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METHODS OF AUTOMATED ALLOCATION
OF CATCHMENT BASINS ACCORDING TO DIGITAL ELEVATION MODELS
(ON THE EXAMPLE OF SKOLIV DISTRICT OF LVIV REGION)

Aim of the work. To develop a method of automated allocation of catchment basins and obtaining their hydrological and morphometric characteristics, which is based on digital terrain models. Methods and results of work. A necessary condition for the correct filling of the terrain is the presence of points of true flow at the edge of the settlement area (if the river flows into the lake, it should not enter the calculated area completely, otherwise incorrect results will be obtained). By performing the operation of filling the relief of the terrain, a new dem is created, which does not contain fictitious depressions and is used in the next step as input data to calculate the flow direction according to the algorithm d8. According to the proposed technological scheme it is necessary to process step by step the following six blocks: filling of closed depressions, calculation of runoff direction, calculation of total runoff, creation of point vector data set of closing points (mouth points), creation of watershed boundaries, raster-vector data conversion. Theoretical research tested the method of automated allocation of watersheds, namely the determination of hydrological and morphometric parameters of the terrain. The pools were ranked according to these parameters according to the existing classifications, a series of relevant thematic electronic maps was compiled. It should be noted that in Skole district of lviv region there are 590 catchment areas, and their area is 1407 km^2. Watersheds are classified by outcrop, namely low-mountain basins in the region of 6, their area is 7 km^2, medium-mountain 360, area 755 km^2, high-mountain 224, area 645 km^2. Pools are classified according to the average slope: the first category from 0–3 degrees, very gentle slopes – pools 27, area 7 km^2; the second category from 9–12 degrees, sloping slopes-pools of 128, the area 303 km^2; the third category from 12–15> degrees, steep slopes – pools of 225, the area 648 km^2. The accuracy between the reference and the original relief model was evaluated. We can say that sle = 0.63 m slope, sle = 5.43 m height. Scientific novelty and practical significance. The technological scheme of automated separation of catchment basins according to digital relief models for Skoliv district of lviv region is proposed and the method of separation of catchment basins is worked out. According to the developed method, maps of watercourses of different orders and their catchment basins and classification of basins by area on the territory of Skole administrative district, which can be used by local organizations on water resources, are constructed.

Key words: catchment basins, DEM, SRTM, morphometric characteristics, hydrological characteristics.

Introduction

A characteristic trend of recent times is the rapid expansion of opportunities for rapid updating of the database, as well as the growth of open spatial information. Basic spatial data (Open Street Map projects, VMap0, VMap1), space images with a resolution of 10–30 m (LANDSAT, SENTINEL), digital terrain models (SRTM, ASTER GDEM), a number of thematic data sources are freely available. All this creates excellent conditions for the development of GIS technologies by specialists of various profiles who work with spatial data.

Information about the quantitative characteristics of the terrain, expressed through its morphometry, is a necessary condition for solving a wide range of scientific and applied problems. Most often, the characteristics of the terrain are involved in the monitoring of exogenous natural hazards. They are used for landscape analysis of the territory and its zoning, in the search for mineral deposits, in assessing the geoecological condition of the territories. With the advent of global digital terrain models based on remote sensing of the earth from space, which are based on regular coordinate grids, the vector of geographical research has fundamentally changed,

which gave a new qualitative impetus for quantitative analysis of various parameters of the earth.

A catchment area is an area on the earth's surface into which surface or groundwater flows, which affects environmental change. Ecological characteristic changes can be investigated using the method of automated determination of hydrological and morphometric characteristics by digital terrain model (SRTM), using appropriate software. Therefore, the characteristics of watersheds can be determined by SRTM radar survey.

The catchment area of each reservoir includes surface and groundwater. A surface catchment basin is a section or area of the earth's surface from which water on the earth's surface enters a separate river system or enters a river. Groundwater catchment forms a loose layer of sediment, from which water enters the river network. Under normal circumstances, surface basins and groundwater basins do not overlap, so it is very difficult to define the boundaries of groundwater basins. Therefore, the size of the pool can be considered only as a surface catchment area. Reservoirs differ in hydrological and morphometric characteristics, which include the position of watercourses, the area of elementary basins and watersheds, the angle of inclination, demarcation of territories.

The traditional data source for the calculation of these parameters are maps and survey results. But there is an alternative way to obtain hydrological and morphometric characteristics of watersheds, which is based on digital terrain models. If this process is automated, it will significantly reduce the time spent on obtaining the necessary parameters.

Digital elevation models are now widely used by professionals working in a variety of areas of geography and geomorphology. One of the most important tasks to be solved with the help of the DEM is the automated allocation of the boundaries of catchment basins, as well as the determination of their main hydrographic characteristics. The high importance of these procedures is due to the variety of fundamental and applied problems, in solving which the basin approach is used, the role of which is currently only growing. The reasons for this are the possibility of using modern information technology, the availability of digital models of the Earth's surface and information on basic hydrometeorological parameters for the entire planet. All this allows us to

study using GIS natural processes and phenomena at different levels of generation.

A significant number of both domestic and foreign scientists deal with applied issues in the allocation of watersheds with the help of GIS technologies.

For example, the article [Maltsev, & Yermolaev, 2014] presents and proposes a comprehensive approach for estimating sludge feed rates. The method includes morphometric analysis of watersheds, mathematical modeling and application of radar monitoring. The effectiveness of the approach is demonstrated by the analysis of the slopes of the Lokna river basin. Morphometric data are collected, the LS coefficient for the treated mountain slopes is calculated and the value of the potential sediment deposition from the foothill slopes in the river valley in the conditions of no-fire and typical yield is determined. Morphometric mapping of the slopes of catchment basins allowed to determine areas with high and very high erosion potential. The use of radar monitoring allowed to confirm the effectiveness of the method and to formulate some ways to improve the approach.

