MINISTRY OF EDUCATION

UNIVERSITY OF PETROȘANI

DOCTORAL SCHOOL

PHD FIELD: MINING, OIL AND GAS

DOCTORAL THESIS
-SUMMARY-

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USE OF MULTI-SOURCE SPATIAL DATA AT MAKING FLOOD RISK MAPS

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Keywords:hazard, hazard maps, 3D modeling

The purpose of the study is to understand the importance given to reducing the risk of flooding on the hydrographic basins, so that a safe life can be ensured for the entire population that carries out its activity in the critical areas, from this point of view, in Romania This study aims to

present the methods of acquisition and processing of geospatial data in order to achieve a complete, accurate and uniform Digital Land Model (DTM) for a hydrographic basin based on which to generate a series of maps, both hazard and flood risk maps with various probabilities of exceedance. In order to achieve the numerical modeling of the propagation of the flood waves that produce floods, it is necessary to accurately map the risk areas, having as main support the numerical terrain model (NTM) with very good resolution obtained from the measurements LiDAR.
The technological progress in the field of sensors for collecting geospatial data finds its immediate applicability in the study of the factors that determine the occurrence of natural hazards. The rapid collection and processing of accurate geospatial data that can be easily integrated into dedicated software platforms are essential elements to support the risk management process and also an essential component for the development of prevention and protection measures for the affected areas.

Essentially, based on the geospatial information obtained from the data provided by the sensors, hazard maps and numerical models are developed in which information about the history of the occurrence of hazard phenomena in a certain geographical area are integrated, having the possibility to create various virtual representation systems, based on which the probabilities and impact in the areas with the highest risk of occurrence are determined. Having an overview of the affected areas, strategies can be developed to prevent, combat and mitigate the effects of these phenomena.

The study was developed having as a starting point the Directive 2000/60/EC of the European Parliament, adopted on October 23, 2000, which laid the foundations for river basin management plans, with the main purpose of mitigating the effects of floods and effectively managing the associated risks. The implementation of Directive 2000/60/EC involved a number of essential steps. First, Member States were obliged to identify areas with high flood potential and assess the risk associated with them. This identification included analysis of flood history, land types and land use, precipitation and other weather factors, as well as anthropogenic factors that may contribute to increased flood risk, such as intense urbanization or changes in land use.

After identifying areas at high risk of flooding, Member States were responsible for developing and implementing Flood Risk Management Plans (FRMPs). These plans had the role of establishing concrete strategies and measures for the prevention, preparation and management of flood situations. These included issues such as the construction and maintenance of the flood defence, early warning systems, evacuation plans, land use management in risk areas, and cross-border cooperation with neighbouring states to address flood risks that cross national borders in a coordinated manner.

In the case of Romania, a country with an extensive hydrographic network, Directive 2000/60/EC was of particular importance. Romania is crossed by 12 river basins, including the 11 most important rivers and the Danube River. This geographical context has exposed the country to significant flood risks, especially during periods of increased river flows and intense rainfall. As for the European Union, Romania ranked fourth in a ranking made from the perspective of flood risks, being preceded by Poland, Slovakia and the Czech Republic. The complex process of identifying the risk areas led to the elaboration, at the river basin level, of the Flood Risk Management Plans. This process involved collaboration between national, regional and local authorities, as well as with other states bordering the common river basins. Measures such as developing flood defence infrastructure, strengthening the existing flood barrier, increasing early warning capacity and informing the public about flood risks were considered. Evacuation plans and procedures for crisis management have also been developed.

The study is structured in 4 chapters of content, to which is added the bibliography covered for the documentation and writing of the paper, as follows:

Chapter I- Basics, Its role is to classify the causes and mode of occurrence of floods, including the implications of stone quarries and gravel pits in the context of flood risk maps and a presentation of the stages of assessment of the natural hazard for floods.

Chapter II – TECHNOLOGIES FOR OBTAINING THE DATA NECESSARY FOR THE 3D MODELLING OF A RIVER BASIN, presents the technologies and stages underlying the obtaining of the digital terrain model on the basis of which the topographic data necessary to carry out hydrological and hydraulic modeling can be extracted in order to make flood hazard and risk maps. The chapter presents most of the modern technologies used in the acquisition and processing of the data necessary for the 3D modeling of a river basin, such as: the use of existing data, the use of photogrammetric data, LiDAR, topobatymetrics, etc.

Chapter III - RETRIEVAL AND PROCESSING OF GEOSPATIAL DATA, presents the steps necessary to obtain the vector data on the basis of which the hydraulic modeling is carried out in order to make hazard and risk maps and to develop pre-established scenarios.
The resulting cartographic materials are used to assess the flood risk for each of the hydrological events with probabilities of exceeding 10%, 1%, 0.5% and 0.1%, modeled in the existing flow regime, maps will be made regarding the classification of the water depth.

