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MINISTRY OF WATER RESOURCES

BANGLADESH WATER DEVELOPMENT BOARD

M E S II

TECHNICAL NOTE MES-028

PROCESSING OF BATHYMETRIC SURVEYS IN THE MEGHNA ESTUARY

DECEMBER 1999 - MAY 2000

March 2001

DHV CONSULTANTS BV

in association with

DEVCONSULTANTS LTD
SURFACE WATER MODELLING CENTRE

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1 INTRODUCTION

Within the scope of the Meghna Estuary Study (Phase II, MES-II) a very extensive bathymetric survey has been carried out. The surveyed area (Fig. 1) covered the complete area of the project.

According to the well established practice within the project, the horizontal and vertical position of the survey vessels was determined by using the Global Positioning System (GPS). This system utilises the signals from the NAVSTAR satellites of US Defence Department. The horizontal positioning accuracy of GPS-system (up to 100m) can usually be significantly improved by using an extra (well referenced) base station and a computer program, which calculates a correction for a given position. MES used in its surveys a correction method called Real Time Kinematic (RTK). According to [1] and [2], this method gives an accuracy of approximately 0.20 m. The experiences from previous surveys by MES were rather positive. However, during the latest survey, the positioning method did not function properly most of the time. The problems were caused by lack of the signal during a substantial part of the time, and a poor quality of this signal, caused by the very high solar activity (a peak in its 11-years cycle), resulting in electromagnetic disturbances in the atmosphere. Until 1 May 2000, the GPS signal was slightly distorted for military reasons, to limit its accuracy (so-called Selective Availability). However, also after 1 May 2000, when the Selective Availability ended officially, the RTK-system did not work properly.

As the problems were detected at the very beginning of the survey (18 December, 1999), many pressure cells were deployed in the estuary to register water levels which were independent of the satellite system. Although some of these pressure cells were lost due to severe erosion or were removed by fishermen, they provided an indispensable set of data, which was used to estimate the water levels during the surveys. The data from the pressure cells were supplemented with the regular observations at a number of stations operated by BIWTA.

The survey vessels registered water depths below the echosounder. Therefore, it was possible to determine the actual bed level relative to the common datum, Public Works Department (PWD) datum,, by knowing the water level.

A two-dimensional flow model, calibrated/verified by SWMC for MES, was applied in the procedure for referencing water levels to the PWD during the survey. This model was calibrated for the 1997 bathymetry. As Meghna Estuary is morphologically a very active area, the bathymetry in the model did not correspond very well to the present shape of the bed in the estuary and also most of the water level gauges in the estuary were not referenced reliably to the national vertical datum, the PWD datum. Most of the water level gauges in the estuary are maintained by the Bangladesh Inland Water Transport Authority (BIWTA) who references water levels to Chart Datum (CD). This CD depends on the available water depth locally for navigational purposes. As the gauges of BIWTA are at many kilometers apart from one another and as there are no regular water level gauges in the water at the south of Sandwip, Nijhum Dwip Char Montaz, Rangabali-Char Biswas and in between Hatia-sandwip, a procedure was developed in which the measurements from pressure cells installed by MES were used to enhance the model results locally by referencing the modelled water levels and estuary bed levels to the water levels collected by the pressure cells. Water levels of pressure cells were referenced to RTK for converting them to PWD. Comparisons with the water levels obtained from RTK (during the short periods when this satellite-based system seemed to have worked properly) showed a good agreement with the estimates. In general, the error of the procedure compared to the fully-RTK based processing was limited to 0.30 m approximately. The overall accuracy of the resulting bathymetric map was estimated at 0.5 m.

2 MEASUREMENT OF WATER LEVELS

2.1 RTK-system

In this section, a short description is given of the vertical levelling system used by MES for the bathymetric surveys. A more extensive description can be found in [1] and [2].

During the measurements, a surveying vessel records its vertical position, expressed in terms of its Everest 1830-ellipsoidal height. This ellipsoidal height is determined by means of the RTK-system, utilizing the signal from at least 4 satellites. The ellipsoidal height is translated by Trimble Hydro software to WGS-84 ellipsoidal height. This ellipsoidal height is converted to geoid height by means of a mathematical model. Geoid is by definition a surface that gives the best approximation of the mean sea level. In Bangladesh, this surface is located 0.46m above the Public Works Department (PWD) datum. Therefore, the measured ellipsoidal height is translated to PWD. For this translation, the original KMS geoid model (see [1]) is used. The principles of vertical referencing through RTK are presented in Fig 2.

Examples of registration of ellipsoidal heights during the survey are shown in Figs 3 & 4. As a survey vessel operates in a relatively small area in the estuary, the registered change in ellipsoidal height corresponds to the actual change in the water level, i.e. the tide. Although the system claims an accuracy of millimeters, from fig 3 & 4, it is clear that the registration contains a lot of noise and irregularities. The noise can be removed by applying either a moving averaging or a time averaging, after removing the irregularities (large jumps in the signal). The resulting filtered signal should follow the variation of water level. This is the case for the registration in fig 3, but certainly not for the registration in fig 4, where there is a lot of noise and the tidal variation of water level cannot be identified. This observation shows that RTK-levels have to be used with caution. A comparison between the registered signal and either calculated water levels or levels measured by a nearby pressure cell is essential to avoid large errors.

DEFINITIONS

Elevation
The vertical distance from a geoid (also called Orthometic Height).

Ellipsoid
A mathematical figure (a spheroid) of the earth, generated by rotating the ellipse around the minor axis. The minor axis represents in geodetic surveying the earth's axis of rotation. An ellipsoid is consequently uniformly defined by its semi-major and minor-axis (normally a and b) or derivatives hereof.

Ellipsoidal Height
The distance measured along the normal to the ellipsoid, between a point and the surface of the ellipsoid.

Everest 1830
Ellipsoid based upon meridian arc observations performed in India and France in early 19^{th} century. The values are not good (compared to the actual size of the Earth, it is far too small), but it is used in India and Bangladesh, since all original material is based upon this spheroid.

Geoid
The gravity-equipotential surface that best approximates mean sea level over the entire surface of the earth.

Geoid Height
The distance between the geoid and ellipsoid at a given point (also called geoid separation or geoid undulation). A collection of geoidal heights, covering an area is called a geoid model.

GPS
Global Positioning System. The navigation/positioning system consisting of Navstar satellites, their ground stations and GPS-receivers, such as Trimble series 4000.

KMS geoid model
A fraction of the World Geoid model, covering Bangladesh, supplied by the Danish Geodetic Institute, KMS.

NAVSTAR
The name of the satellites used in the Global Positioning System. It is an acronym for NAVigation System with Time and Ranging.

S/A
S/A is an abbreviation of Selective Availability. It is utilized to limit the accuracy of autonomous position fixes computed by civilian receivers. S/A works by introducing controlled errors to the GPS satellites' C/A code. When in effect, the horizontal accuracy deteriorates to above 100 meters.
S/A was officially ended on 1 May 2000. From then the horizontal accuracy of GPS is 15 meters.

WGS-84
World Geodetic System 1984, the current standard datum for global positioning and surveying.

2.2 Measurements with pressure cells

Water levels at several locations in the Meghna Estuary were registered with pressure cells. These devices registered the pressure exerted by surrounding water during a period of time varying from several hours to several months. The pressure cells used were ???. Their nominal accuracy is 0.3 m.

The pressure acting upon a cell is related to the water level above it, according to the equation:

$$p_w + p_a = \rho_w g h$$

where h is the water level above the pressure cell, p_w is the water pressure, p_a is the atmospheric pressure, ρ_w is the water density and g is the acceleration of gravity. If the atmospheric pressure is constant, then a change in the water level is directly proportional to the change in the pressure registered by the device:

$$\Delta h = \Delta p / rho * g$$

Air pressure was monitored during the measurements (see Figure 5). The variation in the registered pressure was found to be insignificant. Besides, most of the considered registrations were relatively short (less than a week). It could be reasonably assumed that no significant change in air pressure in this period would occur, unless a depression or a storm would have occurred in the considered period. Therefore, no correction was necessary to compensate the influence in changes in the air pressure.

Water density in the estuary is generally not constant either in time or in space. However, from measurements of salinity distribution in the estuary it is known that this variation during the dry season is rather limited: the salinity varies between 0 ppt and 10 ppt in the area where the cells were deployed. In the calculation of water levels from registered pressure, a constant density of 1000 kg/m^3 (fresh water) was assumed. For slightly saline water with a density of 1010 m^3/s this assumption introduced an error of 0.1% in the calculated water level change (i.e., 5 mm for the water column of 5 meter above the cell), which was found fully acceptable.

