THE METHOD OF MULTI-CRITERIA ANALYSIS FOR DETERMINING THE FLOOD-HAZARDOUS AREA AND THE DEVELOPMENT OF PROTECTIVE STRUCTURES

B. Apshikur [1], T. B. Kurmangaliyev [1], A. G. Goltsev [1], M. M. Alimkulov [2], A. K. Kapasov [1]

[1] D. Serikbayev East Kazakhstan Technical University, Ust-Kamenogorsk, Kazakhstan - bapshikur@edu.ektu.kz; nomad007@mail.ru; AGoltsev-vko@mail.ru; azamat040594@mail.ru
[2] Academy of logistics and transport, Almaty, Kazakhstan - alimkulov_murat@mail.ru

KEY WORDS: Flood detection, Flood mapping, Passive microwave remote sensing, Water resources, River flow regulation, Reservoir cascade, Water intake, Flood protection, Maximum water level.

ABSTRACT:

The city of Ust-Kamenogorsk, East Kazakhstan region, annually has a high risk of flooding and flooding of territories caused by spring snowmelt. These extreme phenomena are one of the most dangerous natural disasters, as they cause enormous socio-economic damage to the coastal settlements of the city. In the flood zone, agricultural and residential facilities, as well as engineering and technical infrastructure facilities are indicated. In some years, the funds allocated by the local buzhet to restore the damage caused by the disaster are not enough. One of the most effective means of stopping the consequences of such natural phenomena is an early warning system. Forecasting and modeling of hydrological phenomena can be provided using new IT technologies, some of which are Geoinformation technologies (GIS technologies) based on the cartographic method.

In addition to modern advanced data processing methods in the GIS environment, the article presents a water collection design for emergency protection by calculating the main influencing factors of flooding and determining specific scales of flood levels in river valleys near settlements, determining the area of reservoirs collected at a risk control point at specific flood sites, as well as analyzing the detected ers material. The prospects for the use of GIS technologies as a means of forecasting and modeling floods caused by annual floods during the spring snowmelt period are also outlined, an analysis of the real situation is carried out, and a simple design of the shore for use in extreme conditions during periods of flooding is given.

1. INTRODUCTION

The issue under study is considered one of the most dangerous natural disasters that can occur in the spring and autumn seasons in this region. The flood disaster, along with economic losses in this region in recent years, caused enormous damage to grain production from the washing of agricultural land as a result of the destruction of the Irtysh Water Valley. In addition, due to the flooding of some settlements of Ust-Kamenogorsk, located on the banks of the Irtysh water basin, the city's infrastructure was destroyed, and in some cases there were cases of flushing of bridges and houses.

A quick assessment of the location and extent of damage caused by natural disasters is necessary in order to be aware of the situation in real time and respond effectively at the stage of disaster management.

Flood risk is a measure of exposure to floods and floods, assessed taking into account physical, climatic, hydrodynamic, economic, social and environmental aspects. When calculating flood risk, risk and vulnerability are combined to determine them by addition (Wang, Li, Tang, & Zeng, 2011) or multiplication (Li, Xiang, Tong, & Wang, 2013).Due to the lack of statistical data required for the calculation, the analytical calculation of flood risk is extremely difficult (Kron, 2005). Instead, risk assessment using numerical modeling of remote sensing materials (Dutta et al., 2007; Liu, Zhang, & Cui, 2012) and index analysis (Chen, Yeh, & Yu, 2011; Kazakis, Kougias, & Patsialis, 2015) make it possible to fully analyze flood risk. Therefore, on the basis of pre-designed monitoring of natural disasters, it is very effective and realistic to develop a strategy for their mitigation. Hydrological and hydrodynamic models are widely used to model floods, the size, frequency and scale of floods at the basin scale (Kuldeep et al., 2016; Liu et al., 2012; Ullah, Farooq, Sarwar, Tareen, & Wahid, 2016). However, since the assessment through several separate criteria gives a superficial solution, the use of an integrated computational approach is an effective solution for assessing the level of danger.

To assess the flood risk, a morphometric analysis method was used using various parameters based on geomorphological and hydrological characteristics based on studies on the use of data on numerical heights of the earth's surface (DEM) (Noman, Nelson, & Zundel, 2001; Samela et al., 2016). However, assessing the spatial impact of flood risk is crucial for early warning and disaster risk reduction.

Over the past two decades, many studies, understanding the role of parameters, have used multidimensional analysis of solutions to assess flood risk based on flood control indices (Hazarika, Barman, Das, Sarma and Bora, 2016; Kazakisetal., 2015).

GIS-based MCDA studies complex decision-making problems by hierarchical organization of criteria (Chen et al., 2011). A literature review conducted by de Brito and Evers showed that about 82% of studies used MCDA, most of which were studied in Asian and European countries (85%), and about 72% of studies used the analytical hierarchy process (AHP - analytical hierarchy process) within MCDA, although the prospects and the number of parameters used in these studies, were not constant. However, location-based event data is not sufficient for MCDA-based threat monitoring, and, conversely, targeted use of special plugins shows effective results.

Using data obtained from space, it is becoming increasingly popular thanks to spatial mapping of floods that have occurred, improved sensory functions and re-coverage. Synthetic aperture radar data, due to its ability to pass through clouds, is very useful in mapping floods, but it is very expensive financially on a small scale. Consequently, the fact that freely available multispectral images, such as Landsat 8 OLI images, are suitable for monitoring and mapping surface water dynamics points the way to solving this obstacle (Du et al., 2014; Xu, 2006). Various methods have been developed for classifying water pixels by processing surface reflection fixed by various spectral ranges of optical sensors. Many studies conducted to study surface water bodies have used a normalized water difference index and for floods (Pandey, Singh, & Nathawat, 2010).

