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Professional paper

GENERALIZATION OF THE SITNICA RIVER DRAINAGE SYSTEM WITH POTENTIAL POLLUTION OF TRIBUTARIES

GENERALIZACIJA REČNE MREŽE REKE SITNICE SA POTENCIJALNIM ZAGAĐENJEM PRITOKA

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Abstract: Maps are miniature graphic representation of distinct area and as not being completely real require generalization. Cartographic generalization represents a specific investigation method in cartography. Generalization includes the processes of selection, simplification, and symbolization of details according to the purpose and the map scale. The river generalization requires the phase classification, selection, magnification and simplification to being used. Linear symbols are given on the map by their corresponding/characteristic length and remained unchanged even after the generalization. Particular cartographic criterions need to be applied during generalization. In the given case of the Sitnica river drainage system were applied the computer supported generalization based on the software Global Mapper 16.1 and the Open source software QGIS 2.6.1. The Sitnica drainage system is generalized in three levels. The first included digitalization of all linear objects related to the river Sitnica and its tributaries. Second level resulted in vector generalized data that indicate on polluted tributaries, whereas the final, third stage led to construction of multilayered vector map of the Sitnica catchments area with polluted tributaries.

Key words: line river generalization, pollution, tributaries, drainage system

Apstrakt: Karte su umanjen, ali ne i potpuno realan prikaz nekog područja pa moraju biti generalizovane. Generalizacija je proces selekcije, uprošćavanja i simbolizacije detalja sa karte zavisno od namene i razmere. Za generalizaciju reka neophodno je uzeti faze klasifikacije, selekcije, uvećanja i uprošćavanja. Kartogarfska generalizacija je specifičan istraživački metod u kartografiji. Linijski simboli se na karti predstavljaju u odgovarajućoj/karakterističnoj dužini i zadržavaju verodostojnost i posle procesa generalizacije. Pri uprošćavanju karte moraju se primeniti pojedini kriterijumi kartografske generalizacije. U konkretnom primeru rečne mreže Sitnice primenjena je kompjuterski podržana

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generalizacija uz pomoć softvera Global Mapper 16.1 i Open source softvera QGIS 2.6.1. Rečni sistem Sitnice je generalizovan u tri nivoa. Prvi nivo je digitalizovanje linijskih objekata reke Sitnice i njenih pritoka. Drugi nivo je dobijanje vektora generalizovanih podataka koja je pritoka zagađena. Treći je dobijanje vektorske karte rečne mreže Sitnice sa pritokama koje su zagađene.

Ključne reči: linijska rečna generalizacija, zagađenost, pritoke, rečni sistem

1. INTRODUCTION

Land waters include water flows, lakes, swamps etc. All the objects given belong to physical and geographical elements of every map. These are water flows that are by all means the most important elements on maps, presented in a waterway hypsometric line - a water line. The water flows which are presented on particular map surfaces joined by river systems represent the river network of a particular territory. Because of their value, they play an important role on maps giving an more natural look to the landscape being presented on a map. On this way, the geographical validity of the content and the plasticity of the topography increase as the waters shown in the map are an inseparable part of the unit presented on the map. Part of the topography plastically shown as a mutually developing unit creates the basis of a hypsometric line network, the network of water lines and water division lines, which enables the complete interpretation and genesis of topographic forms. All the factors contribute to a better orientation of the position of objects themselves and map contents, while the very aesthetics of maps are improved when the generalisation process is properly performed. Water course presentation on a map is performed through generalisation process graphically expressing a river system and a river network, determined along with the length and width of the water course. This is an analogue approach. A cartographic presentation of water course must contain two basic data which are considered to be the primary ones, and these are the length and the width of a water flow. Thereby, a cartographic presentation of water course undergoes the process of generalisation, which is essential for regular map making (Sretenović, 1989). Generalisation leaves space to regular expressions on maps, which has an effect upon river network development, including the development of length and width of water course. The most important factor in creating a good cartographic generalisation is by all means objective reality which itself is based upon the objective discovery of the environment. A map is a comparatively reduced and generalized graphic representation of a determined space. Therefore, generalisation is one of the most important methods in cartography. Generalisation is essentially important, as the geographical unit of 1 km^2 is shown as 1 mm^2 of the map area $P^2 = 1 : 1.000,000$. The form of a graphic sign showing an object or a phenomenon is radically different on a map whose diameter does not exceed 0.4 mm, so that sizes of a smaller scale must be expressed through the point of the same diameter (Benz et al. 2004). As shown, they will collide on the map if two objects are shown by the diameter of 0.4 mm especially on the maps of the following proportion.With regular generalisation, there are three basic elements that have to be known: generalisation elements; features of map objects, phenomena and their mutual relations, and a graphic presentation method. Those factors that operate with typical generalisation are called typical factors. There are factors which will conditionally determine the shape and size of rivers on maps and since determining the very generalisation structure, they seem inevitable: course size-length and width, course development characteristics, and the shape of number flow meandaring courves (Lješević and Živković, 2001). Without knowing physical and geographic characteristics of the river, it is impossible to embark on the process of generalisation (Robinson et al. 1994). The more developed the flow, the higher the degree of the generalisation appearing in proper map proportion. This is a general rule. On some maps, when applying heterogeneous or process generalisation, occurs a slight deviation from a general regularity due to one of eliminating curves must account for accentuating flow development characteristics, including the size and the shape of the curves on maps. With flow hydrographical meandering, the very shapes of the meanders should be observed, as with more visible hypsometric differences, the development of the curves is even more perceptible.

