Mapping the Sea Bottom Using RTK GPS and Lead-Line in Trabzon Harbor

Arzu ERENER and Ertan GÖKALP, Turkey

Key Words: Real-Time Kinematic GPS, Lead Line, Roll Effect, Hydrographic surveys.

SUMMARY

The harbor floor is accumulated with sands, which are carried away by waves and the deep-sea streams. The port surveys are to ensure that the waterways are free from obstructions and harbor depth is sufficient for safe entrance for vessels. In that case, hydrographic chart of the shape of the harbor bottom has to be made periodically to predict the rate of changes in sea-bottom configuration.

In this work, the survey boat worked inside the Trabzon Harbor and its entrance, which has been filled gradually with sand by an adjacent river, impact of significant storm and heavy rain events at surrounding area. Recently popular surveying method RTK system was used for hydrographic surveys on a survey boat for the horizontal positioning. With RTK, a reference station on a known point transmits the corrections via a data link to a rover receiver in the survey boat. This way the rover receiver can calculate GPS coordinates in real-time with the accuracy of centimeter level. In addition to GPS equipment, mechanical lead lines were used to show the sub-bottom profile. When horizontal coordinates (X,Y) of the point were determined by RTK GPS, the depth (d) component of the same point was measured by mechanical lead line simultaneously. The depth measurements are effected by the disordered changes of the water surface. These changes are called heave, pitch and roll effects in wavy environments, which are undesirable. Roll effect is one of the significant error sources of the hydrographic depth measurements caused by vertical movement of the surveying boat, due to the waves. By measuring the vertical movement of the surveying boat by RTK, this effect is reduced from the depth measurements.

Finally, a 3 dimensional hydrographic map of the current shape of the harbor bottom is generated in an Arc View environment, by using the corrected depth measurements and horizontal positions.

Mapping the Sea Bottom Using RTK GPS and Lead-Line in Trabzon Harbor

Arzu ERENER and Ertan GÖKALP, Turkey

1. INTRODUCTION

A hydrographic survey may consist of the determination of one or several of the following classes of data: depth of water; configuration and nature of bottom; directions and force of currents; heights and times of tides and water stages; and location of topographic features and fixed objects for survey and navigation purposes and also hydrography consists primarily of Nautical Charting Surveys, Port and Near shore Surveys, Industrial Offshore Surveys additionally, information on sea bed type, water movements and waves may be sought.

Hydrographic surveys are similar to the classical surveying methods in many aspects. The most important difference between these two indicated surveying methods, are not being able to physically see the surveying sites unlike the classical surveying methods and the continuous motion of the water surface. The Oceanographic Changes, vertical earth crust movement, astronomic tides and meteorological effects are the factors that affect the water surface and cause its change (1).

The port surveys are to ensure that the waterways are free from obstructions and the depth is sufficient for safe shipping (2). The potential dangers to shipping in waters are inadequately surveyed and charted. Shipping casualties can result in loss of life and severe (and costly) damage to vessels. Shipping safety depends not only on component navigation but adequate hydrography and up-to-date charts (3).

The goal of this study is to generate the sub sea bottom topographic profile of Trabzon Harbor and to introduce a method, which determines wave heights from orthometric heights and to correct the wave height changes from the depth measurements.

2. PRACTICING OF HYDROGRAPHIC SURVEYING IN TRABZON HARBOR

In this project, hydrographic surveys within Trabzon Harbor carried out (Figure.1). The hydrographic application was done for getting the sub sea bottom topographic profile of Trabzon Harbor. Trabzon Harbor is approximately rectangular shaped with the dimensions of 495 * 960 m (Figure 2). Hydrographic surveying was done in 3 days, Ashtech Z-Surveyor GPS, which consists of two main component groups, the base and the rover or remote, was used for point positioning. Husky controller and Ashtech Field Mate software was used as a controller on the field. For the depth measurements, a mechanical lead line was used.

Figure 1: Trabzon Harbor

The geodetic works, done in application are written below:

- Determining the accurate position of reference points for RTK measurements and determining the sounding lines for depth measurements.
- Preparing the mechanical sounding lead and Hydrographic surveying.

