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Elevation modelling of an area of the Siverskyi Donets riverbed (near Haidary village, Chuguyevskiy district, Kharkiv region)

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ABSTRACT

Formulation of the problem. The article represents the practical experience of the bottom echo sounding and processing of the data received for digital elevation modelling. The relevance and specificity of using sonar equipment to study the specificity of the morphology of the underwater relief of small hydrological features are covered. The domestic and foreign publications in this area are analysed, and therefore the conclusion of the issue being not studied enough in domestic sources is made.

Methods. The analysis of literature sources on modelling the river network, visualization of relief models. The bathymetric survey data was used to compile a bathymetric map of the river and build a digital elevation model.

The purpose of the article is sharing developer experience in making of digital elevation models of a section of the riverbed on the example of the Siverskyi Donets River (near Haidary village, Chuguevskiy district, Kharkiv region). Processing of measurement data received as a result of echo sounder surveys. Preservation and recording of general information received to expand the river bottom relief database. Provide an overview of the uses and applications of geoinformation technologies, determine the research prospects based on the developed digital elevation models.

Results. The results of echo sounding and post-processing of the data received using specialized software are presented. The section of the Siverskyi Donets River in the area of the geographical educational and scientific station «Haidary» was chosen as the territory for the hydrographic research (Haidary village, Chuguevsky District, Kharkiv region). The field part of the research was conducted using the equipment of the material and technical basis of the Physical Geography and Cartography Department of the V. N. Karazin Kharkiv National University, for instance using the Lawrance Elite 7 TI chartplotter-echosounder with modern scanning modes CHIRP, DownScan, StrucureScan.

Scientific novelty and practical significance. The specificity of creating and visualizing in the ReefMaster software package is covered in the article. A model of the bottom of the corresponding section of the Siverskyi Donets River and a depth map, which will allow the future analysis of the dynamics and the prediction of changes of the bed configuration, have been developed on the basis of the field work results. The advantages of using budget equipment and software for performing underwater relief studies of such hydrological objects are formulated. The novelty of the study is not only the use of the methodological foundations of digital modelling, but also the alternative classification approaches for describing the relief and conducting morphostructural analysis based on the GIS technologies.

***Keywords**: digital elevation model, echo sounder, the Siverskyi Donets, hydrography, bathymetry, map, sonar.*

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Introduction. Modern hydrography has undergone radical changes in recent years, mainly due to the massive introduction of personal computers, satellite navigation technologies and the creation of new sonar tools based on the digital methods of primary and secondary information processing, as well as data registration in digital form. All this facilitated a radical increase in the amount of hydrographic information, which made it possible to receive data on the underwater relief with almost the same accuracy as topographic methods of land survey provide [21, 2].

Geoinformation technologies are widely used in hydrology, considering the main hydrological tasks are distinctly spatial. Currently, there are a lot of developed geographic information systems (GIS) and similar applications-driven technologies. In turn, they have different purposes, means for organizing data, and territorial coverage [7].

Relevant researches, developments and research-based technologies of studying the bottom of water areas and various underwater objects (including potentially dangerous ones) by sonar in the ocean, on the shelf and inland waters, are implemented to increase the effectiveness of underwater research, as well as emergency prevention and monitoring of the environmental situation. In this case, technology is understood as a set of software and

hardware resources, as well as a science-based method of their formation and use for researches, including mapping the relief, objects, their parts, studying morphology, recording changes and sizes of landforms, objects, and trends in their dynamics.

Accurate digital elevation models of riverbed are a fundamental instrument of river research. Through the research area has a wealth of hydrological objects, it will be especially appropriate to conduct more fundamental multidimensional bathymetric researches of the Siverskyi Donets River at modern scientific and technical levels, the results of which would be suitable for further practical use.

Formulation of the problem. To build elevation models of river valleys, satellite images are mainly used, which do not contain enough data to build an accurate map of depths, especially of small hydrological objects. Ground-based observations of rivers, lakes, and reservoirs are often of low quality, their automatization faces a lot of different problems, and they also do not provide a complete picture for the researches. So far, almost all the action taken do not solve the problem of increasing the number and improving the quality of hydrological observations. Researches conducted in Ukraine are mainly focused on navigable rivers and use low-cost equipment. So, our goal was to find an effective and reasonably priced method for studying river valleys and riverbeds.

Analysis of recent researches and publications. In the Ukrainian scientific literature, issues concerning river network modelling and data analysis are not covered enough. A significant number of scientific works are dedicated to the problem of relief models visualization, for instance, we can emphasize the work of scientist I. Yu. Vasilicha [3], which considers the issue of the specificity of digital modelling of complex types of relief. The issue is considered more widely in the studies of V. A. Avdeev, R. S. Filatov, V. A. Mukhudinov and V. N. Radionov [1], dedicated to the research of difficulties of spatial mapping of land, Yu. G. Firsov`s studies [22], which provide an overview of digital models of the bottom; V. V. Khromykh and O. V. Khromykh`s studies [23], dedicated to digital models of relief.

In [15], a method of performing depth soundings works, based on combining the differential method of GPS coordinate determination and the method of radio-controlled echo sounding, is proposed.

To study the dynamics of the relief of the bottom and a number of other practical tasks of hydrology, it is necessary to know the structure of the riverbed, control and take into consideration the modification of its parameters. However, the relief of the bottom of continental bodies of water is not often displayed on topographic maps, and there is not enough up-to-date information about the depths of rivers and even significant bodies of water. The lack of bottom relief images is explained by the labour-intensive process of making measurements [24, 5].

In the researches by A. J. Kaeser, echo sounder surveys are successfully used in various types of bathymetric, biological, and archaeological researches [27, 28].

