CO-090

DELINEATION OF COASTLINE AND MARINE SDI IN CROATIA

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SUMMARY

One of major tasks of hydrographers is to delineate the coastline during the survey, and of marine cartographers to plot it to nautical charts and hydrographic survey sheets. This paper provides a definition of coastline adopted by the Hydrographic Institute of the Republic of Croatia on the basis of recommendations of the International Hydrographic Organization (IHO). The paper describes the coastlining geodetic methods used in the hydrographic practice. Factors that affect the variability of coastline are described. It has been pointed out that the mean sea-level increase recorded on the eastern Adriatic coast is still weak, but in the near future the new coastline should be calculated. The conclusion is that in the national spatial data infrastructure (NSDI) it is advisable to use one single coastline both on nautical charts and topographic maps, so that the users could easily and consistently refer their object in a coastal zone.

Keywords: spatial data infrastructure(SDI), map content, user data/maps.

1. BACKGROUND AND OBJECTIVES

Every maritime country has its coastal zone, which is differently defined in terms of different professions. As a physical-geographical term, coast is a part of the land in occasional contact with the sea. Coast is therefore not a line but a belt, either wider or narrower, depending on the slope of the land and the range of sea level oscillations. As a geographical-economic term, coast has a much wider significance, since the width of the coastal belt depends on land's orography.

Because of the sea-land interaction in the coastal belt, the spatial data in that area are interconnected, usually being examined, represented or used together.

Boundary between the sea and land, as shown on nautical charts and topographic maps, is not the coast but the coastline. According to the recommendation of the International Hydrographic Organization (IHO), most maritime countries define coastline as the intersection of the mean high water with the land (Shalowitz, 1962; Harrington, 1993; IHO, 2005; Quadros and Collier, 2008).

Land data (State Geodetic Administration) and marine data (hydrographic offices) are usually represented by means of different coordinate systems, different projections, different datums (horizontal and vertical), and differents scales, to show different contents. As a result, users are not able to refer to the required object in the coastal area in a simple and consistent way (e.g. Duplančić Leder i Leder, 2009).

Integration of the land and marine data is becoming a serious problem for many countries, and just a few of them have solved it (Murray, 2007), each in its own way.

As in the Republic of Croatia there is no connection (continuity) between the land-sea spatial information, the procedure of locating and referencing the spatial information on the coastline is problematic and complicated, especially for its users.

The paper presents an overview of the Croatian Hydrographic Institute activities on delineating the coastline, as well as the proposal to integrate the coastline into the national marine spatial data infrastructure of the Republic of Croatia.

2. APPROACH & METHODS

2.1. COASTLINE IN THE NATIONAL SPATIAL DATA INFRASTRUCTURE OF THE REPUBLIC OF CROATIA

All spatial data should be stored in the National Spatial Data Infrastructure (NSDI). The stored data should be seamless and continuous, without gaps or data overlaps. However, different spatial data in the Republic of Croatia, as well as in other countries, use different coastlines.

When resolving the above mentioned problem, the past world experience can be used, which is limited because few countries have resolved this problem (Murray, 2007; IHO, 2009).

2.2. DEFINITION OF COASTLINE IN THE REPUBLIC OF CROATIA

Hydrographic Institute of the Republic of Croatia defines coastline as a surface determined by the mean high water on the tide gauges at Dubrovnik, Split, Bakar, Rovinj and Koper in the epoch 1971.5, being called the Croatian Coastline Reference System for Epoch 1971.5 - HRSOC71 (Domijan et al., 2005).

In practice, the coastline is calculated as the mean high water from the 18.6-year series of hourly values of long-period sea level oscillations obtained from tidal measurements (IHO, 2005; Domijan et al., 2005).

Long-period sea level oscillations (implying the periods longer than 1 min) are mostly generated by the tidal force and by atmospheric forces, mainly by the air and wind pressure (Leder, 1988). Tidal force is usually caused by the gravitational attraction of water masses by the Sun and the Moon. Meteorological influence on the sea level oscillation is of two kinds: forced oscillations, which are more significant in the domain of synoptic and planetary disturbances, i.e. on the periods greater than one day, and free oscillations (seiches) occurring in the Adriatic Sea with the periods smaller than one day (Leder and Orlić, 2004). Influence of long-period sea level oscillations in the coastal belt is shown in Figure 1.