2.1 Determining the Accurate Positions of Reference Points and Determining the Sounding Lines

Before hydrographic surveying, we searched for suitable GPS reference stations for RTK measurements that have an extensive view of area on the pier. The location of reference stations must not disturb the receiving of data from the satellites and the location will ensure a stable radio communication between the reference station and the rover (no building, no tall dense trees) coordinates for new points immediately (4). After defining the reference points, accurate positions of the points were determined. The static method of surveying is the most accurate method due to the large amount of data collected. On average, occupation time was 45 minute sessions using a measurement interval of 10 seconds to derive accurate position for the unknown points. Three stationary GPS systems were utilized to collect data from several common satellites over a specific time period. Two systems were commonly centered over the known points in the K.T.U. (Karadeniz Technical University) GPS network while the other system occupies unknown stations. All baselines have ionosphere free, fixed integer solutions are all satisfactory. After static surveying, baselines were inserted into the K.T.U. GPS network on Geo Genius software and accurate position coordinates of new reference points were obtained.

Before the hydrographic surveying application in Trabzon harbor, we had to obtain the sounding lines. The direction and the position of the Vessel were determined by bearing. We stopped the vessel with 25 m. intervals, while the data's for hydrographic surveying on sounding points obtained (Figure.2). Depth measurements and sounding point positioning measurements were constructed on 332 sounding points simultaneously.

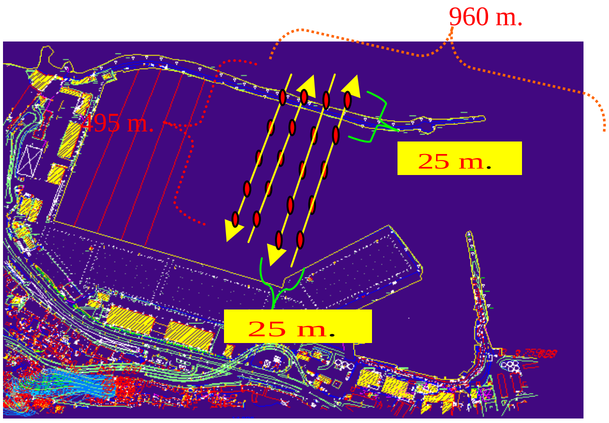


Figure 2: Determining sounding lines

2.2 Preparing the Mechanical Lead Line Device and Hydrographic Surveying

Trabzon Harbor has a silky bottoms containing "fluff" that would give questionable echo sounding readings. Because of this and for being economical, a mechanical reeled lead line was prepared just for surveying the sounding point's depth. The mechanical reeled equipment is constituted by, the tool prepared for measuring the depths and the remote antenna which could be located on the sounding points. It is portable and it can be fixed to the middle of the surveying boat, for minimum effect to the measurements by the waves on the application days. The port depths vary from 4 m to 12 m. as we could obtain from Trabzon Harbor depth chart, which had done 2 years ago. By taking these depths into consideration 17 meter's wire line connected to mechanical lead line tool. Circular steel disk was connected to wire line with the weight of 1 kg just for to run down the line easy to the water and to supply it to become on vertical position in a short time. Leads mechanically dropped to the sounding points. For easy dropping and winding, a reeled system was used. Reeled system movement was provided by encircling its sleeve by hand (Figure.3).

