Task of engineering geology in land-use planning on the example of four selected geofactors

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The paper deals with an evaluation of four selected geobarriers (flood lands, radon hazard, undermining and slope movements) by means of geographic information systems that are geofactors endangering or limiting landscape and environment or make certain land use impossible. The objective is to improve the possibilities of their implementation in land use planning. The research was carried out in the area numbered 4, which is one out of five realized model areas in the future. It is located in Ostrava, the third largest agglomeration in the north-west of the Czech Republic, which has been most affected by anthropogenic industrial and mining activities among the Czech cities as well as in the European scope. The area is defined by a map sheet 15-43-09 in the town districts of Mariánské Hory a Hulváky, Nová Ves, Svinov, Třebovice, Hošťálkovice, Moravská Ostrava a Přívoz, Ostrava – Jih and Vítkovice.

Key words: *engineering geology, town planning, foundation engineering, GIS, Ostrava*

Introduction

The study aims to draw attention to possible wider utilization of geofactors of engineering-geological conditions for the needs of purposeful utilization of landscape by means of land-use planning. The fact is that the utilization of information of such character is negligible.

It focuses on four selected geofactors (flood lands, radon, undermining and slope deformations) of engineering-geological conditions which assess the geological environment in terms of potential implementation of a particular engineering project including taking into account its anticipated interaction with the planned engineering work. It can also be stated that they deal with engineering-geological processes and their potentially bad effect on the engineering work.

From the point of view land use planning purposes are very important special-purpose maps which are one of the most important sources for decision-making on economical utilization of large regions, housing estates and functional zones.

If a land use planning designer [1, 6, 8, 9, 13] respects engineering-geological analyses of the area that are graphically represented in the maps, he anticipates serious and often catastrophic damage that would occur e.g. due to construction in slopes susceptible to slide where damage or even destruction of structures can occur, on overflooded river plains where foundations are difficult and where people are threatened by periodical floods, etc.

Neogene sediments are underlying of Quaternary deposits [7, 10, 11, 12, 16, 19]. They contain pelite sediments especially. Pelite represents greenly grey to grey calcareous clays with the variable carbonate content. Pre-Variscian crystalline basement called brunovistulikum is underlying of Neogene. Brunovistulikum contains migmatites and migmatitic paragneiss. Upper components are Moravian Karst Devonian deposits, and Lower Carboniferous Culm. Upper Carboniferous sediments begin with basal coarse grained sandstone, subsequently siltstone with rooty aleuropelite, coal seam, and, finally aleuropelite or pelite with the limnic, brackish or sea fauna. Based on the engineering-geological zoning map the interest zone [3, 21] is characteristic for the zone of polygenetic loess sediments (Lp); zone of alluviums lowland streams (Fn); spoil banks, stock piles and dumps zone (An); zone of settling basins and waste dumps (Ao); slope sediments zone (D); predominantly non-cohesive glaciofluvial and glacial sediments zone (Gf); slope-fluvial sediments zone (Du); zone of Pleistocene river terraces (Ft); undifferentiated flysch sediments zone (Sf) and predominantly cohesive drift zone (Gm).

Methodology

The methodological procedures were based on three methodological approaches with using geographic information systems, the study and evaluation of archive basic data and field engineering-geological research.

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The methodological procedure for the study and evaluation of archive materials was aimed at introductory assessing the engineering-geological conditions and factors.

In the framework of geographic information systems, the registration of relevant map bases, or aerial photographs was realized. Subsequently, the registration and digitising of maps of engineering-geological zoning and another necessary data layer were carried out. In the next stage, intelligent digitising of built-up areas in the chosen model area of part of the Ostrava Basin was performed.

At the same time, field engineering-geological research was done with the aim to specify engineering-geological conditions of model areas.

Subsequently, the overlap analysis of built-up areas and relevant engineering-geological zones and subzones was made. The result of this process was the identification and areal quantification making it possible to distinguish between more significant and less significant geofactors. The overall evaluation proposed newly was reflect all performed works and results.

Case study of four selected geofactors affecting the conditions for future construction

The first from the evaluated geobarriers are *flood lands*, which are areas in the surroundings of water courses, so-called river flats, which are periodically flooded by increased flood discharge. What makes those areas difficult is the above mentioned flood risk causing higher water levels that followingly overflow along the earth surface.

Floods occur if the geological environment, vegetation, atmosphere or man-made flood protections cannot hold or absorb the water surplus from more anomalous flow rates.