A. V. Pogorelov and Zh. A. Dumit in their monograph, present the analysis of the multi-level morphological structure of the basin relief using digital modelling on the example of the Kuban River Basin [17].

The original method of measuring river depth, which can be attributed to hybrid measurement systems, is proposed in the work by F. Bandini and others who used a compact single-beam echo sounder attached to an unmanned aerial vehicle (UAV) [26].

Bathymetric mapping in Ukraine is mainly used for lakes and reservoirs. For instance, within the framework of the project «Danube lakes: sustainable restoration and conservation of the natural state of ecosystems», conducted in 2001-2002, an integrated study and mapping of lakes of the Lower Basin of the Danube River was carried out. The authors performed bathymetric and lithological surveys of the bottom of Lakes Yalpuh and Kuhurlui. Scientists O. M. Trofymchuk, H. Ya. Krasovsky, V. V. Radchuk, V. I. Mokry conduct sonar studies of the lakes of the Shatsk National Natural Park (NNP) on a regular basis [20]. V. O. Martyniuk, S. V. Andriychuk, and I. V. Zubkovich study the modelling of lakes in the Polissia region using bathymetric surveys [13].

In our previous work, we considered bathymetric studies of the Siverskyi Donets River using echo sounder surveys as an object of study for educational needs during practical training [11].

A. I. Honchar regards a set of measures for the development of sonar devices in Ukraine. It includes fundamental and applied hydroacoustic researches, among which the study of bottom relief, the study of the composition and properties of bottom soils, sedimentary rocks, acoustic interaction of the water column and bottom, the creation of geological and acoustic models of particular areas, as well as the creation of echo sound information and analytical technologies, which is interpreted to mean a holistic process of collecting, processing and delivering of information to the consumer [4].

Summing up the above, we can say that this type of research is in demand, up-to-date and forward-looking, but there are not enough works devoted to this particular topic.

Purpose and objectives of the study. The purpose of this work is to present the experience of de-

veloping digital elevation models of a section of the riverbed on the example of the Siverskyi Donets River (near Haidary village, Chuguevskiy district, Kharkiv region). Processing of measurement data received as a result of echo sounder surveys. Preservation and recording of general information received to expand the river bottom relief database. Provide an overview of the uses and applications of geoinformation technologies, determine the research prospects based on the developed digital elevation models.

Presentation of the main material. The Siverskyi Donets is the largest river in eastern Ukraine and at the same time the longest right tributary of the Don. The length of the Siverskyi Donets River within the country is 723 km of the total length (1053 km), and the basin area is 54500 km², which is 55% of the total catchment area. According to the administrative and territorial structure of Ukraine, the territory of this basin is located within Kharkiv, Luhansk and Donetsk regions, and according to the hydrological zoning of the country, it borders by the Dnipro catchment area in the West, and by the Don watershed in the North and East. The Siverskyi Donets basin is located along the southwestern border of the East European Platform, where the foundation surface is complicated by the Donetsk and Black Sea trenches [2].

The Siverskyi Donets riverbed is quite winding. The valley is asymmetrical at a large length and has a complex of accumulative terraces extending along its left slope. The floodplain terrace of the Siverskyi Donets River in Zmiiv city has a width of up to 3 km and is characterized by a flat, sometimes wetland surface with numerous oxbow lakes. In the river valley, a unique natural complex has developed, that includes a wide floodplain of the river with numerous meanders, lakes, swamps and oxbow lakes. The surface of this terrace in the riverbed part is a pile of sandy hills – «mounds», between which there are lakes and wetlands.

The most important modern geological processes are: water erosion – everywhere; landslide formation – on steep river slopes; flooding – in river valleys and on levelled areas of plateaus. Furthermore, the anthropogenic contribution of these processes prevails over the natural one. The Siverskyi Donets basin has a complex geological structure. Ascending neotectonic motions are its special feature. These motions facilitate the cutting of river valleys, the spread of ravines and the activation of erosion processes.

The Right Bank of the Siverskyi Donets is most vulnerable to rock erosion, as it is located on high and steep catchment areas. In these areas, up to three-quarters of the total land area is destroyed by water erosion processes. Wind erosion is also quite common, especially on sand massifs which are not anchored by vegetation.

Riverbed processes observed on the river include the following: 1) meandering; 2) bottom erosion; 3) bank hydrodynamic scour; 4) siltation, formation of shallows, overgrowth, waterlogging of banks, shallowing of riverbed sections; 4) littering of banks, accumulation of fallen trees, sunken logs, floating garbage [19].

Meandering happens due to the bank hydrodynamic scour on concave sections of the riverbed, moving washed-out soils downstream and causing the sediment of them in curved areas where the current speed slows down. Numerous oxbow lakes, floodplain lakes, swamps that have a characteristic elongated and rounded appearance were formed from the remains of the meanders, and are located mainly along the left-bank part of the floodplain [2].

Bank hydrodynamic scour with their falls, scours and falling trees is a common phenomenon, due to the recent decrease in the intensity of spring floods, scours and destruction of banks has also decreased, but remains significant on the banks which are not anchored. We can observe intense siltation of the riverbed and channels, formation of shallows, overgrowth, waterlogging of the banks along the entire riverbed of the Siverskyi Donets.

For this reason, this area is of particular importance for studying the changes in relief and riverbed processes.

Digital elevation models of the Earth surface, as one of the most important geographical features, are becoming important in geoinformation systems. GIS models are created in three dimensions, and the main part of such models, in addition to latitude and longitude, is also data on altitude [23].