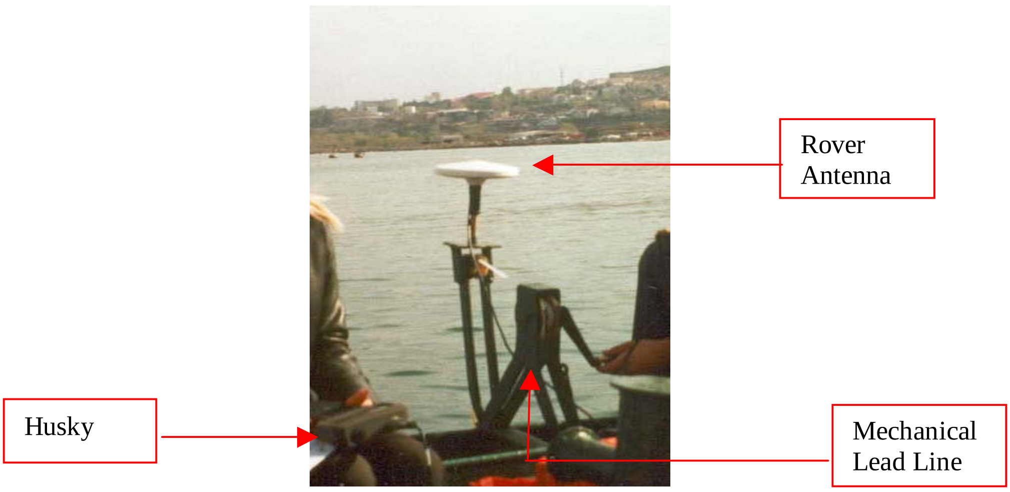


Figure 3: Mechanical lead line device

Any type of positioning method or system may be used to locate the depth measurement device. RTK GPS is currently one of them. As a result of the advantages of the GPS method such as being independent of weather conditions, having no requirement of the surveying points seeing each other, and being able to manage surveying during the night, it is being densely used for both terrestrial and hydrographic surveys. Real Time Kinematic (RTK) GPS receivers can measure the X,Y coordinates and orthometric height within a few centimeters.

In order to obtain high accuracy, the positioning system must use phase corrections to resolve carrier phase ambiguities. This requires good satellite coverage at both the base and the remote sites, and good correction data via the radio link. Once ambiguities have been resolved, the system should maintain high accuracy for the entire survey. Initial resolution times are usually 1 to 2 minutes under good conditions (6). If the system loses lock during the survey, the ambiguity resolution, and high accuracy, should return quickly (usually 30 seconds or less). When the HRMS and VRMS are in the centimeter range the system is again ready for high accuracy.

In this work, the base GPS antenna was located over the reference point. The coordinates of the point were entered into the base receiver. The base receiver make observations from the GPS satellites and uses these observations to calculate correction data, based on known reference point coordinates. Then the base radio broadcasts the correction information through the base radio antenna. The remote GPS antenna with unknown coordinates was placed on a mechanical reeled lead line on the surveying vessel. By means of a radio connection between the reference station and the rover it is possible to transmit data from the reference station to the rover. The remote radio receives the correction information through the Remote radio antenna and sends the data to the Remote GPS receiver via a serial cable. The remote GPS receiver takes measurements from the GPS satellites and applies the correction information from the base to derive a corrected position for the remote GPS antenna.

The position information is transferred to the Husky controller through a serial cable. GPS Field Mate software converts the position data into local coordinates using the transformation parameters entered by the user or uploaded with the mission file. Local coordinates were displayed along with the current positional accuracy. And the sounding point’s position information was logged to handheld memory (5).

In this manner, for all the sounding points, hydrographic surveying vessel was stopped for surveying. Depth measurements were carried out from the instantaneous sea level during the survey intervals. RTK GPS record position information, when depth measurements were taken by mechanical lead line simultaneously. Because of this, occupation time of the surveying depends on the depth measurements, not the RTK.

3. APPLICATION

There are two independent measurements on hydrographic surveying. One is point positioning and the other is depth measurement. In order to define the location of a point on the sea, the horizontal positions and the depth has to be known.

When the RTK system is ready for surveying, hydrographic surveying boat is taken to application line direction. By bearing, hydrographic surveying boat is stopped and trying to fix on the water while surveying on each sounding point. Just on this time, lead line dropped to the water and the depth measurement is read, by paying attention not to degenerate the wire line verticality by water stream and by the movement of the hydrographic surveying boat. While reading the depth measurement from the wire line and writing it down to the list, positioning information and point name of the sounding point are logged in both an ASCII and binary file in the handheld. Beside, determining horizontal coordinates; ellipsoidal height or orthometric height can also be obtained. In this application orthometric height is determined with the horizontal coordinates. All data collected with GPS systems is referenced to the antenna location, namely the phase center of the antenna. In most surveying application, the goal is to position the survey mark on the ground, not the location of the antenna some distance above the mark. Therefore, as part of the post-processing procedure, the GPS data collected must be reduced to ground level where the survey mark is located. Therefore, on each surveying day, vertical height between instantaneous water surface and antenna phase center is measured as the antenna height parameter. This value will be used to reduce the GPS measurements from the antenna height to water surface (6). This measurement is done when the sea surface is silent and without heave.

