GPS SURVEY OF SLOVENIAN COASTLINE AND ITS INTEGRATION WITH HYDROGRAPHIC DATA

Igor KARNIČNIK, M.Sc. Dalibor RADOVAN

Geodetic Institute of Slovenia, Jamova 2, Ljubljana, Slovenia, igor.karnicnik@geod-is.si, dalibor.radovan@geod-is.si

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ABSTRACT:

The aim of hydrography is to ensure safe navigation with aid of modern navigation equipment and nautical charts. Nautical charts play crucial role at the mariner's every day's job. The advent of the ships with exceptionally deep draught, the recognition of the need to protect the marine environment, the maritime trading and the growing importance of seabed resources, have all served to highlight the need for up-to-date hydrographic surveying. With the advent of GPS, the data which may have been adequate a decade ago, today have to be recompiled using new survey techniques, collected to a higher degree of accuracy and providing improved coverage. Fortunately, GPS technology has enabled us to apply accurate positioning on sea and land. The survey of the coastline and coastal objects for navigation has been executed with real-time kinematic GPS method. DGPS corrections have been provided by permanent reference station located in the vicinity of the Port of Koper. Production of a nautical chart demands various types of data (depths, contour lines, aids to navigation, dangers to navigation, geographical names, land topography, restricted areas and navigation routes). Many of them could be in different coordinate systems and are measured with various equipment. Integration of such data will be described in the case of nautical chart production.

1. INTRODUCTION

More than 80% of international trade in the world is carried by sea. Maritime commerce is a basic element for a nation's economy. The shipping industry needs efficiency and safety. Poorly charted areas and lack of information can cause voyages to be longer than necessary, may prevent the optimum loading and unloading of ships and thus increasing costs.

Modern nautical charts are required for safe navigation through a country's waters, along coasts and to enter its ports. A lack of such charts prevents the development of marine trade. It is also very important, that the SOLAS Convention Chapter V considers a ship unseaworthy if it does not carry up-to-date charts necessary for the intended voyage.

Slovenia is a member of the International Hydrograpic Organization (IHO) since 15. April 2002. This brings certain rights and also some responsibilities for Slovenia as a young maritime country. Although we have only some 45 km of a coastline, we have to assure safe navigation through our waters. That means hydrographic activities, production and updating of nautical charts and publications, and also survey of a coastline.

Slovenia started it's hydrographic activity soon after independence. First hydrographic survey was finished in 1998 with a co-operation with Navoceano, USA, in 1999, 2000 and 2003 three surveys were done by Slovenia, in 2002 a joint survey in co-operation of Slovenia, Croatia and Italy was done in area of the Bay of Piran. With this we acquired required data for production of our own nautical chats. In 2001 and 2002 we surveyed also complete coastline from the border with Italy to the border with Croatia.

2. COASTLINE

2.1 The need for a precise coastline

In the past the hydrographic and land surveys were carried out in a different way then today. The equipment was different and less accurate. Acquisition of soundings was done by lead line, today we determine depths by modern ultra sound sonar. The determination of ship's position was done in many ways. From visual methods (measuring angels by optical instruments – sextant or theodolite), electronic methods to today's satellite positioning methods, GPS.

The accuracy of such methods was, comparing to the equipment of today, poor. The lack of funds and need for fast and precise navigational information resulted in a way, that many hydrographic offices integrated old coast line with newly acquired soundings. This of course reflected in a difference of position of old survey of a coastline and new depths. There is also the effect of transformations of co-ordinates between old coordinate systems, in which nautical charts used to be and new system (nowadays based on ellipsoid of WGS84). There were occasions where new depths "landed" on a coast.

In order to avoid such a situation, the best way is to survey (or re-survey) a coastline. This is also practical since in years a coastline changed. The erosion, accumulation by rivers, construction of new ports and marinas created a new coastline.

2.2 Definition of a coastline

There are many definitions of a coastline. The Hydrographic dictionary uses the following definition (IHO, 1994): "Coastline is the line, where shore and water meet."

Terminology of coast and shore is rather confused and terms shoreline and coastline are generally used as synonymous.

The definition is rather obvious. Looking into details of that one may soon be faced with difficulties. Determination of a coastline for navigation must mean that it is safe for navigation. And what is safe for navigator? The coastline in high or low tide? In both cases the definition stands correct – the land and sea meet. This case needed from us to go into details and determine what level of water to be used as coastline used for navigation.

The basic for that is The Law of the Sea (IHO, 1993) which recognizes three different and for navigation important coastlines (figure 1):

- Hydrographic coastline (which is determined as High Water Level),
- Geodetic coastline (which is determined as Mean Sea Level, and is usually used as datum level for land (topographic) maps),
- Limit for drying heights also known as Chart Datum (which is determined as Low Water Line).

