

# RISK MAPS IN THE WATER MANAGEMENT OF THE CZECH REPUBLIC FROM THE CARTOGRAPHIC PERSPECTIVE

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## **Abstract**

*The The European Directive on the assessment and management of flood risks of EU Parliament (2007/60/ES) assigns to member states to prepare flood hazard and flood risk maps for areas with significant flood risk. The process of standardization of the flood mapping methods began in the Czech Republic several years prior to the directive's approval. Apart of the methods, developed for flood risks mapping, there was a question of its presentation. In the Czech Republic, there was an endeavour to make the visualization of the scientific hydrological assessment of the land under the flood risk more accessible to various groups of users. Final visualization proposal is thus necessary compromise between cartographical effectiveness and the effort to preserve most of the map content. Paper presents not only parts of the final visualization proposal of the flood hazard and flood risk maps, but also some of the cartographic bifurcations which arisen during its creation and necessary view on the background of the flood risk mapping.*

**Keywords:** *Water management, Floods, Risk maps, Cartographic visualuzation, Crisis management*

## **1. INTRODUCTION**

The necessity of a complex flood mapping, consisting of flood hazard maps (maps of water depth and flow velocity) and flood risk maps, was enacted by The Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks (hereafter the Flood Directive) [European Parliament, Council, 2007]. The Flood directive's main goal is to "establish a framework for the assessment and management of flood risk, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods in the Community" [Article1 of the Flood Directive, European Parliament, Council, 2007]. The Flood Directive puts Member States of the European Union under obligation to evaluate flood risk and flood hazards on their territory and to create respective maps, based on the Flood Directive's definitions. The Flood Directive has fixed dates for completing appointed tasks, the first being 22 December 2011 for completing preliminary flood risks assessment.

The process of standardization of the flood mapping methods began in the Czech Republic several years prior to the Flood Directive's approval, promptly after the floods in the 1997 and 2002. The resulting proposed Methodology of Flood hazard and Flood risk mapping (hereafter the Methodology) [Drbal, Drab et al, 2010] is based on a matrix of risk [Connell et al, 1998, Beffa, 2000] and closely connected to the standard database established, operated and administrated within the Czech Republic. The Methodology was approved by the Ministry of Environment of the Czech

Republic. Using this Methodology was the one of main requirements for application of subsidies from 14<sup>th</sup> call of Cohesion Fund (Technical Assistance of Operational Program Environment) for mapping of flood hazard and flood risk of chosen river segments with potential significant flood risk [river segments were chosen by Drbal, Dzurakova at al, 2010]. The responsibility for the compilation of the methodology was entrusted by the Ministry of Environment of the Czech Republic to the T.G. Masaryk Water Research Institute. The Methodology consists of several main articles covering:

- Information about related documents and deadlines;
- Definition of terms and acronyms;
- Definition of the input data, its sources and hydraulic calculations;
- Methods of flood risks and flood hazards assessment;
- Definition of the output data;
- Cartographic visualization of the output data;
- Dissemination of results.

The Methodology was compiled with the purpose to offer a complex manual for the flood risk assessment to institutions and companies potentially interested in the flood risk and flood hazard assessment and mapping. As visual appearance of the flood hazard and flood risk maps is not determined by the Flood Directive, it was decided to include aspects of cartographic visualization of the output data into the Methodology as its integral part together with methods of the flood hazard and the flood risk. The inclusion of map keys into the Methodology should hopefully simplify communication between individual providers and users and secure a standard level of quality of the flood hazard and flood risk maps.

When compiling the Methodology, there was an endeavour to make the visualization of the scientific hydrological assessment of the flood prone areas, made by experts, more accessible, not only to the municipality officials, but also to the people working in insurance companies or in urban planning. The possible interest of the public was also taken into consideration. Various types of risk maps, or better said visualized datasets, were part of the water management GISs from its very beginnings and are through the community of experts more or less standardized. Nowadays used types of the cartographic visualization are based on software, knowledge, skills and professional needs of hydrologists working with the water management GIS and as such are not optimized for publication or for use by non-expert individuals. These traditional methods of visualization, used in water management, put restrictions on proposed visualization possibilities the same way as requirements on features on maps or target user groups did.