The first experiment on creating digital elevation models (DEM) was conducted during the oldest stages in the development of geoinformatics and automated cartography in the first half of the 1960s [8]. One of the first DEMs of the land was made in 1961 at the Department of cartography of the Military Engineering Academy [14]. 3D colour models of the sea beds, rivers, and other bodies of water surface, and DEMs, on the basis of which they were developed, are the most common means of visualizing and modelling underwater landscapes.

The digital elevation model is the main element of any hydrological model, or basin geographic information system, since it allows to determine a significant number of morphometric and hydrographic characteristics of rivers and their basins: flow direction vectors, thalwegs, watersheds, catchment areas, stream orders, and stream gradients. Furthermore, the accuracy of automatic determination of hydrographic characteristics depends on the nature of the terrain, as well as on the resolution of the DEM.

Using the data of the bottom DEM, it is possible to conduct morphostructural analysis, which is aimed to study the properties of the modern and ancient relief of the Earth surface in order to study its origin and history of development. The advantageous function of bottom DEM data is the ability to calculate all the necessary morphometric data.

Digital elevation models are the foundation of solving a rather broad range of tasks using GIS technologies, the main of which are:

- visualization of relief in two-dimensional and three-dimensional images;
- determination of morphometric characteristics of the relief;
- mapping of steepness and exposition of slopes;
- mapping of the longitudinal and transverse steepness of slopes;
- calculation and visualization of visibility and invisibility zones for one or a system of points;
- calculations of volumes regarding the requested altitude level;
- constructing profiles;
- mapping streamlines;
- extraction of structural lines of relief, including lines of the erosion network, watersheds, and contouring of catchments.

Therefore, there is a need to use the available geological and geomorphological information. However, when digital mapping the bottom relief, its origin, structural features, paleogeographic conditions of formation and modern features of development are almost not taken into account, geophysical, geological, geomorphological and other data are not involved, and their comprehensive analysis is not carried out.

The most important factors impacting the accuracy and quality of bathymetric DEMs are: 1) the data received from the Triangulated Irregular Network vary in the accuracy; 2) problematic of the DEM results interpolation in areas where depth measurements were not carried out; 3) the presence of artefacts in the DEM, which significantly reduces their quality and limits the possibility of their further use.

River elevation models that continuously represent underwater river topography are useful for hydrological modelling, as well as for their further use. There are two main methods of obtaining data, on which bathymetric DEM systems are based: echo sounding and satellite altimetry. Technological progress in echo sounding and ship navigation systems led to a revolution in depth mapping about three decades ago. Currently, two types of acoustic data are available: single-beam profile survey data and two-dimensional multibeam survey data.

Echo sounder allows visualizing the surfaces of the bottom in quite high definition. Due to the fact, that various sonar devices are available, the capacities to conduct researches on inland waters has significantly enhanced.

There are a large amount of sonar devices that can be used not only for fishing, but also for scientific tasks today.

The development of sonar systems for underwater exploration began in the early 1900s. At the end of the XIX century, the underwater bell was used as an auxiliary instrument for lighthouses or lightvessels as a hazard warning [30].

The Titanic disaster in 1912 caused the use of sound for «echo» underwater, in the same way that bats use sound for air navigation [25].

During the 1960s, a new system that could create two-dimensional images of cross-sectional areas of the bottom emerged. Since then, the side-scan sonar has been widely used for mapping navigation channels, mapping the marine environment, and searching large areas for sunken vessels [27].

The way the echo sounder works is that it sends sound pulses down through the water (Fig. 1), and when these pulses reach objects such as fish, vegetation, or the bottom, they reflect off and return to the surface. The echo sounder measures the time it takes for a sound wave to move down, reach an object, and

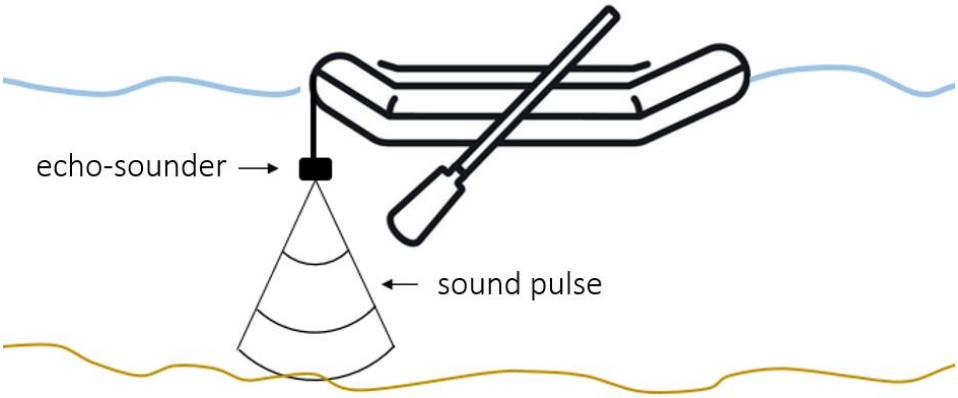


Fig. 1. Scheme of the echo sounder working principle

return. This is the same echolocation system that bats and dolphins use. This information allows the device to estimate the depth at which the detected object is located. It also measures the strength of the feedback pulse – the more solid objects are, the stronger the feedback pulse is [6]. As long as the sound waves move at a speed of about 1600 meters per second in water, echo sounders can send multiple pulses per second. Feedback sound pulses are converted into electrical signals, which are then displayed on the screen, showing the depth and solidity of the bottom and various objects.

During the study of the objects, the following scientific and application-oriented tasks are solved:

- search for objects of synthetic and natural origin, determination of their location, distribution, and building figures showing the location (mapping);
- morphology research, including bathymetric survey of landforms; study of precipitation transfer processes; geological and geotectonic studies;
- archaeological researches;
- engineering and geophysical surveys (preliminary survey of underwater pipelines, cables, oil and gas terminals, trenches);
- survey of engineering sites.

