1CE037P3 LABEL

LABE – ELBE – Adaptation to the Flood Risk in the Elbe River Basin

The study of flooding areas in the Krusne Mountains

December 2010

short report

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1 Data related to the project

Initial data for the project:

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2 Introduction and Objectives

Within central Europe floods are the most destructive regularly occurring natural phenomenon. Several flood events have taken place in the Elbe river basin in recent years that affected large areas in the territory and caused great damage to the health of the people and to the property in affected towns and villages.

The greatest floods can be considered the ones that took place in August 2002 and affected vast areas in the river basins of the Elbe and the Vltava. The floods in 2002 also hit a part of the Krusne Mountains on the German as well as Czech part of the territory.

The area of the Krusne Mountains was hit for the last time by flash floods in 2010 that again affected mainly the eastern part of the mountains.

Based on these events we propose anti-flood measures that can be divided into non-technical interventions in the river basin and technical anti-flood measures in places where floods cause damage.

2.1 The objectives of the Study

The objective of this study is to assess the territory in respect of extreme hydrologic phenomena in the form of a flood risk. The study has been created for the territory evaluating the level of vulnerability from the viewpoint of the flood risk.

The study describes the main drainage directions and their danger level for the area in the direction of drainage. Based on these results it is possible to propose modifications, especially vegetative ones, for the concerned territory.

Another examined parameter is the danger of erosion that represents a threat for arable soil as well as built-up areas located under the affected area. Based on this study it is possible to determine the area that is most vulnerable in respect of the erosion risk and the insufficient level of water accumulation.

Based on the results of this study it is possible to propose suitable places for technical anti-flood protection in the river basin and anti-erosion measures.

3 Description of supportive systems and databases

GIS software (geoinformation systems) with HEC extensions were used to create this study.

3.1 GIS tools

ArcGIS 9.2 software of ESRI company was used as the main environment. In the course of the work on the study 3D Analyst and Spatial Analyst extensions were used too.

3.1.1 3D Analyst

3D Analyst extension makes it possible to create, display and analyze three-dimensional data. Creation and analysis of a digital model of the relief in a grid as well as triangulated form, contours. Inclination, exposition, cross sections, visibility analysis, basic map algebra. Interpolation of measured values, conversion between 3D shapefile, 2D shapefile, TIN and GRID. It also includes ArcScene and ArcGlobe applications for the creation of a 3D model of a territory as an interactive 3D GIS, simulation of moving through the area in real time, videorecording of the movement (flights). Using these tools land survey spatial data were processed.

3.1.2 Spacial Analyst

Spatial Analyst extension is used for spatial analysis on the basis of a raster (grid), that is, it enables working even with the data that continuously change in the area (altitude, demographic data, pollution etc.). A combination of

raster and vector data, the scope of map algebra functions, interpolation of measured values, isolines, modelling and terrain analysis (inclination, exposition, visibility analysis...), hydrologic modelling, dynamic modelling, distance analysis. Using these tools individual source layers were created and evaluated.

3.1.3 ArcHydro 1.3.92

This extension is used to process hydrologic data in the ArcGIS environment.

3.2 HEC tools

Software belonging to HEC tools (The Hydrologic Engineering Center) was created in the developmental centre of Institute for Water Resources working under US Army Corps of Engineers. ArcGIS software extensions were used. All HEC products are distributed as freeware and can be obtained on the sites of US Army Corps of Engineers:

http://www.hec.usace.army.mil/

3.2.1 HEC-GeoHMS 4.2.92

Software HEC-GeoHMS (The Geospatial Hydrologic Modeling System) is used to create a precipitation-drainage model in the geospatial environment of ArcGIS.

Within the study the software was used to create a precipitation-drainage model of the territory and this model was used for spatial assessment of the territory from the viewpoint of drainage conditions. The results from the model are also used as input data for other models (HEC-GeoRAS) and for the assessment of water accumulation level in the river basin.

3.2.2 HEC-GeoDozer 1.0

The software is used to process and edit hydrologic and land survey data within ArcGIS. This means editing of the terrain, watersheds, partial river basins and furthermore the editing of water streams.

The software was used to modify the results of the hydrologic network and the precipitation-drainage model according to the results of terrain reconnaissance.

3.2.3 HEC-GeoRAS 4.2.92

The HEC-GeoRAS software (The Geospatial River Analysis system) is used to create a hydraulic mathematical model of flow directions in the river bed. The software provides a wide scope of tools for the evaluation of a flood situation.

Within the study HEC-GeoRAS was used to create a hydraulic model for the concerned area with the overflow evaluation in respect of water depth and water streaming speed in the concerned area. The results are used to determine the flood risk in the flood area. The results are used for the proposal of anti-flood measures.

3.2.4 HEC-DSSVue 2.0.1

The product is used to process databases of hydrological data. Databases can be used for data export to other HEC systems or can be transported to the spreadsheet for further editing.

In the course of the study creation the software for the data evaluation of the HEC-HMS precipitation-drainage model and for the data editing and export to the HEC_RAS hydraulic model. Furthermore, by using the HEC-DSSVue software the results of the hydraulic model were evaluated and processed in a graphic form.

4 The methodology of the study creation

The existing methodology, subsequently modified for and adapted to the project's assignment, was used to create the study. The methodology can be divided into the following points:

1. Processing of data for GIS environment
2. Processing of the terrain and hydrological network model
3. Processing of the precipitation-drainage model for the territory
4. Assessment of the territory from the viewpoint of drainage conditions
5. Creation of a hydraulic model for the territory
6. Assessment of the flood risk
7. Assessment of the influence of vegetation on flood risks
8. Assessment of the erosion risk in the territory
9. Proposal of anti-flood and anti-erosion measures

The assessment is carried out within a case study that assesses the selected part of the Krusne Mountains via several scenarios. Execution of individual steps of the methodology is preceded by the selection of a suitable locality and the reconnaissance of the selected territory.

4.1 Processing of data for GIS environment

ZABAGED documents provided by the Regional authority of the Ústí region were used as input data. These documents concern layers describing the following characteristics of the territory:

- Vegetative cover and the utilization of the territory
- Soil types (BPEJ – which means Evaluated soil ecological units)
- Built-in areas

Individual layers were processed using GIS tools and prepared for further processing. The layers are used to enter parameters for the precipitation-drainage model.

4.2 Processing of the terrain and hydrological network model

Documents provided by GIS centre of the Regional authority of the Ústí region were used to create a digital model of the terrain. This means especially three main resources:

1. Elevation point field – the Ústí region
2. Contours – ZABAGED
3. Subsequent measuring on the spot in the area

These source data were used to create TIN layers (triangulated irregular network) and DTM (Digital Terrain Model) for the concerned area. The terrain was modified according to the real situation measured in the course of terrain reconnaissance using the Hec-GeoDozer tool. These terrain models were then used for further analyses of the territory and as input data for the processing of another model.

The hydrological network was generated on the basis of DTM input and ArcHydro tools. The resulting network was calibrated according to the hydrological network of water management maps in the database of the Hydroecological information system of T.G. Masaryk Water Research Institute.

