Hydrographical network of the Danube Delta Biosphere Reserve - modelling the morphological dynamics

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1 Introduction

This paper presents an innovative technology to investigate the natural environment, particularly the water regime, focusing on hydro-morphologic changes (as a result of fluvial processes) and their effects on water quality and biodiversity. This technology is based on field measurements and field data processing by using research equipment and computational techniques of high performance /high accuracy compatible with GIS. They result in geospatial databases for hydrologic regime, hydro-morphological dynamics, water quality, and biodiversity. Numerical /spatial maps are processed in ArcGIS /ArcMap /ArcCatalog program and contain all these databases. Ultimately, these geospatial data have been used to construct the mathematical /hydraulic model for hydro-morphology dynamics, using as workbench the Delft3D software – a product of DELTARES – Delft Hydraulic Institute, The Netherlands.

Since 2008, this technology has been developed in the Danube Delta Biosphere Reserve (DDBR) hydrographical network. Its main objective is to emphasize the zones where fluvial processes (erosion and, especially, alluvial sedimentation) are active. It addresses to end users, especially the Danube Delta Biosphere Reserve Authority, to scientifically justify the management decisions made on the DDBR's protection, preservation and ecological reconstruction of protected aquatic ecosystems.

The DDBR represents one of the main components of the Danube River - Danube Delta - Black Sea geo-ecosystem. In 1990, it was declared as UNESCO World Heritage site and RAMSAR wetland of international importance. Its area of about 5,800 km^2 (on Romanian territory) makes it one of the greatest wetlands in the world. It contains 30 types of terrestrial and aquatic ecosystems, out of which 23 are natural or artificially modified and 7 are man-made ecosystems.

The Danube Delta plays an important role as a chemical and physical filtering system for the Western Black Sea coastal waters, especially when floods pass the various river branches and inner canal systems. In this context, the large and compact surfaces of reed beds play a significant role as sinks of nutrients (Cioaca 2000, 2004).

The DDBR hydrographical network is very complex, formed by the Danube Delta inner network, the Razim-Sinoie lake area, and the Black Sea north-western coastal waters up to the isobaths of 20 m depth. It consists of about 3500 km of channels /canals which connect /supply about 500 lakes (200,000 ha), naturally structured in 7 hydrographic units (Figure 1). The upstream zone of the Sontea-Fortuna hydrographical unit presents a detail of the DDBR landscape complexity (Figure 2). The main canal supplying this area is Mila 36. Being directly connected to the Tulcea Arm, this canal is subject to active fluvial processes, and erosion and sediment accumulation occur in different zones and at various intensity (Cioaca et al. 2009).

2 Material and method

In order to evaluate the morphological changes, zones with active fluvial processes (erosion and /or alluvial sedimentation) have been identified. For these zones, the hydraulic model has been constructed to simulate morphological changes for real scenarios. Hydro-morphologic (bathymetric and topo-hydrographical)

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measurements have been performed in the DDBR since 1998 and resulted in geo-spatial data of channel /lake measured tracks, as follows:

- Channel depth data in cross-section bathymetric profiles;
- Channel depth data in longitudinal bathymetric profile;