The consequences may be various damage on property, ecological damage, casualties, but also devalued utilization of the area for land-use planning or possible limitations when selecting or assessing the future building site within engineering-geological survey.

We distinguish several types of floods such as torrential, simple, complex, seasonal and anthropogenic accident. Torrential floods form after short rain torrents. Simple floods have one maximum. These are brought about by heavy rain with several hundred millimetres of precipitation in a few days. Complex floods have several maximums and may last several days or weeks. They occur if rainfall is distributed in a longer time period and its intensity varies. Seasonal floods inseparably belong to the river course chronology and are connected with regular changes in meteorological conditions related to long-term rain, melting of snow, clogging of the watercourses by ice blocks, etc. Anthropogenic accident floods are so-called special floods forming as a result of water management water work breakdown, for example during construction or operation of water works disrupting the water work dam body, breakdown of damming construction of safety and discharge facilities of the water works during uncontrolled outflow from the reservoir, emergency solution of critical situations in terms of water work safety during extraordinary discharge of water from the reservoir.

The geofactor of floodlands [14] was rated as a lines of 100-year flood and by means of characteristic floods which occurred in the study area in 1997.

From the point of view of 100 year's flood (fig. 1) it was discovered that in the study area of the 18.28 km^2 total area 2.63 km^2 was flooded during cent year's flood, which represents 14.4 % out of the total area. The most affected zone in the study area was the zone of alluviums lowland streams (85.5 % out of the total flooded area), which could have been expected as it is a zone situated predominantly in the surroundings of water courses. The most important finding is how the individual landscape elements would be flooded if cent year's flood occurred. The majority of the flooded area, i.e. 57.4 %, would be fields and meadows, built-up area (21.7 %) and forests with 10.8 % of the area. It was also found out that newly built-up area in the monitored period since 1946 to date participated on the total flooded built-up area with up to 84 %, which means that neither developers nor authorities respected this significant geofactor.

The *selected flood of 1997* substantially exceeded the level of hundred-year flood, which is clearly apparent from the percentage abundance of the total area, but also in terms of geometrization of this phenomenon on the map (fig. 2).

In 1997 after heavy rain devastating floods took place in the study area. It concerned 47.4 % , i.e. 8.66 km^2 out of total interest area. The most flooded zone was the zone of alluviums lowland streams (68.3 %); more than one quarter of the flooded area made up the spoil banks, stock piles and dumps zone (15.7 %) and the zone of settling basins and waste dumps (12.9 %). Out of landscape elements the most affected was built-up area (44.2 %) and fields and meadows with 44 % out of the total flooded area. The multiple increase in the built-up area flooding when compared with cent years' flood had been caused by the character of the built-up area which was built in the vicinity of this floodplain border and thus, surpassing it in 1997 flowage flooded proportionally larger area of built-up area (fig. 2). It was also identified that newly built-up area in the period since 1946 to date participated on the totally flooded built-up area with up to 54.1 %.

