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Production of Navigational Charts for Rosetta Branch

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Abstract
Nile Research Institute (NRI) conducts technical studies for; improving navigation in the River Nile, mainly Rosetta Branch, protection of the river banks, studying the changes in river bed, and deposition and erosion of the river. Therefore, hydrographic survey, which provides raw data needed for basic and applied research, is of primarily importance. The process of Navigational charts generally consists of converting existing information to a digital format that can be used directly by the target GIS and users. The final products will play pivotal role in studying the followings:-
1- Aggradation and degradation of the river.
2- River regime including; bed level and water surface level.
3- Management lines of the river.
4- Suitability of new sites for new hydraulic structures.
5- The development of the river for navigation.
6- Physical response of the river to new structures or man made development.

Introduction
The process of Navigational charts generally consists of converting existing information, predominantly paper maps such as those produced for the Nile by Kenting Earth Science of scales 1:10,000, 1:5,000, etc. and records such as soundings data and samples acquired by the hydrographers and surveyors team to a digital format that can be used directly by the target GIS and users. The module of the production is run in three phases; the first phase:- the input data acquisition for different sources of data such as existing Kenting 1982 maps for the River Nile, field survey data, existing digital data (scanned orthophotos, vectorized Kenting maps). The second phase:- the conversion of the different data sources using different techniques such as records preparation and digitizing into GIS files using CARIS GIS software. The third phase:- the output products which are the raster files, Nautical Charts, GIS database, Volumetric work, reports for all clients interested for these different products.

Implementation of Hydrographic Survey
1- Establishment of DGPS
The mandate of Hydrographic survey was to establish a DGPS (differential global positioning system) control network to provide the framework within which accurate hydrographic surveying and mapping could be conducted leading eventually to the production of navigational charts for the Nile. The DGPS extended within the Rosetta Branch, with GPS control points established at a spacing of 5 km on both banks of the branch, defined a common and consistent reference system, initially defined in WGS84 datum, the native datum for GPS surveys, and subsequently transformed to Helmert 1906 Egyptian datum, to support future NRI surveying and mapping within the reach. The transformation parameters to convert between WGS84 and Helmert 1906 were

determined. The most significant aspect of establishing the DGPS control network in the Rosetta Branch was to provide an easily repeatable and reliable methodology for combining the DGPS control network along with existing survey control, primarily Kenting control points, in addition to national Egyptian control. A number of Kenting control points, established in 1982 by Kenting Earth Science of Canada, were recovered by NRI surveying team and re-occupied by GPS receivers to provide GPS coordinate (in WGS84) for these points were originally tied to the first order national Egyptian control network in Upper Egypt, established by (ESA) Egyptian Survey Authority.

In Areas where Kenting control monuments were destroyed, new GPS control monuments were constructed. The objective of the DGPS control network was to keep a spacing of 5 km, between control points along both banks of the Nile. SKI software was used for DGPS data processing, adjustment and analysis. The adjustment component within SKI software used least square adjustment of GPS baselines. The adjustment component is network related. A network consists of points which are connected via multiple GPS baselines. The use of four receivers for the establishment of DGPS control network module provided redundancy of observations, an advantage that is essential for reliable control determination and quality control. Adjustment procedures for the GPS control network in relation to sounding data and shoreline expressed in WGS84 datum are consistent. Problem of inconsistency of GPS/sounding data/shoreline when transformed into Helmert 1906 was resolved. GPS field control points, shoreline survey with respect to GPS control points and sounding data captured by combined echo sounder/GPS configuration are all consistent with WGS84 datum.

2- Hydrographic Survey Field Data Acquisition

Since NRI is abiding by the International Standards, certain procedures were followed during field work and data processing. The followings are description of principles and methodologies that have been established for field survey.

2.1- Definition of datums for hydrographic survey

1. Horizontal Datum: The horizontal datum which is used in Egypt by ESA is Helmert 1906. The same datum is used in maps produced by Kenting in 1982 for NRI. Since NRI is implementing Global Positioning system (GPS), hydrographic field survey is based on WGS84. Old control points which had been established by Kenting in 1982 were recovered and reobserved by DGPS in WGS84 system. It was possible to locate some points in good condition; that is; well fixed in place and intact. Therefore, there were needs for establishing a new geodetic network to serve hydrographic survey by installing control points close to the course of the River. The new network is based on WGS84. It consists of control points which were built at 5 km space on both banks of the Rosetta Branch. The total number of points is 67 point. The procedure also includes the calculation of the shift which is applied in order to convert WGS84 system into Helmert 1906.

2. Vertical Datum: The vertical datum, which is used for the River Nile in staff gauges, is the mean sea level datum Alexandria, 1906. This datum is used also for Kenting maps and all irrigation works in Egypt. A chart, which is essential for hydrographic survey, has to be established as desired before. Therefore, information about low water and high water levels were compiled using historical data after the construction of Aswan High Dam.

