Hydrographical Survey – Technical Observations and Strategic Role for Sustainable Development

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Key words: Coastal Zone Management, GPS, Hydrography, Marine cadastre

SUMMARY

The necessity to know the topography of the seabed for both environmental problems and construction of marine works and infrastructures produced new techniques of hydrographical surveys which, thanks to the use of GPS instruments, are able to provide for detailed techcnical maps useful to satisfy all planning requirements. In this report, the author wants to analyse the most important elements connected with the hydrographical surveys as the planning and execution of measures, the data analysis and collection, the vertical reference surface, the value of hydrographical surveys within the territorial situation of Taranto in order to defend the coast and to build strategic marine works for the development of the seaport.

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1. INTRODUCTION

As provided by law n. 68 of 2 February 1960, the surveys in the territorial waters are of competence of the Hydrographical Mercantile Marine Institute (IIM). The port surveys, being understood that the IMM has the faculty to carry out where and when necessary, are instead of competence of the "Genio Civile Opere Marittime" and of the Port Authority.

In order to satisfy a series of new needs, for some decades other qualified Bodies have been interested in hydrographical surveys. This creates a strong impulse that, together with the availability of advanced technologies, develops an increasing interest in the bathymetry and hydrography on behalf of professional men and enterprises.

The system more used in the recent past for the bathymetric surveys of the seaboard, of the internal water and of the ports, happened using empirical instruments based on the positioning of boas, lines and sounding leads, or through a topographical survey of the rising out of waters fulfilled with the total station and bathymetric survey with echo-sounder placed on a craft boned from the earth through the total station.
More recently, thanks to the use of the technology GPS, it is possible to utilize for the planimteric and altimetrical positioning of the surface the satellite system with metodology Real Time Kinematic (RTK), with data acquisition with board instrumentation for navigation and echo-sounder.
The modern bathymetric survey makes use, substantially, of 2 technologies:

- G.P.S. and echo-sounder
- G.P.S. and laser scanner (Lidar)

while the first one characterizes the application oriented towards engineering and building of marine works, the second one is developing above all for strategical studies to contrast the coast erosion.
The aim of this paper is to stigmatize briefly the main problems inherent to the bathymetric survey carried out with GPS and echo-sounder single beam.
On this subject, before facing in detail the matter, it is useful to quote some notions:

GPS and echo-sounder

Omitting the treatment of the systems of positioning and of satellite navigation, that are taking for granted, it is useful to dwell upon the echo-sounder as an instrument of primary importance within the hydrographical survey.
The echo-sounder is an instrument that produces periodically an underwater signal (ultrasound) and measures the time between the transmission of the signal and the reception

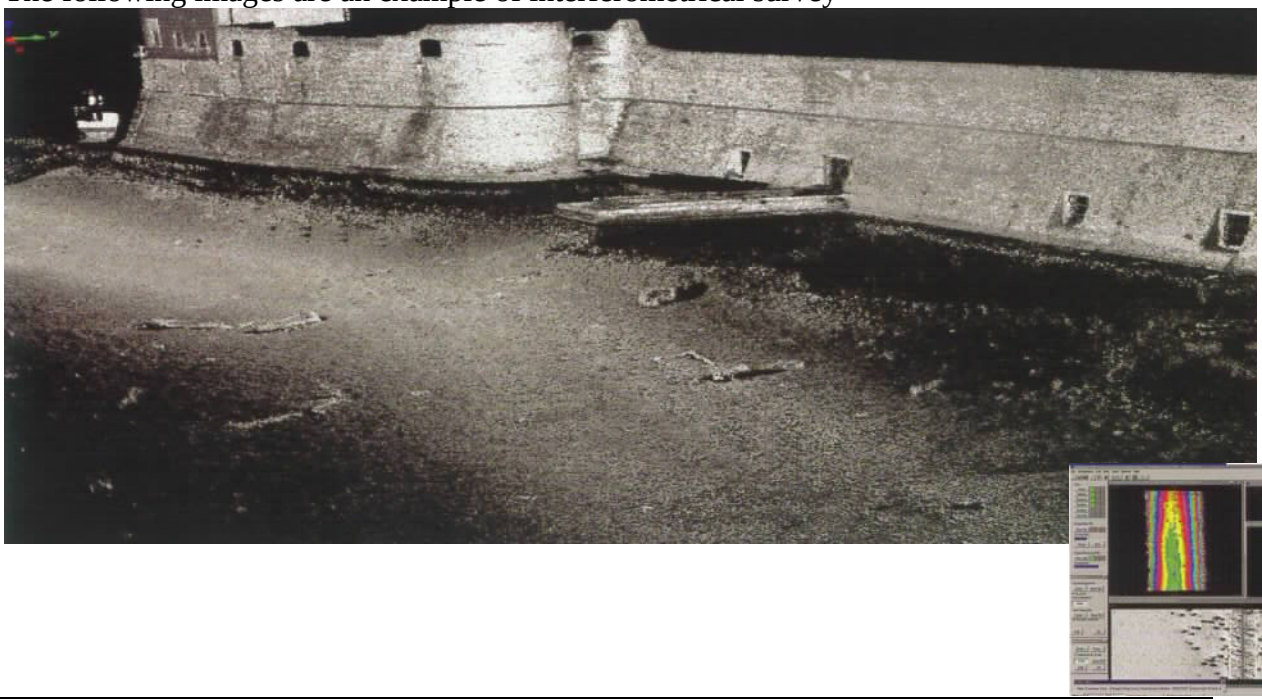
of the echo reflected by the seabed. Fixed the velocity of sound in water, this slot is converted in distance, (in this case the depth) following this simple expression:

depth = 1/2Vs x T
where:
Vs = velocity of sound in water
T = necessary time for the sonorous impulse to achieve the seabed and to go back .

