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Full Length Research Paper

Implementation of selected geobarriers for the landscape planning purposes in Slezska Ostrava (Czech Republic)

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This article deals with the analysis of engineering-geological zones, flood lands and radon hazard. The main reason of the study is the insufficient use of engineering-geological data for land planning and designing activities of competent authorities. The applied method makes use of the possibilities of geographical information systems, terrain research, documentation and study of archives. The research is localized in the selected area of the city of Ostrava affected by former mining of black coal. An appreciable factor for the characterization of engineering-geological conditions in the monitored areas is an analysis of potential flooding of the current and future development. The potential danger characterized by the 100-years flood concerns 5.2% of the studied area, while 18.1% of this area is currently built up and the rest are fields and meadows (28.3%) and forests (24.8%). This implies that neither people nor state administration respected the natural conditions in the interest area. For future developers, investors, building offices, it is also important to pay more attention to the radon hazard because of health safety for the future users of the environment. It can be orientation determined, based on the radon hazard maps that can be used along with other specific purpose maps, especially the map of engineering-geological zoning for the foundation engineering needs. The significance of the radon hazard evaluation in the form of maps permits consideration of this geo-factor further during the selection of places of future constructions. In the study area there are two categories of radon index, that is, one is medium and one transient, while the medium category is bound to the indiscriminate flysch sediments zone and the rest falls in the category with a transient radon index. Based on the observed orientation map category, vital attention must be paid to the implementation of measures preventing radon leaks from the bedrock (special insulation of foundations, etc.).

Key words: Engineering-geological zones, flood lands, radon hazard, mining area, landscape planning, geographical information systems (GIS).

INTRODUCTION

The basic pre-condition for land use planning or building the foundations of constructions in a certain area, is the integrated knowledge of engineering-geological conditions which are a decisive factor of high-quality and effectively building the foundations of potential construction works. The main reason for the study is the insufficient use of engineering-geological data for land planning and design activity by competent authorities. What is of great importance to these relevant land planning institutions, is providing, for the benefit of needed quality and feasibility of planned operations, required information about engineering-geological factors conditioning the rational use and development of area of interest in sufficient advance.

The overall project deals with an analysis of engineering-geological zones, workability of rocks, type of pre-quarternary bedrock, floodlands, subsidences caused by undermining, slope movements and radon hazard, while the presented paper rates only two of those geo-factors - flood lands and radon. The methodology used in the paper can be seen in Figure 1. The study has been used and applied experiences from previous studies (Barvínek et al., 1987; Yilmaz and Yavuzer, 2005; Yilmaz and Bagcı, 2006; Yilmaz and Yıldırım, 2006; Türer et al., 2008; Yilmaz, 2009, a, b; Marschalko et al., 2008, a, b, c, d, e, f; Marschalko and Duraj, 2009; Marschalko and Treslin, 2009; Nefeslioglu et al., 2010; Pradhan et al., 2010; Bednarik et al., 2010; Sezer et al., 2011; Yilmaz, 2010; Yilmaz et al., 2011a-c).

Geological and engineering geological frameworks

The study area represents a part of cadastral territory of Ostrava city. From the regional geological point of view, the study area belongs to Ostrava Glacial Basin which is a part of front Carpathian fore-deep of Outer Western Carpathians (Figure 2).

Quaternary sediments (Figure 3) represent Holocene fluvial deposits of lower and upper alluvium plane and anthropogenic deposits such as backfills and dumps. Quaternary deposits represent glaci-fluvial, fluvial, deluvial deposits, loess loam and Tertiary eluvia (Chlupáč et al., 2002). Quaternary aquifer systems are created by pores, incoherent sands, and gravel-sands. The water is an atmospheric origin. It keeps oxidized environs within the area of intensive circulation with the earth ground (Dopita, 1997).

Neogene sediments (Figure 4) are overlied by quaternary deposits and they especially contain pelite sediments which represented by greenish gray to gray calcareous clays with the variable carbonate content.

Pre-Variscian crystalline basement called “Brunovistulikum” which 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 (Chlupáč et al., 2002).

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Based on the engineering-geological zoning map (Sloboda, 1990), the study area is characteristic for the zones 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); deluvial sediments zone (D); predominantly cohensionless glaciofluvial and glacial sediments zone (Gf); deluvial-fluvial sediments zone (Du); zone of Pleistocene river terraces (Ft); undiscriminated flysch sediments zone (Sf) and predominantly cohesive drift zone (Gm). Each zone is described with age and the character of soils, subzones and orientation classification of soils into classes based on the grain-size distribution and workability of rocks based on the characteristic properties and difficulty in disintegration, which is dealt with in ČSN 73 3050 (1963) Standard (Earthwork) (Motlík and Hofmanová, 1963).