The goal of this paper is not to discuss hydrological aspects of the flood risk and flood hazard assessment, or enumerate different approaches in flood risk mapping through the World as an extensive research on flood mapping practices was done by The Exchange Circle on Flood Mapping (EXCIMAP) in 2006 and has resulted in a Handbook on Good Practices for flood mapping in Europe [EXCIMAP, 2007, van Alphen et al, 2009], but to discuss possibilities and challenges of cartographic visualization in very restricted boundaries where many compromises must be made. The second objective is to present the first results of the Flood directive implementation in the Czech Republic.

## **2. IN FRONT OF THE TASK – BASIC INFORMATIONS**

When making a map, there are of course always various aspects influencing the final result. In the case of flood hazard and flood risk maps was necessary to re-establish traditional methods of cartographic visualization according to the new conditions. These conditions were created not only by acceptance of the Flood Directive, but also by deliberate expansion of targeted user group and by new definition of the medium of presentation. Impossibility to significantly manipulate or generalize the base topography map was another challenge.

### **2.1 Target groups**

Before the floods in Moravia in 1997 (eastern part of the Czech Republic, basins of rivers Morava and Odra) and in Bohemia in 2002 (western part of the Czech Republic, basin of river Labe) the core of users of various flood maps was concentrated mostly on hydrology experts. Whereas these floods also led to the collapse of several insurance companies, the interest in the flood risk mapping has through the time exponentially risen. For a long time this type of maps remained, thanks to the high level of expertise going into their making, inside of the hydrology GISs, operated by water management institutions (for individual river basins) or research institutes. The Flood Directive's request to release the flood hazard and flood risk maps to public provided legal frame for possible expansion of the so far limited user group. The existence of guaranteed and promulgated flood hazard and flood risk maps could very well be answer to decision making of urban planners on construction closures or insurance agents on land assessment issues.

The output data shaping the flood hazard and flood risk maps are a result of risk analysis. To fully interpret and understand such a map, there is necessity to possess at least basic knowledge about the processes that led to its formation. The target group is assumed to have knowledge and ability to work with State Map Series (cadastral maps, topographical base ZABAGED, water management maps) [COSMC] and with land and urban plans (the graphical visualization of land and urban plans is not standardized in the Czech Republic [The law act no.183/2006]). As such, into the target user group is possible to include people from:

- Water management;
- Local and state government and municipalities;
- Land and urban planning;
- Insurance industry;
- Crisis management;
- Universities;
- Informed public.

## 2.2 Methods of presentation

Although the user group of the flood hazard and flood risk maps is assumed to have a high level of understanding of the methods of the flood risk assessment, the Flood Directive imposes an obligation for Member States to make the flood hazard and flood risk maps available to the public [Article10 of the Flood Directive, European Parliament, Council, 2007]. For the storage of the data the Methodology proposes to form a central database connected to a map portal, enabling quick and safe management. The Internet WWW presentation of the flood hazards and flood risk maps seems to be the most effective way to fulfil the obligation of the Article 10 of the Flood Directive. The flood hazard and flood risk maps will be made available to the public by the way of Web Map Services (WMS) or Web Feature Services (WFS). The specific appearance and functionality of the portal is still under advisement. As there already exists The Water Management Informational Portal [<http://www.voda.gov.cz/portal>], representing Water Information System [Pokorny et al, 2008] to the public, is probable that the connection between the two will be made.

Secondary to the web presentation is in this case possibility of printed maps. The possible use of the printed version is concentrated mainly on reconnaissance.

## 2.3 Base map and Processed area

The flood hazard and flood risk mapping belongs into the category of thematic state map series. As such is under the obligation to use as a base map the topographical database ZABAGED (1:10 000). ZABAGED exists in both raster and vector formats and includes more than 100 object types [Pressova, 2010]. In the case of the vector format, the ideal situation would be to use some form of the task oriented generalized version, similar to the proposal of the BASETPO in the project Dynamic Geovisualization for Crisis Management [Friedmannova, 2010]. Water management institutions are responsible only for hydrological parts of the flood hazard and flood risk maps. The manipulation with the base map is not only outside of their jurisdiction, but also outside of their competence and capacity. Similar problems with the inability to adapt the map content to better suit to the flood risk mapping also applies to urban plans, which are a vital part of the flood risk mapping process. The process of task oriented generalization is not an easy one and calls for intimate cooperation between hydrologists, cartographers and users.