Apart from the varying development (meandering) of the flow, it is a characteristic of development (meandering) that affects the whole flow image (size, shape, the number of curves). The development of the flow with the change of meandering and different shape sizes and total number of flow curves (Figure 3), presents a basic water flow shift, which is river related (Peterca et al. 1974).

Course of rivers on maps of medium and smaller scales are usually represented by a single line, as on such maps, the body's width is considerably increased. In order to express the direction of the flow and its natural magnifying, the line gradually becomes thicker form the spring to the confluence, and as a general rule the mainstream line is thicker than the tributary line. These are the general principles of generalisation in creating maps of different proportions and purposes. During the generalisation of flow width on maps, it is essential that the quotients of the width increase on the map should be known. There are general postulates on maps which need to be taken in consideration in respect to width quotient. The width of flow lines on a map along the river direction from the spring to the confluence, including the lines of a particular map flow, get a various increasing value if the river branches off. Downstream the main flow, the increasing quotient decreases. This depends on the very flow width in relation to a map proportion as if the flow is naturally wider, the increasing quotient is lower. Near the confluence, the flow width is shown more realistically (Marković, 2009).

The conclusion states that the expansion quotient downstream is lower than the upstream expansion quotient, so that the downstream width is presented more realistically. This has an effect on the map as a natural quality of downstream part expansion from the tributary confluence. With longer flows whose flow width gradually increases to the confluence where it is impossible to express the width of the flow by the thickness of the line, the increasing quotient considerably increases. Additionally, it is needed that the flow direction, including the value and the importance to other flows, should be emphasised by the thickness of the line. The thickness of the line in a relatively smaller proportion is more disproportional. A natural flow expansion from the spring to the confluence can be put in per mille with the following formula (Салишчев, 1974):

$$B\downarrow \%_{oo} = \frac{B_u - B_i}{L} = \frac{\Delta B}{L} \tag{1}$$

where:
ΔB - flow width near spring and confluence,
L - particular flow part width.

In the next step of generalization we use the digitized generalization, which can be provided for the maps of 1:25,000 and 1:300,000 scale using programs QGIS 2.6.1 and Global Mapper 16.1. Next step of generalization is to select the main phases of those processes. In the first phase is selected a part of the map where the Sitnica drainage systems exist. In second phase the all tributaries including the Sitnica river watercourse, from the maps in two scales, being digitized. Afterwards should be digitized a drainage system of the whole region of the Sitnica river in two ratios. The third and final phase presents all vector data in a new digital map, enabling to data of all polluted tributaries to be assumed and present on the map. Generalization process in summary process presents all generalized tributaries which are polluted and also place of potential accident on the final maps (Figure 1).