Antenna height measurement (a) has to be reduced from the mechanical line measurements (k) in order to get the depth measurements (d).

Figure.4 shows the measurement of X, Y, H positioning coordinates by RTK GPS and depth measurement (d), with mechanical lead for a single sounding point.
MSL_T = Mean sea level of Trabzon.
a = GPS antenna distance above the daily sea surface.
k = Measurement collecting on sounding points by mechanical lead line.
d = Calculated depth measurement of the sounding point.

$$d = k - a \tag{1}$$

This calculation is done for every sounding point for each survey day.

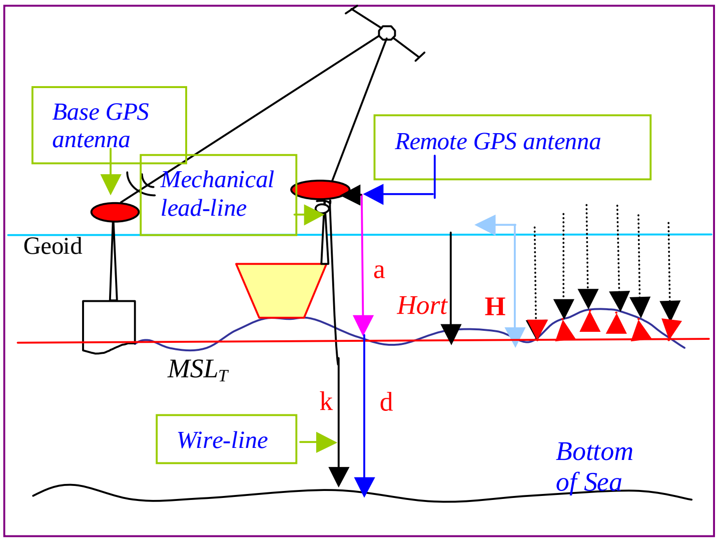


Figure 4: Mechanical lead line and RTK GPS equipment

The calculated depth measurements and positioning information is combined, on the PC. Handheld Transfer provides communication between a PC and a handheld controller. The m.out file transferred from data logger (handheld) to PC. The data's collected from a GPS receiver transferred to PC and displayed on WordPad additionally, calculated depth data's added to same worktable.

3.1 Wave Effect

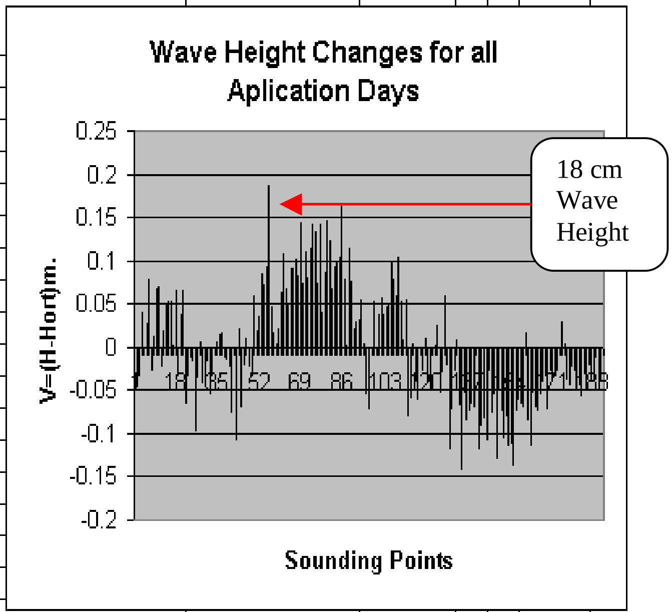
Water in oceans, seas and lakes move due to the variation of reasons, thus it is time and space-dependent. The depth measurements are effected from the disordered changes of the water surface. These changes are called heave, pitch and roll effects in wavy environments, which are undesirable. Roll effect is one of the significant error sources of the hydrographic depth measurements caused by vertical movement of the surveying boat, due to the waves.

