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HYDRODYNAMIC MODELING ON SUCIU RIVER (MARAMURES COUNTY)

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Abstract. The GIS database containing the topographic and land use information was made in 2012, followed by field measurements surveys in 2013 and 2014. A number of 11 cross-sections were topographically appraised in the valley along the 11 km river reach. The geometric data requirements for the modeling software were prepared in ESRI's ArcGIS™ 9.2 software using the HEC-GeoRAS extension. The steady flow data was edited in the HEC-RAS one-dimensional flow modeling software. Four scenarios were used for the river discharge, from normal to overflow. The results come in different forms, from tabular output, to stage hydrograph, to velocity distribution or 3D diagrams, all of which give a clear vision on the overflow high risk areas. The results were exported back to the GIS extension for additional spatial operations. Flow velocity maps were generated for each discharge scenario. Although the scenarios included very high discharge values, the flood impact on people assets is minimal. The reasons for this are the high slope of the riverbed and the proper placement in the floodplain, due mainly to the flood management works that took place after the 1970 flood.

1. Introduction

The hydrodynamic modeling of a river course is a difficult task, as the riverbed is continually changing and high accuracy measurements in river cross-sections are required. Moreover, the field surveys should be repeated once every 5 to 10 years (depending on the extent of riverbed morphology changes).

Although a lot of hydrodynamic modeling software exists at this time, the inputs for all of them are highly dependent on field data accuracy.

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The U.S. Army Corps of Engineers' River Analysis System (HEC-RAS) is software that allows you to perform one-dimensional steady and unsteady flow river hydraulics calculations, sediment transport-mobile bed modeling, and water temperature analysis (Warner et al, 2010). A lot of recent papers show either that the application of HEC-RAS is simple and convenient, with a good applicability (Wang, 2014), or successful application on high accuracy triangulated irregular networks without the need of field survey measurements (Iosub et al, 2015).

The current paper covers the steady flow water surface profile calculations for an 11km stretch along the Suciu River.

The HEC-GeoRAS is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS using a graphical user interface (GUI). The interface allows the preparation of geometric data for import into HEC-RAS and processes simulation results exported from HEC-RAS (Cameron & Ackerman, 2009).

2. Study area

The Suci River hydrodynamic modeling project started in 2012 as an attempt to provide accurate information for use in flood risk management to local authorities. The study area location – although close to a high flood risk region (Târgu Lăpuș City) – is not a highly risk prone area. The big flood from 1970 in the Somes catchment had a huge impact on the area situated below the Suci and Lapus rivers confluence (fig. 1). Although the Suci river discharge ($112 \text{ m}^3/\text{s}$) flooded the nearby villages, the impact was not as critical as other areas in the Somes catchment. A series of flood management works took place after the 1970 flood especially in the Lapus riverbed below the Suci-Lapus confluence, in the form of riverbed dredging. For Suci River, the flood management works included the construction of embankments and dikes in some parts on the floodplain. Because of these, the highest discharge ($115 \text{ m}^3/\text{s}$) recorded in 1987 did not have the impact of the previous flood. The natural narrowing in the valley slopes as it crosses between Suci de Sus and Suci de Jos villages is yet a reason for concern, as most of the people assets are placed in the floodplain.

Tab. 1. Suci River annual flow (m^3/s)

Annual flow:	2009	2010	2011	2012	2013	2014
Average	3.37	5.18	2.30	2.85	3.14	1.95
Maximum	57.9	55.5	20.1	67.0	30.9	21.7
Minimum	0.382	0.520	0.192	0.210	0.193	0.341

* Information extracted from The "Romanian Waters" National Administration database

The Suci River is classified as a mountainous stream (Somes-Tisa hydrographic area management plan, 2015), yet the study area falls into the hilly

areas, with 7° slope, with a riverbed composed mostly of gravel and sand, and a well-developed floodplain.

As shown in Tab. 1, in the past 5 years (2009-2014), the Suci River flow oscillated greatly among 0.341 and 67 m³/s. For a better flood forecasting, the chosen values for the annual average and maximum flows are 4m/s, respectively 50m/s.