The article [Yermolaev, et al., 2012] considers general theoretical and methodological issues of creating and using a global geographic information system, which reflects the basic patterns of formation and spatio-temporal variability of the flow of suspended sediments of the Earth's rivers. The role of the river basin as a geosystem approach to the study of sediment runoff is shown. Approaches to automated delimitation of river basin boundaries, methods of integration of geoinformation system and thematic databases for the purposes of geomorphological analysis of the flow of suspended river sediments are proposed and tested.

The study [Kinnell, 2005] presents and proposes a method for calculating the slope length coefficient that does not meet other criteria. It is shown that alternative approaches that take into account the contribution of the lifting section to the determination of the slope length coefficient, when the runoff coefficient of the runoff coefficient upwards varies from the cell level, meet both criteria.

The article [Lindsay, 2014] presents the tools of geospatial analysis of GIS Whitebox with open source, highlights some of its capabilities and design goals. Learn how these tools are used to select hydrographic features.

The study [Maltsev, et al., 2015] presents the mapping of river sediment yields on a continental or global scale, and points to a number of technical difficulties that have been largely ignored. Maps should show large zonal features of the river sediment crop, as well as the level of (smoothed) local anomalies.

The study [Maltsev, et al., 2012] presented the potential use of GIS and related databases for mapping and analysis of global sediment yield models.

The article [O`Callaghan, & Mark, 1984] presents the extraction of drainage networks from digital altitude data important for quantitative research in geomorphology and hydrology. The method of extraction of drainage networks from mesh altitude data is presented. The method processes artificial pits introduced by data collection systems and extracts only the main drainage channels.

The publication [González-Díez, 2000] presents land use planning. It requires consideration of various alternatives in land use, which provide for different spatial distributions to assess their effectiveness in terms of resource use and environmental impact. Environmental impact assessment can help identify the most appropriate alternatives at an early stage of planning.

The article [Damoiseaux, 2000] provides digital satellite images that provide important qualitative data for displaying, inventorying, monitoring, and describing terrain. The article focuses on the use of images from different satellite sensors for topographic mapping, terrain modeling and evaluation of the accuracy of the results of the analysis of different data sets.

The research [Arthur N. Strahler, 1957] presents quantitative geomorphological methods developed over the past few years that provide a means of measuring the size and shape properties of watersheds. The two general classes of descriptive numbers are, first, linear scale measurements, by which geometrically similar units of topography can be compared in size; and secondly, dimensionless numbers, usually angles or ratios of measures of length, by which the shapes of similar units can be compared regardless of scale. Linear scale measurements include the length of the flow channels of a given order, the drainage density, the service constant of the channel, the perimeter of the basin. Dimensionless properties can be related to hydrological and sediment yield data, which are given as masses or volumes of the flow rate norm, regardless of the total catchment area.

The article [Bors, 2001] presents the construction of a relief model that provides the selection of hierarchical units of its surface. Differences in natural ecological properties and potential geophysical characteristics make it possible to compare potential and real (in thermodynamic conditions of specific morphological systems) geophysical fields. Such sampling allows to construct vector fields of gradients of geophysical fields of geosystems, to reveal parameters of the order of self-organization of geosystems and to investigate regularities of drawing up of their vertical and horizontal structure.

The system of vertical hierarchy of relief objects with their corresponding parametric descriptions corresponds to the following number of spatial units: morphological structure (hierarchy of tectonic blocks, nodes) – morphoclimatic region (type of exogenous relief) – hierarchy of relief surface objects. The selection of the hierarchy of objects of the class of tectonic structures that control the formation of modern relief at the level of morphological structures is carried out according to the method of morphostructural zoning (MCR) (E.Ya. Rantsman and MP Glasko), hierarchy of objects.

Also, geomorphological processes have been studied in [Bussettini, et al., 2014; Fuller, et al., 2013; González del Tánago, et al, 2015; Meitzen, et a, 2013, Rinaldi, et al, 2013].

Aim

The aim of the work is to develop a method of automated selection of catchment basins and obtain their hydrological and morphometric characteristics based on digital terrain models.

Methodology and results of work

Automated determination of hydrological and morphometric parameters of the watershed according to the digital relief model SRTM

With the help of Spatial Analyst tools in ArcGIS, the "hydrology" group, you can determine the order of watercourses and the length of flow lines. all standard algorithms for creating DEM, and are always available in terrain models obtained from remote sensing.

A necessary condition for the correct filling of the terrain is the presence of points of true flow at the edge of the settlement area (if the river flows into the lake, it should not enter the calculated area completely, otherwise incorrect results will be obtained). By performing the operation of filling the terrain depression, a new DEM is created, which does not contain fictitious terrain depressions and is used in the next step as input data to calculate the flow direction according to the algorithm D8.

Figure 2 shows a block diagram of the allocation of watersheds by DEM.

Calculation of the direction of runoff.

This method is based on the assumption that the flow formed in any cell is completely directed to one of the eight adjacent cells (which has the lowest height). As the input raster for calculating the direction of flow is used DEM with filled local depressions. The flow vector is determined by the direction of the steepest descent or maximum descent. If the maximum decrease in height to the nearest cells is the same in several directions, the neighborhood expands until the steepest descent is found. If the direction of the steepest descent is found, the original cell is given a value representing that direction. The input of the flow direction tool is an integer raster, the values of which are in the range from 1 to 128. In essence, this raster is an exposure of the slope, classified by eight rhumbs. Their values in the raster are coded as follows: 1 – East, 2 – South-

East , 4 – South, 8 – South-West, 16 – West, 32 – North-West, 64 – North, 128 – North-East (Fig. 1). The flow direction raster is used in the next step to calculate the Flow Accumulation. As additional input data, a reduction raster can be created, which characterizes the ratio of the maximum height change for each cell along the flow direction to the distance between the centers of the cells.