4.3 Processing of the precipitation-drainage model for the territory

The precipitation-drainage model was created using HEC-GeoHMS software, which is an extension to ArcGIS. This is a model which, on the basis of the characteristics for the territory, determines drainage conditions in response to an entered rainfall situation. The characteristics of drainage parameters are determined on the basis of vegetative and landscape cover and the map of the original cover.

The model processing is characterised by three steps :

1. Preparation of input data (pre-processing)
2. Calculation via a model (processing)
3. Processing of output data (post-processing)

The precipitation-drainage model is calibrated and verified via current measurements at measuring cross sections performed by the Czech Hydrometeorological Institute.

4.4 Assessment of the area from the viewpoint of drainage conditions

Based on the results of the precipitation-drainage model the drainage conditions of the concerned area are evaluated. The results are further evaluated in the GIS environment via Spatial Analyst tools. The results are presented graphically via map outputs.

The results from the evaluation of map outputs are described in more detail in the Conclusions part at the end of this report.

4.5 Creation of the hydraulic model for the territory

Based on the results of drainage conditions a hydraulic model for open river beds is created. These models evaluate the flood situation in a given territory caused by extreme precipitation. HEC-GeoRAS programme was used to create a drainage model – the results of this programme can be further edited in the GIS environment.

4.6 Assessment of the flood risk

Based on the results of a hydraulic model flood statuses are evaluated for various scenarios of drainage parameters. Using the water levels of the flood-prone area a peak level of individual flood surges based on the precipitation-drainage model is assessed.

4.7 Assessment of the influence of vegetation on flood risks

By evaluating the aforementioned points the territory is described from the viewpoint of the influence of vegetation on the flood situation. In order to assess the extent of the influence of the vegetation cover on flood risks various scenarios are created for the concerned territory describing the same area with different types of vegetation cover. These are variants that describe the current situation, a wooded territory, a territory after parts of the woods were removed up to the variant when no vegetation cover is present.

4.8 Assessment of the flood risk for the territory

The assessment of the erosion risk focuses on the evaluation of the potential level of water erosion danger for the territory. The danger potential is determined on the basis of long-term average soil washing-off (G).

Water erosion is caused by the destructive activity of rain and surface drainage and the subsequent transport of soil particles. The intensity of water erosion depends on the character of rains and surface drainage, soil conditions, the morphology of the territory (especially in inclined areas and along continuous slopes), vegetation conditions and the management method used for the land.

Water erosion manifests itself on the soil surface via selection of soil particles and by the occurrence of drainage routes of various sizes, in the place of significant concentration of surface drainage gullies may appear. Soil particles are then mostly deposited in depressions and in places of lesser inclination located in lower areas. Particles transported beyond the borders of land plots get into the hydrographic network and create sediment discharges. These sediments set in water reservoirs and in sections of water streams with reduced transport capability. From the viewpoint of the volume of sediments the largest source is the washing off of arable soil; nonetheless it is necessary to take into consideration also erosion of building sites' surfaces, erosion of woods soil in places where wood is harvested by mechanical means, and river bank and river bed erosion in water streams. These sources can also contribute significantly to the increased transport of sediments.

The most frequently used method for determination of the water erosion intensity is so-called Universal soil loss equation - USLE (Wischmeier, Smith 1978):

$$G = R \times K \times L \times S \times C \times P$$

In this equation individual letters have the following meaning:
G – average long-term soil loss (ton.hectare^{-1}.year^{-1}),
R, K, L, S, C, P – see below

Rainfall and runoff factor (R) – erosive efficiency of rain storm
The R factor depends on the kinetic energy and intensity of erosion causing rains. The recommended mean value for the Czech Republic is R = 20 MJ.ha^{-1}.cm.h^{-1}. The use of this method is recommended by the newest methodologies (e.g.. Janeček et al. 2008) and this is because a more precise distribution of the R factor on the territory of the Czech Republic is not possible due to the lack of evaluated data. The average value of the R factor is, in our conditions, the value for a vegetative season since rain storms causing erosion occur mainly from the end of April till the beginning of October.

Soil erodibility factor (K)
The K factor is defined in USLE as soil loss on a standard land plot expressed in ton.hectare^{-1} per the erosive rain efficiency unit R. The value of the K factor depends on the texture and structure of arable soil, the content of organic substances and the permeability of the soil cross section. This factor represents susceptibility of soil to erosion, that is, the soil capability to resist the effect of rain and the transport of the surface drainage.

Slope length and slope steepness factor (LS)
The topographic factor (LS), or, in other words, the slope length factor (L) and slope steepness factor (S), expresses the influence of the terrain morphology on the occurrence and development of erosive processes. The topographic factor represents the ratio between the soil losses for a slope area unit and the soil loss on the unit land area of the length of 22.13 and the incline of 9%.

L – the slope length factor expresses the influence of the continuous slope length on the size of soil loss caused by erosion.
S – the slope steepness factor expresses the influence of the slope steepness on the size of soil loss caused by erosion.

Vegetation cover protective factor (C)
The C factor depends on the development of vegetation and the used agricultural techniques; it represents a ratio between the soil loss from land under a specific crop and management system to the corresponding loss from continuously fallow and tilled land. The USLE methodology aims to determine the vegetation cover protective factor (C) for a concrete sowing method, including the periods between the exchange of crops while it also determines the timing and the methods of agricultural works in five periods (Janeček et al. 2007) for every land.

Anti-erosion efficiency factor (P)
If it cannot be expected that maximum lengths of land plots and the number of crop strips (alternating of strips of different crops) will be observed, the efficiency of the given measure expressed by the value of the P factor cannot

be taken into consideration in the course of the calculation of average long-term soil loss and the value of P factor = 1.“

The results are then divided into three categories that represent the level of danger for the land from the most endangered areas to areas without any danger. The results are presented graphically via map outputs.

4.9 Proposal of anti-flood and anti-erosion measures

All results of this study are to be used for the proposal of anti-flood and anti-erosion measures for the examined river basin. The results determine the most endangered areas in terms of erosion and the built-up area that have been affected the most by damage caused by floods.

Anti-flood measures can be divided into two groups. The first part concerns interventions in the water stream basin, which means especially the change of the vegetation cover in the basin. Other anti-flood measures focus directly on the locations in which flood damages have occurred for which suitable technical anti-flood measures are proposed.

The other group is formed by anti-erosion measures. This group focuses especially on vegetative and technical measures in the place of the greatest risk of erosion.

5 Solution of the case study

The basin of the Jílovský potok (Jílovský brook) in the eastern part of the Krusne Mountains (the Nature Park of the Krusne Mountains) has been selected for the case study. This area is affected by extreme rainfall events that cause flood situations.

5.1 Characteristics of the territory

The landscape in the water stream source area of the concerned territory can be characterised as a hilly area with difference in altitude of up to 200 m. Important landscape elements in the area are ecosystems of the Ager type – regularly managed and cultivated pastures that run through ecologically significant societies of old hollow ways. Vast meadows are also divided by societies alongside small water streams that tend to run in straight lines.