In the zone of polygenetic loess sediments (Lp), there are Holocene loess loams and deluvial sediments. As a foundation soils, they have intermediate-bearing, mainly stiff consistency, low to intermediate plasticity, intermediate permeablity. The sediments can be utilized as a material for brickware. The soils in this zone are classified into F6 class (clays with a low to intermediate plasticity) according to ČSN 73 1001 (1988). The workability class is 2-3 according to ČSN 73 3050 (1963) Standard – Earthwork – (Motlík and Hofmanová 1963).

Around the water courses of the Ostravice and the Lučina, there is a zone of meadow loam (Fn) represented by Holocene fluvial sandy loamy and gravely sediments which are nonhomogeneous and non-uniform compressible foundation soils occurring with loams and have low-bearing capacity and soft to stiff consistencies. These sediments have clays with low and intermediate plasticity (F6), sandy clays and loams (F3 and F4), sands (S3, S4, S5) and gravels (G2, G3, G4). The workability class of this zone is 2-3. The ground water level is very shallow and is observed almost under the ground surface.

In the study area, there is an uneven zone of banks, spoil banks and dumps (An). These are recent anthropogenic deposits connected with the mining, metallurgical and chemical industries. They are characteristic for the occurrences of carboniferous waste rock, slag and fly ash. Their utilization as foundation soil is decided based on the local conditions and compaction of loose soil materials. According to ČSN 73 1001 (1988), it is anthropogenic sediments (class Y) and dumping ground (class Z), the workability class is 2-4.

The zone of setting pits and rubbish (Ao) is typical for not only anthropogenic deposits but also for building, solid and municipal rubbish. These soils are not suitable for construction foundation as they are anthropogenic sediments (class Y) and dumping ground (class Z) with the 1-3 workability class (Barvínek et al., 1987).

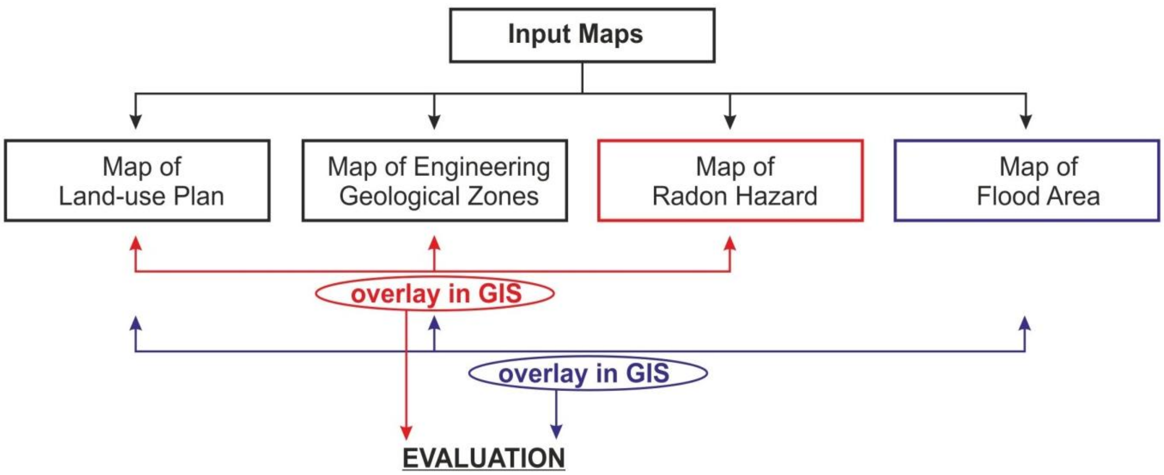

Figure 1. Methodology used in the study.

