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Remote sensing monitoring of anthropogenic changes in the Desenka river channel (Kyiv, Ukraine)

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The article is devoted to developing an universal methodological apparatus of ecological monitoring and practical assessment of the state of hydroecosystems to determine the nature of the anthropogenic impact. The authors analyzed the transformation of the Desenka river channel (Kyiv, Ukraine) in the 1965–2021 years. The primary attention is paid to changes in the coastline of Kyiv to determine the nature of the anthropogenic impact on the study area. The authors improved the technology of monitoring the dynamics of the water regime of the riverbed by building bathymetric maps based on the results of hydroacoustic measurements and the space imagery interpretation.

The study used the integrated use of methods of selection and processing of information through the use of GIS technologies (thematic classification of remotely-sensed imagery in terms of data exchange of terrestrial animals and independent features of objects). The results are presented in a way that is easy to interpret. It was found that the main reason for the change in area is sand mining. The bathymetric survey allowed to specify the maximum depth of the reservoir, which is 16.8 m. It was determined that the relief of the bottom is typical for a quarry. The river's depth in its central part increases from west to east in proportion to the increase in the width of the reservoir. The study found that sand was mined in the same place, washing away huge underwater quarries and forming numerous silt alluvium. According to the results of the analysis of changes in areas presented in this study, the authors proved that uncontrolled sand mining has a negative impact on the biotic stability of landscapes and causes irreparable damage to the environment. The effectiveness of remote sensing methods for determining the ecological status of hydroecosystems is proved. The presented studies indicate the need to stabilize the ecological balance of the river ecosystem, take appropriate measures to increase the productivity of hydrolandscapes, improve the environment and ensure the environmental safety of the Desenka river and coastal areas.

Keywords: anthropogenic transformation, the dynamics of the river course change, monitoring, remotely-sensed data, bathymetry

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1. Introduction

The state and restoration of water resources and the provision of society with quality drinking water today is one of the keys not only in the list of environmental problems but also among the most pressing problems of humanity. Today, the conservation of water resources is being talked about at the highest international level. In line with the Global Sustainable Development Goals (Global Sustainable Development Goals by 2030), namely the 6th target: clean water and sanitation, 41 countries have faced water shortages, 10 of which have effectively depleted their renewable resources fresh water and now have to rely on alternative sources. This global environmental problem attracted the attention of the authors of the publication in the framework of the project for introducing foreign technical talents of Jiangsu (BX2021052). The main goal of this project is to share the experience of scientists and develop a universal methodological apparatus for monitoring and practical assessment of hydroecosystems.

Hydrological observations on water bodies should be comprehensive with different periodicity: monitoring the flow and level of water in rivers, changes in the riverbed, chemical composition, temperature and ice regimes of river waters, etc. Accordingly, determining the characteristics of anthropogenic pressure on freshwater resources of urban agglomerations should provide an assessment of the actual state of the environment and forecast changes in its state under the influence of anthropogenic factors and evaluation of the forecast state of the environment (on the decision of the National Security and Defense Council of Ukraine of July 30, 2021).

Numerous rivers and streams are one of important components of Kyiv's urban environment. Determining the features of anthropogenic pressure on freshwater

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resources of urban ecosystems should assess the actual state of the environment and the forecast of changes in its state under the influence of anthropogenic factors. The value of the islands of Kyiv and its environs as a component of the Dnipro Ecological Corridor lies in the uniqueness of landscape-biocenosis formations (Dubrovsky, 2008). The fact is that the typical habitats of the river floodplain on the islands are much better preserved than on the neighboring coastal areas within Kyiv. At the same time, the state of island landscape groups disturbed by the anthropogenic impact is not yet hopeless and can be restored in the case of establishing a protected regime. In current conditions, in order to understand what we are losing, it is necessary to clearly imagine the nature of this corner of the Dnipro before the development of the city here, which it was even relatively recently. This is possible with the use of modern geographic information technologies and archival aerospace materials, as evidenced by the presented work. Although a large number of scientific papers and newspaper publications are devoted to such research, many issues remain insufficiently studied. Identifying the features and patterns of anthropogenic impacts on the ecological status of urban aquatic ecosystems and changes in the riverbed to this day is relevant (Dubrovsky, 2008; Udod, 2007; Malets, 2017; Tomchenko, 2018). The most significant contribution to this topic was made by such scientists as V. I. Vyshnevskyi, S.V. Batog та I. Yu. Parnikoza (Vyshnevskyi, 2018; Parnikoza, 2021; Batog, 2015).

