port were predicted for a period from October 1993 to December 1994. The typical predicted tide levels for the month of June 1994 is shown in Table 3. The predicted tides for Gopalpur based on the present study are compared with the predicted tides of Paradip based on the Indian Tide Table for the month November 1993 (Fig. 5).

CONCLUSIONS

The tides predicted for Gopalpur based on the limited data collected during the present study is found to agree very well with the measured tides and with the tides predicted for Paradip and Visakhapatnam with an appreciable time lag. In order to improve the accuracy in the tidal prediction additional tidal harmonic constituents are to be evaluated which can be obtained by measuring the tides for a longer period, at least for an year.

ACKNOWLEDGEMENTS

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REFERENCES

- DOODSON, A T(1921) The harmonic development of the tide generating potential, Proc. Roy. Soc. Series A, 100, 306-323.
- FOREMAN, M G G (1984) Manual for tidal heights analysis and prediction, Pacific marine science report 7-10, Institute of Ocean science, Patricia bay, Victoria.
- GODIN, G (1972) The analysis of tides, University of Toronto Press, Toronto, 264 pp.
- Indian Tide Tables (1993), Surveyor General of India, Dehra Dun, 238 pp.

Table 1. The spring and neap tidal ranges measured at Gopalpur.

Date	Spring tidal range (m)	Neap tidal range (m)
9.1.93	1.95	..
18.1.93	..	0.87
23.1.93	1.55	..
1.2.93	..	0.46
8.2.93	2.02	..
16.2.93	..	0.68
22.2.93	1.52	..
3.3.93	..	0.69
9.3.93	2.08	..
17.3.93	..	0.58
24.3.93	1.57	..
2.4.93	..	0.76
7.4.93	1.78	..

Table 2. Estimated tidal constituents for Gopalpur.

No	Name	Frequency (hr ⁻¹)	Amplitude (m)	Phase lag (deg)
1	Z0	0.00000000	1.3726	0.00
2	MM	0.00151215	0.0517	322.78
3	MSF	0.00282193	0.0088	348.07
4	ALP1	0.03439657	0.0022	36.52
5	2Q1	0.03570635	0.0051	75.89
6	Q1	0.03721850	0.0041	1.48
7	O1	0.03873065	0.0429	323.69
8	NO1	0.04026859	0.0109	321.33
9	P1	0.04155259	0.0409	345.53
10	K1	0.04178075	0.1237	338.46
11	J1	0.04329290	0.0099	313.36
12	OO1	0.04483084	0.0103	326.54
13	UPS1	0.04634299	0.0047	350.26
14	EPS2	0.07617731	0.0023	274.81
15	MU2	0.07768947	0.0223	196.19
16	N2	0.07899925	0.1257	238.37
17	M2	0.08051140	0.5150	248.26
18	L2	0.08202355	0.0283	266.73
19	S2	0.08333334	0.2599	283.68
20	K2	0.08356149	0.0707	306.08
21	ETA2	0.08507364	0.0021	307.30
22	MO3	0.11924210	0.0028	3.88
23	M3	0.12076710	0.0053	336.87
24	MK3	0.12229210	0.0023	145.11
25	SK3	0.12511410	0.0046	128.34
26	MN4	0.15951060	0.0028	18.75
27	M4	0.16102280	0.0036	15.29
28	SN4	0.16233260	0.0014	146.85
29	MS4	0.16384470	0.0038	81.26
30	S4	0.16666670	0.0036	127.16
31	2MK5	0.20280360	0.0024	179.19
32	2SK5	0.20844740	0.0019	9.19
33	2MN6	0.24002200	0.0012	235.12
34	M6	0.24153420	0.0013	42.16
35	2MS6	0.24435610	0.0034	235.14
36	2SM6	0.24717810	0.0016	290.06
37	3MK7	0.28331490	0.0011	314.08
38	M8	0.32204560	0.0015	327.92
39	M10	0.40255700	0.0014	113.52

Table 3. Predicted tides for Gopalpur in June 1994.