The RTK systems are used on the survey boat to provide real-time heave corrections. By measuring the vertical movement of the surveying boat by RTK, this effect is reduced from the depth measurements.

After each application day, the orthometric height information for each sounding point collected by RTK GPS is utilized on PC environment on Excel software and wave effect for each sounding point is examined. Mean value of orthometric heights subtracted from each point's orthometric height value (eqn.3), this means that wave range is obtained for each sounding point while measuring depths by mechanical lead line. Table.1 represents wave height changes for all application day. Also wave amplitudes for each application day are examined

Table1: Modeled amplitude of the wave for all application day

Sounding Points	**Orthometric Heights**	**Mean of H(Hort)**	**Wave Amplitude(V)**	**Standard Deviation**					
f.137	0.421	0.398	**0.023**	0.058777488					
f.138	0.354		**-0.044**						
f.139	0.365		**-0.033**						
f.140	0.437		**0.039**						
f.141	0.398		**0**						
f.142	0.426		**0.028**						
f.143	0.476		**0.078**						
f.144	0.372		**-0.026**						
f.145	0.411		**0.013**						
f.146	0.465		**0.067**						
f.147	0.468		**0.07**						
f.148	0.377		**-0.021**						
f.149	0.416		**0.018**						
f.150	0.447		**0.049**						
f.151	0.451		**0.053**						
f.152	0.451		**0.053**						
f.153	0.399		**0.001**						
f.154	0.463		**0.065**						
f.155	0.366		**-0.032**						
f.156	0.435		**0.037**						
f.157	0.464		**0.066**						
f.158	0.333		**-0.065**						



$$H_{ort} = \sum H / n \quad (2)$$

$$V = H - H_{ort} \quad (3)$$

$$S = \pm\sqrt{\frac{[vv]}{[n-1]}} \quad (4)$$

n = Total number of sounding points for all application days
H_{ort} = Mean of orthometric heights measured by GPS
H = Orthometric heights measured by RTK GPS
V= Amplitude of wave
S = Standard deviation

Results show that the significant error sources of the hydrographic depth measurements caused by vertical movement of the surveying boat, due to the waves are obtained. Maximum wave height obtained by study is 20 cm. And these error sources reduced (eqn.5) from the depth measurements as it is shown in Table 2.

Table 2: Reduced depths

Sounding Points	H-Hort	d(m)	d'(m)
f.137	-0.403	10.34	9.937
f.138	-0.403	10.68	10.277
f.139	-0.403	10.44	10.037
f.140	-0.403	10.54	10.137
f.141	-0.403	10.27	9.867
f.142	-0.403	10	9.597
f.143	-0.403	9.44	9.037
f.144	-0.403	11.07	10.667
f.145	-0.403	11.18	10.777
f.146	-0.403	11.32	10.917
f.147	-0.403	11.47	11.067
f.148	-0.403	11.45	11.047
f.149	-0.403	11.57	11.167
f.150	-0.403	8.47	8.067
f.151	-0.403	11.47	11.067
f.152	-0.403	11.94	11.537
f.153	-0.403	11.68	11.277
f.154	-0.403	11.89	11.487
f.155	-0.403	11.56	11.157

$$d' = d - V \qquad (5)$$

d' = Corrected depth measurement, d = Depth measurement

3.2 Generating 3D View of the Harbor Bottom

In terms of animating the entry and exit route of the ships and the situation of sea bottom more clearly in the mind, the 3D vision of sea bottom has been created in the ArcView environment. By utilizing the corrected depth measurements; a three-dimensional hydrographic map of the current shape of the harbor bottom is generated (Figure.5).