In this stage of the flood hazard and flood risk mapping process was decided to use the raster version of the standardized visualization of the topographical database ZABAGED in shades of grey with 40% opacity (Figure 1.). Possible changes in the base map were left for future discussion.

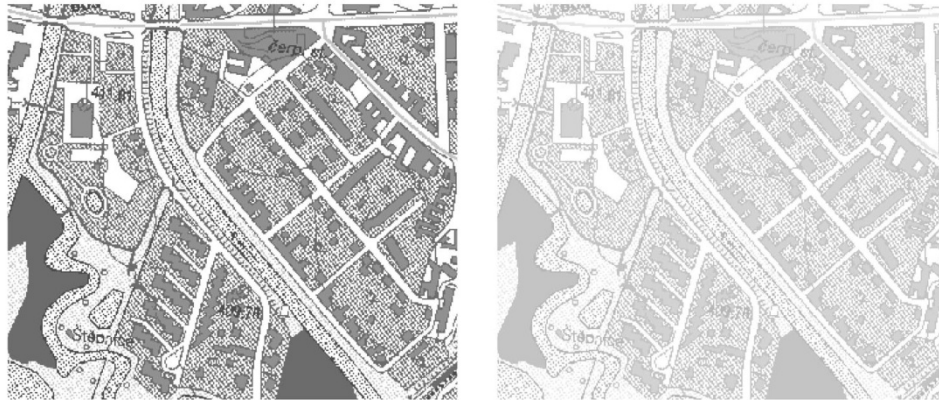


Figure 1. The base map: left – full coverage, right – 40% opacity.

From its very nature, the flood hazard and flood risk mapping does not cover the whole territory of the Czech Republic. The mapped areas are concentrated into the buffer around relevant water bodies. The extent of the buffer for individual water bodies is defined by the flood extent of the most extensive flood extent, usually flood with the low probability (in the Czech Republic was agreed scenario with the return period 500 years).

### 3. THE HAZARD MAPS - WATER DEPTH AND FLOW VELOCITY

Maps of the water depth and the flow velocity are the starting point of the flood mapping. Both are basic isopleths maps with one variable. The longstanding visualization of the water depths is a blue colour range (bathymetry), in this case with 75% opacity. From the five specified water depth intervals, first two are mandatory and the last three are optional. The mandatory intervals' limits are 0m - 0,5m - 1,0m. Limits of the optional intervals' are determinate individually, by the water depth variation in specific areas and conditions. The basic isopleths water depth map is enhanced by a layer of symbols representing the flow velocity.

The flow velocity map is done in the shades from yellow to red-orange with 75% opacity. The colour ranges for the water depth and for the flow velocity are made in complementary colour tints. The flow velocity map exists, apart from an individual isopleths map, also as a symbol layer on the water depth map (depending on used hydraulic model – 1D or 2D). The colours of the symbols on the water depth map are identical to the colours on the flow velocity map (with 100% opacity) to preserve the visual link between the two types of visualization – the isopleths and the symbols (Figure 2.). The shape of a circle was chosen to point out the inability to determinate the vector of the flow in the floodplain.

The original proposal combined the change of the symbol's colour with the change of its size. The goal was to create visualization resembling a pulse-field of the flow velocity on top of the water depth map. In the end it was deemed unnecessary to emphasize the change in the flow velocity further (Figure 2. – the part “rejected proposal”).

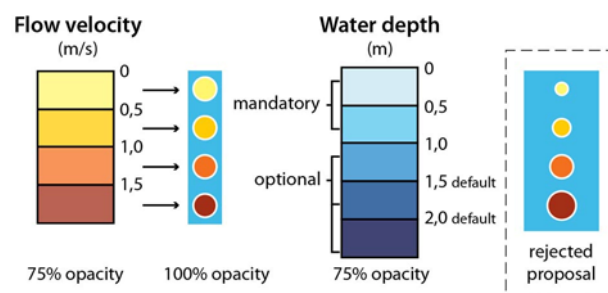


Figure 2. Map keys for the water depth and the flow velocity maps.