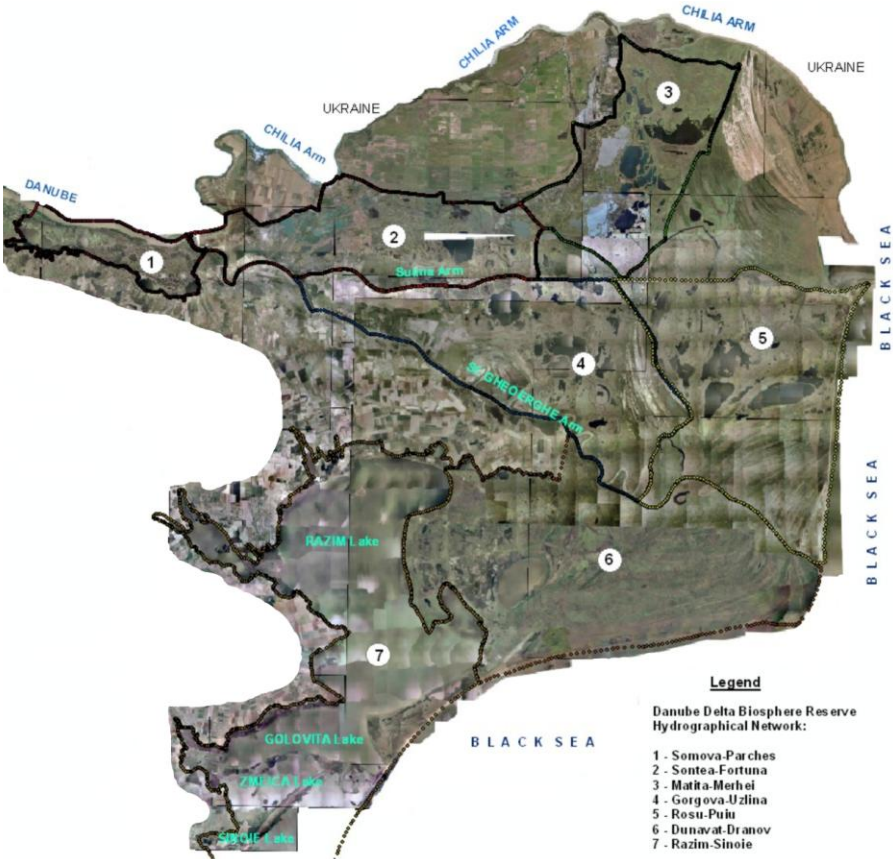

Figure 1. *Danube Delta Biosphere Reserve hydrographic units.*

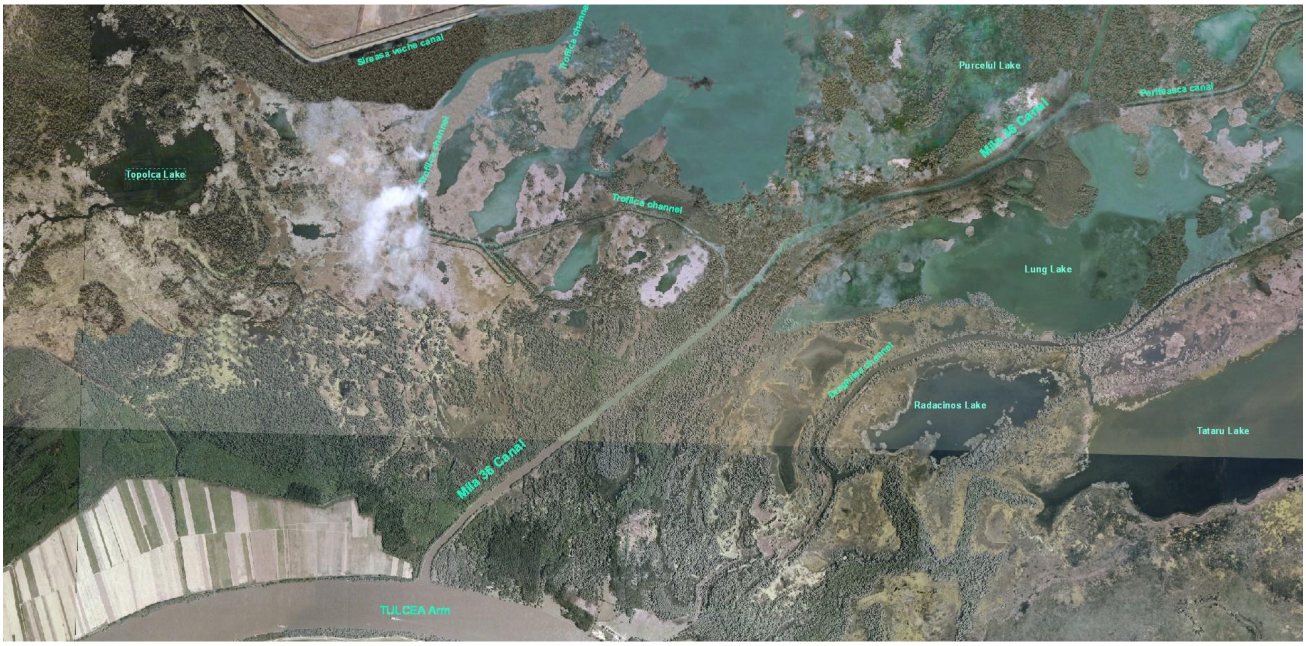

Figure 2. *The upstream zone of the Sontea-Fortuna hydrographic unit detail: Mila 36 canal case study for morphological modeling.*

- Lake depth data in longitudinal bathymetric profiles;
- Land elevation data for the channel sides /banks.

The equipment used for bathymetric measurement (well fitted to a boat) has as component parts:

The transducer: an ultrasonic device fitted to the bottom end of a vertical metallic bar and deployed 15 ÷ 20 cm into water. It “reads” (2 readings per second) the water depth and transmits it to the SonarMite;

SonarMite instrument: the “brain” of the entire bathymetric measurements equipment. It makes all the transducer “readings” corrections and combines the incoming GPS antenna messages with the transducer (echo sounder) messages and sends them to its specialized software, OHMEX;

GPS antenna captures and transmits geospatial position data (1 reading per second) on a target moving on water;

Portable computer with multiple serial interfaces to which both SonarMite and GPS antenna are connected to transmit for measured point its water depth and geographic position, respectively. The specialized software OHMEX is installed in the laptop, to which field data are transmitted at the same time, for each point measured by SonarMite;