Coastline of the Republic of Croatia consists of a mainland part 1880 km in length, and an island part 4398 km in length, amounting to 6278 km (Duplančić Leder et al., 2004). It is the second best indented coast in the Mediterranean. The Republic of Croatia is committed to defining spatially its land and marine territory.

An example of charting the coastline in the area of the Port of Split is given in the harbour chart "Split – Gradska luka" at 1 : 5000 scale (Figure 2). Besides the coastline, the chart shows the soundings and the heights on land, measured from two different height datums: chart datum (depths) and geodetic datum (heights).

"Chart Datum" is a geoid surface determined by the mean lower low waters of spring tide on the tide gauges at Dubrovnik, Split, Bakar, Rovinj and Koper in the epoch 1971.5", being called Hrvatski referentni sustav dubina mora za epohu 1971.5 (Croatian Reference System of Soundings for Epoch 1971.5) – abbreviated HRSDM7. Chart Datum is used as a reference for measuring soundings (Domijan et al., 2005).

According to the Decision on establishing official geodetic datums and plane cartographic projections of the Republic of Croatia (NN 110/2004), "geodetic datum" is a geoid surface determined by the mean sea level on the tide gauges at Dubrovnik, Split, Bakar, Rovinj and Koper in the epoch 1971.5, being called "Hrvatski visinski referentni sustav za epohu 1971.5 (Croatian Height Reference System for the Epoch 1971.5) – abbreviated HVRS71". Geodetic Datum is used as a reference for measuring heights on land.

Relative relations between Coastline, Geodetic Datum and Chart Datum for the area of Split are shown in Figure 3.

Figure 1. Oscillations of sea level heights in the coastal belt on a gently sloped coast (Bačvice beach in Split).

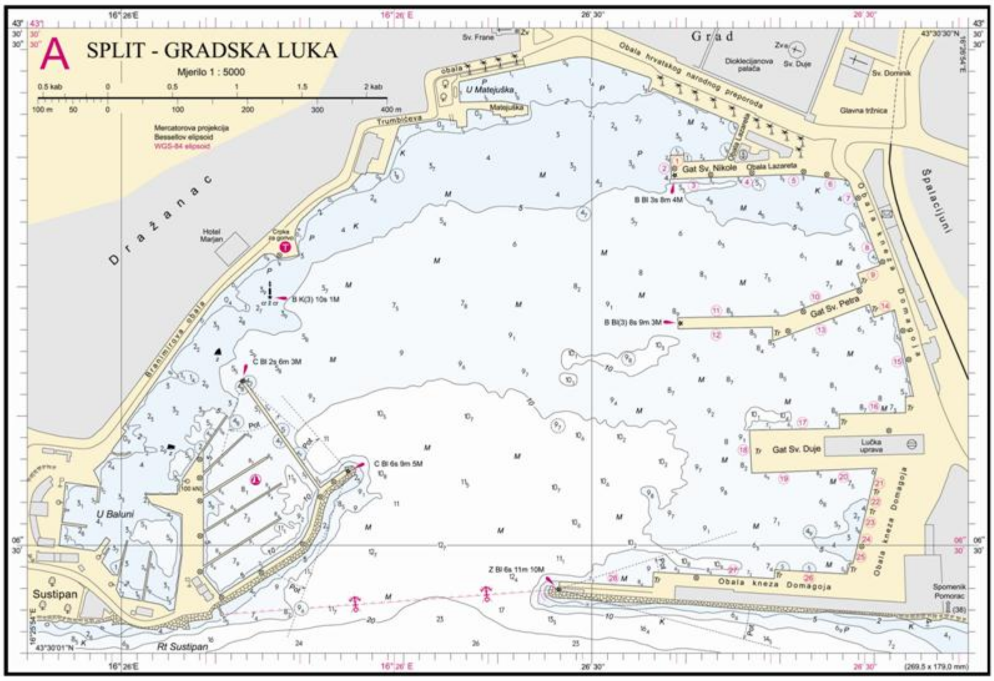

Figure 2. Harbour chart of the Port of Split (Hydrographic Institute of the Republic of Croatia, 2009.