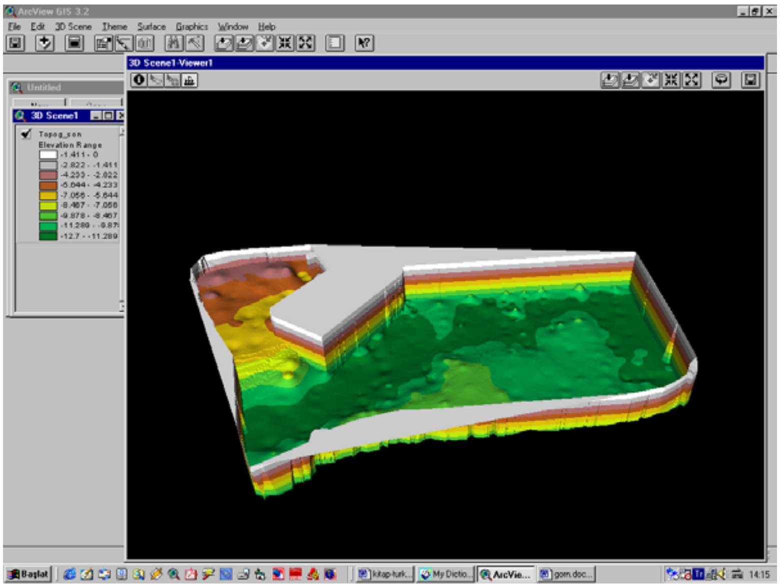


Figure 5: Trabzon Harbor 3D display

4. CONCLUSION

In this paper, the usage of popular surveying method RTK system on hydrographic surveying for sounding point position information and the mechanical lead line for depth measurements are applied. Considering the size of measurement area in the application, the method of mechanical sounding has been used to measure the depth of the water as it is easy to prepare the measurement mechanism and cost-effective. As the bottom of the harbor is covered with alluvium, sounding the hard ground is one of the reliable methods, but after the application it has been understood that measuring the depth of water by means of mechanical sounding both takes time and the sensitivity depends on the weather conditions and the flow at the bottom of the sea.

Due to the facts that the points must see each other, they must not be affected by the weather conditions, and the results can be taken rapidly, the method of GZKGPS which provides superiority against the local tools has been used in order to establish a location in all stages of the application. After the application, it has been seen that the method of GZKGPS which can be used in almost all areas of the ground cartography can also be used for the sea cartography. But no matter how it is quick to get the measurement results, as well as the weather conditions extending the application period, the vehicle of hydrographic has been stopped and measuring the depth of the weather has been continued by means of mechanical sounding mechanism.

Today, in most of the studies of depth measurements which are carried out in the water environment, the acoustic method is used as it is the much healthy method for measuring the depth. The depth measurements which are achieved via the acoustic sounding are also drawn up to the paper. But it is not very economical to use the acoustic sounding for small areas such as harbor.

In order to eliminate the affects of the wave on the measurement values achieved in the sounding points, the calculations has been made by using the data of orthometric obtained via GZKGPS and the affects of wave causing important errors for each of sounding points have been determined. The errors representing different values in each sounding points and having the maximum value of 20 have been eliminated from the depth measurements.

It has been possible to read the length of wire with ± 1-5 cm precision. Due to the flow pressure, it is accepted that the wire is bend in the shape of chain curve. In a theoretical research, it has been determined that the difference between the bent length of string and the stretched and perpendicular length is 0.7 m/s flow speed and within the limit of maximum 12 m and will not be more than the value of, ± 0,10 m. When the other effects mentioned after the effects of wave in the depth measurements are considered, it has been determined that the sensitivity of the depths with the mechanical sounding mechanism is ± 15 cm.

5. REFERENCES

http://www.pol.ac.uk/psmsl/training/canadian_manual/canadian.pdf
Hydro International, Volume 4, Number 3, Page28, April 200.
FIG Publication, Hydrography in Ports and Harbors, No. 8 1994
http://www.ddl.org/figtree/pub/fig_2003/TS_19/PP19_1_Pirti.pdf
GPS Field Mate operations and Reference Manual
Gökalp, E., Gerçek Zamanlı Kinematik GPS konumlarının Statik GPS ile kontrol edilmesi, Harita Dergisi, 122, (1999), 56-64.

CONTACTS

Arzu Erener
Middle East Technical University (METU)
Graduate School of Natural and Applied Sciences Geodetic and Geographical Information Technologies
Vakifbank Guzelsu Sitesi 1. Blok No:10 Cayyolu
06810 Ankara
TURKEY
Tel. + 90 312 241 4326
Email: erener@metu.edu.tr