	Date	Time (hrs)	Ht. (m)	Time (hrs)	Ht. (m)	Time (hrs)	Ht. (m)	Time (hrs)	Ht. (m)
1	6 94	210	1.5	756	1.1	1415	1.7	2115	1.0
2	6 94	345	1.5	935	1.1	1527	1.6	2240	1.0
3	6 94	520	1.6	1110	1.1	1640	1.6	2334	0.9
4	6 94	613	1.7	1210	1.1	1737	1.6
5	6 94	11	0.9	647	1.8	1251	1.0	1819	1.7
6	6 94	39	0.8	713	1.9	1322	1.0	1854	1.7
7	6 94	105	0.7	737	2.0	1349	0.9	1927	1.8
8	6 94	133	0.7	802	2.1	1417	0.8	2000	1.9
9	6 94	205	0.6	831	2.2	1449	0.8	2033	1.9
10	6 94	238	0.6	902	2.3	1524	0.7	2107	2.0
11	6 94	314	0.6	937	2.3	1601	0.7	2142	2.0
12	6 94	351	0.6	1013	2.3	1641	0.7	2221	1.9
13	6 94	429	0.7	1052	2.2	1724	0.8	2305	1.9
14	6 94	511	0.8	1134	2.2	1810	0.8
15	6 94	0	1.8	559	0.9	1221	2.1	1901	0.8
16	6 94	109	1.8	701	1.0	1315	2.0	2000	0.9
17	6 94	226	1.8	821	1.1	1423	1.9	2110	0.9
18	6 94	349	1.8	946	1.2	1541	1.8	2222	0.8
19	6 94	507	1.9	1108	1.1	1656	1.8	2327	0.8
20	6 94	608	2.1	1219	1.0	1803	1.9
21	6 94	23	0.7	658	2.2	1317	0.9	1901	1.9
22	6 94	114	0.6	742	2.3	1408	0.8	1952	2.0
23	6 94	202	0.5	825	2.3	1454	0.7	2039	2.0
24	6 94	247	0.5	907	2.3	1539	0.6	2123	2.0
25	6 94	330	0.5	950	2.3	1621	0.6	2208	1.9
26	6 94	412	0.5	1032	2.2	1703	0.6	2253	1.9
27	6 94	453	0.6	1114	2.1	1743	0.7	2340	1.8
28	6 94	535	0.8	1157	2.0	1824	0.8
29	6 94	31	1.7	620	0.9	1240	1.9	1906	0.8
30	6 94	126	1.6	712	1.0	1325	1.7	1953	0.9