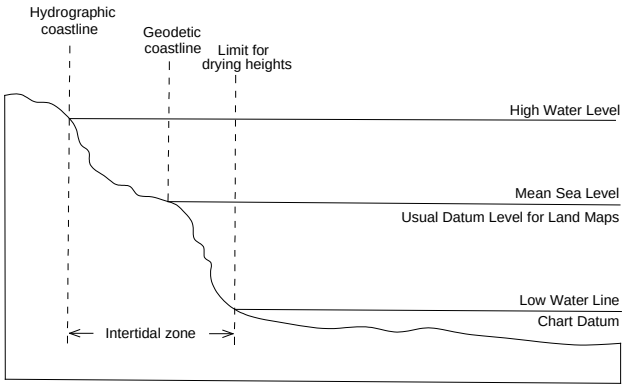

Figure 1: Different coastlines

Slovenian Maritime Law unfortunately doesn't have the definition of a coastline. This we find in Slovenian Water Act as: " Coastline extends to the line of highest tide."

Further investigation leads us to IHO chart specifications (IHO, 2001b) where we find the following definition: "The coastline (shoreline) shall be represented by high water mark, or by the line of mean sea level where there is no appreciable tide. In tidal waters where there is a beach the coastline is landward limit of the beach and therefore corresponds roughly to the high water line of the highest tides."

Analysing all the available information and definitions, we decided what level shall be used as coastline on Slovenian nautical charts. In order to facilitate the survey and give some general guidance for the surveyor we put together some guidance:

- For coastline we use Mean High Water;
- The level of high water mark can be determined on the field by observing the dark line of some typical sea organisms and algae;
- Where such a line cannot be seen, survey must be done in high tide;
- In order to eliminate other effects tide must be observed at all times;
- In build-up areas the edge of constructed coast objects shall be used for determination of coastline;
- The accuracy of coastline determination must be better than 2 m.

2.3 Survey of a coastline

Survey of Slovenian coast was concluded in two parts. First part was surveyed in 2001 and covered area between Izola and border with Croatia. Second part was done in 2002 and covered area from Izola to border with Italy.

Survey team was composed by two people, GPS operator and hydrographer who was responsible for determining the right level of water, writing the notes and remarks. A great deal of photographs was also taken. With this we gathered great amount of documentation about our coastline. Survey was done in high tide, in build-up areas also in other periods, since the water level has no effect on coastline.

Figure 2: Survey team at work

For the purpose of the survey Ashtech GPS receiver and antenna were used. Surveyed data were stored in Compaq Palmtop with appropriate software. For precise GPS correction Ashtech GPS reference station was set in the vicinity of the Port of Koper. DGPS correction was transmitted using GSM network. Data processing was done using home made software for PC. GPS equipment was daily calibrated on very precise reference point, and that gave the precision of 1 cm. The accuracy of RTK survey was very good, around 1 cm. Due to difficult determination of a coastline (especially when the coast was very flat), the accuracy of established coastline is estimated to be better than 2 m. Since the IHO standard for hydrographic survey describes minimum accuracy for natural coastline to be 10 m, our survey is much better.

Figure 3: GPS antenna and palmtop

During planning and conducting of survey some other information and data were helpful:

- nautical charts;
- topographic maps at the scale 1 : 5000;
- colour aerial-photographs;
- digital orthophoto at the scale 1 : 5000;
- tide tables for the Bay of Koper.

3. HYDROGRAPHIC DATA

Nautical chart is integration of hydrographic and topographic information. Topographic information are acquired by geodetic and photogrametric surveys. On nautical chart this area is presented very schematic and generalized. Mariner doesn't need this information so precise as maritime information, information on sea and close to the sea, on the coast.

As mentioned previously there were several hydrographic surveys in Slovenia. Chronological they are:

- 1998: Survey by Navoceano, USA at the scales 1 : 1000, 1 : 2500, 1 : 5000 and 1 : 10 000;
- 1999: Survey by Slovenia (up to 200 m from shore) at the scale 1 : 1000;
- 2000: Survey by Slovenia (up to 200 m from shore) at the scale 1 : 1000;
- 2002; Survey by IMA, Trieste 100% coverage;
- 2003: Survey by Slovenia at the scale 1 : 1000.

All surveys adhere to Order 1 of IHO hydrographic survey standard (IHO, 1998), which requires the accuracy of soundings to be better than 0.5 m, accuracy of horizontal positioning to be better than 5 m and line spacing to be 25 m. All our surveys satisfy this demands. All together we acquired about 130 millions of soundings, most of them for the Bay of Piran, where 100 % coverage was accomplished by surveying by multibeam sonar.

Positions of aids to navigation (lights and buoys) was also determined by means of GPS. Same IHO standard for hydrographic surveys also gives some directions for accuracy of positioning of such objects: for fixed aids to navigation and features significant to navigation up to 2 m, for floating aids to navigation up to 10 m. The mean position of our objects adhere to this standard. For all we checked also the light characteristics and other important information such as shape and colour. We put all information into database and for all we follow the changes and if necessary we up-date database, nautical charts and publications.