The equipment used for hydrologic measurement is an ADCP - Acoustic Doppler Current Profiler, type Workhorse Rio Grande. It measures: water velocity, flow direction, discharge, cross-section bathymetry in geographical coordinates. The specialized software is WinRiver II – Teledyne RD Instruments. It processes the gathered field data in tabular and graphics format, as shown in Figure 3.

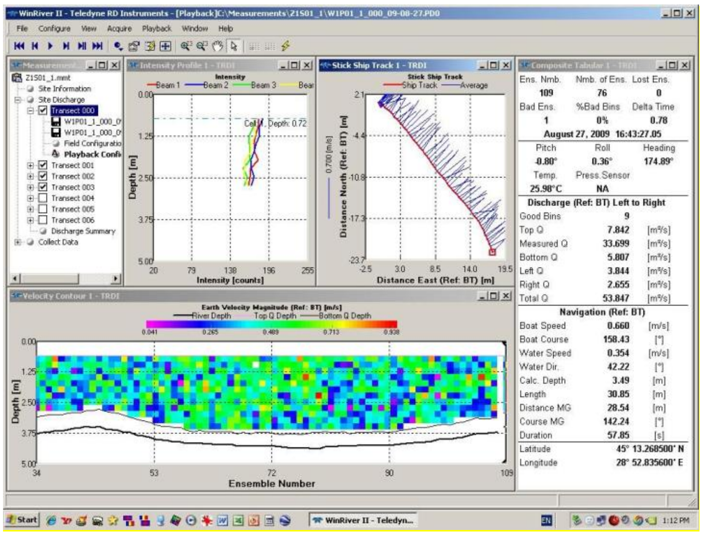

Figure 3. *Hydrologic data gathered by the ADCP equipment for Mila 36 canal upstream end cross-section.*

Digital (numerical) maps are processed in ArcGIS /ArcMap software, in Geographic Coordinate System (either GCS_WGS_1984 or GCS_Dealul_Piscului_1970) and /or Projected Coordinate System (either WGS_1984_UTM_Zone_35N or Stereo_70, respectively). They show the spatial distribution /location of hydrographical network zones where fluvial processes are studied. The maps present data in distinguished thematic layers of information, for each channel /lake studied. Thematic layers of information contain, in most cases, the following data: channel /brook /lake description; X_coordinate; Y_coordinate; Z_Depth of channel /lake bottom or land [m BSL]; Water depth [m]; Water level [m BSL]; Distance [m].

