4. Physical-geographic factors of development of Belgrade

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Physical-geographic factors determine the basic directions of the development of the city. They, on one side, enable the spatial development of the city, offering favourable conditions for space usage, construction and life of citizens (favourable terrain slopes and expositions of slopes, enough drinking water and technical-technological waters, favourable climate conditions, etc.), while on the other side, they can represent the obstacle/limitation for the further development of the city (rockslides, landslides, floods, earthquakes, etc.), which is sometimes impossible to overcome or the exceeding of the obstacles demands large financial investments.

The physical-geographic identity of Belgrade is based on the connection of its different natural wholes, i.e. the position on the Šumadija, Srem and Banat side, as well as in the Posavina and Podunavlje belt.

The administratively established border of the City of Belgrade (17 Belgrade municipalities) does not coincide with its natural borders, mostly due to different terrain configuration. The natural borders of the City of Belgrade are approximately corresponding to its metropolitan area which is located on the edged area of two large, completely different natural wholes: the Pannonian Plain and the Balkan Peninsula.

The natural conditions mean the complex of influences of different elements of the natural environment (relief, climate, waters and type of vegetation) and man, defining its basic characteristics, but also different aspects of the area usage. Good knowledge of all natural conditions is necessary for understanding the contemporary processes in the natural environment of Belgrade, with the aim of regular and rational approach in the use of the natural potentials. Therefore, it is necessary to make a regular analysis of the physical-geographic conditions and to establish all the potentials and limitations as the basis of the optimal purpose of a certain territory and its spatial development.

4.1. Geographic position

The natural position of Belgrade is unique in Europe. The city is located at the confluence of two large rivers-the Sava and the Danube and in the contact zone of the southern ridge of the Pannonian basin and the northern border of the Balkan Peninsula.

Geographical position of Belgrade is defined by the following coordinates: 44° 49′ 14″ of Northern latitude and 20° 27′ 44″ of Eastern longitude (coordinates in Knez Mihailo Street). Actually, Belgrade extends from the utmost point in the north (45° 06′ of Northern latitude, 20° 23′ of Eastern longitude) - Palilula, to the utmost point in the south (44° 16′ of Northern latitude, 20° 18′ of Eastern longitude) - Lazarevac, and from the utmost

point in the east (44° 27' of Northern latitude, 20° 52' of Eastern longitude) - Mladenovac, to the utmost western point (44° 38' of Northern latitude and 19° 59' of Eastern longitude) - Obrenovac.

The average altitude of Belgrade is 132 m and it is presented by the altitude of the Meteorological Observatory (44° 48' of Northern latitude and 20° 28' of Eastern longitude). The lowest point is 71 m above the sea-level (Grocka), while the highest is 628 m (Kosmaj).

The highest peak elevation of Belgrade in the inner urban area is on Torlak (Voždovac) – St. Trinity Church 303.1 m, while Ada Huja has the lowest one of 70.15 m.

4.2. Relief

The relief of Belgrade is in the morphological and genetic sense very complex, so that different forms of the relief intersect on relatively small area: tectonic, fluvial, abrasion, karst and eolian.

In the morphologic-tectonic respect, the area of the city of Belgrade belongs to two large wholes: the Pannonian Plain in the north and hilly terrains of central Serbia (Šumadija) in the south. In the relief of the Šumadija hilly terrain, two mountains stand out: Avala (511 m) and Kosmaj (628 m). The terrain descends gradually from south towards north, divided by the valleys of small rivers and brooks. South from the Sava and the Danube, the relief is characterised by great plasticity, so that the city extends over many hills (Banovo, Lekino, Topčidersko, Julino, Petlovo, etc.), while alluvial flats and loess plateaus stretch north from the Sava and the Danube.

The Pannonian basin includes the parts of the Sava, the Danube and the Pannonian Plain. The Danube entrenched its valley in marine-lake sediments of the Pannonian basin bottom, lowered along large faults and inclined towards south. The Danube valley is asymmetrical; the escarpment even 100 m high is on the right side, moved towards the south by lateral erosion. The alluvial flat of the recent bottom of the Pannonian basin is on the left side. The Sava entrenched its valley along the north-south fault line. The fault scarp is moved and changed by lateral erosion. The absolute height of the Danube alluvial flat is 68 - 74 m, while the lowest river terrace 2 - 6 m high is above it. The alluvial flat of the Sava is narrower and there are not alluvial terraces on it. The highest heights of the Pannonian Belgrade are in Surčin (104 m) and on the loess plateau of Zemun (84 m).