During the weekend expedition on September 18, 2021, at the initiative of the Physical Geography and Cartography Department of the V. N. Karazin Kharkiv National University, the measurement works were carried out to build an elevation model of the Siverskyi Donets River bottom section. The first phase involved bathymetric examination of the river bottom. The survey was performed using the Lowrance Elite 7 Ti. This chartplotter-echosounder is a multifunctional device that allows not only to scan the bottom relief and measure water temperature, but also to create maps of depths.

This device was installed behind on the transom of a small rubber boat, directly in the water and usually slightly below the bottom of the boat. The echo sounder model equipped with a built-in 16-channel GPS/GLONASS, which provides a quite high positioning accuracy and the possibility of additional refinement using WAAS+EGNOS+MSAS data [29].

The main advantages of the echo sounder Lowrance Elite 7 Ti is the availability of CHIRP, DownScan Imagin and StructureScan HD, which provide a complete survey of the bottom of water areas. CHIRP is a compressed pulse of high-intensity that sends a high pulse energy into the water column. A standard sonar sends just one pulse into the water column, which provides a limited report that is affected by many factors and conditions in the aquatic environment. CHIRP technology improves bottom monitoring at higher depths and at higher speeds, it sends a whole beam from low to higher frequencies. This allows to generate images using the full frequency range. The pulse enables a clear and accurate identification of objects that are close to each other, and gives an accurate view of the image. As a result of using this technology, the detailing and accuracy of the image received by the echo sounder significantly increases.

Using the DownScan sonar, the beam is emitted not in the form of a cone, but in a very narrow longitudinal and wide transverse direction. Due to the fact, that the beam is very narrow in the direction of movement of the boat, the resolution of scanning of the DownScan is much higher than that of a classic echo sounder.

The StructureScan HD sonar allows to scan the underwater relief in three different directions, enabling a clear panoramic image of everything under the boat, scan the bottom from the left and right sides of the boat at a depth of up to 100 m. It creates a connected to coordinate sonogram in the form of a bitmap image of the bottom, which allows identifying objects of natural and anthropogenic origin visually.

After the measurement is completed, the results are stored in the memory of the device, and then they are processed on-site.

In most cases, the volume of each echo sounder profile is from 5 to 30 thousand measured values, depending on the frequency and time of recording to a single file. Each value contains information about the coordinates of the survey point, depth, date and time of echo sounding, water surface temperature, shift relative to the previous measurement point, and other supporting information. Only coordinate and depth values are used in the processing process.

3D colour models of the seabeds, rivers, and other bodies of water surface, and DEMs, on which basis they were developed, are the most common means of visualizing and modelling underwater landscapes. Special software is used to create 3D colour models of the bottom surface and DEMs, on which basis they were developed [16].

There are several software packages for creating bathymetric maps, for example: ArcGIS, DrDepth, HumViewer, SASPlanet, Surfer, PyHum and ReefMaster, etc.

The steps of obtaining a bathymetric chart involves converting echo profile data to visualize the results of hydroacoustics sounding. The depth distribution map was made using the ReefMaster software, due to the fact, that this program is one of the most accessible and easy to use. Using it, one can view sonar scanner logs and edit course, as well as create three-dimensional bathymetric maps and side view mosaics [31]. This program allows

collecting sonograms received by the echo sounder into a single hydrographic mosaic and perform its geographical reference. In general, the use of the Lowrance chartplotter-echosounder and the ReefMaster program is sufficient for working in small reservoirs with insignificant depth in order to obtain a high-quality bathymetric map.

The data, that is imported from the echo sounder, is stored as a file with the *.sl2 extension, therefore, the converting for the future use is needed. The advantage of the chosen program is the ability not only to convert, but also to see the map before converting to a two-dimensional visualization form of the profile. Another feature of this program is the ability to correct data (Fig. 2) if the echo sounder recorded them incorrectly.

At this point, it is possible to record the features of the bottom relief characteristics and determine their coordinates. Analysing the received sonogram, we can conclude that it can be used to detect small objects (Fig. 3), as well as to analyse riverbed processes and structural elements of the bottom relief.

To clarify the shape of the coastline, we used the Google Earth Pro software (Fig. 4). Using the polygon function, the riverbed of the surveyed sec-