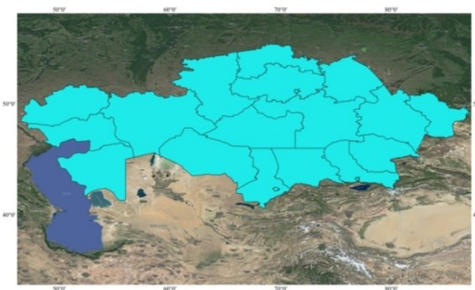
The conducted studies were carried out to identify the threat of flooding of settlements located on both banks of the Irtysh River in the Republic of Kazakhstan, the East Kazakhstan region, the city of Ust-Kamenogorsk and the suburbs.

The purpose of this study is to determine the degree of flooding based on a quantitative model of the Earth's surface to assess the potential danger with a theoretical justification for the application of engineering measures to dangerous places based on flood risk analysis and analysis to determine the danger zone. SRTM space materials were used here to prepare a flood risk map based on the index by combining the Basic Terrain Analysis criteria of the SAGA program. Along with the identification of flood sites, it is proposed to build flood control structures as the water level in them rises (Toguzova et al., 2022).

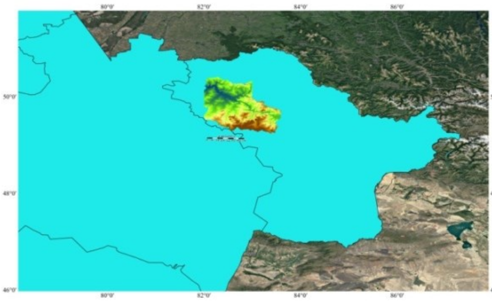
The proposed method allows assessing floods for a certain safety of the population, using remote sensing technologies, making effective decisions in advance and making engineering decisions to prevent natural disasters.

1.1. Research area and brief geographical character

The city of Ust-Kamenogorsk is located on the plain floodplain of the mountain massif of the East Kazakhstan region of the Republic of Kazakhstan with a geographical coordinate of 49°58'17"N, 82°36'21.2"E, with an area of 540 km2 (Figure 1).



a)



b)

Figure 1. Geographical location of the research area: a) Regional borders of Kazakhstan, b) research area boundaries.

The relief height in the area ranges from 280 to 1120 m on mountain peaks, the average height of the city is 283 ± 1 m. The city is located on both banks of the Irtysh River watershed. In the study area, in addition to the main Irtysh River, there are water sources from mountain gorges and the Ulba River. In the north, the structure is a mountain range, and in the West and south -numerous low-lying steppes. From a meteorological point of view, the climate in this region is unstable, humid and sharply continental. The cold period is from November to March, the record minimum air temperature in January is -49 °C, in July + 4 °C. the record high is +8 °C in January and +43 °C in July. The population of the city according to statistics for 2021 is 335,406 people.

1.2. Purpose of the study

The regime of tributaries in the mountainous part of the river often originates in high-altitude snows and glaciers. Spring and summer floods on rivers occur annually. For example, the average height of the catchment area on the Bukhtarma River near the village of Ormandy hor = 1520 m. The maximum level of spring-summer flooding usually falls in May, and the thinning period falls in June-July. For cereals in the village of Berel (hsr = 2200 m), the transition period from maximum to normal is the end of May–June. Rain floods occur in May-June or May-July, and floods, falling into the main flow water drain (Figure 2).

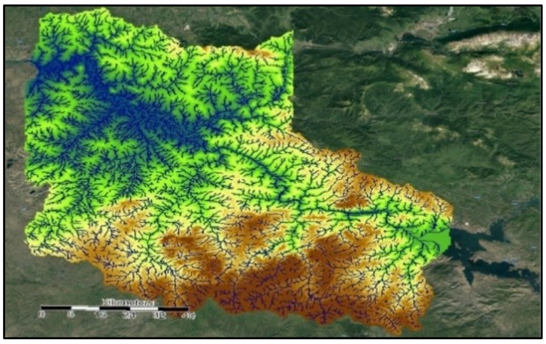


Figure 2. Massive arrangement of water drains.

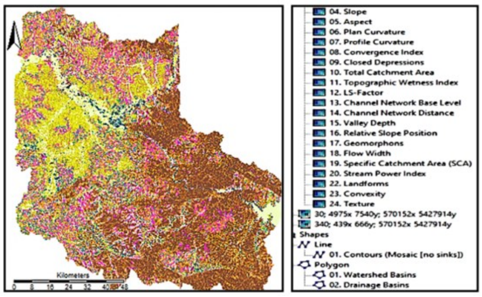


Figure 3. The main criteria for determining the catchment basins in the studied area of possible flooding of the territory.

The area is prone to flooding due to its location on the banks of several large aqueducts and in the floodplain of the western northern part of the city. At the junction of the Ulba River with the Irtysh River in the city center, in comparison with the height of the high water flow, the reservoir level in flood seasons begins to wash away the soil banks and rise to the lands of settlements.