The professional instruments for the bathymetry are equipped with command for the control and the regulation of the speedy of propagation of sound in water and with serial ports for the registration of data.
They can also be classified in 2 categories:
- *single beam echo-sounders with single or double frequency*;
- *multibeam echo-sounders.*

The echo-sounders *single beam* consent to survey sections of the seabed at level with the course covered from the boat;
the echo-sounders *multibeam producing*, unlike the first ones, a variety of contemporaneous sound impulses are able to give a model of sound waves that cover a large strip for each line or route of survey .
- In a third category we can mention the new hydrographical systems based on measures of *interferometry*. A single wave sound emitted by the transducer is reflected by the seabed and received by a series of receptors placed in order so to return clouds of geo-supplied points. In this way bathymetrical sections can be acquired treating the data similarly to the terrestrial laser scanners. The big quantity of information and density of points consent to return in real time also a side scanner sonar image of the seabed surveyed at high resolution.

The following images are an example of interferometrical survey



In order to make clearer the matter of the hydrographical survey and to better analyze the case study here presented, it is useful to dwell upon briefly the following definitions:

2. REFERENCE SYSTEM

In order to return the surveyed bathymetrical data in the existing cartography, it is necessary that the same data are expressed in the reference system.
The Italian hydrographical and nautical cartography is represented in the projection of "Mercatore" on international ellipsoid.
Altitudes and depths are both expressed in metres but have different references.
The altitude of emersed parts are referred to the **middle level of the sea**, while the depths of the floors are referred to the **middle level of the ebb tides** coinciding with the so called **L.R.S.** (*reference level of sounding leads).*

In the Italian official cartography for the Mediterranean Area the difference between the 2 reference levels is called *Z with zero* and is equal to *0.12 m (Z0 = 0.12 m).*
In the bathymetries carried out for technical goals, unlike the official cartographies, the surveys are returned with level projections and the reference for the depths is established through institution of an altimetrical bench mark derived from the Italian geometrical levelling net, or established in relation to the local level of the sea within a fixed instant and monitored for all the period of survey.

3. TIDE

Considering all the periodical movements of the surface of the sea, the most evident is the one normally characterized by 2 elevations and 2 lowerings of the level of the water in about 24 hours.

These vertical oscillations of the sea level form exactly the *tide,* and are necessary accompanied by horizontal movements of the water that must flow where the level rises and must stream where the level subsides. To the tide are therefore associated the so called *riptides.*

Focusing the attention on the vertical movements, the oscillation of the tide consists in a progressive elevation of the surface of the sea that achieves a maximum level called high tide (HT) and then a slow lowering that achieves a minimum level called ebb tide (ET) and in the repetition of these.

To better understand the existing link between altimetry and level of the sea mentioned above, it is necessary to remember that the geoid is an equipotential surface of the gravity field that better brings the middle level of the sea near. From a conceptual point of view, the geoid can be imagined as extension of the sea under the continents, and the surface so defined is assumed as *reference of altitude:* the recourse to that particular equipotential surface cancels every kind of uncertainty in regard to what has to be defined as "*level sea"* and

permits to define without ambiguity a concept of altitude from a physical point of view called *altitude of geoid* or on *the middle level of the sea*.
The definition of the altitudes and of an altimetrical net that is valid for a whole territory involves the need to establish a starting altitude to use after as reference for all the following surveys. This starting altitude is determined through the evaluation of the middle level of the sea in a fixed place with an instrument called *marigraph* able to register the oscillations in a very long period of time.

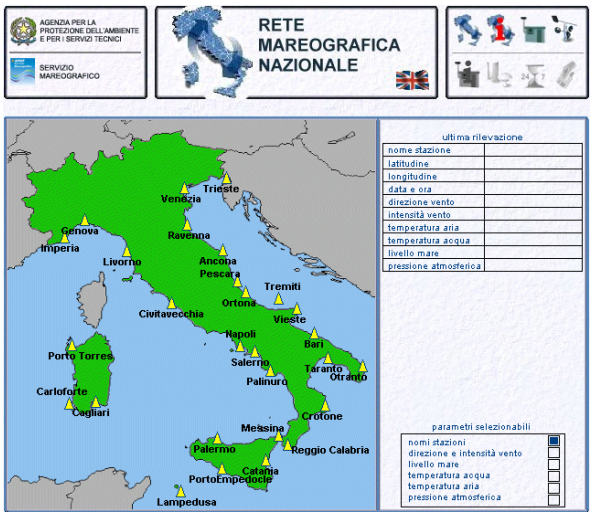
Those variations result from several causes that act in a periodical way: mediating therefore the data measured in a period of time that takes the above mentioned periodical characters into consideration (for Italy the IMM adopted a period of 10 years), the so called middle level of the sea can be individualized.