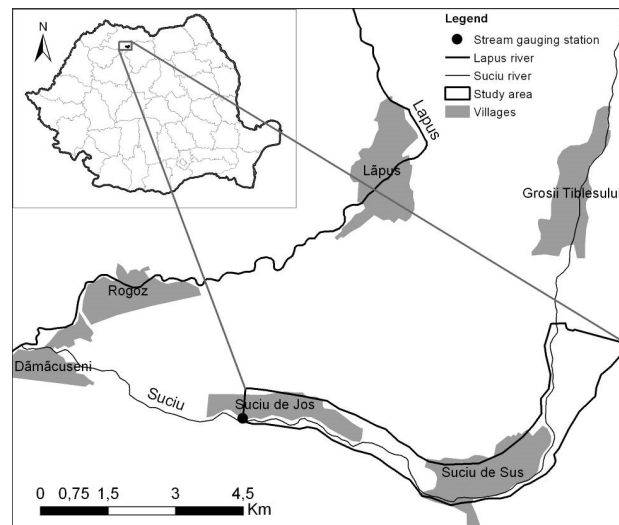


Fig. 1. Study area location

3. Materials and methods

The floodplain morphology was extracted from the 1:5.000 topographical maps by digitizing the contour lines and elevation points in 2012. The land use map (used for Manning's n coefficient) was extracted from Corine Land Cover 2006 vector layers and aerial photographs.

The riverbed morphology was measured by direct surveys in 2013 and 2014, following the thalweg and the left and right banks. For every 10 to 50 meters – depending on morphology changes – a riverbed cross-section was conducted.

The main result comes in the form of a triangulated irregular network (TIN) that accurately shows the riverbed and floodplain morphology along the study area (fig. 2).

Using the HEC-GeoRAS extension for ArcGIS, the geometric data for import into HEC-RAS was prepared. The themes created are the Stream Centerline, Flow Path Centerlines, Main Channel Banks (Left and Right), and Cross Section Cut Lines referred to as the RAS Themes. As the themes intersect the TIN, all the 3D shape files are generated (fig. 2). The intersection of the cut lines with the other

RAS layers will determine bank station locations, downstream reach lengths and the land-use Manning's n values.

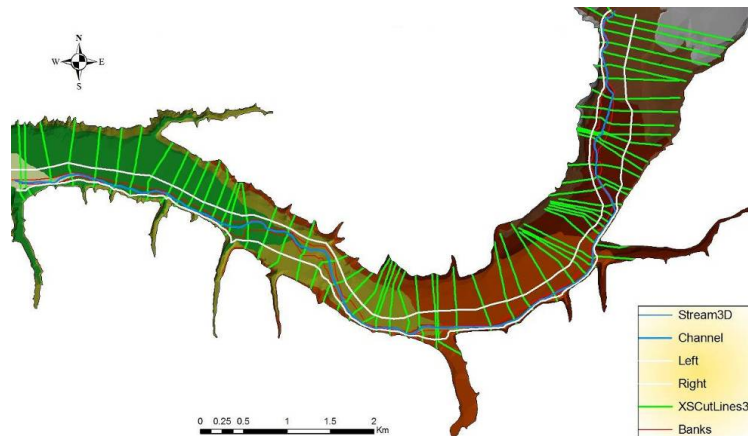


Fig. 2. Suci river TIN, 3D cross-sections and flow-paths

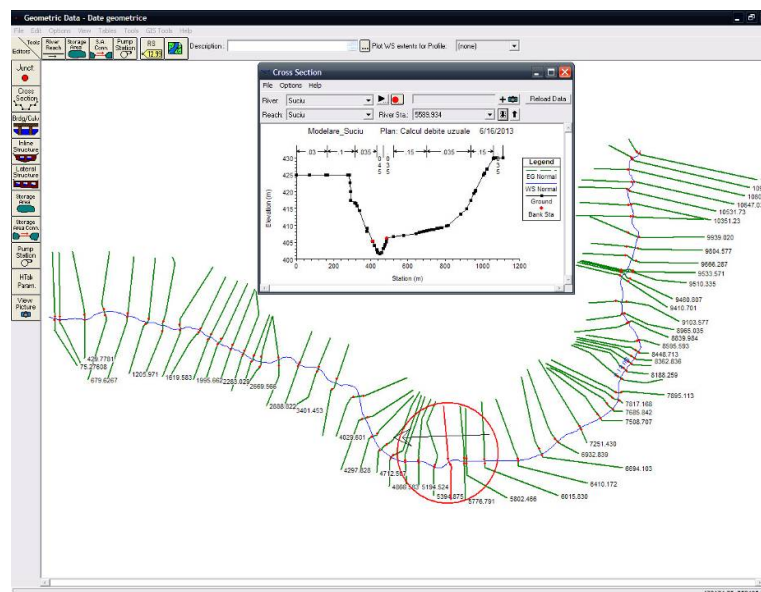


Fig. 3. HEC-RAS Geometric Data interface

For export to HEC-RAS, a RAS GIS import ASCII file is generated. Once imported into HEC-RAS, the geometry data interface shows the 2D cross/sections

