Notes

Co-tidal Reductions in Digital Hydrographic Survey

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Observation and reduction of tidal heights during post processing of bathymetric data is a common practice for areas of relatively uniform tidal phenomenon. However, in gulfs and estuarian areas, there are complex tidal characteristics where large variations in terms of ranges and times of High Water (HW) and Low Water (LW) are observed in a relatively short spatial spread. Some post processing software do provide an area based approach to the application of tides, in which the hydrographer can divide the survey area into subsets based on tidal characteristics for applying the tidal reductions to observe depths. The Indian Naval Surveying Ship *Sutlej* successfully devised a grid based approach for application of co-tidal reduction in during post processing of data, in the Gulf of Khambhat (Cambay), on the West Coast of India. This paper discusses the algorithms adopted for application of co-tidal reductions as used by the ship. Software routines were developed during the conduct of survey and used, after due validation, with highly satisfying results.

The Gulf of Khambat

The tidal phenomenon in the Gulf of Khambhat spread over 150 Km² is predominantly semidiurnal with large diur-

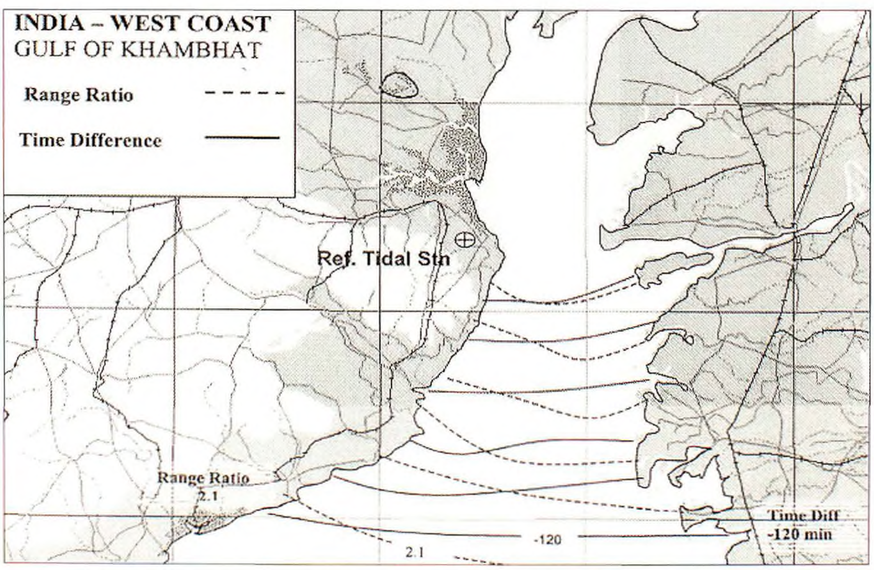

Figure 1: Describes the magnitude of co-tidal variations in the survey area with respect to the reference tidal station situated at the North West bank of the Gulf

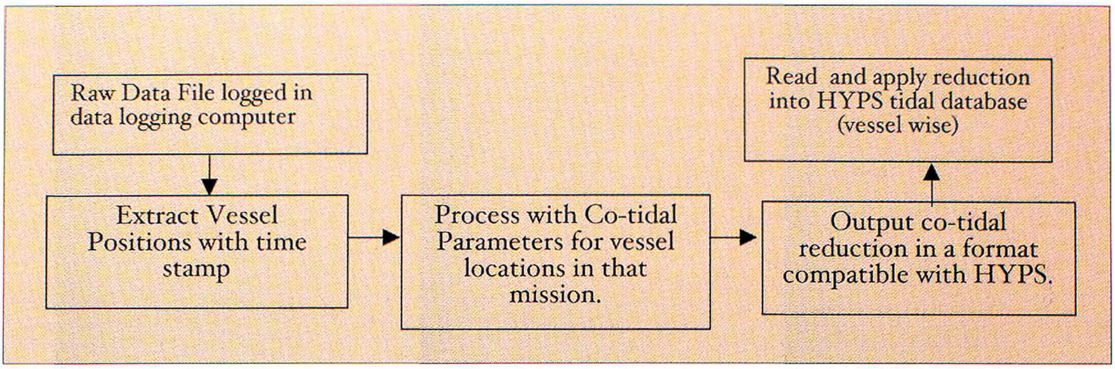

Figure 2: The process of co-tidal application was developed to be seemeless with the data processing system

nal inequalities. The survey area covered the entire expanse of the gulf, which is notorious for very strong tidal currents (6 knots) a large range of tide (10 m) and much co-tidal variations across its entire extent.