The southern slopes of the Krusne Mountains are characterised by steep inclines with the difference in altitude of 300 m. River streams have created deep valleys in this locality. The southern slope of the Krusne Mountains is covered in woods in which the composition of tree types has been partially preserved.

The entire surroundings of the concerned area are formed by the rocks of the Krusne Mountain’s crystalline complex created in the Proterozoic period consisting mainly of partially magmatized biotitic and muscovite-biotitic paragneiss and micas.

5.2 Climatic characteristics

Lower top planes belong to the cool CH7 category, locations above 800m to CH6 category and locations above 1000m to CH4 category, which the coolest Czech climatic category. The top parts of slopes belong to CH7 category, the lower parts of slopes to mildly warm MT4 category and exceptionally to MT9 category. The temperature on top planes ranges between 2.7 °C on the top of Klínovec (Keilberg) and 5 °C in warmer areas. Precipitations oscillate between 900 - 1200mm. The influence of the mountain top phenomenon is perceivable in the locality. The climate on the slope manifests a very steep gradient from the cold wet climate of the plateau to the warm and extremely dry climate of the foothill basin. The local climatic gradient is the biggest one in our lands and one of the steepest ones even from the viewpoint of entire central Europe.

The concerned area climatically belongs to CH 7 district, which means the climatic type characterised by short summer, a long transient period and a long-lasting snow blanket and long mild winter. Precipitations are approximately 750 mm. The mean annual temperature is approximately 7 °C.

5.3 Jílovský potok (Jílovksý brook)

Jílovský potok (hydrological reference number ČHP 1-14-02-026) rises in the area of Nakléřovský průsmyk (Nakléřovský pass) at altitude of 713 m. Within its whole length the stream runs mostly eastwards. It passes through the village of Libouchec, towns of Jílové, Bynov and Děčín where it flows as a left-side tributary into the Elbe river at the altitude of 122 m. The brook is managed by the state-owned company of Povodí Ohře. At the edge of Bynov it flows into a nameless water reservoir. The reservoir is used to retain water at the times of high flow rates or in the event of floods.

The largest floods in recent times were recorded in 2002 and 2006, when water flooded almost a half of the Děčín's quarter called Podmokly. On 7th August 2010 the brook overflowed its banks heavily after a rain storm (100 mm in 2 hours) and undermined road no. 13 in the village of Modrá and a half of the road collapsed. Later, on 12th August 2010 the stream overflowed its banks again (80 mm in 2 hours) while causing no significant material damage. Other flash floods were recorded in July 1979 and July 1987 and resulted in huge material damage.

A reporting cross section of the Czech Hydrometeorological Institute is located at the 14.00 river kilometre in the village of Libouchec at the foothills of the Krusne Mountains. The river basin area at this cross section amounts to 13 km^2. For this cross section the following n-years flow rates have been determined :

Table 1 N-years flow rates – the Jílovský potok stream (The Czech Hydrometeorological Institute)

N-year flow rate	Q_1	Q_5	Q_{10}	Q_{50}	Q_{100}
m^3s^{-1}	2.6	9.8	15.4	34.5	47

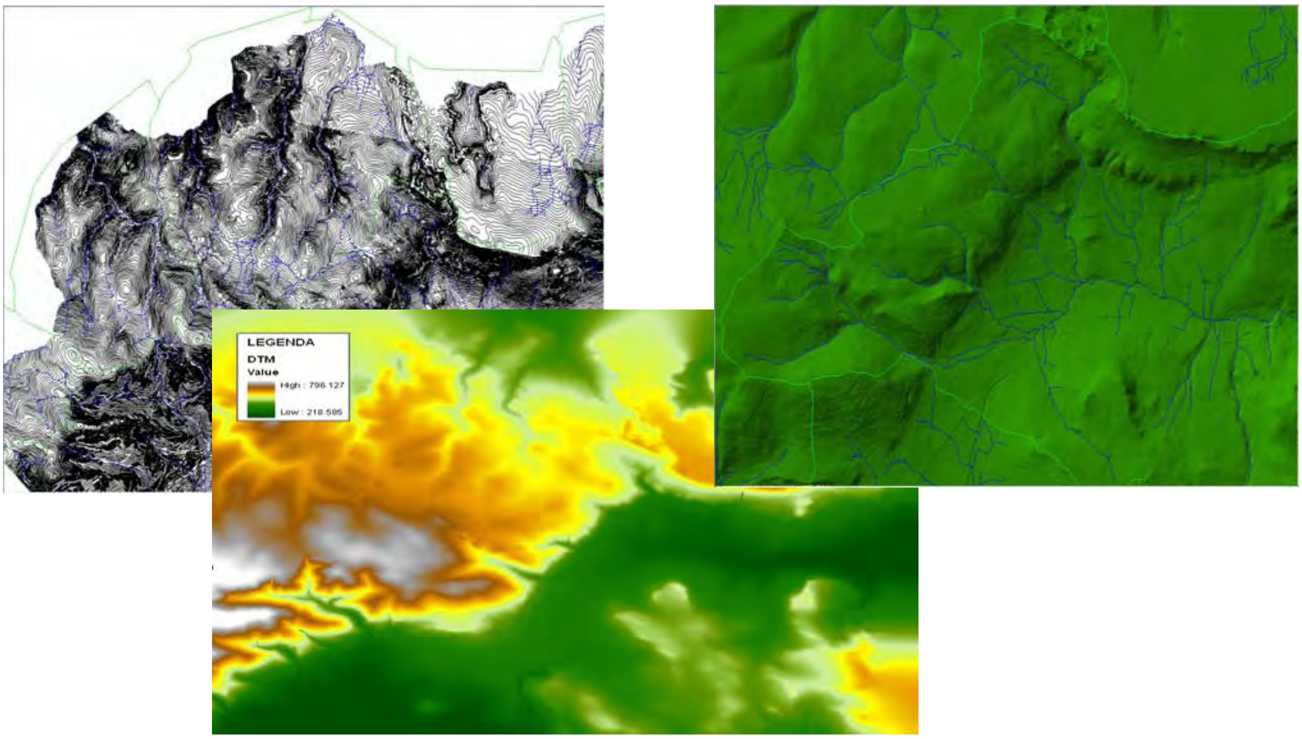
5.4 Land survey input data

Land survey data were obtained from the point field, contours and measurements. In order to make the calculation more precise a vector map of water streams was used.

1. Elevation point field – the Ústí region
2. Contours – ZABAGED
3. Subsequent measuring on the spot in the area
4.

The result was converted to the digital terrain model (DTM) and an irregular triangulated network was created. These terrain models were used for further analyses of the terrain.

Figure 1 Creation of digital terrain model



5.5 Precipitation-drainage model

A digital terrain model was used to analyse the basin and drainage streams in the concerned area. Based on the model the drainage directions for the concerned area were determined. These were used for the analysis of drainage concentrations and the determination of partial basins. Furthermore, parameters of individual basins were evaluated, such as the basin area, steepness, the length of the water stream and other parameters that are used in the course of schematic representation and in the calculation of precipitation-drainage properties of individual basins.