along the river stretch (fig. 3). The graphical Cross Section Editor allows the editing of each point values.

After the geometric data was entered, a four scenarios steady flow analysis was preformed. The steady flow data consists of the number of profiles to be computed, the flow data and the river system boundary conditions (Brunner, 2010).

For the yearly average ($4\text{m}^3/\text{s}$) and maximum ($50\text{m}^3/\text{s}$) flows, a subcritical analysis was performed, requiring downstream boundary conditions. The placement of the Suci River gauging station was used as the downstream boundary, for reasons of model calibration.

The upstream boundary conditions were used in the $115\text{m}^3/\text{s}$ and $500\text{m}^3/\text{s}$ scenarios where a supercritical analysis was performed.

4. Results and discussions

The results come in different forms, from Profile output tables (fig. 4), to profile plots (fig. 5), cross-section plots, 3D plots or rating curves (fig. 6).

Reach	River Sta	Profile	Q Total (m³/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m²)	Top Width (m)	Froude # Chl
Suci	11052.02	Normal	4.00	448.46	449.11	448.95	449.15	0.007459	0.87	4.59	14.90	0.50
Suci	10946.83	Normal	4.00	447.23	447.74	447.72	447.84	0.024068	1.39	2.88	11.17	0.88
Suci	10804.56	Normal	4.00	445.66	446.06		446.11	0.007298	0.97	4.13	10.83	0.50
Suci	10647.03	Normal	4.00	444.69	445.13		445.16	0.005059	0.76	5.25	15.55	0.42
Suci	10531.73	Normal	4.00	444.12	444.52		444.55	0.005497	0.73	5.51	18.71	0.43
Suci	10351.23	Normal	4.00	442.94	443.34		443.38	0.007813	0.80	5.02	17.91	0.48
Suci	10207.21	Normal	4.00	442.00	442.44	442.30	442.47	0.005243	0.71	5.62	19.01	0.42
Suci	9939.020	Normal	4.00	439.12	439.42	439.42	439.50	0.036463	1.27	3.15	19.29	1.00
Suci	9804.577	Normal	4.00	437.40	437.75	437.62	437.77	0.004605	0.58	6.91	29.03	0.38
Suci	9666.287	Normal	4.00	436.49	436.84		436.87	0.009802	0.75	5.32	26.64	0.54