The study of (Xuechun Zhang, 2020; Wesley J, Moses, 2019; Allouis, 2010) the structural and functional organization and dynamics of water bodies based on bathymetric survey, morphology, and hydroecological regime are considered in the works. The most commonly used method of creating a digital terrain model with accurate bathymetry is to combine topographic data with another source of bathymetric data. Acoustic Doppler current profilers, sonar and range detection methods (SONAR), theodolites, and Global Positioning System (GPS) stations are often used for this purpose. The study of (Merwade, 2006) the main advantage of these methods and their high accuracy of the obtained data is highlighted. Interpolation approaches have been developed to reduce the amount of measured data required to represent river bathymetry. The analysis of literature sources confirmed the preliminary study of the processes of formation and functioning of urban aquatic ecosystems, the study of which is an urgent scientific and practical task. In each case, the water body is affected by an individual set of factors, individual or complex action of which may be a determining factor in assessing the environmental safety of each individual object. In the conditions of intensive anthropogenic impact on natural hydroecosystems, several important environmental problems are traced, which significantly affect the state of water bodies and aquatic organisms that inhabit them. These problems are primarily related to the deterioration of water quality, significant reductions in species biodiversity, marine productivity, fish productivity, and the biological performance of living components of ecosystems.

The relevance of research is determined by the growing requirements for improving completeness of information in monitoring in order to create optimal forms of environmental management of rivers. Such studies are conducted both by contact methods and by methods of remote sensing of the Earth. However, in the current development of infrastructure and information technology, the combination of these methods is most effective. This is due to the fact that contact methods allow you to explore different parameters of the object under study simultaneously, and with the help of remote methods is not only geographical reference to the results obtained by contact methods but also monitoring the dynamics of river flow, construction bathymetric maps, assessment of anthropogenic load of coastal areas, etc.

The purpose of the study is to assess the historical changes in the shape of the Desenka riverbed (Kyiv, Ukraine) with the help of archival space images and to display a modern depth map based on field research to develop a universal methodological apparatus for monitoring and practical assessment of hydroecosystems and anthropogenic impact.

2. Description of the study area

Kyiv's coastline has begun to change rapidly over the past 100 years due to the city's rapid growth and redevelopment. Before that, the Dnipro floodplain in Kyiv was formed by glaciers. This became the basis of the floodplain of Kyiv for a long time. The change in the landscape of the coastal part of Kyiv was most influenced by the channel-directing works of the XIX century. In connection with the construction of bridges and the development of navigation, large-scale measures were taken to regulate the Dnipro within Kyiv. Since the second half of the XX century, islands near the city of Kyiv have again undergone significant changes. This is due to the reconstruction of the city after the World War II, its expansion, and the construction of Kyiv's hydroelectric power plants. In the northern part of Kyiv, work was carried out to create a bypass canal from Kyiv's hydroelectric power plants, which flowed into the main course of the Dnipro unification of the island of Murom and Trukhanov Island. The construction of the Kyiv and Kaniv hydroelectric power plants slowed down the flow of the Dnipro and led to a specific "fixation" of the boundaries of the Dnipro islands and tracts. As a result, Desenka's water content and speed decreased significantly, turning it into an almost floodplain river (Parnikoza, 2021).

River Desenka – a channel in Kyiv that omits the Trukhaniv island and the Gorbachykha island. The river begins at the mouth of the Desna and flows into the Venetian channel. Length – 13 km; runoff area – 68 km²; valley width – 1 km; the widest light brown – 100 m. Near the floodplain, there are a lot of lakes with a total area of 1.5 km², and there are wetlands. The middle depth is 9–11 m, and the largest is 16 m. The lower part of the river at the Metro bridge is called the Rusanivska inflow. The coastal zone of the river Desenka is a recreational zone. The river banks are a popular area for the local population (Rusanivsky gardens).

Analysis of literary sources showing another half of the twentieth century was the most active for molding the Kyiv flood of the Dnipro, including the principles of changing the channel of the Desenka river. For the same reason, in our research, we looked at the period from 1965 to 2021. The study is focused on identifying the features of changing the bed of the Desenka river under the influx of anthropogenic factors. The authors monitored the coastal line of the river's territory.