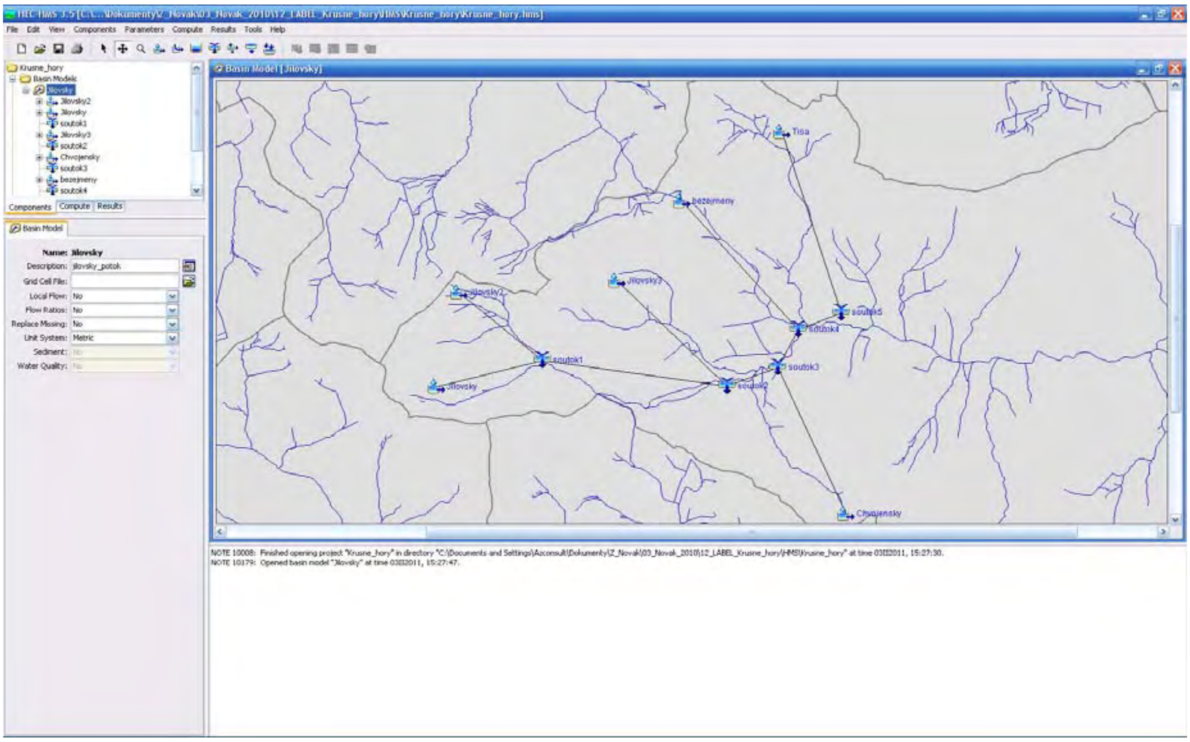


Figure 2 *Schematic representation of the basins in HEC-HMS environment*

The basic characteristic obtained from drainage conditions from partial basins is the CN curves analysis. Individual basins have been allocated CN numbers according to the vegetation cover of the area. Furthermore, an existing study of CN curves for the Czech Republic was used too. These are presented in the following map and table.

Figure 3 *The map of the division of the territory according to CN values*

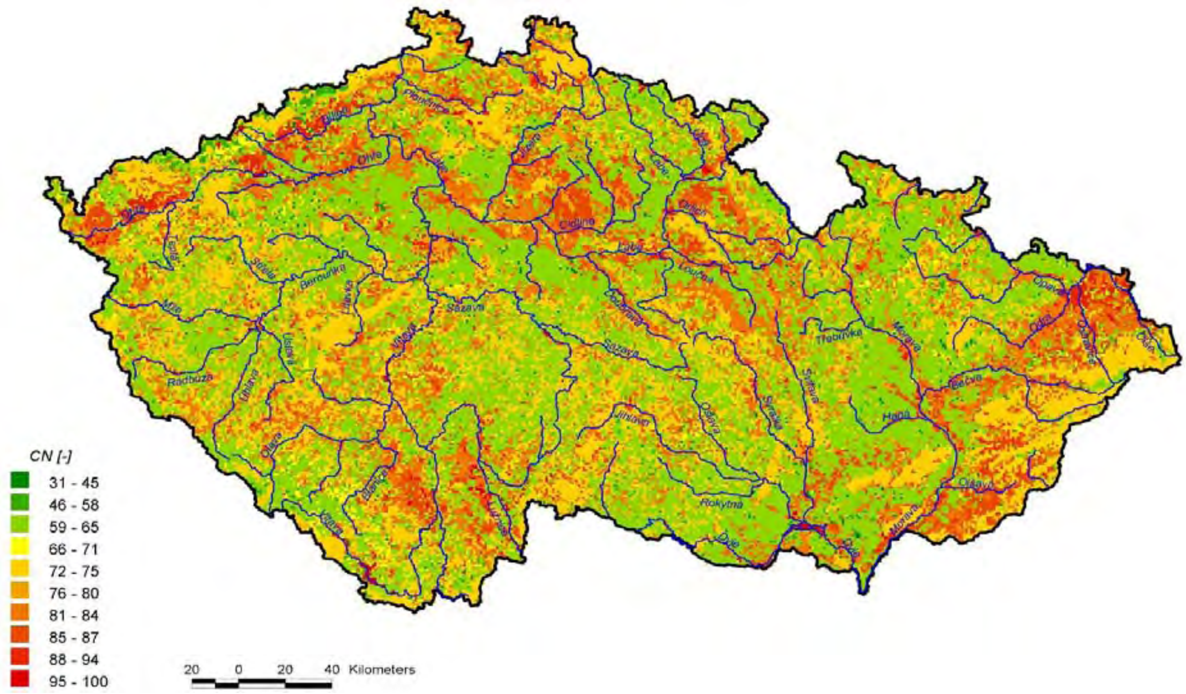


Table 2 *Tabular presentation of the values of CN curves for selected surfaces*

ID	Category	A	B	C	D
124	Airports	85	90	93	94
131	Mining of minerals	85	90	93	94
132	Waste dumps	85	90	93	94
133	Housing development	85	90	93	94
141	Town vegetation	44	65	77	82
142	Sport grounds	44	65	77	82
211	Arable soil	64	73	83	87
221	Vineyards	54	70	79	84
222	Fruit trees	45	66	77	83
231	Meadows and pastures	49	69	79	84
241	Annual plants	65	75	83	86
242	Fields, meadows, plantations	54	72	82	87
243	Agricultural premises	71	82	87	90
311	Deciduous woods	35	61	74	80
312	Coniferous woods	35	61	74	80
313	Mixed woods	35	61	74	80
321	Natural meadows	35	60	73	79
322	Moors and marshy land	99	99	99	99
324	Areas covered in trees and bushe	31	58	72	78
331	Beaches, dunes, sand settlement	77	86	91	94
332	Rocks	77	86	91	94
333	Thin vegetation	63	77	84	89
334	Sites of fire	77	86	91	94
335	Glaciers and permanent snow	99	99	99	99
411	Bogs and peat bogs	99	99	99	99
412	Peat bogs	99	99	99	99
511	Water streams	100	100	100	100
512	Water surfaces	100	100	100	100

Values for proposal hyetographs of the Czech Hydrometeorological Institute were used as input hydrologic data. The division of areas for proposal 100-years precipitations is presented in the following figures. The figures are based on the values determined by the observations of the Czech Hydrometeorological Institute.