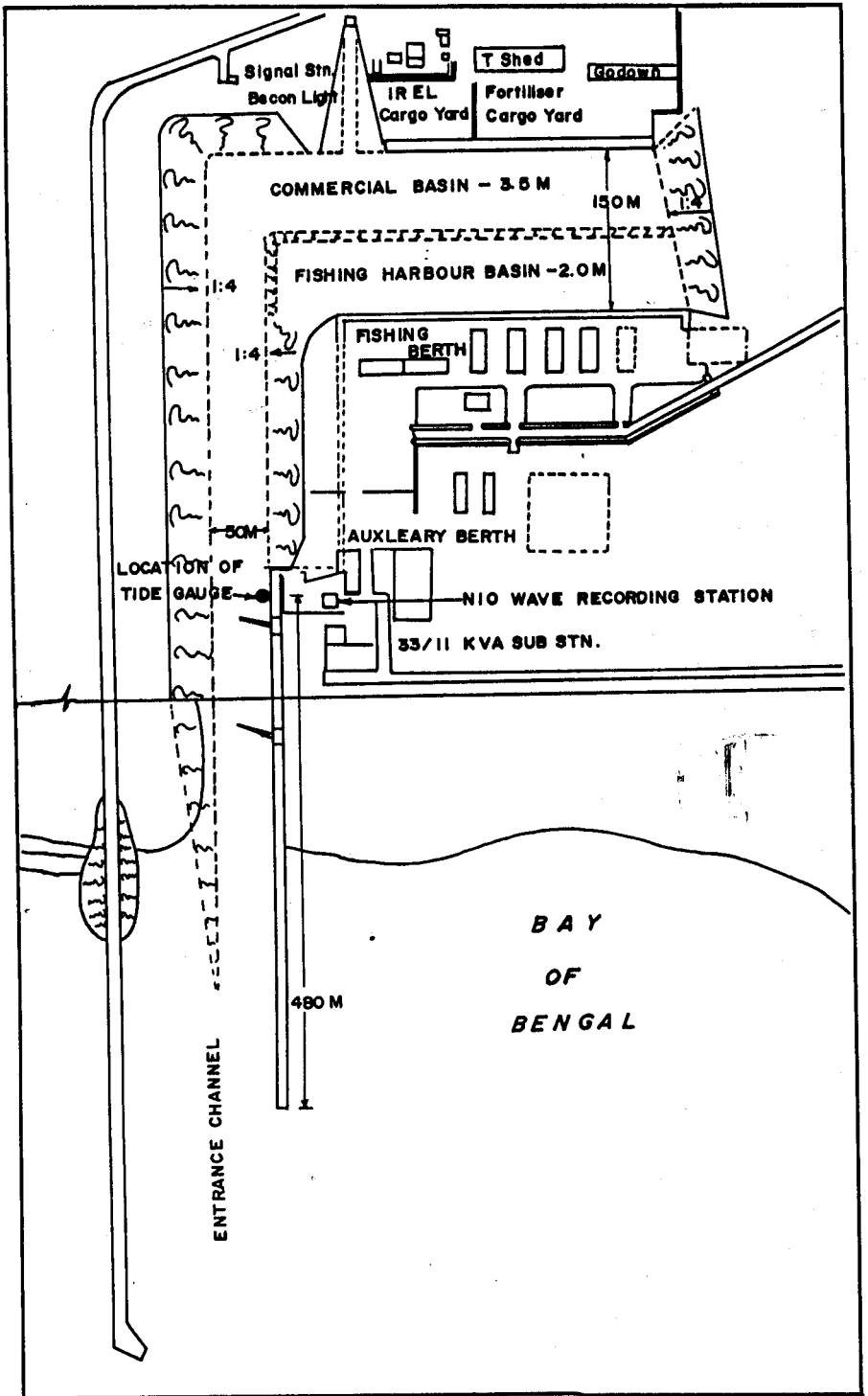


FIG. I. LOCATION MAP.

