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Sediment Transport Modelling with Advanced Hydroinformatic Tool Case study - Modelling On Bega Channel Sector

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Abstract

Understanding of sediment transports related phenomena's (soil erosion, particles entrainment, transport and deposition) is important for predicting sediment and contaminant transport in surface water networks. Sediment transport is a critical process in many environmental and hydrotechnical systems, due to its negative effects (eutrophication and siltation of reservoirs, water courses, channels and harbours, earth dam's failures, decreasing of reservoirs storage capacity, damage and loss of wildlife habitat, flooding, especially flash flooding, damage to public health, increase costs of water treatment for drinking, decreased fertility of agricultural land etc.). The management of most aquatic ecosystems and hydrotechnical arrangements requires a detailed understanding of sediment dynamics, with their environmental and economic implications, especially where there is any anthropogenic involvement. Numerical simulations of sediment transport with advanced hydroinformatic tools are often the most efficient and practical methods for predicting sediment transport in complex hydrotechnical systems. Numerical modelling requires descriptions of the individual processes involved in sediment transport: erosion, entrainment, movement of sediments and deposition in the water column. This paper analyzes the necessity and possibility of sediment transport modelling with advanced hydroinformatic tool.

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Keywords: sediment transport, hydroinformatic tool, hydrodynamic modelling, navigation;

The study case shows the sediment transport modelling on Bega Channel sector (City of Timisoara to Romanian - Serbian border, Bega Channel is transboundary water course), in order to reopen the navigation and Bega Channel sustainable development, the modernization of the channel corridor for inclusion in the Danube - Rhine (navigation possible for ships up to 1000 tons).

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For the modelling are use MIKE11 by DHI software, HD and ST module. On the ground of obtained results from modelling, we can identify sectors with problems in terms of river bed silting.

1. Introduction

Understanding of sediment transports related phenomena's (soil erosion by water, particles entrainment, transport and deposition) is important for predicting sediment and contaminant transport in surface water networks. Sediment transport is a critical process in many environmental and hydrotechnical systems, due to its negative effects. Causes and the most important effects of sediment transport on a watershed are illustrated in Figure 1.

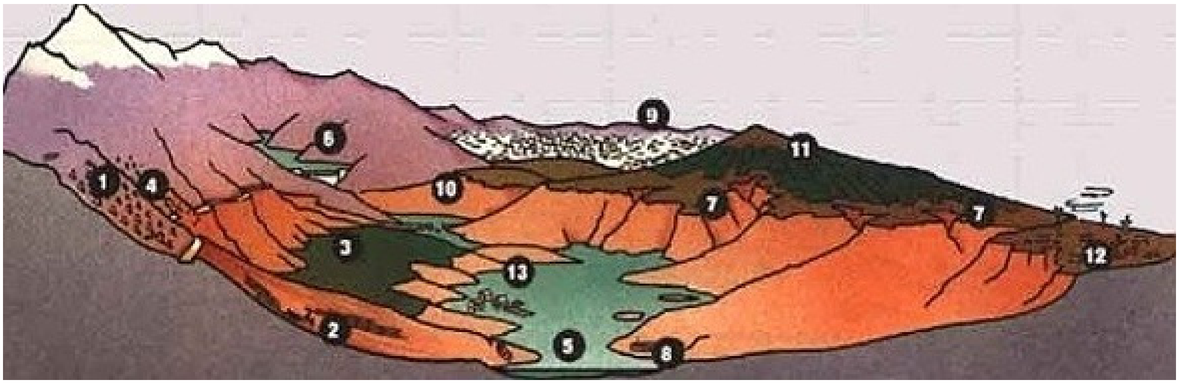

Fig. 1. Environmental impacts of sediment transport [1].

Where: 1 – deforestation; 2 - work agricultural land with high slopes as the steepest slope line, uses inappropriate; 3 - monocultures over large areas of land; 4 - landslides, collapse of rocks; 5 - degradation of the fish population in shallow waters; 6 - eutrophication and siltation of reservoirs, watercourses, channels and harbours; 7 - surface and depth soil erosion; 8 - worsening of navigation conditions; 9 - development of large urban agglomerations by population migration from rural to urban areas, due to the inability to meet the needs of living; 10 - destroying bridges and land communication routes during floods; 11 - leaving derelict agricultural land (unprotected); 12 - wind erosion of land; 13 - leaving frequently flooded human settlements.