Fig. 4. Suci River HEC-RAS Profile output table for $4\text{ m}^3/\text{s}$

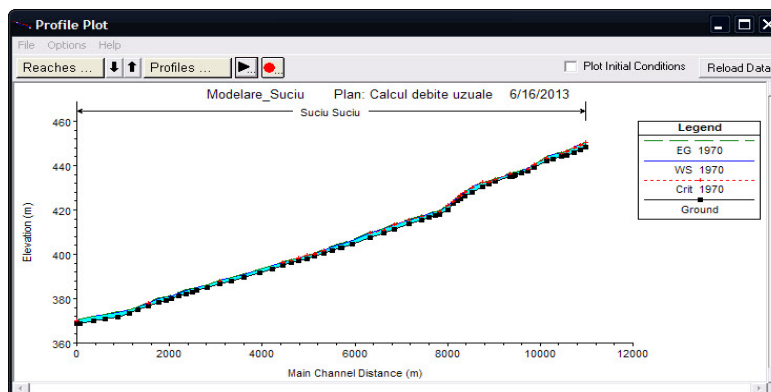


Fig. 5. Suci River HEC-RAS Profile plot for $115\text{m}^3/\text{s}$

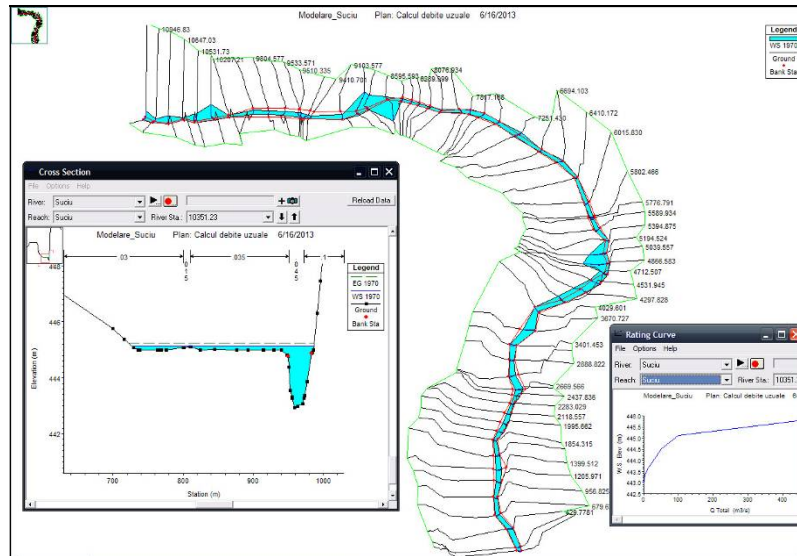


Fig. 6. Suceia River HEC-RAS 3D plot, cross-section and rating curve for $115\text{m}^3/\text{s}$