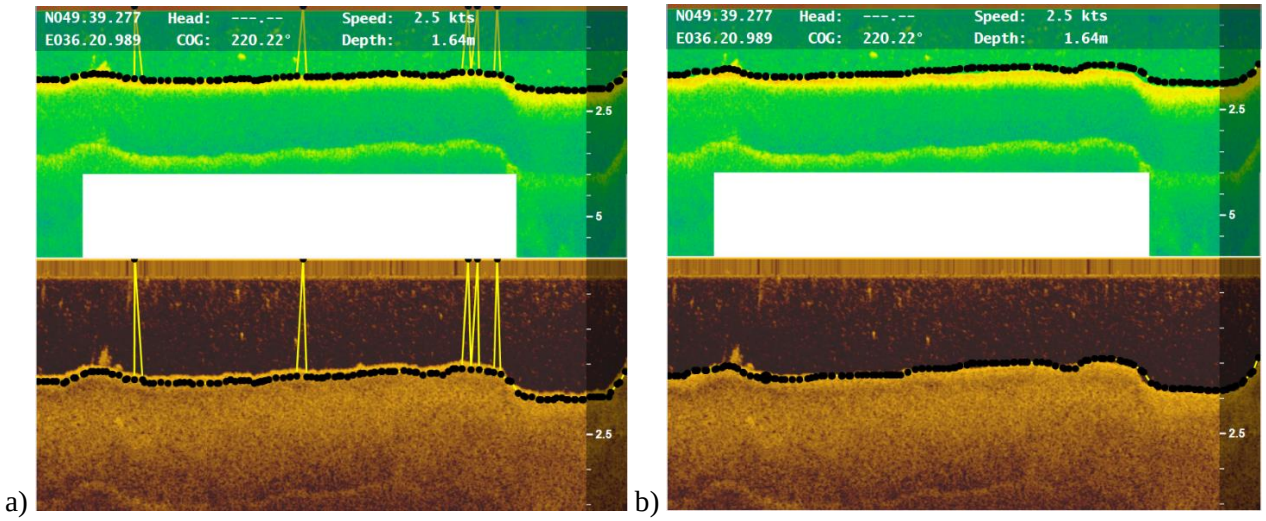


Fig. 2. Editing the echo sounding in the ReefMaster software: a) before editing b) after editing

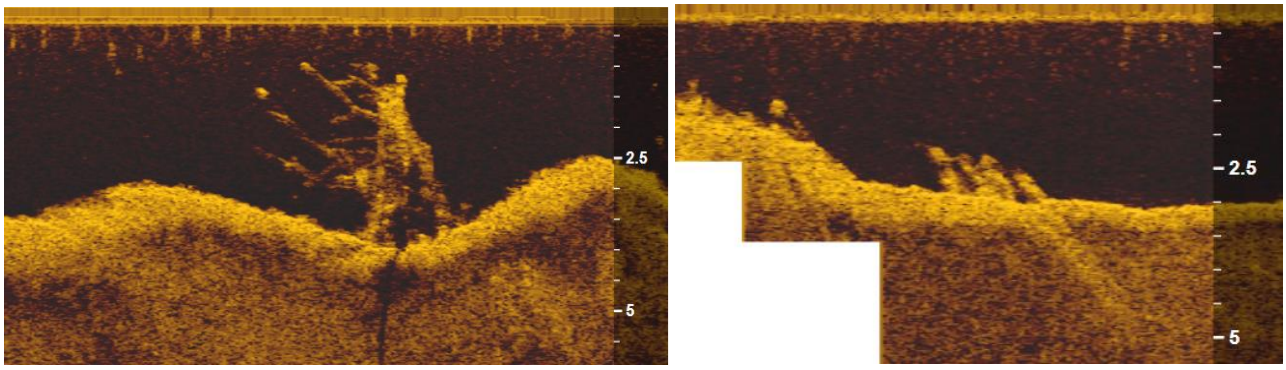


Fig. 3. Objects found using StructureScan

tion of the river was modelled. After that, this layer was saved in the *.kmz extension, which can be directly uploaded to ReefMaster (Fig. 5).

The depth values received using the chartplotter-echosounder are automatically converted into a bathymetric map, where it is possible to see the features of the bottom relief. It is appropriate to compare the results received as a digital map of the bottom relief (Fig. 6.) and the results of multi-year observations, which were obtained using traditional methods, during student practical trainings, as well as the results of scientific researches and expeditions in the geographical educational and scientific station «Haidary» area.

Unlike a two-dimensional map, three-dimensional elevation models allow seeing with your own eyes and visually assessing the shape and «plasticity» of the relief, boundaries of geomorphological units, and even features of the riverbed structure (Fig. 7) [23].

Specialists, working in various areas of geography and geomorphology, quite widely use digital elevation models, based on regular coordinate grids. The demand for this kind of data is mainly determi-

Fig. 4. Territorial localization of the surveyed section of the Siverskyi Donets River