Calculation of total runoff

The function allows you to calculate the area for each cell of the pixel of the input raster of the total flow and displays the number of cells through which the conditional water flow moves to a given cell (catchment area for each cell).
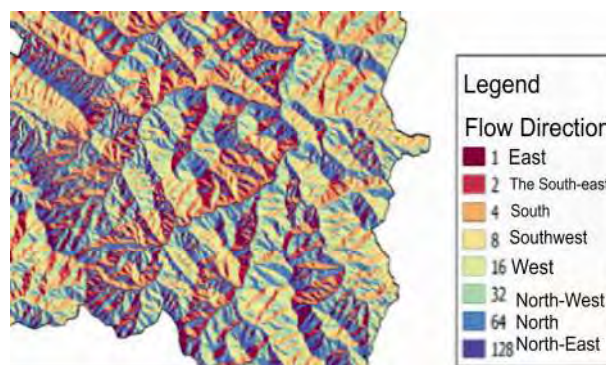

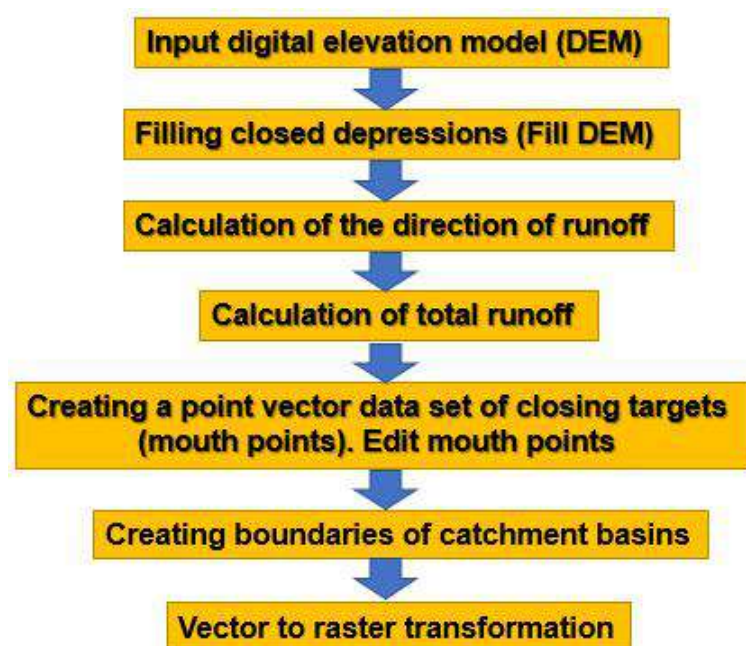*Fig. 1. The result of calculating the flow direction*

Fig. 2. Block diagram of watershed allocation according to the digital terrain model in ArcGIS

Values n the input raster that reflect significant flow accumulation can be used to identify watercourses. In turn, cells with a total runoff of zero can be used to identify ridges or watershed lines. As a result of raster contrast, the lines of watercourses corresponding to high values in the cells of the total flow are better visible.

The raster calculated by the DEM is a source for creating a raster model of a network of watercourses (drainage), and the very concept of a raster network of watercourses means some coherent set of thalweg cells.

The degree of generalization of the raster network of watercourses depends on the choice of the critical value of the catchment area. There are several ways to get cells from a raster that relate to watercourses: using the condition tools (Con) and set Zero (Set Null), (Arc Toolbox, Spatial Analyst group), or using a raster material calculator (Spatial Analyst tool group, subgroup). algebra of maps.The results obtained by these tools allow you to set Zero (Set Null) to extract the network of watercourses.

According to the results of using this tool, all watercourses in which the value of runoff accumulation is more than 2000 are distinguished (Fig. 3).
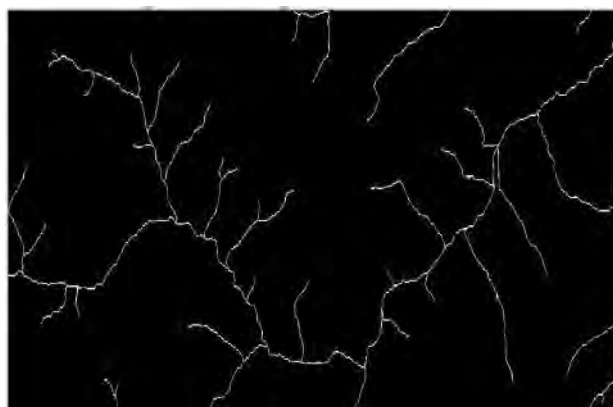

Fig. 3. Watercourses received on a raster of accumulation of a drain

In the next stage – the selection of catchment basins, the creation and editing of vector or raster data at the points of the mouth (closing lines). The easiest way to set closing loops manually as point vector objects, namely when creating a vector set of data points of the mouths, keep in mind that its coordinate system must be the same as that used by the DEM. The locking line can be installed in any cell of the raster of the total runoff. Due to this, you

can select a catchment pool of any size (catchment to any last in the line of hydro post). The points of the mouths are edited so that they are exactly on the axis of the calculated watercourses (drainage).

It is necessary to pay attention to various lateral tributaries and not to put points in places of their mouth (as in this case the water catchment not of the whole river, and its tributaries will be allocated). In the ArcGIS toolkit, you can simultaneously select multiple watersheds. A necessary condition for this is to specify the closing sights for all selected catchments. Dedicated watersheds should not be included in each other as components, so you need to consider the order of watercourses. You can determine the order of watercourses using the Stream Order tool in the "hydrology" group of the Spatial Analyst module.

The watercourse order method involves assigning a sequence number of connections in a watercourse network based on the number of their tributaries. The watercourse order tool allows the use of two calculation methods. The most commonly used method is Straler. In this method, all segments of watercourses that do not have tributaries are assigned the first order. The order increases only if the watercourses merge with the same order. Therefore, after the merger of the first and second order segments, the resulting watercourse will be a second-order watercourse, and the merger of two watercourses of different orders will not lead to its growth (Fig. 4).
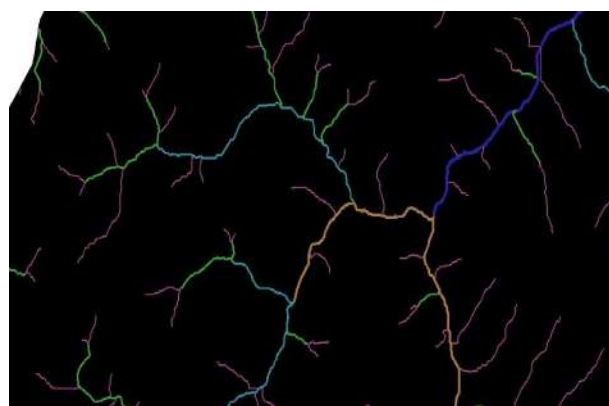
Fig. 4. The method of determining the order of watercourses by the method of Straler

In the use of the Shreve method, the orders of watercourses are additive. For example, when two first-order ties intersect, a second-order connection is created, when a first- and second-order connection intersects, a third-order connection is created, and when a second- and third-order connection intersects, a fourth-order connection is created. .