2. MATERIALS AND METHODS

2.1. Model inputs

This study used multidimensional spatial data analysis (SRTM-DEM), GIS (QGIS, SAGA GIS (System for Automated Geoscientific Analyses) to determine flood risk zones. Comparative effects of criteria, taking into account their impact on floods, using the method of structural analysis of the relationships between the selected criteria (Saaty, 1980) and an effective method for determining and filling surface cavities in numerical relief models for hydrological analysis and modeling Wang, L. & H. Liu (2006) was calculated. The AHP- (analytical hierarchy process) method includes the necessary step (Lee, Chen, & Chang, 2008; Papaioannou et al., 2015). This study used the natural gap method because it reduces variance in classes and maximizes inter-class variability. Consequently, this method reduces the average deviation from the average value of each class, and also maximizes the deviation from the average value of other class groups (Stefanidis & Stathis, 2013). Combining relative weights to evaluate criteria and parameters, a geomorphometric criteria map showing flood risk was prepared in the GIS environment (Sadenova et al., 2022).
The selection of suitable criteria is most important in a semi-quantitative method based on MCDA. Previous studies have used different criteria according to local geographical conditions that affect the physical process of the flood mechanism (Chen et al., 2015; Kazakis et al., 2015; Papaioannou et al., 2015; Wu et al., 2015). There are many rivers in the studied zone, i.e. in the upper reaches of the basin, before reaching the plain, the Irtysh forms a number of tributaries representing the largest number of waters of the rivers Kurchum, Narym, Bukhtarma, Ulba, Uba, etc. The regime of the river and its tributaries in the mountainous part is largely determined by the presence of high-altitude snow and glacial nutrition. Since rivers are characterized by spring-summer floods, analyses related to physical-geographical, hydrological and surface characteristics were determined by criteria (Figure 3). These criteria are wastewater catchment, drainage capacity, height, depth of basins, exposure, runoff coefficient, slope and total catchment of basins.

Since the accumulation of runoff determines the cumulative flow of inclined runoff, and this is one of the main criteria for determining a flood-prone area. In addition to floods, a significant part of low-lying areas are flooded due to insufficient water absorption as a result of the influx of coastal wastewater. Therefore, drainage capacity was considered as appropriate parameters, since it reflects the ability to remove excess precipitation. Thus, spatial changes in wastewater, the size of the slope with the slope of sunlight, were used to account for the complex interactions of soil and slope with precipitation by decomposing their individual effects.

The indexes of the selected criteria are prepared in a GIS environment with the same spatial resolution of -30 m. Thematic layers of accretion of flow, height and slope were prepared on the basis of DEM with a spatial resolution of 1 angular second (-30 m). Drainage accumulation, inclined layer (hail) was assessed on the basis of DEM using the SAGAGIS surface analysis tool, the "surface analysis" extension. A controlled risk classification based on maximum probability, as well as pre- and post-processing methods were used. Rural settlements vulnerable to flooding were taken using a Google Terrain map with an elevation map applied to the estimated basin area. The drainage coefficient was calculated by analyzing the slope overlap. To output the overlap, a reference table was compiled, and a coefficient value was assigned to each combination.

The range of values of each parameter has been classified to increase objectivity. Using the natural discontinuity classification method, quantitative parameters such as wastewater accumulation, drainage capacity, height, and flow rate were grouped together. On the other hand, as a result of morphometric analysis of the terrain, qualitative parameters, such as the depth of mountain arms, woodlands and geomorphological conditions that hold a layer of snow on the surface of the earth, were classified in accordance with local conditions. Consequently, the slope map was grouped into classes according to the classification, as it was found to be very similar to the natural divergence method in the study. Basic Terrain Analysis has been grouped into basic classes, with the exception of Geology, where each parameter has only three lithological units. Taking into account the influence of each parameter during flooding, a value was assigned from 1 (for the minimum effect) to 11 (for the maximum effect) for each parameter.

The flow strength index (SI) * is determined taking into account data on the catchment area and the inclined surface Moore, I. D., Grayson, R.B., Ladson, A.R. (1991) (Figure 4):

$$SI = \ln (CA \cdot \tan G), \quad (1)$$

Where CA and G are, respectively, the catchment area and the slope of the waterfall.

The flow power index can be used to describe the potential erosion of the flow at a given point on the topographic surface. As the catchment area and slope increase, the amount of water flowing from the slope zones increases, water consumption increases and, consequently, the Flow Power Index and the risk of erosion increases.

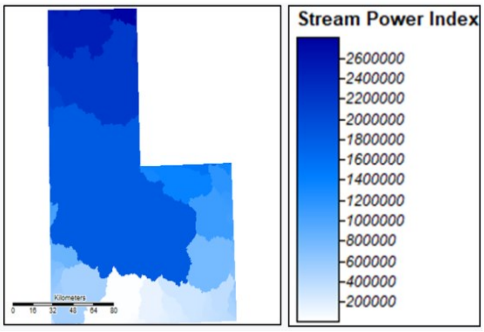


Figure 4. Flow power index.

The accumulation of the flow was determined as a result of expert analysis as the most important parameter, since it reflects the degree of concentration of the surface flow. The flow accretion values increase in the lower flow as the flow strength index (SI) increases. Consequently, the areas below it are more prone to flooding. Calculating the accumulation of the flow at the level of the object location is an error, since it is estimated at the scale of the basin. The study assessed the accumulation of wastewater not for the entire basin of the East Kazakhstan region, but for a subset of the basin of the city of Ust-Kamenogorsk, in which the region under study is calculated. For this large river basin, since the processing of DEM takes a long time, there is no need for the actual cost, the speed of collecting the flow for the study. The result shows that the greatest value of the flow is concentrated in the Lower mouth of the Irtysh River, since the confluence of the rivers from the city center is a tributary, where the main mountain waters are completely collected (Figure 5). According to the results of the analysis of the territory considered dangerous, the area is respectively 1-11.08 sq. km, 2-97.47 sq. km, 3-11.92 sq. km. water is collected through three main pools. The calculation parameters show a very dangerous value with a limited area of the river valley (Table 1).

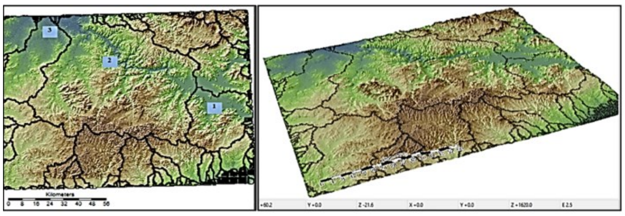


Figure 5. The main pools in which water is collected.

Field	Name	Type	Minimum	Maximum	Mean	Standard Deviation
1	ID	Signed 4 byte integer	0	8030	4011.69	2314.79
2	VALUE	4 byte floating point number	54	17255.9	8218.4	4572.49
3	NAME	String				

Table 1. Parameters of the main catchment basins.