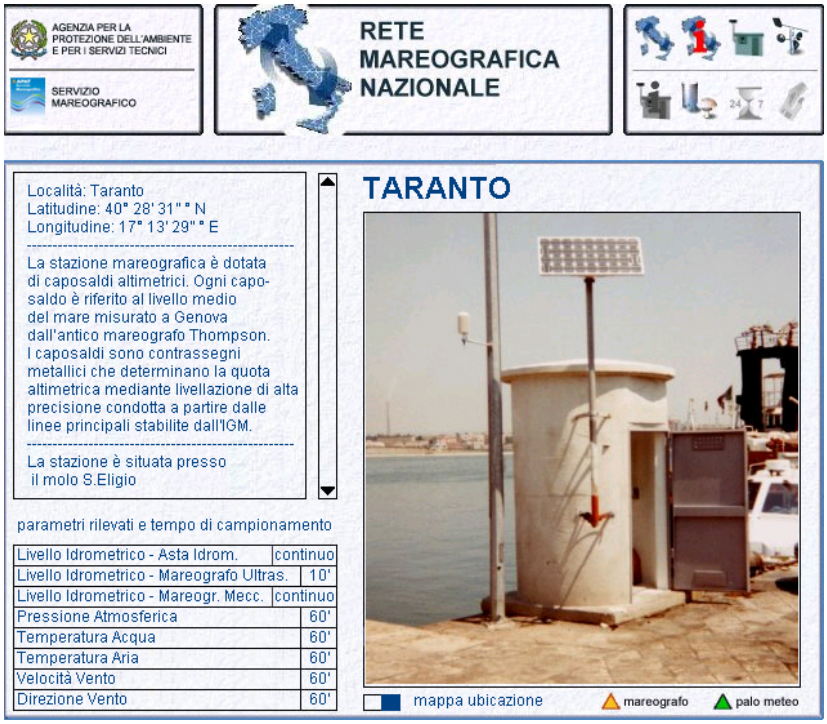
In Italy in 1954 during the 45° plenary meeting of the National Geodetic Commission it was decided that the altitude of reference should be the height of a particular point, located near the plate of the marigraph of Genova on the middle level of the sea and deduced for 10 years of measurements from 1937 to 1946.

Starting from the 3.249 metres, as the result of that calculation, the Military Geographic Institute (IGM) transferred, from1950 to 1970 through operations of high precision, the altitude along levelling lines identified by bench marks distributed in all the peninsula with a global development of about 14000 Km. Being impossible to link with geometrical levelling to the continental Italy the 2 big islands Sardinia and Sicily, they relate their own altitude to the definitions of the middle level of the sea of the marigraphs of Cagliari and Catania. In particular, the *sea-level* in Catania is the result of the average of a year of registrations carried out in 1965, while Cagliari refers to a series of observations from 1st June 1955 to 31st August 1957.

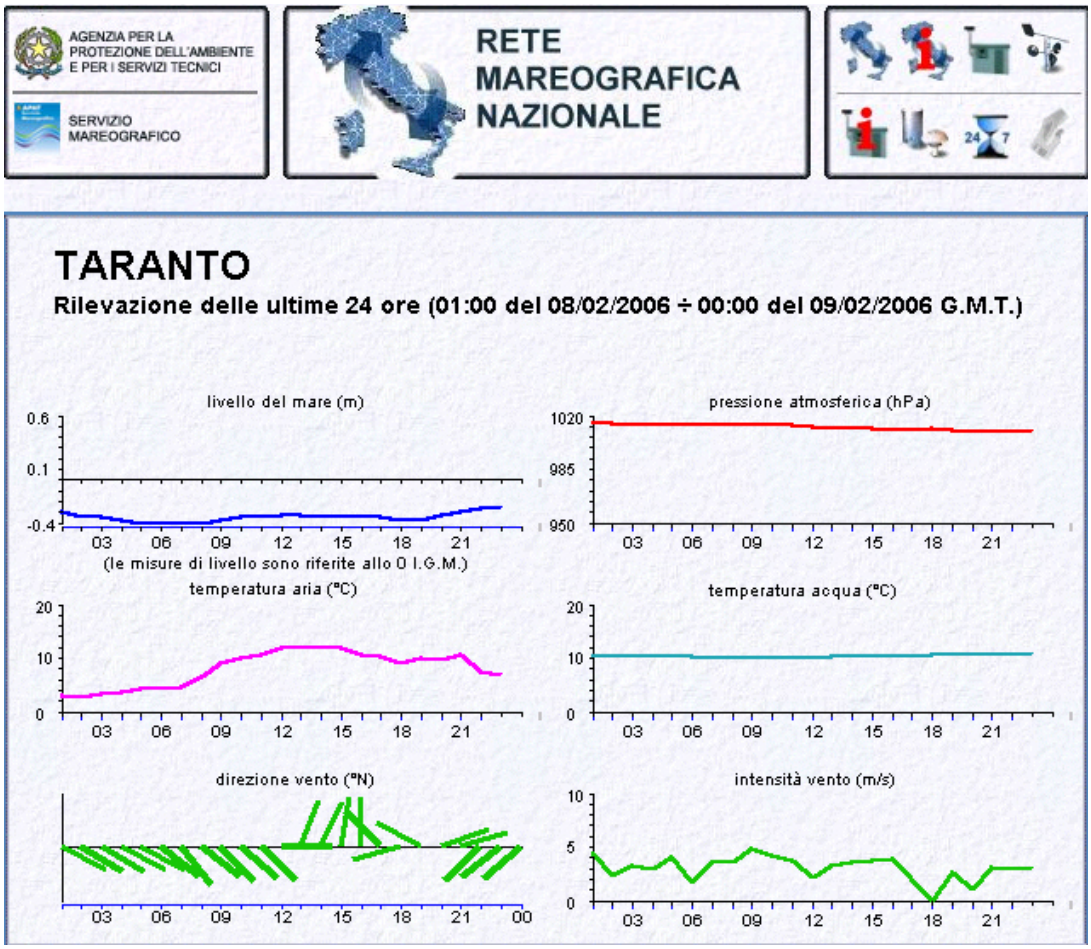
3.1 The Marigraphs and the National Marigraphic Net