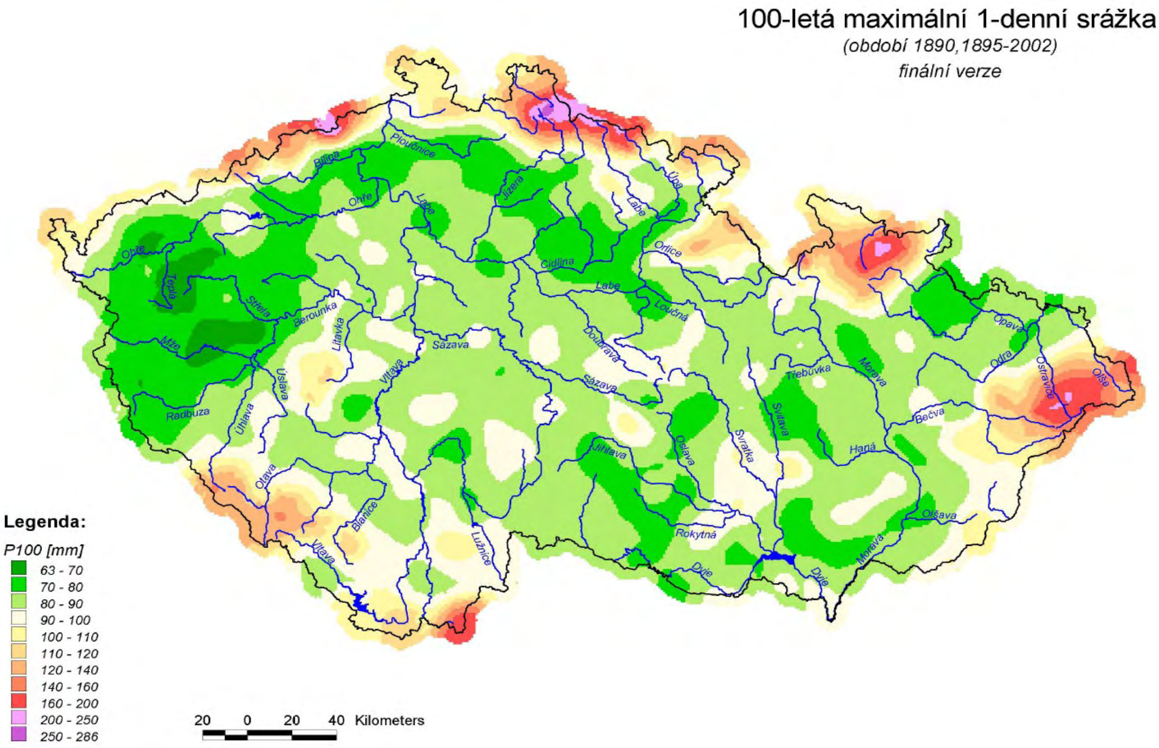


Figure 4 *The map of land division according to 100-years maximum one-day precipitation*

Figure 5 *The map of land division according to the ratio of one-day and one-hour 100-years precipitation*

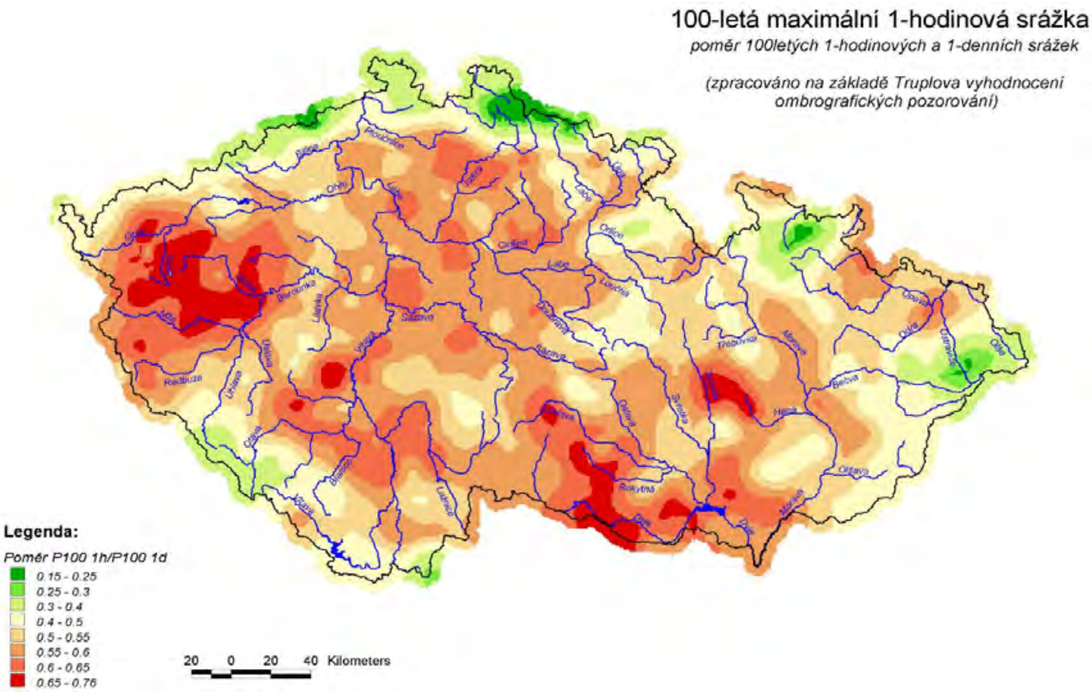
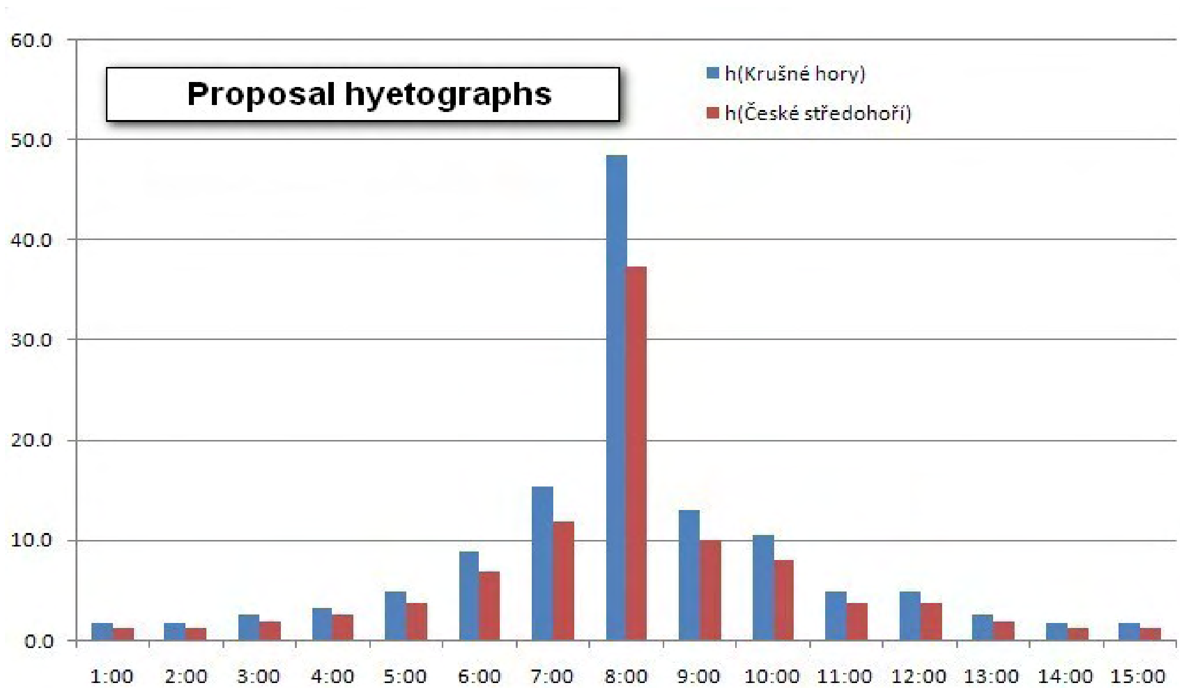