3. Material and Methods

3.1. Satellite data

Mapping the historical sight of the river the gums were consecrated for the materials of the archives from 1965 to 1975 from satellites of KeyHole placements on the resource "Machine for time and space" distributed by the Kyiv Polytechnic University (Kyiv on maps). All other years, including the current state of the Desenka river, have been studied using satellite information from the Spot, Landsat, and Sentinel spacecraft. Below we will describe in more detail the remote sensing materials used in work (Table 1).

KeyHole is the general name for a series of US intelligence reconnaissance satellites. The primary purpose was detailed optical reconnaissance of the USSR, China, and other countries. A total of 13 types of satellites have been developed and launched. The satellites were launched into orbit from 1959 to 1986. Initially, it was part of the peaceful space program "Discoverer", and since February 1962 it has become a separate program "Corona" which was exceptionally secret.

Satellite types KH 1-4, 4A, 4B had a general name "Corona". This is a code word, not an acronym. Spacecraft of these types were launched in the period from 1959 to 1972 and had a spatial resolution of ~ 1m (Fig. 1a–b).

KH-9 Hexagon, another name "Big Bird" in orbit since 1975. The complete collection of original KeyHole space images is stored in the US National Archives and Records Administration (NARA). Some of this declassified data was transferred to the U.S. Geological Survey's Earth Resources Observation and Science (EROS) in 2002. And now published for full download on the site USGS EROS EarthExplorer (USGS science for a changing world).

SPOT (Satellite Pour l'Observation de la Terre) is a commercial satellite-based Earth observation system launched by CNES (Centre national d'études spatiales – French Space Agency) in 1970, and was developed in collaboration with SSTC (Belgian Service Scientific, Technical and Cultural) and SNSB (Swedish National Space Board). SPOT was developed to disseminate knowledge about the Earth and improve governance by researching the earth's resources, identifying and forecasting phenomena related to climatology and oceanography, monitoring human activities and natural phenomena. SPOT 1 was launched on February 22, 1986. This made it possible to obtain panchromatic images with a spatial resolution of 10 meters and 20 meters of multispectral images. The space image used (Fig. 1c) in the original is published on the website USGS EROS EarthExplorer.

Landsat is the longest-running satellite imagery program with a spatial resolution of 15 to 60 meters per pixel. Landsat 5 is the fifth remote sensing satellite within the Landsat program. Launched on March 1, 1984, and operated until 2012 (had the most extended satellite earth observation mission: 28 years, ten months) (Fig. 1d–e).

Landsat 8 is a satellite of the Earth's remote sensing, the eighth satellite launched under the Landsat space program and launched into orbit on February 11, 2013.

Sentinel is a space mission for remote sensing of the Earth, launched by the European Space Agency (ESA) under the Copernicus program, created under the project of global monitoring of environment and security GMES (European Earth observation system was developed under the name of Global Monitoring for Environment and Security (GMES) which was later re-branded into Copernicus). The first satellite, Sentinel-2A, was launched on June 23, 2015. Currently, data from the Sentinel-2 satellite are the basis for modern research, as they have sufficient detail and are freely available. (Fig. 1f).

Table 1. Review of the remote sensing data of the Earth used in the study of changes in the Desenka River

Shooting date	Satellite	Specification
23.09.1965	KH-4A-24 (Corona 100)	Observation satellite KH-4A-24 (Corona 100), mission 1024-1 (COSPAR 1965-074A), in orbit since 1965-09-22
27.10.1972	KH-9-4 (Hexagon 4)	Observation satellite KH-9-4 (Hexagon 4), mission 1204-2 (COSPAR 1972-079A), in orbit since 1972-10-10
06.09.1975	KH-9-10 (Hexagon 10)	Observation satellite KH-9-10 (Hexagon 10), mission 1210-4 (COSPAR 1975-051A), in orbit since 1975-06-08
1987–1988	SPOT	SPOT Controlled Image Base 10 meter (CIB-10) – synthetic (composite) orthotransformed panchromatic image generated by the French Space Agency between 1986 and 1993 based on data from the satellite system SPOT. In orbit since 1986-02-22
02.06.1995 and 31.07.2005	Landsat 5	Landsat 5 – satellite within the program "Landsat". In orbit since 1984-03-01. Contains tools Thematic Mapper (TM) i Multi-Spectral Scanner (MSS)
09.07.2021	Sentinel-2	Sentinel-2A – ESA space mission under the Copernicus program. The satellite has a multi-spectral instrument (MSI) with 13 spectral channels in the visible, near infrared (VNIR) and infrared shortwave (SWIR) spectral ranges. In orbit since 2015-06-23