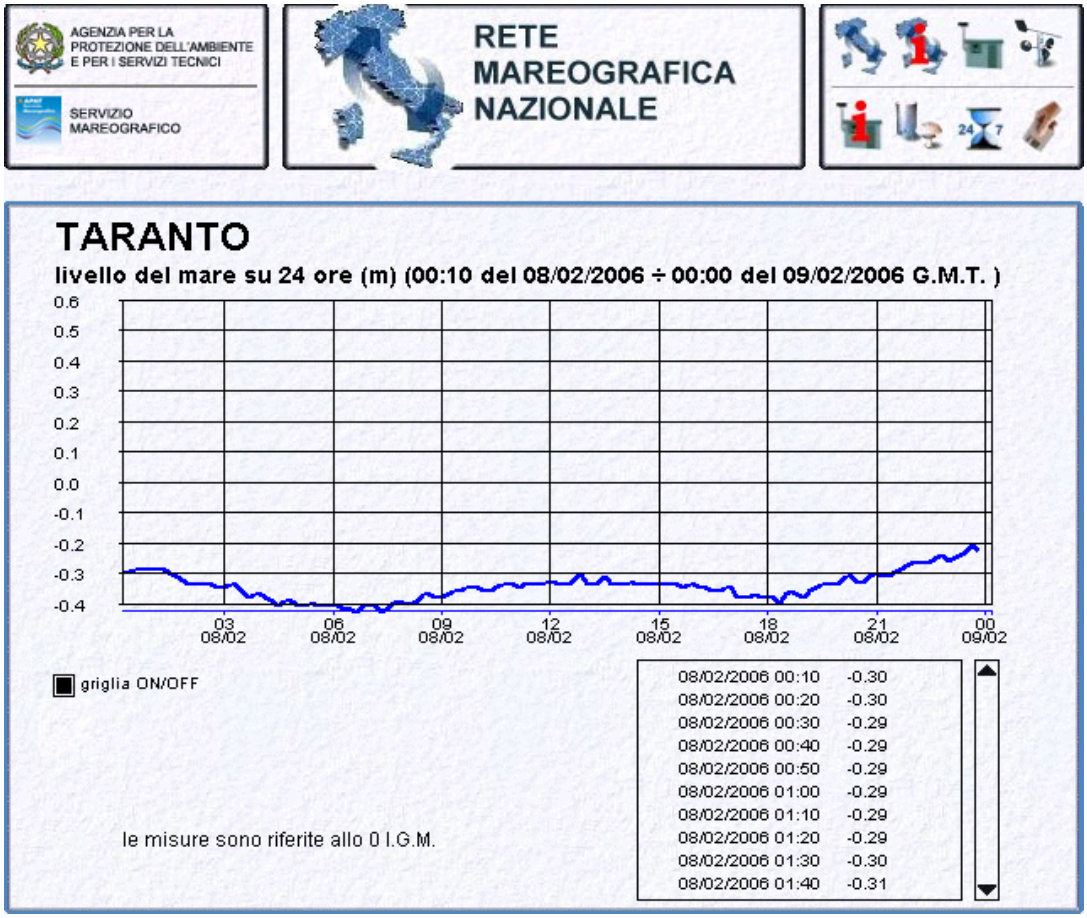
In Italy the tidal excursions are monitored by the national marigraphic net made by a system of marigraphs coordinated by the NATIONAL MARIGRAPHIC SERVICE..