The time differences at the East-west extremities of the gulf (Figure 1), are nearly two hours, and the range ratio is of the order of 2. Substantial geomorphological changes and perennial shifting sand banks are the other well-known features of the seabed in the area.

Co-tidal Model

Co-tidal models for the area prepared from earlier surveys are available in the archives. However, it was necessary to update the model to cater to changes, if any. The first step therefore, was simultaneous observation of tides at the extremities of the survey area to enable analysis of the tidal phenomenon in the area and compilation of a co-tidal model by classical methods in which charts for range ratios and time differences, with respect to a

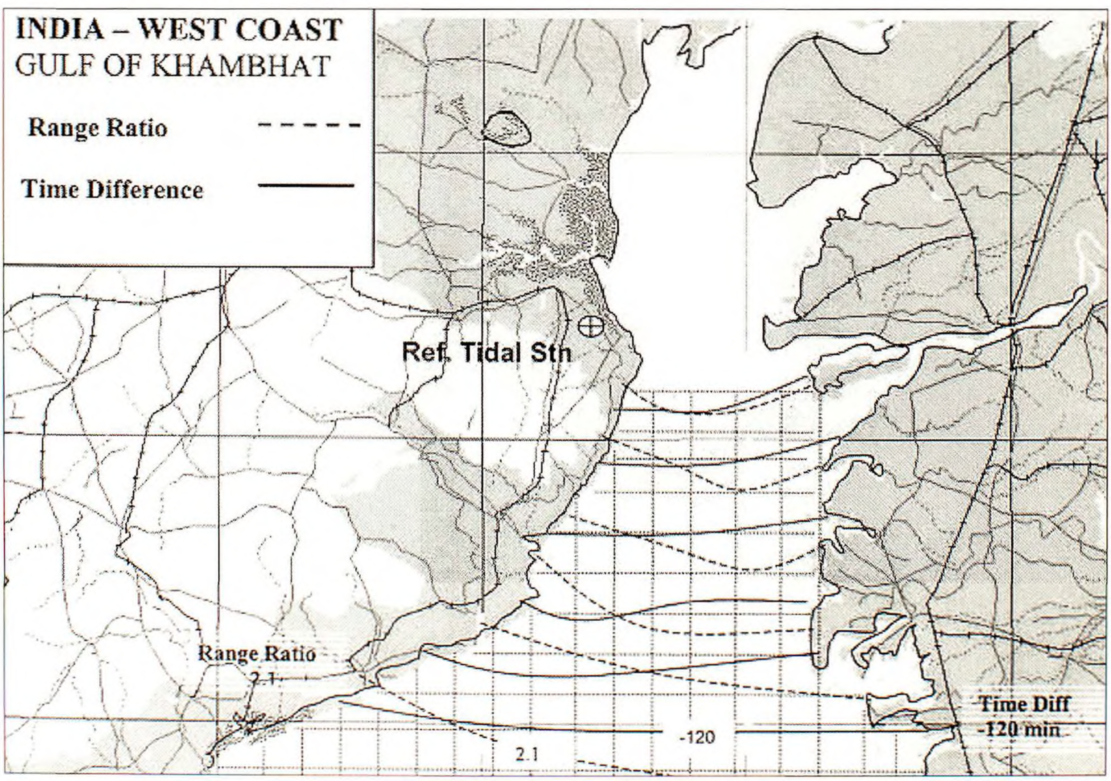

Figure 3: Grid overlay on co-tidal chart

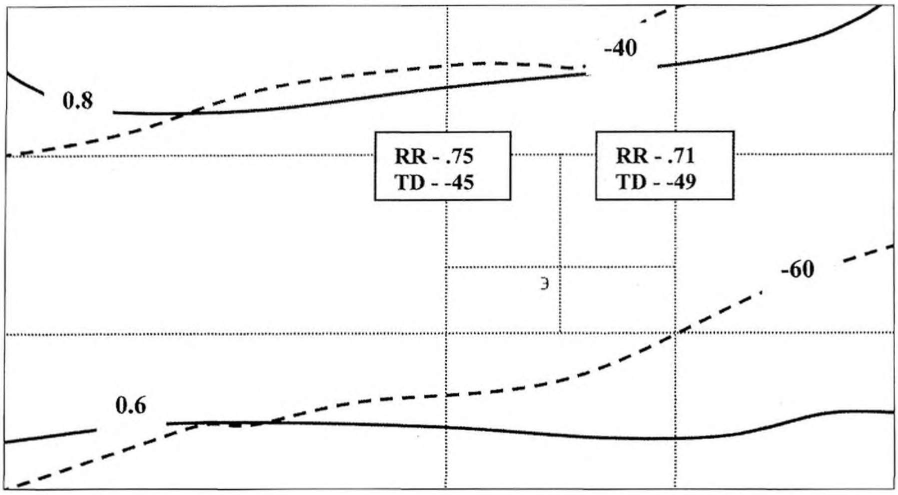

Figure 4: Manually interpolated nodal values RR – Range Ratio TD – Time Difference