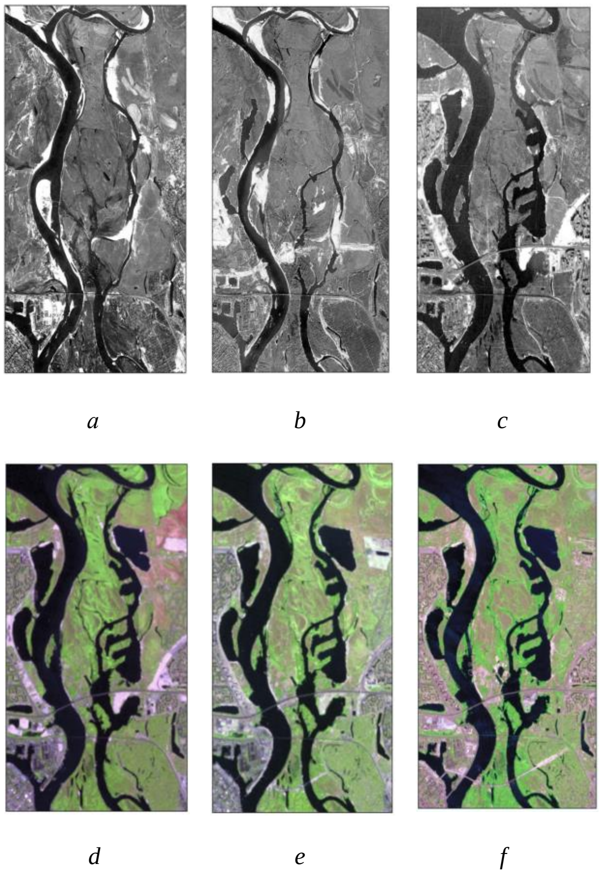


Fig. 1. View of a fragment of Kyiv near the Desenka river in space images: *a* – 1965; *b* – 1972; *c* – 1987; *d* – 1995; *e* – 2005; *f* – 2021

The use of the described satellite imagery data allowed to reliably reflect the historical and modern appearance of the Desenka riverbed. Combining archival materials with modern ones, the transformations of the Desenka floodplain, which took place as a result of the construction of the Troyeshchyna residential area, Kyiv (Ukraine), were determined.

3.2 Materials of bathymetric research

The inflatable rubber boat "Brig Baltic" on which the Lowrance "LMS-527 CDF IGPS" echo sounder is mounted was used for bathymetric research. Field surveys of the riverbed of the studied river were conducted in the period of September 21–24, 2021. Landsat-8 space image with a spatial resolution of 30 m was also used to clarify the depths, namely using channel 1 – 0.45–0.52 (blue spectral range). This range is most suitable for the study of water bodies due to the fact that sunlight penetrates in this spectral range to greater depths. (Jianwei Wei, 2020).

3.3. Methodology

The methodology of research on the change of the Desenka riverbed involves the use of remote sensing data of the Earth and limnological-geographical analysis of the studied water body to interpret the results of sounder profiling.

The study consisted of the following stages:

- comprehensive analysis of the results of previous studies of changes in the Desenka riverbed;
- analysis and selection of an available data of the Earth remote sensing and aerial photography, creation of geometrically correct remote basis;
- creation of thematic vector layers, namely the boundaries of the shoreline of the Desenka river for different years and the calculation of areas;
- limnological-geographical bathymetric field analysis (field research of river depths) using echo sounding.

Mapping of the river shoreline change was performed using historical and current remote sensing data. The authors created vector layers – contours of the river shoreline for a period of 55 years in the ArcGIS program. After the construction of the topology, its area was clearly defined.

The authors used a modern hydroacoustic method for bathymetric studies. This method consists of sonar sounding with synchronous GPS binding of sonar profiles. The software environment provides a graphical interpretation of data while eliminating interference from secondary reflections of the signal from the water surface and other extraneous noise. Also inhomogeneities of the water column in the form of boundaries with different temperatures are recorded. At this stage it is possible to fix the features of the characteristics of the bottom relief with the definition of their coordinates. The data is then exported to a .csv text file, which the table editor imports into the standard .xls table format. The authors filtered the information array by using GPS data on the change of position to obtain values of coordinates and depths in the table. The resulting table is exported to the Surfer program. This creates the .srf file, which is a rendered table. As a result, the authors obtained a planar map of the reservoir, and only the necessary information remains in the form of well-photographed and visible main isobaths. Then a graphic .jpg or .bmp file is created. When opening a file in the editor, errors are eliminated, depth scales, symbols, necessary image fragments are added. This process ensures the condition of the synthesized bathymetric scheme. The authors corrected the median filter on the image to reduce noise. Depth determination was performed on a Landsat-8 space image using one channel – 0.45–0.52 (blue spectral range). This range is best suited for studying water bodies because sunlight penetrates to greater depths in this spectral range.