Chapter IV - TAKING OVER AND PROCESSING GEOSPATIAL DATA IN ORDER TO GENERATE FLOOD RISK MAPS FOR THE PRUT RIVER BASIN, represents the case study and includes the categories of works carried out for the generation of risk maps in the Prut river basin, respectively:

- making topo-bathymetric measurements on the Prut River and on the Stânca Costești reservoir;

- realization of an integrated Digital Land Model for the Prut meadow on both banks by integrating the topographic-bathymetric data made within the project in the available digital land models;

- Acquisition of satellite images/orthophotoplans and other types of geospatial data necessary for the production of flood hazard and risk maps;

- Hydrological and hydraulic modeling in order to generate flood hazard and risk maps along the Prut River.

The main step in the production of maps is the collection of geospatial data based on which a 3D model of the entire river basin is made.

Considering that the area of the smallest hydrographic basin exceeds 10,000 km2, photogrammetric methods were used to obtain the data necessary for modeling (digital land model, vector map with land use categories).

The digital model of the land at the level of the hydrographic basin was made for 3 classes of detail:

- Level A – very detailed, with a resolution of 1-2 m, comprising small areas of complexity and special importance that require detailed analysis;

- Level B - detailed, with a resolution of 4-5 m, comprising the courses of rivers and their main tributaries of sufficiently long length, so that the results of hydraulic modeling are relevant

- Level C - with a resolution of 10-15 m for the rest of the hydrographic basin.

The digital model of the A-level terrain was obtained exclusively by aerial laser scanning, made so that a density of 2-4 points/m2 was obtained.

The digital model of the B-level terrain can be obtained either by aerial laser scanning, made in such a way as to obtain a density of 1-2 points/m2, or by extracting the numerical model of the terrain from the images.

The C-level digital terrain model was generally obtained from the integration and calibration of existing data, respectively the acquisition of the digital terrain model with a resolution of 5-10 m from ANCPI or the vectorization of the contour lines on the 1:5000 scale topographic plans.

The time required to acquire the data necessary to generate the digital terrain model of level A and B by aerial laser scanning was approximately 20 hours, including the movement of the aircraft in the project area.

For a better interpretation of hazard maps, they are superimposed on satellite images or orthophotoplans.

In the case of aerial laser scanning to obtain a density of 1-2 points/m2, a medium format camera with a focal length of 70 mm can be used, which allows a resolution of 30-35 cm/pixel to be obtained.

From the LiDAR point cloud, the Digital Land Model (DTM) and the Digital Surface Model (DSM) were obtained by classification.

The resolution of the Digital Land Model was 1 x 1 m.

In order to generate the Digital Land Model, the following steps were taken:

- a TIN (Triangulated Irregular Network) was created from the point cloud, then a raster was created from the TIN;

- the height value obtained by triangulation in the center of the grid cells has been selected;

- a uniform grid with a resolution of 1 x 1 m was generated, regardless of the density of the cloud points;

The surface model was generated from all valid points on the land surface (ground and non-ground points). The point with the highest height (in a cell) was used to calculate the grid. Regardless of the density of the cloud points, a new grid will be generated.

On surfaces with large voids such as waters, the values of the grid height were determined by interpolation by the nearest neighbourhood algorithm method.

DTM and DSM were generated in GeoTIFF format, cut into tiles.

In addition to the Digital Land Model (DTM) and the Digital Area Model, in hydrological modeling it is necessary to extract information from the cloud of unclassified points for certain areas.

Following the classification, the classes of ground points, low vegetation, medium vegetation, tall vegetation, constructions, unclassified points were generated. The ground class also included points located on the surface of the water.

At the same time as the LiDAR data, images with a resolution of 25cm/pixel were acquired. The longitudinal coverage of the frames was at least 60% and the transverse coverage was at least 25%.

Prior to the flight, the photogrammetric landmarks (GCP) have been pre-marked, which must be clearly identifiable on the frames. The pre-marking of the photogrammetric landmarks (GCP) was made with specific materials (white paint, polystyrene), and the coordinates were determined by GPS measurements, a static measurement method. The coordinates of the control points were determined in the Stereographic Projection System 1970 and the Black Sea Altitude System 1975 and were placed in relatively flat areas. The image processing was carried out with the ULTRAMAP V 3.9 program.

The topo-bathymetric measurements were carried out for the restoration and completion of the existing support network, the acquisition of topographic data necessary for the generation of transverse and longitudinal profiles, the acquisition of data on water depth, the survey of engineering structures.