The Šumadija territory of Belgrade was built of fluvial-denudation plateaus, lined up sloping, the altitude of which decreases towards the north. These are: Ripanj (310 - 330 m), Pinosava (210 - 240) and Belgrade (120 - 140 m) with two stages: Terazije (125 m) and Bulbuder (80 m) (Petrovic D., Manojlović P., 2004). The most known relief forms of the Šumadija hilly terrain are Kosmaj (628 m) and Avala (511 m) which belong to the meridian expansion of limestone reef of Šumadija.

The river basin and the valley of the Topčiderska River are morphologically very interesting (the whole basin is entrenched into the Šumadija reef), as well as the epigenetic gorge of the Bolečica river which flows north from Avala and empties into the Danube near Vinča.

The territory of Belgrade also includes the parts of the river basins of the lower Kolubara, Peštan, Ralja and Veliki Lug.

The limestone terrain appears in the surroundings of Belgrade, around Žarkovo, Železnik, Sremčica, Guncat, Lisović and Manić. It is the so-called Belgrade merokarst, characterised by dolines, dry valleys, smaller abysses and caves.

4.3. Climate characteristics

The territory of the City of Belgrade is located in the area of temperate-continental climate with local varieties. The mean annual air temperature is 11.7 °C, but the temperature changes from year to year due to anthropogenic influences of the urban area, as well as due to global warming.

February is the coldest month with the mean temperature of 0.0 °C, while July is the warmest month with the mean temperature of 22.1 °C. The amplitude of the absolute maximum and minimum temperature is 68 °C, which points to the continentality of Belgrade climate.

All four seasons prevail. Autumn is longer than spring, with longer sunny intervals. In winter, the average number of days with temperatures below 0 °C is 21. Spring is short and rainy. The average number of days with temperatures higher than 30 °C is 31 °C.

The lowest temperature ever measured in Belgrade is - 26.2 °C (January 10th 1893). The highest measured temperature is of August 12th 1921 and September 9th of 1946 - it was 41.8 °C. In the period from 1888 to 1995, only six days with the temperatures over 40 °C were registered.

The average annual precipitation amount is 666.9 mm. Most rains come during the months when it is mainly needed for vegetation (in May and June). Hence, the conditions for the development of fauna and flora are favourable. June is the month with the highest precipitation (the average of 86.6 mm). The average number of snowy days is 27, while the number of days with snow lying on the ground ranges from 30 to 44 days, with the depth of the snow from 14 to 25 cm.

The average annual relative air humidity is 69.5 %. July is the month of the least moisture (mean relative humidity is 62.7 %), while December has the highest humidity (81 %).

The average annual number of clear days is 67, while the number of cloudy ones is 111.

The mean atmospheric pressure in Belgrade is 1001 mb. The highest atmospheric pressure was 1003.8 mb in 1921, while the lowest was 998.5 mb in 1915.

The greatest insolation of about 10 hours per day is in July and August, whereas December and January are the cloudiest months, when the sun shines only two hours.

The characteristic of Belgrade climate is košava, the south-eastern and eastern wind, which blows in autumn and winter, bringing clear and dry weather. It mostly blows 2-3 days. This wind has the significant role in cleaning the air in Belgrade. The western and north-western winds also blow throughout the year.

The mean annual insolation and the dominant air-streaming, point to the possibility of using the solar and eolian energies in the future, i.e. the economic and ecologic significance of these potentials.

4.4. Surface and underground waters

4.4.1. Surface waters

The territory of the City of Belgrade is characterised by very low quantities of water originated on its own area (domicile waters). The greatest part of the territory is in the zone where the specific runoff is about 1 – 2 l/s - km2, which, according to the indexes of domicile waters, makes it one of the most lacking areas of the Republic of Serbia. The transit waters of the Danube and the Sava rivers are very significant resource with average annual balance of over 210 milliards m3.

