SOBEK Hydrodynamic Model
Danube Delta, Romania

Report on Technical Assistance

November 1997

WL | delft hydraulics
SOBEK Hydrodynamic Model
Danube Delta, Romania

Report on Technical Assistance

M. Laguzzi
CLIENT: Rijkswaterstaat RIZA
Inrichting en Herstel, Lelystad
Contact person: A.W. de Haas

TITLE: Sobek hydrodynamic model of the Danube Delta, Romania
Technical Assistance Project

ABSTRACT: Delft Hydraulics provided technical assistance to the Romanian Danube Delta Institute about the subject one-dimensional mathematical modelling with the package SOBEK. The expert from Delft Hydraulics, Ms. M. Laguzzi, worked for 6.5 weeks in close cooperation with the local team validating data and improving the schematisation and calibration of the global model of the Danube Delta. She also prepared two models for the complexes Roșu-Puiu and Matișa-Merhei. Modelling methodologies have been explained and technology has been transferred.

REFERENCES: R3055, RBM; RIZA Contract nr. RI-2260 (12 September 1997).

<table>
<thead>
<tr>
<th>REV.</th>
<th>ORIGINATOR</th>
<th>DATE</th>
<th>REMARKS</th>
<th>REVIEWED BY</th>
<th>APPROVED BY</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.</td>
<td>M. Laguzzi</td>
<td>20/1/97</td>
<td></td>
<td>J. Dijkman</td>
<td></td>
</tr>
<tr>
<td>M.</td>
<td>Laguzzi</td>
<td>30/1/97</td>
<td></td>
<td></td>
<td>E. van Beek</td>
</tr>
</tbody>
</table>

KEYWORD(S) |
--- |
Danube Delta, Romania
Sobek, hydrodynamics
technical assistance

CONTENTS |
--- |
TEXT PAGES:
TABLES:
FIGURES:
APPENDICES:

STATUS |
--- |
PRELIMINARY
DRAFT
FINAL
Contents

1 Introduction ............................................................................................................. 1

2 Objective of the mission .......................................................................................... 2
  2.1 Acknowledgements .............................................................................................. 2

3 The Danube Delta - Generalities ............................................................................. 3

4 Preliminary global model made at DDI .................................................................. 5

5 Improvements to the global model ......................................................................... 6
  5.1 Schematisation ................................................................................................... 6
    5.1.1 Topology .................................................................................................... 6
    5.1.2 Cross-sections ............................................................................................. 6
    5.1.3 Roughness ................................................................................................. 9
    5.1.4 Structures .................................................................................................. 9
    5.1.5 Boundary conditions ................................................................................... 9
    5.1.6 Initial conditions ....................................................................................... 10
    5.1.7 Computational grid .................................................................................... 10
  5.2 Calibration ......................................................................................................... 10
  5.3 Validation .......................................................................................................... 11
  5.4 Conclusions and recommendations global model .............................................. 11

6 Sub-model Complex Roşu-Puiu ............................................................................ 12
  6.1 Schematisation .................................................................................................. 12
  6.2 Calibration ......................................................................................................... 13
  6.3 Exploitation run ................................................................................................ 14
  6.4 Conclusions sub-model ...................................................................................... 14

7 Sub-model Matiţa-Merhei ...................................................................................... 15
  7.1 Schematisation .................................................................................................. 15
  7.2 Next steps ......................................................................................................... 15

8 General conclusions and recommendations ......................................................... 16
  8.1 Conclusions ...................................................................................................... 16
  8.2 Recommendations ............................................................................................. 16

9 Literature ............................................................................................................... 17
1 Introduction

In 1992 the Ministry of Water Management, Transport and Public Works of the Netherlands and the Ministry of Waters, Forests and Environment Protection of Romania agreed upon working together in the Danube Delta. This has been translated into a co-operation programme between the Institute for Inland Waste Water Management and Treatment (RIZA) from The Netherlands, the Danube Delta Institute (DDI) and the Danube Delta Biosphere Reserve Authority (DDBRA) from Romania. One of the main objectives of this programme is to build knowledge on the improvement of the ecological values within the Danube Delta.

Within this framework, new hardware equipment and software has been provided to the Romanian counterpart. The capacity building up to now has been centred around training on geographical information systems (GIS, specifically ARC/INFO) and transferring and training of the Romanian staff on the one-dimensional modelling system SOBEK (property of RIZA and Delft Hydraulics), among other subjects.

The biodiversity has been studied and a soil map and a vegetation map of the Danube Delta have been made with ARC/INFO based on satellite images (Munteanu and Curelariu, 1995). A comparison of the hydrology in the Danube and Rhine Deltas has been also reported (Trache, G. and J.Meinders, 1994).

In this last report, it has been recommended to realise a hydrological model for the circulation of the water in the Danube Delta (especially inside of it), and to get a good overall view of the water quantity and quality processes going on in the Delta, and to create the possibility to focus on a specific study area in the framework of ecological restoration, in stretch co-operation between all disciplines (chemistry, biology, hydraulics and others).

Based on this and other motivations described in the following sections, RIZA would like to build a hydrodynamic water-quality model of the Danube Delta with the package SOBEK. The final objective of this model will be to study the water motion, quantity and quality aspects, nutrients balance and the eutrophication of the Delta system in the framework of ecological restoration and management. This model could be extended in a later phase in order to allow for morphological simulations.

Requested by RIZA, Delft Hydraulics (DH) of The Netherlands made, in July 1996, a preliminary proposal about the one-dimensional hydrodynamic mathematical modelling of the Danube Delta with the package SOBEK as a first step towards the final objective.

During the period January - July 1997, DDI's staff has already built an extended Sobek hydrodynamic model of the Danube Delta. The model still required some improvements in order to operate properly. Main problems were detected around the schematisation of lakes and flooding areas, and during the calibration of the model.

Due to the advanced stage of the model, RIZA requested Delft Hydraulics to modify the previous proposal ('Sobek Hydrodynamic Model of the Danube Delta Romania', July 1996, R3055/ Delft Hydraulics). Delft Hydraulics was then asked to provide expert-assistance on hydrodynamic mathematical modelling, in particular with the package SOBEK.

In August 1997 RIZA by means of the contract RI-2260 (29/08/1997) committed Delft Hydraulics to provide this assistance according to the modified proposal RBM5740/R3055 from July 11, 1997.
The preparation and supervision of this project, on behalf of RIZA, was carried out by Mr. A. de Haas, in agreement with the director of DDI, Mr. R. Stiucă.

2 Objective of the mission

The objective of this project was to provide technical assistance and expert knowledge on one-dimensional mathematical modelling to the staff of the Danube Delta Institute.