The recording from a pressure cell gave the variation of water surface as a function of time, but no information about the relation of the registered water levels to PWD. To reference the transducers to PWD, several methods were used:

- the recordings from several cells were referenced directly by measuring the water level variation with a staff gauge, which on its turn was referenced to PWD by determining its 0-level from the GPS-height (RTK-reading during 30-45 minutes);
- when a direct method was not possible, the 0-level of a transducer was determined by comparing the water levels registered with RTK-system on survey vessels within the range of 2 km from the device (see figure 6) where no signal was found within 2 km, the search radius was extended to 5 km.
- for some cells it was possible to establish the 0-level of their recordings by comparing them with the recordings from a water level station (see Figure 7) and cross-checking with water levels registered in the neighbourhood on the survey vessels (method described above) ;
- for a number of cells no RTK-signal could be found in the recordings of survey vessels; recordings from these cells were referenced using water levels computed by the flow model after applying necessary corrections (for more detail see next chapter);
- for a number of cells it was impossible to obtain the zero-level of their recordings.

Figures 8(a) & 8 (b) show the positions and periods of registration of the deployed pressure cells.

In several cases water level registrations showed significant oscillations, which most probably can be attributed to waves (see e.g. Figure 9). Moving average method was applied to smooth the time series of water levels.
In a number of cases the pressure cells were installed at insufficient depth, which influenced the recording as the transducers fell dry. In several cases a pressure cell with a small registration range was used. This caused cutting off the signal when the water level in the river exceeded the instrument's maximum. The recordings were still useful as at least a part of the tidal curve was registered.

The accuracy of vertical referencing of pressure cells was estimated at 0.3 m, when RTK-system was applied. This error consisted of the general error related to vertical positioning (0.2 m, see [2]), and the error in matching the signal with the measured water levels, estimated at 0.2 m, caused mainly by a high content of noise in the RTK-signal, see figure 4.

2.3 Data from BIWTA-stations

The data collected with pressure cells were supplemented with the gauge readings from several water levels stations operated by BIWTA. The data collected comprised water levels at stations:

- Sandwip
- Chandpur
- Khal no. 10
- Khal no. 18
- Cox's Bazar

The gauge readings from the above stations were given with reference to Chart Datum (CD). The relation between CD (defined separately for each station) and PWD was not available for all of the stations.

- The reference level in PWD for the station in Sandwip could be established by fitting the water level curves from the model with the gauge readings. The modelled water levels were shifted vertically to match water levels from the survey, which had been determined with RTK (see figure 10)
- For Khal no. 18 it was assumed that its reference level should be approximately the same as that at Khal no. 10.

3. ESTIMATION OF WATER LEVELS

3.1 Hydraulic model

3.1.1 General

A two-dimensional numerical flow model of the Meghna Estuary, based on MIKE21-software, was developed by SWMC for MES. The development of the model was started in 1996. As the bathymetry of the estuary changes significantly from year to year, an iterative development strategy was adopted. The model was calibrated using data (water level measurements and bathymetry) from 1996, followed by the data of 1998. In the beginning of 2000, a significantly improved model was prepared by SWMC. The improvements concerned mainly the formulation of boundary conditions and the choice of the friction coefficient. The bathymetry in the model was based on 1997 data. For many areas (especially shallow areas) only very scarce information had been available at that time. A final enhancement of this model, expected to be completed by October, 2000, would consist of introduction of the newest bathymetric data from the present survey.

Calibration of the model for 1998 data set showed a relatively good agreement with the measurements. For this reason it was decided to use the model in the procedure to estimate water levels which occurred during surveys. It was assumed that the tidal elevations predicted by the model could be enhanced on the basis of measurements to such a degree that the phase shifts due to changed bathymetry could be sufficiently eliminated, as long as the area considered would be small.

3.1.2 Model set-up

The 2D hydraulic model applied in the work presented in this report is basically the same as delivered to MES by SWMC in June 2000 and described in [3]. The only changes concerned a new set of boundary conditions provided to MES by SWMC, and extension of the fine grid model to the west by 15 km to include the region west of Kuakata, which had been also included in the bathymetric survey[1]. The southern boundary of the model was based on the tidal constituents from the Admiralty Tidal Tables, while the northern boundary was derived from the measured water levels at Chandpur, obtained from BIWTA.

During processing of data in the first phase it was observed that the boundary condition in Chandpur did not match the measured water levels too well: the amplitude calculated by the model was in some cases 100% higher than measured (1m calculated versus 0.5m measured). Furthermore, the water level boundary was created by applying some corrections for each month separately, without any smoothing for a transition from month to month. As a result, sudden changes of the mean water level were introduced. This problem was reported to SWMC.

3.2 Matching simulation results with measurements

<u>1st step in the procedure</u>

The results of simulations for the periods corresponding to the period of measurements were compared with the readings of pressure cells and/or gauges. It appeared that:

- the model reproduced the form and the amplitude of the tidal curve rather well, but with a considerable phase lag, which increased from approximately 15 minutes at the Southwest of the estuary (Kuakata) to 30 minutes near Nijhum Dwip and 60 minutes in the Sandwip Channel. The tidal wave in the model travelled apparently too fast up the estuary.

[1] This modification, introduced by SWMC, made the model of the Bay of Bengal prepared for MES to be exactly the same as the model prepared for the CERP2 project.

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- the water levels needed a vertical shift, varying between approximately -0.4 m in the northeast in the Sandwip area, to approximately 1.1m in the Southwest of the area, near Kuakata.

The mean water levels in the southwest (between Kuakata and Nijhum Dwip), derived from RTK-registration, were found to be significantly higher than what could be expected: 1.0 m+PWD at Kuakata and 0.8 m+PWD at Nijhum Dwip, while the Mean Sea Level during the dry period is approximately 0.5m+PWD in this area (MSL=0.46m+PWD by definition in the open sea). A difference of more than 0.5m in mean water level was found between Char Montaz and Char Biswas, which are about 25km from each other. The mean water level near Char Biswas was lower, while this point is located more upstream. The measurements were taken in different periods and using different reference stations. A discrepancy between the levels obtained through RTK and from geodetic survey in the southwest of the estuary was already reported in [1]. .After analysing the differences it was concluded that the relationship between the ellipsoidal height and the geoid height (directly related to PWD) had been derived inaccurately for this area. For this reason, it was decided not to use RTK-levelling in the southwest and to apply 0.5 m+PWD as Mean Sea Level at the considered area for calculation of corrections for the model.

After performing the transformation (shifting of water levels predicted by the model in time and in vertical), the model results and the measurements gave a good match. The standard deviation did not exceed 0.3m and was less than 0.2m in most cases. Table 1 gives an overview of applied corrections.

Special attention was paid to obtain a good match of the phases, as a phase shift of only 30 minutes would give an error up to 1 m (for explanation see table 1).

Table 1. Results of matching model with measurements

Code	Location	Time shift (min)	Vertical shift (m)	Standard deviation (m)
A	Kuakata	-15	0.30	0.08
B	Char Rangabali	-30	0.30	0.09
C	Rupa Char	-30	0.25	0.09
D	Dal Char South	-30	0.20	0.07
D	Dal Char West	-30	0.20	0.13
E	Char Montaz dam SW	-30	0.40	0.28
F	Nijhum Dwip NW	-30	0.20	0.14
F	Nijhum Dwip NE	-30	0.20	0.16
G	Hatia North East	-45	-0.10	0.17
H	Urirchar West	-45	-0.20	0.24
I	Urirchar East	-60	-0.45	0.28
J	Hatia North West	-30	-0.10	0.15
K	Ramgati	-30	-0.30	0.20
K	Gazaria South	-30	-0.30	0.19
L	Char Alexander	-30	-0.30	0.18
M	Ludua Noakhali coast	-30	0.25	0.09
N	Burir Kangali Bozu	-30	-0.10	0.23
O	Burirdone Kalam Bag	-30	-0.10	0.21
P	Sandwip	-60	-0.30	N/A
Q	Khal No. 10	-30	0.00	N/A
R	Cox Bazar	0	-1.00	N/A

Code	Location	Time shift (min)	Vertical shift (m)	Standard deviation (m)
S	Char Bishwas	-45	0.10	0.22
T	Char Kolmi	-30	0.20	0.10
U	Char Nazirpur	-30	-0.30	0.11
V	Gongapur dam	-30	-0.40	0.10
W	Nemer Sripur	-30	-0.10	0.11
X	Hajimara	-30	-0.20	0.10
Y	Gosiar Hat	-30	-0.20	0.20

Note : N/A means no continuous measurement is available, insufficient information for error analysis

3.3 Procedure for estimation of water levels

After determination of transformation parameters (phase shift and vertical shift) for each location of measurement, the estuary was divided into small areas (longest distance 25 km) where these transformation parameters were considered constant. For practical reasons, the extent of survey lines in each considered area was taken into account when dividing the estuary into patches. The applied division is presented in fig 12.

Simulations were carried out for the full period of surveys. A computer program was prepared to calculate water levels at each point of the survey, taking into account the required transformation, and to derive bed levels by combining the estimated water levels with the measured water depths. The results from the model were available with the frequency of 15 minutes, therefore a linear interpolation in time was carried out to obtain water level at the moment of echosounding registration on a survey vessel. As the computer model had a spatial resolution of 600 m, the water level for all survey points with a 600m x 600m square was taken equal to the value in the centre of the square (calculated by the model). In some cases, survey data were available in points that were considered dry in the model, showing discrepancy between the bathymetry in the model and in the nature. The missing water level data were supplemented by linear interpolation of water levels in the adjacent water points.