The Danube flows through Belgrade in a length of 60 km. The width of the river is between 450 and 1200 m under the mean water level, while the depth is from 4.6 to 9.5 m. The left bank of the Danube is low, plain, swampy, while the right bank is with the loess escarpment of the Zemun loess plateau. The highest water levels are in April, whereas the lowest ones are in September. The average annual discharge of the Danube near Zemun is about 3000 m3/s and the temperature of water is 11.5 °C.

Figure 8: Confluence of Danube and Sava river (with protected island „Veliko ratno ostrvo").

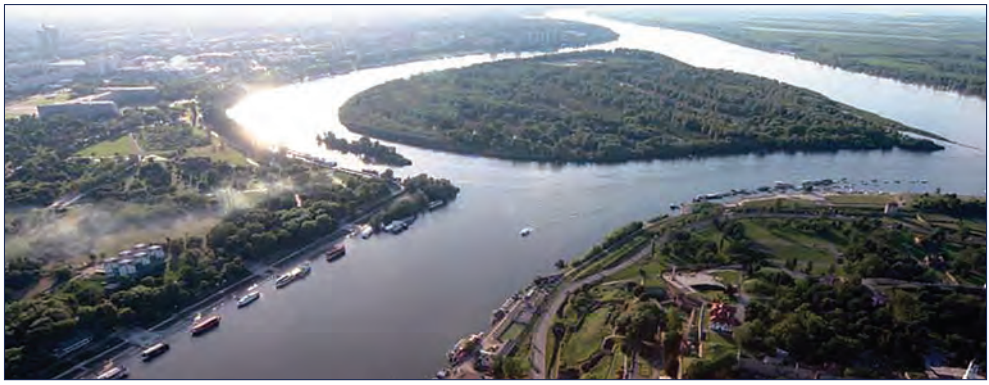


Photo: N. Čović.

The Sava flows through Belgrade in a length of 30 km and it joins the Danube below Kalemegdan, on 68 m above the sea-level. The Sava is from 230 to 600 m wide and 3 - 20 m deep. The highest mean monthly water level is in April, whereas the lowest one is in September. The average annual discharge of the Sava near Belgrade is 1172 m3/s and the temperature of water is 13.1 °C.

Even though Belgrade lies on two large rivers, it does not descend completely at the river banks. The length of the river banks of Belgrade is 200 km. The area of the Sava and the Danube in the Belgrade settlement is 22.25 km2, while the area of the river islands is 5.41 km2. Within the area of the City of Belgrade, there are 16 river islands on the Sava and the Danube, whereof the most famous are Ada Ciganlija, Veliko ratno ostrvo and Gročanska ada.

Figure 9:
Sava river with its two islands – Ada Ciganlija (right) and Ada Medjica (left).

Photo: N. Čović.

Besides the two most significant rivers, the Danube and the Sava, many other smaller rivers flow through the territory of the City of Belgrade, among which the following ones stand out: the Kolubara, the Topčiderska river, the Železnička river, the Barička river, the Veliki Lug, the Relja, the Bolečica, the Gračanska river, the Lukovica, Peštan, the Turija, the Beljanica, and the canals are the following: the Gealovica, the Sibnica, the Kalovita and the Vizelj.

Table 1: Basic hydrological data on rivers in Belgrade zone and relevant hydrological surroundings.

River	Gauging station	Area of drainage basin (km^2)	Average discharge (m^3/s)	$Q_{min,95\%}$ (m^3/s)	$Q_{max,1\%}$ (m^3/s)
Danube	Pančevo	525.009	5222.00	/	/
Sava	Sremska Mitrovica	87.966	1532.00	285.4	6408
Tisa	Novi Bečej	145.415	766.00	122.6	3867
Tamiš	Tomaševac	9717	46.40	/	/
Kolubara	Draževac	3588	20.80	1.4	/
Kolubara	Beli Brod	1869	16.10	1.33	540
Veliki Lug	Mladenovac	122	0.38	0.02	55110 (0,1%)
Ub	Ub	214	1.01	0.005	/
Ljig	Bogovađa	679	4.70	0.10	/
Paljuvi Viš	Kladnica	74	0.26	/	/
Tamnava	Koceljeva	209	1.09	0.006	120200 (0,1%)
Onjeg	Brana	22	0.16	/	(0,1%) 95
Peštan	Zaoke	125	0.73	0.031	/

Source: Regional spatial plan of administrative area of Belgrade, 2004.