An expert of Delft Hydraulics, Miss M. Laguzzi travelled to Romania to work together with the local DDI team in order to try to improve the schematisation of the existing SOBEK hydrodynamic model of the Danube Delta, followed by a new calibration and validation of the model. Also a methodology was developed and transferred to the local team in order to model the complicated water complexes.

Technology transfer took informally place while working together with the local team formed by Mr. Adrian Constantinescu and Mr. Gabriel Trache. Also Ms. Laura Bogdan was introduced to the principles and use of Sobek.

2.1 Acknowledgements

First of all, I would like to express my gratitude to the Director Mr. R. Stiucă and employees of the Danube Delta Institute for their effort and support during my stay at Tulcea. Specially to Adrian Constantinescu and Gabriel Trache, the “parents” of the hydrodynamic global-model of the Danube Delta. Thanks as well to the soil-site expert Mr. J. Hanganu, the GIS-room members and to Miss Jeny for the wonderful morning teas.

Last but not least, I would like to thank Mr. A. de Haas and the RIZA team who made this project possible.
3 The Danube Delta - Generalities

The Danube river has a catchment area of 817000 square kilometres, an average discharge of 6350 m³/s at the Constanţa Chilia (Chilia bifurcation) and a length of 2860 km.

The Danube Delta is situated in Romania and Ukraine. The total surface of the area is 564000 ha (440000 ha in Romania and 124000 ha in Ukraine). The apex of the delta is just upstream from the town of Tulcea (Ceatal Chilia). Here the Danube divides into the northern Chilia branch, while the southern branch divides just downstream from Tulcea into the central Sulina and the southern Sfîntu Gheorghe branches (See Figure 3.1).

The distribution of the water within the main branches of the Delta is known and has changed along the years. In 1991 this distribution was: 58% on the Chilia branch, 19% on the Sulina branch and 23% on the Sfîntu Gheorghe branch at an average discharge of 6370 m³/s.

Connected to these branches, there are a lot of networks of small rivers and lakes. There are also other networks of channels and lakes that are not connected to the main branches. Some of these lakes serve as fishpond.

The links between the main branches and the interior of the delta were originally natural, but for different purposes (navigation, water supply, etc.) extensive water management works were carried out.

The water systems inside the delta are named "Complexes". Seven big complexes can be distinguished: Somova-Parches, Sontea-Fortuna, Matita-Merhei, Gorgova-Uzlina, Rosu-Puiu, Dunavat-Dranov and Razim-Sinoie (see Figures 3.2 to 3.9).

The following table gives an indication of the surface and averaged bed level of the most important lakes present at the Danube Delta.

<table>
<thead>
<tr>
<th>Name lake</th>
<th>Surface (ha)</th>
<th>Bed level (m +MNS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depression Sireasa</td>
<td>530</td>
<td>-0.5</td>
</tr>
<tr>
<td>Baciu</td>
<td>90</td>
<td>-0.5</td>
</tr>
<tr>
<td>Tătaru</td>
<td>220</td>
<td>-0.5</td>
</tr>
<tr>
<td>Lung</td>
<td>220</td>
<td>-0.5</td>
</tr>
<tr>
<td>Depression Pardina</td>
<td>820</td>
<td>-0.5</td>
</tr>
<tr>
<td>Antipa</td>
<td>120</td>
<td>-0.5</td>
</tr>
<tr>
<td>Tihaiul mare</td>
<td>400</td>
<td>-0.5</td>
</tr>
<tr>
<td>Bacili</td>
<td>300</td>
<td>-0.5</td>
</tr>
<tr>
<td>Depr. şontea-Fortuna</td>
<td>300</td>
<td>-1.0</td>
</tr>
<tr>
<td>Lideanca</td>
<td>300</td>
<td>-1.0</td>
</tr>
<tr>
<td>Fortuna, Nebunu ?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>Area</td>
<td>Distance</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td>Depr. Matita Merhei</td>
<td>4400</td>
<td>-1.0</td>
</tr>
<tr>
<td>Merhei</td>
<td>1100</td>
<td>-1.0</td>
</tr>
<tr>
<td>Matita</td>
<td>600</td>
<td>-3.0</td>
</tr>
<tr>
<td>Babina</td>
<td>400</td>
<td>-1.0</td>
</tr>
<tr>
<td>Dolhei (east of Matita)</td>
<td>300</td>
<td>-1.0</td>
</tr>
<tr>
<td>Cioticul-Dracului</td>
<td>100-200</td>
<td>-0.5</td>
</tr>
<tr>
<td>Radacinoasele</td>
<td>100-200</td>
<td>-0.5</td>
</tr>
<tr>
<td>Poludianca (north-east of Matita)</td>
<td>100-200</td>
<td>-0.5</td>
</tr>
<tr>
<td>Poludeanca (Miazazi)</td>
<td>100-200</td>
<td>-0.5</td>
</tr>
<tr>
<td>Iacub (channel Eracle &amp; Pardina)</td>
<td>100-200</td>
<td>-0.5</td>
</tr>
<tr>
<td>Roșca</td>
<td>100-200</td>
<td>-0.5</td>
</tr>
<tr>
<td>Argintiu</td>
<td>100-200</td>
<td>-0.5</td>
</tr>
<tr>
<td>Merhei Mic</td>
<td>100-200</td>
<td>-0.5</td>
</tr>
<tr>
<td>Trei Iezere</td>
<td>500</td>
<td>-1.0</td>
</tr>
<tr>
<td>Bogdaproste</td>
<td>300</td>
<td>-1.0</td>
</tr>
<tr>
<td>Depr. Litcovul de Est</td>
<td>3200</td>
<td>-1.0</td>
</tr>
<tr>
<td>Gorgova</td>
<td>1300</td>
<td>-1.0</td>
</tr>
<tr>
<td>Obrețiunul mic</td>
<td>300</td>
<td>-1.0</td>
</tr>
<tr>
<td>Obreținciuc</td>
<td>100</td>
<td>-1.0</td>
</tr>
<tr>
<td>Isac</td>
<td>1000</td>
<td>-2.0</td>
</tr>
<tr>
<td>Uzlina</td>
<td>500</td>
<td>-2.0</td>
</tr>
<tr>
<td>Depr. Roșu-Puiu</td>
<td>3800</td>
<td>-2.5</td>
</tr>
<tr>
<td>Roșu</td>
<td>1300</td>
<td>-2.5</td>
</tr>
<tr>
<td>Puiu</td>
<td>800</td>
<td>-2.5</td>
</tr>
<tr>
<td>Lumina</td>
<td>900</td>
<td>-2.5</td>
</tr>
<tr>
<td>Puiulet + Roșulet</td>
<td>300</td>
<td>-2.5</td>
</tr>
<tr>
<td>Iacob</td>
<td>300</td>
<td>-2.5</td>
</tr>
<tr>
<td>Vâțafu</td>
<td>200</td>
<td>-2.5</td>
</tr>
<tr>
<td>Depr. Zateamelov</td>
<td>1200</td>
<td>-0.5</td>
</tr>
<tr>
<td>Zatonu Mare</td>
<td>350</td>
<td>-0.5</td>
</tr>
<tr>
<td>Zatonu Mic</td>
<td>50</td>
<td>-0.5</td>
</tr>
<tr>
<td>Periteasca M.</td>
<td>550</td>
<td>-0.5</td>
</tr>
<tr>
<td>Periteasca-mica</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Pahane + Rinec</td>
<td>100</td>
<td>-0.5</td>
</tr>
<tr>
<td>Depr. Dranov</td>
<td>2250</td>
<td>-2.0</td>
</tr>
<tr>
<td>Dranov</td>
<td>2050</td>
<td>-2.0</td>
</tr>
<tr>
<td>Selciug</td>
<td>100</td>
<td>-2.0</td>
</tr>
<tr>
<td>Erenciuc</td>
<td>100</td>
<td>-2.0</td>
</tr>
<tr>
<td>Depr. Mageom-Sulina</td>
<td>230</td>
<td>-0.5</td>
</tr>
<tr>
<td>Raducu</td>
<td>130</td>
<td>-0.5</td>
</tr>
<tr>
<td>Raduceulet + Cazacu</td>
<td>100</td>
<td>-0.5</td>
</tr>
<tr>
<td>Depr. Somova</td>
<td>6800</td>
<td>-0.5</td>
</tr>
<tr>
<td>Somova</td>
<td>6750</td>
<td>-0.5</td>
</tr>
<tr>
<td>Saun</td>
<td>60</td>
<td>-0.5</td>
</tr>
<tr>
<td>Comp, Razelu-Sinoe</td>
<td>88000</td>
<td>-2.0</td>
</tr>
<tr>
<td>Razim lake</td>
<td>49500</td>
<td>-2.0</td>
</tr>
<tr>
<td>Babadag</td>
<td>3500</td>
<td>-2.0</td>
</tr>
<tr>
<td>Golovita</td>
<td>9500</td>
<td>-2.0</td>
</tr>
<tr>
<td>Zmeica</td>
<td>7300</td>
<td>-2.0</td>
</tr>
<tr>
<td>Cearnullia</td>
<td>800</td>
<td>-2.0</td>
</tr>
<tr>
<td>Leahova (*)</td>
<td>900</td>
<td>-2.0</td>
</tr>
<tr>
<td>Sinoie</td>
<td>13200</td>
<td>-1.5</td>
</tr>
<tr>
<td>Caranasuf (*)</td>
<td>1000</td>
<td>-1.5</td>
</tr>
<tr>
<td>Tuzla-Duungi (*)</td>
<td>2300</td>
<td>-1.5</td>
</tr>
</tbody>
</table>