As example the data of the marigraphic station of Taranto


AGENZIA PER LA PROTEZIONE DELL'AMBIENTE E PER I SERVIZI TECNICI
SERVIZIO MAREOGRAFICO
RETE MAREOGRAFICA NAZIONALE
TARANTO
Rilevazione delle ultime 24 ore (01:00 del 08/02/2006 ÷ 00:00 del 09/02/2006 G.M.T.)
livello del mare (m)
0.6
0.1
-0.4
03 06 09 12 15 18 21
(le misure di livello sono riferite allo 0 I.G.M.)
pressione atmosferica (hPa)
1020
985
950
03 06 09 12 15 18 21
temperatura aria (°C)
20
10
0
03 06 09 12 15 18 21
temperatura acqua (°C)
20
10
0
03 06 09 12 15 18 21
direzione vento (°N)
03 06 09 12 15 18 21 00
intensità vento (m/s)
10
5
0
03 06 09 12 15 18 21



4. NORMATIVE SCHEDULE OF REFERENCE

IHO is the acronym of International Hydrographic Institute, international body composed by 64 nations, including Italy, whose aim is to coordinate the activities of hydrographical services, to take care of the standardization of nautical documents and to promote the international cooperation for the progress of subjects concerning hydro-oceanographic surveys.

The Hydrographic Institute of the Marina represents Italy within the International Hydrographic Organization and participates in several international activities of specialized education and survey campaign. It carries out also the important task of coordination for the standardization of hydrographic surveys ordered, in national field, to some bodies as private enterprises and professional men by harbour-offices.

To obtain the validity of the surveys, the Hydrographic Institute has recently sent to all the interested persons precise dispositions as regards the execution of the barymetric surveys, imploring them to respect the guidelines **IHO S-44** with referring particularly to :

- Classification of Hydrographic Port Surveys
- Accuracy of positioning data
- Accuracy of depth data
- Observation of the tide
- Measurements of the speedy of sound in water
- Characteristics of data

4.1 Case Study

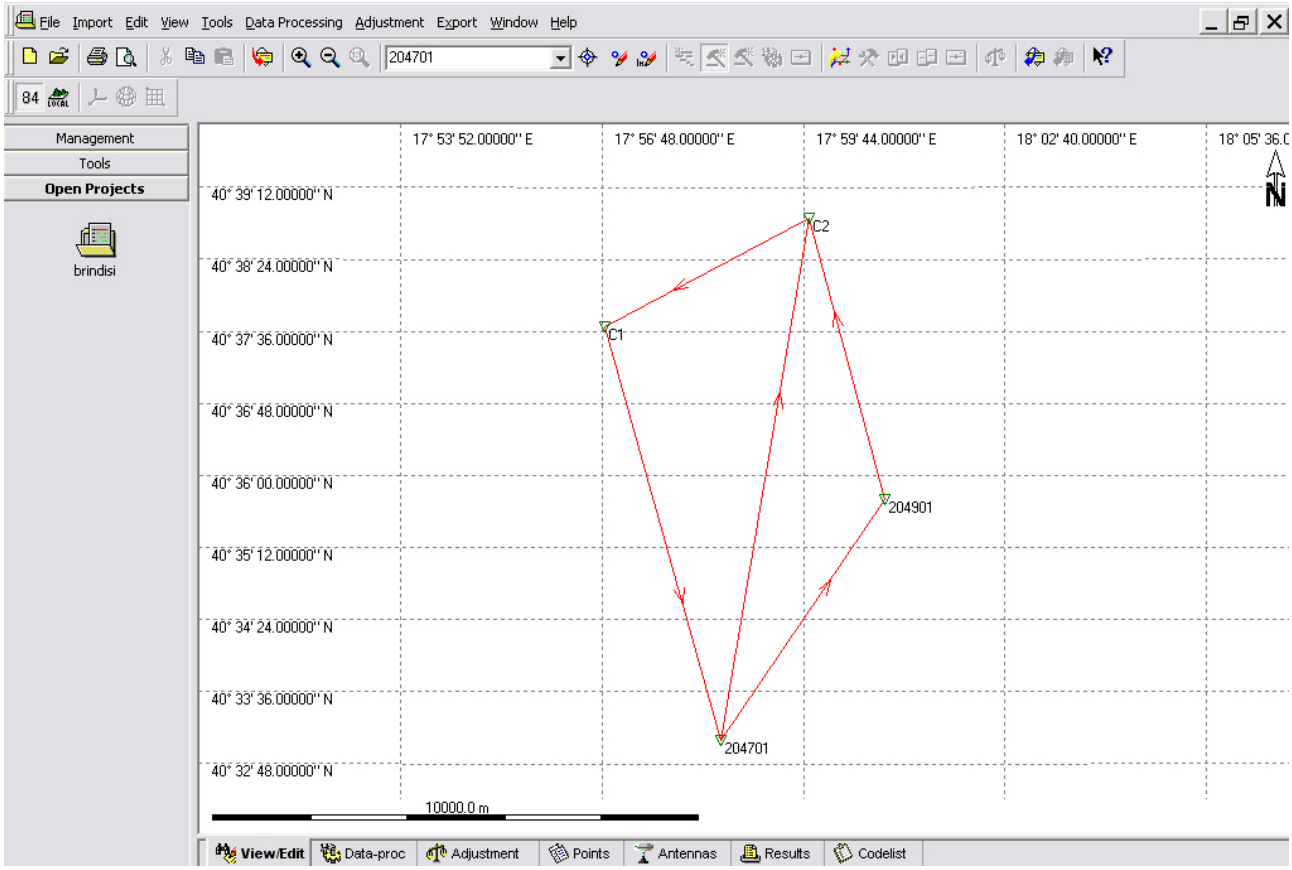
To examine more specifically the phases of project, the execution of measures and the treatment of data concerning the bathymetric survey, we examine as case study the one fulfilled in the expanse of sea facing "Costa Morena" in the harbour of Brindisi from 9th to 14th March 2005 and from 12th to 30th May 2005.