The systems of small waters are especially significant for planning the usage of surface waters. They are extremely unfavourable on all internal streams. It is particularly important to examine the systems of small waters on the Kolubara River in a zone of the mouth of the Peštan River because the industrial plants within the PD mining basin "Kolubara" use water from the Kolubara for technological needs.

The unevenness of discharge on all rivers, also including the Sava and the Danube, has been the unfavourable fact in regard of the exploitation of Belgrade springs, and especially in regard of work of the up-stream power stations in Obrenovac that operate with open cooling systems, due to which it comes to warming of the Sava, especially during the periods of low water levels. With an aim of protecting the water purification plants and the protection from eutrophication of the aquatorium in the zone of the City, it is necessary to define the concrete measures for diminishing the consequences of this phenomenon by a special project.

The Savsko Lake - On the Sava River, in the immediate vicinity of its confluence into the Danube, only four kilometres from the centre of Belgrade, the former island and the present-day peninsula of Ada Ciganlija is situated. The Sava flows on the northern side of Ada Ciganlija, while the lake (80 ha) and the Čukarički branch (16 ha) are on the southern side. The lower and upper dams on the branch of the Sava were built in 1967, so that Belgrade got a unique lake 4.2 km long with average width of 200 m, depth from 6 to 10 m and with 3 million cubic meters of water. The lake is named popularly "the Belgrade sea", because even about 300.000 visitors are swimming in it during the season. The total area of the centre of Ada Ciganlija with Ada Medjica and the aquatorium is 800 ha. The lake is intended for two specific purposes - it is suitable for mass recreation and all water sports, but moreover, it plays an important role in the water supplying (the inner zone of the protection of Belgrade water source), so its protection is of considerable significance.

Figure 10:
River Sava – island Ada Ciganlija and lake – recreation center.

Photo: N. Čović.

Besides the Savsko Lake, the accumulations near Avala are of the significance for the territory of the City of Belgrade, the main function of which is to keep the flooding wave, while their waters have rarely been used for watering agricultural crops and recreation. The accumulations are the following: Pariguz at Resnik, Bela reka at Ripanj and Duboki potok at Barajevo.

4.4.2. Underground waters and capacity of Belgrade springs

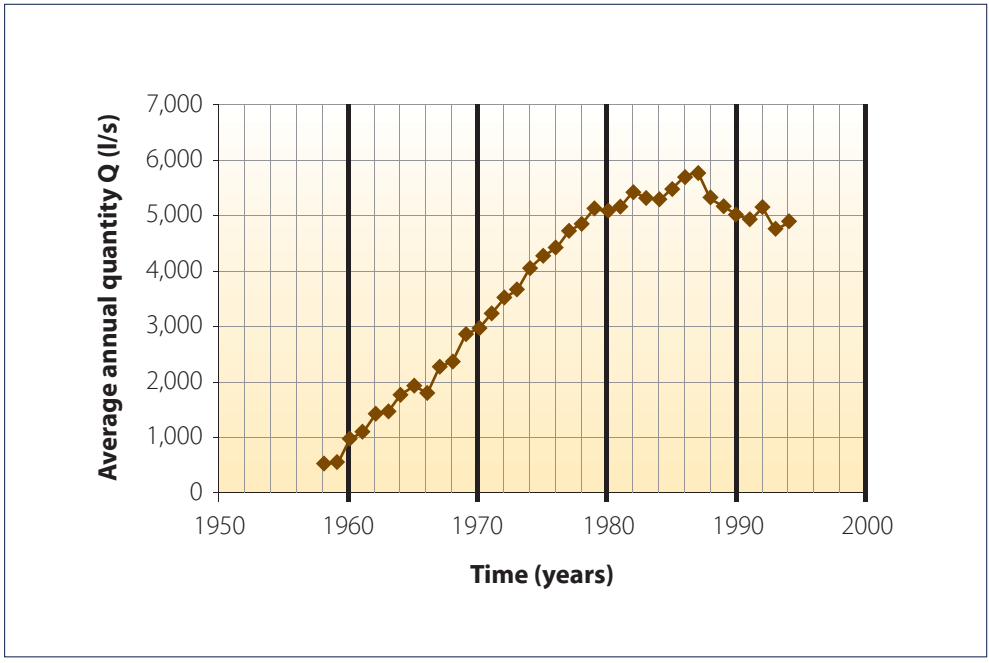
Underground waters represent valuable resource, but they are very unevenly arranged. The zones along both banks of the Sava and partly the Danube represent valuable springs of underground waters, the system of protection of which should be strengthened.