4. Results and Discussion

The authors created vector layers – contours of the river shoreline as of 1965–2021 (Fig. 2) using GIS technologies. After the construction of the topology, the area of the Desenka river was clearly determined by the years surveyed. The results obtained are shown in Table 2.

Analyzing the dynamics of change during the study period, we can observe a gradual increase in the spill of the river water mirror. In 2021, the area of the Desenka river was 4.9624 km^2, which is almost three times more than in 1965. In Fig. 2 and Fig. 3, the emergence of new floodplain lakes, rapid changes in natural ecosystems, and flooding can be seen. These changes occurred as a result of sand mining for construction purposes.

The water area of the Dnipro river has always been one of the primary sources of river sand in Ukraine. In Kyiv and Kyiv region, all river sand is extracted from the Dnipro and other rivers that flow into it. Currently, 652 deposits of construction sand are registered in Ukraine. Also, here is the largest number, namely 59 registered deposits. On average, river sand accounts for about 20–25 % of the total extracted construction sand. According to the results of 2020, Kyiv and Kyiv region accounted for 32 % of construction sand production in Ukraine. (Pro-Consulting). Sand washing in Kyiv began in the 70s of the last century. The sand was taken not only from the Dnipro, but also from the quarry. On the site of those quarries in Kyiv, there are several lakes: Tjaghle, Vyrlycja, Verbljud and Sobache Ghyrlo (Gharasym, 2019).

Table 2. The area of the Desenka river, obtained during the decoding of remote sensing data

Year	1965	1972	1975	1985	1995	2005	2015	2021
Area, km^2	1,4305	1,6375	1,9327	3,9708	4,9389	4,9426	4,9537	4,9624