Figure 6 *Proposal hyetographs for the concerned area (as per values of the Czech* Hydrometeorological Institute*)*

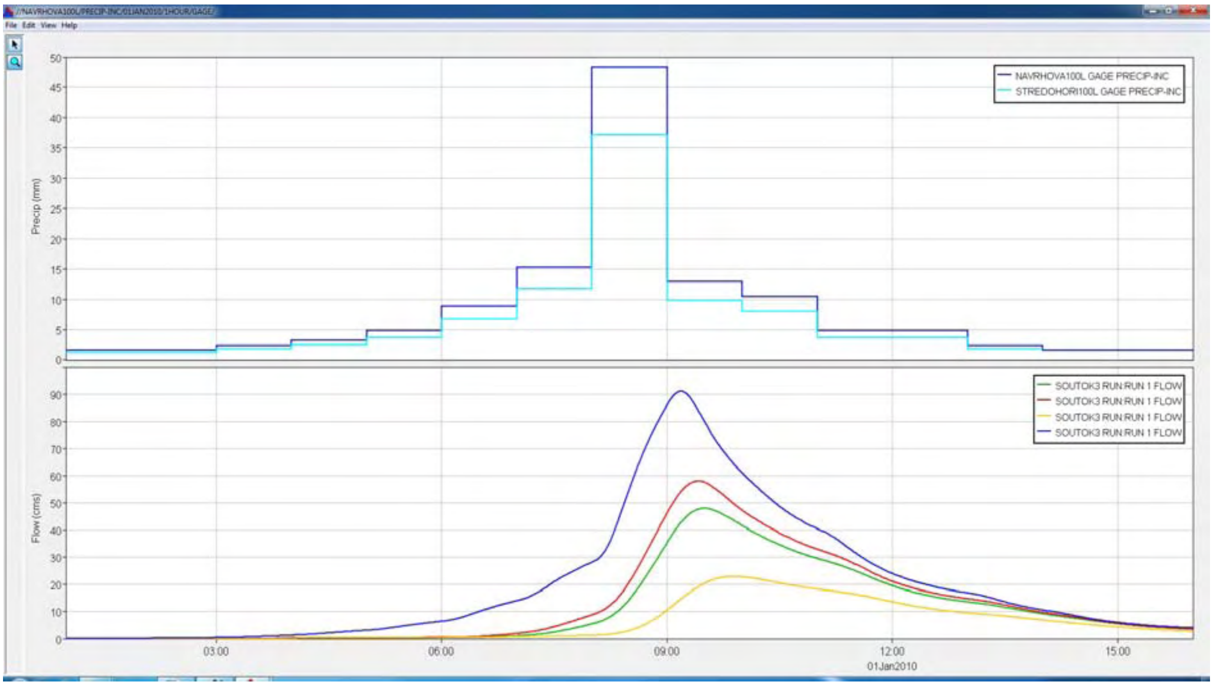


The results of the precipitation-drainage model are presented via the course of a 100-years flood in the concerned area.

The graphs assess the current status. Other model situations have been created to evaluate the significance of vegetation. The first situation represents removal of the woods in the concerned area of the Krusne Mountains as a consequence of the trees having been affected by cucurbitaria piceae. Other situations represent extreme

situations, if the area of the Jilemnický potok basin were fully covered in woods and the last situation presents an extreme scenario for the basin, if it were free of any vegetation. These graphs are related to the cross section at the water level recording station in the village of Libouchec. The Clark unit hydrograph with parameters derived on the basis of physiogeographic characteristics of the basin has been used for the transformation of the direct outflow.

Figure 7 Comparison of flood surges for various scenarios of the vegetation cover



The graphs obviously show the positive influence of vegetation of the reduction of the peak flow rate from the concerned area. The current situation (green curve) deteriorates as a result of the cutting down of the tree cover (red curve). On the other hand, complete forestation (yellow) has a significant impact on the drainage parameters and improves the anti-flood function of the basin area. The removal of the vegetation cover (blue) has a very negative impact on the flood situation alongside of the stream. The proposal hyetographs in the upper part of the graph represent proposed precipitations for the territory of the eastern part of the Krusne Mountains and the following part of the České středohoří mountain range (in German: Böhmisches Mittelgebirge).

The values of the results of the precipitation-drainage model serve as input hydrologic data for the hydraulic model.

5.6 Hydraulic model

The hydraulic model describes the results of the precipitation-drainage model converted to the hydraulic model focused on the flood risk. The maps present the flowing over the stream banks (outflow) under the current situation and the flowing over in the case of other variants for the basin. The calculations were performed using the HEC-GeoRAS software and converted to raster layers in the GIS environment.