Table 1: Principal lakes - Surface in hectares and averaged bed level in metres above zero Black Sea Sulina (MNS). Remark (*): under the administration of Constanza, instead of Tulcea.

Figure 3.10 shows the data availability and the location of the hydrometric stations at the Danube Delta (See further Section 5).

4 Preliminary global model made at DDI

During the period January - August 1997 DDI’s staff-members, Constantinescu and Trache, built already a SOBEK hydrodynamic global-model of the Danube Delta. They calibrated the model based on data from the period March-September 1996.

Although the DDI team had made its best, the modelling expert found some errors / irregularities in the model during the first mission (September 21- October 4 1997). They can be summarised as follows:

- Some branches, specially on the Ucranian side of the Chilia arm were missing. The islands Cisita, Tataru, Stepovoi, Babina, Ermakov, Cernoea and other minor ones were not included. The increase in cross-sections due to these extra branches was ignored.
- The model was built with a few available cross-sections.
- Each complex was schematised by means of very long branches, with a total length of 1000 km. The total surface of a complex as function of the level, obtained from the elevation maps, was divided by this arbitrary length of 1000 km in order to translate the surface to the width of the profiles associated to these long branches. All the surface was supposed to contribute to the flow (no storage areas). This approach does not affect much the behaviour of the main branches (almost 85-90 % of the Danube discharge reaches the Black Sea through the main branches Sulina, Chilia and Sfintu Gheorghe), but it does not represent properly the real hydrodynamics of the complexes.
- Not realistic roughness coefficients were used in order to compensate for errors in the geometrical schematisation (Chézy values larger than 100; even 140 was used)
- The model was calibrated using only levels, not checking for the discharges.
- No floodplains were included. The model was incompletely for high waters. This gave considerable differences between computed and measured levels, as well as differences in the discharge distribution at bifurcations.
- Some connections between the complexes and the main channels were wrongly schematised (for example: Erenciuc was closed and Ivancea was open instead of the opposite).
- The crest-level of the weir at Drenor (connection complex Roșu-Puiu - Black Sea) and the reference levels of some profiles were wrong.
- The hydrological measured series were incomplete and some of the measurements were not corrected to the reference level (m above MNS: Marea Neagră Sulina: Black Sea Sulina).

5 Improvements to the global model

All data used for the construction of the Sobek hydrodynamic model was referred to the zero Black Sea Sulina (MNS). This reference level lies 0.35 m below the zero Black Sea Level (1974-Constanza).

![](image)

5.1 Schematisation

The geometrical schematisation has been improved, as much as we could, taking into account the limited data availability.

5.1.1 Topology

The necessary nodes and extra branches were added. The errors in the connections between complexes and main branches were corrected.

5.1.2 Cross-sections

Unfortunately, a few cross-sections were available for the main branches during the execution of this project. These are the following:
<table>
<thead>
<tr>
<th>Branch</th>
<th>Cross-sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Danube between Isaccea and the bifurcation</td>
<td>two cross-sections available along 25 kilometres at: Isaccea (Mile 57) and at Mile 44.</td>
</tr>
<tr>
<td>Chilia</td>
<td>three cross-sections available at: near the Izmail bifurcation (Km 115), Chilia Veche (Km 43) and Periprava (Km 20).</td>
</tr>
<tr>
<td>Tulcea</td>
<td>only one cross-section available at Mile 34.</td>
</tr>
<tr>
<td>Sulina</td>
<td>three cross-sections available along 65 kilometres at the following places: Mile 33, Crișan (Mile 11) and Sulina (Mile 0)</td>
</tr>
<tr>
<td>Sfintu Gheorghe</td>
<td>three cross-sections available along 108 kilometres at: bifurcation Sf. Gheorghe-Sulina (Km 108), at Murighiol and at the village Sfintu Gheorghe (Km 4)</td>
</tr>
<tr>
<td>Channel Mile 35</td>
<td>one cross-section near the confluence with the branch Tulcea.</td>
</tr>
</tbody>
</table>

These are the cross-sections at the discharge / level measurement points of the Hydrometric station of Apele Romana in the Delta. These points were selected at deep places suitable for discharge measurements. However in most of the cases they are not representative for a longer stretch. Data from the years 1993 and 1997 was available. Because some profiles measured during 1997 show irregularities, it was chosen to built the models with the profiles from 1993.