The available quantity of water which is used for water supplying of the City is limited by the capacity of activated springs and the capacity of the water purification plants.

The problem of the capacity of Belgrade water spring is very complex and it requires various and detailed researches. The capacity of springs means the quantity of underground water which can be obtained under the existing condition of wells. On the other side, the capacity of resources represents the maximum possible exploitation of water on the spring, under the supposition that the existing wells are put into ideal condition, i.e. that they are all in function.

In the case of Belgrade spring, the capacity of springs is far lower than the capacity of resources which is partly the consequence of an inadequate estimation of the capacity of resources. That brought to the exaggerated exploitation of underground waters and the decline of their level. Its exploitation increased from year to year. It was the highest in the 1980s. In 1982, it was 5300 l/s on the average, while in 1987 it reached its maximum with the average of 5700 l/s. From that period, the exploitation decreased which was attributed, among others, to putting the purification plant PS "Makiš I" into operation. In 2003 the exploitation was 5123 l/s and in 2007 the capacity was reduced to 4048 l/s.

Figure 11: Average annual quantity of underground waters obtained by wells of Belgrade spring.



Source: Belgrade Waterworks, 2003 (www.bvk.rs).

Table 2: Wells of Belgrade spring and their capaticies in 2003.

Number of zone	Zone	Number of wells	Q_{uk} (l/s)	Q_{pros} (l/s)
1	New Belgrade	15	1067	71,13
2	Bežanijsko polje	16	957	59,81
3	Jakovačko polje	4	154	38,50
4	Boljevačko polje	8	389	48,63
5	Progarsko polje	17	893	52,53
6	Ada Ciganlija	21	833	39,66
7	Makiško polje	19	830	43,68
	TOTAL	100	5123	51,23

Source: Belgrade Waterworks, 2003 (www.bvk.rs).

Today, the spring of Belgrade water supply is dominantly connected with the Sava River. It is supplied by crude water from the underground spring at the foreshore, as well as by the direct catchment from the Sava and partly from the Danube.

During 2007, the underground water was obtained from 99 wells with horizontal channels. The proportion of catchment of underground water and river water was 57.83 % to 42.17 %.

Table 3: Total quantity of produced water and the capacity of Belgrade water spring.

	Produced water (m^3)	l/s	%
Underground water	127.665.550	4048	57.83
River water	93.097.343	2952	42.17
Total	220.762.893	7000	100

Source: Environment in the City of Belgrade, 2008.

In accordance with the City's needs for water, in 2007, 220.762.893 m^3 of water were produced on the installations of Belgrade Water Supply (7000 l/s on average, whereof 4048 l/s of underground water).

From the period when the Belgrade spring was opened up to present day, the situation in the field of water supplying changed to a great extent. The number of residents and consumers increased, wells and equipment got old, while the capacity of spring declined[2]. Consequently, the projects of expanding the existing springs have been considered for years, i.e. the project of the construction of new springs.

[2] At the beginning of the exploitation, the copiousness of wells was around 200 l/s, while 10-15 years later it decreased on 1/4 or 1/5. Such situation was the consequence of the decline of the level of underground waters due to a long-range operation of wells on the foreshore, i.e. the weakening of the hydraulic connection between the river and the surrounding on one side, and on the other side, old wells and ruined channels (of the previous 792 channels, 610 or 73 % were in function in 2003).