In particular, the following parts will be described:
- Topographical organization
- Project of bathymetric survey
- Execution of measures
- Data processing

A) TOPOGRAPHICAL ORGANIZATION

Once taken all necessary inspections, the stable present structures for the installation of the topographical references will be individualized in suitable areas.
Those structures were individualized in a cement handmade in the municipal graveyard, called "C1", and on a building of reinforced concrete, not anymore in use and in the past used as concreting station, called "C2".

Those references were materialized through nails steel fixed in reinforced concrete and on them a GPS with receivers will be established to link them with the bench marks of the national geodetic net IGM 95: cs. 204701 – Tuturano port – e cs. 204901 – Villanova – according to the following scheme:



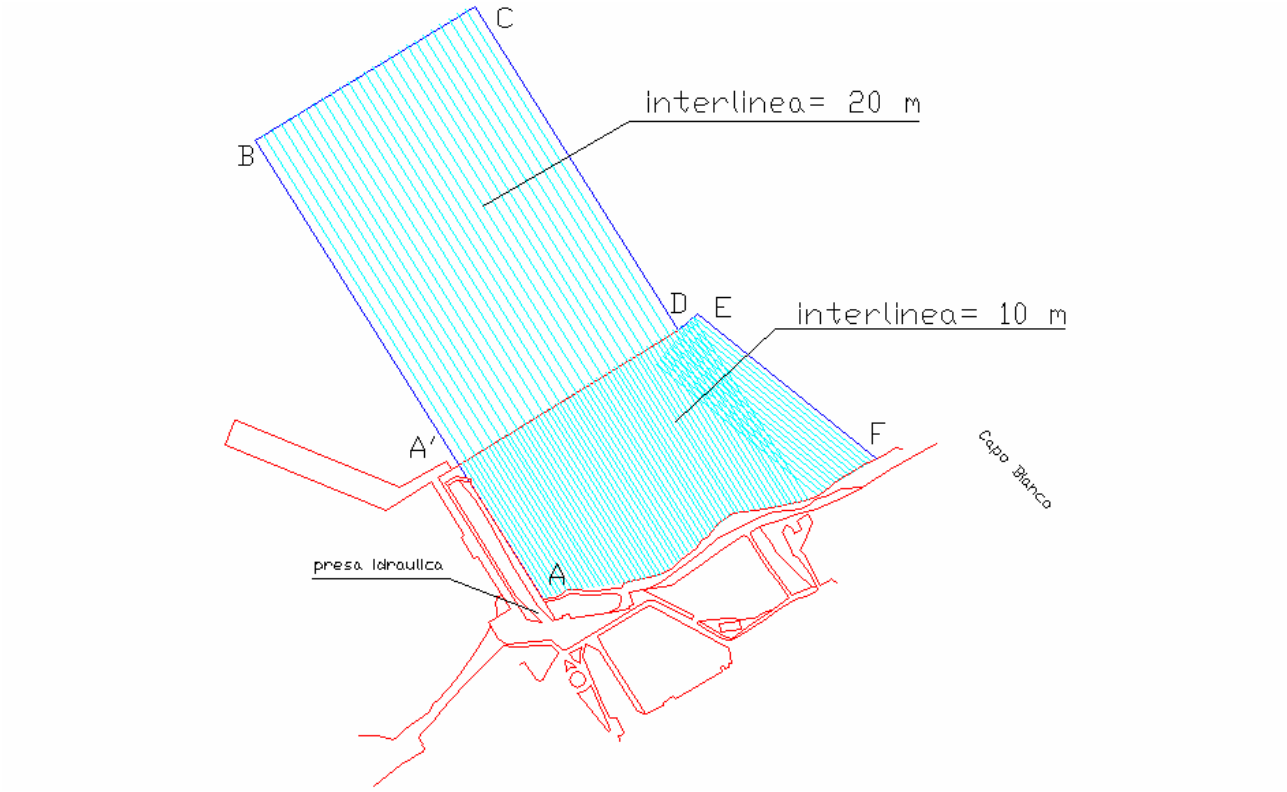
at the end of the data processing operations and of the compensation of measures, the coordinates WGS84 of the measured bench marks are the following:

PNT		DATE	LON	H	LAT
204701	Adjusted	06/11/2005 14:29:01	40° 33' 03.62123" N	17° 58' 32.28279" E	78.8037
204901	Adjusted	06/11/2005 14:29:01	40° 35' 43.71100" N	18° 00' 55.25473" E	51.2759
C1	Adjusted	06/11/2005 14:29:01	40° 37' 38.99041" N	17° 56' 50.05801" E	54.6470
C2	Adjusted	06/11/2005 14:29:01	40° 38' 51.64592" N	17° 59' 49.45466" E	49.9199

From the bench mark C2 with GPS survey and the method RTK (Real Time Kinematic) the survey of the profile of the coast for the tract interested by the bathymetric survey was subsequently carried out.

