FRI- 20.21-1- SITSTL-05

GIS APPLICATION FOR ANALYSIS AND EVALUATION OF INFRASTRUCTURE RISK AREAS[5]

Prof. AsenAsenov, PhD
Department ofTransport,
UniversityofRuse
Phone: +359 82 888 605
E-mail: asasenov@uni-ruse.bg

Prof. VelizaraPencheva, PhD
Department ofTransport,
UniversityofRuse
Phone: +359888293341
E-mail: vpencheva@uni-ruse.bg

Prof. Juliana Popova, PhD
UniversityofRuse
Phone: +359887899654
E-mail: jppopova@uni-ruse.bg

Assist. Prof. StanimirPenev, PhD
Department of Mechanics, MachineElements,
EngineeringGraphicandPhysics,
UniversityofRuse
Phone: +359889658713
E-mail: spenev@uni-ruse.bg

Abstract: *The report examines risk areas in which emergency situations related to drought or flooding are possible. One of the options for assessment and analysis of these situations, with the aim of prevention, is the use of GIS. The capabilities of GIS allow, provided sufficient preliminary information is available, to take quick and adequate measures to impact critical areas threatened by natural disasters. In this connection, the method of using GIS models and dealing with possible threats in critical infrastructure areas, including problems in the protection of areas such as Kalimok-Brashlen located on the Danube River, is presented. The results show that it is possible to take preventive measures and to avoid or limit dangerous situations based on preliminary forecasts. зи.*

Keywords:*превантивнимерки, GIS, рисковиучастъци, Modelling, защитенизони.*

INTRODUCTION

In recent years, Geographical Information Systems (GIS) have developed significantly and have begun to enter massively to assist in risk assessment and monitoring of various processes in the environment. Active application of GIS has been reported in the following areas related to real-time monitoring of environmental pollution: water, soil and atmosphere, (Chen, L. & et al, 2022). Based on the results obtained, it can be predicted and evaluates the pollution of the studied environment over time and thus to take adequate actions. In addition to air, soil and water pollution, the risk of flooding is also considered (Farhan, Y. &Anaba, O., 2016). A flash flood risk assessment was made in Wadi Yutum valley in southern Jordan, where 17 risk lakes were monitored with the help of sensors and GIS, and prevention measures were presented. Preventive measures were set as the main outcome of the risk assessment. In connection with this, the European Commission has prepared special

[5] Докладът е представен на пленарната сесия на 25 октомври 2024г. с оригинално заглавие на български език: ГИС ПРИЛОЖЕНИЕ ЗА АНАЛИЗ И ОЦЕНКА НА ИНФРАСТРУКТУРНО РИСКОВИ ЗОНИ

requirements on the issue, where it connects risk with hazard, exposure and vulnerability (European Commission, (2021).

The risk assessment is considered according to a methodology that grades the possible dangers in five levels, according to the collected points from zero to 100: Very Low – from 0 to 20 points; Low from 20 to 40; Medium from 40 to 60; High from 60 to 80 and Very High over 80 points, (Frantzova, A. 2023). An assessment of the Northern Bulgarian Black Seacoast regarding geophysical hazards such as earthquakes, landslides and tsunamis was made with the mentioned methodology. The obtained results can be visualized by GIS, by using a database of sensors or recorded by cameras of flying objects. For overall observation of the Earth or large areas, information from Earth Observation (EO) is used (Avalon-Cullen, C.&et. al., 2023). This was done to reduce the risk of flood and landslide related disasters in Jamaica. In addition, in Belgium they used a modified version of the LATIS risk assessment tool, where with the help of IKONOS satellite images they made a detailed map in which they noted the possible damage for the disaster region (Glas, H.&at. al., 2017). Another option for accessing precipitation information is the US-based The Climate Hazards Group Infrared Precipitation with Stations (CHIRPS), which provides worldwide data from 6-hourly to 3-monthly periods. It uses ground and satellite techniques to obtain better models and results in forecasting extreme situations (Funk, C.&etal. 2015).

Another possibility is the unmanned aerial vehicles "drone", which allow to capture with high resolution and accuracy the features of the earth's surface and the objects that are located on it (Çömert, R.&et. Al., 2023). The authors photographed the Akçakalecave in Turkey and determined the area of the cave, its shape and direction. In this way, they presented the risk of possible rock collapses. After that, they are presented in GIS in a visual form with a 3D model, which is suitable for further analysis and risk assessment.