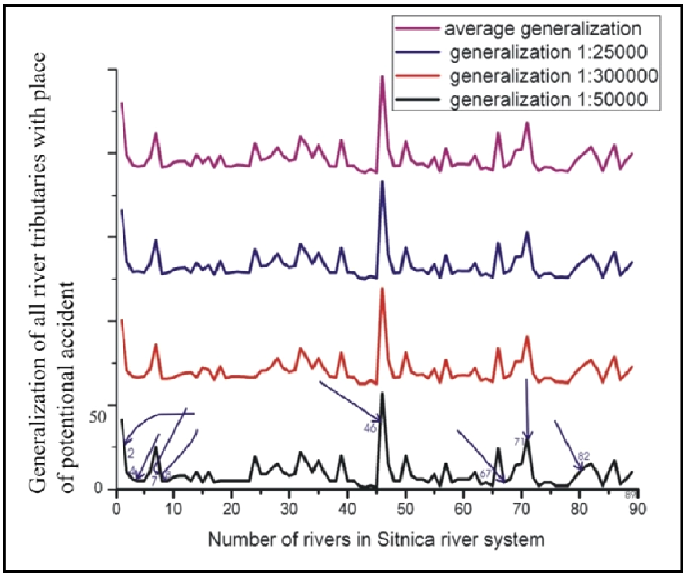

Figure 1 - Sitnica river system with position of potentially polluted tributaries given in three ways of cartographic generalization

2. A COMPUTER SUPPORTED GENERALISATION

The GIS belongs to the group of information systems which is applicable to geographical data supported by the computer tools, which serve for mapping an analysis of real system events in the very base. Computer supported cartography has gradually developed into digital cartography whose basic aim is the data processing and visualisation of space which has to be supported by computer technology and technique. Digital technology has emphasised map importance as a crucial information medium because it is most important that map users themselves understand the function of the very map. Particular cartographers have shared different opinions concerning the relationship between the GIS (geographical information system) and cartography and also for connection in other sciences. Geo information is a phenomenon directly or indirectly linked with a particular location on Earth, so in this way digital cartography becomes important (Beljin, 2001**)**. Digitally appearing information is a result of systematic data (collection, analysis, summary, ordering in a logical unit). Data types within the GIS can be spatial and non-spatial. Spatial data describe a particular position directly and indirectly, depending on the type of digital data. By placing maps and other spatial information in a digital format with later abstracting on the global network, users are allowed previously to show, find and update maps on-line. The GIS is used in every field which use maps as data. Today's GIS is composed of four interactive components: the input subsystem, which converts maps and other spatial data in a digital form, the storing and data recalling subsystem, the analysis subsystem and the output subsystem for map, chart, and data base making. The analogue map used to be the only way of showing spatial data (Taylor, 1994). The phenomenon of the GIS has improved the possibility of the organisation, storage and the management of spatial data which are now digitalised. Information technology development boosts the terms of organisation and management of spatial data, as well the creation of geo information infrastructure, spatial data infrastructure. Spatial data infrastructure should contain sources, data base and meta data, and a network of data and users in the end (Kraak and Ormeling, 1996).

3. SOFTWARE QGIS 2.6.1 AND SOFTWARE GLOBAL MAPPER 16.1 IN USE OF COMPUTER SUPPORTED GENERALISATION FOLLOWING THE EXAMPLE OF THE SITNICA RIVER

Software QGIS 2.6.1. was manufactured by the corporation OSGEO. The software is officialy open source, as an overview tool for analysing geo spatial data. This package offers a guarantee of geographic data from different sources, in different formats and with different projects with all these in the same environment. By using this software, complex queries with spatial and attributive data of different sources may be performed, inducing numerous bases with highly sophisticated data. QGIS 2.6.1. has the possibility of printing these images on a single sheet of paper, and in such a way, it is possible to arrange maps in different proportions presenting them in different formats of printing paper. The concrete advantage is that QGIS 2.6.1 is capable of characterising and integrating vector and raster data. The software is also capable of creating phase digitalisation and vector data with the very help of geometric transformation. The other tools are supported and generated into the very data base. The software Global Mapper 16.1 is also software for GIS, but in comparison with QGIS software easier achieves good results, because is it good for using two imputed data for more then 100 differential sources of data. In our case, this data is from HGT source. With help of software Global Mapper 16.1 we downloaded from the USGS (United States Geological Survey), Aster DEM data to created drainage network for river Sirnica (Figure 2).