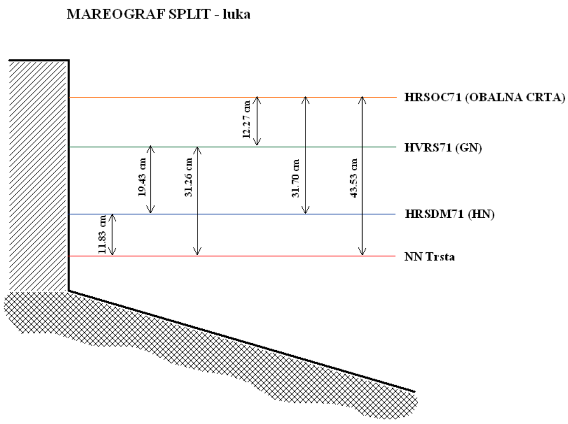

Figure 3. Diagram of relative relations between Coastline (HRSOC71), Geodetic Datum (HVRS71), Chart Datum (HRSDM71), and old geodetic datum, so called "Normal Datum of Trieste (NN Trieste)" for the area of Split (according to Domijan et al., 2005).

2.3. GEODETIC METHODS OF COASTLINE DELINEATION

In the proces of delineation of coastline, the following methods are used:

1. Topographic or terrestrial survey method
2. Levelling method
3. Marking of coastline during mean high water
4. Aerophotogrammetric method
5. Topographic and bathymetric LIDAR method

Each of the above mentioned methods has its advantages and disadvantages.

2.3.1. Topographic or terrestrial survey method

Topographic or terrestrial survey method defines the coastline on the basis of sea traces left on the coastal edge. Until recently this method was often used in the Adriatic, because major part of the coast is steep (about 90%), while a smaller part is flat (about 10%). The amplitude of sea level oscillations is clearly visible on the stony edges of steep and gently sloped stony coasts, but this method cannot be used to define the coastline on flat and sandy coasts. Neither can it be used on the coasts of open seas or in marsh areas (Jovanović, 1978).

During low water, one can see on the stony coast the layers of yellow, green and brown algae, the layer of filth on the stone, covered by a thin layer of clean stone whose colour is different from the rest of the stone

(Figure 4). The lowest edge of algae is the level of lowest low water, the boundary between green and brown algae is the chart datum level, the layer of filth is the mean level of high water or the coastline, and the upper edge of clean stone is the level of highest water.

Figure 4. Sea levels can be determined from the traces on the coastal edge.

2.3.2. Levelling method

Before applying this method, it is necessary to carry out tide-gauge levelling works along the coastal area to establish a levelling network, to be the basis for defining the coastline (Jovanović, 1978). Benchmarks should be distributed so as to ensure delineation of all parts of the coastline. This method is suitable for delineating the coastline on the flat stony, sandy or shingly coasts. Disadvantage of this method is that it requires long-lasting preparatory tide-gauge levelling works.

2.3.3. Marking the coastline during the mean level of high water

In the period of occurrence of the mean high water, the coastline is marked (with stakes or colour) as a line dividing the land from the sea. Afterwards, the marked points are surveyed by geodetic methods. This method requires that long-lasting tide-gauge measurements be done previously, and in certain cases a mobile tide gauge should be used. Advantage of this method is accuracy of the results obtained, while its disadvantage is the long duration of the procedure and preparatory works.

2.3.4. Aerophotogrammetric method

A large part of the hydrographic fair charts was produced by aerophotogrammetric method. At the time of the recording, the line of contact between the land and the sea was corrected for the calculated value of the rise of sea level, obtained from tide-gauge measurements.

2.3.5. Topographic and bathymetric LIDAR method

In recent times, an automated process of linking the following two basic data sets has been used: digital terrain model of the coastal zone, and the reliable tidal model. The coastline is determined from the above mentioned data (Quadros and Collier, 2008). Digital terrain model is obtained from the bathymetric and topographic LIDAR recordings of the coastal zone (Figure 5), whereas tidal model is derived from the mathematical interpolation of tide-gauge data or by hydrodynamic tidal model.