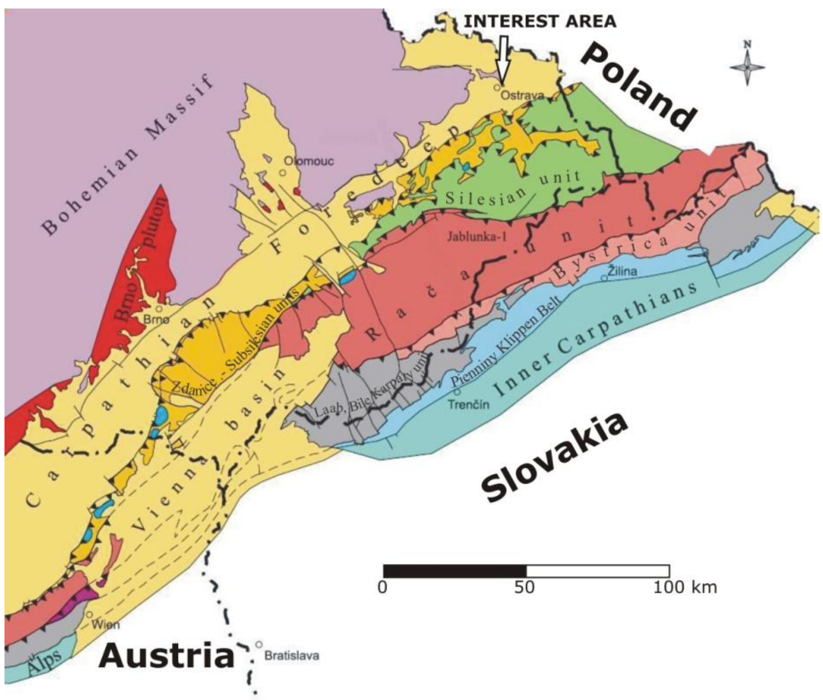

Figure 2. Schematical geological map with position of interest area.

In a very small extent, the study area comprises a zone of deluvial-fluvial sediments (Du), which is represented by Holocene sediments of the following classes: clays with a low and intermediate plasticity (F6), sandy clays and loams (F3, F4), sands (S3, S4, S5) and gravels (G2, G3, G4). According to ČSN 73 3050 (1963), soils are of the 2-3 class of workability. They are nonhomogeneous and non-uniform compressible foundation soils with loams of soft to stiff consistencies, and have low-bearing capacity. The ground water level often observed as shallowly as 2 m.

Insufficient utilization of the impacts of flood lands and radon hazard in study area for the landscape planning purposes

The first rated geo-factor in this paper is flood lands in

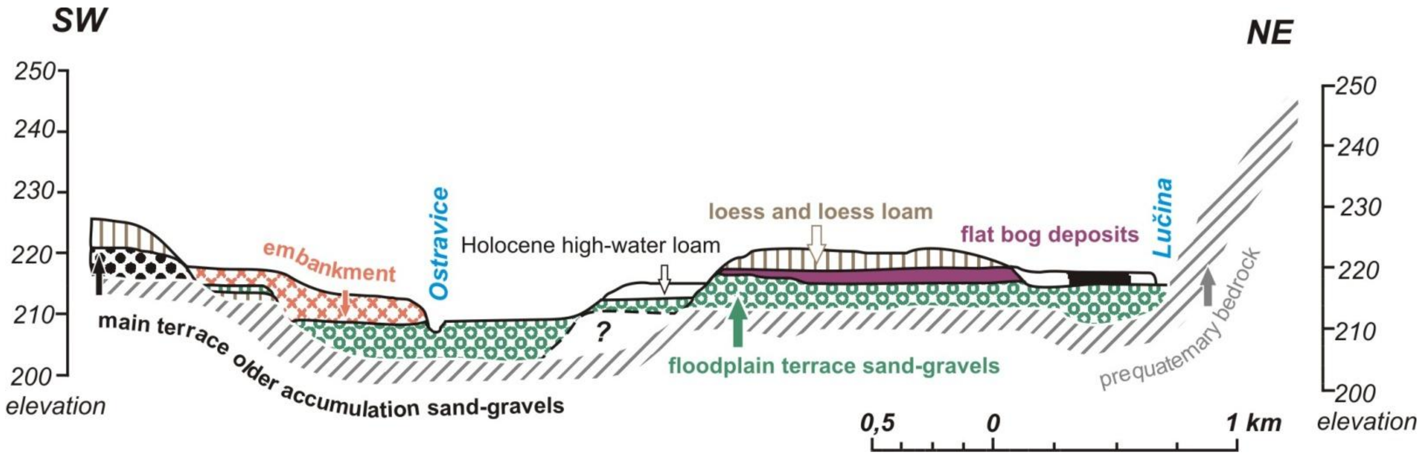

Figure 3. Schematical quaternary geological cross-section of part interest area in accordance with Macoun (1965).