For instance, no cross-sections are available at the many channels between the islands in the Chilia branch. Adding the width of each channel measured on the chart we can conclude that they offer much more width to the flow than the original branch. However we do not have data about their depth. We can only expect a step in the bed levels (bed levels at the channels higher than at the main branch) but we cannot guess how high this step might be.

The flood plain areas connected to the main branches were defined based on the data and expertise available at DDI’s Design Department (Mr. David, personal communication). This department provided an estimation of the inundation width and the level for which the inundation starts. These data have been added to the Sobek schematisation. Most of the flood-plain areas along the main branches are surrounded by levees designed in order to contain very high floods (such as the one from 1971). Active flood plains are found at the beginning, centre and eastern reach of the Sulina branch, at the lower reach of the Sf. Gheorghe branch, at the beginning and the end of the Tulcea branch, at the beginning of the Chilia Branch, upstream of Pardina and west of Periprava, and the whole complex Parches-Somova along Danube between Isaccea and the bifurcation.

These amount and type of information is too little to be able to model the area properly. It is strongly recommended to collect more information about the cross-sections in order to proceed to the definitive calibration of the model.

**Complexes (within the global model):**

The Danube Delta is formed by a very complicated network of channels and lagoons. Due to the memory capacity of Sobek and the simulation times, it is not advisable to try to include every network detail in one model.
The principal three branches carry almost 85 - 90 % of the incoming discharge at Isaccea directly to the Black Sea (Trache and Meinders, 1994). The degree of detail and accuracy required for the main branches may signify large uncertainties in the complexes. A request for limited error at the complexes might be impossible to be fulfilled at the main branches.

Therefore, it was decided to build the model in stages: first a global model where the main branches are treated carefully. The water-complexes are replaced in this case by “equivalent flow-storage” branches (See Figure 5.1a).

Second, each complex can be schematised in more detail, using as boundary conditions the levels and discharges computed by the global model (in fact both models interact and they should converge to the same global water-balance results). The detail models give the information required in order to study other aspects such as water quality and eutrophication at the complexes.

The complex “equivalent flow-storage” branches in the global model were determined as follows: an elevation map of each complex is available at DDI in Arc-Info format. In the same way, there are maps available containing the type of soil and vegetation per area and the averaged period per year these areas are under water. This allowed us to make a distinction between areas always under water, floating reed areas (water is stored and / or travels under the reed), areas with no-floating vegetation but prone to flooding and high lying areas never inundated.

For the global model, we adopted a practical approach. We summed up all “open water” channels and lagoons length and surfaces. The difference in surface between the open water and the total surface has been schematised as a partly flowing / partly storage flood-plain. These surfaces (open water = main channel and rest = flood-plain) were divided by the total channel and lakes length in order to determine the width required for the Sobek cross-sections profiles. Every complex is represented by equivalent segments (all with the same cross-section) and connection-channels between the complex and the main branches (see table 2). This approach have still the disadvantage of simplifying the complexity of the network. The branches are connected in series, which may give a wrong idea about the time of permanence of water in the complex.

A different more accurate approach has been chosen for the treatment of these problem in the complex-sub-models (See Section 6).

<table>
<thead>
<tr>
<th>Complexes</th>
<th>Matița</th>
<th>Șoneta</th>
<th>Somova</th>
<th>Roșu-Puiu</th>
<th>Gorgova-Uzлина</th>
<th>Dranov</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface lakes (ha)</td>
<td>5705</td>
<td>4290</td>
<td>1710</td>
<td>6215</td>
<td>5558</td>
<td>4478</td>
</tr>
<tr>
<td>Length lakes (m)</td>
<td>60000</td>
<td>80000</td>
<td>56000</td>
<td>50000</td>
<td>65000</td>
<td>10000</td>
</tr>
<tr>
<td>Surface channels (ha)</td>
<td>220</td>
<td>330</td>
<td>27</td>
<td>221</td>
<td>102</td>
<td>472</td>
</tr>
<tr>
<td>Length channels (m)</td>
<td>146000</td>
<td>220000</td>
<td>18000</td>
<td>147300</td>
<td>68000</td>
<td>314430</td>
</tr>
<tr>
<td>Water surface (l+c) (ha)</td>
<td>6000</td>
<td>4620</td>
<td>1800</td>
<td>6500</td>
<td>5660</td>
<td>5000</td>
</tr>
<tr>
<td>Length complex (m)</td>
<td>210000</td>
<td>300000</td>
<td>75000</td>
<td>210000</td>
<td>140000</td>
<td>315000</td>
</tr>
<tr>
<td>Length segment (m)</td>
<td>30000</td>
<td>75000</td>
<td>25000</td>
<td>30000</td>
<td>35000</td>
<td>35000</td>
</tr>
<tr>
<td>Number of segments</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>7</td>
<td>4</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 2: “equivalent flow storage” branches characteristics for the water complexes included in the Danube Delta global model.
5.1.3 Roughness

Instead of using Chézy coefficients (C m^1/2/s) it was decided to use Manning coefficients (n). In this way the roughness coefficient varies with the water depth (C = R^1/n ; R hydraulic radius). As a first start, a value of n=0.025 was used for the channels and a value of n=0.030 was assumed for the vegetated flood-plains / reed areas (Chézy values varying from 40 to 65). This assumption gave immediately a good first approach during the calibration stage.

5.1.4 Structures

Only one structure was included in the global model for the simulations after 1994: a broad crest weir at Drenor communicating the channel Tataru in the Rosu-Puiu complex and the Black Sea. The crest level is 1.30 metres above zero Black Sea Sulina.

The weir started to function in 1994. Previously, the Roșu-Puiu complex was freely connected to the sea through small channels and inundation areas. In the past, this caused a significant salinisation of the eastern part of the complex.