2.2- Water level records

Ministry of Public Works and Water Resources (MPWWR) maintains a series of Staff Gauges along the Nile River from Aswan to the Mediterranean Sea. A large number of those Staff Gauges enjoy the telemetric capabilities for broadcasting to Cairo. The MPWWR can provide the water level reading on a daily basis. Overall, station readings are sufficient for the need of hydrographic survey.

2.3- Collection of data

1. Vertical Position (Measurements of Depth): The flow depth is recorded referring to the bed level. The output data can be in the form of paper chart and /or digital file. The output depth in the form of digital data is logged into data logger.

2. Horizontal Position: Every boat is equipped with GPS antenna and controller. A reference GPS station is installed over a defined controlling point. Momentarily, The corrected horizontal position is logged into data logger to be integrated with vertical position and to adjust boat position to assist the coxswain follow his route, which is planned before the survey operation.

3. Logging in data: Data from DGPS system and digital depths from Echo-sounder are logged in an ISAH data logging system (Integrated System for Automated Hydrography). The recording of horizontal and vertical

position is carried out at the rate of one event per second to secure enough information.

2.4- Data Processing

Sounding and position data are saved on optical disk and transferred to office where it can be processed on SUN work station. The positions are plotted on the screen and erroneous data are rejected. The depths obtained from the optical disk are plotted and compared to those on sounding paper roll and the erroneous depths are deleted. For the production of navigation charts, depths were reduced to the chart datum which was defined previously.

2.5- Shoreline Survey

The total station instrument is mounted over existing control points and measurements are made every 50 meters for the horizontal and vertical position of the high water line to the actual water line. The position of control points is checked on permanent basis by observing all permanent control points established previously. It is found that coordinates obtained by the total station are in good agreement with those obtained by the GPS (variation is between 1-2 cm).

2.6- Conversion of existing paper charts into digital format

This step aims at converting paper charts, produced in 1982 by the Nile Research Institute and Kenting Earth Science, into digital format and acquiring necessary information for map production. The goals for conducting digitization of Kenting maps are to prevent loss and corruption of data which are in paper form. Having these data on digital format allows for data manipulation, handling, and carrying out sedimentation studies by comparing old data with new ones.

In this step, the followings have been achieved:
1- Scanning and digitizing of 1:5,000 bathymetric charts;
2- Scanning of 1:10,000 line maps of the river banks;
3- Acquiring ortho-photos, scale 1:40,000, and producing of ortho-photos, scale 1:10,000;
4- Acquiring 1:50,000 maps;
5- Acquiring coordinates of the first order for some control points in Helmert 1906 and WGS84.

2.6.1- Scanning and digitizing of 1:5,000 bathymetric

Kenting 1:5,000 maps present the topography of the River Nile bed. NRI did scan the maps on a high resolution scanner (600 dpi) and digitized them. NRI produced print out of the digitized maps and DXF format on 8 mm tape.

2.6.2- Scanning 1:10,000 maps

Overlaying 1982,1:10,000 maps over 1991 areal photos are needed for planning field work of land survey. That is, locating areas which suffer from severe changes between 1982 and 1991. NRI produced these maps on TIFF format.

2.6.3- Ortho-photos

Along with the scanned line maps of 1982, these ortho-photos are used for planning of the field work and having information about shoreline. The ortho-photos were produced at a scale of 1:10,000 from aerial photographs at a scale 1:40,000 produced in 1991. The photos cover 2 km on both banks of the River Nile. The produced ortho-photos are in a digital TIFF format and including the digital elevation model in vector and raster format and print out of ortho-photos.

2.6.4- Coordinates of First Order Points

In order to establish the geodetic network along the banks of the Nile, it was necessary to establish a base line using a precise first order points.

3- Establishment of Index Map

Maps indexing is an efficient tool provides the decision makers and the users with quick reference and access to the data available on digital format. An Index map include the following information:
1- Bathymetric charts at scale 1:5,000 for River Nile produced in 1982 by Kenting Earth Sciences and Nile Research Institute. These maps were digitized in AutoCAD format and converted into CARIS format program

using some parameters and qualifiers to make good transformation.
2- Line maps at scale 1:10,000. The produced scanned maps are in TIFF format and converted into CARIS format program.
3- Ortho-photos which were produced at a scale 1:10,000 in 1994 from Aerial photos taken in 1991 at a scale 1:50,000. NRI scanned the ortho-photos in TIFF format and transformed into CARIS and displayed it through CARIS as an image with gray scale. NRI digitized the flight line and photo numbers and locations to make an index to be easy to reach any photo.
4- Maps presenting the Nile Valley at a scale 1:50,000.

The index map contains the outlines of the 1:5,000, 1:10,000, ortho-photos, and 1:50,000 with there numbers for the Nile Basin.

