

DESIGN OF CARTOGRAPHIC PRODUCTS TO SUPPORT DISASTER MANAGEMENT

Jaromír Kolejka

Assoc. Prof. Dr. Jaromír Kolejka, Masaryk University, Faculty of Education, Department of
Geography
Poříčí 7, CZ-60300 Brno, Czech Republic
Tel.: +420-549495073, Fax: +420-549491620, E-mail: kolejka@ped.muni.cz

Abstract

Special cartographic outputs are required by the disaster management. Such 2D, 3D and/or 4D territory models have to present area features important for: 1. understanding the accident wider territory layout, 2. personal orientation in the territory (landscape landmarks), 3. direct disaster location surroundings imagination, 4. assessment of area features important (and sensitive) for disaster behavior and development (Fig. 1), 5. viewing access routes (Fig. 2), 6. selection of appropriate measures for a) human lives protection, b) property protection, c) environment protection, 7. possible calculation of endangered values, 8. future adjustment of preventive measures. Respecting these viewpoints a set of map and 3D area models were developed using commonly accessible digital geodata from public and government data bases open for disaster management teams in Czech Republic. 3D model animation and flights over the territory make such outputs very suitable for operative and long-term decision making. The formalized geographic expert knowledge and standard GIS technology serve and support such special cartographic production.

Keywords: disaster management, geodata visualizing, risk map, 3D model

1. INTRODUCTION

The cartography served since the earliest time two main purposes: a) the transmission the information about the territory using graphic form, b) offering practical applications for the decision-making support. During the whole history, the cartographers made effort to give information correctly both from the viewpoint of location and theme, as well offer the right way for map reading. This way, the main goals are represented by the reliable recording of territorial information on one hand, and by the reliable transmission of information on the other hand. There is a rich literature dealing with geometric, semantic and syntactic features of map compilation available here. Simultaneously with the origin of new cartography applications in the human society, new requirements grow in respect fulfilling both the above mentioned main tasks of cartography. The introduction of capable computing technology brought a quantitative and qualitative break in the common cartographic production. The robust accession of the computer cartography started at the turn of 1970s and 1980s. Advances in geoinformatics, rapid development of hardware and software, mobile information equipment, improvement of the public education as well as the computer literacy led to widening of map and other cartographic product application in more spheres of human life. While the aesthetic aspect of maps has withdrawn, their role of the decision making support tool was highlighted.

2. DISASTER MANAGEMENT

The disaster management belongs to so called “everyday cartography users”. Modern disaster management (DM) represents a set of activities focused on preparatory, operational and mitigating phases of facing the disaster in the landscape threatening human life and property. Following the technological progress, present DM insists on capable computing, information and communication technology. With the rising number of population and property values, the volume of damages caused by natural processes as well by human activities grows immediately (Bryant, 1991, Mazur, Ivanov, 2004) . Also the moral impact on the population is rising regardless it is evoked by real personal experience or by media. All such processes run in the landscape dealing with natural, economic and social area features. The disaster management is organized according to the “Crisis management law No. 240/2000”. This originally military institution was by the end of 20th century reversed for coping various endangering situations of natural, human accelerated, social, economic and enterprise character. (Antušák, Kopecký, 2003). In the civil sector, it is accepted in wider sense as “emergency management” and includes defined approaches, attitudes, experience, recommendations, methods, measures and relationships applied in the hierarchized and operationally linked systems, including public administration, juridical and physical bodies securing:

1) crisis possibility minimizing or prevention,

2) damage extent reduction, crisis term shortening, consequences mitigation, return to common state (Dvořáčková, 2008).

The Czech disaster management systems consist of three semi-independent parts: defense planning, civil emergency planning and accident planning (Antušák, Kopecký, 2003). Everyone needs expert support, knowledge and data, including cartographic products. Disaster situations are managed by the Integrated salvation system (Integrovaný záchranný systém – IZS) coordinating activities of subordinated components: Fire brigades (Hasičský záchranný sbor ČR), Medical services (Zdravotnická záchranná služba) and State police (Policie ČR). In some cases the military assistance can be involved (Rektořík, et al., 2004). The emergency system is in the permanent service 24 hours per day. Various geodata can be efficiently used in the individual stages of the disaster management. Its cartographic presentation can play crucial role during the prevention, operational and mitigation DM period.