The management of most aquatic ecosystems and hydrotechnical arrangements requires a detailed understanding of sediment dynamics, with their environmental and economic implications, especially where there is any anthropogenic involvement. Numerical simulations of sediment transport with advanced hydroinformatic tools are often the most efficient and practical methods for predicting sediment transport in complex hydrotechnical systems. Accurate numerical modelling requires descriptions of the individual processes involved in sediment transport: erosion, entrainment, movement of sediments and deposition in the water column and estimation of several model parameters that are not otherwise known from experimental data. For the more accurately represents the relevant physical processes is necessary to combine the site and laboratory data and a sediment bed dynamics model with a unified treatment of cohesive and non-cohesive sediment erosion and transport [2, 3, 4].

2. MIKE11 Advanced hydroinformatic tool

MIKE11 by DHI is a professional engineering software package for the simulation of flows, water quality and sediment transport in estuaries, rivers, irrigation systems, channels and other water bodies. MIKE11 is a user-friendly, fully dynamic, one-dimensional modelling tool for the detailed analysis, design, management and operation of both simple and complex river and channel systems. The Hydrodynamic (HD) module is the core of the MIKE11 modelling system and forms the basis for most modules including Advection-Dispersion and Non-cohesive sediment transport modules. The MIKE11 hydrodynamic module (HD) uses an implicit, finite difference scheme for the computation of unsteady flows in rivers and estuaries. The MIKE11 HD module solves the vertically integrated equations for the conservation of continuity and momentum, i.e. the Saint-Vénant equations.

The advection-dispersion (AD) module is based on the one-dimensional equation of conservation of mass of dissolved or suspended material, i.e. the advection-dispersion equation. The module requires output from the hydrodynamic module, in time and space, in terms of discharge and water level, cross-sectional area and hydraulic radius. The advection-dispersion equation is solved numerically using an implicit finite difference scheme which, in principle, is unconditionally stable and has negligible numerical dispersion.

The cohesive sediment transport (CST) module is part of the AD module. In contrast to the non-cohesive sediment transport (NST) module, the sediment transport cannot be described by local parameters only because the settling velocity of the mostly very fine sediment is very low. The cohesive module uses the AD module to describe the transport of the suspended sediment. Erosion/deposition is modelled as a source/sink term in the advection-dispersion equation. The erosion rate depends on the local hydraulic conditions whereas the deposition rate depends on the concentration of the suspended sediment and on the hydraulic conditions. The CST module is not provided with a roughness predictor. It does, however, calculate the erosion/deposition rate directly without applying a continuity equation for the sediment as performed in the morphological NST module. In a similar way to the explicit NST module, the accumulated sediment erosion/deposition during the simulation period is determined [5].

3. Study Case

At the III Pan-European Conference, hold in Helsinki (June 1997), it was decided to develop a series of international transport connections (corridors), that will be interest to Europe. Timisoara could connect the Rhine - Maine - Danube Corridor (which is an important shipping route between the North Sea and the Black Sea), when Bega Channel would become navigable again. Currently, ships which traveling on the route Rhine - Danube cannot use the channel because the channel and locks dimensions permit only the passage of ships of up to 500 tons. This requires, among other studies, the modelling of sediment transport in the bed of the canal, in order to identify sectors where erosion and deposition may occur, which could hinder the movement of ships. The sediment transport was modelled on Bega Channel sector (City of Timisoara to Romanian - Serbian border, Bega Channel is transboundary water course), in order to reopen the navigation and Bega Channel sustainable development, the modernization of the channel corridor for inclusion in the Danube - Rhine Corridor (navigation possible for ships up to 1000 tons) [6, 7].

The data required for modelling are: longitudinal profile of studied driver sector (Figure 2); 13 cross-sections - P1 – Km 76+000 - RO-SRB border, P2 – Km 78+000, P3 - Km 88+000, P4 – Km 89+200, P5 - Km 98+200, P6 - Km 104+200, P7 - Km 106+200, P8 - Km 109+800, P9 - Km 112+700, P10 - Km 114+100, P11 - Km 114+400, P12 - Km 115+300, P13 - Km 115+900 – upstream Timisoara **-** where was performed over time bathymetric measurements by Banat Water Basin Administration (Figure 3) ; time series: discharge hydrograph – average monthly discharge for 2005 in cross-section upstream of Timisoara – duration of simulation 1; boundary conditions: Q-H curve in cross-section situated downstream, on the state border; ST parameters- non-cohesive sediments, average diameters of sediments $d_{average}$ = 0,001 m (Figure 4) [8].