The obtained values were processed to calculate the relative significance of each criterion and the corresponding weighting factor (*w*). These relative weights were determined using an analytical hierarchical process (AHP) [11]. The corresponding significance between the various parameters was determined on the basis of relevant experience in the literature, as well as specific recommendations presented as a result of expert consultations. According to the obtained values, various parametric flood risk maps were compiled.

3. RESULTS AND DISCUSSION

Calculation of flood zones taking into account the main criteria. In this study, the concept of drainage abilities was analyzed, since floods in the floodplain of the Irtysh basin are usually caused by the expansion of the riverbed due to the lack of diversion of excess water from the urban area. Thus, using only the drainage density used in many previous studies (Ouma & Tateishi, 2014; Wu et al., 2015) may deviate from reality during the analysis.

Here are places with a very high altitude of 500-800 meters, with a low altitude of 280-300 meters (Figure 6) and the lack of concreting of the river bank in this place indicates the likelihood of flooding of these areas by floods, and since the riverbed in the foothills at very high altitudes flows along the mountain channel, the channel in them is stable and a minimum rating is assigned for floods.

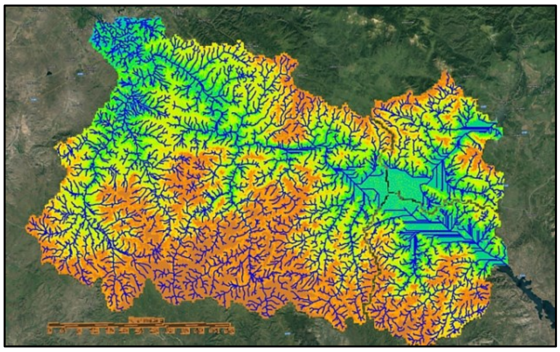
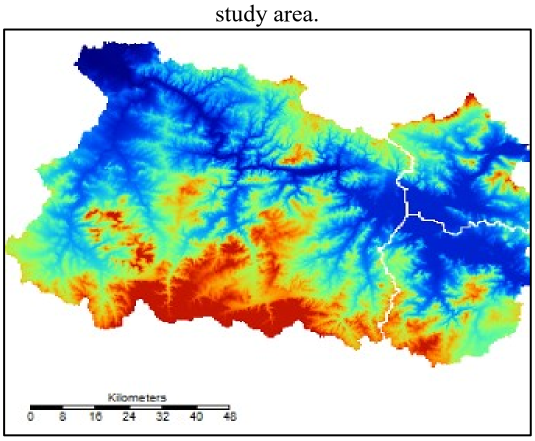


Figure 6. Map of sewage drains in the study area.

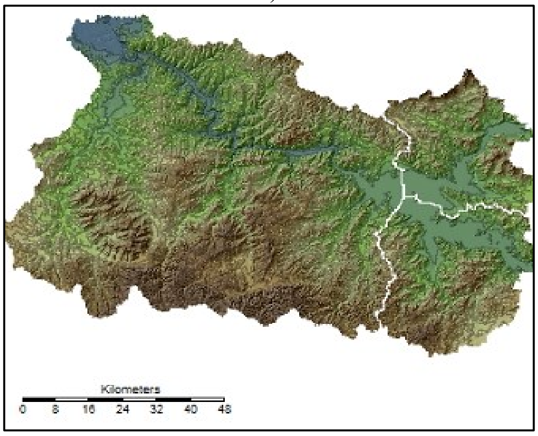
The abundance of water sources flowing from the innovations of the river within the city is observed in the western northern part (Figure 7a, b, c Table 2).

Field	Name	Type	Minimum	Maximum	Mean	Standard Deviation
1	SEG MENTID	Signed 4 byte integer	1	7063	3532	2038.9
2	NODEA	Signed 4 byte integer	1	7084	3538.96	2041.5
3	NODE A	Signed 4 byte integer	6	7083	3545.34	2030.3
4	BASIN	Signed 4 byte integer	1	21	12.2033	3.3122
5	ORDER	Signed 4 byte integer	1	7	1.97833	1.2920
6	ORDER CELL	Signed 4 byte integer	5	11	5.97833	1.292092
7	LENGTH	8 byte floating point number	30	12719.1168	993.048	880.5987

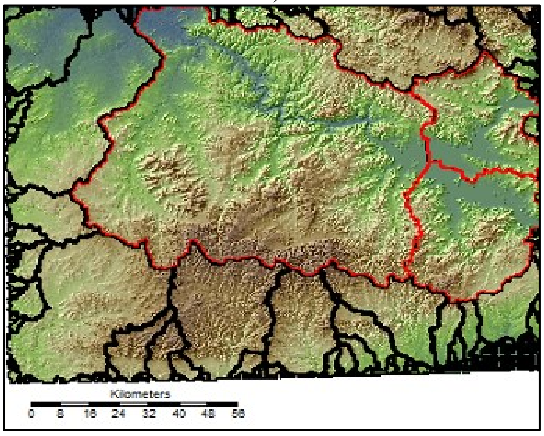
Table 2. Estimated characteristics of catchment basins in the study area.



a)



b)



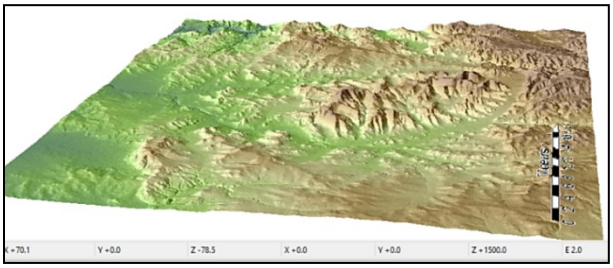
c)

Figure 7. Topographic map of the research area; a) DEM; b) topographic map, c) basins in the research area.