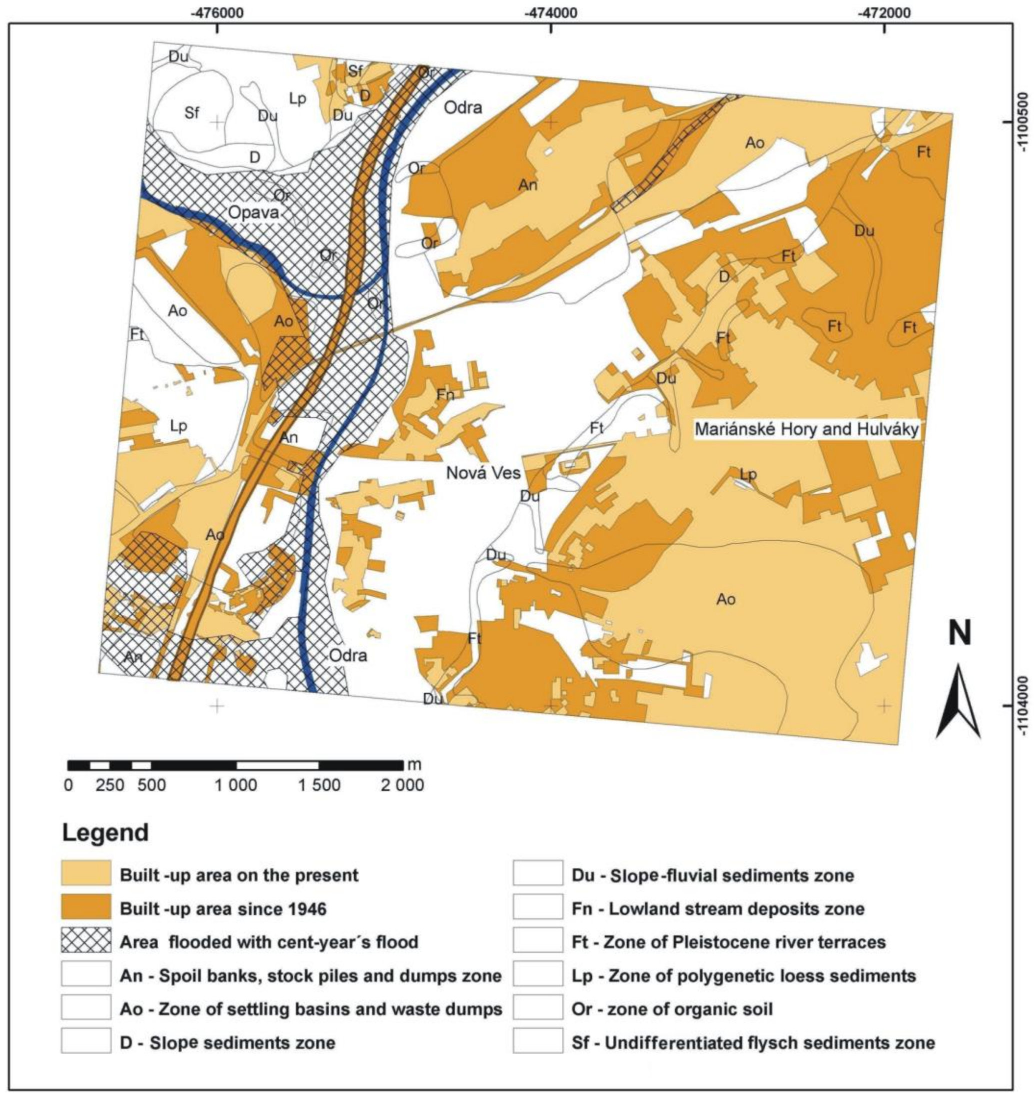

Fig. 1. Map of the area flooded with 100-year flood and area flooded with 100-year flood with marked changes in the built-up area and engineering-geological zones.

The next evaluated geofactor is the occurrence of *radon* in the subsoil, while Radon Rn-222 is formed by radioactive transformation of uranium U-238 and the assessed criterion is the radon index of the geological subsoil. Radon is constantly generated from the underlying rocks and with regard to the transformation half-life of the mother element uranium U-238 (about 4.5 billion years) its liberation is an unlimited in time phenomenon in this respect.

Radon further changes to daughter products (isotopes of polonium and bismuth) which are of a metallic character. They combine onto aerosols in the air, stick to the lung epithelium when breathed in and increase the internal irradiation of the human organism. The danger of this geofactor is thus the added risk of lung cancer and according to the latest European studies it has the value of 9 - 15% in non-smokers. Possible unfavourable conditions are evaluated by means of exceeding the guiding values in the ordinance of the National Institute for Nuclear Safety (SÚJB) 307/2002 Coll.

The concentration of uranium in the individual rock types has a different character. In general, in the sedimentary rocks the concentrations of uranium are lower than in the metamorphic rocks, which is given by their different physical-chemical conditions of origin. The highest concentrations are common in magmatic rocks, such as granitoids, because already in the time of their formation they were enriched with uranium and contain some heterogeneously dispersed rock-forming minerals (e.g. zircon) with higher uranium content. Sedimentary rocks that contain grains of metamorphic or magmatic rocks may have a higher content of uranium. The study area is made up by sedimentary rocks that are formed, apart others, by sediment fragments without the rock content of the above mentioned genetic types.

The volume activity of radon is also connected with rock genesis and mineral composition. Its values for a given site cannot be however calculated from the values of uranium concentration as radon migration from the place of its origin to the surface depends on a number of factors, pedological and climatic ones in particular.