In the areas where sufficient RTK-signal was available to process at least some survey lines, this processing was carried out according to the method used in the previous surveys (a.o. removing noise in the signal). Outcome of both methods was compared to obtain an indication of accuracy. The comparison showed that the results showed a reasonably good match with an error less than 0.4 m.

4. MAPPING OF BATHYMETRIC DATA

4.1 Conversion of bathymetric data to PWD datum

During the surveys, the depth below the echosounder was registered and stored in digital format. A computer program was written which combined these depths with the estimated levels, taking into account the draft of the echosounder. The recorded depths were smoothed by applying the moving average method over 10 points. This way the disturbance caused by the waves and by the movement of the survey vessel was filtered out. The result of this processing was a set of bed levels referenced to PWD datum measured along survey lines, with an average spacing of 2 to 4 meters along a line and 200, 600, 1000 and 2000 meters between the lines.

4.2 Preparation of a new model bathymetry

The new bathymetric data, processed as described in this report was delivered to SWMC. A new model bathymetry was prepared by SWMC. Hydrographic information was combined with the data from other sources (topographic data, satellite imagery). The model bathymetry had a spatial resolution of 600 m. In two areas such as North Sandwip and Nijhum Dwip, more detailed model bathymetries were prepared, with a resolution of 200 m.

4.3 Preparation of bathymetric charts and maps

Bathy charts and maps have been produced from the bathymetric data which were referenced to m, PWD. The whole area have been subdivided into 8 sheets. Each sheet covers 60 km x 60 km with a 10 km superimposition on each side. Bathy charts include all the survey points and the skipped & referenced m, PWD values. The values were skipped in the chart because of fair visibility. To produce bathy maps all the survey points have been considered in the computation and minimum curvature method was applied for gridding with a 200 meter grid spacing in both x and y direction. Contours in the maps have been produced from the created grid and were superimposed on the satellite images of December 1999 and January 2000.

5. DISCUSSION

The water levels during surveys were estimated by combining the actual measurements from pressure cells, measurements of water levels through RTK and the model simulation. The method proved to be reliable and to give results that can be considered as good. The standard deviation of estimated water levels compared to the measured ones was less than 0.2m in most of the cases.

The estimated water levels are free of disturbances like noise and irregularities in the satellite signal and waves which disturbed measurements by RTK. This means that, if the disturbance caused by waves are filtered from the depths measured by echosounding, the resulting error in the bathymetry can actually be less than the error of the procedure that fully relies on RTK.

The bed levels obtained from the same data set using both methods were compared for a number of survey lines. A very good agreement between the methods was found, with the difference not larger than 0.3-0.4 m. This means that the overall error in the bathymetric chart will not exceed 0.5m.

The mean water level in southwest, obtained through RTK, is much higher than could be expected. Also a large discrepancy in mean water levels (more than 0.5m) between points located only about 25km from each other (Char Montaz and Char Biswas) was found. This suggests that the translation from ellipsoidal height to PWD is not correct in this area, and is significantly different for different reference stations. As these findings give rise to serious questions about the accuracy of vertical referencing through RTK, it is suggested to re-evaluate the whole system and re-check the benchmarks and reference stations.

In the future surveys, use of pressure cells should be continued. Preferably, the recording should comprise periods of at least 2 tidal cycles (25 hours). Attention should be paid to establish the 0.0 value of the instrument with respect to the national vertical datum.

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6. REFERENCES

[1] Government of the People's Republic of Bangladesh, Ministry of Water Resources, Bangladesh Water Development Board: Geodetic (BM) survey by RTK-GPS. Final Report submitted to Meghna Estuary Study (FAP5B) by SWMC, June 1996.

[2] Technical Note MES-016: Estuarine Surveys. Submitted to Ministry of Water Resources, Bangladesh Water Development Board, by DHV Consultants BV and associates, August 1998.

[3] Government of the People's Republic of Bangladesh, Ministry of Water Resources, Bangladesh Water Development Board: Maintenance of the two-dimensional general model of the Meghna Estuary, first update report. Submitted to Meghna Estuary Study, April 2000.

Fig-1 Bathymetry surveyed area of Meghna Estuary Study (phase II)
Date of survey : December 1999 - May 2000