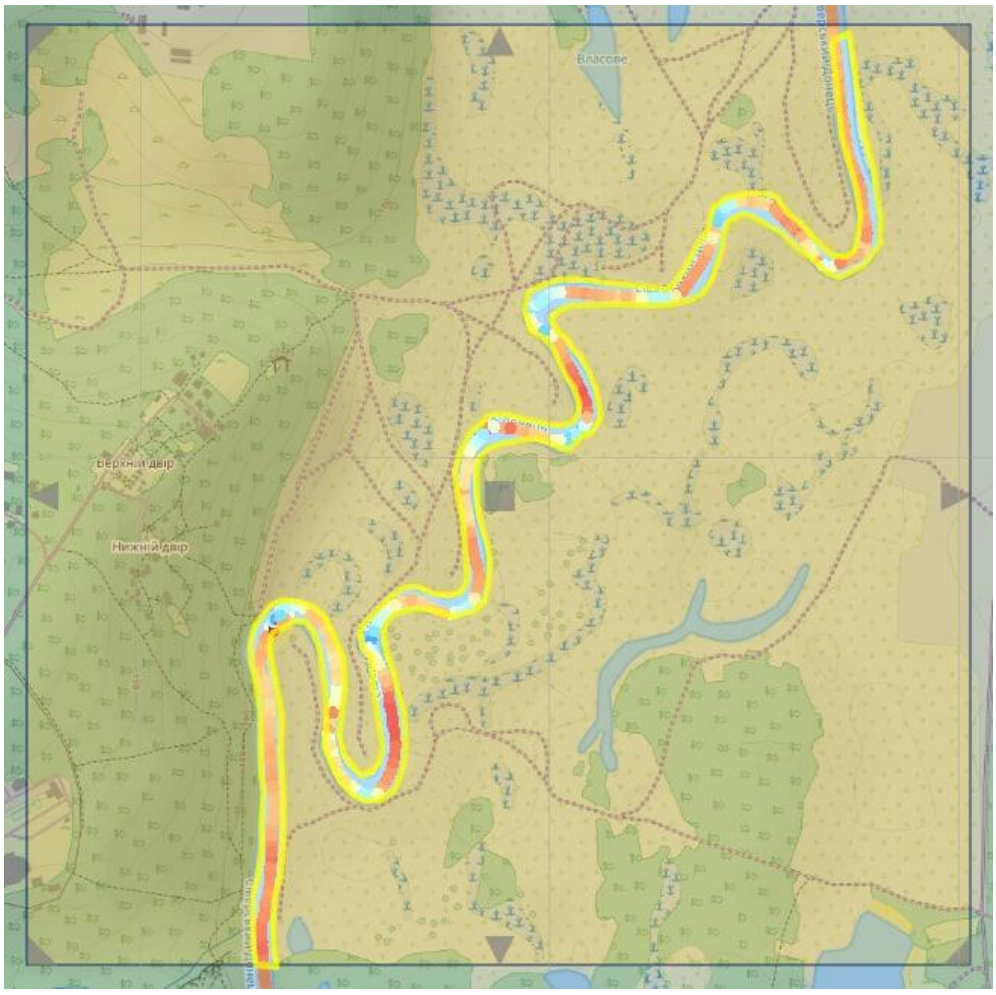


Fig. 5. Clarified coastline of the Siverskyi Donets River

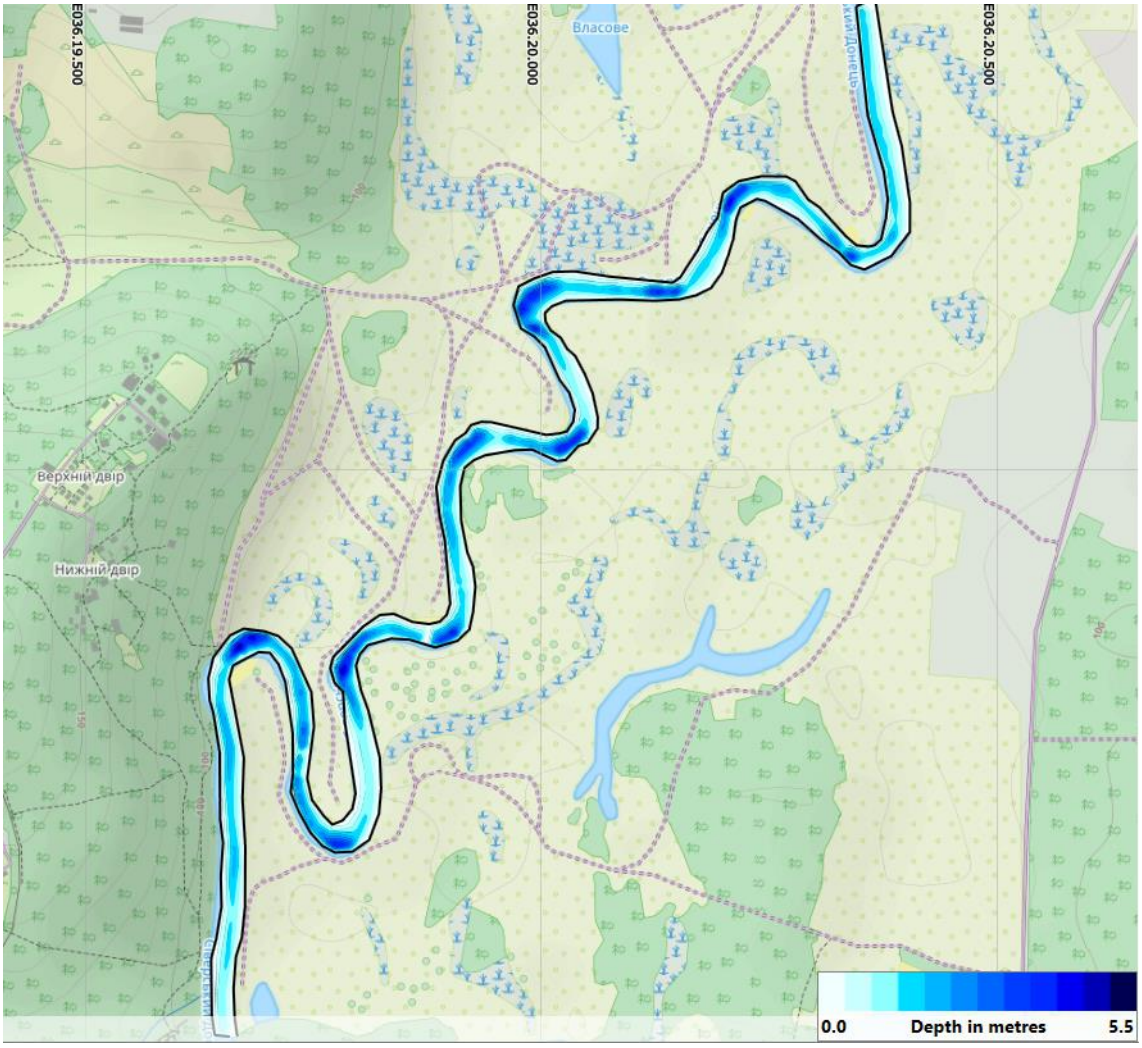


Fig. 6. Digital 2D model of the bottom relief of a section of the Siverskyi Donets River

ned by the increasing availability of these models, the globality of the territory coverage, the ability to use different levels of generalization and the promptness of solving various problems that require a quantitative approach with their help [12].