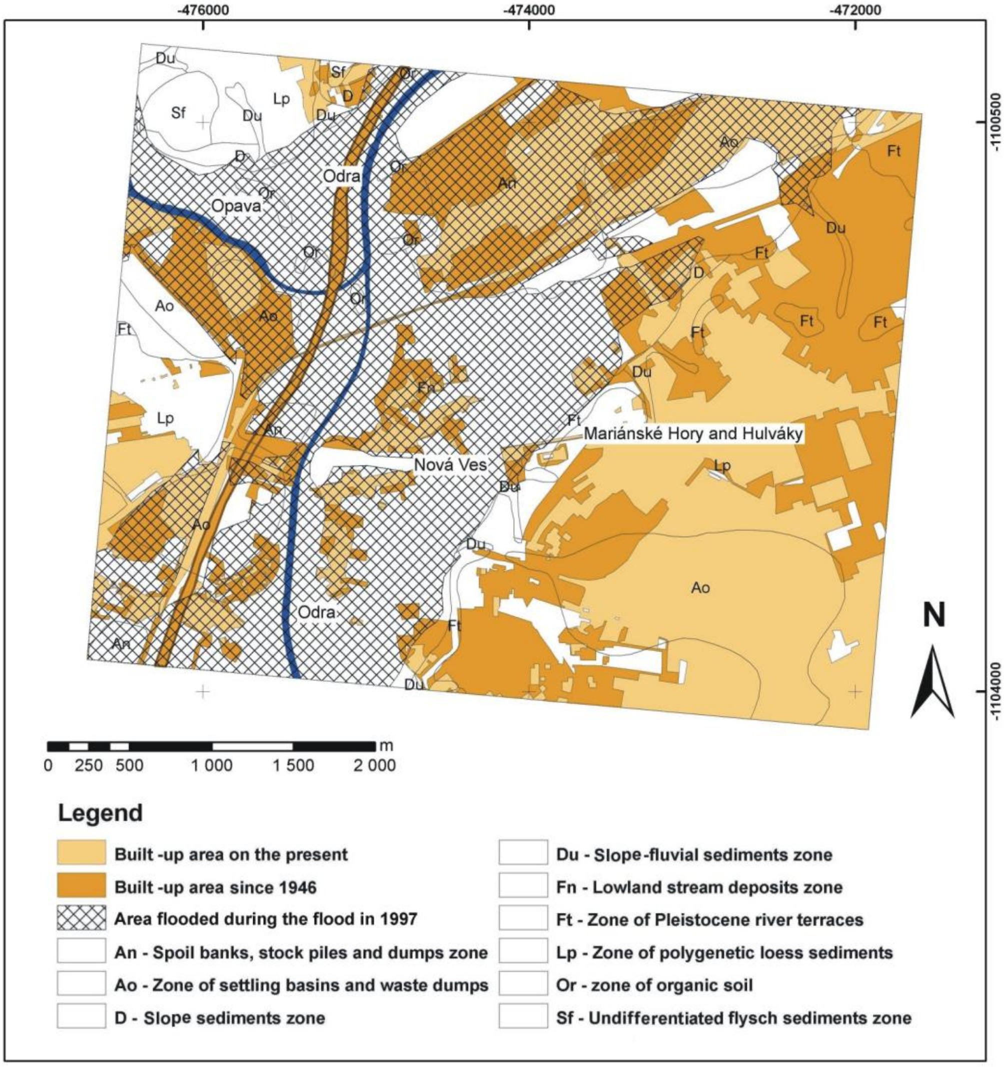

Fig. 2. Map of the area flooded during the flood in 1997 with marked changes in the built-up area and engineering-geological zones.

On the maps of radon hazard (fig. 3) which are used as a means of prevention to estimate the radon hazard this geofactor is evaluated by two methods. The first is areal evaluation (fig. 3) when on the basis of statistically processed specific radon measurements and geological structure and rock permeability, areas with different radon index are determined. In the study area there are two categories of radon index, i.e. transient (low to medium) and medium.

The medium category is related to the undifferentiated flysch sediments zone which is located in the north-west of the study area.

According to radon index, the rest of the area is defined as an area with a transient radon index.

The second method of evaluation and information retrieval is pointwise measuring of radon (fig. 3). In this case the represented pointwise measuring is characterized by a specific value, while it is common that in the area with a low category of radon index there may be a value falling in the medium category. These documents the fact that such maps are only for reference purposes and the developer must carry out measuring in situ, not only for the methodology's sake but also subject to legal duty based on the building law. In the study area there are 12 pointwise measuring of radon (fig. 3), out of which only 1 is categorized as medium radon hazard. The rest of the pointwise measuring falls in the category with low radon hazard.