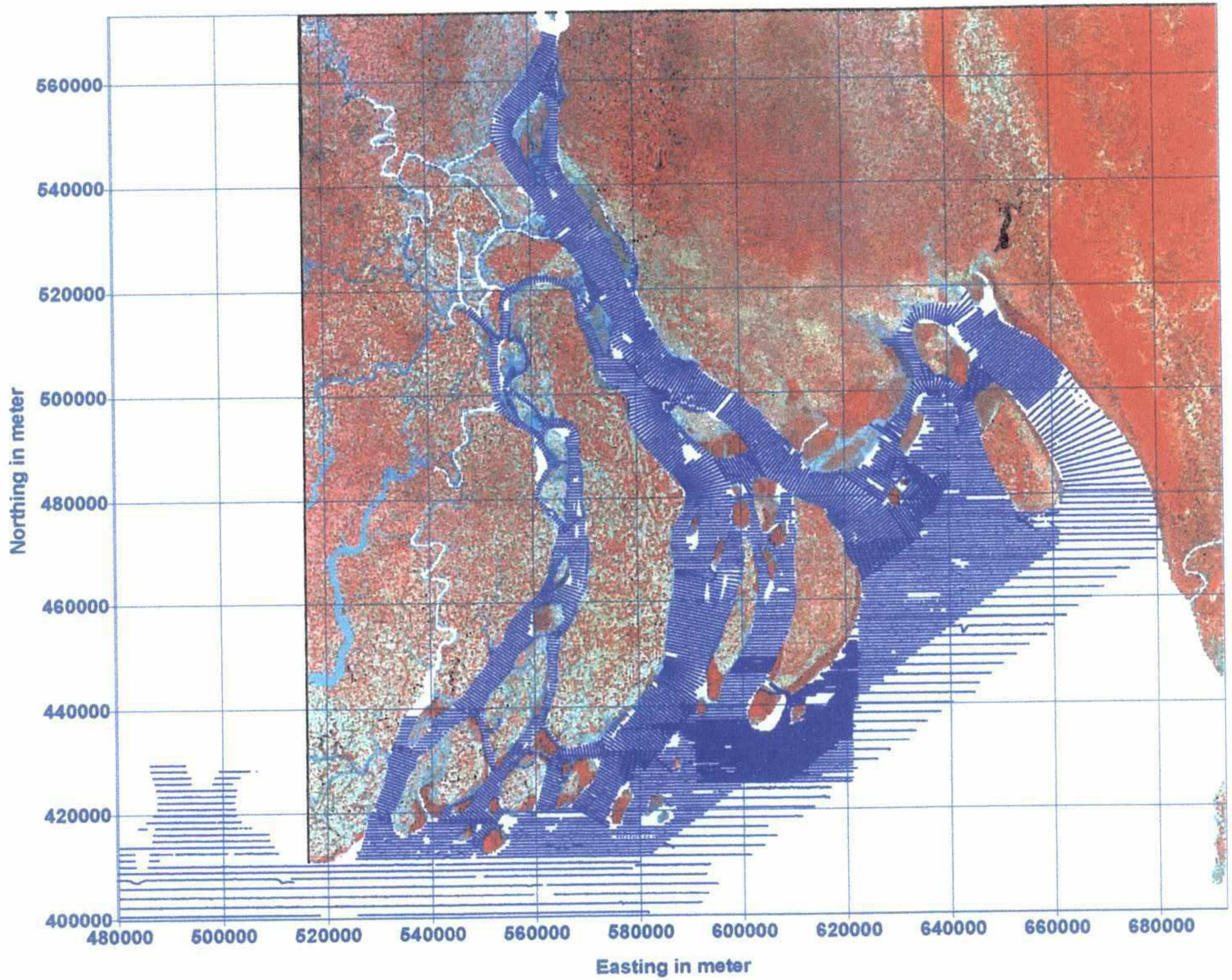


Fig-2: Schematic diagram of Orthometric, Ellipsoidal and Geoid heights

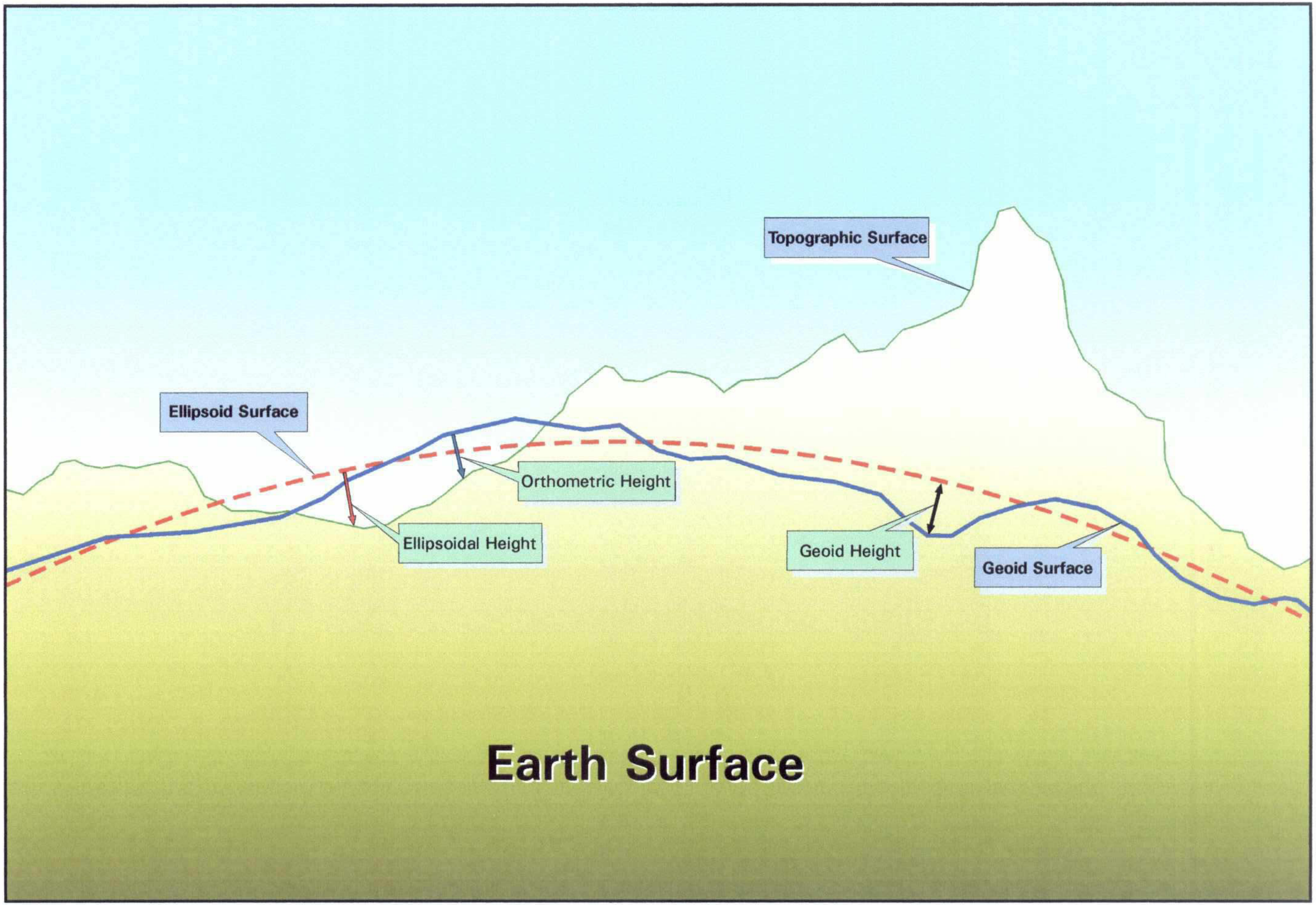


Fig.-3 Registration of ellipsoidal height during survey Date : 19 December 1999

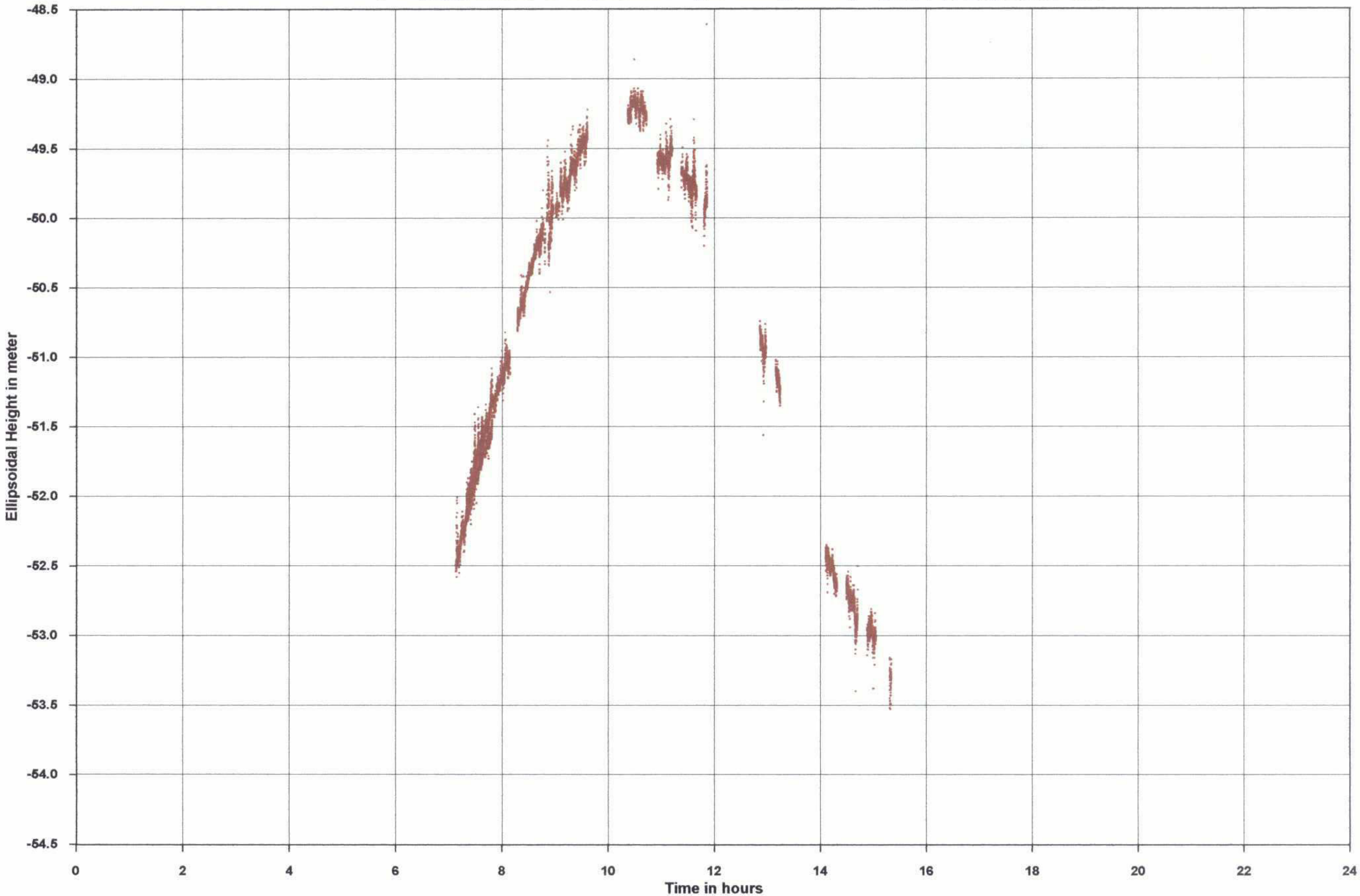


Fig.-4 Registration of ellipsoidal height during survey Date : 07 April 2000