5.1.5 Boundary conditions

Table 3: Position of the level-gauges and discharge measurement stations in the Danube Delta

<table>
<thead>
<tr>
<th>Station</th>
<th>Measured variable</th>
<th>Number</th>
<th>Zero gauge (m MNS)</th>
<th>Branch</th>
<th>Special file names</th>
<th>Position (km or mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isaccea</td>
<td>h, Q</td>
<td>1</td>
<td>0.63</td>
<td>Danube</td>
<td>M44</td>
<td>km 102</td>
</tr>
<tr>
<td>Mile 44</td>
<td>Q</td>
<td>2</td>
<td>(Tulcea)</td>
<td>Danube</td>
<td>M44</td>
<td></td>
</tr>
<tr>
<td>Tulcea</td>
<td>h</td>
<td>7</td>
<td>0.56</td>
<td>Tulcea</td>
<td>M39</td>
<td></td>
</tr>
<tr>
<td>Mile 34</td>
<td>Q</td>
<td>8</td>
<td>(Tulcea)</td>
<td>Tulcea</td>
<td>brtlm34</td>
<td>M34</td>
</tr>
<tr>
<td>Mile 35</td>
<td>Q</td>
<td>10</td>
<td>(Tulcea)</td>
<td>Mile 35</td>
<td>M35</td>
<td>km 0.5</td>
</tr>
<tr>
<td>Ceatal Izmâi</td>
<td>Q</td>
<td>3</td>
<td>(Tulcea)</td>
<td>Km 115</td>
<td>km115</td>
<td>km 115</td>
</tr>
<tr>
<td>Pardina</td>
<td>h</td>
<td>4</td>
<td>0.40</td>
<td>Chilia</td>
<td></td>
<td>km 78</td>
</tr>
<tr>
<td>Chilia Veche</td>
<td>h, Q</td>
<td>5</td>
<td>0.36</td>
<td>Chilia</td>
<td></td>
<td>km 45</td>
</tr>
<tr>
<td>Periprava</td>
<td>h, Q</td>
<td>6</td>
<td>0</td>
<td>Chilia</td>
<td></td>
<td>km 22</td>
</tr>
<tr>
<td>M33 Sulina</td>
<td>Q</td>
<td>9</td>
<td>(Tulcea)</td>
<td>Sulina</td>
<td>M33sl</td>
<td>M33</td>
</tr>
<tr>
<td>Crisan</td>
<td>h</td>
<td>11</td>
<td>0.19</td>
<td>Sulina</td>
<td>M13</td>
<td></td>
</tr>
<tr>
<td>Sulina</td>
<td>h</td>
<td>12</td>
<td>0</td>
<td>Sulina</td>
<td></td>
<td>M0</td>
</tr>
<tr>
<td>Caraorman</td>
<td>h</td>
<td>27</td>
<td>0</td>
<td>C.Caraorman</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mîlă 23</td>
<td>Q</td>
<td>22</td>
<td>0</td>
<td>DunăreaVeche</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Sf.Gheorghe</td>
<td>Q</td>
<td>13</td>
<td>(Tulcea)</td>
<td>Sf.Gheorghe</td>
<td>km108sfgm</td>
<td>km 108</td>
</tr>
<tr>
<td>Mahmudia</td>
<td>h</td>
<td>15</td>
<td>0.41</td>
<td>Sf.Gheorghe</td>
<td></td>
<td>km 88</td>
</tr>
<tr>
<td>Murighiol</td>
<td>Q</td>
<td>-</td>
<td></td>
<td>Sf.Gheorghe</td>
<td>km63sfgm</td>
<td>km 63</td>
</tr>
<tr>
<td>Dunăvăt Sf/Gh17</td>
<td>Q</td>
<td>17</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gorgova</td>
<td>h</td>
<td></td>
<td>0.30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rosu-Puiu</td>
<td>h</td>
<td>24</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matita</td>
<td>h</td>
<td>23</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sf. Gheorghe</td>
<td>h, Q</td>
<td>18</td>
<td>0</td>
<td>Sf.Gheorghe</td>
<td>k8sfgm</td>
<td>km 4</td>
</tr>
</tbody>
</table>

The measured series (corrected to Black Sea Sulina level) were used as boundary conditions. At the Black Sea boundary where no series were known, a constant level of 0.45 m MNS was adopted.

Figure 3.10 shows the location of the stations and the periods where data is available (source DDI).
5.1.6 Initial conditions

Most of simulations started with the "auto-start" option given by Sobek. Due to the complexity of the network, Sobek finds difficult to start on his own when a discharge is placed at the upstream boundary. Therefore, and only in order to have an initial condition, a simulation of one day is carried out with a water level boundary at Isaccea. These results are used for the restart of the desired simulation using a discharge boundary at the upstream end.

5.1.7 Computational grid

The computational grid is not uniform. It was chosen to have a limited amount of computational points in order to speed simulations. More density was added where needed.

5.2 Calibration

During the first calibrations attempts it was observed that some data were not compatible with other set of measurements. The expert and DDI's staff consulted and visited often the local Hydrometric station in order to try to investigate the cause of the discrepancies. After some consultations and a long-lasting validation of the data, we arrived to more consistent set of measurements in order to proceed with the calibration of the model.

Three periods were selected for different reasons: 
1992 - measurements of water levels were available at the channel Roşu-Puiu (necessary for the complex model). The levees and the structure at the coast connecting the Black Sea and the complex Rosu-Puiu did not exist. Sea water intrusion took place during low water periods. This was a dry year with very low levels and moderate high levels. The data from this period is quite completed at most of the gauging stations data come from the Head Quarters of Apele Romana in Bucharest.

1996 - measurements available at DDI (data chosen for the first calibration). The period January-February was excluded due to an strong ice-cover. Considerable high-water was registered at the end of April and beginning of May (The levees and the structure at the coast already existed but the structure did not operate during this period due to the relatively low high-water levels).

1997 - measurements available at DDI up to september 1997. A quite regular year. During the spring-time high water, the structure at the coast was in operation.

Year 1996

On Figure 5.1b are shown the calibration results for 1996 for the global model improved during this mission. The cross-sections used in the model are the ones measured in 1993. Changing the roughness coefficients it is possible to get a very good discharge distribution and levels at Tulcea and Isaccea (Chézy coefficients varying from 40 to 70). However the water levels computed for the Branches Chilia, Sulina and Sf. Gheorghe are not realistic (these graphics have not been included in Figure 5.1b).

Year 1992
The Chézy values chosen for the calibration with the data of 1996 did not correspond to the logical physical trend. A much higher roughness was given to the Tulcea and Sulina branches in comparison with the roughness of the Sf. Gheorghe branch, in order to improve the calibration. The reality shows the opposite: the Sulina branch is shorter than the Sf. Gheorghe branch and has no meanders; we expected therefore less roughness at the Sulina branch than at the Sf. Gheorghe branch.