The Stream to Feature tool is used to obtain vector watercourse lines. After starting the tool, vector lines of watercourses are added to the table of contents. In Fig. 5. reflected watercourses in accordance with their order from 1 to 5.
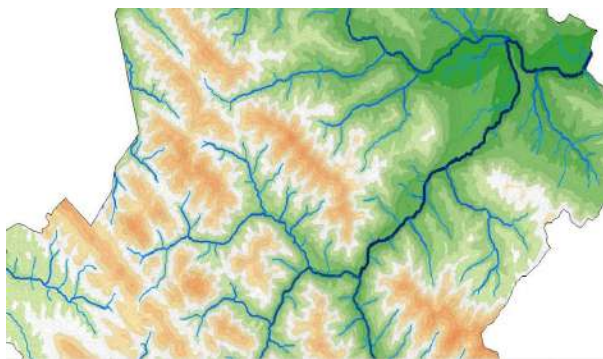

Fig. 5. Classified vector lines of watercourses

Selection and division of mouth points

The catchment area in the working process of hydrological analysis of the DEM is built for one point. If you choose the mouth of the river as a point, the resulting pool will correspond to the basin of the whole river. However, if the mouth is the confluence of two watercourses, a pool common to both watercourses will be built. The problem can be solved by slightly shifting the end points of watercourses upstream.

To build around the points of small buffer zones with a radius of 2R, where R is the cell size of the DEM raster (DEM resolution), run the Buffer tool, which is responsible for the construction of buffer zones and set the radius parameter in 2R (200 m) (Fig. 6). The resulting buffer zones cut off the source lines of watercourses, thus reducing them (Fig. 7).
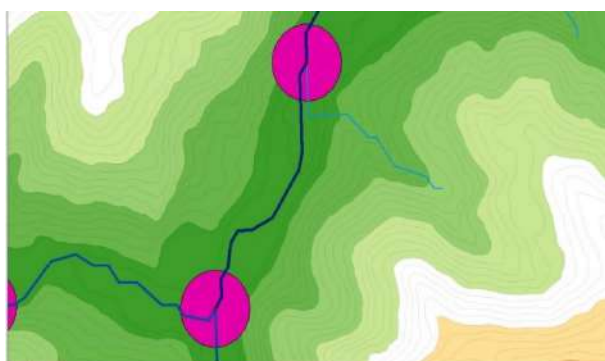

Fig. 6. Buffer zones with a radius of 200 m at the end points of river sources

Using the Feature Vertices to Points tool again, endpoints were constructed for the cut watercourses of the rivers, which do not coincide for each pair of tributary alignment (Fig. 8). The given sequence of actions is a classic example of interpretation of the task in terms of GIS analysis tools.
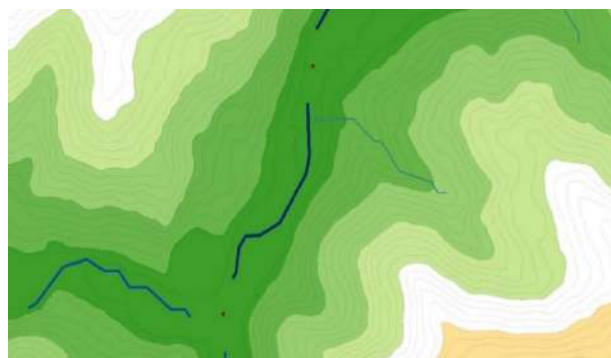

Fig. 7. The result of pruning the sources of rivers in the buffer zone

Fig. 8. Merger points are displaced upstream

Construction of catchment areas

Construction of catchment basins consists of three operations: binding of mouth points to the raster of accumulation of runoff, carrying out of borders of catchments in the raster mode, vectorization of pools. The search radius is specified, within which a cell with the maximum accumulation of runoff will be around each given point of the mouth. In this case, it was equal to 100 meters – the expansion of the DEM.

To construct the boundaries of catchment basins, a raster image with a unique color is created to interpret the boundaries of the basins (Fig. 9).

The resulting pools are converted into vector polygons. The result of the conversion is shown in Fig. 10.
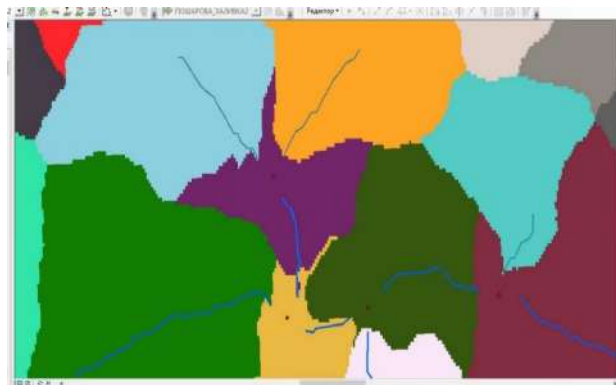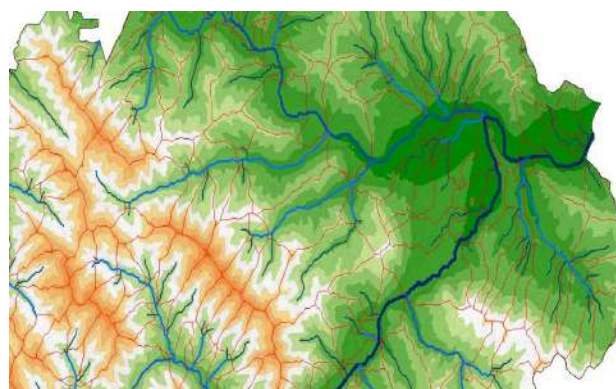
Fig. 9. Raster layer of catchment pools

Fig. 10. Vector layer of watersheds

Obtaining statistics of watersheds

Within the boundaries of watersheds, it is possible to calculate statistics according to the DEM. Statistics on heights and a slope are calculated. Next, these statistics are attached to the source layer of the basins (Fig. 11).