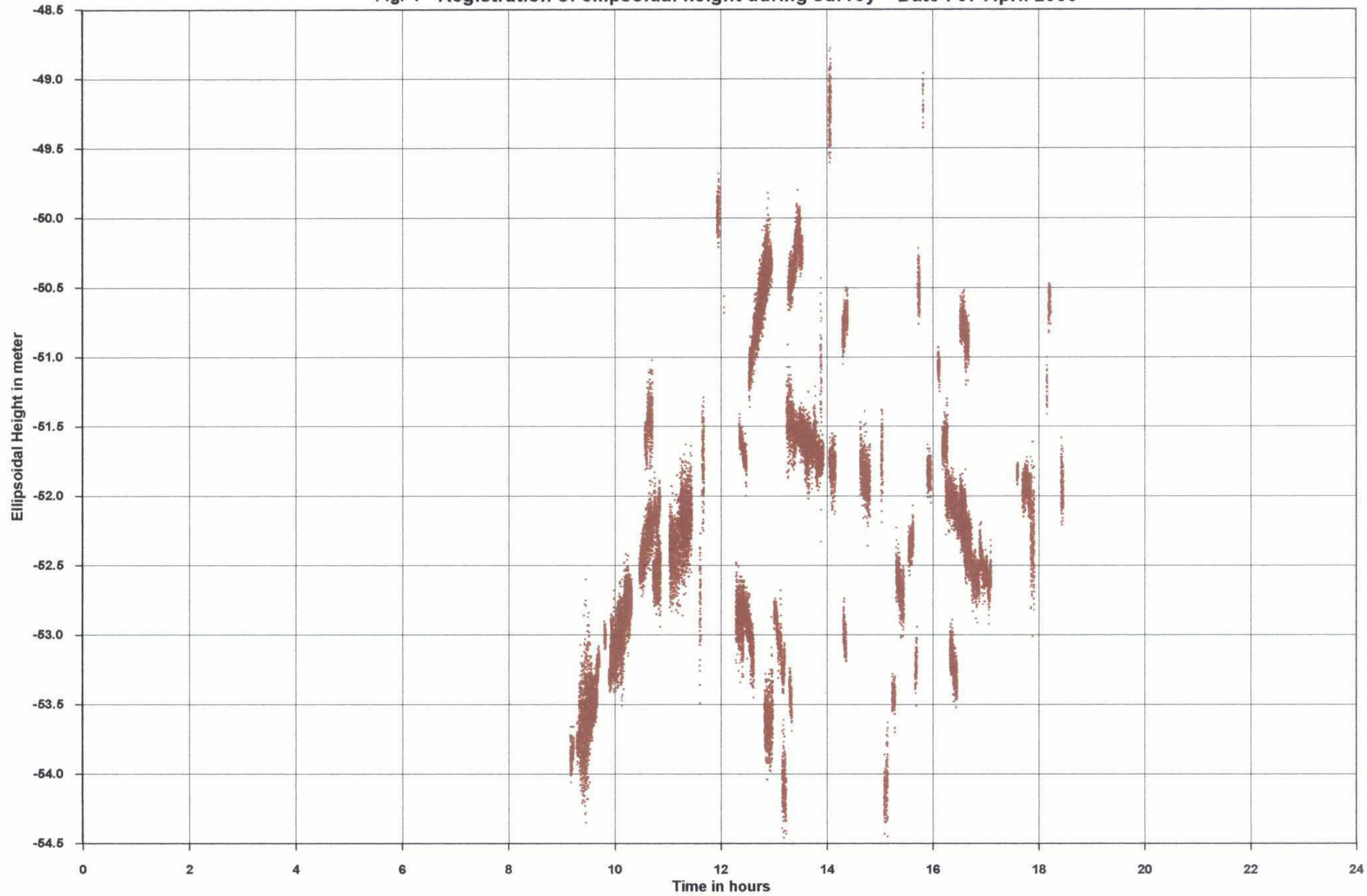


Fig.-5 Nijhumdwip Air Pressure (Pressure cell data)

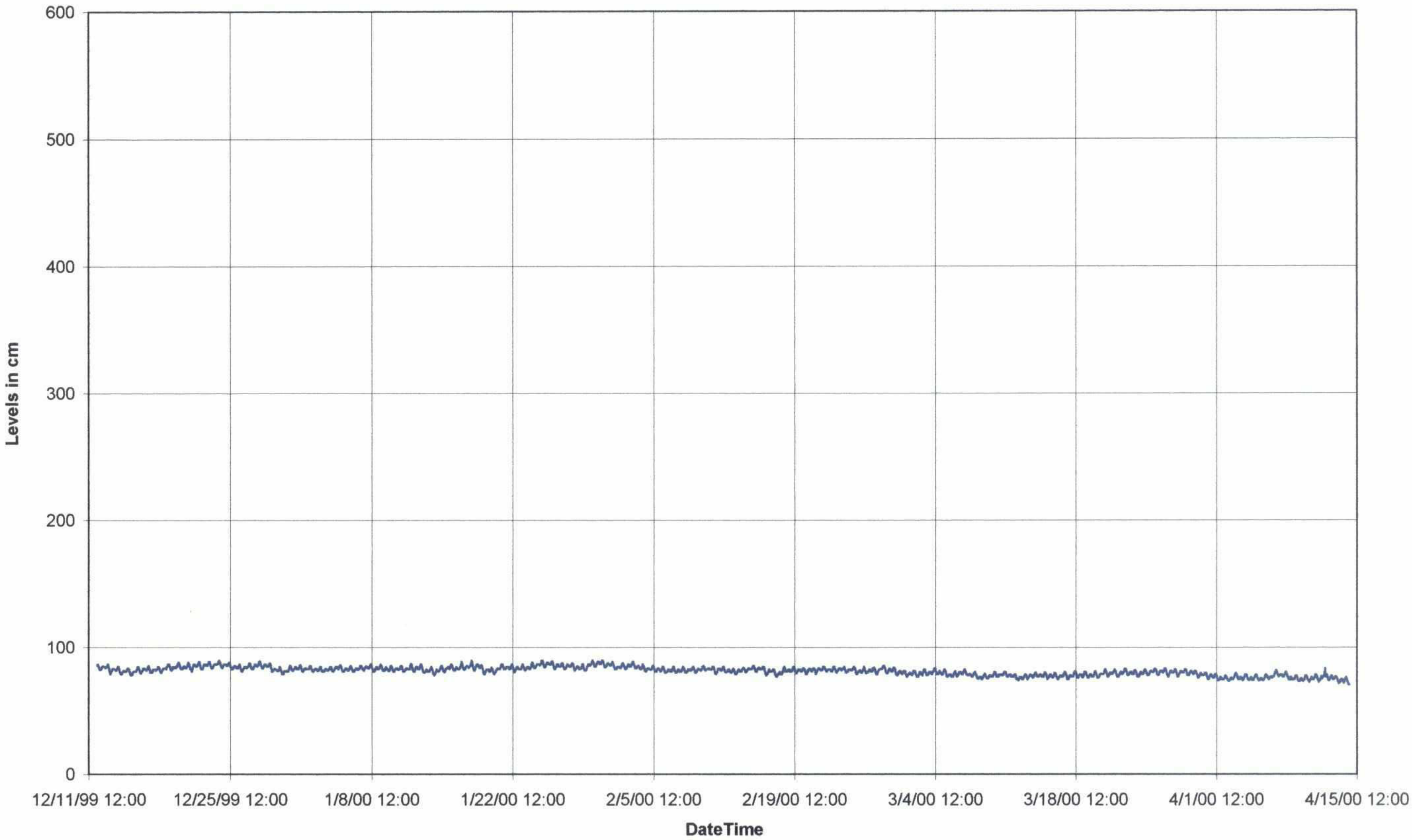


Fig.-6 Referencing pressure cell using water levels obtained during survey (RTK-based)
Hatia North West

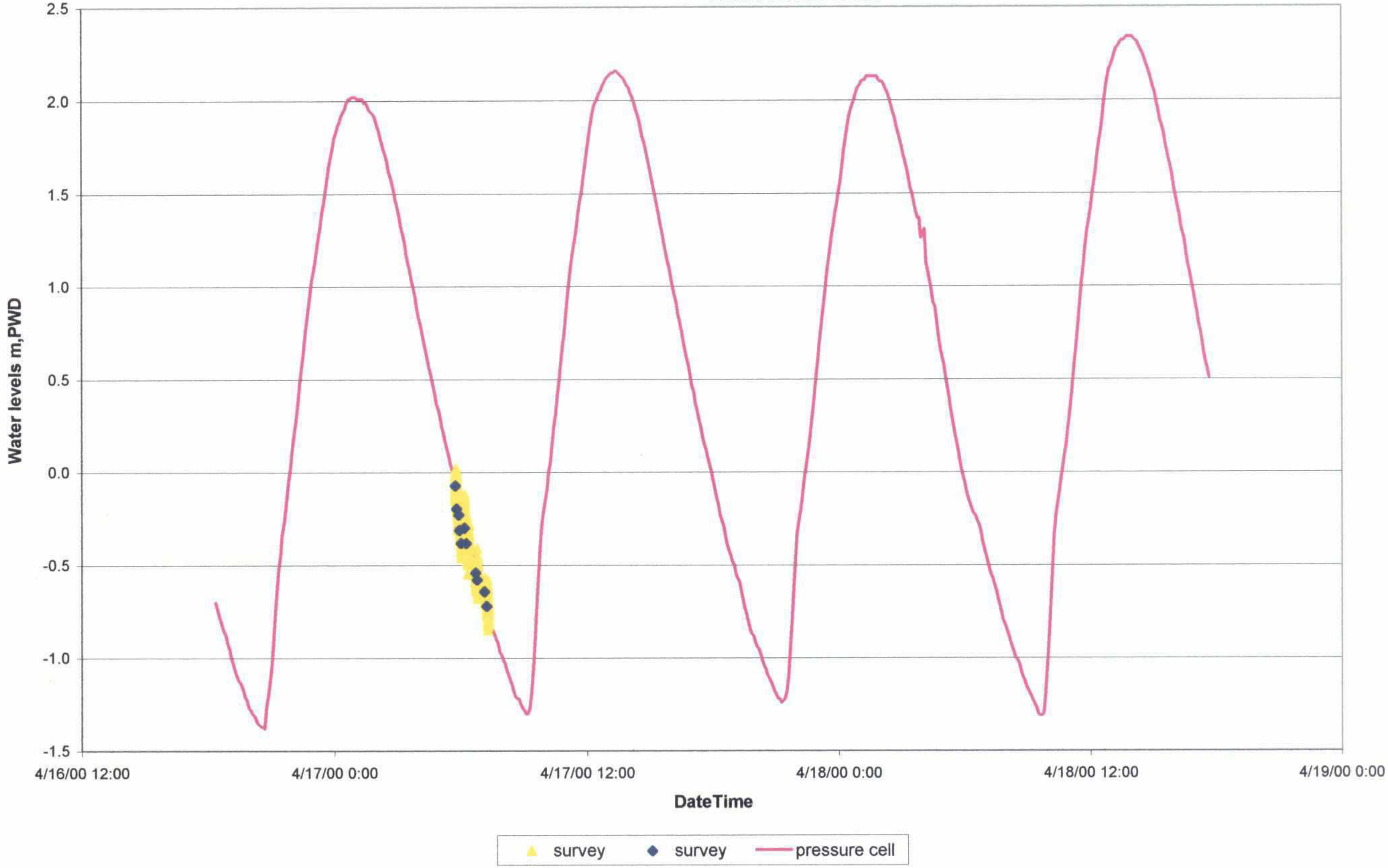


Fig.-7 **Referencing pressure cell using water levels from gauge and survey (RTK-based)**
Nijhumdwip North East