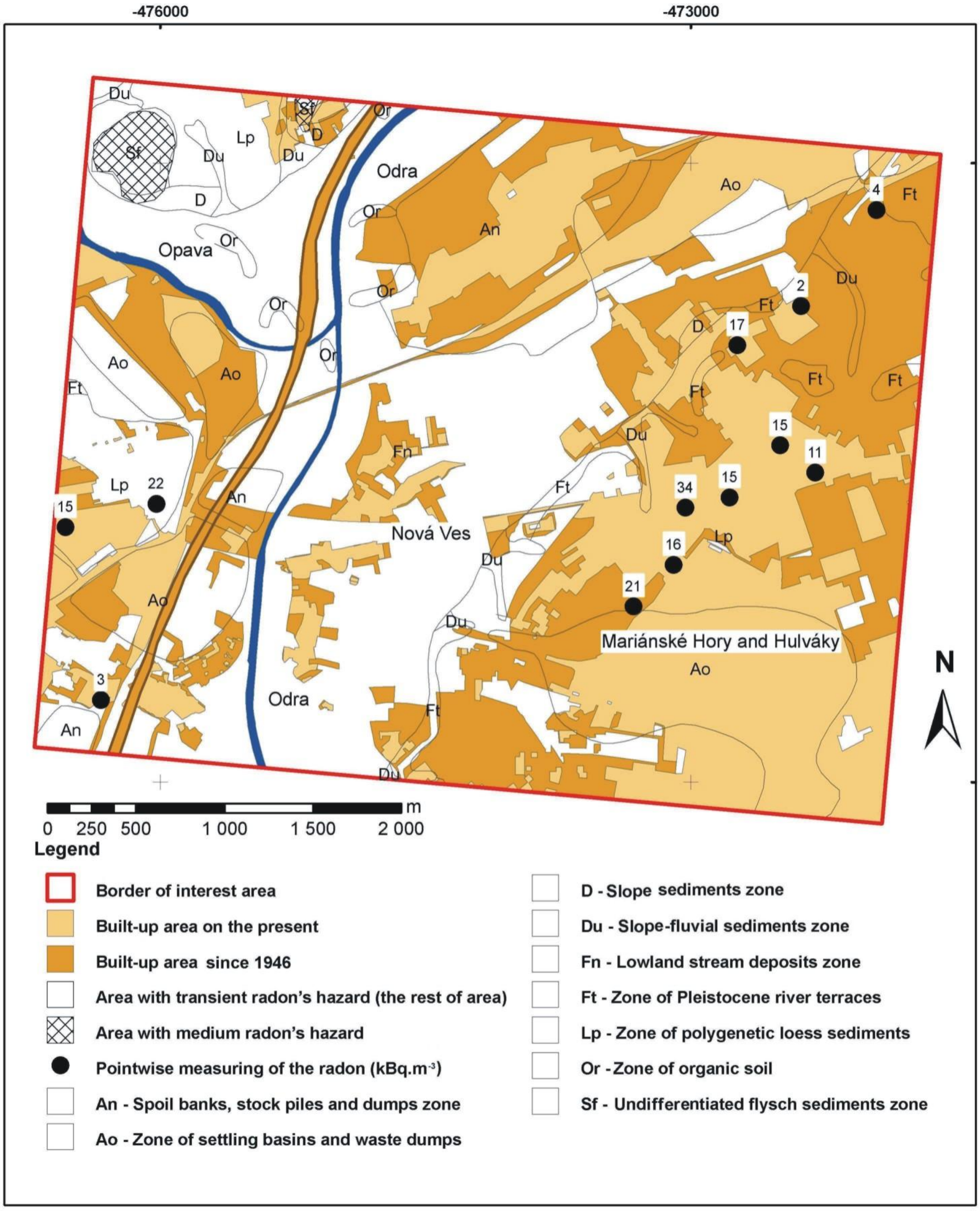

Fig. 3. Map of radon hazard in the study area with marked areal categories and pointwise measuring of radon and marked engineering-geological zones of current built-up area and changes in the built-up area since 1946 to date (Radon data - Czech Geological Survey).

In the past, mining of black coal falling in the Ostrava-Karviná District took place in the study area.

The effects of undermining [4, 15] were assessed by means of subsidence isolines (isocatabases) in two time sections with a time overlap. As the underground mining had been terminated at the early 1990s the regressive trend of the impact of undermining is apparent. This is implied comparing the following paragraphs stating the results of the factor in question, while comparing both time sections it is clear that the trend of subsidence will slowly approach zero towards the future.