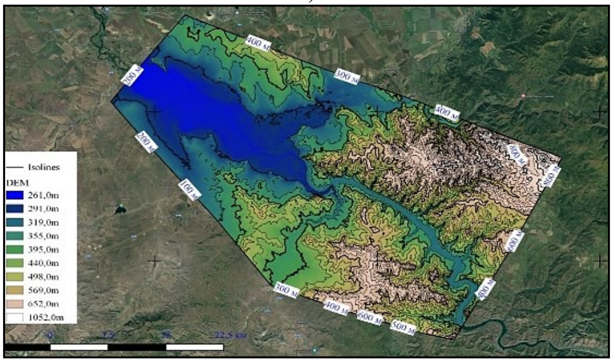
.

Height is one of the most important parameters determining the consequences of flooding in floodplains (Ouma & Tateishi, 2014). Areas with low altitude are vulnerable to flooding because a water pressure channel flowing from a mountain height into a stable valley can quickly wash away weak soil from the coast. In this study, the height range was divided into ten groups and obtained a value from 2 to 10 at equal intervals (Figure 8). The height of the districts near the confluence of the Irtysh and Ulba rivers is very low (200-300 m), and most of the central and higher mountain gorges of the district to the mouth are moderately low (300-350 m). These areas are considered likely flood sites, so they are assigned categories 8 and 10 for low and very low altitude zones, respectively.

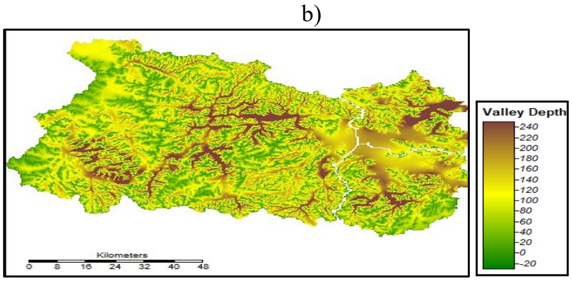
The depth of the valley is calculated as the difference between the height and the interpolated ridge. Ridge interpolation uses an algorithm implemented in the vertical distance to the channel network tool. It performs the following steps: - definition of comb cells Kron (2005).



a)



b)

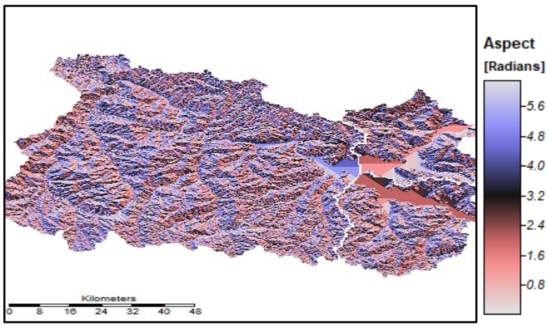


c)

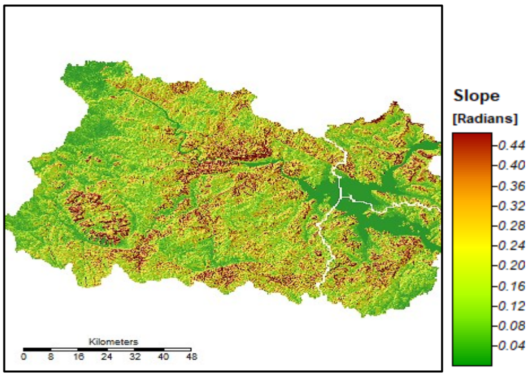
Figure 8. Class of the study area by height: a) 3D view, b) elevation map by horizontal, c) Depth map of watersheds flowing into catchment basins.

The slope of the surface determines the flow rate of the Earth, as well as the concentration of the flow. The upward slope helps to drain water faster, and the downward slope can lead to stagnation of water and floods. Since the studied area is located above the floodplain, the slope of the surface is very small. Thus, most of the area has a low slope (< 5%) with a high estimate for very high parameters (Figure 9).

Infiltration and fluidity of the territory are also controlled by the main geological structure. Since the soil near the water-holding reservoir has good permeability, it was assigned 1 point, and the upper mountain range-9.1-11 points (Figure 10). The study showed that geology plays the least important role in the occurrence of floods, since it cannot exercise strict control of spatial variability.



a)



b)

Figure 9. Slope classification map of the study area, a) slope, b) aspect azimuths of sunlight.

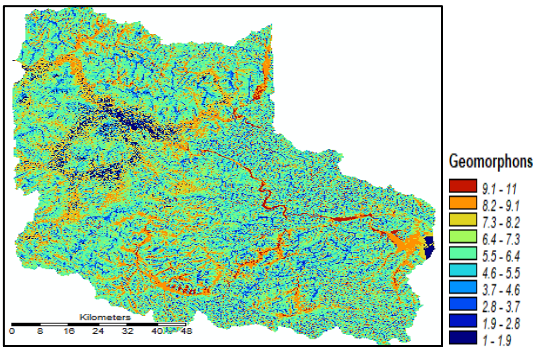


Figure 10. Relief forms, from a digital relief model using a machine vision approach.

Land use controls hydrological processes in various ways, for example, forest cover contributes to the capture and infiltration of snow precipitation, thereby reducing the formation of wastewater, and the area treated off the coast of the Irtysh helps to produce surface runoff. We gave a very high priority to water for floods, since the maximum flow is concentrated in the river, since when analyzing the dangerous part of the Irtysh River in the city territory consists of loose sandy rock with banks and is not concreted. A significant part of the study area is covered by the lands of settlements, which are assigned six points, taking into account the average impact of the flood.