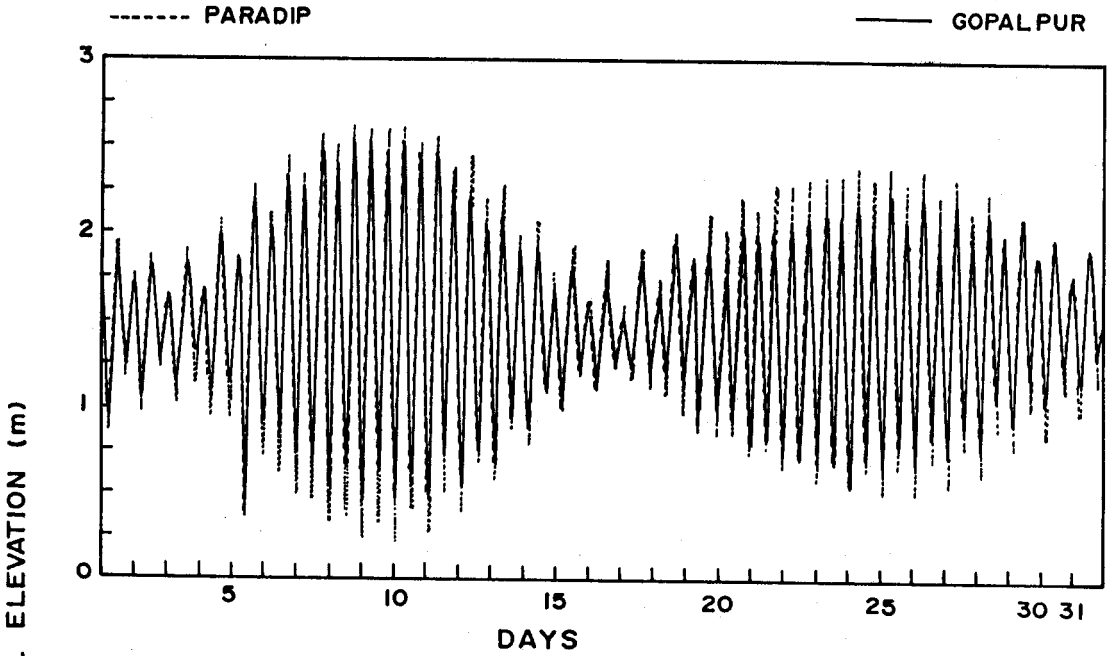


FIG. 2. VARIATION OF TIDE LEVELS - MARCH 1993

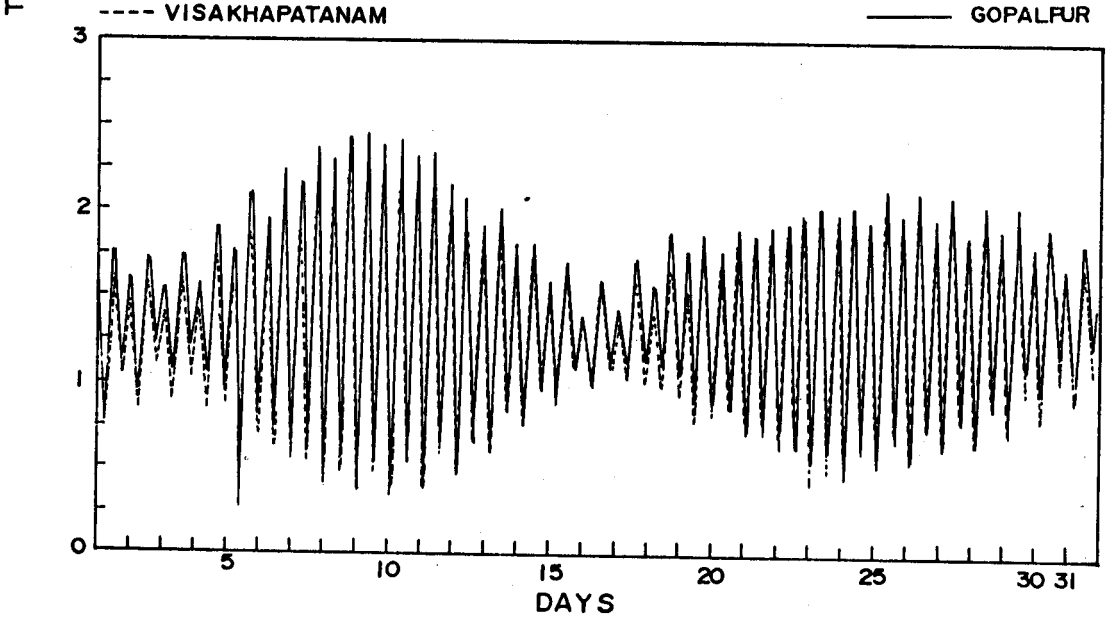


FIG. 3. VARIATION OF TIDE LEVELS - MARCH 1993