OBJECTID *	ID	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	1	1	10000	220.3973	220.3973	0	220.3973	0	220.3973
2	2	1	10000	222.6155	222.6155	0	222.6155	0	222.6155
3	3	1	10000	241.1273	241.1273	0	241.1273	0	241.1273
4	4	850	8500000	145.4833	222.8799	77.39661	184.5493	23.09977	156866.9
5	5	1	10000	260.4547	260.4547	0	260.4547	0	260.4547
6	6	1	10000	244.5152	244.5152	0	244.5152	0	244.5152
7	7	2198	21980000	195.7846	261.7631	65.97845	240.3712	14.64094	528335.9
8	8	1	10000	241.6034	241.6034	0	241.6034	0	241.6034
9	9	2	20000	142.9754	150.9643	7.988922	146.9699	3.994461	293.9398
10	10	4	40000	160.6833	188.5732	27.88995	174.1799	9.957454	696.7195
11	11	1	10000	195.6826	195.6826	0	195.6826	0	195.6826
12	12	2164	21640000	124.9571	220.0333	95.07621	192.3886	17.46154	416328.9
13	13	5754	57540000	140.0826	223.0824	82.99973	184.8574	19.06441	1063669
14	14	2193	21930000	187.991	261.956	73.96495	238.3093	13.8947	522612.3
15	15	3	30000	188.2518	198.1561	9.904282	192.2685	4.254304	576.8055
16	16	4948	49480000	174.5771	260.5574	85.98032	220.4731	15.47697	1090901
17	17	4583	45830000	201.0031	244.6497	43.64661	229.2684	9.123389	1050737
18	18	9800	98000000	149.3031	261.1561	111.8531	212.5401	22.67742	2082893
19	19	3784	37840000	160.5399	252.5933	92.05331	229.2196	18.16866	867367.1
20	20	2208	22080000	187.3759	261.8065	74.4306	234.981	13.9175	518838.1

Fig. 11. Table of statistics on watersheds

After receiving the table of statistical data, you need to attach them to the source layer in the key field ID.

The area of catchment basins was also calculated, for this purpose a table of attributes was opened in the catchment layer and a new field (shape_ area_km^2) was created in which the area was calculated using the context menu of the field to calculate geometry (Fig. 12).

Calculation, binding and visualization of statistics on watersheds.

On the territory of Skole district of Lviv region, 590 basin geosystems have been identified, which include both small river basins and their tributaries. The analysis of the main morphometric indicators of the relief of the basins of the administrative district is carried out. Initially, the main statistical indicators (minimum, maximum, mean, standard deviation (SCR)) were calculated, and frequency histograms were constructed (Figs. 13, 14). Also, the indicators were ranked according to the existing classifications or expertly in the absence of such. According to the classifications, the corresponding thematic maps for each indicator are constructed.
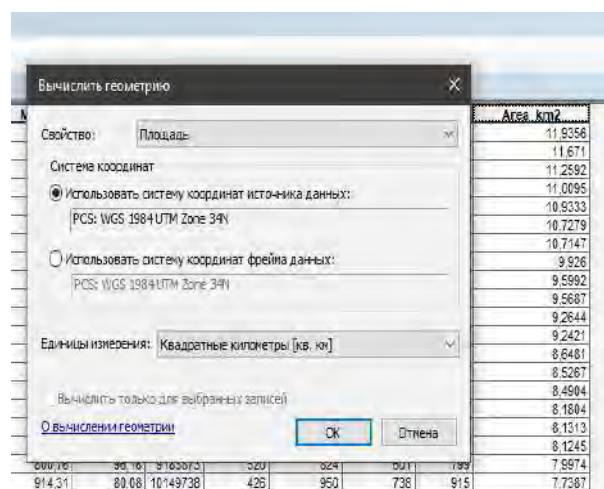

Fig. 12. Calculation of catchment area

Average height (Fig. 16). When ranking pools by average height (Tables 1, 2), the standard classification of relief by absolute height was performed. As all pools with an average height below 400 m are located in the area, they were classified as low-mountain.

Area (Fig. 17). Since the catchment areas in the study area are small, the standard classification of relief by the average area is performed (Fig. 15, Table 3).
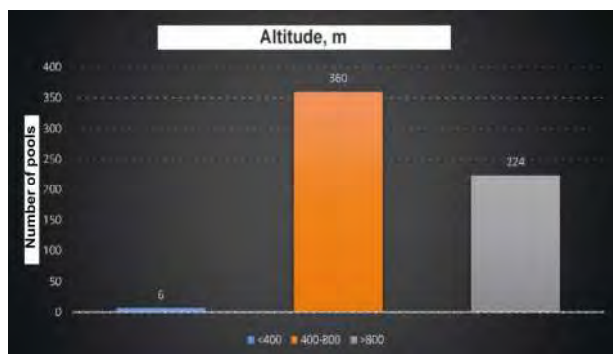
Fig. 13. Distribution of pools by height
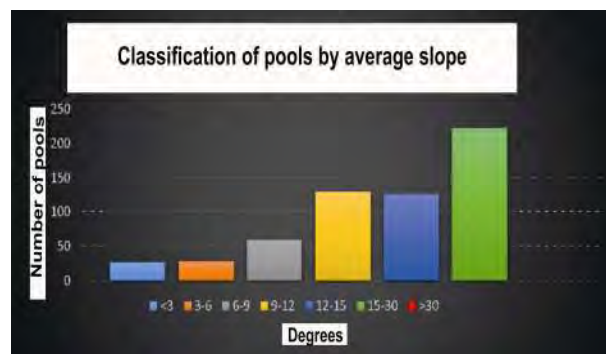
Fig. 14. Distribution of pools on an verage slope