Database is constructed for the entire DDBR, meaning the hydrographic network and the land.

3 Morpho-hydrographical dynamics model

Geospatial data provide input to the mathematical /hydraulic model, Delft3D. The morphological profile of the hydrographic network is constructed in Delft3D-QUICKIN module. Figures 4 and 5 show, as examples, such a morphological profile, for Mila 35 canal (including the banks) and Fortuna Lake, respectively, both of them belonging to Sontea-Fortuna hydrografic unit.

The average depth of Mila 35 canal is about 5m. Compared to this value, due to fluvial processes, the deepest zones (subject to erosion, dark-blue) reach 11m depth, while the shallow zones (subject to alluvial sedimentation, light blue) 1m depth. In Fortuna Lake, alluvial sediments are mainly discharged by the Cranjala channel (from Sulina arm) and deposited in the south-western zone, where the highest deposits reach 1.65m above Black Sea Level (yellow and light blue color).

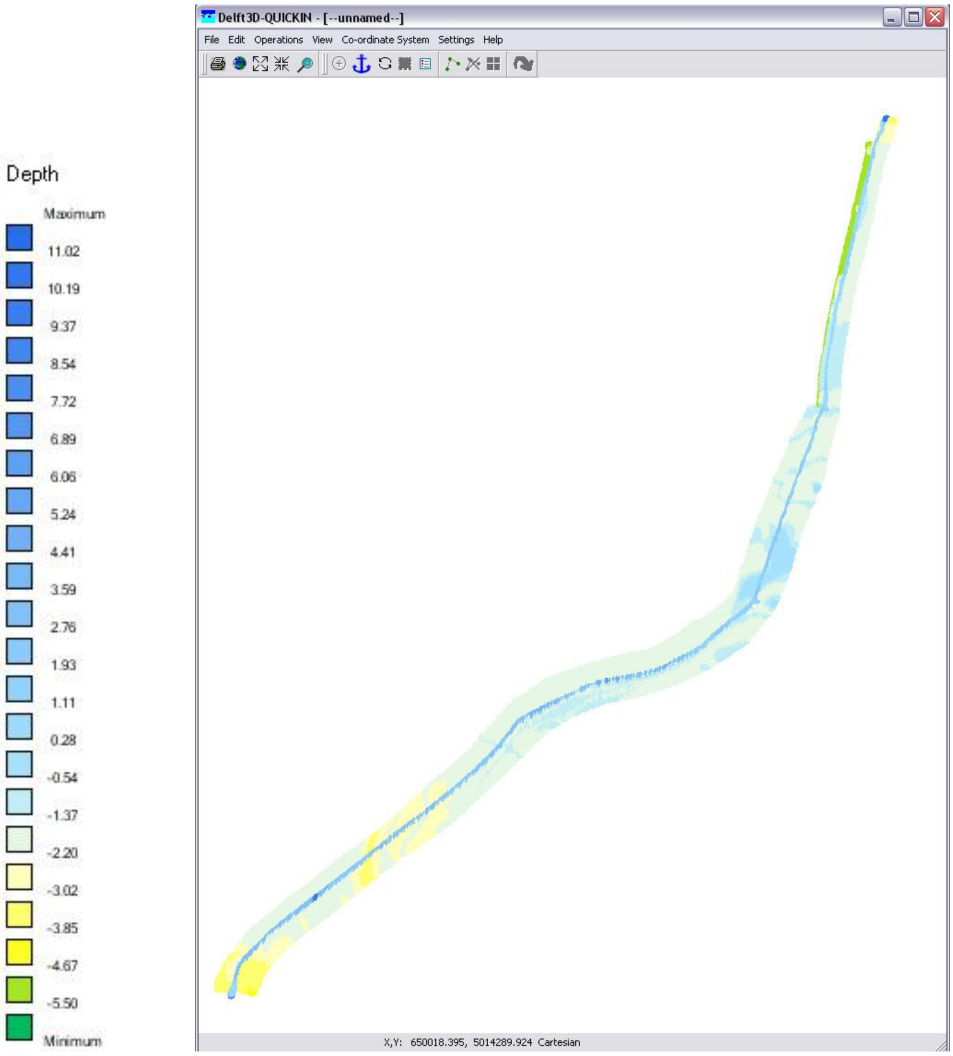

Figure 4. *Morpho-hydrographical profile of Mila 36 canal constructed in Delft3D-QUICKIN module.*