From the point of view of the first time section evaluation (from 1961 to 1999) subsidence affected 94.6 % of the study area (fig. 4); the most pronounced effects of undermining being manifested by maximum values of up to 200 cm were observed in the area between Nová Ves, on the right bank of the Odra River. In terms of affected area we classified localities with the following centimetres of subsidence: 0 - 10 cm (2.35 km^2 – 12.9 % out of the total area), 10 - 50 cm (3.77 km^2 – 20.6 %), 50 - 100 cm (6.2 km^2 – 33.9 % of the area), 100 - 200 cm (4.87 km^2 – 26.7 % of the area) and 200 - 300 cm (0.09 km^2 – 0.5 % of the area). The most affected landscape element from the people's point of view is built-up area. It was found out that during the given period subsidence applied to 98.8 % of the built-up area (subsidence below 10 cm – 1.17 km^2 – 10.8 % of the built-up area; 10 to 50 – 1.65 km^2 – 15.2 % of the area; 50 to maximum values – 7.86 km^2 – 72.7 % of the area).

The influence of ground subsidence regression values in time is documented by the second time section (fig. 5 - from 1990 to 1999). This is naturally apparent when compared with the first longer period (fig. 4).

Approximately half of the area has been affected by subsidence (50.2 %, out of which 62.3 % is built up) with local maximum values of up to 30 cm. In that period there were the following centimetres of subsidence: 0 to 5 cm concerned 30.5 % of the area (5.58 km^2 of the area), 5 to 10 cm 9.8 % (1.79 km^2 of the area) and 10 to 20 cm 8.1 % (1.48 km^2 of the area) and 20 cm to 30 cm 1.8 % (0.34 km^2 of the area). However, more significant is the relation to the built-up area; in the area with subsidence 0 to 5 cm 35.7 % out of the built-up area was affected (3.86 km^2), 5 to 10 cm 13.3 % (1.4 km^2) and 10 to 20 cm 10 % (1.1 km^2) and 20 cm to 30 cm 2.5 % (0.27 km^2).

The fourth evaluated geofactor in the study area for the requirements of foundation engineering and land-use planning is the existence of landslides**.** A landslide is relatively fast, short-term landsliding movement of the rock mass in the slope along one or more through slipping planes. It is characteristic that a part of the mass is pushed onto the original ground in the glacis. For the sliding movement to happen, morphological, geological, hydrogeological and climatic preconditions must be fulfilled. Landsliding occurs when slope stability is disturbed due to natural processes or as a result of human activities. Bigger predisposition to sliding, which is statistically identified, is at slope gradient over 22 degrees.

In the study area one slope deformation was identified; it is a potential slide in Zábřeh – Hulváky. According to the ground plan of the deformation shape it is a flow slide (length being considerably bigger than width). It is almost completely afforested. The landslide in question is marked in the maps of subsidence caused by undermining (fig. 4 and 5).