Table 1

Classification of pools by height

Average height, m	Shape relief	Number of pools, pcs	Share of the total quantity,%	Area, km²	Share of total area,%
<400	Low mountain	6	1.02	6,76	0.48
400-800	Middle mountain	360	61.02	755.55	53.69
>800	High mountain	224	37.96	645.01	45.83
Total		**590**	**100**	**1407.32**	**100**

Table 2

Classification of pools by average slope

Average height, m	Shape relief	Number of pools, pcs	Share of the total quantity,%	Area, km²	Share of total area,%
<3	Very gentle slopes	27	4.58	7.11	0.61
3-6	Sloping slopes	29	4.92	16.88	1.35
3-9	Slightly sloping slopes	59	10.00	100.61	7.25
9-12	Sloping slopes	128	21.69	302.54	21.69
12-15	Strongly sloping slopes	125	21.19	313.99	22.48
15>	Steep slopes	222	37.62	648.16	46.62
Total		**590**	**100**	**1407.32**	100
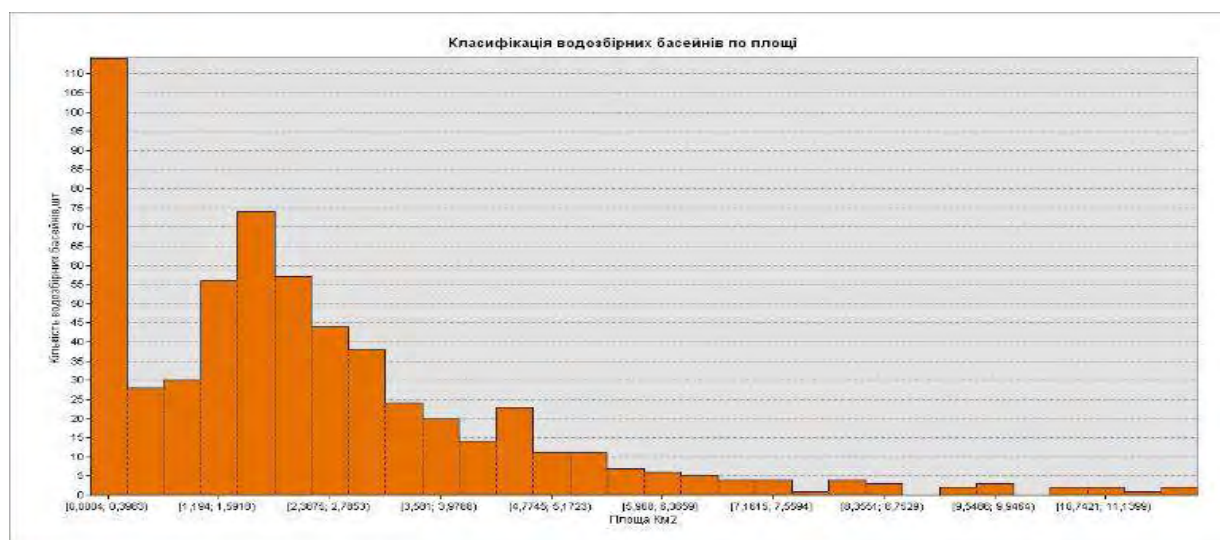
Fig. 15. Distribution of pools on the average area

Table 3

Basic statistics (area, km^2)