selected reference station were drawn up. These compilations were carried out in accordance with the method described in the Admiralty Manual for Hydrographic Surveying (Vol. II) for semidiurnal tides.

Manual Method of Application of Co-tidal Values

The classical manual method of application of co-tidal reduction is well known and well documented in the Admiralty Manual of Hydrographic Surveying (Vol. II). It is a very labour intensive method and the room for human induced errors is tremendous. The process involves the following steps:

(a) Plotting the survey vessel's tracks for a mission
(b) Overlaying it on the Co-tidal Charts and manually interpolating the co-tidal factors for each fix
(c) Manually applying the co-tidal factors to the corresponding interpolated value in the reference tide table and, thereby, deriving the co-tidal reduction
(d) Compiling reduction tables
(e) Applying the co-tidal reductions

Digital Surveying System and Co-tidal Reduction

The digital post processing system HYPS supplied by M/S Quester Tangent Corporation (QTC) of Canada and available onboard the ship did not have a provision for application of co-tidal reduction. The data logging system ISAH (DAS 5500) logs sensor data in ASCII files, which is downloaded and organised mission wise for each of the ship's survey launches. This provided a possibility of extracting the vessels' positions at predetermined time/space intervals from the raw data files to enable interpolation of co-tidal reduction at these locations. The software routines developed

Node No.	Time Difference	Range Ratio
001	-20	0.40
002	-22	0.38
003	-25	0.36
004	-26	0.34

Figure 5: ASCII file containing nodal values of co-tidal data

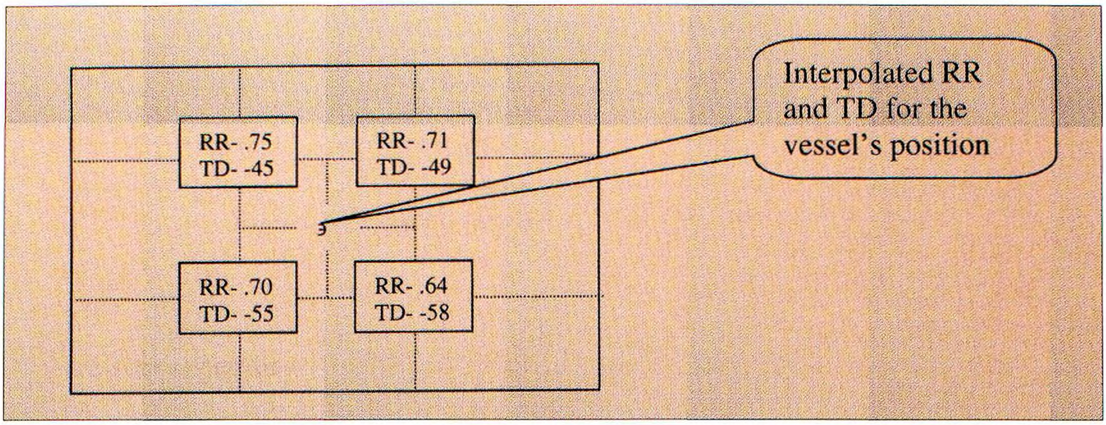

Figure 6: Interpolating RR and TD at a point in a grid square

onboard were designed to fit snugly into the scheme of things with our logging and post processing systems. One routine was developed to extract position values from the raw data files and compute the co-tidal factors for these locations, and finally output a co-tidal reduction file, which was formatted to be read in HYPS for applying the co-tidal reductions to the processed bathymetric data. The process was thus planned and implemented to operate smoothly with the primary data logging and post processing algorithms, as depicted in Figure 2.

Methodology

Once the co-tidal model is developed and co-tidal curves are drawn as discussed earlier, the co-tidal chart is superimposed with a suitable grid commensurate with the importance of the survey area and the accuracy standards. For the Gulf of Khambat we used a grid interval of 2' x 2' as depicted in Figure 3.