### 4. CARTOGRAPHY FACING HYDROLOGY – FLOOD THREAT MAP

From the cartographical point of view is a flood threat map result of a trivariate flood risk analysis resulting in a simple isopleths map with four defined categories. The variables included in the flood risk analysis are:

- Water depth;
- Flow velocity;
- Frequency of the flood (period of the flood recurrence).

The quantification of the flood threat is determined in two steps. The first step is calculation of **the flood intensity**, which is defined as a function of the water depth and the flow velocity [Beffa, 2000, Drbal et al, 2005, Riha et al, 2005]. Second step is determination of **the flood threat** itself. The flood threat is defined as a function of the flood intensity and the flood recurrence probability. The function of the flood threat is visualized by **the flood risk matrix** (Figure 3.). There are defined four levels of the flood threat together with their colour representation [Connell et al, 1998]:

- High - red;
- Middle - blue;
- Low - orange;
- Residual - yellow.

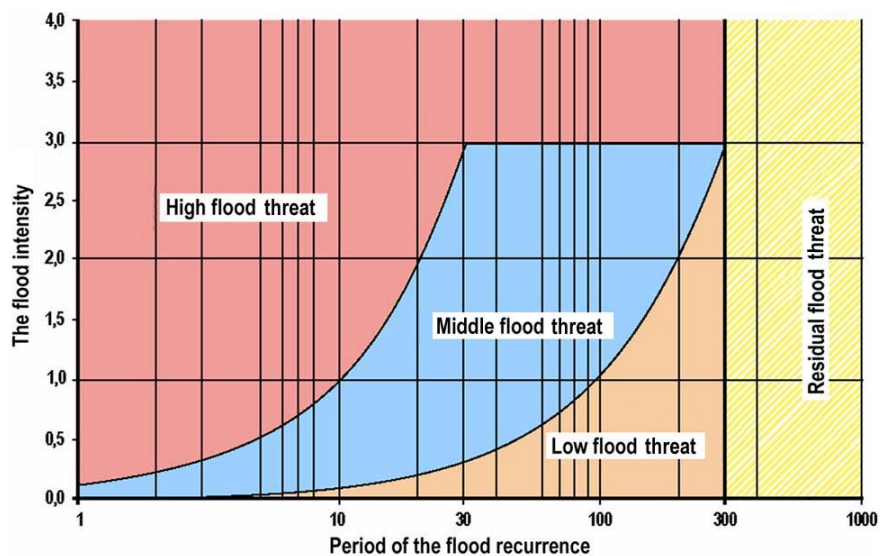


Figure 3. The flood risk matrix by [Connell et al, 1998].

The defined levels of the flood threat (residual – low – middle – high) have logical succession with strong inclination to be understood as increasing intensity of the phenomenon. The chosen colour schema used in the flood risk matrix (yellow – orange – blue – red) does not follow commonly accepted logic of the colour spectrum and ranges arrangement [Itten, 1973, Quiller, 2002]. Although several alternative colour ranges were suggested, monochromatic and spectral alike, in the case of the map key for the flood threat maps was given preference to the traditional visualization derived from the colours in the flood risk matrix (with 60% colour opacity). Example of the final proposal of the flood threat map together with two of the suggested alternatives of the map key is shown on the Figure 4.