EXPOSITION

По Under project No. 101113015 "Danube Wetlands and flood plains Restoration through systemic, community engaged and sustainable innovative actions — DaWetRest" financed by the Horizon Europe Climate program, HORIZON-MISS-2022-OCEAN-01, it is planned to make a 3D model of the main areas in the protected wetland "Kalimok-Brashlen", in which they occur annually risk situations related to ensuring a normal living environment for aquatic inhabitants, (EC, 2023). For this purpose, it is intended to use data to be processed and visualized in Arc GIS PRO. The action steps are two, one is to determine, through preliminary data and observations, which are the risky areas and then to photograph these areas with an unmanned aerial vehicle.

The software product Arc GIS allows, through a built-in function, after selecting the studied section, to make a simulation, in which it is established how the dry and flooded part changes when the water level changes. An area in the protected wetland area "Kalimok-Brashlen" was studied, which has such a status resulting from Order No. RD-451/ 04.07.2001 of the Ministry of Environment and Water (MoEW). According to the Area Management Plan from 2006, the area of the "Kalimok-Brushlen" PA is 5771.6 ha, (MOES 2006) fig.1.

It is distributed between different owners: State Public - 1502.4 ha; State private – 2724.1 ha; Municipal public – 98.3 ha; Municipal private – 159.1 ha; Private – 485.0 ha; Public organizations – 272.9 ha; Foreign - 0.9 ha; Managed by the municipality - 488.9 ha and Owned by religious communities - 40.0 ha. The distribution is on the territories of two municipalities. Slivo Pole municipality has a total of 1535.2 ha, which are divided into 598.9 ha of forest fund and 936.3 ha of agricultural fund. Tutrakan municipality has a total of 4236.4 ha, of which 1058.4 ha is a forest fund and 3178 ha is an agricultural fund.

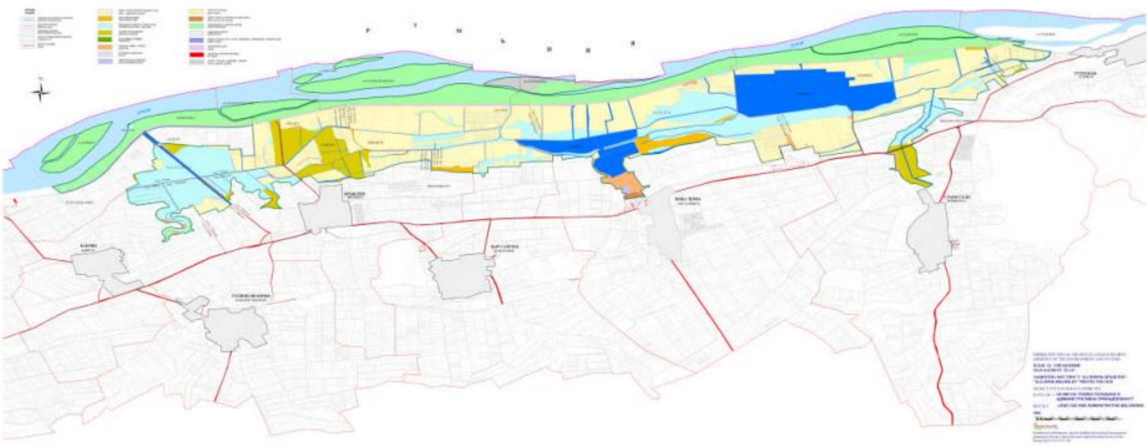


Fig. 1. General view of the digital model of the "Kalimok-Brashlen" CA

The entire area is divided into 4 zones.

I. Heartland area - 222.1 ha. In it, access is generally restricted to humans, except for the purposes of management, monitoring and scientific research. Any type of construction is prohibited here, unlike the other zones, where it is possible under certain conditions;

II. Biodiversity Management Area - 3094.5 ha. It has strict access control. In it, access is allowed in order to ensure the physical and spiritual pleasure of the visitors;

III. Zone for sustainable use - 2445.7 ha plus 1264.5 ha from the Danube river or a total of 3710.2 ha. Certain economic activities may be carried out in this area, in accordance with the objectives of the management plan. These include sustainable agriculture and forestry, fisheries and the promotion of environmentally sustainable activities;