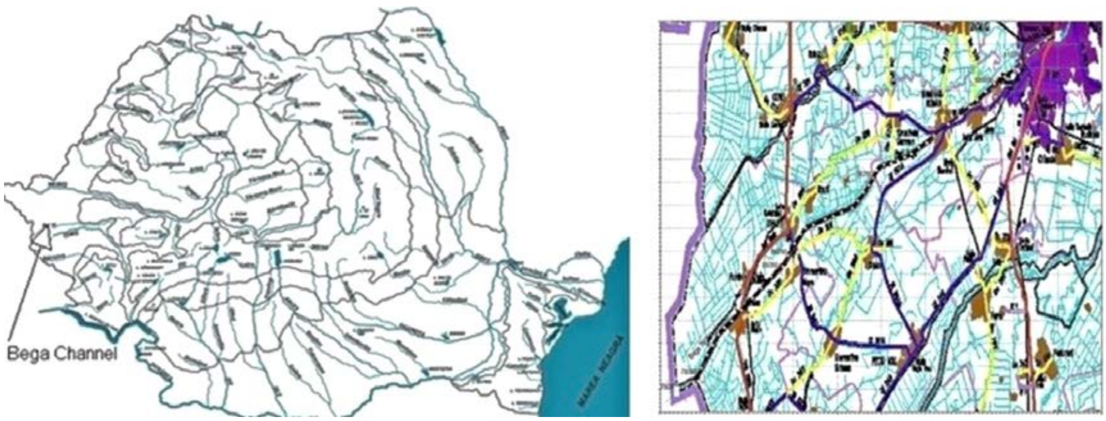

Fig. 2. Area plan of Bega Channel and studied sector.

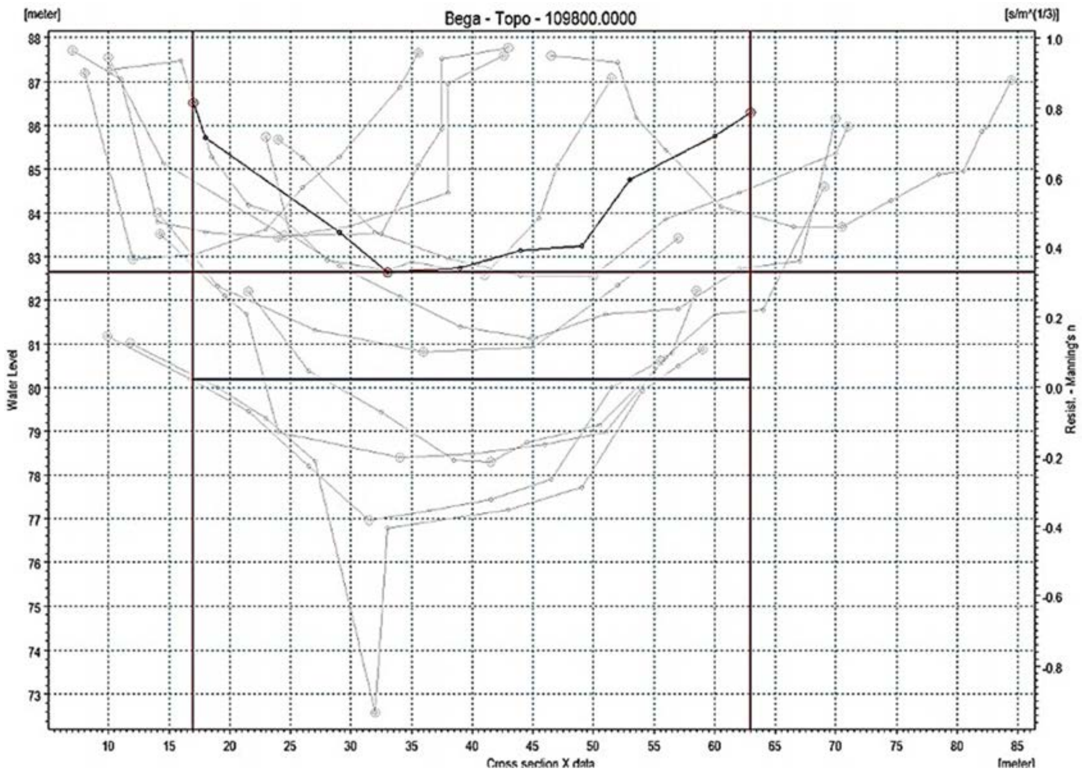

Fig. 3. Cross sections between upstream Timisoara and RO-SRB border.