The Topographic Humidity Index (TWI) (Figure 11) is a widely used method for analyzing the hydrological behavior of the landscape (Hazarika et al., 2016), is calculated using a simple mathematical formula that includes both the topographic slope and a certain catchment area. TWI is used in fields such as hydrology, geomorphology, ecology, and soil science to identify regions with high or low hydrological potential, identify potential erosion and sedimentation problems, and map wetlands and mountain plants. TWI values can also be used as predictors of soil moisture, evaporation, and runoff. This is a widely used method of identifying a network of streams and determining the drainage scheme, which gives a good idea of the hydrological behavior of the landscape. It is calculated using Python or GIS as follows:

$$TWI = \ln(a / \tan(slope)), \quad (2)$$

Where: a is a certain catchment area (the total area that contributes to leakage in a certain place in our example, three basins). "slope" is the local slope of the terrain, measured in radians.

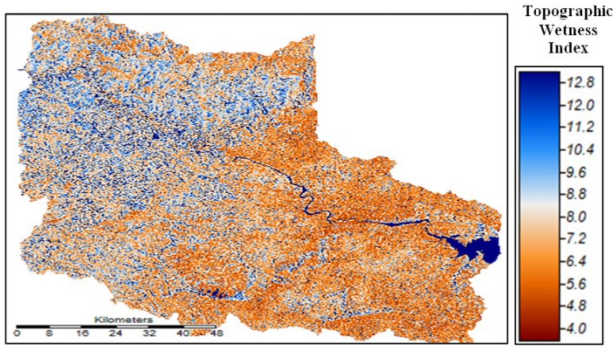


Figure 11. Topographic wetness index.

The result of the analysis (Figure 12) shows that 37.64% of the territory is located in a high flood risk zone, followed by very high and medium risk zones covering 27.17 and 21.56% of the territory, respectively. Only 5.80 and 7.85% of the territory are located in areas with a very low and inconspicuous risk of flooding. The analysis shows that 50-75% of the territory in a particularly dangerous zone is occupied by inner-city riverbanks, and concreted and safe places make up 6 and 7% of the territory, respectively. In general, the city is recognized as the most vulnerable to flooding in all classes of dangerous zones, with the exception of places of shorter length in the upper part of it. It has been established that the forest cover of the Irtysh and Ulba rivers, located in high-altitude zones, is located above the territory where the main part of the waters connected to floods enters, has a low protection index. Most of the study area is located between Medium and very high risk areas.

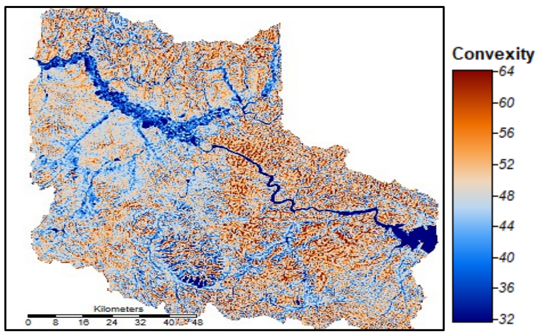


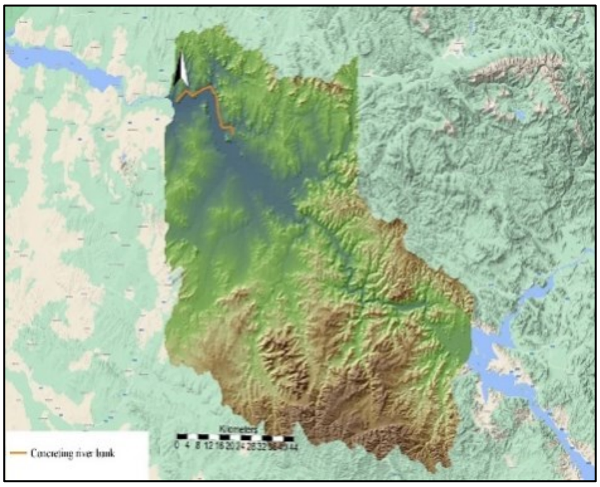
Figure 12. Convergence Index analysis.

.

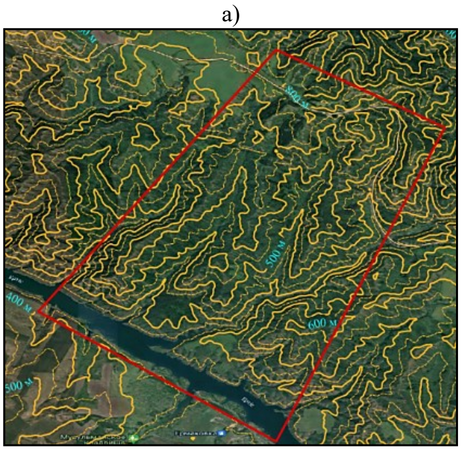
The MCDA was tested to confirm the analysis carried out by determining the relevant relief factors using flood risk zone indices, using a satellite flood map that has been real over the past few years. The comparison shows that about 21 basins and 53% of the entire flooding zone are high and very high risk zones, respectively, and about 5 and 10% of the flooding zone are low and medium risk zones inside mountain gorges, respectively. In the nearby territories to the city of Ust – Kamenogorsk and in the urban development itself there are areas of possible flooding, 24% of the territory is in a very high danger zone, i.e. an urban environment with two banks. The lower part of the hazard zone study area, based on indexes and a flood map obtained from satellite data, showed that the locality of Praporshchikovo is under threat. In general, the analysis showed that the predicted flood risk zones based on the index are very realistic and close to flood conditions.