B) PLANNING OF THE SURVEY

The boundaries of the area of intervention indicated in the specifications were reproduced on the topographical map of the place, appropriately geo-referenced and integrated with the survey of the coast, as represented in the following scheme:



The area of inquiry invests in total an extent of about 65.00 hectares

Using the hydrographic software WIN-BAT on the base prepared cartography, the navigation lines in the direction of the waterfront of the wharf ENICHEM were traced out so to cover the whole area. Each line was characterized by a progressive cardinal number to which the coordinate EAST and NORTH of its extreme points were associated.
That procedure allowed during the period of survey to choose a precise route (or navigation line), to go along its whole length registering position and depth, monitoring the quality of measured values and deviations of the real route.

B) a. GEO-REFERENZE

Concerning the geo-reference of the basic cartography, a bench march was installed on the waterfront (Fincosit Area) which was derived from the IGM 95 net with coordinates expressed in the reference system GAUSS-BOAGA – International ellipsoid MONTEMARIO orientation – having the following characteristics:

Ellipsoid	:	INTERNATIONAL
Datum	:	ROME 1940
Central Meridian	:	15° EAST
Original Latitude	:	0°
False East Origin:		2.520.000
False North Origin	:	0.000

Bench mark C 3 (Fincosit Waterfront)

C3 E= 27071416.084 N= 4504276.564
h= 4.092

B) b. DESCRIPTION OF THE MARINE WEATHER CONDITIONS

The survey campaign was carried out from 12/05/2005 to 30/05/2005 with good marine weather conditions.
There were not particular difficulties to signal except for big perturbation due to the passage of considerable naval transports. During those perturbations the data survey was interrupted and was started again when they finished.
The areas with shallow water were surveyed using a pneumatic boat equipped with GPS and echo sounder instruments.
Calibration tests of the instrument were carried out many times in a day and in different places to take always in consideration the different physical condition of water .

B) c. DESCRIPTION OF THE TRANSPORTS USED

The transports of inspection used for the execution of the bathymetry are:

1) Wooden motorboat “Alessandro” built in 1986

Gross tonnage	t	12.73
Lenght	m	10.50
Net width	m	3.29
Immersion	m	1.50

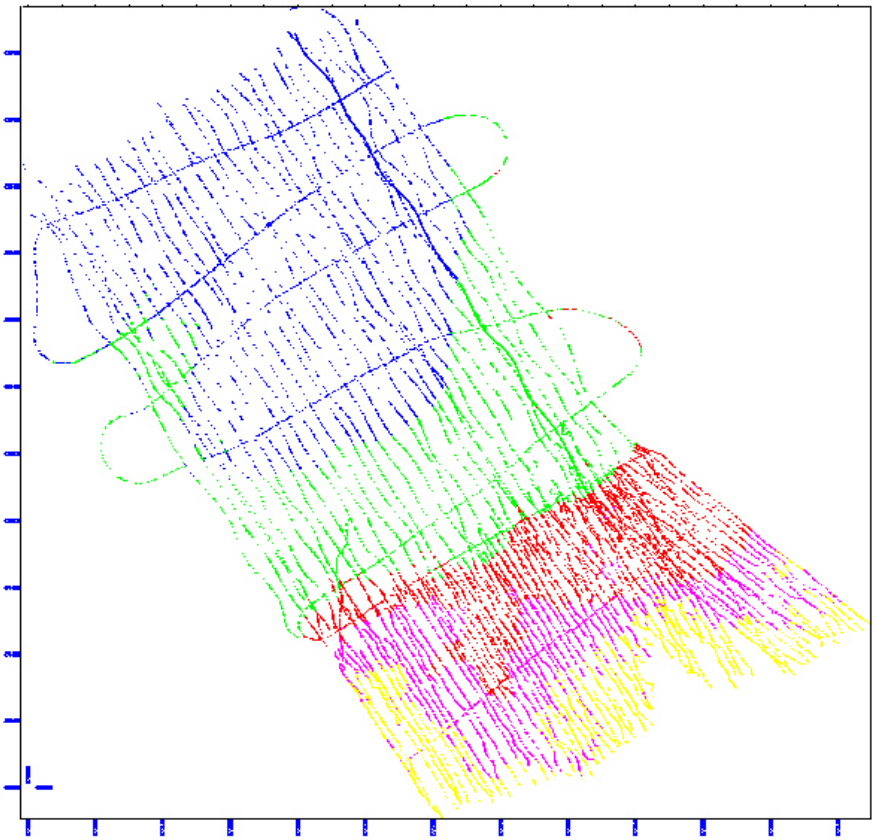
Motorization n.1 motor AIFO FIAT Hp 165

- GPS positioning system;
- navigation system;
- echo sounder

2) Rubber Boat lenght m. 4.50 motor 15 HP

The transducer of the echo-sounder fixed at the centre of the walling on the left side through special stirrup was immersed 0.40 m. under the surface of water and was places in an area not influenced by hydraulic turbolences.
The same conditions were respected on the pneumatic boat.