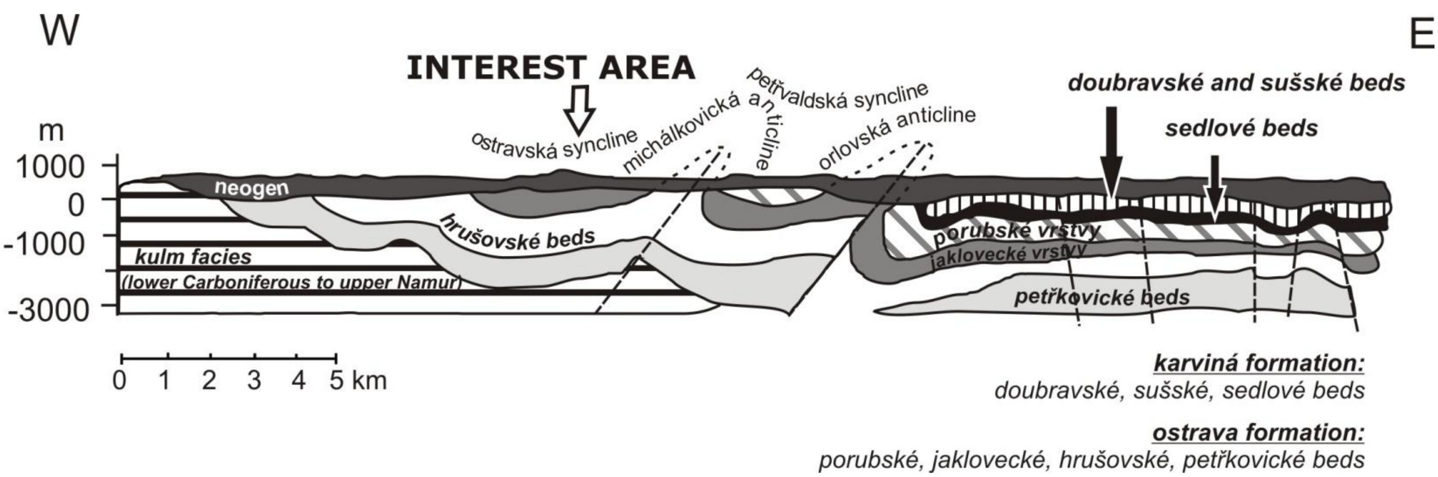

Figure 4. Schematical geological cross-section of interest area in accordance with Dopita (1997).

which floods occur and are potentially dangerous in terms of high damage to properties (damage to and destruction of engineering structures, devastation of agricultural land, etc.). This geo-factor was rated by means of lines of the so-called 100-*years* flood and by means of characteristic floods which occurred in the study area in 1997. As for the 100-years flood rating (Figure 5), it was discovered that in the study area, the flood lands represent up to 5.2% (0.95 km^2) out of the whole area.

This area is mostly formed by the zones of alluviums lowland streams (80%) – 0.76 km^2, followed by the zone of settling basins and waste dumps (16.2%) – 0.15 km^2, in case of which local contamination must be considered. As for affected landscape elements, it was found out that the most damaged landscape element were fields and meadows (28.3%) – 0.27 km^2 and forests (24.8%) – 0.23 km^2. The next was especially significant element of built-up area, which is represented by 18.1% (0.17 km^2) and it was discovered that the newly built-up area in the monitored period since 1946 to date was affected by up to 44.7%, which means that neither builders nor authorities respected this significant factor.

By evaluation of the floods from 1997 (Figure 6) which exceeded the level of 100-years flood, it was found out that the proportional area of this territory is identical as in case of Q_{100}. This was caused by the fact that in the studied area only the Ostravice River significantly exceeded the level of 100-years flood and the Lučina River near the confluence with the Ostravice, and in the remaining area, the levels are low. As for foundation soils, this flooded area was located from 60% on the zone of alluviums lowland streams and from 36% on the zone of settling basins and waste dumps. In terms of landscape elements, up to 27.4% of fields and meadows, 25.2% of anthropogenic shapes (complications with contamination) and 19.4% of forests were damaged in the whole interest area. In the flooded area there is 14.8% of built-up area, while it was found out that the