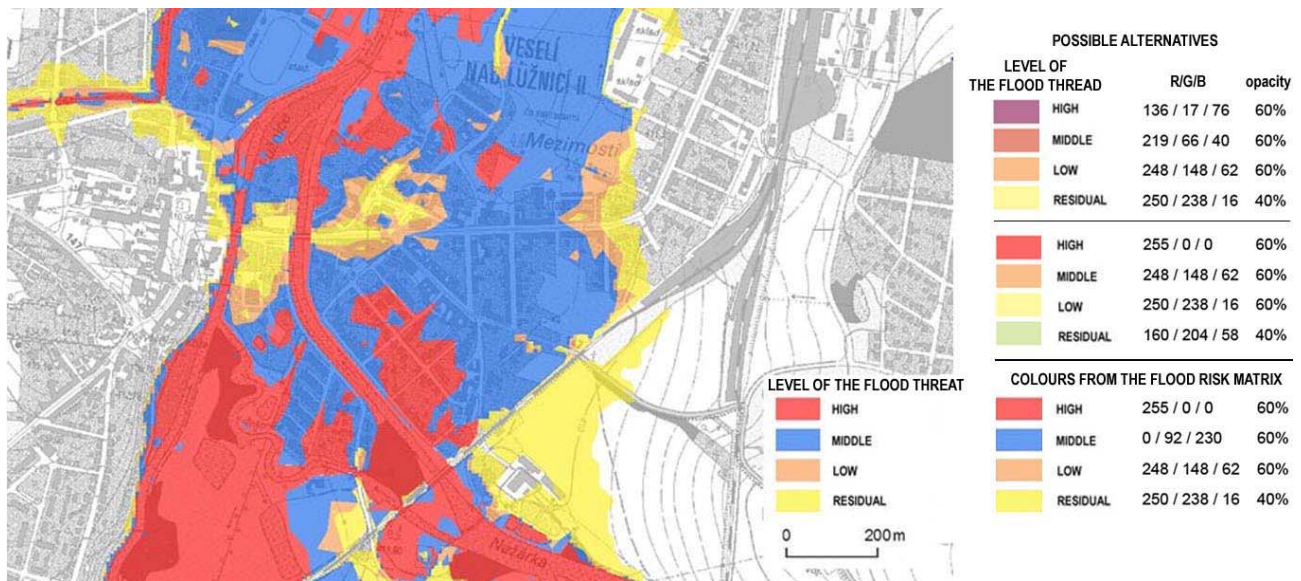


Figure 4. Example of the flood threat map visualization and possible map key alternatives (resized).

The visualization of the flood threat maps subsequently impacted the map key for the flood risk maps, but as there were used only categories middle and high, the illogicality in the colour range was not conveyed into the flood risk maps' map key. Nevertheless, the obligation of the public presentation of the flood threat and flood risk maps should in this case have bigger impact on the cartographic visualization than traditional but illogical visualization used by hydrologists.

## 5. STEP FURTHER – FLOOD RISK MAP

When simplified, the flood risk map is basically combination of the flood threat map and an urban plan. From the flood threat map to the flood risk map enter only areas of high and middle level of the flood threat. The colouring, used on the flood threat map, is transferred into the flood risk map. The opacity is reduced from 60% to 40%. Only when the relevant level of the flood threat overlaps with an area of specified vulnerability, the overlapping area is depicted on the flood risk map. The assessment of **the area vulnerability** is based on information about the land use recorded on urban plans [Drbal et al, 2010].

Urban plans are extremely complex and detailed and there is no standardization of graphical parts of urban plans in the Czech Republic to speak of [The law act, 2006/2009]. Part of urban plans is still only in a paper form or exists as a scanned document. To enable hydrologists to work on the flood risk maps, there were specified eight categories of the land use, common to urban plans as a whole. Where an urban plan does not exist, there is possibility to generate areas with specific land use directly from ZABAGED. The simplified urban plan consists from:

- Housing areas;
- Mixed areas (housing, services, small businesses);
- Services, municipality, business;
- Technical services;
- Transportation - traffic areas;
- Factories and warehouses;
- Recreation and sport;
- Parks and gardens.

Each category has set an acceptable level of the flood risk (levels are consistent with the flood threat map categories or the flood risk matrix). If the level of an acceptable risk is breached by the level on the flood threat map, the area is evaluated as risky and in need of the flood risk management plan.

The colour scheme of the simplified urban plan is loosely linked to the most common type of the urban plans visualization (based on empirical observation). Urban planners are prone to try to bring the appearance of the map as much as possible to the visual reality (for example, the historically most common roofing tiles in the Czech Republic are red, which is colour on urban plans generally used for housing areas; gardens are green; water is blue etc.). Naturally, with red and blue already assigned to the levels of the flood hazard and with highly complicated base map in

the shades of gray, the options for the visualization were limited. The final colour scheme is in rich jewel tones. The areas have relatively wide margin and the transparent filling pattern is dependent on the area existence in the time frame (the defined land use areas have three possible time frames – existing, proposed and in prospect). The example of the flood risk map, including the map key is on Figure 5.