The lines, as really surveyed in accordance with the designed plan, are presented in the following figure:



B) d. VALIDATION AND DATA PROCESSING

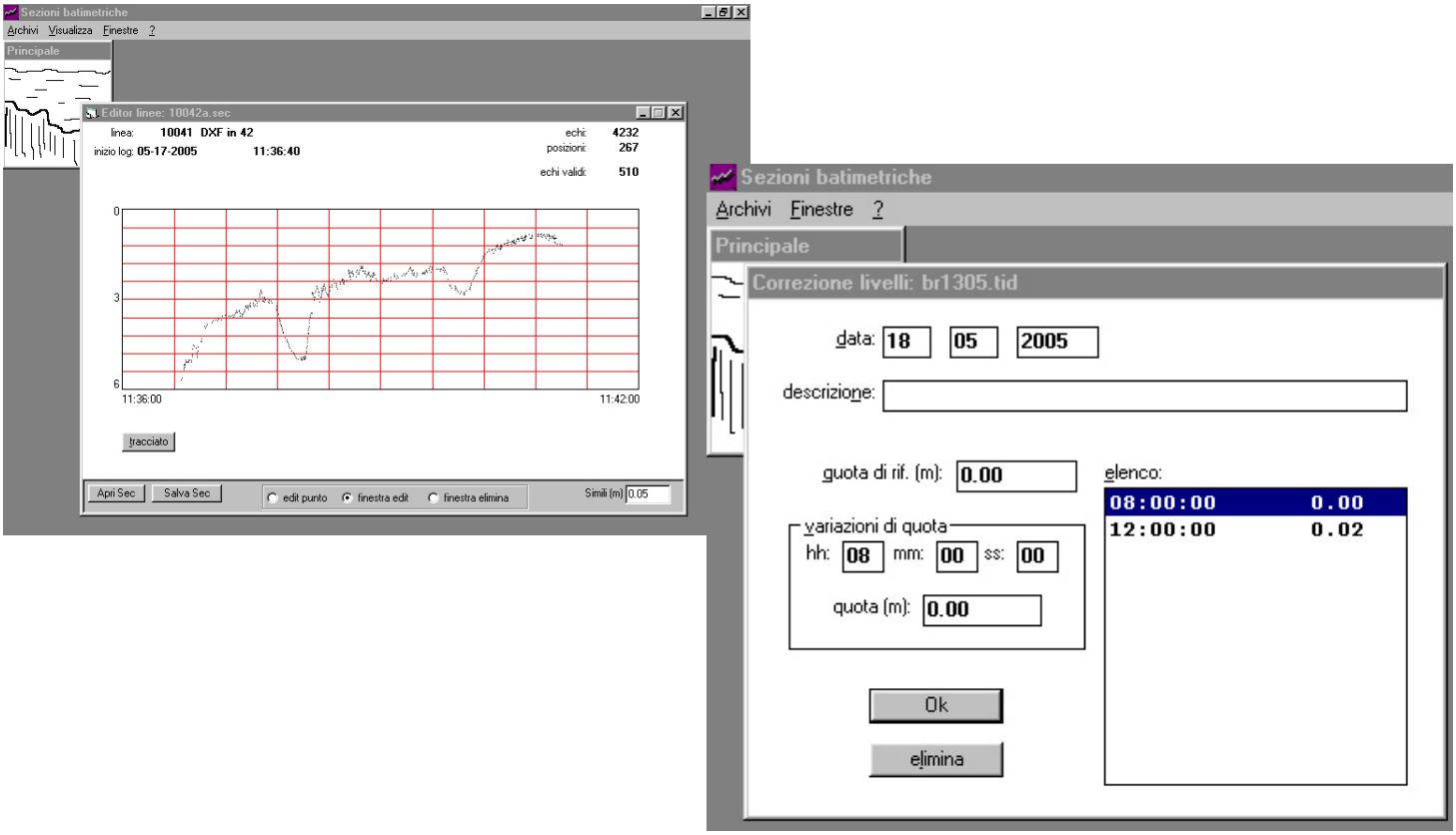
The acquired data were convalidated in advance examining the graphic registrations of the bathymetric strips when they were obtained.
The calibration of the echo-sounder was repeated many times in a day confirming always the relation between the digital value on the instrument and the immersion of the plate.
The data processing with the specific software WINSECT was carried out producing the corrections of the tide resulting from the periodical observations effected on the hydrometric staff fixed on the wharf.

B) e. EVOLUTION IN TIME OF THE SEA LEVEL

The variations of the tide were automatically produced correcting the data obtained with the special processing programme.

The following figure is an example of the correction scheme of the programme:

A diagram of an examined section:
The corrected data were saved in files “word” and in XLS (EXCEL) for the formation of DTM and elaboration of curves of the level.



CONCLUSION

With the consciousness that the present paper does not represent a technical-scientific report but wants to put simply in sequence the essential and recurrent aspects of the hydrographical survey and, as a case study, wants to underline the need to adopt as much as possible surveying methodologies and specific techniques share by the European Countries for the exchange of data and the sharing of hydro-topographical data within a total informative system which is in service of knowledge, development and progress of the people.

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