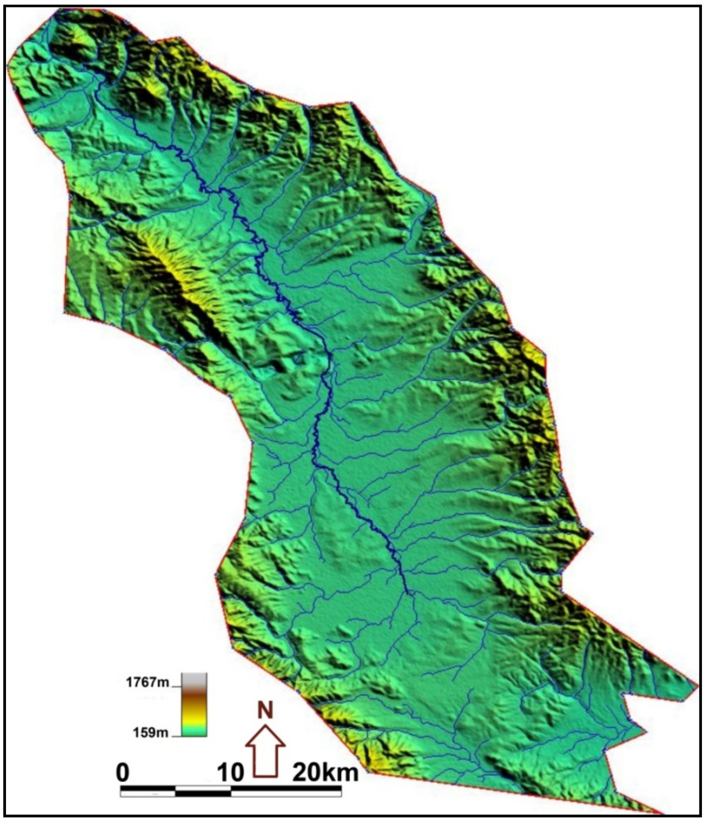

Figure 2 - Sitnica drainage network with hypsometric data derived from Digital elevation model with specific accuracy of 30 m

4. COMPARISON OF ANALOGUE AND DIGITAL GENERALIZATION ON THE EXAMPLE OF SITNICA RIVER

The Sitnica river ($L = 110$ km, $F = 2{,}861$ km^2) is the largest Ibar tributary, occupying the central place and is the largest river of Kosovo Polje. It runs through the bottom of the Kosovo valley, collecting the waters coming down from the edge taking them to the Ibar river. The Sitnica river network has been formed in an area of 2,861 km^2, taking 26% of the Kosovo and Metohija territory or taking 35% of the total Ibar flow area. The Sitnica waters only participate in the Ibar flow with 22.6 %, which indicates a low value of the Sitnica River and its tributaries (Ivanisevic, 1996). Our experts, who deal with the hydrological exploration of rivers, show some disagreement on the Sitnica spring. It is believed that the Topila River and the north Nerodimka leg should be taken for the Sitnica river legs. Plana thinks that the spring leg should be viewed as the river Topila, and Labus thinks that the Sitnica emerges at the village of Robovac from two streams, Sazlija (its right tributary) and Stimljanka (its left tributary) (Labus, 1978). However, it is the left tributary Stimljanka that should be viewed as the Sitnica spring. All the water flows of leading to the village of Rabovac comprise the upper stream of the Sitnica River. These are small rivers of little water quantity and a slight fall. They are often affected by drought in the summer.

5. DEM DATA FOR SITNICA RIVER DRAINAGE NETWORK

On defining the geographic position of Sitnica drainage network, what is done next is the download of LANDSAT satellite image applied onto a topographic map of the designated river Sitnica area. There are numerous methods and ways for inserting a DEM. One of the method is involves the drawing of contour lines on a particular topographic map. As the lines are sorted according to their altitude, with the major contour line being 100 m, and the basic ones 20 m, all the altitudes are sorted in a specially designated layer called Modify Feature Info. This is the place where the layer name and feature class are inserted, which are then stored. The line is designated a name as well as the name of the basic altitude parameters, (the altitude layer matters most without which the DEM cannot be initiated). The function where the layers are drawn is signed by the algorithm Elevation. It is enough to draw the altitude and put the letter where the altitude is marked, (x, y, z), for the software to recognize the altitude coordinate. On all the layers being inserted into the basis, all the lines are obtained which now need to be transferred into the area, so that the DEM altitudes will be derived from the lines, getting the effect of a Digital Elevation Model. The procedure is considerably more difficult to perform than the next one, but better results are achieved for being more precise. The next way for creating a DEM is its download from an available server. One of the possibilities involves is data download and transfer from the very software server (Global Mapper 16.1), which is to be found in the command called Download Online Data. When the window is opened following the command Aster GDEM, inside the very link, the data which can be viewed in various formats are downloaded, including DEM, GeoTiff, DEM/USGS, KML, OZI and ASCII. The selected area is cropped and along with the projection, the coordinate is determined, later to be stored in a PJR file. Global Mapper 16.1 later extracts the data from the DEM. After that, we selected special function (Generate Watershed) into software Global Mapper 16.1 to derive drainage network.