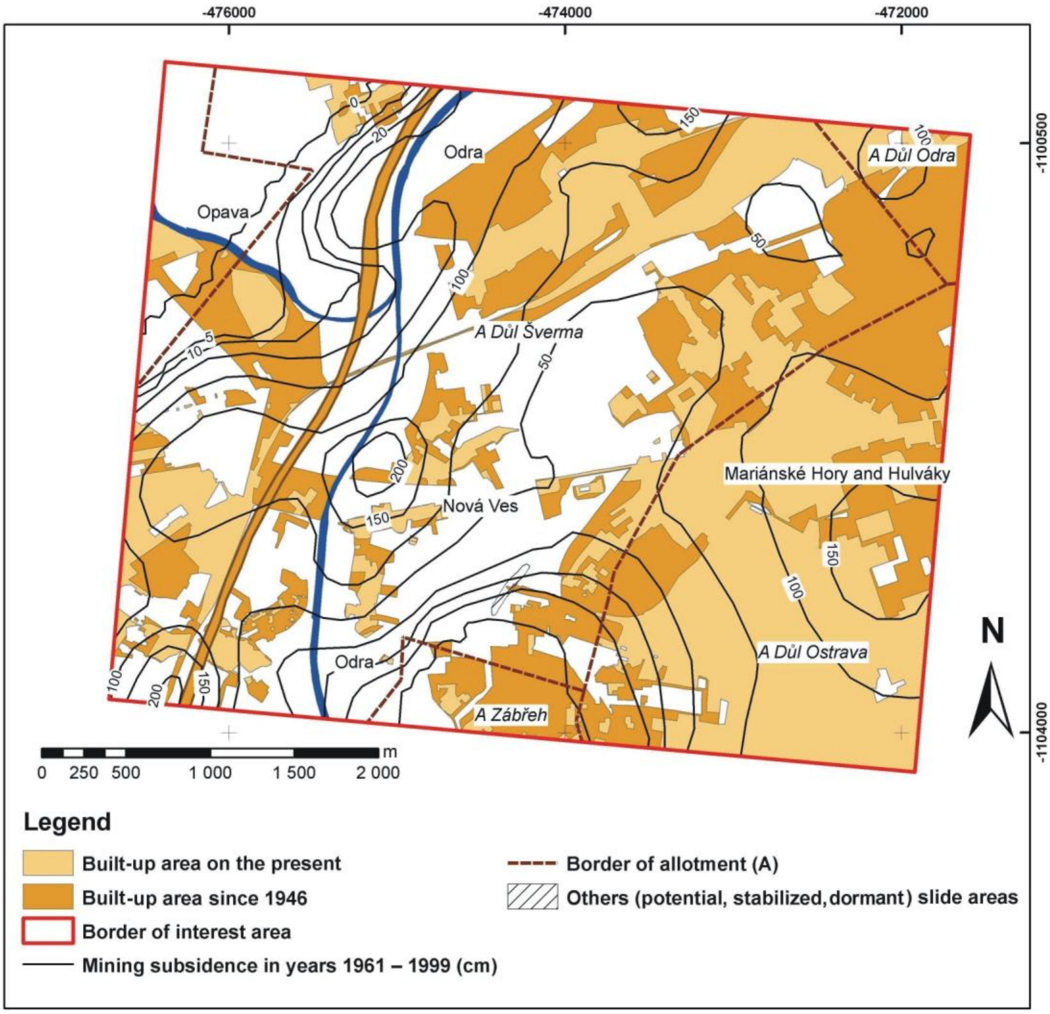

Fig. 4. Mining subsidence between 1961 and 1999 with marked changes in the built-up area.