The efficiency of DM can be assessed with its speed and measures accuracy with respect to given event. About 70 types of disaster situations were classified in the Czech Republic. The scientific, cartographic and etc. support for the right decision making can be formulated, formalized and algorithmized using computer technology including GIS. The multidisciplinary cooperation in the data selection, processing and visualizing is necessary with regard to the natural, economic and social area features.

Different data, expert knowledge and cartographic output requirements characterize individual activities of DM in the stage of:

1. prevention measures (including risk assessment – especially natural disasters are repeating in certain localities with specific features). Risk assessment maps represent a traditional DM support informing the DM dispatch and common citizens about risky sites. The risk level maps can be applied in the process of reduction endangering events these can trigger given hazard (Chung, et al., 2005). Interpreted basic thematic maps can be applied for these purposes (analytic maps of nature features, land use/land cover. Risk maps can play important role in the early warning system after the damaging process already started.
2. intervention measures (includes the event modeling in possible alternatives – search for optimum way and site of intervention). The operational intervention (the main aim is to save human life and protect health) can use digital terrain model (DTM) and its derivatives (e.g. slope, aspect), as well for the compilation of a photorealistic 3D area model. Very important decision making depends on the analysis of recent meteorological data.
3. operational decision making (access route to the intervention site, selection of the intervention way and management). Visualizing the situation by a 3D way and highlighting the neighboring sensitive objects as well as area appropriate risks can be involved in the event development.
4. short-term and medium-term mitigation measures (the expert knowledge based activity selection, location, extent and intensity statement). The primary goal is represented by the human health, property and the environment protection and to stop the accident development. Wide range analytic maps on natural, economic, social and technical area features can be used in their original, but much better in purpose oriented map derivatives. The expert assessed territory reaction to the accident and its direct consequences can play the leading role in the thematic map application. The medium-term measures intend the average settlement.
5. long-term measures (based on the expert knowledge only) use interpreted maps on relevant landscape features generally from the viewpoint of landscape resistance and restoration ability as well as of population education and event prevention.
- 6.

Application of ICT and problem related expert systems can substantially improve the decision making in the DM and the relevant geospatial information can be presented and transmitted by the cartographic in 2D, 3D and/or 4D way. Such approach can potentially shift the present dominantly administratively and technocratically led DM to possible more efficient expert led measures in all the stages of disaster management.

3. GEOSPATIAL DATA SUPPORTING DECISION MAKING IN DISASTER MANAGEMENT

Governmental institutions, regional/district/town/community administrations, research institutes, higher education institutions, private companies, etc. developed digital geodatabases serving them with specific data in the past three-four decades (Bernaerts, Hellemaans, 2005). With exception of regional administrations, most existing databases are managed separately for institution own purposes and are not accessible from outside for the most possible users. The large scale accidents and consequent damages in the environment, lost of human life and property highlighted interests in wide range application of already stored geodata for successful combat with various both natural and human accelerated or ignited disasters. The decision making during the individual stages of the society disaster response needs territorial data of different kinds, especially these support faster location of disaster sites, the best access routes selection, identification of disaster endangered zones and short-term disaster consequence mitigation.

Traditional geodatabases for crisis management in general consists of topographic, technical, utility etc. map layers. The most hazardous events interact with natural territory features as well as with topography. Disaster management authorities have to be prepared to solve various dangerous situations. The decision making on the short-term, medium-term and long-term level require different data and also the different are the procedures of their application.

The aim of disaster management activities at the short-term (operational) level is represented by the dominant human life salvation and consequently the property protection. The access/escape route selection based on topography and other data (transportation capability of roads, infrastructure, soils, hydrological objects) is the primary task. Risk assessment maps supporting operational decision making are necessary for the endangered area delineation. They can be generated in advance using standard thematic maps on relevant territory natural features, or operationally after the area of concern is defined. The ground infiltration and surface runoff risk maps for toxic liquids were constructed as examples.