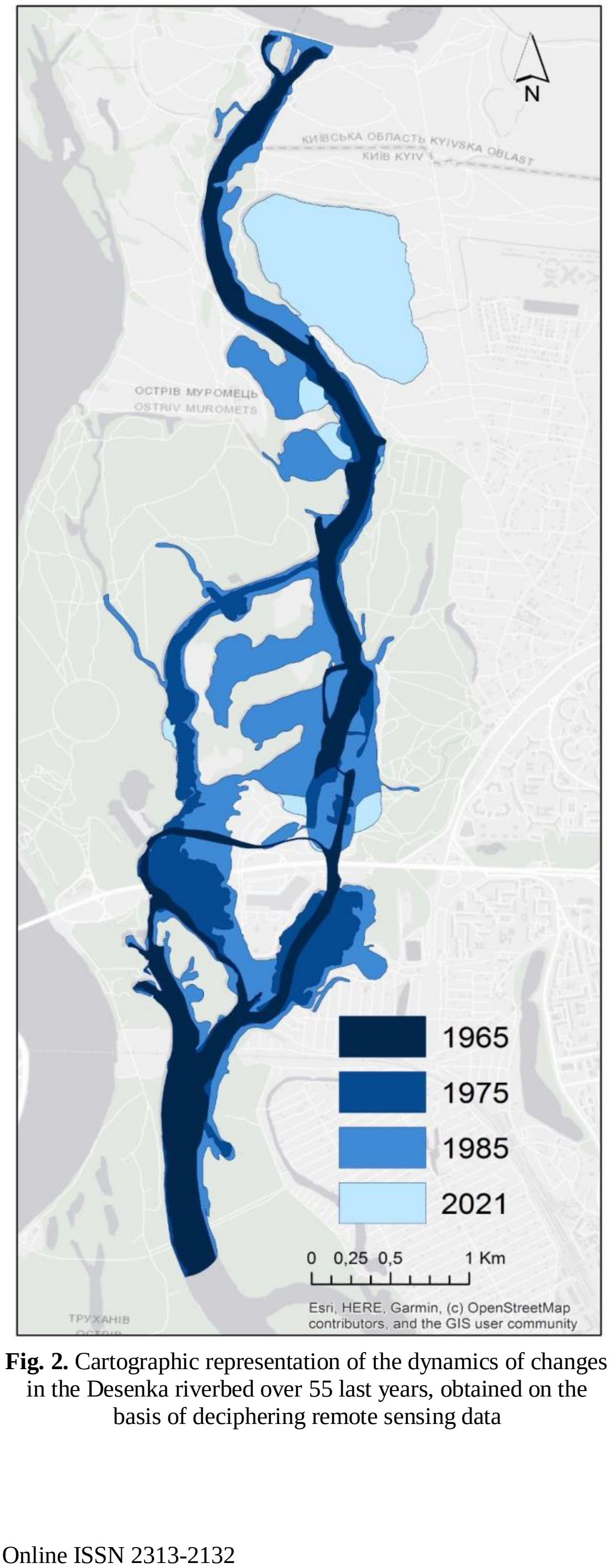


Fig. 2. Cartographic representation of the dynamics of changes in the Desenka riverbed over 55 last years, obtained on the basis of deciphering remote sensing data

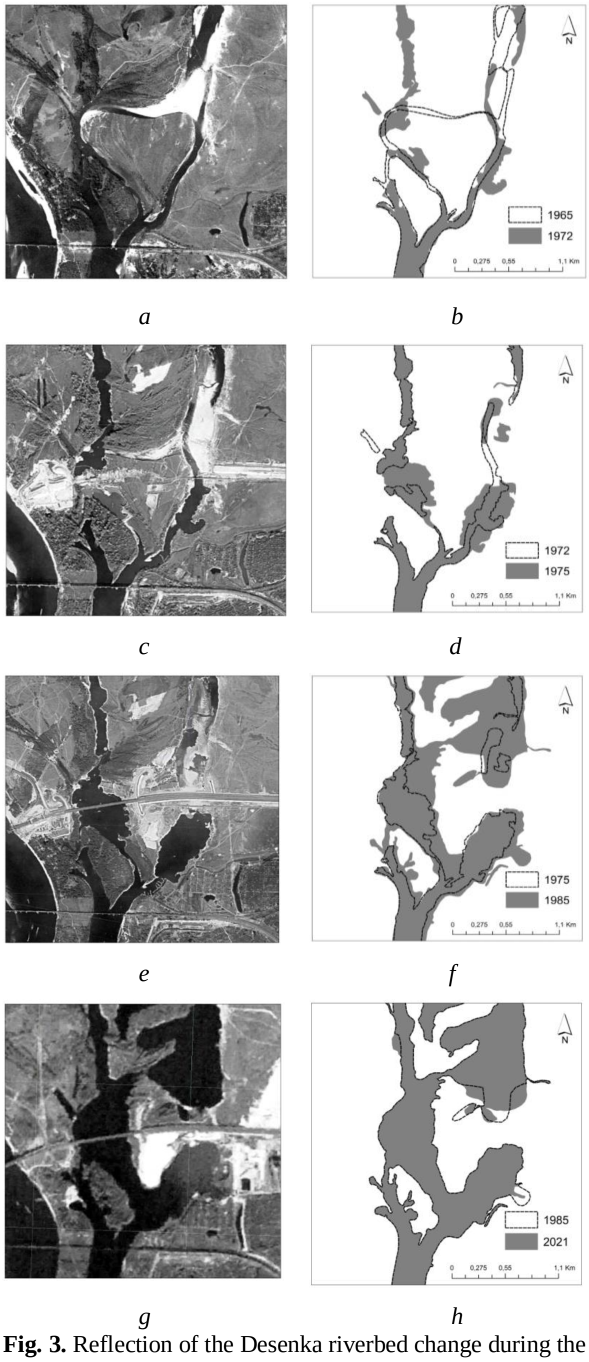


Fig. 3. Reflection of the Desenka riverbed change during the construction of the North Bridge in aerial photographs (*a* - 1965; *c* – 1972; *e* – 1975; *g* – 1985) and the results of their deciphering (*b, d, f, h*)

Hydrous and construction of the first stage of the Troyeshchyna – Vyhurivshchyna residential area (Kyiv, Ukraine) began in February 1981. Hydraulic engineering working at the construction has traditionally led to the fact that part of the small reservoirs was filled up. But because the hydraulic washing itself has to take soil from somewhere, its extraction nearby has led to the emergence of new reservoirs, the largest of which is Lake Almazne. The process of lake formation is clearly demonstrated in Landsat archival space images (Fig. 4).