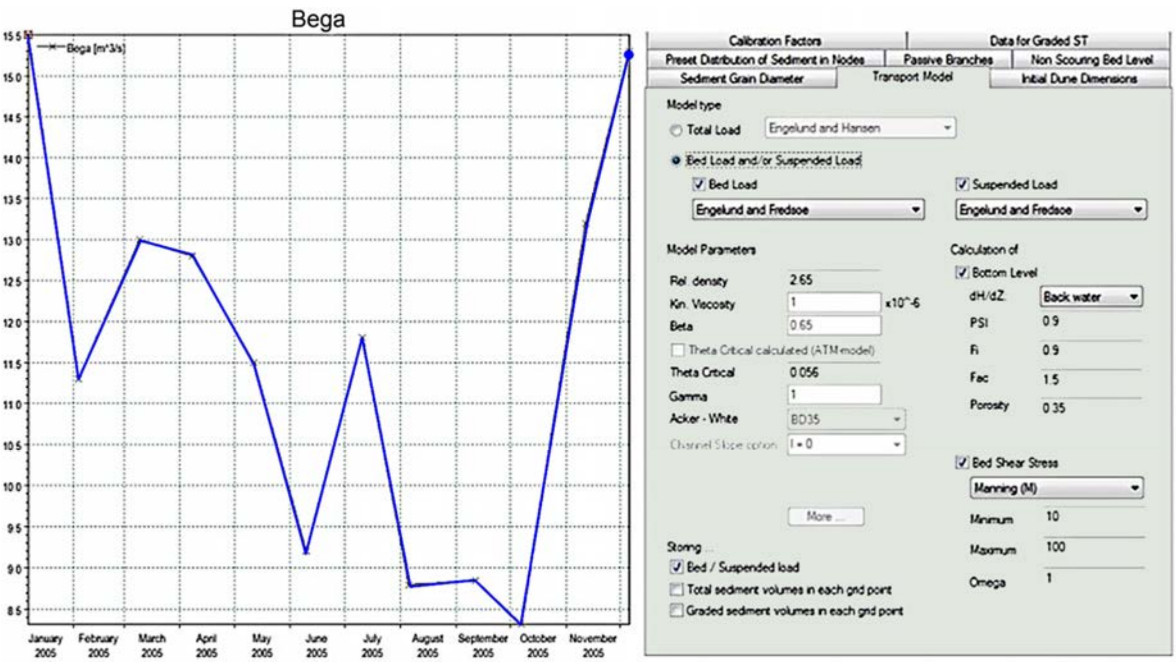

Fig. 4. Average monthly discharges hydrograph and ST parameter data.

4. Results and Discussions

The obtained results regarding to sediment transport from modelling are: variations of bed load (Figure 5), suspended load (Figure 6), variations of total sediment transport (Figure 7) and bottom level evolution in the longitudinal profile (Figure 8).