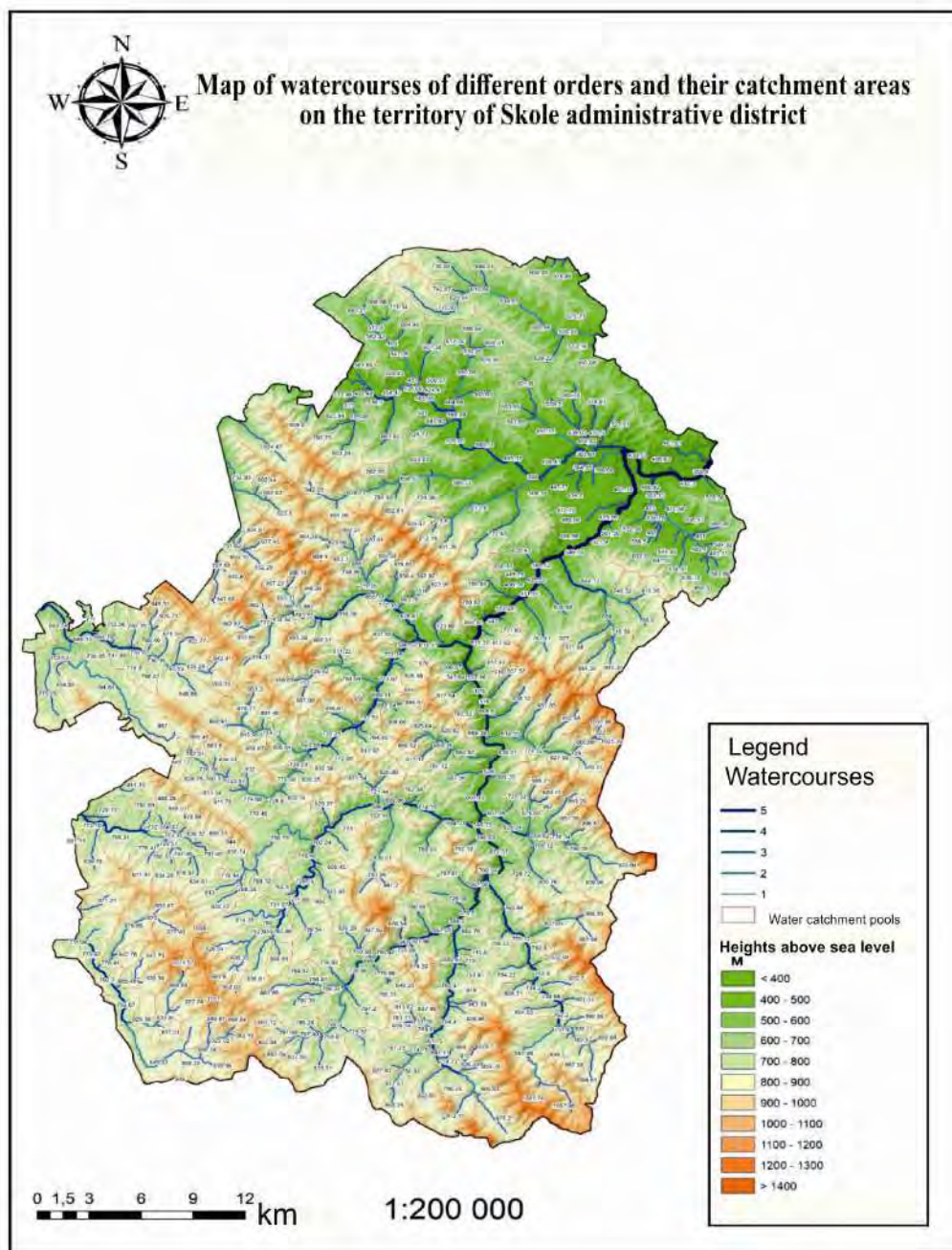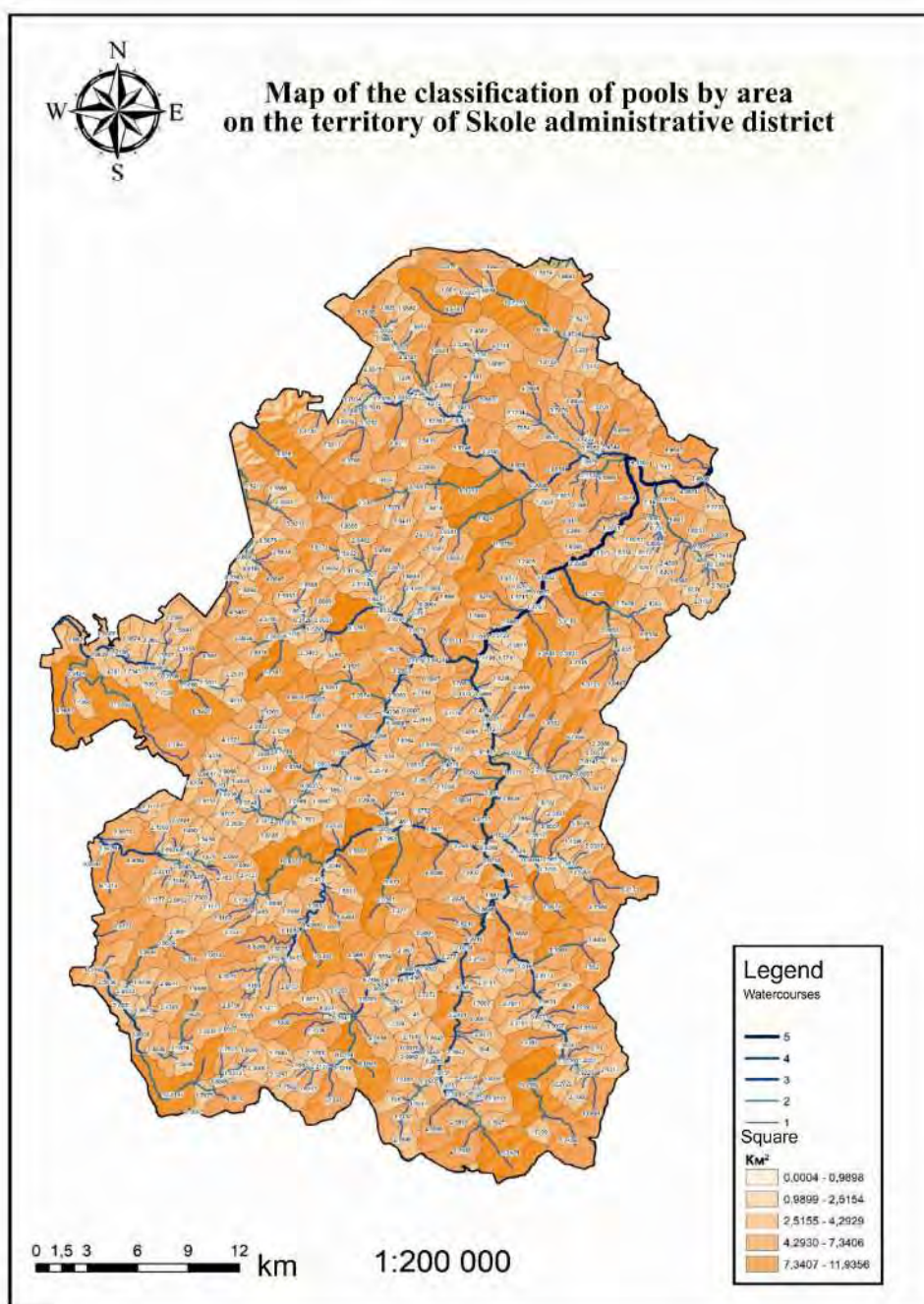| minimum	0.000447
maximum	11.9356
average	2.3852
median	702.44
mode	736.87
SLE	2.1645

*Fig. 16. Map of watercourses of different orders and their catchment areas
on the territory of Skole administrative district*

*Fig. 17. Map of the classification of pools by area
on the territory of Skole administrative district*

Accuracy assessment.

The accuracy of the obtained morphometric characteristics is primarily related to the accuracy of the input DEM. As only 1:100000 scale maps (larger scale maps are classified or restricted in use) or SRTM data, which are more accurate than maps of this scale, are freely available for the analysis of the relief of large parts of Ukraine, it was decided to use the global digital model. According to the literature, the average absolute error in SRTM height is less than 10 m. According to the consolidated report of the variation of ASTER GDEM data, the average height accuracy is about 20 m. (1:50 000). On these data in the ArcGIS program by means of the Topo to Raster tool the DEM is constructed. In order to exclude from the estimation the errors associated with generalization, the spatial distinction of the reference DEM was also set to 100 m.