4- Data Management

Data management division can handle different data sets coming out from different sources.

4.1- Management of Data

Using CARIS software, which is the main software used by NRI, Data management division can exchange data in different formats such as; DXF, and TIFF digital formats into CARIS NTX format.

4.2- Topological structuring and data validation

Data management division provides the mapping division with intensive data integration, structuring of topology and map feature coding.

4.3- Volume computation

It is associated with the design of the navigation path and proposing the amount of dredging required to be carried out. In addition, volume computation is essential in sedimentation studies which is of great importance for NRI work.

5- Chart file standards

These files are intended to facilitate production of chart files in support of paper chart reproduction. It is recommended to update all the existing data to NRI standards to produce a nationally consistent data-base.

5.1. Contents

Digital chart file contains, at least, the same information as that on the current edition of the corresponding paper chart. This requires that the cycle of the digital file maintain the cycle of printed paper chart.

5.2. Presentation

The paper charts contain information according to the customer needs. Therefore, digital files may contain information above the needs of specific customer. These additional information is retained in a separate layer of easy remove when there is no need for it. In some cases, an exact match is not possible. In such cases, a digital chart file should duplicate as closely as possible the intent of data portrayed on the paper chart using the latest symbology available. Whenever a deviation from exact digital/paper duplication occurs, it must be documented precisely.

5.3. Headers

The chart border, picture frame, exterior notes, and all data within the border that geographically relates to it, are in data under the main header. Any data not geographically relevant to the main border must have their own header.

5.4. Data conversion

Specific criteria of basic outlines for conversion of data are established in NRI.
These procedures are:

- Procedure of converting vectorized maps;
- Procedures for digitization of paper maps;
- Procedures for digitization of scanned maps; and

- Heads-up digitization from ortho-photos.

5.5. Thematic layers

Data is assigned to thematic layers for building topologically structured files. This is necessary in order to organize chart features into common groupings of non-overlapping polygons.

5.6. Feature codes

The digital chart files contain only feature codes that are valid at time of completion and release of the data. Listing of all feature codes, data codes, thematic layer were carried out.

6- Production of the hydrographic chart

Since the objective of this map is to be used for the design of navigation channel, the contour lines on the map were reduced to chart datum. The produced charts comply with standards of IHO and CHS. The production of the hydrographic charts passes through the following steps:-

6.1. Setting-up the size of the charts

The size of the charts is chosen according to customer needs and the standards of chart production. In the preliminary stage, a standard size of 40 cm x 100 cm was decided to be used by NRI.

6.2. Setting-up the scales of produced charts

From the index map that was established, the map scale can be decided. Several options were available to produce the hydrographic chart which lead to the production of navigation chart. These are

1- Scale 1:10,000 and paper sheet size is 40 cm x 110 cm
2- Scale 1:15,000 and paper sheet size is 40 cm x 110 cm
3- Scale 1:25,000 and paper sheet size is 40 cm x 110 cm

The second choice was selected because of its flexibility for dealing with and the clarity of the feature and data on the map. The hydrographic charts can be produced by a scale up to 1:5,000. The alternatives of 1:15,000 and 1:25,000 are available in the index map and it can be decided which one to choose from. It has to be noted that the scale of the chart is governed by the hydrographic field survey process. For example, the interval between contour lines on the chart should not be more than 0.5 cm. Therefore, to produce charts at a scale 1:5,000, the interval between cross section should not be more than 25 m.

7- Basic data used for the charts production

Extracting information from different sources of data:

Line maps at scale 1:10,000: These line maps were produced in 1982. The scanned information is used for comparison with recent information of 1994 available through ortho-photos. Through the comparisons, areas of severe changes in topography were defined and position of certain features on the River Nile were extracted.

Ortho-photos at scale 1:10,000: These ortho-photos were produced in 1994 from aerial photos taken in 1991. NRI is employing these photos to get a clear view of the land features, shore line and to determine zones which underwent severe changes in topography and land features.

Maps at scale 1:50,000: Those maps were produced by NRI and are useful for extracting roads, channels, buildings, mosques, churches, ... etc.

New field survey data: New hydrographic survey has been carried out up to the international standards. Therefore, the produced maps are in consistent with the standards of International Hydrographic Organization (IHO) and Canadian Hydrographic Service (CHS). Information about shore line was gathered to be integrated with the data collected in the field. The field survey was carried out at cross sections at a spacing of 25 m.

The field data are of two types

1. Shore line data X, Y, Z (Longitude, Latitude, Elevation) in spreadsheet format on floppy diskette. The shore line data can be converted from spreadsheet format (QuattroPro) into CARIS by making a script file in QuatroPro containing all the CARIS commands to draw the shore line using X, Y, Z, data.