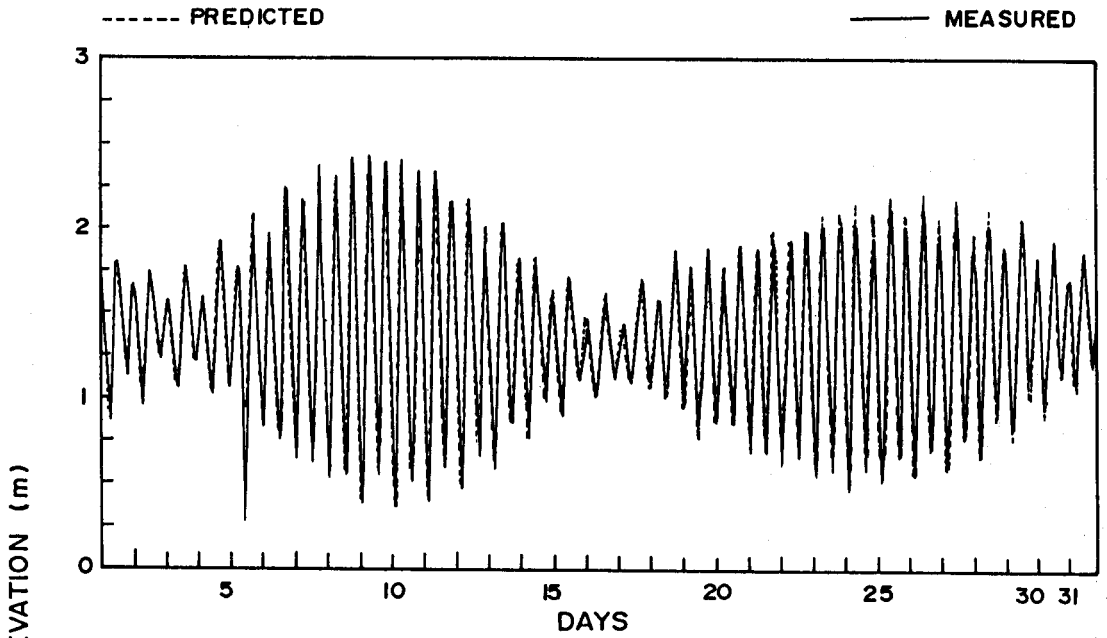


FIG. 4. COMPARISON OF PREDICTED AND MEASURED TIDES AT GOPALPUR
MARCH 1993

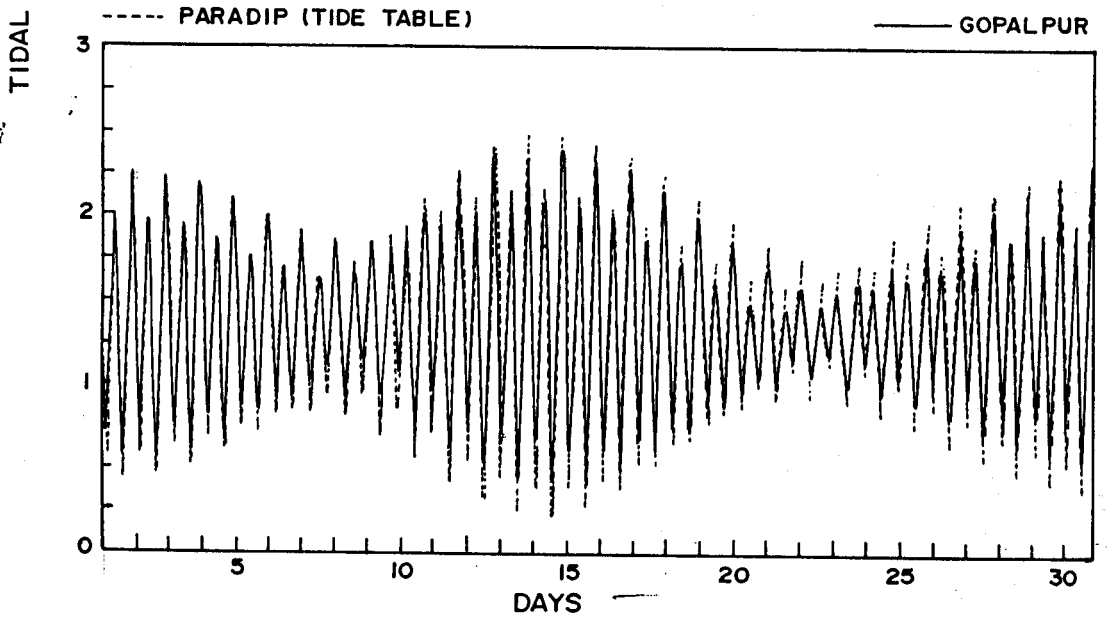


FIG. 5. COMPARISON OF PREDICTED TIDES - NOVEMBER 1993