Flood protection design structures prepared in places where there is a risk of flooding identified as a result of the analysis

This study was analyzed by the MCDA method to determine the flood risk in the city of Ust-Kamenogorsk, located on the banks of the Irtysh and Ulba rivers. The methodology adopted by DEM for creating flood maps based on satellite data showed good compliance with the index-based threat map. The most commonly used methods of flood risk mapping are parametric (index) approach and numerical methods. Both of these methods have advantages and disadvantages in terms of the quality and quantity of data, the structure of the model. The index approach is better suited for understanding floods than for spatial scale modeling. In this study, a parametric approach based on MCDA is used because of the simplicity of the methods and the emphasis on subjectivity, which is very important for flood management. The spatial distribution of flood-prone zones showed a very close similarity with the criteria levels of drainage capacity and height. The area under study usually suffers from flooding because it is located in a floodplain characterized by small topographic differences. The study may be recommended to consider the ability of water drainage as an important criterion for creating risk maps in floodplain areas. It can be argued that the inclusion of a parameter for the preparation of various criteria may affect the final decision. The study showed that in the territory of a city with a high risk of flooding of the Irtysh River, the coefficient of its inflow is very small (Figure 13), which can lead to a repetition of flooding even with a slight rise in the level.



a)



b)

c)

Figure 13. Analysis of the topographic terrain of the studied area: a) A topographic snapshot of the investigated area; b) the highest point of the drainage basin; c) the problematic (lowest) area.

Based on the results of the study, one of the effective solutions in some research papers (Doudkin, Fadeyev, Pichugin, 2013; Doudkin, Pichugin, Fadeyev, 2013; Kim et al., 2020) is more fully studied and proved this problem is the application of the following proposed design with a mark of the minimum height of the flooded shores (Figure 14).

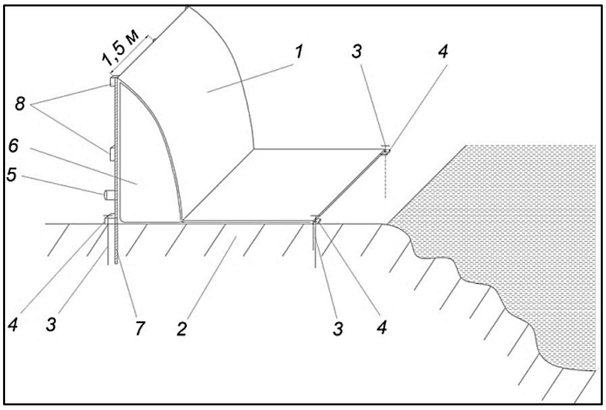


Figure 14. Water intake (Protective structures).

Figure 14 shows the proposed device. The device includes a shell 1 made of durable rubberized fabric, base 2, anchors 3, hinges 4, valve 5. internal cavity 6, reinforcement anchors 7, special hinges 8 (Saveliev et al., 2019; & Kurmangaliyev et al., 2013).

The device works as follows: first, the water intake is laid out near the shore where flooding is expected, for example, near the bridge part of the road, then the shell is fixed 1 with anchors 3 into the base (soil) 2 through loops 4, then the flat part of the water intake is sprinkled with earth (Alyzhanov et al., 2016; & Sherov et al., 2020). After filling the inner cavity 6 of the shell 1 with compressed air through the valve 5, in order to give greater stability and rigidity to the structure, it is fixed with reinforcing anchors 7 through special loops 8, located 1.5 meters apart, reinforcing anchors 7 into the ground. Thus, the installed water intake can protect from flooding up to a height of about 1.5 meters. The length of the water intake can be different, depending on the conditions of manufacture and transportation. The authors also developed other designs and methods of flood protection, for which applications for inventions were submitted (Goltsev et al., 2020).

4. CONCLUSIONS

In this study, the definition of flood zones on the banks of the Irtysh River, a reservoir passing through the center of Ust-Kamenogorsk, is adopted by a multidimensional GIS-based assessment system. The study tried to include the weight of criteria and the rating of parameters based on AHP for decision-making in difficult conditions. With the BasicTerrainAnalysis of the SAGA GIS program and the ability to determine individual indexes

With the imposition of thematic layers of the main criterion, a hazard index was prepared, which was confirmed by static flood data compiled on the basis of data from local services and remote sensing. The parameter related to hydrogeomorphological characteristics was prepared in a GIS environment and classified into groups for assigning ratings based on their impact on floods. The analysis showed that about 65 % of the studied territory is located in a high or very high risk zone, of which the part located in the northwestern part of the city is most at risk. Based on the results of the analysis, a design for emergency protection of flood-prone places is proposed, which is an engineering solution to the current problem under study, which is characterized by ease of installation and cheapness with less material consumption, and also ensures the stability of the coastline.

REFERENCES

Alyzhanov, M.K., Sikhimbayev, M.R., Kuzembayev, S.B., .Musaev, M.M., Buzauova, T.M., Kurmangaliyev, T.B. Optimization of the conditions of convective drying of thermosensitive materials. Journal of Theoretical and Applied Mechanics (Bulgaria) this link is disabled, 2016, 46 (4), 76–84.

Doudkin, M.V., Fadeyev, S.N., Pichugin, S.Y.Studying the machines for road maintenance. Life Science Journal, 2013, 10 (SPL.ISSUE 12), 134–138, 24.

Doudkin, M.V., Pichugin, S.Y.U., Fadeyev, S.N.The analysis of road machine working elements parameters. World Applied Sciences Journal, 2013, 23 (2), 151–158.

Goltsev, A.G., Kurmangaliev, T.B., Sherov, K.T., .Mardonov, B.T., Sikhimbayeva, D.R.Determining limit displacements in spacer propping single bolting. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciencesthis link is disabled, 2021, 2(446), 55–61.

Goltsev, A.G., Kurmangaliyev, T.B., Sherov, K.T.,.Mardonov, B.T., Yessirkepova, A.B.Aligning method of structures during installation in vertical plane. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciencesthis link is disabled, 2020, 5(443), 63–70.