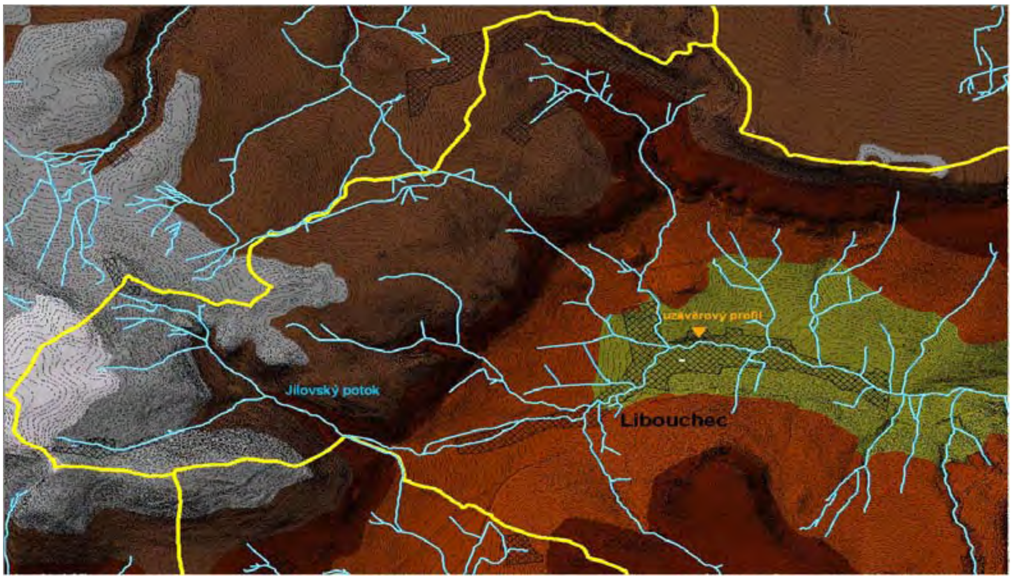
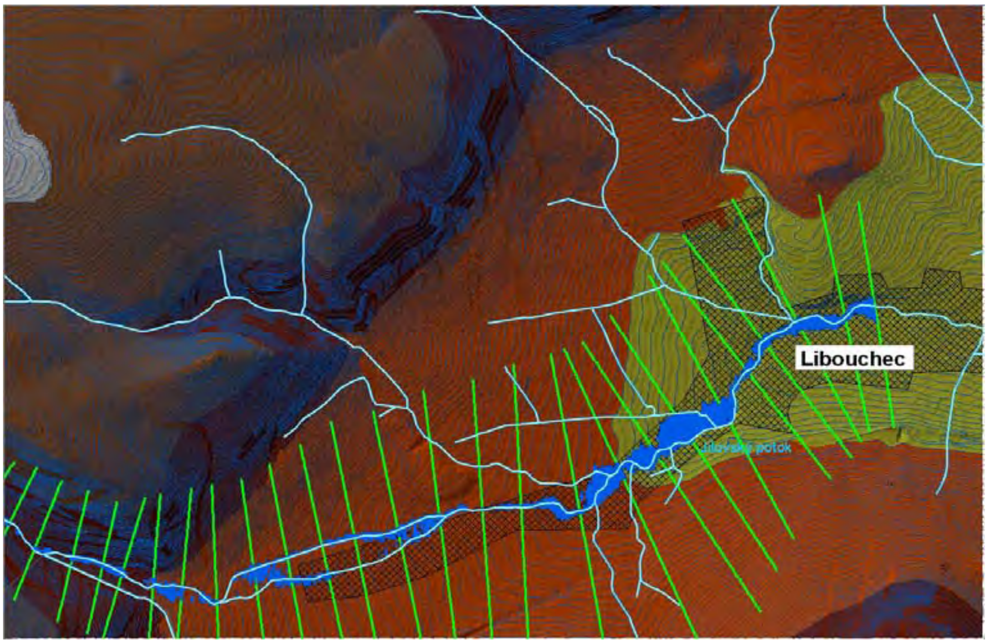


Figure 8 *Demarcation of the basin of the Jílovský potok stream and hydrologic network*

Figure 9 *Demarcation of the concerned section of the case study and cross sections for the calculation of the hydraulic model*



The calculation of the hydraulic model is related to the main drainage stream in the built-up area of the village. The Jílovský potok stream in a part of the village of Libouchec has been selected for the case study. The calculation is schematised by cross sections that are used to calculate the water level regime. The result is then the area of the outflow during the peak of proposed flood surges.

Figure 10 *Calculated of the flood-prone area in the HEC-GeoRAS environment in the ArcGIS 9.2 for various scenarios of drainage conditions (the Jílovský potok stream – Libouchec)*

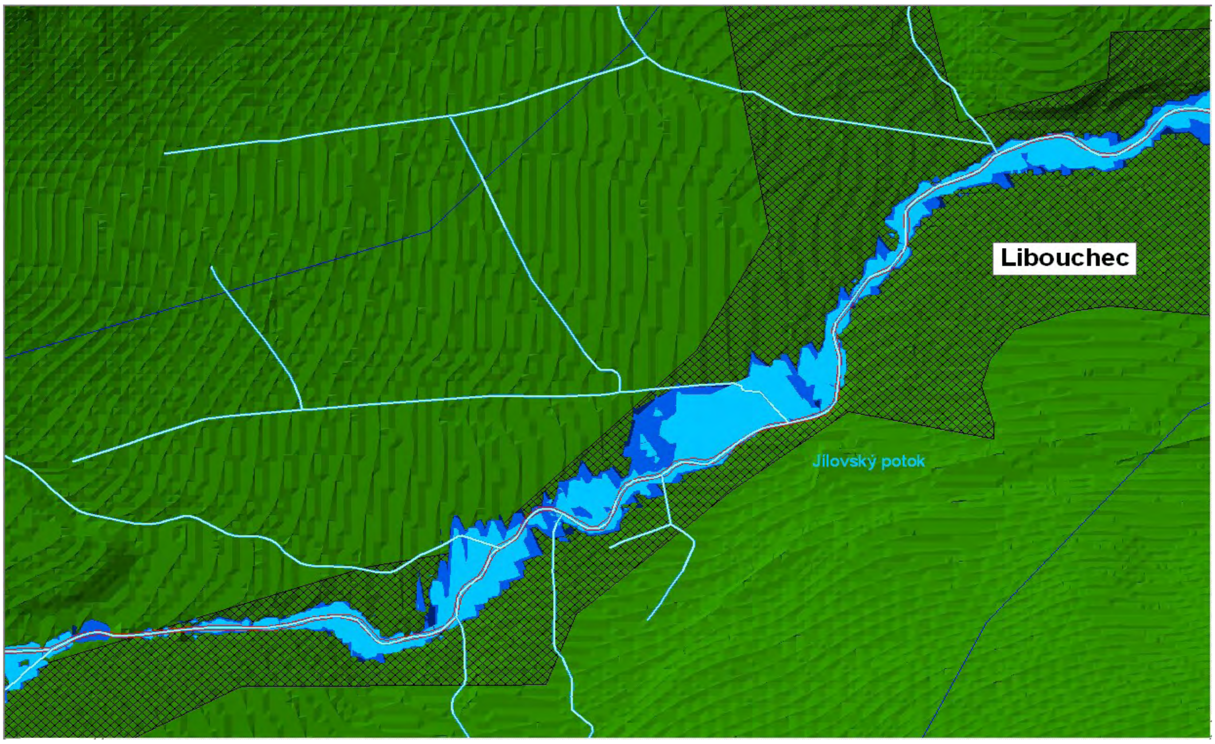
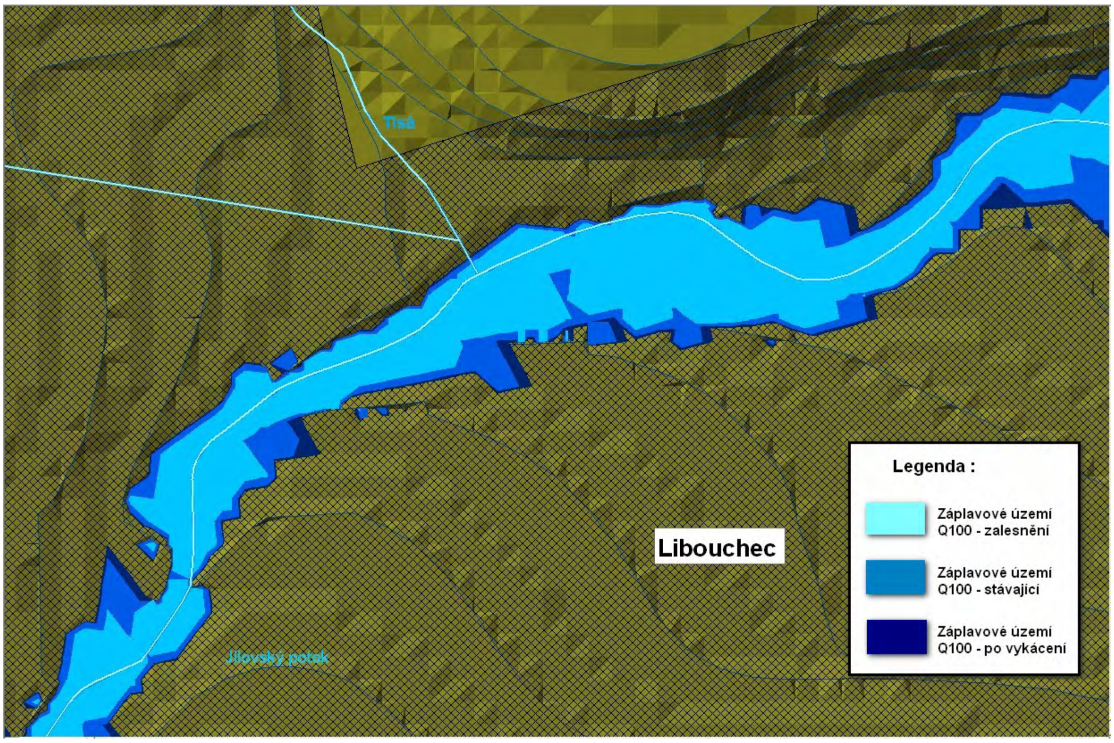