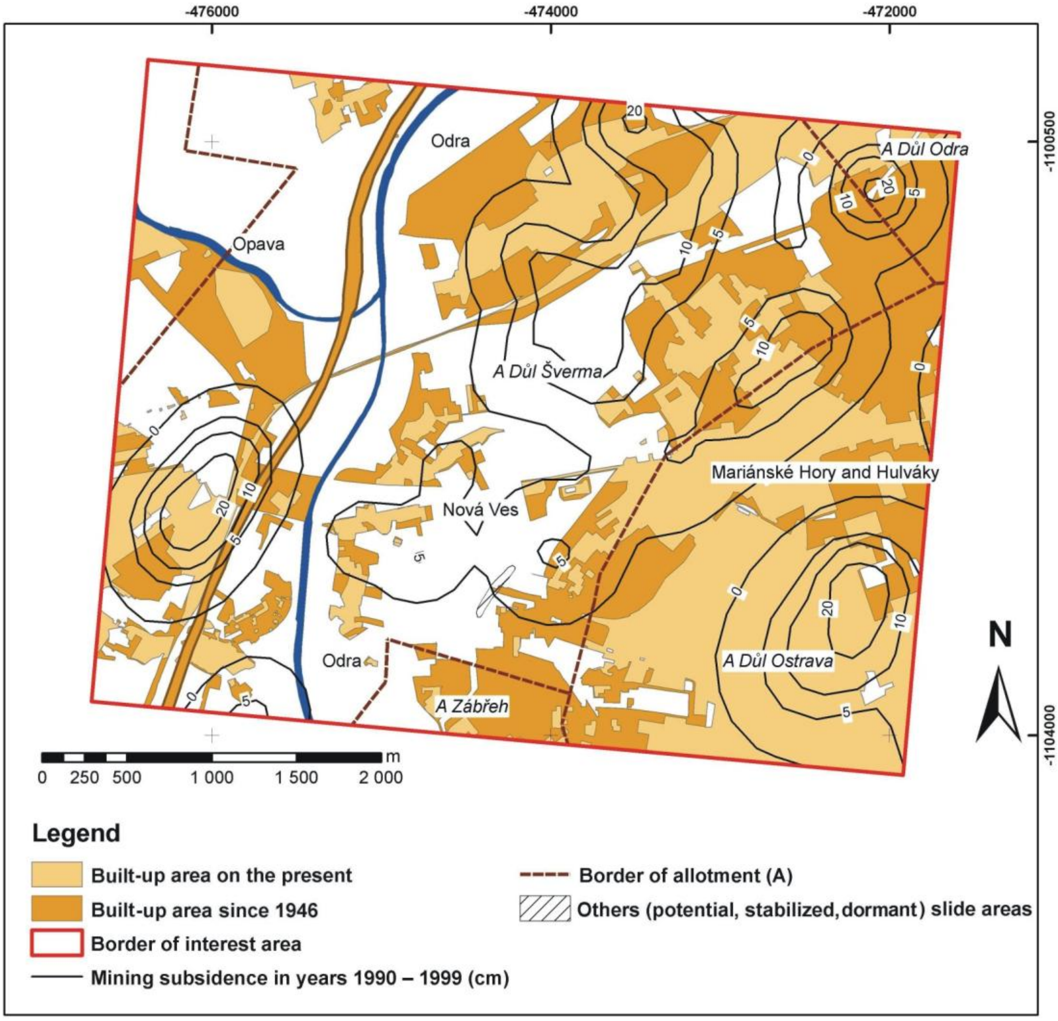

Fig. 5. Mining subsidence between 1990 and 1999 with marked changes in the built-up area.

Conclusion

The need to incorporate the geofactors affecting the engineering-geological conditions of the future engineering structures is recognizable and past experience from ignoring those natural conditions make the need even more amplified. The study dealt with four selected geofactors that should unambiguously make part of land-use planning.

The first evaluated geofactor was the study of potential *flooding* of the existing and future built-up area in the study area. The criterion which allowed this monitoring is the identification of 100-year flood and the border of the dominant flood for the study area which occurred in 1997.

The potential hazard *characterized* by cent-year's flood concerns 14,4 % of the studied study area, while 21,7 % of this area is currently built-up and the rest is made up by fields and meadows (57,4 %)and forests (10,8 %). During the selected typical flood of 1997, up to 47.4 % of the study area was affected where it is perceivable that without evaluation of this factor no further development of the area by means of land-use planning is possible. At the same time it is apparent from the acquired results of the evaluated period since 1946 to date that neither developers nor state authorities have taken the natural conditions into account, which is an alarming fact.

In general, increased surface leads to paludification, flooding and mud filling of the area, rock hydratation and their swelling, worse consistency and strength of the soil. Frequent accompanying phenomena are collapsible loess and soil lixiviation. The changes in the hydrodynamic regime may lead to internal erosion, disturbed filtration stability of soils, decantation of the krast hollow fillings and leaching of soluble rock components. In terms of municipal, industrial and transport construction the city considerably changes the run-off conditions and the hydrological network of the surface waters. Thick construction and paving inhibit natural infiltration and downfall run-off; artificial network of drainage and sewage is built.

Smaller courses are eliminated and larger regulated. Fencing and building-up of the valley flats causes "necking" of the flow rate profile with the hazard of soggy wide fluvial plains and their flooding during floods.

The second evaluated geofactor was the existence of radon hazard. Radon index is expressed in the maps only as reference according to the prevailing category of radon index in four degrees - low, transient, medium and high, while the transient index marks quaternary heterogeneous sediments. With regard to the marked character of the geological structure in the study area there is a relatively positive second and third degree. However, this is only an auxiliary means which permits certain projections during direct measuring or it can instigate possible check-up measuring having detected pronounced differences between the facts and the projections. The final category of radon index on a building site is then determined by direct measuring in place by a company licensed by the National Institute for Nuclear Safety.

The geofactor that must be unambiguously taken into account for the needs of the existing and future built-up area is the manifestations of underground mining activities. This is also the case of the study area which was affected by mining activities within the Ostrava-Karviná District terminated by the early 1990s. Because of uneven settling, slope deformation, changes in the hydrogeological conditions, etc. may occur in the sites with subsidence troughs. The evaluated criterion was time and quantitative change in the subsidence represented in the area by means of isocatabases, i.e. lines with the identical subsidence values. Their course and mutual comparisons of two time sections provide clear details on the levelling off of this factor trend. In the first time section 94.6% of the area was affected and 50.2 % in the second, while this did not only concern the areal impacts but mainly reached subsidence values.

The last evaluated geofactor was the occurrence of slope deformations. In the study area there is one flow slide in Zábřeh - Hulváky. It is recommended to mark the area endangered by slope deformations in all maps relevant for land-use planning or engineering-geological conditions as they represent most risky areas in terms of potential risks. Those areas may be used, which becoming reality due to improving technological possibilities of foundation is engineering. Nevertheless, the necessary requirement is marking the slope deformations in all land-use planning documents so that potential users of the sites could be sufficiently informed. Then, quality engineering-geological survey must follow, which is a precondition for land improvement and the condition for possible future construction projects is to increase the slope stability degree, not the reverse.

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