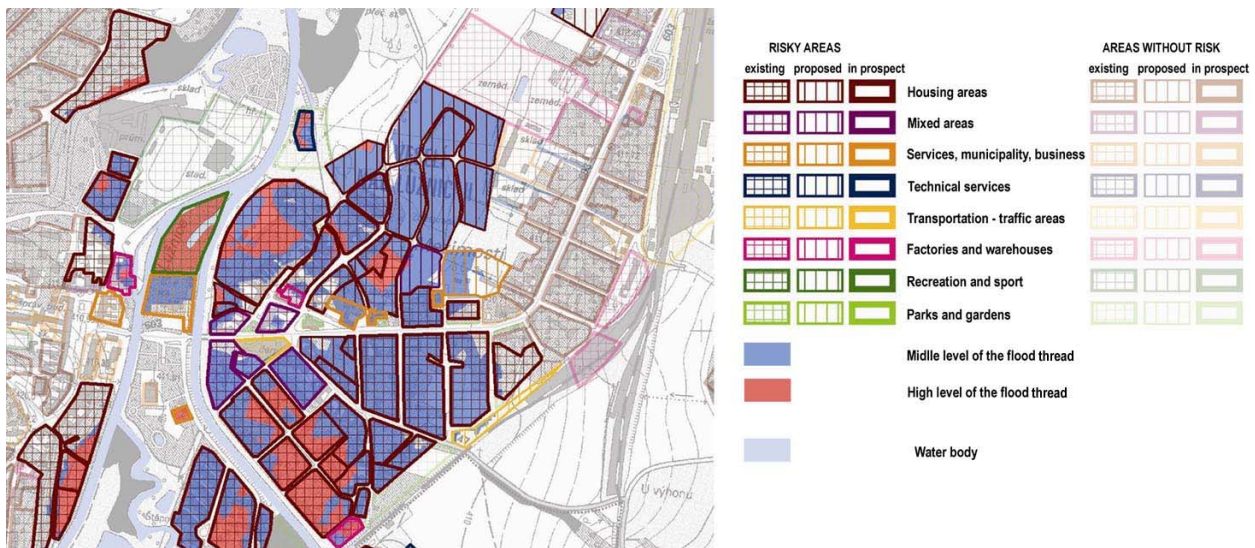


Figure 5. Example of the flood risk map (resized).

There is a visual connectivity or link between the map key of the flood thread map and the map key of the flood risk map [on principles of visual connectivity see Friedmannova, 2010]. A change in one would necessarily bring up a change in the other. Furthermore, in accordance with some of the user groups' knowledge and needs, was proposed to visually preserve areas of urban plans without the flood risk. To distinguish un-risky areas from the risky ones, their opacity was severely reduced. The visual preservation of un-risky areas should enable better orientation in the area particularly to the people more used to work with urban plans than with ZABAGED.

Visualization of the flood risk map is mostly area oriented and in a scale where it may be difficult to distinguish individual objects. To highlight so called "sensitive" objects the map can be enhanced by layer of symbols. These geometric symbols represent categories of objects (schools, culture, health service, etc.) especially sensitive for crisis management (objects of critical infrastructure - [Ministry of the Interior of the Czech Republic, 2009]). Annotations were not solved in this stage.

From the beginning there was also considered different approach. The idea was to literally move the hydrological content (the flood thread) up and the urban plan content down (see Figure 6.). Instead of lowering the opacity of the flood thread areas, there was used texture with transparent background. For the simplified urban plan was chosen pastel colour scheme to make it seem more as a part of the base map. In the end this approach was deemed unsuitable. The reason was that the visual link between the flood thread maps' map key and the flood risk maps' map key would be insufficient.