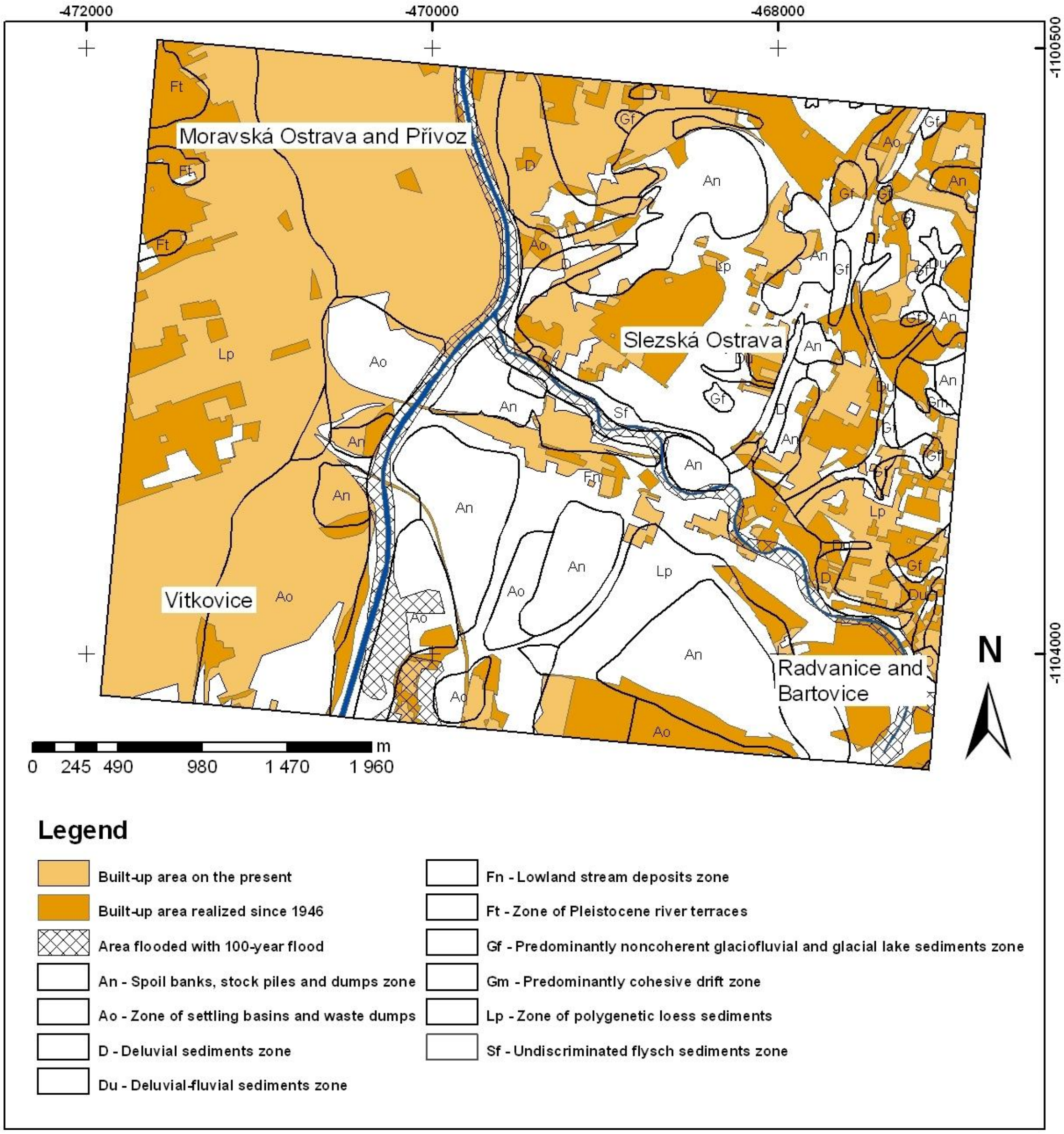

Figure 5. Map of the area flooded with 100-years flood and area flooded with 100-years flood with marked changes in the built-up area and engineering-geological zones.

newly built-up area since 1946 to date participates in it with 51.2%.

The second rated geo-factor in this paper is radon hazard. Radon Rn-222 is formed by a radioactive transformation of uranium U-238. The concentration of uranium in the individual rock types varies. In general, it can be said that in sedimentary rocks, which form the majority of the study area, there are lower concentrations of radon than in the metamorphic or magmatic rocks.

The main source of the radon is thus geological bedrock. In the Czech Republic, some of the highest concentrations of radon are identified in premises compared with other European countries. However, this cannot be said about the study area as for the above mentioned occurrence of sedimentary rocks.