Hazarika, N., Barman, D., Das, A. K., Sarma, A. K., & Borah, S. B. (2016). Assessing and mapping flood hazard, vulnerability and risk in the upper Brahmaputra River valley using stakeholders' knowledge and multicriteria evaluation (MCE). Journal of Flood Risk Management, 11, S700–S716. https://doi.org/10. 1111/jfr3.12237

Huan, H., Wang, J., & Teng, Y. (2012). Assessment and validation of groundwater vulnerability to nitrate based on a modified DRASTIC model: A case study in Jilin City of Northeast China. Science of the Total Environment, 440, 14–23. https://doi.org/10. 1016/j.scitotenv.2012.08.037

Jenks, G. F. (1967). The data model concept in statistical mapping. International Year Book of Cartography, 7, 186–190.

Kazakis, N., Kougias, I., & Patsialis, T. (2015). Assessment of flood hazard areas at a regional scale using an index-based approach and analytical hierarchy process: Application in Rhodope-Evros region, Greece. Science of the Total Environment, 538, 555–563. https://doi.org/10.1016/j.scitotenv.2015.08.055

Kim, A.,Savelyev, A.,.Gribb, V., Mikhailovskaya, V.Modernization of the metal structure of the grader working equipment. International Review of Mechanical Engineering, 2020, 14 (1), 1–8.

Kron, W. (2005). Flood risk = hazard values vulnerability. Water International, 30(1), 58–68.

Kuldeep, Garg, P. K., & Garg, R. D. (2016) Geospatial techniques for flood inundation mapping. 2016 IEEE International Geoscience and Remote Sensing Symposium (IGARSS), 4387–4390.

Kurmangaliyev, T.B., Goltsev, A.G., Sikhimbayev, M.R.,.Zharkevich, O.M.,Sherov, A.K.Analytical and experimental studies of pneumatic vibration exciter in inertia vibroabrasive machining of parts based on beryllium oxide. Journal of Vibroengineeringthis link is disabled, 2013, 15 (2), 863–871.

Lee, A. H. I., Chen, W.-C., & Chang, C.-J. (2008). A fuzzy AHP and BSC approach for evaluating performance of IT department in the manufacturing industry in Taiwan. Expert Systems with Applications, 34, 96–107. https://doi.org/10.1016/j.eswa.2006. 08.022

Li, G. F., Xiang, X. Y., Tong, Y. Y., & Wang, H. M. (2013). Impact assessment of urbanization on flood risk in the Yangtze River Delta. Stochastic Environmental Research and Risk Assessment, 27(7), 1683–1693.

Li, W., Du, Z., Ling, F., Zhou, D., Wang, H., Gui, Y., … Zhang, X. (2013). A comparison of land surface water mapping using the normalized difference water index from TM, ETM+ and ALI. Remote Sensing, 5, 5530–5549. https://doi.org/10.3390/ rs5115530

Liu, Y., Zhang, W., & Cui, X. (2012) Flood emergency management using hydrodynamic modelling. In: Procedia Engineering, 750–753.

Pratik Dash, Jishnu Sar. Identification and validation of potential flood hazard area using GIS-based multi-criteria analysis and satellite data-derived water index. CIWEM Journal of Flood Risk Management, 2020;1–14.

Sadenova, M.A., Beisekenov, N.A., Apshikur, B.,.Mamysheva, A.M., Klemeš, J.J.Modelling of Alfalfa Yield Forecasting Based on Earth Remote Sensing (ERS) Data and Remote Sensing Methods Chemical Engineering Transactionsthis link is disabled, 2022, 94, 697–702.

Saveliev, A., Zhileykin, M., Mikhailovskaya, V.,.Kustarev, G., Grib, V.Icreasing the reliability of the autograder metal construction by modeling and re-assembling of the working equipment. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 2019, 6 (438), 276–286.

Sherov, K.T., Mardonov, B.T., Buzauova, T.M.,.Kurmangaliyev, T.B., Elemes, D.E.The research of micro-hardness of side surfaces of teeth cylindrical wheels processed by shaver-rolling device, Journal of Theoretical and Applied Mechanics (Bulgaria)this link is disabled, 2020, 50 (1), 50–56.

Suriya, S., & Mudgal, B. V. (2012). Impact of urbanization on flooding: The Thirusoolam sub watershed—A case study. Journal of Hydrology, 412–413, 210–219. https://doi.org/10.1016/j. jhydrol.2011.05.008

Tiwari, M. (2013). Residents recall the flood of 1978. The Times of India. Retrieved from https://timesofindia.indiatimes.com/city/ allahabad/Residents-recall-the-flood-of-1978/articleshow/ 22110756.cms.

Toguzova, M.M., Rakhymberdina, M.Ye., Kulenova, N.A.,Apshikur, B., Beisekenov, N.A.Analysis of Process Modeling in Modern Software Program to Support Smart Agriculture Chemical Engineering Transactionsthis link is disabled, 2022, 94, 871–876.

Topographic position index based landform analysis of messaria (ikaria island, greece)Athanasios Skentos[1, 2] ,[1] National and Kapodistrian University of Athens, Greece, [2] Mott Macdonald Ltd, United Kingdom. ActaGeobalcanica, 4-1, 2018, 7-15.

van der Veen, A., & Logtmeijer, C. (2005). Economic hotspots: Visualizing vulnerability to flooding. Natural Hazards, 36, 65–80. https://doi.org/10.1007/s11069-004-4542-y

Vladimír Fárek[1] , Jan Unucka[2] , Iva Ponížilová[3], Marcela Gergeľová[4] , Dušan Židek[5] and Radek Pallós[6]. Assessment of the runoff conditions of small ungauged catchments using GIS and fully distributed hydrologic models ActaMontanisticaSlovacaRočník 19 (2014), číslo 1, 22-30.

Wang, Y., Li, Z., Tang, Z., & Zeng, G. (2011). A GIS-based spatial multi-criteria approach for flood risk assessment in the Dongting Lake region, Hunan, Central China. Water Resources Management, 25, 3465–3484. https://doi.org/10.1007/s11269-011- 9866-2