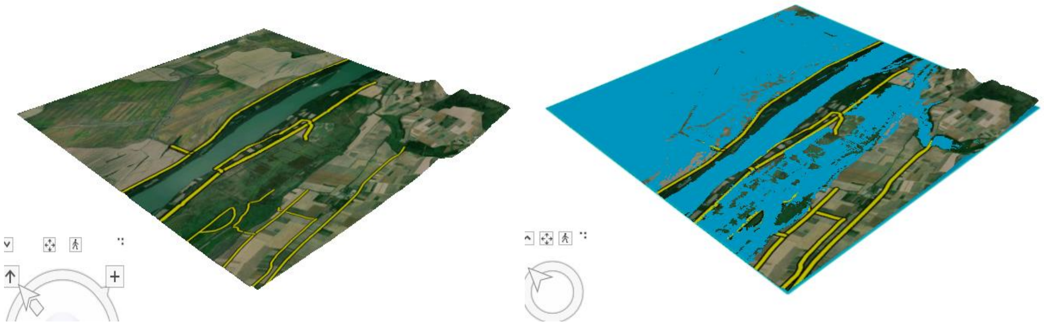
IV. Zone for tourism and infrastructure - 9.3 ha. In this zone, human access is allowed for various activities, which include recreation and visitor accommodation, development of specialized tourism and nature-friendly sports activities.

Apart from these zones, a division is also made according to whether the zones are flooded or not. In this case, the following areas are considered:

- Flooded, waterlogged, alluvial and meadow swamp soils (typical willow) 64.5 ha;
- Flooded, moist meadow-swamp soils (willow-poplar) 254.3 ha;
- Flooded, semi-humid, on alluvial soils (typically poplar) 662.9 ha;
- Flooded, fresh on alluvial soils (drained poplar) 227.5 ha;
- Drained, fresh, meadow-swamp soils (drained former marshes) 31.9 ha.

In the Kalimok-Brushlen National Park, roads have been built that can be used by motor vehicles for agricultural activities (tractors, combines) and vehicles for hunting, fishing, tourism and others. These roads pass through areas where the water level changes throughout the year and sometimes individual sections of them are flooded. This does not allow passing through them and creates obstacles for people. In connection with this, three locks were built connecting the Danube river and the protected area and a pumping station was built, which is currently not working. The sluices can supply or drain water into the area. The pumping station is intended only for draining water from the area. In this way, a certain water level is maintained so that the natural life of plants, aquatic inhabitants, birds and animals can develop normally.

When the water level in the area is low, usually during the summer months of July and August, the area is accessible to vehicles, fig2.a. Fig. 2.b shows the situation through simulation in Arc GIS, where the water level is predicted to be 2 m from the level assumed to be zero on the horizontal plane of the area. In this case, he sees that a large part of the area is flooded. This shows where the low spots are in the area. It can be seen that the northern zone is lower than the southern one. Therefore, in the event of flooding or the presence of groundwater, roads in low-lying areas are expected to be flooded. In a simulation with a smooth increase or decrease of the water level, it is possible to predict and predict how the roads and the entire surrounding area will be flooded.



a) in the absence of water in the area b) in case of flooding, areas with a level of 2 m

Fig. 2. General view of part of the 3D digital model under different conditions

With such a model in place, drainage solutions or traffic routes can be proposed. By linking rainfall information to area information, access restrictions or bans can be introduced, as well as proposed measures to change the infrastructure in permitted areas, such as digging drainage channels, cleaning constructed channels or other facilities , time and duration of opening and closing of the locks, etc. For more accurate analyses, it is necessary to use specific information with dimensions accurate to the millimeter. This can be achieved by purchasing one or by obtaining it by taking a picture with accurate measuring equipment.

The GIS analysis of the water levels of the Danube River offers valuable information to identify areas at high risk of infrastructure flooding, including roads. Using data on water level changes in combination with topographic and infrastructure layers, GIS technology enables the creation of maps with designated vulnerable areas. This allows analysts to determine which sections of roads are at risk of flooding during high water levels, as well as the frequency and duration of these floods. The ability to analyze historical data also provides insight into seasonal patterns of water levels and risk periods, helping to plan maintenance and repairs, as well as possible measures to increase infrastructure resilience.

The diagrams fig. 3.a and 3.b present a GIS analysis of the Danube river region and the potential flooding of roads at high water levels. The first diagram shows a standard visualization of the terrain and road network under normal conditions. The second diagram shows the same territory, but with simulated flood zones marked in blue that cover part of the road network. The analysis highlights at-risk sections that could be inundated with increased river water levels and visualizes the potential impact on transport infrastructure.