Radon measurement in the buildings and building sites is subject to the Atom Act No.18/97 Coll. and its executing notices (SÚJB 2002). After initial ambiguities due to bad wording of § 6 of the Act, the duty to deal with the radon issue was unambiguously defined by the amendments to the "Building Law" No.83/1998 in Article VI and amendments to the original notice 146/98 Coll. Since then, the building offices must require documentation for the rating the hazard of radon inhalation in construction sites, which is carried out by its measurement as so-called "Site radon index" directly on

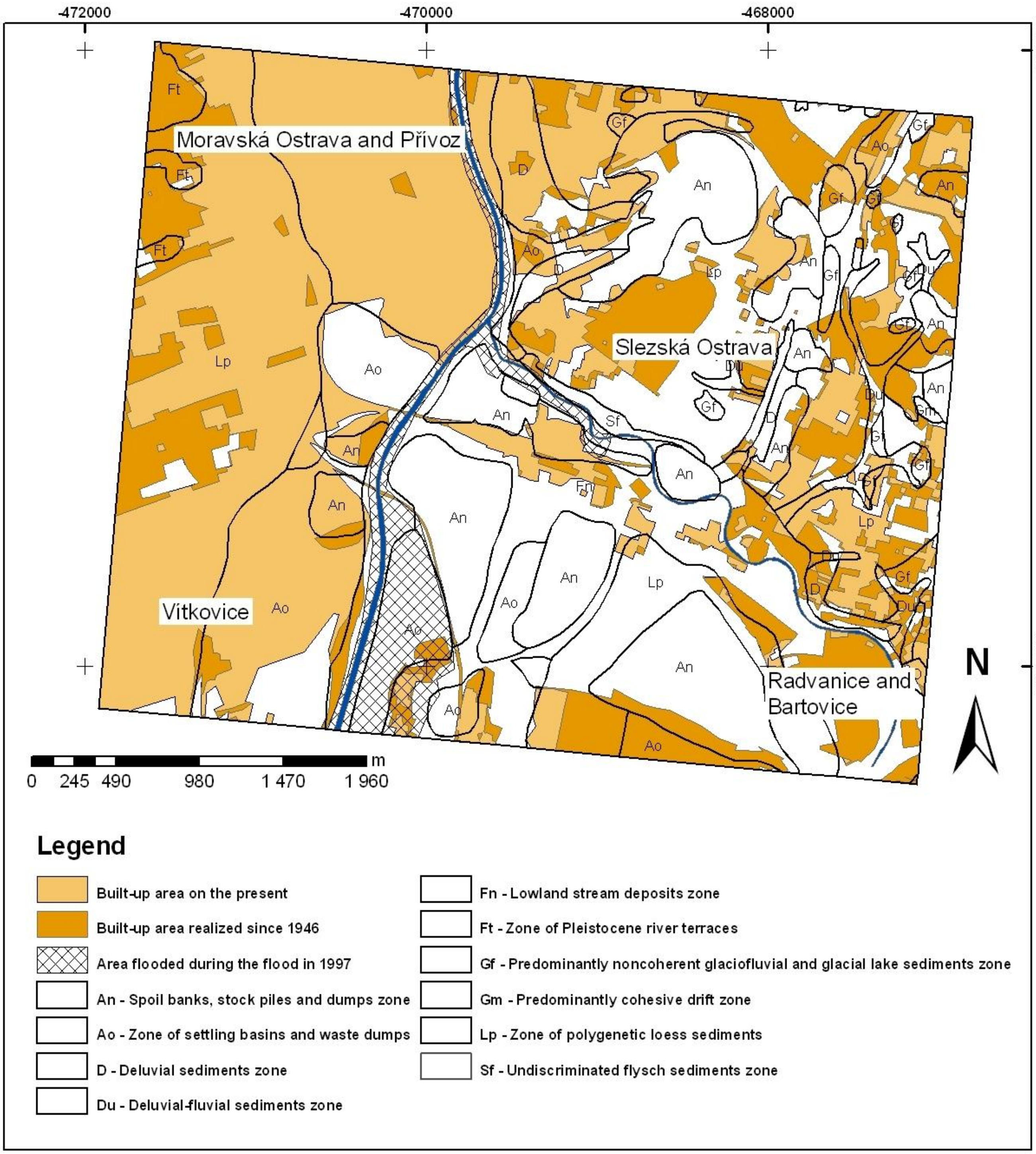

Figure 6. Map of the area flooded during the flood in 1997 with marked changes in the built-up area and engineering-geological zones.

the building plots or in already finished, closed premises (as a rule during their process of approval or before reconstruction).