Figure 11 *Detail of the assessment of the flood-prone area for 3 different scenarios (the Jílovský potok stream – Libouchec)*



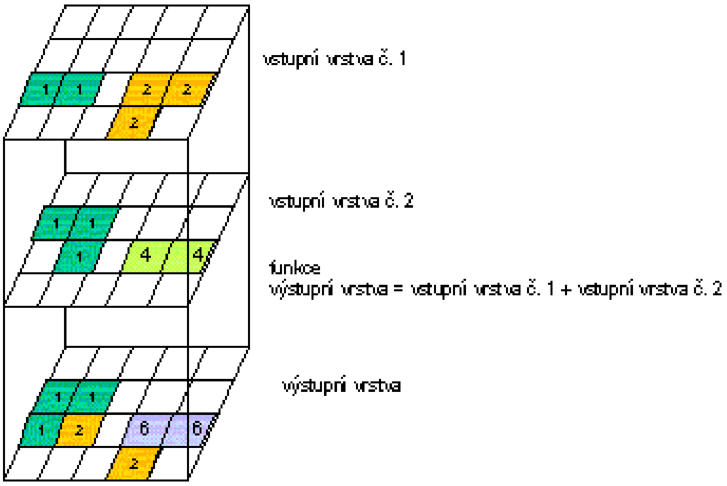
The evaluation of the results of the hydraulic model is given at the end of this report.

5.7 Erosion risk

From the viewpoint of the erosion risk assessment according to the Universal equation (USLE) the values of the rain storm risk for the entire area can be calculated as a constant value. Furthermore, it is possible to leave out the anti-erosion measures factor.

The erosion risk is the result of map algebra of the layers expressing individual factors of the Universal equation (USLE).

Figure 12 The scheme of map algebra to determine the endangered area



(upraveno podle „Cell based modelling with GRID, ESRI, 1991)

*(*translation of terms in the figure: vstupní vrstva č. 1, č. 2 = inlet layer no. 1, no. 2; funkce = function; výstupní vrstva = outlet layer*)* (modified according to "Cell based modelling with GRID, ESRI, 1991)

The result is the layer of the potential endangerment of the area by water erosion. The layer is divided into 6 categories according to the endangerment level. The scale ranges from 1 – no risk of water erosion up to 6 – extreme risk which requires anti-erosion measures. No area with such value has been detected in the concerned area.

6 Conclusions

Using the CN curves method and the Clark unit diagraph a study of the influence of vegetation on the drainage conditions in the Krusne Mountains has been created. The results of the precipitation-drainage model manifest that vegetation has a cardinal influence on the surface drainage in the concerned area. At the same time it is the significant parameter that can be anthropologically modified in respect of drainage conditions. From the viewpoint of drainage conditions the best vegetation cover is woods and natural meadows. On the hand, areas covered with buildings have a very negative influence on the flood situation.

The forests in the Krusne Mountains are currently under the danger of being affected by a cucurbitaria piceae fungus. For this reason it is necessary to perform complete deforestation in some areas with affected trees, which will have a negative influence on drainage conditions. This fact has been taken into consideration within this study and is expressed by a change of drainage conditions in the basin that are presented by a change in the drainage curve for Q_{100}. This causes faster drainage from the area and thus also the higher flow rate Q_{100} in the bottom part of the basin. For the concerned cross section in the village of Libouchec at the Q_{100} peak this means an increase of the water level by ca 8 cm.

The impact of the change of the flow rate parameters is subsequently mutually compared using the hydraulic model. This model shows that the water level will increase slightly and the flood-prone area will be extended after the felling of the trees is performed in the affected area. Therefore it is necessary to introduce some anti-flood measures to reduce this risk.

The first variant is anti-flood measures in the basin that will reforest the affected area of the basin, and possibly some other areas of the basin too. This will increase the water concentration in the basin and thus also lower the peak flow rates. These are presented in the results via the comparison of drainage curves Q_{100} and the comparison of the flood-prone area Q_{100} in the concerned area. It is obvious that reforestation of the lands in the basin has a significant positive influence on the flood situation. In the monitored cross section this, according to the model, decreases the water level at the peak time by approximately 30 – 40 cm.

Other anti-flood measures are of technical nature. Using the hydraulic model it is possible to monitor and localize flood-prone areas. Based on this it is possible to propose locations suitable for the construction of linear anti-flood measures. Subsequently it is possible to evaluate economic suitability of the proposed measures via the analysis of damages and risks. The proposed lines for the anti-flood measures are presented in the graphical annexes of the case study.

From the viewpoint of serviceability it can be said that the proposed methodology based on freely available products of the US Army Corps Engeneers - Hydrologic Engeneering Center is serviceable for the concerned area of the Krusne Mountains.

As far as the erosion risk is concerned the area is only slightly endangered by water erosion. Therefore it is not necessary to perform any anti-erosion measures. Vegetative measures in the form of reforestation of endangered areas will suffice.

7 References

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