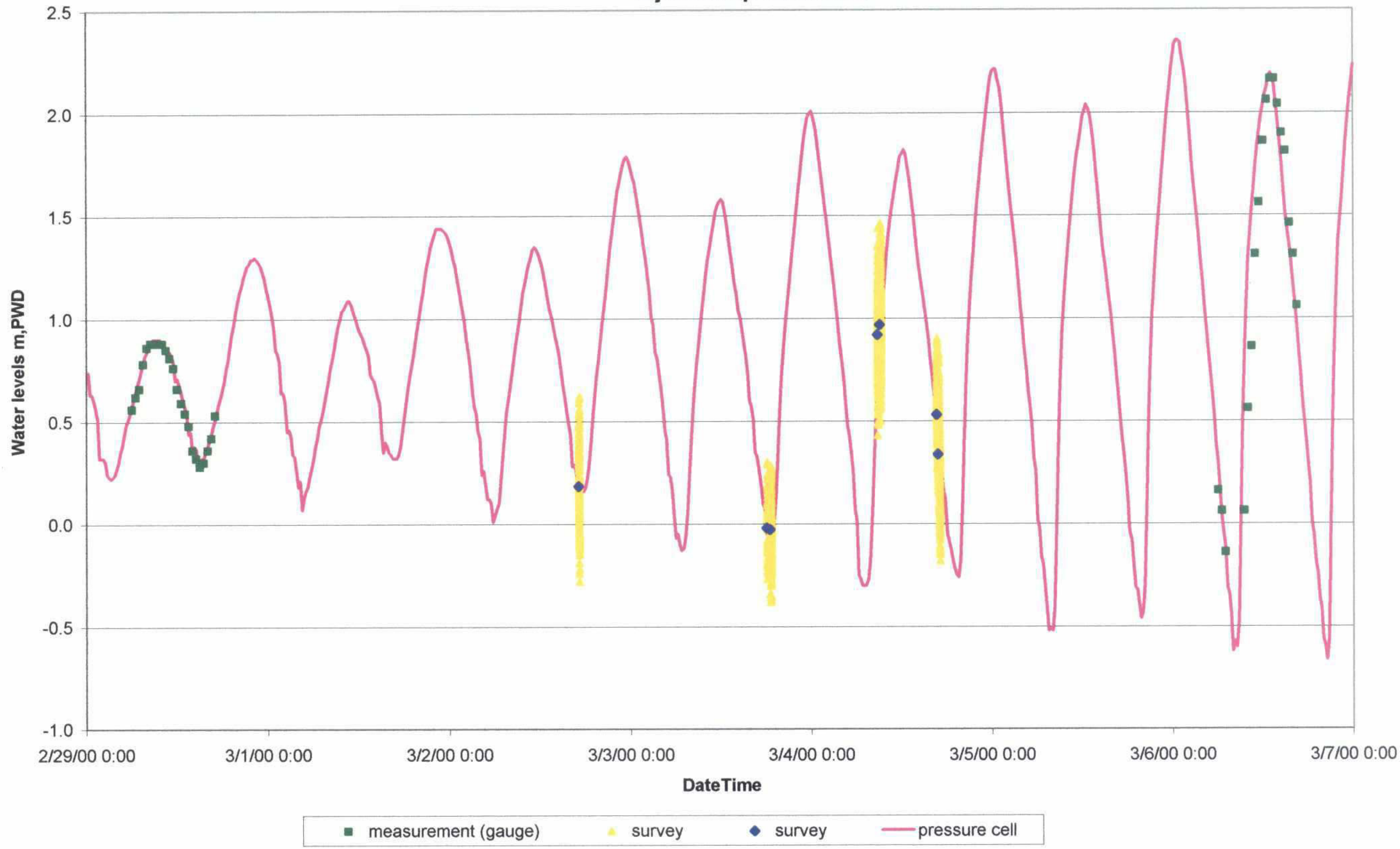


Fig.-8(a) Positions of the deployed pressure cells

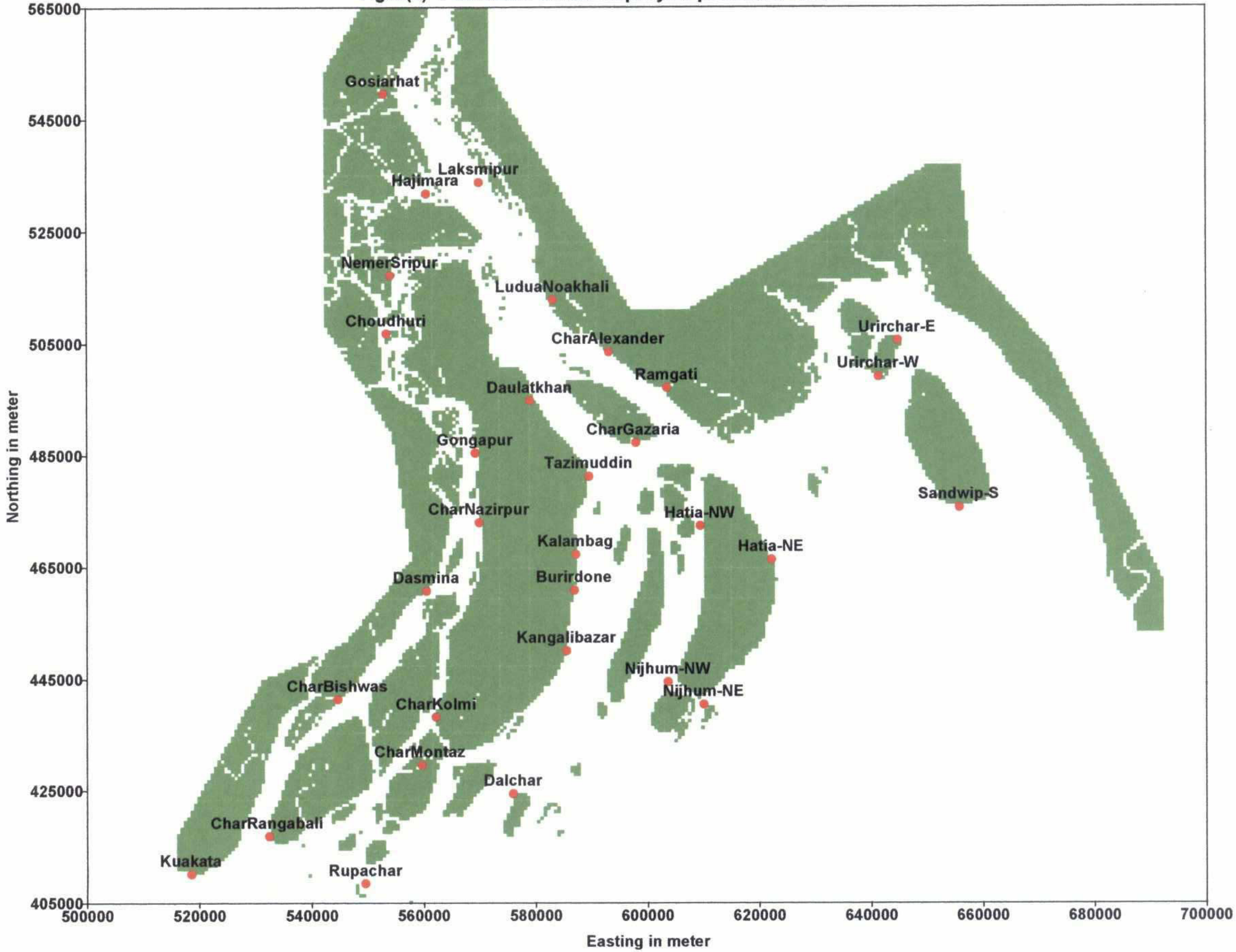


Fig.-8(b) **Positions and periods of registration of the deployed pressure cells**