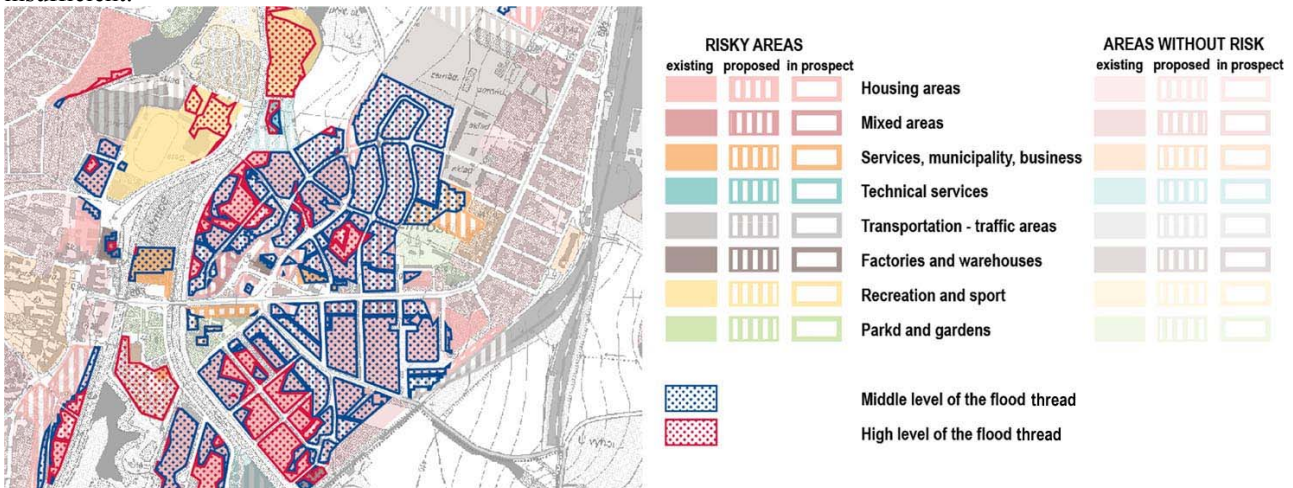


Figure 6. Example of one of the rejected types of the flood risk map visualization (resized).

## 6. CONCLUSIONS

The authorization of the Methodology of Flood hazard and Flood risk mapping and its publication in the Bulletin of the Ministry of the Environment of the Czech Republic [Drbal, Drab et al, 2010] is significant step towards fulfilment of obligations given by the Flood directive to the EU member states. Apart of the methods, developed for assessment of flood risks and hazards, is in the Methodology also included description of the visual presentation of the output data. The inclusion of the cartographic visualization description into the Methodology will secure a standard level of quality of the flood hazard and flood risk maps.

The flood hazard and flood risk mapping consist from:

- The Map of water depths;
- The Map of flow velocity;
- The Flood threat map;
- The Flood risk map.

Each of the themes is build over the standardized visualization of the topographical database ZABAGED [COSMC]. ZABAGED is reduced in opacity and drawn in shades of gray (Figure 1.). The possible task-oriented generalization of the base map is for the future strongly recommended.

Maps of the water depth and flow velocity are basic isopleths map, with colour ranges in shades of complementary colours – blue for water depths and yellow-orange for the flow velocity (Figure 2.). The selection of the complementary colour enables users to make easy visual link between isopleths map of the flow velocity and the symbol layer representing the flow velocity on the map of the water depth and flow velocity. The symbol is a circle to point out the inability to determinate the vector of the flow in the floodplain.

The flood threat map is a trivariate isopleths map (Figure 4.). The function of the flood thread is visualized by the flood risk matrix (Figure 3.). There are defined four levels of the flood thread together with colours representing them. Although several alternative colour ranges were suggested, there was given preference to the traditional visualization derived from the colours in the flood risk matrix (with 60% colour opacity).

The flood risk map is basically combination of the first two levels of the flood thread (high and middle) and a simplified urban plan (Figure 5.). The colouring, used on the flood thread map is transferred into the flood risk map to preserve visual link between the two maps. Each area category of the urban plan has set an acceptable level of the flood risk. If the level of an acceptable risk is breached, the area is evaluated as risky and in need of the flood protection. The colour scheme of the simplified urban plan is in rich jewel tones with transparent filling patterns. The defined land use areas have three possible time frames – existing, proposed and in prospect. To highlight individual sensitive objects the map can be enhanced by layer of geometric symbols.

The final visualization proposal implemented into the Methodology is necessarily a compromise between cartographical effectiveness, the effort to preserve most of the map content, the traditional visualization used by water management experts and some other external influences, as is for example inability to impact the content of the base map.

In the final stage of the Methodology's preparation the question of the colour range for the flood thread map was re-opened. Unfortunately there was not enough time to change the map key; as such a change would significantly impact the map key of the flood risk map. Nevertheless the chosen method of dissemination through www presentation leaves the possibility of a future change in the visualization open.

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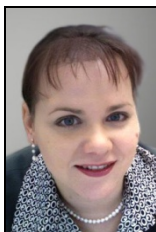
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