The digital elevation model displays the bottom relief on the specified scale without losing the initial details, and also makes it possible to build bottom relief profiles with any frequency and in any direction and use morphometric analysis tools in GIS.

Modelling of the bottom relief of large water areas is always carried out with scarce hydrographic survey data, so a balanced and detailed study of the bottom relief should not be expected in the near future.

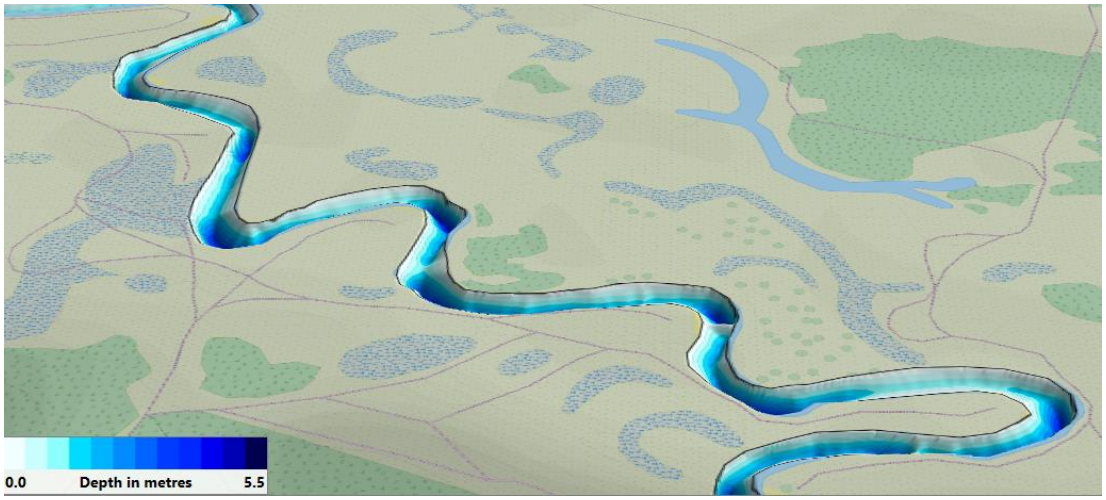
Algorithms integrated into modern GIS software also allow to calculate several hydrological parameters using DEM (length of runoff lines, drainage area, volume, water consumption), and map algebra tools allow to arbitrarily transform and combine DEM according to the certain rules. For instance, the use of appropriate algorithms helps to calculate important environmental parameters involved in the morphology of the Earth surface [18].

The digital elevation model of the bottom of marine areas is the most important component of the spatial database of geoinformation systems. Data on the properties of the bottom relief are necessary both for solving fundamental problems and for a wide range of applied researches [9].

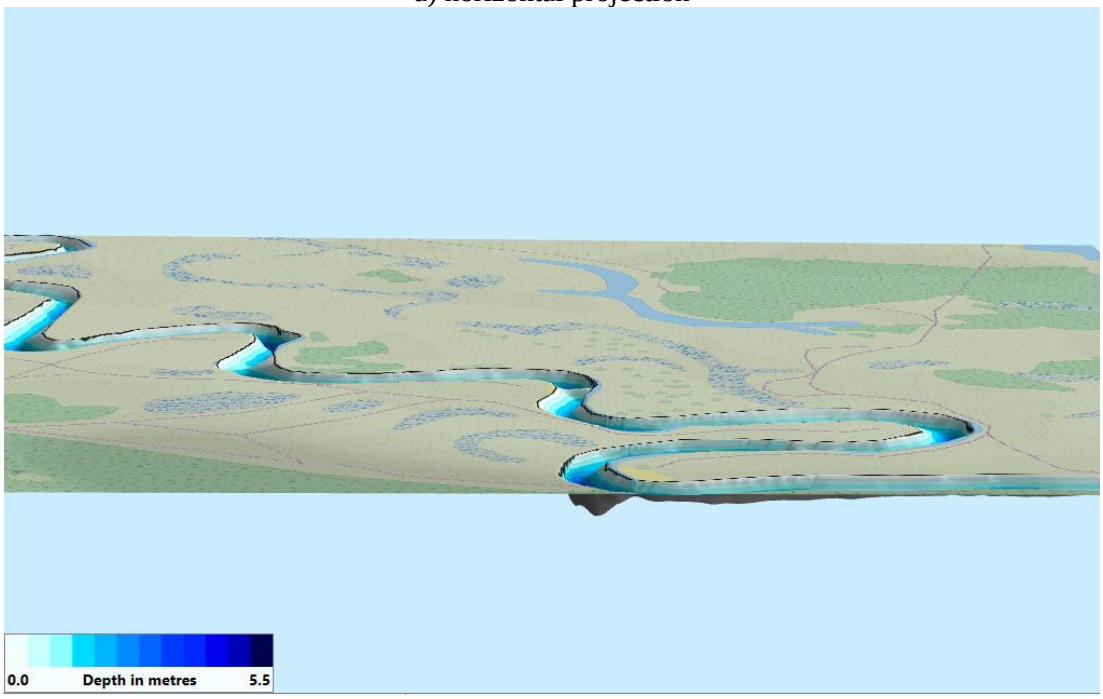
Conclusions. The relief mapping is one of the constant and relevant problems of cartography. Throughout history, new ways of depicting it have been emerging. They have been developing, improving, and emerging, ranging from perspective to the latest digital methods.

The development of three-dimensional modelling and animation technologies has led to the creation of virtual geo images that combine the characteristics of a map, perspective image, block map, and computer animation. They create an illusion of being present in the real space and the possibility of interactivity.