Pressure Cell no.	Location	Easting	Northing	Start Time	End Time
18481	Char Montaz	559640	429640	11/29/99 9:30	4/14/00 10:29
18481	Hatia North East	622152	466390	12/13/99 10:30	4/7/00 15:30
18481	Nijhum Dwip NW	603600	443000	12/12/99 12:00	3/26/00 11:29
18480	Nijhum Dwip NE	610500	440500	12/12/99 12:30	3/26/00 11:30
18215	Urirchar East	644795	505514	12/18/99 18:00	3/24/00 10:30
17590	Urirchar West	641327	499066	12/20/99 16:00	3/25/00 0:00
18662	Dal Char South	576000	416810	3/1/00 10:20	3/7/00 15:40
20682	Rupa Char	549510	408480	3/1/00 11:40	3/7/00 13:30
20682	Kuakata	518450	410180	3/1/00 14:10	3/4/00 16:40
18661	Char Rungabali	539870	414961	3/27/00 8:45	3/29/00 12:15
18481	Hatia North West	609375	472407	4/16/00 6:30	4/16/00 17:20
16901	Ramgati	603461	497083	4/15/00 13:10	4/19/00 16:00
18661	Char Alexander	593047	503534	4/18/00 17:35	5/2/00 7:34
17590	Gazaria South	597940	487265	4/17/00 10:25	5/2/00 8:14
18481	Burirdone	586868	460900	4/23/00 9:19	4/24/00 12:34
18481	Daulatkhan	578987	494797	4/27/00 8:34	4/27/00 17:49
18481	Ludua Noakhali coast	583068	512803	4/29/00 16:49	5/1/00 14:24
16901	Kangali Bazar	585437	450127	4/21/00 16:00	4/23/00 9:59
16901	Kalam Bag	587122	467290	4/24/00 10:34	4/25/00 12:34
16901	Tazimuddin	589498	481280	4/25/00 15:04	4/26/00 16:59
16901	Sandwip South	655800	475700	3/23/00 12:55	3/23/00 17:00
16901	Char Bishwas	544555	441423	5/8/00 8:08	5/9/00 6:00
18661	Char Kolmi	562111	438222	5/8/00 16:56	5/10/00 10:35
18354	Dasmina	560400	460760	5/9/00 10:23	5/10/00 18:10
18481	Char Nazirpur	569843	473049	5/10/00 16:45	5/12/00 6:45
18354	Gongapur dam	569186	485437	5/11/00 14:18	5/12/00 6:20
18481	Choudhuri	553360	506798	5/13/00 7:39	5/13/00 13:34
18481	Nemer Sripur	554059	517171	5/13/00 16:34	5/14/00 5:19
18481	Hajimara	560488	531800	5/15/00 9:09	5/16/00 5:34
18481	Laksmipur	569949	533790	5/16/00 9:04	5/16/00 17:29
18481	Gosiar Hat left	552922	549563	5/17/00 8:59	5/17/00 17:44

Fig.-9 Kuakata Water levels (Pressure cell data)

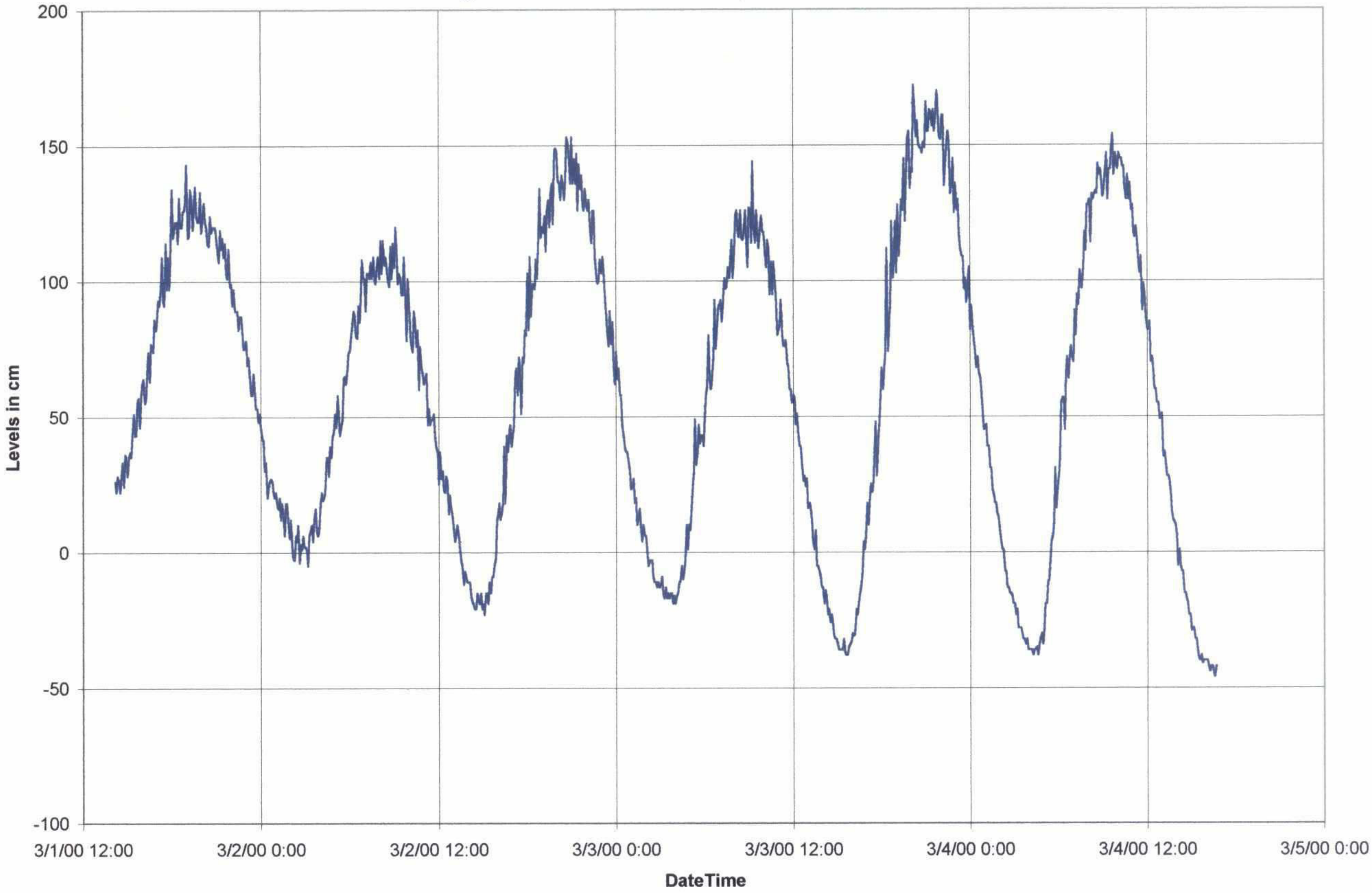
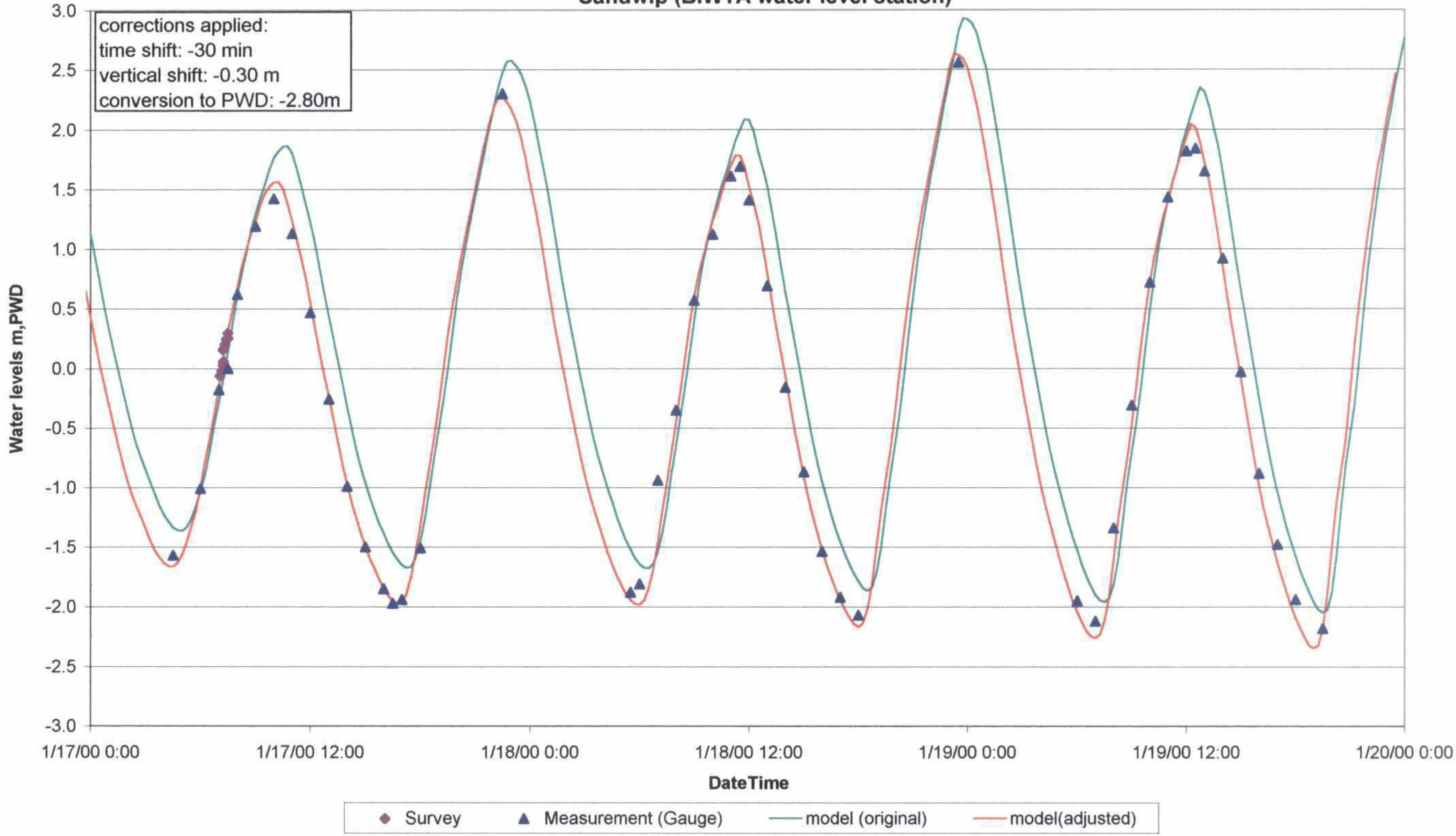