In order to carry out the modeling, it was necessary to determine a number of 260 transverse profiles, the distance between the transverse profiles is relative, varying depending on the morphological characteristics of the minor riverbed, so for the bathymetric profiles intermediate measurements were also performed, on shorter profiles, especially in the meandering areas of the watercourse (inflection zones). Also, transverse profiles were made in the areas of sudden slope changes, respectively in the areas with reverse slope, to the extent that these areas can be identified in the field.

At each cross-sectional profile, in order to connect the dimensions resulting from the Digital Land Model with the topo-bathymetric measurements, common points were determined. The coordinates were determined by GPS measurements, RTK measurement method, using the ROMPOS reference stations, the closest to the project area, respectively the RO VRS 3.1 virtual station system GG. The accuracy of measuring the points on the transverse profile was +/- 5 cm, in plane (Stereographic System 1970), and +/- 10 cm for normal elevations, reference Black Sea 1975. In the terrestrial measurements on the transverse profiles, points were measured at a maximum of 20 m, as well as at changes in the slope of the terrain.

The elaboration of the hazard and risk maps corresponding to the probabilities of exceeding 10%, 1%, 0.5% and 0.1%, for the Prut riverbed, was carried out on the basis of a coupled hydrological and hydraulic modelling. It allowed the determination of the contribution of the tributaries of the Prut River corresponding to the flood waves on the Prut River.

The stages of modeling are as follows:

- Introduction of the route of the main river and of the important tributaries in vector form (arches and nodes);

- Introduction of calculation cross-sections (cross-sections);

- Introduction of roughness coefficients from the minor and major riverbed;

- modeling of the hydraulic structures in the riverbed, including bridges, pipe crossings, spillways, dams, etc.

- The introduction of the values of the maximum flows and/or the flow hydrographs both at the upstream end and of the components of the hydrographs due to the tributaries;

- defining the settings of the calculation model.

Results of the study

The hydrological / hydraulic modeling took into account the contribution of all tributaries of the Prut River, both on the territory of Romania and on the territory of Ukraine and the Republic of Moldova.

In the calculation, all the hydrotechnical works carried out in the Prut riverbed were analyzed and it was established to what extent each hydrotechnical work influences the hydraulic regime of the Prut River.

The hydrological/hydraulic model contains all the constructive elements of the existing hydrotechnical works on the Prut River (longitudinal and transverse), which influence the hydraulic regime, as well as the exploitation rules provided for in the Exploitation Regulations in force.

The hydrological modeling was carried out on river sectors between 2 successive hydrometric stations on the Prut River.

The number of calculation cross-sections was 434, of which:

- 360 sections downstream of the Stânca-Costești Accumulation;

- 41 sections in the Stânca-Costești Accumulation area;

- 33 sections upstream of the Stânca-Costești Accumulation.

The flood maps were generated in pdf format, containing the orthophotoplan, information about localities and land use and the limits of the flood zones generated for different probabilities of exceedance.

Conclusions

Activities related to the organization and development of the territory, as well as to urban planning and administration, require the correct and up-to-date use of hazard and risk maps, developed at appropriate scales and levels of detail. The procedure for creating and using these documents in the context of natural risk factors is regulated at European level by directives and at national level by administrative acts that establish responsibilities at central, regional, county and local level, as well as the management of associated databases.

However, as regards the risks posed by human activities, regulation is less developed. Although the extent of instability phenomena induced by anthropogenic activities is more limited compared to natural ones, their impact can be significant at local or regional level. For example, subsidence caused by mining affects a significant proportion of the territories in certain areas. It is therefore crucial to develop and adopt rules and norms in this area, as well as to introduce the obligation to include specific information in the development process of spatial planning and urban planning.

In the context of sustainable development and mitigating the negative impacts of extraction activities, mitigation measures and risk management strategies are essential. The creation of retention basins, ecological rehabilitation of exploited areas, slope stabilization and effective storm water management are some of the strategies that can be implemented to reduce the risk of flooding. In addition, the involvement of local communities and stakeholders in the development and implementation of risk management plans can contribute to the development of solutions that are well adapted to the specific context of each site.

The ecological health and safety of human communities are closely linked to the effective management of natural resources and the landscape. Stone quarries and gravel pits, in the context of the changes they induce in the environment, require special attention in modeling and interpreting flood risk maps, thus guaranteeing effective planning and response to extreme events.

The rapid expansion of the urban environment is one of the most important problems worldwide today. In order to successfully control the situations resulting from this rapid urbanization, geospatial information needs to be as accurate and up-to-date as possible.

Correct geospatial information leads to correct calculations, which is reflected in the increased effectiveness of hydrological forecasts and warnings in case of floods. The creation of a 3D model at the level of a river basin is the first and most important step in flood risk management, since flood maps are developed based on geospatial data and a plan of measures to combat and mitigate the effects of floods is generated.