The results were exported to HEC-GeoRAS, for the generation of floodplain maps (fig. 7). For a better visualization of results, the floodplain boundary for each of the four scenarios was overlaid on aerial photographs (figs. 8 to 11).

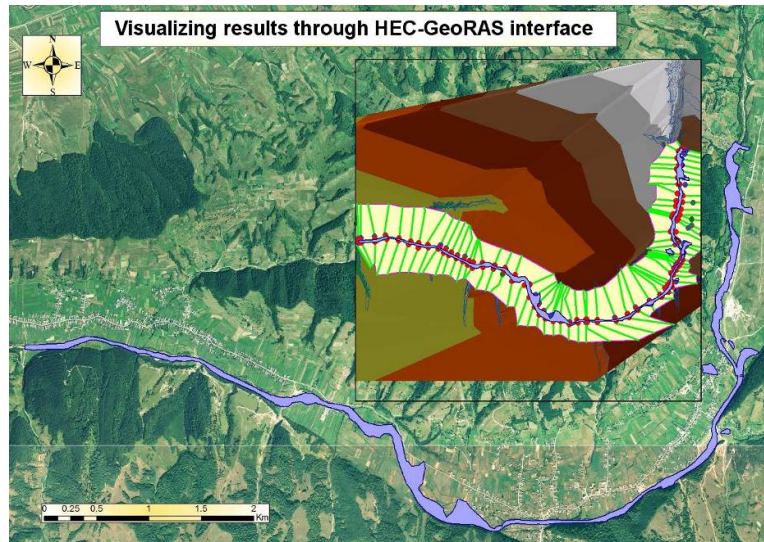
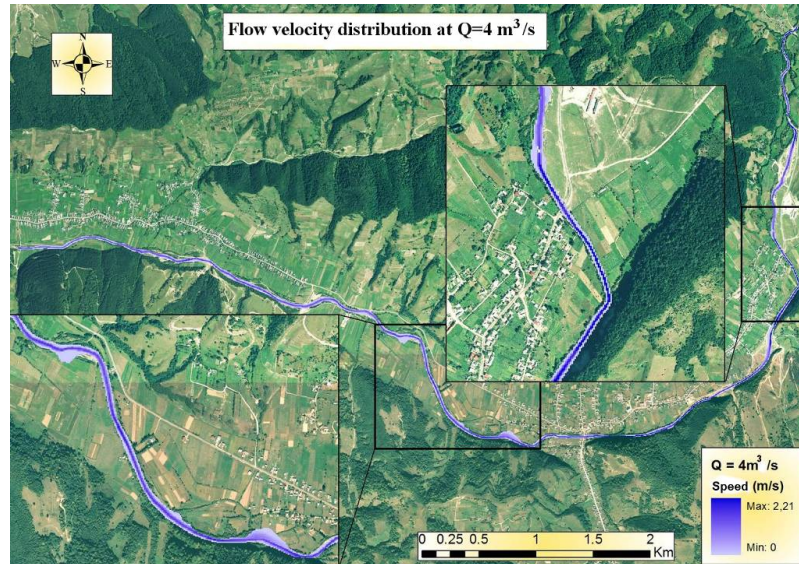
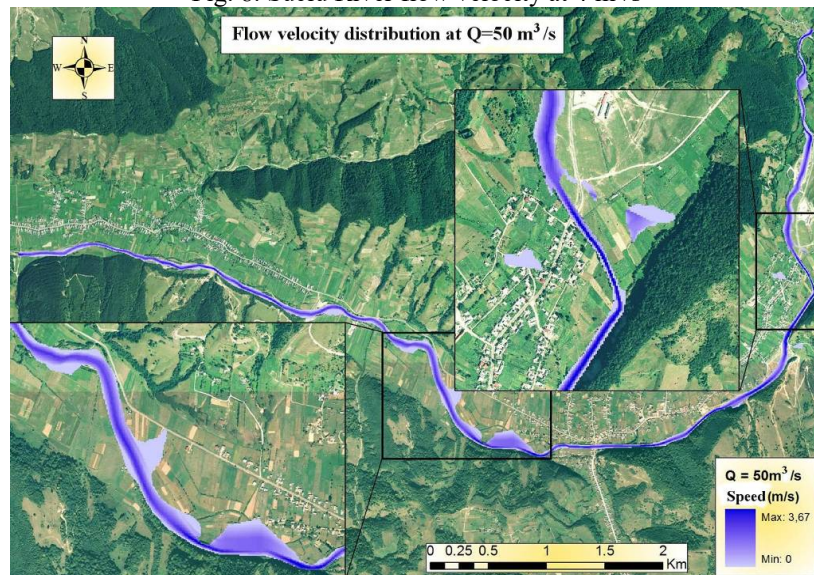