Fig.-10 **Estimation of correction of tidal elevations computed by the model Sandwip (BIWTA water level station)**



2 0

Fig.-11 Difference in estimation of correction of tidal elevations due to phase shift of 30 minutes
Sandwip (BIWTA water level station)

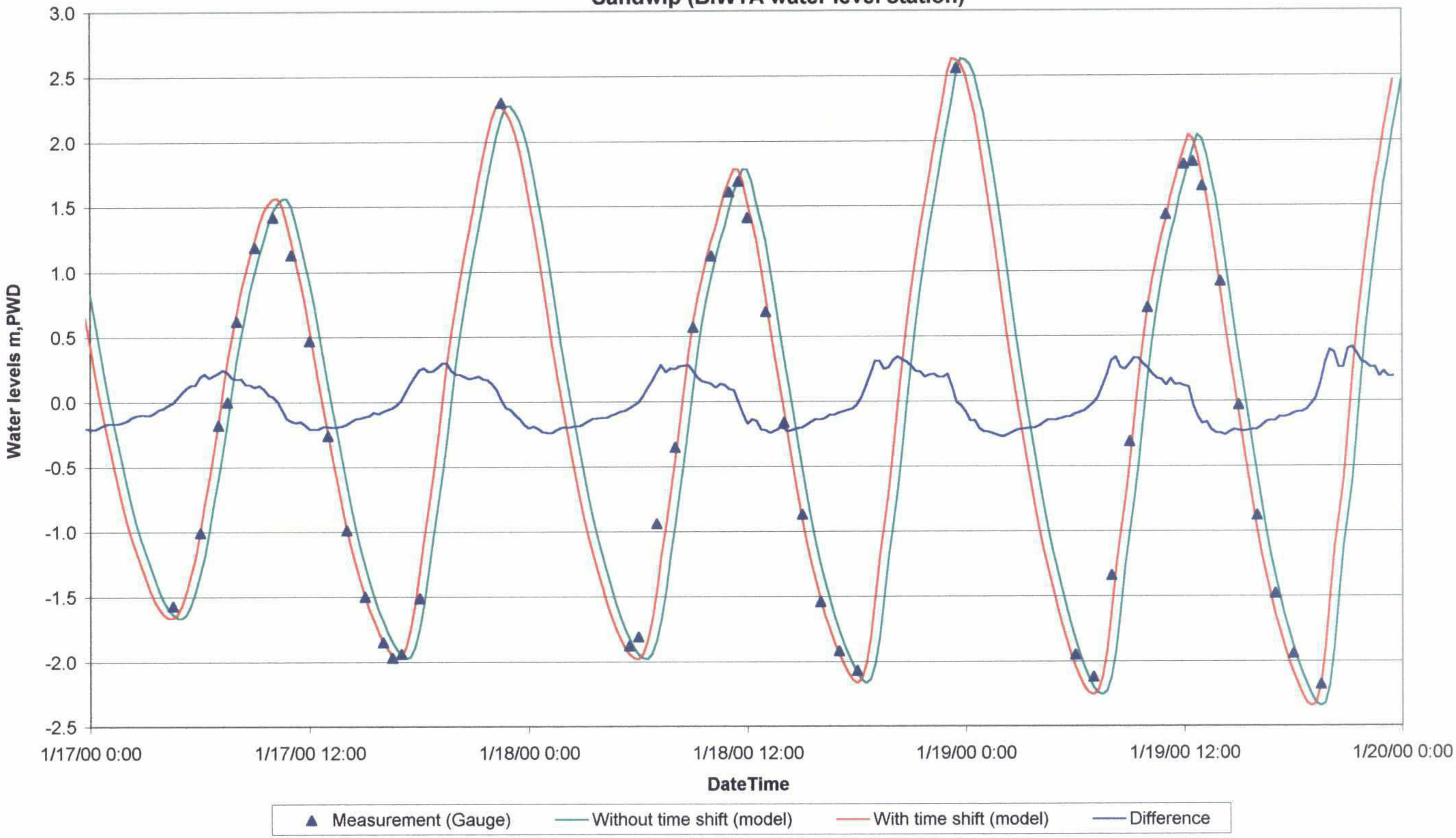
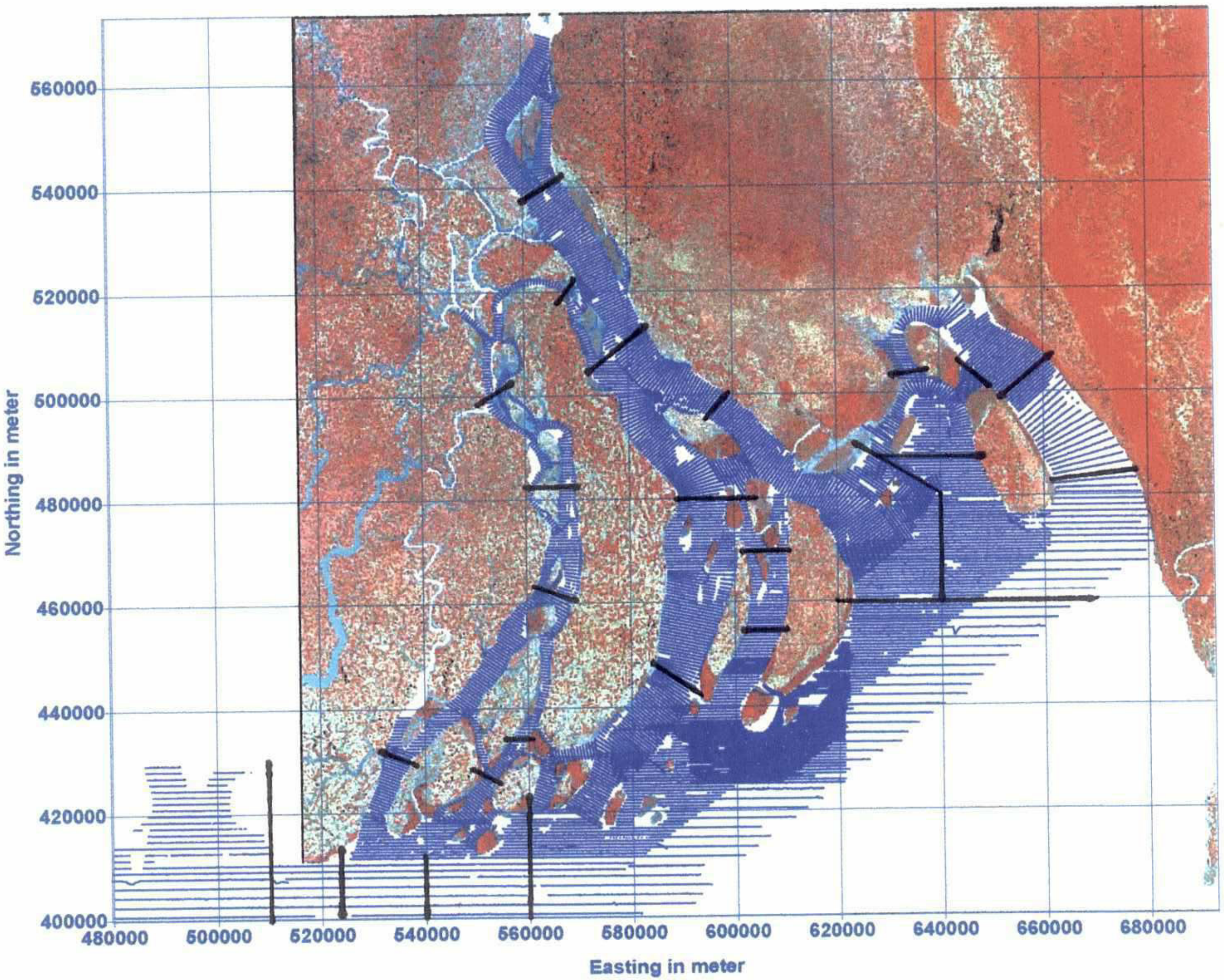


Fig-12 Bathymetry surveyed area of Meghna Estuary Study (phase II)
Date of survey : December 1999 - May 2000



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