These observations made us wonder about the validity of application of the sparse measured profile for larger reaches.

The bed-level longitudinal profile of the Danube branches from 1962, taken from the book "Hydrological description of the Danube Delta catchment" (IMH & DDI, 1963) is presented in Figure 5.2. Although these are old levels, we could observe the general trend, and compare the average-depth along the main channels against the average depth of the available profiles.

Based on these levels the expert tried to "create" more suitable data for the global model (also using small pilot models like the stretch Chilia Veche - Periprava). We checked the performance of these "create" sections for the hydrometeorological conditions of 1992.

The profile at Sulina, Mile 33 was corrected (from 16 m at the deepest point to 12 m) in order to represent better the real situation. This improved significantly the results on discharge distribution and water levels at Crișan and Mahmudia even using standard and more roughness coefficients (Manning values of 0.025 for straight reaches and 0.030 for loops and island channels). Figures 5.3 to 5.13 show the improvements.

The same kind of approach for the Chilia branch did not help. The uncertainties here are too many (many channels). Surprisingly (and this happens all years) the measurements and the Sobek computations are differing in constant values (surprisingly equal to the level correction to Black Sea Sulina level of the zero of the gauge stations Chilia Veche and Pardina). DDI will try in the coming period to find out if there is a "systematic" error in the measurements (the error could not be found during the expert mission).

If we add a boundary condition at Chilia Veche, with the measured levels as boundary, we get a very nice agreement between Sobek computations and measurements at Pardina. However, in 1992 during low water, the "corrected" measurements indicate that the levels at Tulcea are lower than at Pardina. In this case the discharge at channel M35 will change direction. This is not indicated by the discharge measurements at this channel from any year. These inconsistencies indicate that something is systematically wrong in the measurements / cross-sections set provided by Apele Romana for the Chilia Branch at the stations Pardina and Chilia Veche.

5.3 Validation

In order to validate the model, simulations where carried out with data from 1997. The results show the same trend as the ones from 1992 and 1996, depending on the schematisation used. The Sobek model performs good for 1997, with exception of the already mentioned problems related to the inconsistencies registered in the cross-sections profiles and measurements at the gauges Pardina and Chilia-Veche.
5.4 Conclusions and recommendations global model

There is an evident lack of data. Even more, the available data shows inconsistencies. Therefore we cannot consider this global model as completed. However, it gives well very good results base on the data available, and we can conclude that Sobek simulates very good the water distribution at the Delta. And it can be used for general purposes, such as planning and testing of alternatives.

The model has to be completed with more cross-sectional data and it must be run under an extreme flood (for instance 1971). A calibration for wind must still be carried out (curving points must be added to the branches) since this might play an important role specially for wind blowing from the East side (IME-DDI, 1963).

It is therefore recommended here to collect the necessary data as soon as possible in order to finish the fine tuning of this model.

6 Sub-model Complex Roșu-Puiu

This complex is characterised by the presence of several lakes interconnected not only through natural and man-made channels but also by means of large inundation areas covered by floating reed. Figure 6.1a shows the natural flow direction along the reed fields and the natural sand barriers at the complexes Matița-Merhei and Roșu-Puiu (Soil Map from Munteanu, 1996, and personal communication with Mr. J. Hanganu).

The complex Roșu-Puiu is connected with the Sulina branch on the North through three important channels: channel Crișan-Caraorman, Vătăfu channel and Busurca channel. To the south, it is connected to the Sf. Gheorghe branch through the channel-lake Erenciu and the Tataru channel. On the West side the system is connected to the Gorgova-Uzina complex through the branches Ceamurlia and Litcov; this complex provides a considerable amount of water to the Roșu-Puiu complex.

In the past this system was connected to the Black Sea on the East side through some short branches. In 1994 the closure works were finished. Nowadays, only a wide weir allows for discharge from the complex to the sea during high waters (Structure Drenor; crest level: 1.30 m above Black Sea Sulina; width: 195 m).

6.1 Schematisation

Figure 6.2 shows the Sobek schematisation of the Roșu-Puiu complex as well as the location of the available profiles. The existing network of channels and lakes were included in the schematisation. Flow- and storage areas were added to the channel profiles in order to account for the linked neighbouring floating and fixed reed areas (The method used to include these areas has been already described in Section 5).

The “main channel discharge” resulting from Sobek simulations, gives us the discharge flowing through the channel network. The “flood-plain discharge” gives the indication of the water transported over the fixed reed fields and other inundation areas.
Special "reed" channels where added in order to represent the flow under the reed-fields which is not physically confined to the channels / has a different flow direction from the existing channel network.

Most of the floating reed areas are "buckets" where the water stays quiet until higher water comes and then water start to flow under the reed cover (The soils and vegetation expert from DDI, Mr. J. Hanganu, assisted us in this subject).

Depending on the geographical situation of each area (see Figure 6.1a), floating reed may be modelled as flood-plain parallel to the existing channels or as flow area and/ or storage area at overland flow regions where flow may assume a different direction than that of the channels network. We decided to model this last form of floating reed area as a flood-plain which at low levels only works as storage, but where flow takes place when water level rises. This has been schematised by means of the so-called "reed" branches. They function as storage areas during low water and contribute to the flow during high water when the Sobek-“weirs” are over-topped (See Figure 6.1b). The weirs simulate the natural low-barriers between lagoons / flooding areas.

The most important lakes have been schematised by means of branches converging to a central point in the lake. Their surface as a function of the depth has been divided by the total length of the equivalent branches in order to derive the lake cross-section profile. This point provides the "averaged water level at the lake". The branches provide the incoming - outgoing discharge. Adding up the discharges and / or looking at the water level at the lake we can make an estimation of the water balances at those systems. The "level" at other lakes not schematised in this way, can be taken from a significative grid-point of the branch which represents the lake.

The boundary conditions at taken from the Global model (discharge incoming at Sulina, Sf. Gheorge and from the complex Gorgova-Uzina) and from the measurements (level at the Black Sea at Sulina Port and the village of Sf. Gheorghe). Discharge boundaries at Sulina and Sf. Gheorghe branches are preferred to water-level boundaries during the calibration phase (if water levels are used instead of discharges at the boundaries, discharges should be checked during calibration).

The roughness was given by means of Manning coefficients; n=0.025 was used for the channels and n=0.030 was assumed for the vegetated flood-plain / reed areas (Chézy values varying from 40 to 65). This assumption gave immediately a good first approach during the calibration stage.