Geography and cartography can support objective disaster decision making efficiently. Geography provides the decision making procedures with adequate knowledge, cartography gives to the accessible geodata the adequate visual form. Because the time is a very important procedure factor, the whole process of efficient disaster management runs using digital technologies for the partner communication, geodata selection, processing, presentation and delivery. But the fast technological development for needs of disaster management is not followed with same intensity of relevant geospatial data preparation. There are two ways, how to provide necessary geodata: 1. basic field and distant mapping, 2. purpose oriented geodata assessment and conversion of existing maps for disaster management purposes. Examples of social and nature risk maps are presented here. The nature can operate as: 1) target of human made/accelerated damaging processes, 2) damaging process catalyst, 3) danger for humans. Perspectives of future risk mapping are given as well.

With regard to the usual time shortness, the data selection, mining, processing, visualizing and delivery (to different groups of users) must be standardized up to certain grade and differentiated according to the final utilization for individual time periods (short-term: life and property protection, medium-term: reduction of property and environment damages, long-term: consequences mitigation). The present state of the situation is as follows:

- a) suitable geodata layers are stored in different databases in different data formats under different access conditions,
- b) technology available can overcome formal data differences in real time and deliver it for special application
- c) expert knowledge for geodata processing is available and partially formalized, such procedures can be ready for data processing in advance or for operational purposes,
- d) ICT and cartography experts, and communication means can provide disaster participants with territorial information necessary for efficient decision making.

The task of cartographers is to provide disaster participants with clear visualized geodata giving necessary information. Some of them can be distributed also among wide publics by TV, internet, mobile instruments (iPad, GPS, cellular phones, etc.) and information kiosks installed at community administration in settlements.

4. GEOSPATIAL DATABASES AS SOURCES OF RELEVANT INFORMATION FOR CARTOGRAPHIC VISUALIZING IN DISASTER MANAGEMENT

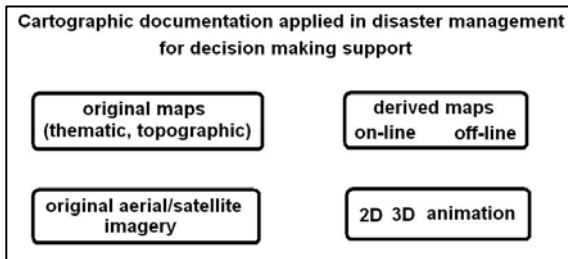
Digital geodatabases were systematically built in the Czech Republic since 1970s. Their basic purpose was represented by the territorial planning. Dominantly analytic geodata with varying resolution served: 1) territorial documentation, 2) territory assessment for selected goals, 3) searching for scenarios suitable for strategic planning (especially for given territory economic specializing).

Since 1990s, many administrative units of the Czech Republic (regions, districts, town and rural communities) and governmental institutions started to compile own geodatabases included into information systems. Individual data sets were delivered commonly on the commercial base by private GIT companies using different GIS technologies. Present geodatabases includes this way geodata in various formats (shp, dwg, dgn, etc.). Since the turn of milenia, many data layers were published at map servers. Catastrophic floods in 1997, 1998, 2002 and 2008 followed with enormous damages represent a turning point in the development of DM based on application of digital technologies and geodata. Some disaster modeling techniques were imported from abroad and many developed in the country. The large scale collection of geodata was carried out over the country by the governmental organizations as well as by private companies. Analogue archived geodata was massively vectorized. Since the second half of 1990s, all the geospatial data must be delivered in a digital form.

The present situation is characterized by:

1. relative sufficiency of DM relevant geodata (Fig. 1),
2. wide variability of data formats,

3. varying data quality and resolution,
4. graded data access,
5. ambiguous way of purpose geodata interpretation,
6. absence of general decision to compile special DM geodatabases or to ensure legislatively direct access to data in the case of disaster situation



As a result of this situation, the application of available geodata is rarely systematic and its total information potential is not sufficiently used.