Sand mining destroys the flora and fauna of the islands, as sand mining requires drainage. Excessive sand mining also reduces the area of islands, which can lead to their partial or complete disappearance. Thus, nowadays the main reason for the dynamics of changes in the area of islands is the extraction of sand from them, which negatively affects the stability of biocenoses. According to the results of the analysis of changes in areas given in this study, the authors proved that uncontrolled sand mining causes irreparable damage to the environment. At the location of swamps, lakes, streams create huge areas of sandstone.

a

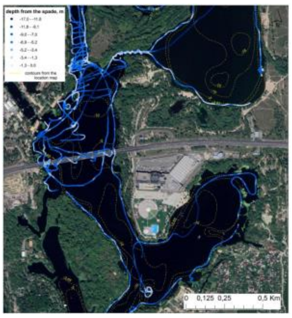
b

c

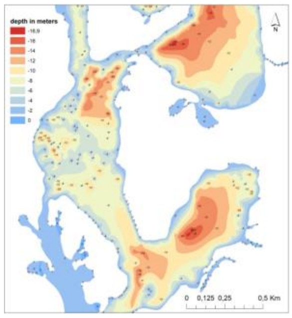
Fig. 4. Dynamics of hydraulic washing and growth of buildings of Troyeshchyna residential area (Kyiv) on Landsat space images from 1985 to 2021: *a* – 1985, *b* – 2000, *c* – 2021

Sand extraction leads to water turbidity in the river, siltation and flowering. Tiny particles of sand settle and silt the eggs during spawning fish. Spawning grounds for fish disappear due to the formation of deep quarries on the river bottom and flood meadows fall asleep. As a result of sand extraction, fish, plants, the fertile soil layer on land and at the bottom of reservoirs are destroyed. That is why it was important for the study to conduct natural research to verify the data obtained during the processing of space images.

According to the results of natural research, measurements of the depth and relief of the bottom of the riverbed of the Desenka river, the area of the North Bridge of Kyiv, Ukraine, were measured. Sonar measurements were made by automatically recording the file log. Depth models are built in the 3D Analyst extension module. According to the results of research, a prototype of the layout of the vector electronic depth map has been developed. This map shows the relief of the bottom and depth. The constructed model of the relief of the bottom of the Desna river is combined with the Landsat space image in the ArcGIS Analyst (Fig. 5) for visual information display.



a



b

Fig. 5. Map of depths obtained by Desenka river in the North Bridge area of Kyiv: *a* – route and depth of echolot measurement and isobbing digitized from the location map; *b* – gradient depth map

The authors made a spatial binding of measurements. This allows us to correctly replenish databases and present the measurement results in a format suitable for use in GIS. The minimum number of measurement points (with a distance of 500 m between them) exceeds a hundred, the working path without taking into account the approaches to the desired courses is about 100 km (Fig. 5*a*). To determine the depth, the authors used the image of Landsat-8 with a spatial resolution about 30 m. When examining water bodies, there must be minimal cloudiness and favorable environmental conditions (no wind). Such conditions are necessary to minimize turbidity to determine the depth and type of the bottom of the reservoir. With the help of echolocation technologies, electronic models of the bathymetric map of the Desenka river in the North Bridge area of Kyiv were obtained.

The purpose of this study was to determine the exact prior information for the study of the riverbed in order to obtain the configuration of the riverbed within the entire studied area. According to the study results, the maximum depth of the reservoir was specified, which is 16.8 m. It is determined that the bottom relief is typical for hydraulic washing. Near the coastline there are 1–2 terraces, which abruptly break off to a depth of 4–8 m. The depth of the river in its central part increases from west to east in proportion to the increase in the width of the reservoir (Fig. 5*b*). The outlines and forms of the banks, the composition of the banks, the presence of ledges and bank ridges of the Desenka river were studied. Bathymetric data is important for tracking water levels in urban areas. Recently, in these territories, we have observed various hydrological conditions associated with extreme weather conditions (floods, droughts). These processes are accelerated by human activity and climate change. Bathymetric data in shallow water areas are important for the safety of navigation, hydrographic bottom mapping, and coastal zone management. According to the results of the study, deep hydraulic alluvium quarries were discovered. This indicates that sand is predominantly mined in the same place, washing out huge underwater quarries and forming numerous silt deposits along almost the entire fairway of the river. The course of the Dnipro, slowed down by dams, can no longer evenly distribute sand throughout the channel.