6.2 Calibration

The calibration was carried out with the data from 1992. We only have one water level point at the channel Roșu-Puiu as reference for calibration (Station 2). This is in fact to little information. A very few discharge measurements are available (four days in 1996). The discharge interchange from this system with the rest of the Delta, has not been recorded. Some approximations can be obtained from Mr. Bondar studies compiled by Driga (Driga, 1994) for the period 1972-1990. This approximations are no more valid since the closure works were started.

The water level boundary conditions at the mouth of the branches Sulina and Sf. Gheorghe come from measurements. These levels take into account the river discharges and the seasonal and due to wind Black Sea Level variations. However the historical levels along the coast have not been measured. Due to that the DDI staff tended to use a constant value of 0.45 m MNS at the sea boundaries where no measurements were available.
The influence of using a constant or a variable sea level boundary at the coastal structure (Drenor) can be seen in Figure 6.3 which shows the measured and by Sobek computed water levels in 1992 at the channel Roșu-Puiu (then the connection to the sea was still open) for both cases. The variable sea level series at the sea-side of the structure was arbitrary generated from the series at Sf. Gheorghe, by excluding the highest levels due to river discharge.

Figures 6.4 and 6.5 show the discharge time series at the channels Crisan-Caraorman (before and after receiving the discharge from the complex Gorgova-Uzlina), Vatafu and Busurca on the northern part, Erenuciuc and Tătaru on the southern part, and the water interchange with the sea in 1992 (without the structure Drenor).

Some general conclusions could be extracted at this stage. The discharge at the lake-branch Erenuciuc changes direction along the year and its magnitude could be neglected. The amount of water coming from the Gorgova Complex is important and should properly be estimated by the global model. The discharge coming from the Gorgova complex is more important than the discharge entering the complex from the Sulina branch. Even, during low water at the Sulina branch, the flow at the Crișan-Caraorman channel could eventually change direction.

A definitive calibration of this model must be made in the future. The functioning of the submodel depends as well from the inputs coming from the Gorgova-Sulina complex (data provided by the global model). New periodical measurements of discharge and levels will help to improve the quality of the model.

6.3 Exploitation run

The same model with the same boundaries (1992) was used to simulate the situation when the connection to the sea is closed and only the structure at the coast (Drenor) is in functioning. The results showed the same trend as the naturally observed discharge direction and order of magnitude for this case. The flow in the Tătaru and the Busurca channels go always from the complex to the main river branches (no flow takes place through the structure from the sea-side to the complex during low water).

6.4 Conclusions sub-model

This sub-model is a first approach. However it allows already for expeditious water balance computations and to carry out analysis of impacts when alternatives are compared.

It must be “finely” calibrated once more discharge and level measurements will be available. With this new data, it will be possible to adjust the now uncertain geometrical schematisation of the flow- and storage reed areas.

It is therefore recommended here to record discharges, specially at the entrances of the complex and at the main internal channels as well as levels at the most important sites.
7 Sub-model Matiţa-Merhei

The complex Matiţa-Merhei is probably one of the most complicated of the Danube Delta complexes. Its lakes are connected by a network of channels but they are also two-dimensionally connected through reed fields. As shown by Figure 6.1a, a natural barrier south of the lake Merhei separates the complex and the overland flow in two two-dimensional big areas.

7.1 Schematisation

The same methodology developed for the complex Roşu-Puiu was applied for this schematisation. Figure 7.1 shows the branches, nodes, boundaries and available channel cross-sections. Also special “reed” branches have been included here.

The complex is connected to the Chilia branch through four branches: two channels one at the west (Channel Pardina) and one on the eastern side of the Chilia Veche elevated area, the channel feeding the northern “reed” fields / drainage system and the channel Sulimanca on the eastern boundary. The southern part of the complex is connected to the Old Danube branches (Dunărea Veche) through the channels Eracle, Cazanel, Bogdaproste and Dovnica. The complex is connected to the West with the Şonetea-Fortuna complex through the Stipoc channel.

Boundary conditions have to be placed at these points. It is recommended to use discharge boundaries at the channels Stipoc (input from the Şonetea-Fortuna complex), Pardina and Eracle, and water-level boundaries at the channels Sulimanca and Dovnica. The other external boundaries might be discharge of level. The boundary series must be derived from the global model. If water level boundaries are also used at the channels Pardina and Eracle, the discharges should be checked against measurements or against the calculated values by means of the global model.

7.2 Next steps

The calibration of this model has not yet been carried out due to time constraints. The next step will be then the calibration. The same comments made for the complex Rosu-Puiu are also applicable here. Discharge and level measurement at this complex will improve the calibration quality. At this moment only levels are available at the lake Matiţa in the period 1996. The water interchange with the rest of the Delta has not been registered.
8 General conclusions and recommendations

8.1 Conclusions

Partial conclusions have been presented already for each model. In this sections we present the general conclusions of the mission:

- During the mission the local staff and the expert worked together in a very pleasant atmosphere. The hard-working local team demonstrated a deep degree of involvement and enthusiasm. Technology and knowledge were transferred daily on the job. Many modelling concepts and methodology have been extensive explained and clarified. However, the expert observed that the basic-hydraulics background and the knowledge about the scope, range of application and limitations of mathematical models of some of the DDI staff involved in this project is sometimes limited and could be improved. This background is necessary in order to be able to make critical evaluations of the data and simulations results.

- Despite of this fact, the DDI team has now a good basic knowledge of the methodology to go further with the schematisation of the water complexes at the Danube Delta.

- The available data is insufficient. This serious lack of data affects the quality of the hydrodynamic models. Therefore, it is necessary to improve it (fine tuning) before starting with other related developments such as water quality.

- Despite of the inconsistencies in de data, we can conclude that the Sobek models reproduce reasonably well the given hydrometeorological scenarios.

8.2 Recommendations

- The information existing at DDI is insufficient. In order to carry out a definitive calibration of the global model it is necessary to compile already existing cross-sectional data along the main branches. The existing data can be obtained from the Institute of Meteorology and Hydrology at Bucharest (the latest river soundings are from 1987). More data may be available at the Headquarters of Apele Romana.

- For the areas where no information is available, new data could be measured. Measuring-campaigns are expensive and time consuming. New bathymetries could be measured in the coming period. Profiles measured every 2 or 2.5 kilometres and profiles measured at the critical locations along the main branches (and island-channels) will give enough detail for a proper calibration of the global model. This will also bring more light to the incompatibilities encountered between profiles and measured water levels.