Fig. 1: Basic groups of geodata applied in disaster management in the Czech Republic

5. VIZUALIZED GEODATA APPLICATION IN DISASTER MANAGEMENT

After some kind of DM issues standardizing in the Czech Republic, there are about 70 types of disaster situations distinguished. This range starts with pure natural processes (e.g. floods, land slides, drought, windthrows, avalanches, etc.) through human triggered ones (e.g. forest fires, agricultural plant diseases, domestic animal diseases, etc.) to entirely technical accidents (e.g. rail/road accidents, hazardous production breaks, pipeline failures, etc.). There are formal guidelines available how to face them. The map application is inevitable in all of them to visualize original supporting data (Fig. 2), DM derivatives, special analyses outputs and modeled situations.

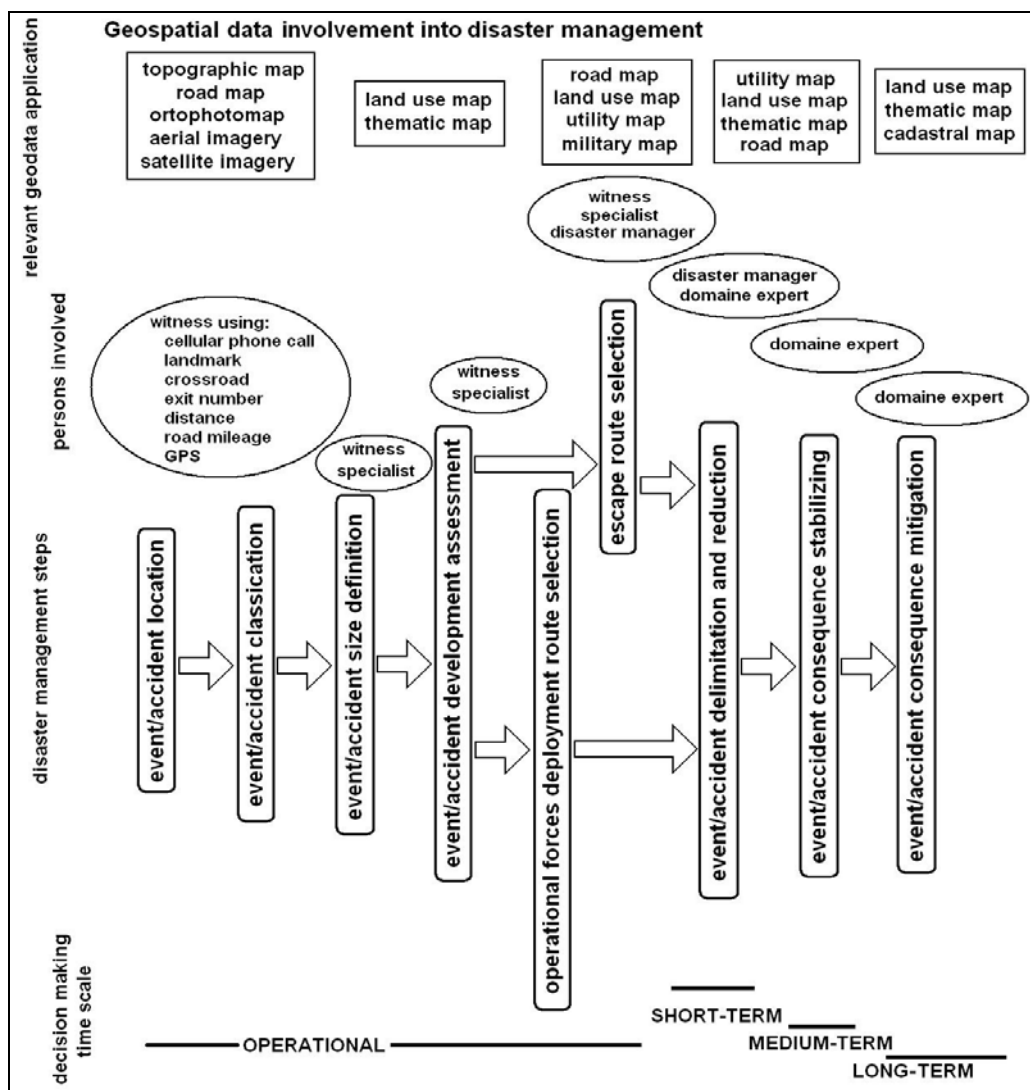


Fig. 2: Differentiated demand on geospatial data for decision making in individual stages of DM

The multi-stage cartographic visualizing process is typical for the application in the most of disaster situations. Because of time plays the decisive role in facing the problem, the preliminary long-term data and purpose oriented map preparation is necessary. Different cartographic outputs serve individual phases of DM as well as different participants in the disaster event. Regardless to the usage of original and/or derived geodata and cartographic products “on-line” or “off line”, an appropriate flow-chart of problem relevant thinking and execution processes from the cartographic viewpoint has to be at disposal (Fig. 3).