6. DRAINAGE SYSTEM OF THE SITNICA WITH POLLUTED TRIBUTARIES

By means of GeoMedia 6.1 professional programme, the whole Sitnica river system is presented through vectors on the grounds of topographic maps in proportion of 1:25,000, 1:300,000. The data of an analogue and a computer supported generalisation are compared. The degree of the very generalisation indicates the advantages and flaws of both generalisations (Brunner, 1997).

Computer assisted generalisation has certain similarities comparing analog and automatic generalisation such as: identity, general methods of generalisation, general principles of generalisation, special principles of water course generalisation. The only defect which is manifesting is a presence of stratified database within ASCII code

(Harrie and Weibel, 2001**)**. Then all attributes change so that the softwer could detect them with a help of some general algorithm like colors, with ASCII code, for example: what is the main watercourse and on what base the lines (their sizes) can be presented, so that the map is properly generalised. Digital cartographic generalisation is very active and fast when it comes to data processing, but it is fully possible if the person who is doing it well aware of all cartographic rules and regulations. Softwer GeoMedia 2.6.1 is used for digitizing of topographic map with scale 1:25,000. All map papers with rivers which belong to Sitnica river system are treated in same way. Segmental line generalisation was done on maps, and processed later with OriPro 8.1 software. The processing of all generalisation factors showed some deviations when it comes to generalisation algorithm (Muslims et al. 2006) It follows that if the scale is large error of generalisation will be smaller. There are some deviations from Table 1 in Sitnica drainage system. Some marked rivers have certain generalisation errors that could make serious problems during the use of map. Therefore some comparative methods were used to show that the best solution is to use both analog and digital methods in corelation, because there is no softwer which can fully replace human decisioning during generalisation process. After that we added the data file for sources of polluted tributary from period 1971-2005 (http://www.ammk-rks.net/?page=2,1) The all data of Sitnica drainage system with data of pollution is presented in (table 1). Other data we imputed into GIS software QGIS 2.6.1 and derived final digital vector map of Kosovo and Metohia with special view of Sitnica network system and their polluted tributaries (Figure 3).

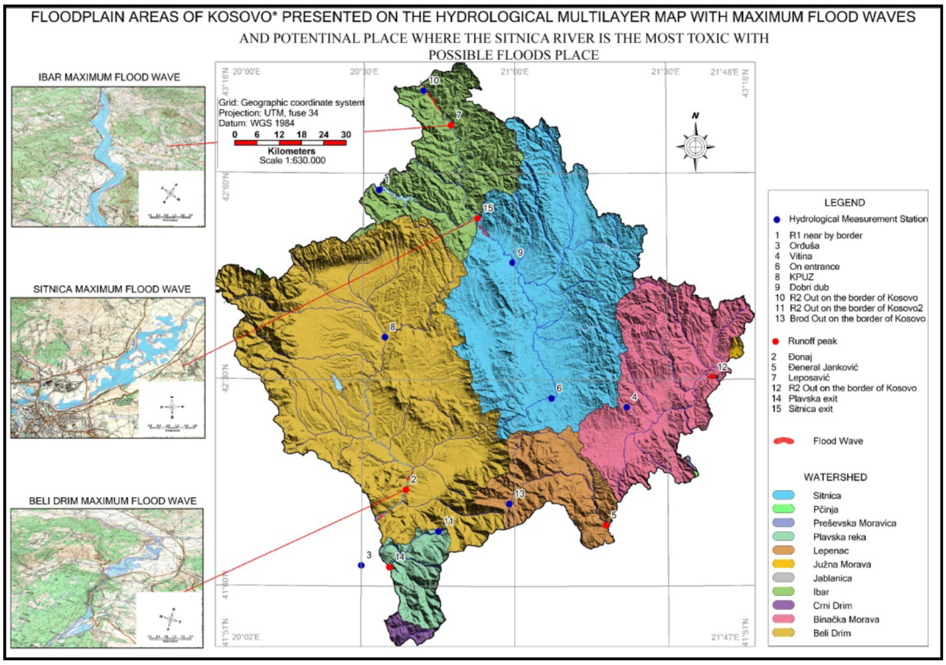

Figure 3 - Multilayer digital maps of Kosovo with potential flood waves on main rivers including the river Sitnica