- More measurement stations are needed at the water-complexes. Water levels and discharges (and derivated rating curves) have to be recorded at strategic points such as the main entrances to / outlets from each complex. Water levels must be recorded at representative points like for instance at the most important lakes (i.e. for Rosu-Puiu: measurements of discharge and water level at channel Crișan-Caraorman, Lîtcov / Cearmurla, Busurca, Vătăfu, Tătaru, Erenicu, channel Roșu-Puiu; water level measurements at Lumina, Iacob, Puiu, Roșu, Roșulet, etc)

- The data should be validated and saved on a database on a central place in order to avoid the inconsistencies found during this project.
9 Literature

Danube Delta Research Institute (DDI or ICPDD in romanian) (1997)
Solution to reduce the anthropological impact in the Danube Delta Biosphere Reserve

Directia Generala de Gospodarire a Apelor (1962)
Topo-hydrographical maps scale 1:25000 from 1962 (system of coordinates: 1942;
reference level: Black Sea Sulina).

Driga, Basaras V. (1994)
Academia Romana - Institute of Geography - Sistemul circulatiei apei in Delta Dunari -
PHd. thesis not published (Bucharest 1994).

Institute of Meteorology and Hydrology (IMH), Danube Delta Research Institute (DDI) (1963),

Institute of Meteorology and Hydrology / DDI (1992)
Studiu Hidrologic al Complexului Hidrografic Parches-Somova

Trache, G. and J. Meinders (1994),
A comparison of the Hydrology in the Danube and Rhine Deltas, page 33, RIZA - DDI.
Figures
Danube Delta (after Găstescu, 1997)

November 1997

DELT HYDRAULICS

R3055 FIG. 3.1
SUPRAFAȚA COMPLEX:
- totală = 9.170 ha
- acvatica = 2.025 ha

Termen de pune în funcțiune - nov. 1997

Legenda
- Limiță complex
- Canale și gările existente reprofilate L = 21,5 km
- Zone cu protecție integrală
- Gura de admisie
- Gura de evacuare
- Inchideri din pământ
SUPRAFAȚA COMPLEX:
- totală = 24.636 ha
- acvatnică = 2.219 ha

Legenda
- Limită complex
- Canale și gările existente reprofilate L = 48,2 km
- Zone cu protecție integrală
- Gură de admisie
- Gură de evacuare
- Inchiideri de pământ

Termen de punere în funcțiune nov. 1997
Suprafața Complex:
- totală = 24,420 ha
- acvatică = 20,000 ha

Executat - 1995

Legenda
- Limită complex
- Canale și gări existente reprofilație L = 45,6 km
- Zone cu protecție integrală
- Gură de admisie
- Gură de evacuare

Water complex Matița - Merhei (after DDI, 1997)

November 1997

DELFIT HYDRAULICS

R3055 FIG. 3.5
SUPRAFATA COMPLEX:
- totală = 25.150 ha
- acvatică = 5.845 ha

Termen de puncere în funcție - nov. 1997

Legenda
- Limită complex
- Canale și gârle existente reprofilate L = 61,9 km
- Zone cu protecție integrală
- Gură de admisie
- Gură de evacuare
- Consolidări de maluri

Water complex Gorgova - Uzlina (after DDI,1997)

November 1997

DELFIT HYDRAULICS

R3055 FIG. 3.6
SUPRAFATA COMPLEX:
- totală = 42,300 ha
- acvată = 6,660 ha

Termen de punere în funcțiune - nov. 1998

Legenda
- Limită complex
- Canale și gărle existente reprofilate L = 48,0 km
- Zone cu protecție integrală
- Gură de admisie
- Gură de evacuare
- Batardou de pământ

Water complex Roșu - Puiu (after DDI, 1997)

November 1997

DELFIT HYDRAULICS

R3055 FIG. 3.7
Water complex Dunavată - Dranov (after DDI, 1997)

November 1997

DELT HYDRAULICS

R3055 FIG. 3.8
SUPRAFATA COMPLEX:
- totală = 66,200 ha
- acvatica = 60,000 ha

Legenda
- Limită complex
- Canale și gărzile existente reprofilate L = 62.9 km
- Zone cu protecție integrală
- Gurtă de admisie
- Gurtă de evacuare
- Consolidare mal canal Lipoveni
- Executat 1995

Water complex Razim - Sinoie (after DDI, 1997)

November 1997

DELFTHYDRAULICS

R3055 FIG. 3.9
Calibration Danube using available cross-sections

- Periprava
- Sulina
- ROSU-PUIU
- VOV
- Ciotica
- Sf. Gheorghe

Global model

Boundary condition
Node
Branch
Branch representing points of calibration

001
R3055
FIG. 5.1b
Longitudinal profiles: Averaged depth (m) at:
a) Danube between Braila and bifurcation Chilia branch,
b) Branches Tulcea and Sulina,
c) Branch St. Georghe (date from 1962)
Total discharge in Branch tu3, Location 2000.00
Total discharge in Branch su4, Location 865.00
Measurements
Total discharge in Branch cnm35cnFltl, Location 596.00

Measurements
Water level in Branch tu2, Location 8062.00

Measurements

92qsu\92qsu

Water level (m N.N.G.)

Time (year 1992)

Jan 02, 1992
00:00:00.00

Dec 31, 1992
00:00:00.00

SOBEK global model Danube Delta
Delft - water level at Tulcea

1992 - 92qsu

November 1997

F. 5.11

R3055.00
Water Level in Branch SFgh2, Location 14872.00

Measurements

Water level (m NGSXm)
Complex Matița/Merhei - SOBEK schematization and location measured profiles

November 1997

DELFT HYDRAULICS
Floodplain view from the channel mile 35
(complex Șonte-Fortuna)

Complex Șonte-Fortuna =
connection between channel and lagoon / inundation area through bank overtopping

(September 1997, ML)
Fixed reed = high water mark visible on the reed

(September 1997, ML)

Floating reed - channel connecting the lakes Roșu and Puiu

(September 1997, ML)
Floating reed between lakes Lumina and Puiu-complex Roșu-Puiu

Structure (broad crested weir) at Drenor communicating the channel Tatoru (Roșu-Puiu complex) with the Black Sea during high waters
Forested floodplain at complex Ţontea-Fortuna

(September 1997, ML)
WL | delft hydraulics

Rotterdamseweg 185
postbus 177
2600 MH Delft
telefoon 015 285 85 85
telefax 015 285 85 82
e-mail info@wldelft.nl
internet www.wldelft.nl

Rotterdamseweg 185
p.o. box 177
2600 MH Delft
The Netherlands
telephone +31 15 285 85 85
telefax +31 15 285 85 82
e-mail info@wldelft.nl
internet www.wldelft.nl