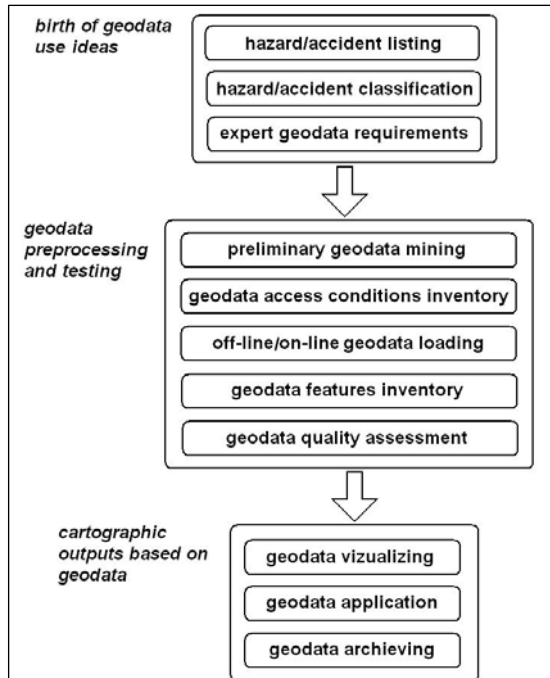


Fig. 3: General overview of possible steps leading to generation and cartographic visualizing digital geodata to support decision making in given situation DM

At the beginning of the process, the accident site and an accident general description in delivered to the DM dispatcher. Then the primary classification of the given situation is done. The real work with geodata started after successful relevant data search (data mining). Available map servers make the initial condition. The most map servers store map layers in the original (analytic) form. Metadata accompanying the map layers are available in some cases only but the top data quality of some thematic maps does not play the decisive role in their application because of time is the most important issue. Using the relevant expert knowledge selected maps have to be interpreted for the purpose of the given stage of DM. Preliminary knowledge about the links to relevant map layers makes an advantage.

The final list of relevant data layers (regardless their “on-line” or “off-line” access) should be available in the preliminary stage of each type disaster situation monitoring, coping and mitigation. Every data layer if it is available in the original form only, must

by accompanied with the expert knowledge for its efficient processing.

The dispatcher at the DM center can download relevant layers, use standard legend for geodata visualizing, apply expert module for geodata purpose interpretation and derive suitable measure operationally. Another option is the compilation own geodatabase with original and derived map layers and with a guideline for the appropriate layer selection in the case of certain disaster event. Generated maps can be delivered to the DM staff with and/or with the utilizing recommendation.

6. EXAMPLE OF GEODATA LAYERS APPLICATION IN ROAD TOXIC ACCIDENT

The operative stage of DM is focused on the protection of human life and property. The operative decision making is predominately based on application of digital geodata presenting site location, its wider neighborhood and general access routes for the intervention. Such situation was simulated on the example of the Ráječko village (a part of the town Rájec-Jestřebí about 25 km to the north from the regional capital City of Brno) as an accident of a road liquid tank (Fig. 4).