Fig. 7. HEC-GeoRAS data import

Fig. 8. Suci River flow velocity at $4 \text{ m}^3/\text{s}$ Fig. 9. Suci River flow velocity at $50 \text{ m}^3/\text{s}$

The flow velocity distribution for $4 \text{ m}^3/\text{s}$ (fig. 8) was used for the model calibration. At $2 \text{ m}^3/\text{s}$, the river does not reach the floodplain areas. At $50 \text{ m}^3/\text{s}$ (fig.

9), although the water covers small areas in the floodplain, the simulation found a series of sinkholes in the uninhabited vicinities.

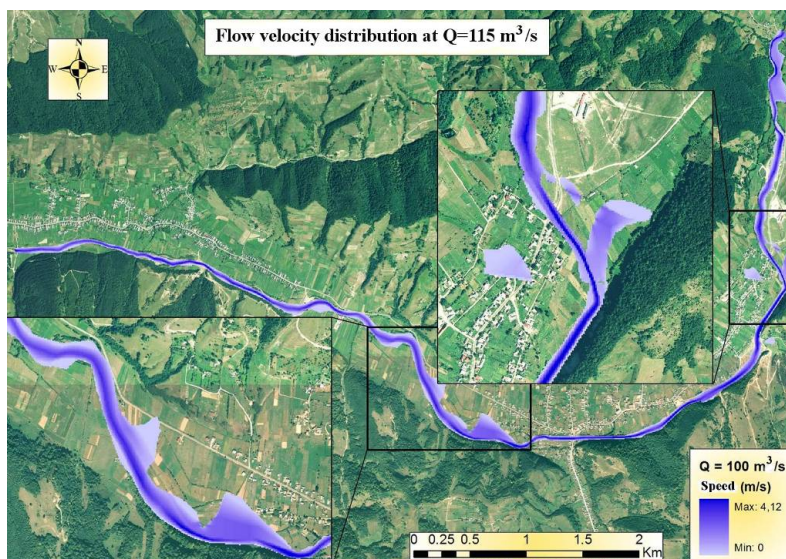


Fig. 10. Suci River flow velocity at $115 \text{ m}^3/\text{s}$

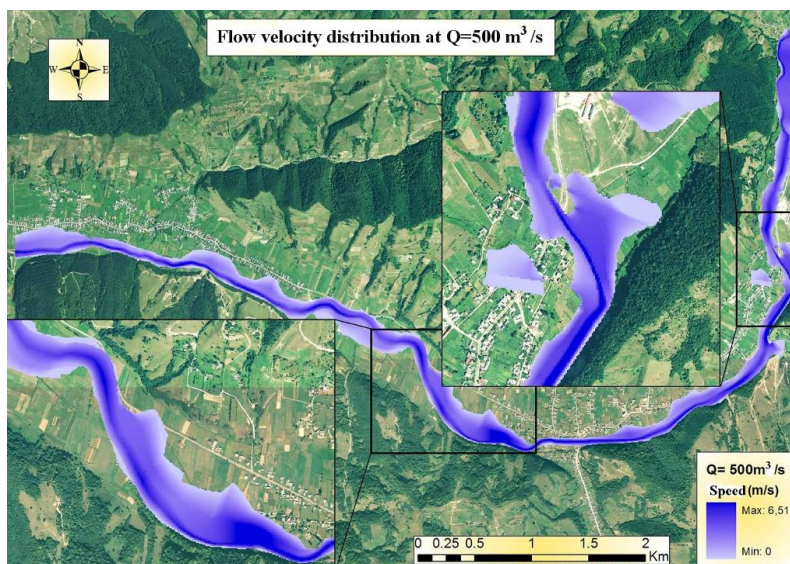


Fig. 11. Suci River flow velocity at $500 \text{ m}^3/\text{s}$

The peak recorded discharge ($115\text{m}^3/\text{s}$) shows large areas in the floodplain covered by water, reaching the edge of the inhabited space and flowing mainly over croplands (fig. 10). The highest flow scenario ($500\text{m}^3/\text{s}$) shows extensive land cover by flood, although only 15 households are being affected by the overflow (fig. 11).

The Suci River is continuously shifting morphology after the $9\text{m}^3/\text{s}$ discharge is reached, mainly in the form of bank erosion (fig. 12). The present critical areas can be protected by simple measures like inundation basins, banks consolidation or dikes re-consolidation.



Fig. 12. Suci River left bank erosion at $9\text{m}^3/\text{s}$

Conclusions

The use of field measurements surveys coupled with high accuracy morphology and land use maps can produce very precise triangulated irregular networks to be used for flood forecasting. The required hydrological data and flood extents through eye-witnessing are as important for model calibration and accuracy of simulation runs.

Although the Suci River flood forecast scenarios included high discharge values, the flood impact on people assets is minimal. The reasons for this are the high slope of the riverbed and the proper household placement in the floodplain, due mainly to the flood management works that took place after the 1970 flood.

This study results can be used by any interested factors (local authorities, universities, NGO's) for a better flood risk management in the studied area.

References

- Brunner, G.W.**, (2010) *HEC-RAS River Analysis System User's Manual*, US Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center, 790 p.
- Cameron, T., Ackerman, P.E.**, (2009) *HEC-GeoRAS. GIS tools for Support of HEC-RAS using ArcGIS. User's Manual*, US Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center, 246 p.
- Iosub Marina, Minea, I., Hapciuc Oana, Romanescu, Gh.** (2015) *The use of HEC-RAS modeling in flood risk analysis*, Air and water components of the environment, Presa Universitară Clujeană, ISSN: 2067-743, pp. 315-322
- Wang, C.H.** (2014) *Application of HEC-RAS Model in Simulation of Water Surface Profile of River*, Applied Mechanics and Materials, Vols. 641-642, pp. 232-235
- Warner, J.C., Brunner, G.W., Wolfe, B.C., Piper, S.S** (2010) *HEC-RAS, River Analysis System Applications Guide*, US Army Corps of Engineers, Hydrologic Engineering Center, 351 p.
- * * * **(2014)** Corine Land Cover 2006 (CLC 2006) seamless vector data, version 17 (12/2013)
- * * * **(2015)**, The "Romanian Waters" National Administration database
- * * * **(2015)** *Somes-Tisa hydrographic area management plan*, The "Romanian Waters" National Administration - Somes Tisa Branch, consulted on 15 November 2015 <http://www.rowater.ro/dasomes/Planul%20de%20management%20al%20spatiului%20hidrografic%20Some/Planul%20de%20management%20al%20spatiului%20hidrografic%20Somes-Tisa/PM%20Somes-Tisa/Plan%20de%20Management%20sh%20Somes-Tisa%20vol.I.pdf>