Also all other information and data important for navigation (wrecks and other dangers to navigation, tide information, bottom sampling, sub-bottom profiling, Secci disc survey data) are stored in special database.

4. INTEGRATION OF DATA

The result of a hydrographic survey is a set of fair sheets in different scale. From our surveys we gained quite a number of fair sheets:

- 5 fair sheets form 1998 survey (at the scale 1 : 25000, 1 : 7500 and 1 : 5000);
- 21 fair sheets from 1999 survey (at the scale 1 : 1000);
- 26 fair sheets from 2000 survey (at the scale 1 : 1000);
- 43 fair sheets from 2002 survey (at the scale 1 : 2000, 1 : 12 000, 1 : 75, 1 : 60, 1 : 150).

Since the 2003 survey is still in post processing phase the fair sheets are not yet produced.

Until now we have 86 different aids to navigation in our database:

- 22 lights;
- 1 beacon;
- 61 different buoys;
- 2 leading lights.

For the purpose of nautical chart we used land (topographic) maps at the scale 1 : 5000 for compilation of land part of a chart. Land information were generalized and simplified in order to satisfy the needs of a mariner and not to overload the chart with unnecessary information and data.

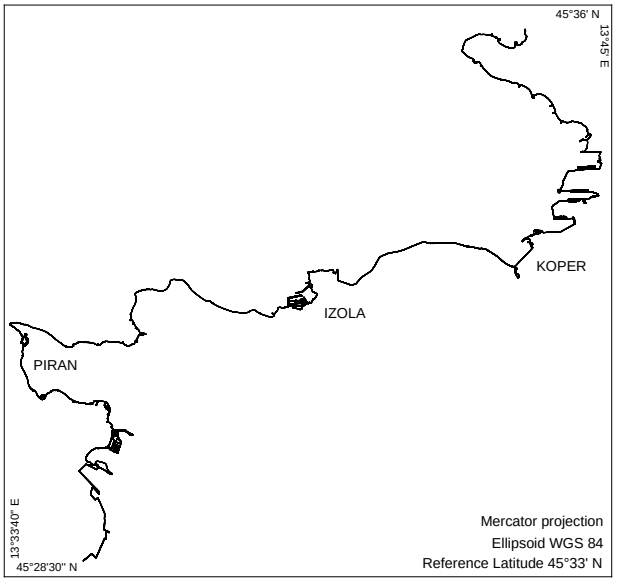

Figure 4: Slovenian coastline in Mercator projection

We expanded the database also with newly surveyed coastline. Original coastline survey data are of course in geographical co-ordinates on WGS 84 ellipsoid. All the post processing (cleaning and smoothing of data) was also done on the original

data. After completing this phase, the quality control was done in order to assure that all the important information were stored and surveyed properly. During the survey also some additional objects on or close to the coast were surveyed (bridges, lights). Those were added to the checked coastline. The final coastline data were then transformed in to three different systems:

- Original in geographical WGS 84 co-ordinates;
- Transformation in Gauß-Krüger projection on Bessel ellipsoid (in this system all fair sheets are);
- Transformation in Mercator projection (figure 4) on WGS 84 (in which the final result, the nautical chart is).

New coastline was used in production of fair sheets of two latest hydrographic surveys, and of course it will be used for 2003 survey. The updating of the Bay of Koper chart with new coastline has not been done yet. Due to the complexity of up-dating the whole chart with new coastline, it is better to produce new edition of a chart rather than up-date it. Until now, the new coastline was inserted in Electronic Nautical Chart (ENC) of the Bay of Koper. This ENC is in last phase of production and it waits to be checked and validated before releasing it for use on board ships.

5. CONCLUSION

Nowadays a great deal of international trade is done by sea. Small, big and enormous vessels are steaming up and down major maritime traffic routes. All of them need precise and accurate information which they need to make their voyage safe, efficient and on time.

Maritime countries have their special organizations, hydrographic offices in order to assure, that these kind of information are acquired, processed, organised and delivered to mariner. Hydrographic surveys are essential in this process. Ships are faster and better equipped as they were not so long ago. They cannot use old information, based on a survey made half a century or more ago. The coast changes, new ports are build and new piers added. The master needs all available information in real time. They have modern navigational equipment on board ships, which process more information faster as navigating officer could.

Hydrography is here to provide up-dated nautical charts and publications; conducting hydrographic and geodetic surveys of sea, coast and land in the vicinity of the sea; integrating all these data and information and process them until they are suitable for daily use on board. That means to clean and subtract overload of information and use only the relevant ones. The ones that are important for safe navigation. Hydrographer has to know what is relevant information for mariner and then has to decide how will process them so mariner can quickly and easily understand them.

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