Consequent short-term measures are focused on stopping the accident consequences spreading and are based on area features analysis leading to the production of derived purpose oriented maps. The advantage is given to the those intervention that saves human life, health and property. Shortly afterwards, the accident consequence reduction measures have to start. They are based on the area features assessment. The important role is played by those features they impact on the surface pollutant runoff to the neighboring area and water objects, liquid pollutant infiltration into soil and geological infiltration, fire risk and population endangerment

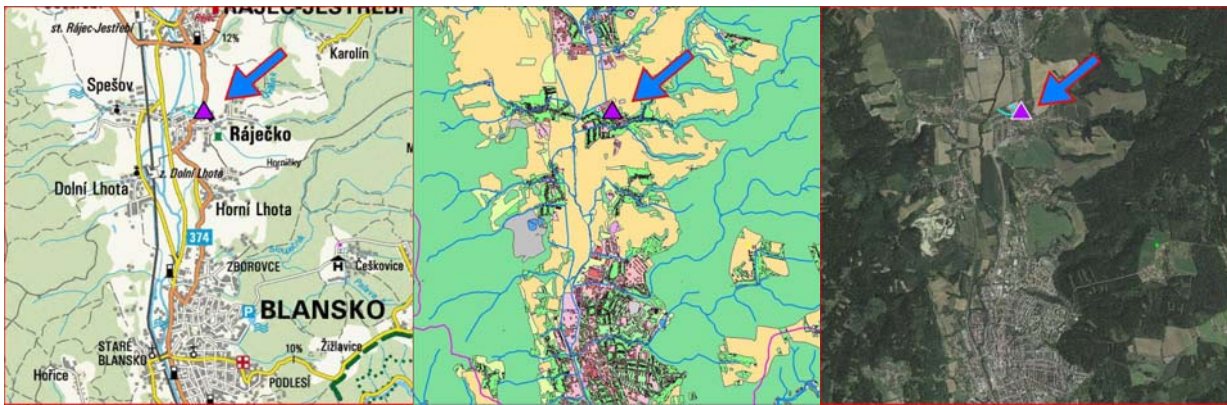


Fig. 4: The first approximation to road accident location: raster road map (left), vector land use map (center) and recent orthophoto (right)- blue lines near the accident site show estimated pollutant flow course

Suitable analytic geodata is available on web sites of governmental bodies and regional map servers with limited access (forest maps, soil maps, geological maps, land use maps, utility maps, nature protection maps, community master plans, etc.). They are stored in different resolution with regard to the original survey scale. These maps are applicable depending on their resolution. Map at the scale of 1:50 000 can be used for the first accident site approximation. Large scale maps 1:10 000 support operative stages of DM. In some cases is necessary to settle with maps at smaller scale if no one better is available (Fig. 5).