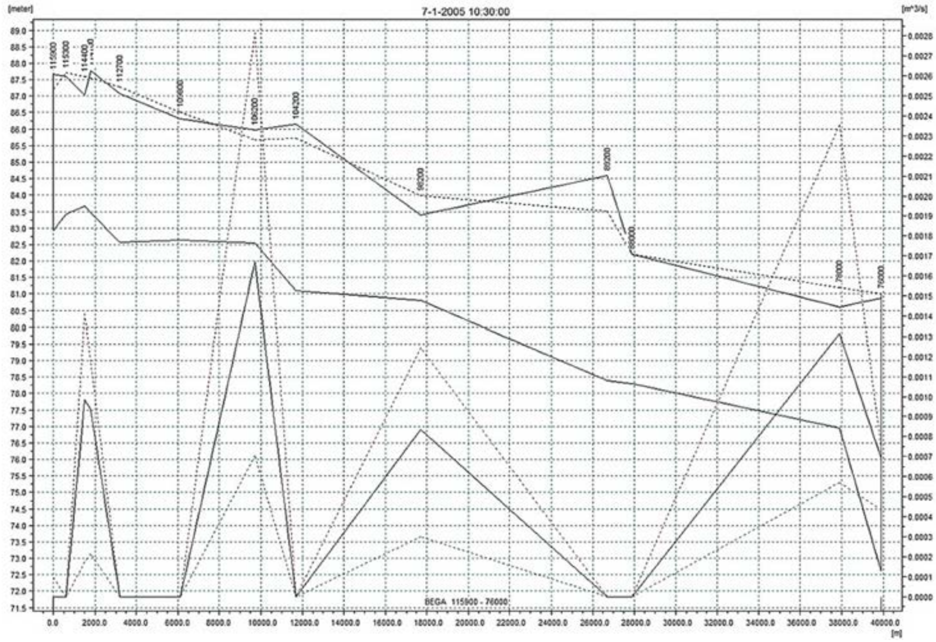

Fig. 5. Variations of bed load (m^3/s).

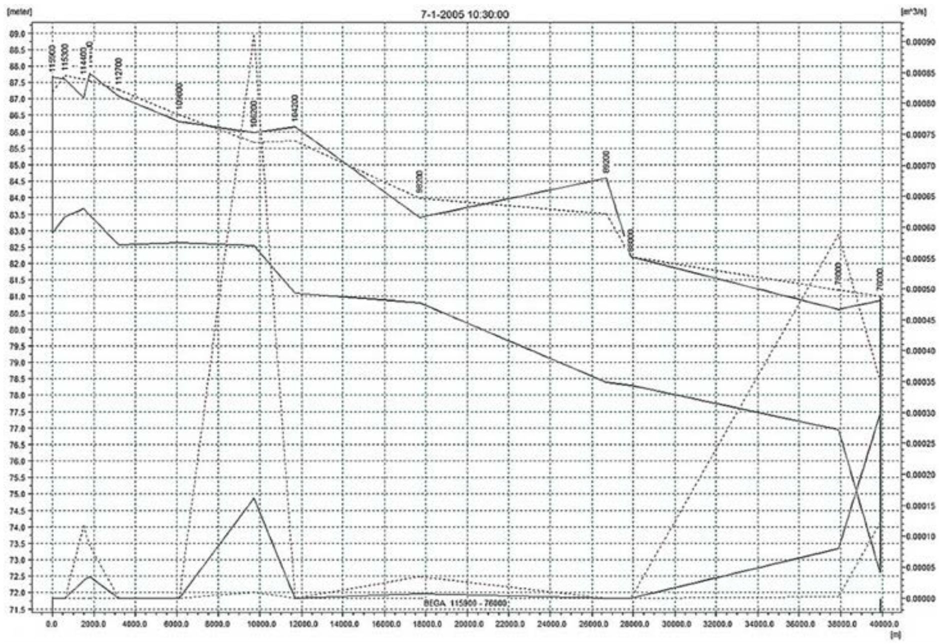

Fig. 6. Variations of suspended load (m^3/s).

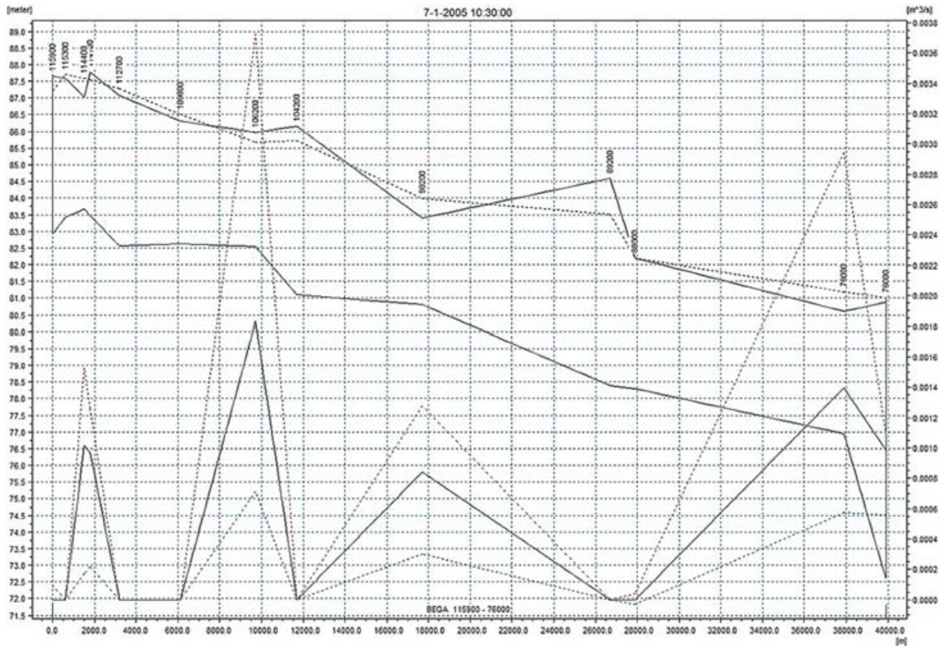

Fig. 7. Variations of total sediment transport in the longitudinal profile (m^3/s)