4 Outlook and conclusions

Within the DDBR hydrographical network, alluvial sedimentation zones are of greater interest, compared to erosion zones, as these depositional zones are ”bottlenecks” for navigation during low water level conditions. Alluvial sedimentation occurs when certain hydraulic conditions are fulfilled, such as: the water flow velocity decreases under a critical value, the stream hydraulic slope is flat and sediment load is high. These zones are mostly located at the bifurcation of smaller and larger channels, or at the channel mouth into a lake (delta formation). In the upstream part of a fluvial delta sedimentation intensity is high and can hardly occur in the downstream part of both the fluvial and fluvial-maritime delta, where the water is clear - very clear (Cioaca 2005).

At low water level condition, especially in summer, these “obstacles” may disconnect some channels and lakes from their supplying channels and can even become dry. The result is a significant modification of flora and fauna, reducing biodiversity ((Bondar 1993, 1994; Cioaca & Tudor 1999; Cioaca 2002, 2004).

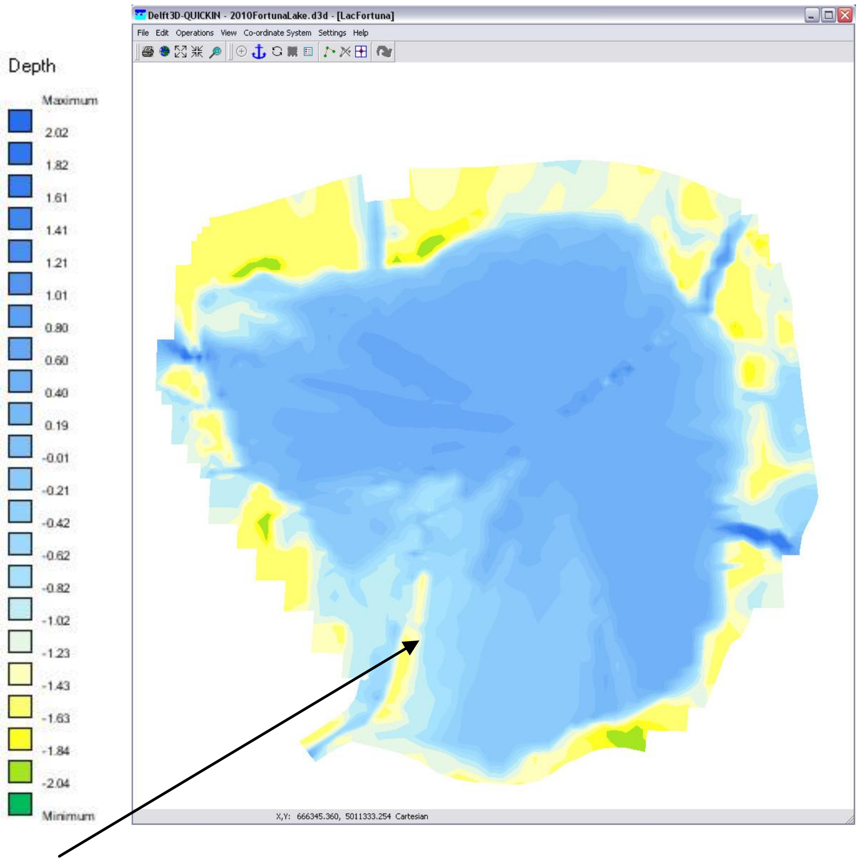

Figure 5. *Sedimentation zone inside Fortuna Lake: The arrow shows alluvial sediment deposits caused by discharges of Cranjala channel from Sulina Arm. These deposits are covered with young vegetation, mostly forests of willow.*

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