Based on the results of the expedition conducted near Haidary village, the depth and bottom relief of the Siverskyi Donets were studied using a chartplotter-echosounder. Based on the data recei-



a) horizontal projection



b) vertical projection

Fig. 7. Digital 3D model of the bottom relief of a section of the Siverskyi Donets River

ved using echo sounding, a bathymetric chart of the river is created. Data from bathymetric surveys and future creation of the DEM allow to assess the dynamics of changes in morphometric indicators of the Siverskyi Donets and analyse the spatial altitude and geological heterogeneity of the relief of the Siverskyi Donets River Basin within the Kharkiv region.

Similar researches can be developed at the interface of a number of disciplines – geomorphology, geology, geophysics, cartography, geoinformatics, acoustics, and mathematical modelling. At the same time, geomorphological studies are the basis for studying the morphology and dynamics of the relief; and geological, geophysical and geomorphological studies determine the genesis, age of the relief and its paleogeographic development; acoustic studies provide data on propagation speed of acoustic signals; cartographic and geoinformation studies make it possible to form a database, develop algorithms and programs, find solutions to cartographic and geodetic problems, and so on.

The novelty of the study is not only the use of the methodological foundations of digital modelling, but also the alternative classification approaches for describing the relief and conducting morphostructural analysis based on the GIS technologies.

The image of a relief is one of the most relevant problems of cartography, throughout history the forward-looking ways of depicting it have been emerging. The development of three-dimensional modelling and animation technologies has led to the creation of virtual geo images.

To sum up, it can be stated that the main components of the technology of studying the bottom of

water areas and underwater objects by sonar methods are: hydroacoustic means; means of navigation data binding; support equipment, including watercraft, as well as the methodology for developing hardware and software complexes to collect and process information and the methodology for their use to conduct researches. The use of a well-designed science-based methodology for carrying out work and a flexible system for processing the information received sometimes give a greater effect than the use of expensive equipment.

Bottom relief mapping can be attributed to consistently relevant problems of cartography. And the development of modern technologies provides a wide range of opportunities for studying the underwater environment, and the relief, for instance. The creation of the bottom DEM takes hydrographic observations, researches and mapping of the bottom of water areas to a new level, providing efficient and accurate underwater data collection.

Also, in further field studies, a comprehensive survey using UAV is planned to develop a more complete characteristic of the Siverskyi Donets River.

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Моделирование рельефа участка русла реки Северский Донец (в районе села Гайдары Чугуевского района Харьковской области)

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В статье освещен практический опыт эхолотного сканирования дна водоемов, и обработка полученных данных для построение цифровых моделей рельефа. Раскрыта актуальность и особенности использование сонарной техники для изучение особенностей морфологии подводного рельефа небольших гидрологических объектов. Сделан анализ отечественных и зарубежных публикаций в этой сфере, по каким делается заключение о недостаточной разработанности вопрос в отечественных источниках. Представлены результаты эхолотной съемки и пост-обработки полученных данных с помощью специализированного программного обеспечения. В качестве территории гидрографического исследования было выбрано участок реки Северский Донец в районе учебно-научной географической базы «Гайдары» (с. Гайдары Чугуевского района Харьковской области). Полевая часть выполнена на оборудовании материально-технической базы кафедры физической географии и картографии Харьковского национального университета имени В. Н. Каразина, в частности с использованием эхолота-картплоттера Lawrance Elite 7 TI с современными режимами сканирования CHIRP, DownScan, StrucureScan. В работе рассматриваются особенности создания и визуализации в программном пакете ReefMaster. По результатам полевых работ разработана модель дна соответствующего участка реки Северский Донец, карту глубин, которые позволят в будущем анализировать динамику и прогнозировать изменения русловой конфигурации. Сформулированы преимущества использования бюджетного оборудования и программного обеспечения для выполнения исследований рельефа дна подобных гидрологических объектов.

Ключевые слова: *цифровая модель рельефа, эхолот, Северский Донец, гидрография, батиметрия, карта, сонар.*

Моделювання рельєфу ділянки русла річки Сіверський Донець (в районі села Гайдари Чугуївського району Харківської області)

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У статті висвітлено практичний досвід ехолотного сканування дна водойм та обробки отриманих даних для побудови цифрових моделей рельєфу. Розкрито актуальність та особливості використання сонарної техніки для вивчення особливостей морфології підводного рельєфу невеликих гідрологічних об'єктів. Зроблено аналіз вітчизняних та зарубіжних публікацій у цій сфері, за яким робиться висновок про недостатню розробленість питання у вітчизняних джерелах. Представлено результати ехолотного знімання та пост-обробки отриманих даних за допомогою спеціалізованого програмного забезпечення. У якості території гідрографічного дослідження було обрано ділянку річки Сіверський Донець у районі навчально-наукової географічної бази «Гайдари» (с. Гайдари Чугуївського району Харківської області). Польову частину виконано на обладнанні матеріально-технічної бази кафедри фізичної географії та картографії Харківського національного університету імені В. Н. Каразіна, зокрема з використанням ехолота-картплотера Lawrance Elite 7 TI з сучасними режимами сканування CHIRP, DownScan, StrucureScan. У роботі розглядаються особливості створення та візуалізації у програмному пакеті ReefMaster. За результатами польових робіт розроблено модель дна відповідної ділянки річки Сіверський Донець, карту глибин, що дозволять у майбутньому аналізувати динаміку та прогнозувати зміни руслової конфгурації. Сформульовано переваги використання бюджетного обладнання та програмного забезпечення для виконання досліджень рельєфу дна подібних гідрологічних об'єктів.

***Ключові слова**: цифрова модель рельєфу, ехолот, Сіверський Донець, гідрографія, батиметрія, карта, сонар.*

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