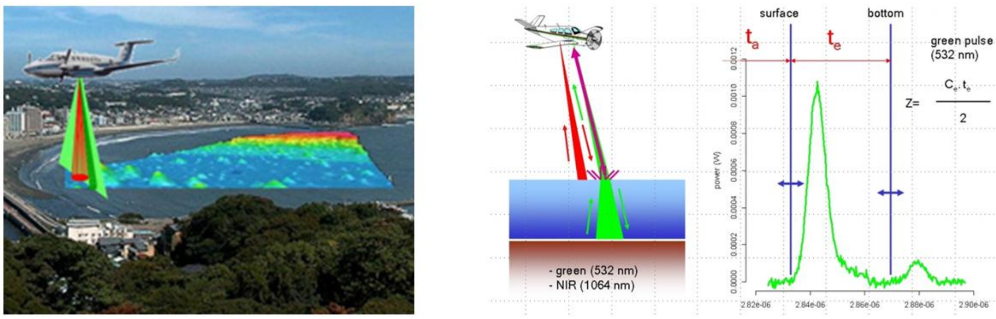

Figure 5. Bathymetric LIDAR (according to http://www.coastalwiki.org).

2.4. VARIABILITY OF COASTLINE

Coastline has a 4D (four-dimensional) character, i.e. it changes both in space and time. The most intensive change occurs due to the impact of human factors – construction of hydrotechnical marine structures (eg. harbours, boat harbours, marinas, piers, etc.).

Mechanical effect of waves and sea currents on the coast is a much slower process which influences the variability of coastline. However, according to the Hydrographic Institute data (Hydrographic Institute, 1955-2009), the increase of the mean sea level in the Adriatic, most probably caused by climatic changes, started being recorded recently (Leder et al., 2010). It is therefore expected that in the near future new height datums should be calculated for the new epoch, as distinguished from the epoch 1971.5 which is currently in force (see Chapter 2.2).

3. RESULTS

Different spatial data in the Republic of Croatia use different coastlines. The coastline plotted on the nautical charts produced by the Hydrographic Institute of the Republic of Croatia was defined according to the recommendation of the International Hydrographic Organization as the intersection between the mean high water level and the land. As it is an unambiguous definition, it could be said that the coastline is a consistent feature object on nautical charts.

The coastline plotted on the topographic maps produced by the State Geodetic Administration was derived as the intersection between the land and the sea from aerophotogrammetric recordings at particular time. As the height of the sea level constantly varies in time, such method of determining the coastline is not consistent because it depends on the recording time.

Consequently, topographic maps and nautical charts use differently defined coastlines. Moreover, to represent the land and marine spatial data, different datums (horizontal and vertical), different projections and scales are used, and different contents are displayed. The result is that users cannot easily identify their object in the coastal zone.

In order to resolve this problem, it is proposed to define all the vertical cross sections in the marine spatial data infrastructure (MSDI) as an integral part of NSDI, or all the height datums (coastline, geodetic datum and chart datum) using unique and consistent methodology. Users should be enabled effective recalculations between the stored data, as well as easy changeover to new height datums in the future.

The best solution would be the unique coastline data for topographic maps and nautical charts.

4. CONCLUSION AND FUTURE PLANS

What is shown on nautical charts and topographic maps is not the coast but the coastline as a boundary between the land and the sea.

According to the recommendation of the International Hydrographic Organization (IHO), the Hydrographic Institute of the Republic of Croatia defines coastline as the intersection of the mean high water with the land for the epoch 1971.5. Coastline, defined so, was plotted on the hydrographic fair charts and navigational charts and plans.

The coastline plotted on the topographic maps produced by the State Geodetic Administration was derived as the intersection between the land and the sea from aerophotogrammetric recordings at particular time. As the height of the sea level constantly varies in time, such method of determining the coastline is not consistent because it depends on the recording time.

In the Republic of Croatia, different horizontal and vertical data, different projections and scales, are used for the representation of land data (topographic maps) and marine data (nautical charts). As a result, users are not able to refer to the required object in the coastal area in a simple and consistent way. The National Spatial Data Infrastructure (NSDI) should therefore integrate the land and marine data in order to define the Marine Spatial Data Infrastructure (MSDI) in a unique and consistent way.

In the world practice, just a few countries attempt to resolve the problem of integration of the land and marine data, each in its own way.

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