The importance of the evaluation of radon hazard in the form of maps permits the consideration of this geo-factor during selection of the place of future constructions and in case of placement of a building into unsuitable conditions because of radon. Insulation helps to protect

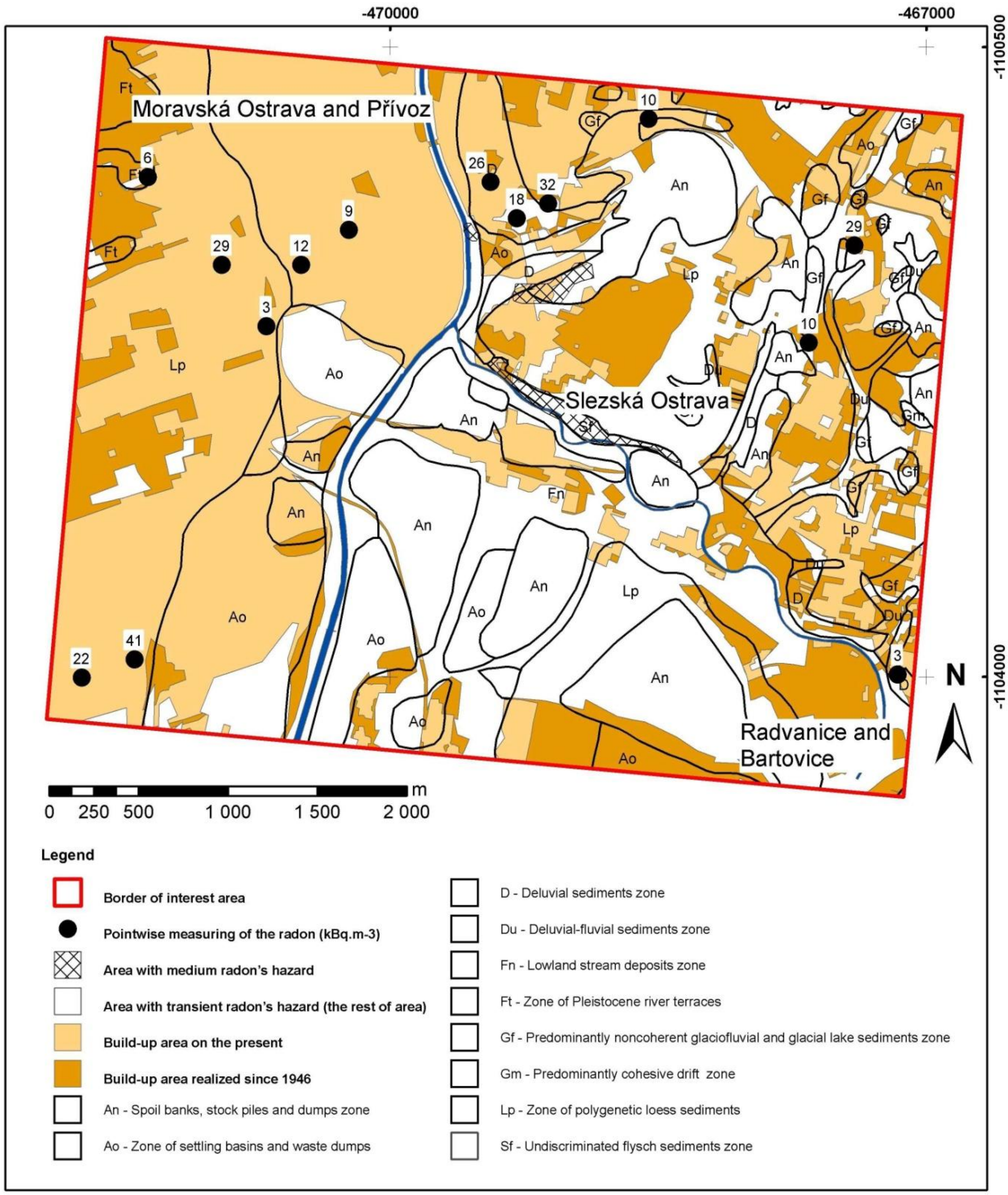

Figure 7. Map of radon hazard in the interest area with marked areal categories and point wise measuring of radon and marked engineering-geological zones of current built-up area and changes in the built-up area since 1946 to date - Radon data - (Czech Geological Survey, 2008).

the construction. Therefore, in both cases it helps to protect the builder's or user's health from the harmful effects of radon from geological bedrock. This means that construction protection from radon leaks from the bedrock must correspond to the site radon index, which, however, must be measured according to maps in situ having estimated it.

On the radon hazard maps (Figure 7) which are used as a preventive measure for orientation estimation of the radon hazard, this geo-factor is evaluated in two ways.

Table 1. Classification of foundation soils in terms of radon index (Czech Geological Survey, 2008).