Interpolation of Nodal Values

This is an important part of the process and was carried out carefully and counter checked to rule out errors and inaccuracies. In this part, co-tidal parameters are interpolated for nodal values in the grid. Example of a portion of the co-tidal chart with interpolated nodal values (in box) is displayed in the Figure 4. The nodal values are stored in a ASCII file against serially numbered nodes as in Figure 5.

Locating Vessels Position in the Grid and Interpolation

A software routine loads the nodal values in a multi-dimension matrix. Another software routine reads a position (ɜ) from the ASCII file and locates it in a square with four surrounding nodes. Linear interpolation from the surrounding four nodes is performed to arrive at the co-tidal parameters (RR

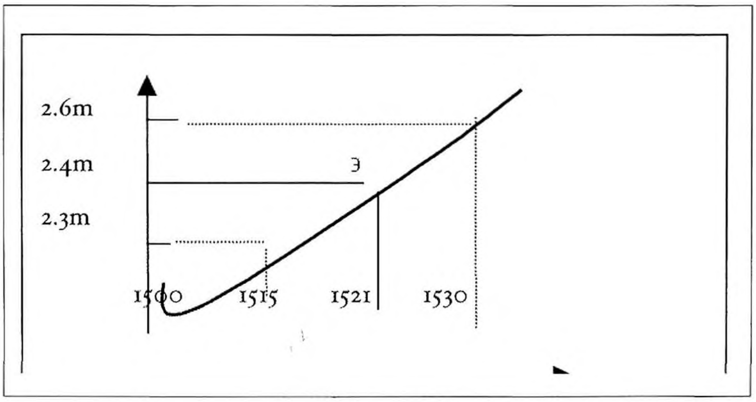

Figure 7: Interpolation of tidal ht for ɜ at Reference Tide Data

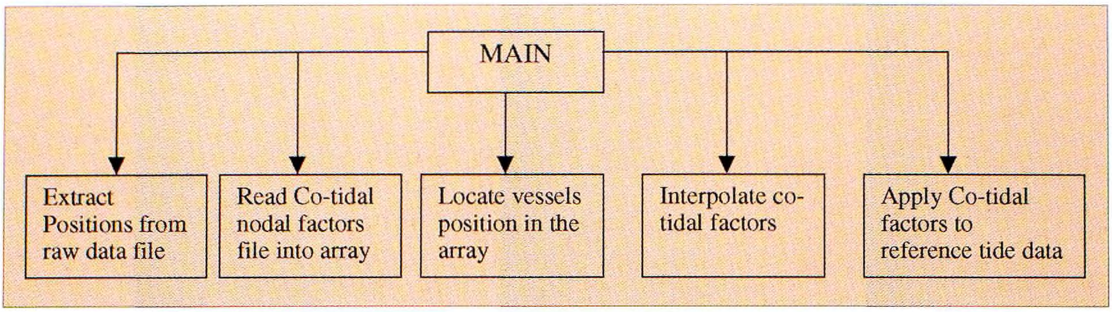

Figure 8: Configuration of 'C' Program

and TD) for that particular time and position of the survey vessel as in Figure 6.

Application of Factors on the Reference Tide Pole

Because of the very large range of tide and low lying coast, the tidal observation had to be in manual mode on a series of round tide poles erected in the inter-tidal area. Automated tidal observations would not be efficient in such conditions and therefore not employed. The tide table was compiled every day with manual observations every 15 minutes on this series of tide poles.
Of the interpolated co-tidal factors tidal difference is applied to the time of the vessel's position to arrive at time at the reference tide pole. The corresponding height of tide is linearly interpolated by another software routine between tidal data points. The resultant co-tidal reduction value is written to an ASCII file in a format readable into the post processing software HYPS.

The Software Modules

The software consisted of 'C' programs (Figure 7) and ASCII data files as follows:

(a) Co-tidal data file
(b) Position data file
(c) Reference tide data file
(d) Output data file

Results

The software was experimented with test data and compared with manual results and found to be consistent. The error analysis part is beyond the scope of this paper and dealt with separately. The ultimate test, however, was in successful application to the survey data with accurate results which were quite evident from matching soundings in adjacent and cross lines. The software is quite cumbersome to work with, for those who were not involved in its development. It lacks the aspects of input error trapping/handling and user friendliness. The software houses in the field of hydrographic processing must come forward and develop a module for accurate co-tidal application.

References

(i) Admiralty Manual for Hydrographic Surveying, Vol. 11, 1970 Edition

(ii) INS *Sutlej* Report of Survey 738/11/02/98-99 dated 12 October 1999 on Survey of Gulf of Khambat

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