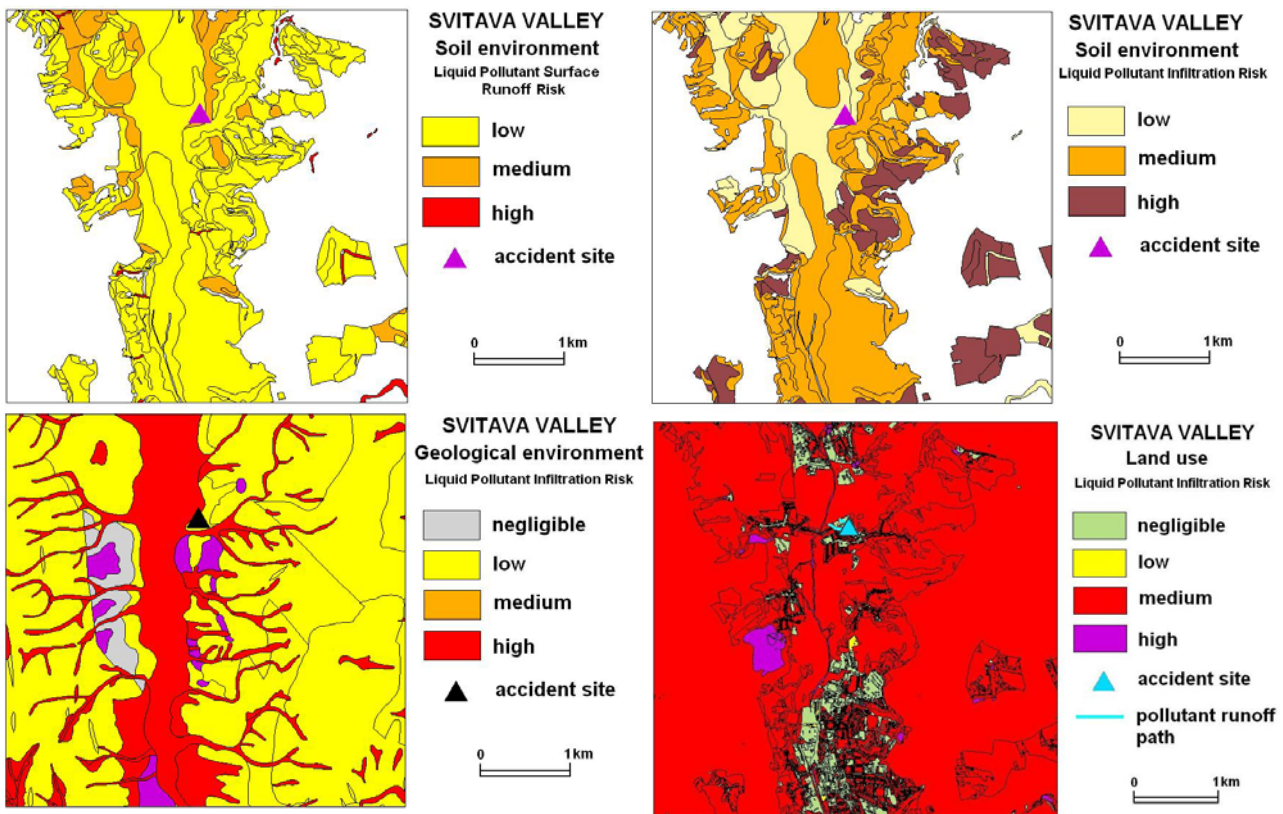


Fig. 5: Overview risk map of surface runoff and infiltration into soil and geological environment, and land use based on expert interpretation of digital agricultural soil maps BPEJ originally at the scale of 1:5000, geological map 1:50 000 and land use 1:10 000

The first step of the short-term decision making can start from the pollutant runoff route derivation from the digital terrain model. Available DTM is based on 10 m pixel what is enough for the modeling (Fig. 6).

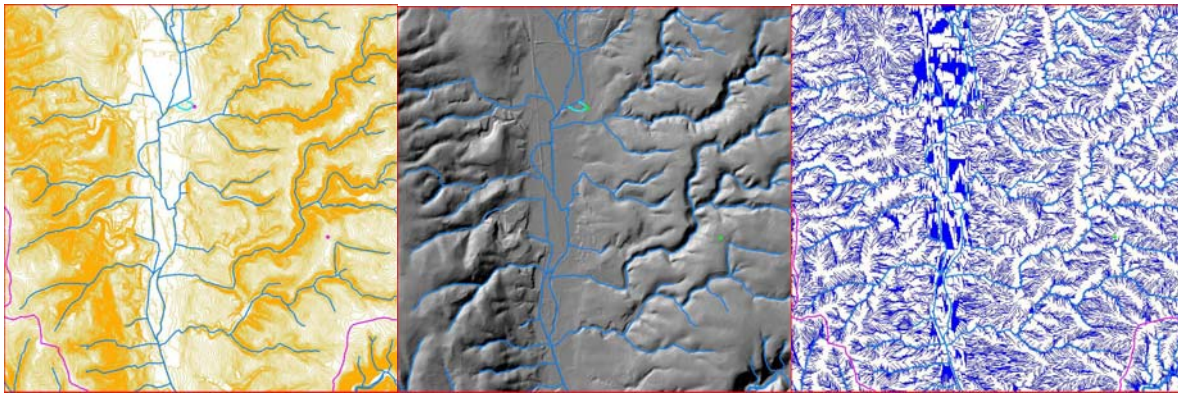


Fig. 6: Application of DTM with 10 m pixels for pollutant runoff route modeling and visualizing

The estimated pollutant runoff routes were later combined with other relevant data layers (see Fig. 4, 5, 6, 7 and 8). The detail approximation to the accident site supports some right located measures according to the public objects with the population concentration (people possible to be evacuated), to the site and technology utilizing to stop pollutant spreading and with respect to the property value represented by the official (not market) land price (Fig. 7).