The detailed GIS analysis of the water levels of the Danube River regarding flooded usable areas can provide important information about the economic and environmental impacts on cultivated land, residential areas and industrial areas. First, by combining spatial data on water levels with topographic and land-use layers, GIS analysis identifies areas at high risk of inundation when water levels rise. This includes arable agricultural land that can be inundated by high waters, as well as infrastructure that is critical to economic activity in the region.

Second, through historical flood data, GIS can predict what the long-term impacts on usable areas will be. For example, flooded agricultural lands may suffer erosion, loss of productivity or crop destruction, which will affect the local economy. Flooding of residential areas results in property losses and forced evacuations, while industrial areas may experience business interruption and damage to facilities. In addition, GIS analysis can help plan preventive measures and strategies for adapting to climate change, such as building new dikes or creating flood control zones to limit the risk to usable areas.

From the information provided (MTS 2024) with water levels for the Bulgarian section of the Danube River for 25.10.2024. we can see the measurements of various hydrometeorological stations, including at Novo Selo, Oryahovo, Nikopol, Svishtov, Ruse and Silistra. The water table levels varied between 285 and 342 cm, and the water quantity in m^3/s was also measured. The connection with the

Kalimok and Brashlen localities is direct, as the river levels in these regions affect the flooding of wetlands and ecosystems. High water levels can affect nature reserves where wetlands are critical for maintaining biodiversity.

The average water level of the Danube River in the Kalimok-Brashlen region fig.3 varies depending on the seasons and hydrological conditions. Generally, average water levels hover around 300-350 cm, but these values can vary greatly depending on water inflow, snowmelt and rainfall. Wetlands such as Kalimok-Ivy play an important role in regulating water levels by holding water during high water levels and providing habitat for native species.

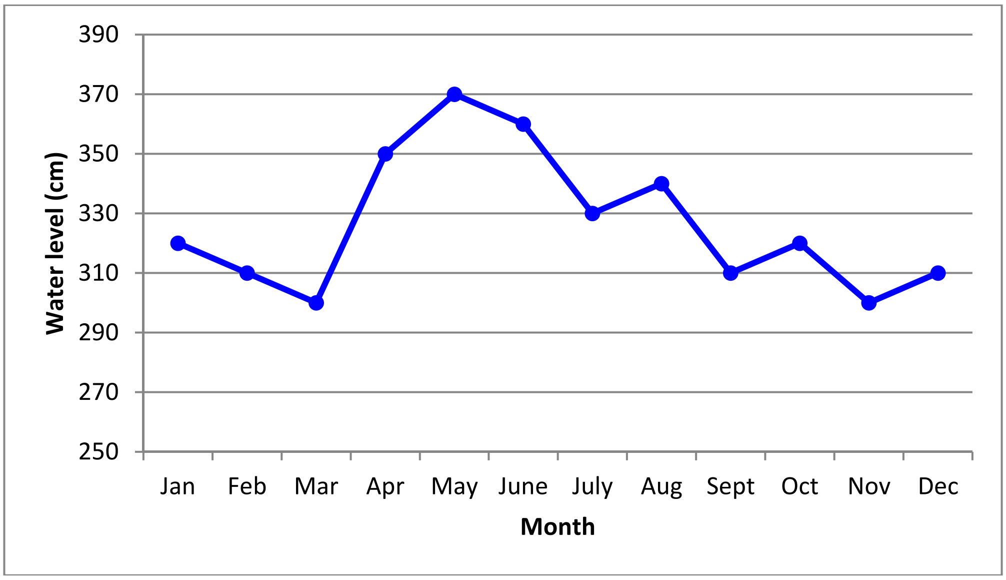


Fig. 3. Average water level of the Danube River in the Kalimok-Brashlen area by month for 2024. with forecast for months 10,11,12

The graph shows the approximate average water level of the Danube River in the Kalimok-Bršhlen region during the different months of the year. Water levels fluctuate between 300 cm and 370 cm, with the highest values usually occurring in spring and early summer (May-June), which can be explained by snowmelt and seasonal rainfall. Levels are lower in winter and late autumn when water inflow is lower. These data are important for flood monitoring and management planning of nature reserves in the area.