5. Conclusions

The authors created cartographic models of technogenic and anthropogenic load on the Desenka river, Kyiv, Ukraine as a result of the study. The presented research combines contact and remote methods at the same time. A bathymetric survey was made, as well as mapping of the depths and topography of the bottom of the reservoir. Unlike the existing descriptive registration of recreational loads, this approach ensures the objectivity of primary, analytical and predictive environmental monitoring information. As well as the consistency of regulatory, organizational and methodological support for the analysis of the recreational potential of river ecosystems. The effectiveness of Earth remote sensing methods for monitoring studies and determining the ecological state of hydroecosystems has been proven.

Comparison of historical aerial photographs and modern remote sensing data made it possible to calculate changes in the area of the Desenka river channel for the last 55 years. The cartographic models show the results of a gradual increase (almost three times) in the overflow of the river's water surface. It was revealed that the main reason for the dynamics of the areas of the islands is the extraction of sand. This activity negatively affects the biotic stability of landscapes. Field studies were carried out to verify the data obtained by processing satellite images. According to the bathymetric survey results, the maximum depth of the reservoir was specified, which is 16.8 m. It was determined that the bottom topography is typical for a hydraulic washing quarry (1–2 terraces are distinguished not far from the coastline, which abruptly breaks off at a depth of 4–8 m.) The river's depth in its central part increases from west to east in proportion to the increase in the width of the reservoir. According to the results of the study, deep hydraulic alluvium quarries were discovered. Sand is mined in the same place, washing out huge underwater quarries and forming numerous silt deposits almost along the entire fairway of the river. Based on the results of the analysis of changes in areas given in this study, the authors proved that uncontrolled sand mining causes irreparable damage to the environment. Therefore, in order to preserve this archipelago, sand mining should be stopped.

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МОНІТОРИНГ АНТРОПОГЕННОЇ ЗМІНИ РУСЛА РІЧКИ ДЕСЕНКА (КИЇВ, УКРАЇНА) НА ОСНОВІ ДИСТАНЦІЙНИХ АЕРОКОСМІЧНИХ ДАНИХ

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Стаття присвячена напрацюванню універсального методологічного апарату екологічного моніторингу та ефективного оцінювання стану гідроекосистем для визначення характеру антропогенного впливу. Авторами проаналізовані трансформації русла р. Десенка (Київ, Україна) протягом 1965–2021 рр. Основна увага приділена змінам берегової лінії ріки у межах міста Києва для визначення характеру антропогенного впливу на територію дослідження. Вдосконалено технології моніторингу динаміки водного режиму русла річки шляхом побудови батиметричних карт за результатами гідроакустичних вимірів та дешифрування космічних знімків. Застосовано комплексне використання методик відбору і обробки інформації шляхом застосування ГІС-технологій (тематичну класифікацію результатів дистанційного зондування в умовах обміну даними наземних завірок та незалежними ознаками об'єктів) з приведенням результатів до вигляду, зручного для інтерпретації. Виявлено, що головною причиною зміни площ є видобуток піску. Батиметрична зйомка дала змогу уточнити максимальну глибину водойми, що становить 16,8 м. Визначено, що рельєф дна є типовим для кар'єру гідронамиву. Глибина річки в його центральній частині збільшується із заходу на схід пропорційно збільшенню ширини водойми. За результатами дослідження виявлено, що пісок добувають на одному й тому самому місці, вимиваючи величезні підводні кар'єри та утворюючи численні намиви мулу. За результатами аналізу зміни площ, наведеного в цьому дослідженні, авторами доведено, що неконтрольований видобуток піску негативно впливає на біотичну стійкість ландшафтів та завдає непоправної шкоди довкіллю. Доведена ефективність методів дистанційного зондування Землі для моніторингових досліджень та визначення екологічного стану гідроекосистем. Представлені дослідження свідчать про необхідність стабілізації екологічної рівноваги річкової екосистеми, проведення відповідних заходів для підвищення продуктивності гідроландшафтів, покращення стану довкілля та забезпечення екологічної безпеки русла річки Десенка та прибережних територій.

Ключові слова: антропогенна трансформація, динаміка зміни русла, моніторинг, дистанційні аерокосмічні дані, батиметрія

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