Fig. 7: Derived operational intervention maps for in accident site mitigation activities (people evacuation – left, pollutant flow management – centre, land and property protection – right)

7. DISASTER MANAGEMENT CARTOGRAPHIC PRODUCTS FOR APPLICATION AMONG WIDER PUBLICS

The present DM systems pay less attention to the cartographic quality of the map documentation. Visualizing process is emphasized on the production of cartographic outputs for the DM dispatch and the intervention staff outside. Their primitivism is not contradictory to the map purpose in some cases. Especially, the one-layer maps are very readable and understandable, but do not provide the user with the spatial relationships with other important area features. An important role can be played with realistic 3D model of the accident situation what can be derived using the combination of the DTM and other relevant thematic maps. The combination the DTM with the topographic map or land use map is quite common, accident site is also included into the cartographic site presentation. For the operational purposes and also for the wide public notifying, some other 3D geodata combinations could be very useful. The mitigation technology employment depends on the correct conjunctive presentation of the proposed pollutant movement, differentiated risk areas (points, lines), access routes and obstructing objects positions. Such information classes can be visualized commonly in a 3D view and are understandable not for the DM specialists only but also for general publics (Fig. 8)



Fig. 8: More realistic 3D area model presenting simulated accident site location (yellow cone), estimated liquid pollutant runoff routes (yellow lines), closest water objects (blue lines), differentiated pollutant infiltration risk areas (lower risk – green, higher risk – purple), land use structure (orthophoto) and buildings – information given is applicable especially for DM staff

With respect to growing number of various accidents and natural disasters, the improved school cartographic education can play an efficient role in the damage reduction. The disaster management plan can be included into the school and community information systems. The unlimited access must

be given to the wide publics. The 3D area models and topic disaster situations can be displayed in the 3D way in public administrative objects and distributed publicly by the internet into desk top and mobile equipment.

Acknowledgments: The geographic research for the needs of the disaster management and the results presented here were supported by the project grant of the Czech Ministry of Education, Youth and Sports No. MSM0021622418 named "Dynamic geovisualizing in disaster management".

REFERENCES

- Antušák, E., Kopecký, Z. (2003): Úvod do teorie krizového managementu I., 2nd edition., Vysoká škola ekonomická v Praze, Praha, 98 p.
- Bernaerts, M., Hellemans, P.: Geo-Information at the Belgian Federal Crisis Centre. In: van Oosterom, P., Zlatanova, S., Fendel, E. M., eds. (2005): Geo-Information for Disaster Management. Berlin-Heidelberg, Springer, pp. 415-424.
- Bryant, E. A. (1991): Natural Hazards. Cambridge University Press, Cambridge-New York-Melbourne, 294 p.
- Dvořáčková, T. (2008): Ohrožení obyvatelstva mimořádnými událostmi v povodí řeky Svitavy. Diploma thesis. Masaryk University, Brno, 90+16 p.
- Chung, Ch. F., et al. (2005): Risk Assessment Using Spatial Prediction Model for Natural Disaster Preparedness. In: van Oosterom, P., Zlatanova, S., Fendel, E. M. (eds.): Geo-Information for Disaster Management. Berlin-Heidelberg, Springer, pp. 619-640.
- Mazur, I. I., Ivanov, O. P. (2004): Opasnyje prirodnyje processy. Ekonomika, Moskva, 702 p.
- Rektořík, J., et al. (2004): Krizový management ve veřejné správě. 1st edition, Ekopress, Praha, 249 p.



Assoc. Prof. Dr. Jaromír Kolečka, studied geography at the Department of Geography, Faculty of Science, J.E.Purkyně (today Masaryk) University in Brno in 1974-79, Dr. awarded in 1980 at J.E.Purkyně University, PhD at Institute of Geography, Czechoslovak Academy of Sciences in Brno (1984), assoc. prof. since 2001 (Faculty of Science, Masaryk University, Brno). Employment: Institute of Geography, Czechoslovak Academy of Sciences, Brno (1979-1991), Masaryk University (1991-present), Mendel University in Brno (2002-2008), Computer Press in Brno (1999-2002), GEODIS BRNO (2001-2006), Institute of Geonics, Academy of Science of Czech Republic, Ostrava (2007-present). Main areas of interests: landscape ecology, landscape mapping, environmental geography, landscape modeling, advanced GIT