Table 1 - Drainage system of Sitnica with data of generalization level, data of tributaries and their polution level

Name of river	Tributary to	Left bank tributary (L) Right bank tributary (R)	The polluted category of river	Length 1:50,000 Analog [km]	Length 1:300,000 Digital [km]	Length 1:50,000 Digital [km]	Length 1:25,000 Digital [km]	Generali-sation algorithm errors for map scales 1:25,000 and 1:300,000
Drenica	Sitnica	L	IV	41	42.9	39.2	42.1	
Nameless	Drenica	L	III	10	12.0	9.4	11.9	*
Klisura	"	L	III	6	6.2	5.7	5.8	
Nameless	"	L	III	5	5.4	5.3	6.1	*
Nameless	"	L	III	10	10.5	10.2	10.1	
Nameless	"	L	III	5	5.9	5.8	5.2	
Vrbica	"	L	III	25	24.7	24.6	24.1	*
Klisura	Vrbica	R	III	5	4.9	4.5	4.3	*
Nameless	"	R	III	5	5.4	5.2	5.1	
Ljug i Kršit	"	R	III	7	7.7	6.8	6.9	
Bog dalj	"	R	III	8	8.3	7.9	8.0	
Nameless	"	R	III	8	8.4	8.3	8.2	
Nameless	Drenica	R	II	2	2.5	2.4	2.3	
Nameless	"	R	II	5	5.6	5.4	5.2	
Nameless	"	R	II	10	10.8	10.6	10.5	
Nameless	"	R	II	6	7.4	7.2	6.9	
Gladni potok	"	L	III	10	10.8	9.7	9.5	*
Nameless	"	L	II	4	4.8	3.8	3.9	
Brosovačka	Sitnica	L	III	12	11.8	11.9	12.1	*
Nameless	Brosovačka	R	II	5	5.5	4.9	4.8	
Nameless	"	R	II	5	5.4	5.8	5.3	
Nameless	"	R	II	5	6.3	5.9	5.8	
Nameless	Sitnica	L	II	5	6.0	5.7	5.4	
Nameless	"	L	II	5	5.6	5.3	5.2	
Trstena	"	R	II	19	18.8	18.7	18.9	
Prodanče	"	R	III	9	9.2	9.1	9.0	
Nameless	Sitnica	R	III	9	10.0	9.5	9.2	
Smrekovnica	"	R	III	12	11.8	11.9	11.6	
Barska reka	"	R	III	15	16.7	16.6	16.4	
Vodovođa	"	L	III	10	11.8	10.9	10.7	
Grika	Vodovođa	L	III	8	8.8	8.6	8.4	
Magurska r.	Sitnica	L	II	9	9.4	9.4	9.1	
Žegovka	"	R	III	22	23.0	22.5	22.3	
Janjevka	"	R	III	16	17.8	16.9	16.5	
Oklapska	Janjevka	L	III	10	10.8	10.7	10.5	
Gračanka	Sitnica	R	III	17	17.8	16.6	16.9	
Labljanska	Gračanka	L	II	10	11.1	10.6	10.3	
Mramorska	"	R	II	5	5.5	5.9	5.2	
Androvačka	"	L	II	5	5.4	5.3	5.2	
Prištevka	Sitnica	R	III	20	20.8	19.8	19.9	

Table 1 (continued) - Drainage system of Sitnica with data of generalization level, data of tributaries and their polution level