Radon index categories	Volume radon activity ($kBq.m^{-3}$) at bedrock permeability		
	Low	**Medium**	**High**
1. low	<30	<20	<10
2. intermediate	(low to medium) for inhomogeneous Quaternary sediments		
3. medium	30 - 100	20 - 70	10 - 30
4. high	> 100	> 70	> 30

The first is areal evaluation (Figure 7) where on the basis of statistically processed specific radon measurements and on the basis of a geological structure and rock environment permeability, areas with a different radon index are determined. In the study area, there are 2 categories of radon index, namely transient (low to medium) and medium, while the medium category is bound to the zone of indiscriminate flysch sediments and occurs in case of one zone of spoil banks, stock piles and dumps. It is the locality near the confluence of the Lučina and Ostravice Rivers, on the zone of indiscriminate flysch sediments. The second locality is found in the vicinity of the first one (northwards) with a prevailing zone of spoil banks, stock piles and dumps. The rest of the area is defined according to the radon index as an area with a transient radon index.

The second method of rating and retrieval of information is the point method (Figure 6). In this case, the point wise measurement is characterized by a specific value while it is common that in the area with low radon index category values falling into the mean category can occur. This confirms the fact that such maps serve as the source of reference values and a builder must carry out these measurements *in situ*, not only from the point of view of methodology but also due to legal requirements arising from the building law. In the study area, there are 14 point wise measurements of radon (Figure 7) and out of which 5 are categorized as medium radon hazard. The rest of the point wise measurement falls into the category with low radon hazard.

Radon testing by direct measurement in the building sites aims of the determination of the radon index and the calculation of the radon potential for undeveloped building plots. The term of radon index is newly used in the terminology of Notice 307/02 Coll. and is equivalent to the original term of radon hazard category. The radon hazard from the bedrock is distinguished in the map by three basic categories (low, medium and high) and one transient category that was reserved for nonhomogenous Quarternary sediments with low to medium hazard (Table 1).

The categories of radon hazard from the geological environment express the statistically prevailing category in the given geological unit. The given categorization is done according to volume activity of radon sampled from driven-in thin probes and according to gas permeability of the given types of bedrock. The low radon index (Table 1) means that the radon content (combined with gas permeability) in the bedrock is of a low significance, thus it should not cause exceeded concentrations in the premises built according to standard procedures with classic hydro insulation. The medium radon index (Table 1) signals that in the place of the future construction there is a source of radon which could cause problems in the future. It is the case of warning of a problem in the phase when it is quite simply solvable both in terms of design and building. The high radon index (Table 1) already expressly points to serious problems with radon in the future premises in case adequate measures are not taken soon. For example, the issue of radon leaks barriers in the premises is dealt with in ČSN Standard (2006) on construction protection from radon leaks from the bedrock.

CONCLUSIONS

An appreciable factor for the characterization of engineering-geological conditions in the monitored areas is an analysis of potential flooding of the current and future development. The criterion which allowed this monitoring is the identification of 100-years flood and the border of the dominant flood for the interest area which occurred in 1997.

The potential danger characterized by the 100-years flood concerns 5.2% of the studied area, while 18.1% of this area is currently built up and the rest are fields and meadows (28.3%) and forests (24.8%). This implies that neither people nor state administration respected the natural conditions in the interest area. This parameter should be expressly observed by the state authorities.

For future developers, investors, building offices, it is important to pay more attention to the radon hazard because of health safety for the future users of the environment. It can be orientation determined based on the radon hazard maps that can be used along with other specific purpose maps, especially the map of engineering-geological zoning for the foundation engineering needs. It is also required subject to the building law. The radon index of the geological bedrock in the map determines the level of probability with which it is possible to expect a level of radon volume activity in the geological environment in question. It is possible to take preventive measures according to the radon index in the map, which is classified by three basic categories (low, medium and high) and one transient category (low to medium in nonhomogeneous quarternary sediments). The risk determined in this way can be further compared with the obligatory direct measuring and thus for example identify observed gross errors in the measurements or its potential skipping in case of significant differences in the measurements and the map data. Based on the observed orientation map category vital attention must be paid to the implementation of measures preventing radon leaks from the bedrock (special insulation of foundations, etc.).

The significance of the radon hazard evaluation in the form of maps permits consideration of this geo-factor further during the selection of places of future constructions. In the interest area there are two categories of radon index, that is, one is medium and one transient, while the medium category is bound to the indiscriminate flysch sediments zone and the rest falls in the category with a transient radon index.

Clerks in the building offices and landscape planners in the environmental departments and zoning, builders, architects, investors and future users of constructions should pay more attention to the geo-factors conditioning the foundation engineering. The objective of the paper was evaluation of two selected geo-factors, for the evaluation of which in practice important map information or their overlap versions are rarely used.

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