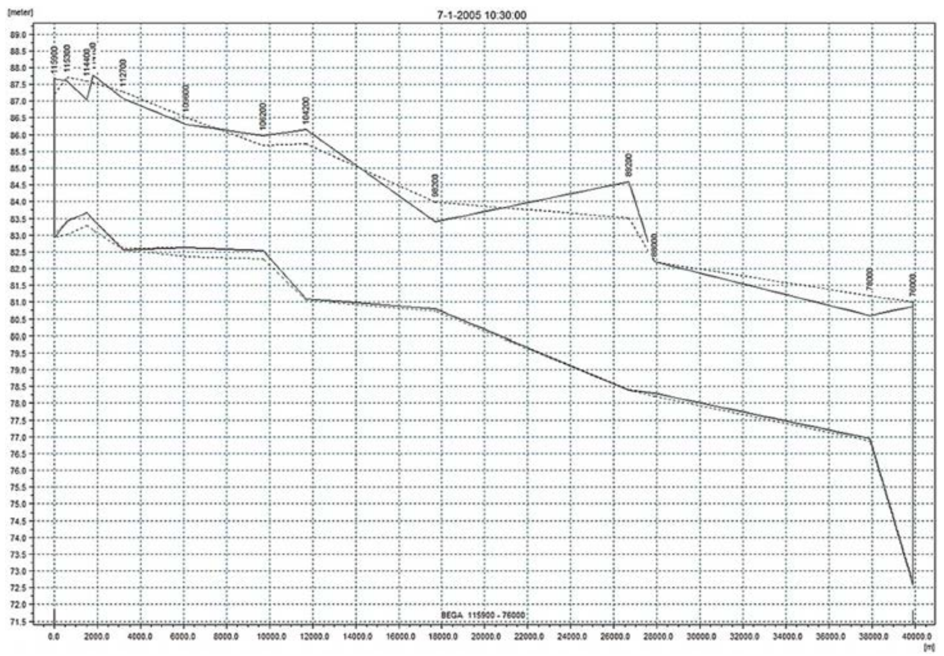

Fig. 8. Variations of bottom level evolution in the longitudinal profile

From Figure 8 it is observed that the high rate variations of bottom level are between P13 and P6 sections (the most silted sector). This is due to the following reasons: the first part is across city of Timisoara, where different wastes are thrown, which increase the riverbed roughness, implying a reduction of water velocity at the bottom of the riverbed; on this section are the most important sources of water evacuation, such as waste water treatment plant of the city, the sugar factory and other industries, which using outdated treatment technology; from years of 80s the cylindrical hindrance of Sanmihai hydronode is blocked, water evacuation made only by surface spillage and the sluice was closed and put out to dry.

The sector between P6 and P3 present on first half relative intensive bed erosion, and in the second half weak depositions. About section between P3 and P1 can say that the bed has stable and the deposition or erosions are not considerable.

In the current Bega river basin management, there shall be no measure to decrease the rate of clogging of about 15 000 m^3 / year along the Romanian sector. For the sectors located between the sections P1 - P2, P5 - P6 and P9 - P10, the bed level increases every year by 15 - 20 cm, which means that in 15 - 20 years these sectors may be completely silted [8].

5. Conclusions

The sediment transport modelling with advanced hydroinformatic tools is important for water courses where may appear problems due to erosion or deposition in river bed: deteriorate the navigation conditions, silting of water intakes, worsening of water quality – like eutrophication etc. A special importance has the quality of input data needed for modelling: topographical data of cross sections, slopes, bed roughness and sediments characteristics. On the ground of obtained results from modelling can establish the measures for river bed erosion and depositions reduction on the sectors with problems. These measures can be applied in river bed and/or in the river watershed, such that technical and economic effect to be optimal.

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