Name of river	Tributary to	Left bank tributary (L) Right bank tributary (R)	The polluted category of river	Length 1:50,000 Analog [km]	Length 1:300,000 Digital [km]	Length 1:50,000 Digital [km]	Length 1:25,000 Digital [km]	Generalisation algorithm errors for map scales 1:25,000 and 1:300,000
Nameless	Prištevka	L	II	5	5.8	5.6	5.4	
Smrdan	"	L	II	5	5.8	5.5	5.3	
Kojilovačka	"	L	II	2	2.7	1.7	1.8	
Crni potok	"	L	II	1	1.8	1.6	1.4	
Baljevička	"	R	III	2	3.5	3.4	2.9	
Šljivaštica	"	R	II	1	1.8	1.6	1.9	
Lab	Sitnica	R	III	57	58.5	58.2	59.1	*
Brnjička	Lab	L	II	15	16.1	15.9	15.8	
Nameless	"	L	II	5	5.6	5.2	4.9	
Kaluđerica	"	L	II	5	5.9	5.6	5.2	
Batlava	"	L	II	20	20.1	20.0	20.2	
Trnavica	Batlava	L	III	8	8.9	8.6	8.4	
Šarbanska	Trnavica	L	IV	6	6.7	6.8	6.4	
Perovića	"	R	IV	6	7.0	7.1	6.9	
Sponca	Batlava	L	III	4	4.9	4.8	4.4	
Balabanska	"	L	III	9	10.8	10.4	10.2	
Kolićka	Balabanska	L	IV	2	2.3	2.5	2.2	
Pljeništa	"	R	IV	4	5.5	4.7	4.6	
Kačikolska	"	L	IV	6	6.8	6.5	6.3	
Brainska	Batlava	L	III	6	6.9	6.7	6.2	
Koljatička	"	R	III	6	6.6	6.5	6.2	
Turučička	"	R	III	10	11.9	10.9	10.8	
Nosovci	Turučička	L	IV	3	3.8	3.6	3.4	
Rakinička	"	L	IV	4	4.7	4.5	4.4	
Dražnja	"	R	IV	2	2.9	2.7	2.4	
Dubnička	Lab	L	III	24	24.9	22.7	22.9	
Mirovački p.	Dubnička	L	III	3	3.9	3.5	3.3	
Lauška	"	R	III	3	4.0	3.6	3.4	
Pakaštička	Lab	R	III	4	4.9	4.8	4.8	*
Nazurski p.	"	R	III	6	7.0	6.5	6.3	
Bradaška	"	R	III	14	14.8	14.6	14.4	
Nameless	"	R	II	15	15.6	14.7	14.8	
Kačandolska	"	R	III	30	31.2	29.6	29.1	*
Lešnica	Kačandolska	L	III	7	7.8	7.7	7.6	
Bajgora	"	L	IV	2	2.6	2.6	2.5	
Stara	"	R	III	4	4.9	4.7	4.4	
Kovačica	"	R	III	4	4.8	4.7	4.5	
Nameless	Lab	R	II	2	2.8	2.7	2.2	
Nameless	Lab	R	II	2	2.9	2.6	2.4	
Nameless	"	R	II	2	2.3	2.2	2.1	

Table 1 (continued) - Drainage system of Sitnica with data of generalization level, data of tributaries and their polution level

Name of river	Tributary to	Left bank tributary (L) Right bank tributary (R)	The polluted category of river	Length 1:50,000 Analog [km]	Length 1:300,000 Digital [km]	Length 1:50,000 Digital [km]	Length 1:25,000 Digital [km]	Generali-sation algorithm errors for map scales 1:25,000 and 1:300,000
Koskovik	Lab	R	III	6	6.8	6.6	6.5	
Đelbište	"	R	II	10	10.9	10.5	10.5	
Dubnica	Sitnica	R	II	13	13.4	13.3	12.8	
Crvena	"	R	III	15	16.9	15.5	15.9	*
Sudimljanska	"	R	III	10	10.8	10.7	10.6	
Repski potok	Lab	L	III	2	2.5	2.4	2.3	
Slatina	"	L	III	10	10.9	10.8	10.5	
Murgulska	"	R	III	17	17.8	17.6	17.5	
Jezerski p.	Murgulska	R	IV	3	3.9	3.8	3.4	
Žitinjska	"	R	IV	6	8.9	7.3	7.2	
Siljevička	Lab	R	III	10	12.7	11.6	11.2	

6. CONCLUSION

Cartography is a science which the most realizes changes because it more often are used modern computer technologies. GIS is a system which accelerate the development of technology, because the interface is moving maps from table to PC monitor. Visualization is containing process where the ultimate goal is production of maps, map doesn't need to be presented in analogical way, but is already completely digitized. Computer-supported generalization of rivers in Sitnica river systems had a goal to present effects of potentional pollution, but also to present results and levels of basic manual generalization, as well as to compare with effects of digital, computer-supported generalization. Territory of part of Sitnica river system was always interesting for studying in hydrological way, on which are compared parameters of rivers and their physical parameters. Generalization is a method which can be used in those purpose and the results can be applicable to various forms of digital maps. With modern technology devices and tools we derived best results and data processing is faster. DEM data is give as many view of maps and hydrological properties of Sitnica drainage network.

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