The accuracy of two parameters was evaluated: absolute height and slope. The depth directly depends on the absolute height. A raster of inclinations in degrees is constructed on the reference DEM. Using a raster calculator, the difference between the reference and the original DEM was calculated to estimate the accuracy of the heights and the difference of the slopes. In this way, the error values were obtained and then their standard statistical analysis was performed (Tables 4, 5).

Table 4

Slope error (m)

minimum	7.29
maximum	3.91
average	-0.099
median	-0.07
SLE	0.63

Table 5

Height error (m)

minimum	-36.76
maximum	28.74
average	1.79
median	2.89
SLE	5.34

It is taken into account that the maximum and minimum errors are primarily the result of boundary effects. It was found that 98 % of height errors are in the range from -11 to 12 m, and 98 % of slope errors – in the range from -2 to 1.5 degrees. The obtained results are within the expected accuracy of the input DEM, which allows us to assert the reliability of the calculated morphometric parameters at this level of generalization.

Scientific novelty and practical significance

This work presents more research on the practical solution of the applied problem. The solution of the set task according to the technological scheme is executed in the ArcGIS software with use of modules of other small softwares. The scientific novelty lies in obtaining and practical substantiation of quantitative indicators of catchment basins, which was given for the first time with this accuracy for this region.

The technological scheme of automated allocation of catchment basins according to digital relief models on the example of the territory of Skole district of Lviv region is offered and the technique of allocation of catchment basins is worked out. Maps of watercourses of different orders and their catchment basins were constructed according to this method. The classification of basins by area into the territory of Skole administrative district has been carried out. These results can be used by local water resources organizations to solve thematic tasks, including monitoring studies.

Conclusions

As a result of experimental and theoretical researches the technique of the automated allocation of catchment basins, namely definition of hydrological and morphometric parameters of a relief is tested. The pools were ranked according to these parameters in accordance with the existing classifications, a series of relevant thematic electronic maps was compiled. It should be noted that in Skole district of Lviv region there are 590 catchment areas, and their area is 1407 km^2. Reservoirs are classified by height, namely low-mountain basins in the region (6 units, area 7 km^2), medium-mountain (360 units, area 755 km^2), high-mountain (224 units, area 645 km^2).

Pools are classified by average slope: the first category from 0–3 degrees, very gentle slopes – (27 pools, area 7 km^2), the second category from 9–12 degrees, sloping slopes (128 pools 128 pieces, area 303 km^2), the third category from 12–15> degrees, steep slopes (225pools, area 648 km^2).

The accuracy between the reference and input relief model was evaluated, namely for the slope of SLE = 0.63 m, and for the height of SLE = 5.43 m area. Based on them, a geobase is formed, which can be used for hydrological and geomorphological modeling, geo-ecological assessment of the territory, and the creation of landscape maps.

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МЕТОДИКА АВТОМАТИЗОВАНОГО ВИДІЛЕННЯ ВОДОЗБІРНИХ БАСЕЙНІВ ЗА ЦИФРОВИМИ МОДЕЛЯМИ РЕЛЬЄФУ (НА ПРИКЛАДІ СКОЛІВСЬКОГО РАЙОНУ ЛЬВІВСЬКОЇ ОБЛАСТІ)

Мета. Вдосконалити методику автоматизованого виділення водозбірних басейнів та отримання гідрологічних та морфометричних характеристик на базі цифрових моделей рельєфу. Методика і результати роботи. Необхідною умовою коректного визначення пониження рельєфу місцевості є наявність точок істинного потоку на краю розрахункової області (якщо річка впадає в озеро, то воно не повинно входити в розрахункову територію цілком, в іншому випадку будуть отримані невірні результати). За допомогою виконання операції визначення пониження рельєфу місцевості створюється нова ЦМР, яка не містить фіктивних понижень рельєфу. На наступному кроці вона використовується в якості вхідних даних для розрахунку напрямку потоку по алгоритму D8. За запропонованою технологічною схемою необхідно опрацювати покроково наступні шість блоків: заповнення замкнутих депресій, розрахунок напрямку стоку, розрахунок сумарного стоку, створення точкового векторного набору даних замикаючих створів (точок гирла), створення границь водозбірних басейнів, растрово-

векторне перетворення даних. В результаті експериментальних та теоретичних досліджень апробовано методику автоматизованого виділення водозбірних басейнів, а саме визначення гідрологічних та морфометричних параметрів рельєфу. Проведено ранжування басейнів за цими параметрами відповідно до існуючих класифікацій, складена серія відповідних тематичних електронних карт. Необхідно сказати, що в Сколівському районі Львівської області розташовано 590 водозбірних басейнів, а їхня площа становить 1407 км^2. Водозбірні басейни класифіковані за вистою, а саме: низько-гірських басейнів в регіоні 6 шт, площа їх становить 7 км^2; середньо-гірських – 360 шт, площа 755 км^2; високо-гірських – 224 шт, площа 645 км^2. Класифіковано басейни за середнім ухилом: перша категорія – це дуже пологі схили (0–3 градуси) – 27 басейнів, площа 7 км^2; друга категорія – це покаті схили (9–12 градусів), 128 басейнів, площа 303 км^2; третя категорія – це круті схили (12–15 градусів і більше), 225 басейнів, площа 648 км^2. Проведено оцінку точності між опорною та вихідною моделлю рельєфу. Отримано для ухилів СКВ = 0,63 м, для висоти – СКВ = 5,43 м. Наукова новизна і практична значущість. Запропоновано технологічну схему автоматизованого виділення водозбірних басейнів за цифровими моделями рельєфу на прикладі Сколівського району Львівської області та опрацьовано методику виділення водозбірних басейнів. За опрацьованою методикою побудовані карти водотоків різних порядків та їх водозбірних басейнів і виконано класифікацію басейнів по площі на територію Сколівського адміністративного району. Ці результати можуть бути використані місцевими організаціями для моніторингу водних ресурсів.