The GIS analysis of the water levels of the Danube River, as well as the obtained data on the average water levels in the Kalimok-Brushlen area, reveal significant dependencies that affect both the natural environment and the infrastructure and usable areas. Periods of high water levels, characteristic of spring and early summer, can lead to flooding of agricultural lands and wetlands in this area. This flooding can have a variety of consequences, including soil erosion, production losses, as well as ecological impacts on the habitats of native species.

Additionally, the data highlight the need for careful management of water resources, as sudden changes in water levels create the potential for extreme flooding. In this regard, the monitoring of water levels and the design of infrastructural improvements (eg dikes or channels to divert water) play an important role in the long-term protection of critical areas and ensuring the sustainability of the regional economy and natural resources.

CONCLUSION

The analysis of a section of critical infrastructure in the area of the Kalimok - Brashlen National Park shows that the use of 3D simulation modeling in GIS can visualize the sections at risk of flooding, which include the roads on which vehicles move. As a result, it can predict which sections will be impassable and suggest alternative solutions or impose access bans.

The constructed network of canals and locks in the protected area allows influencing the water level in two directions, to increase and to decrease. In this way, the normal life of the inhabitants and the possibility of vehicle access on the constructed road network can be ensured.

ACKNOWLEDGEMENT

This work is co-funded by the European Union Horizon Europe programme (HORIZON-MISS-2022-OCEAN-01) under Grant Agreement no. 101113015 (DaWetRest).

REFERENCES

Chen, L., Mao, Y., & Zhao, R. (2022). *GIS application in environmental monitoring and risk assessmen*t. 3rd International Conference on Geology, Mapping and Remote Sensing (ICGMRS), 908-917. IEEE. DOI:10.1109/ICGMRS55602.2022.9849269

Farhan, Y. &Anaba, O. (2016).*Flash Flood Risk Estimation of WadiYutum (Southern Jordan) Watershed Using GIS Based MorphometricAnalysis and Remote Sensing Techniques*. Open Journal of ModernHydrology, 6, 79-100. doi: 10.4236/ojmh.2016.62008.

Frantzova, A. (2023). *Disaster Risk Assessment of North Bulgarian Black Sea Coast*. RevistaMinelor – MiningRevue,vol. 29, issue3, 82-92, ISSN 2247-8590, DOI: 10.2478/minrv-2023-0018.

Çömert, R., Özdemir, S., Bilgilioglu, B.B., Alemdag, S.&Zeybek, H.I. (2023). *3D dataintegrationforgeo-locatedcavemappingbasedonunmannedaerialvehicleandterrestriallaserscannerdata*. Baltica, 36 (1), 37–50. Vilnius. ISSN 1648-858X, https://doi.org/10.5200/baltica.2023.1.4

European Commission, (2021). Recommendations for National Risk Assessment for Disaster Risk Management in EU. JRC123585, EUR 30596 EN, Luxembourg: Publications Office of the European Union, 2021, © European Union, 2021; doi:10.2760/43449; doi:10.2760/80545

Avalon-Cullen, C., Caudill, C., Newlands, N.K., &Enenkel, M. (2023). *Big Data, Small Island: Earth Observations forImproving Flood and Landslide Risk Assessment in Jamaica*. Geosciences, 13(3), p.64. DOI:10.3390/geosciences13030064

Glas, H.,Jonckheere, M., Mandal, A., James-Williamson, S., de Maeyer, P.&Deruyter, G. (2017). A *GIS-based tool for flood damageassessment and delineation of a methodology for future risk assessment: Case study for Annotto Bay, Jamaica*. Nat. Hazards,88, 1867–1891.

Funk, C., Peterson, P.,Landsfeld, M.,Pedreros, D., Verdin, J., Shukla, S.,Husak, G., Rowland, J., Harrison, L.,Hoell, A.& et al. (2015).*The climate hazards infrared precipitation with stations—A new environmental record for monitoring extremes*. Sci. Data 2015,2, 150066

EC (2023). 101113015.*Danube Wetlands and flood plains Restoration through systemic, community engaged and sustainable innovative actions — DaWetRest*. 2023-2027, HORIZON-MISS-2022-OCEAN-01, https://dawetrest.eu/

МОСВ (2006). *Защитенаместност „Калимок-Бръшлен", Планзауправление 2006*г., София

МТС (2024). Водни стоежи в българския участък на река Дунав за 25.10.2024 г. https://appd-bg.org/