2. Sounding data X, Y, Z (Longitude, Latitude, Elevation) in CARIS format on 4 mm tape. The sounding data is in form of NTX file is used to create digital terrain model (DTM). This file can be viewed as a three dimension. Then, contour lines for the river bed is created. The contour interval can be chosen. Sounding selection is created, generalize contour and select the suitable sounding according to the rule of soundings selection.

8- Cartographic editing of charts

The following step after the extraction of data is to close the polygons and filling colors. Also, enhancing linear and other features. Toponyming (place names) is positioned so that it does not interfere with cartographic features. Reference notes are located close to respective map feature without obstructing hydrographic features. Legends and bar-scale is allocated in areas where they don not interface with hydrographic features and do not obstruct information useful for navigation. A visual examination for plotting verification is carried out by a person other than who produced the map to verify the edges with adjacent sheets. Again, the plotted chart is verified by the person who produced the chart initially. The corrected chart is repotted and verified. This process is repeated until the chart becomes acceptable.

9- Handling of field data

The shore line data in QuatroPro files on diskette are converted into CARIS format by making a script file containing all CARIS commands to draw the shore line in CARED. Sounding data is inserted and used to construct the digital terrain model (DTM) for the river bed. Contour lines for river bed created by different intervals through DTM modules and sounding selection is done. This step is carried out for building polygon topology of the contour lines, shorelines and neatlines to create color image.

10- Adjustment of the map

The combination of DGPS derived control with previous Kenting control was important part of the DGPS control network establishment. Thus, the hydrographic surveying and mapping output maps and other products could be presented within the Egyptian Transverse Mercator (ETM), in Red Belt definition, in harmony with previous and current surveying and mapping activities conducted in Egypt.

In order to achieve mathematical rigor, unbiased results, a transformation process has been involved. Full three dimensional (seven parameters- three shifts, three rotations, and one scale factor) transformation parameters relating the two coordinates reference systems, namely the WGS84 and Helmert 1906, were accurately determined in order to maintain the desirable qualities inherent in the GPS surveys.

The Static/Kinematic -SKI software, version 1.09, that is currently used in conjunction with the Leica GPS receivers allows for two methods for computing transformation parameters between two sets of coordinates, namely; the classical three dimensional approach and the interpolation approach. Both transformation methods need a set of common points defined in the two systems for transformation parameters. The condition is satisfied within the DGPS control network design and observation stages.

The classical transformation approach of applying 7-transformation parameter model allows to determine a maximum of 7-transformation parameters (3 shifts, 3 rotations, and 1 scale factor) to enable the transformation from one set of Cartesian coordinates into another. Knowledge about the two reference ellipsoids, namely; WGS84 and Helmert 1906 and associated projection systems, namely; Universal Transverse Mercator (UTM) and Egyptian Transverse Mercator (ETM) is required. SKI offers only Helmert model for this transformation.
The second method, interpolation approach, allows the transformation parameters between Cartesian and grid coordinates related to two different geodetic datum to be determined. However, Knowledge about the reference ellipsoid and the local map projection are not required. Note that the original geometry of the Cartesian solution, obtained from the DGPS surveys, will be distorted in such a way that it best fits into the local grid coordinate system defined mainly by Kenting and partially by NRI control.

The classical approach of computing 7-transformation parameters between two datums was determined to be not suitable due to the limited geographic extent of the DGPS control. The results of these parameters were statistically unreliable, with very large variance estimates. A four transformation model was implemented using three translation and one scale. Reliable local transformation parameters were derived between DGPS control points defined in WGS84 and previous Kenting control points defined in Helmert 1906.

The second method was the method adopted for the transformation of the GPS position coordinates and results obtained from the free adjustment of the whole subsets into ETM. Several common control points observed by DGPS techniques and with known ETM coordinates were selected for this transformation. Some of these points were eliminated from the transformation parameter determination due to minor systematic errors reflected in the estimates of the transformation parameters.

Conclusions

1- Update of 1978 hydrographic survey from Aswan to the Mediterranean Sea.
2- Production of navigational charts for Rosetta branch according to the international standards.
3- Continues improvements through importing and introducing new techniques in regard to hydrographic survey, DGPS, and navigation.
4- Having high quality information about the River Nile. These information serve the different research topics of NRI such as the analysis of water level data, discharge data, lag time analysis, and status of River Nile islands.

Recommendations

1- Increasing the number of control points along both banks of the Nile will improve the accuracy of the transformation parameters.
2- The navigational charts should be produced for the whole length of the River Nile.
3- NRI should keep on self improvements by enhancing its technical capabilities, linkage with similar organizations, improving its data base, and continuous training of its staff.
4- Arrangement of twinning program for technology transfer and exchange of information should take place.
5- Continuous improvements through importing and introducing new techniques in regard to hydrographic survey, DGPS, and navigation.

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