Among the projects of expanding the existing capacities, the project of expanding the springs in the part of Ušće has been emphasized, as well as the project of the construction of the infiltrating spring in Makiško polje, while the following springs have been taken into consideration as the potential water springs: the spring of Zidine (upstream from the Ostružnica bridge in meander of the Sava – left bank), Hrtkovačka draga (the left bank of the Sava, downstream from the Hrtkovci settlement, planned as a part of the water supplying system of "Istočni Srem"), the water spring of Jabučki Rit (the left bank of the Danube, near Jabučki rit, i.e. with the potential locations near Besni Fok, Crvenka and Gradska šuma – downstream from Pančevo; planned as water spring of the Banat part of the City) and the spring of Kovin-Dubovac (also on the left bank of the Danube, at the alluvial plateau between the settlements of Kovin and Dubovac).

4.5. Bio-geographic characteristics

The area of the city of Belgrade in bio-geographic view, represents the part of the Holarctic bio-geographic area: (a) middle European region of plain and hilly deciduous forests with corresponding derivatives of herbaceous vegetation including even nine forest ecosystems: forest of oak pomegranates and cerris, forest of English oak and barberry, forest of silver linden and oaks, forest of English oak and broom, forest of poplars and willows, forest of sessile oak and hornbeams, forest of English oak and hornbeams, montane forests of beech, forest of sessile oak and (b) Pontine-South Siberian region with the characteristic ecosystem of steppes and forest-steppes which is prevailing on the loess plateaus and hills along the Danube.

Except the ecosystem diversity, the diversity of flora and fauna represents the developmental advantage in relation to other large cities in the central and Western Europe.

Due many anthropogenic influences, the natural ecosystems/ areas were considerably modified in the past, so that today the urban, suburban and cultivated area has prevailed.

In regard of the preservation of authentic biodiversity, the work on the conservation of nature's values is of great significance. According to data of the Central Register of protected nature's values (2008), 46 nature's values are protected on the territory of Belgrade:

- three areas of extraordinary characteristics: Veliko ratno ostrvo, Kosmaj and Avala;
- 43 natural monuments (of botanical or geological value), are categorised as nature's values of great significance or significant nature's values.

With an aim of the natural ecosystem preservation of the City of Belgrade, besides the conservation of nature's values, attention should also be paid to autochthonous ecosystems, first of all to characteristic and relatively well preserved forest ecosystems on Avala, Košutnjak, Guberevačke forests, but also in the navigable zone of the Danube, in forelands and islands.

Table 4: Autonomous ecosystems (natural and artificial).

Autonomous ecosystems	Situation	Sensibility
Forests of hilly area (Avala, Kosmaj, Košutnjak, Lipovica)	unequal	Large dependence on strength of anthropogenic influences
Flooding forests by rivers (by levee of Danube, Veliko Ratno ostrvo, peak of Ada Huja)	Very unequal	temperate, due to great power of edificators
Forests, artificially raised (Banjička, Zvezdarska, Jajinska, Medaković, Šumice)	Very different	Larger than at natural
Swampy ecosystems (Veliko Ratno ostrvo, islands near Veliko Selo, Kozara)	unfavourable, caused by eutrophication	Temperate to large, depending on biotical capacity and anthropogenic influence
Artificial lake and swampy ecosystems (Ada Ciganlija, bay of Ada Huja)	Temperate favourable	large, if limiting capacities are exceeded
River system of the Sava and the Danube	unfavourable	large to temperate dependence on degree of pollution and power of self-purification
Segetal ecosystems (deserted agricultural areas)	Very different	Not important, reactivating or changing into green areas
Ruderal ecosystems (deserted urban areas)	very different	small, if left to natural processes

Source: Regional spatial plan of administrative area of Belgrade, 2004.

Protection, spatial distribution and development of the City of Belgrade have opened the key issue on understanding the borders of the present and future exhaustion of natural (autonomous) and agricultural (semi-autonomous) ecosystems of this area, being very often justified by the development and expansion of the city, but reduced to more and more intensive change of autonomous and semi-autonomous ecosystems into urban (non autonomous) ecosystems.

The problem of permanent expansion of Belgrade imposes finding the solution to the problem of preservation of biodiversity and urban surroundings. Therefore, the basic aim is to ensure the future development based on harmful influence on nature as little as possible, by which the degree of its non autonomy will also be lessened. That means the preservation of: (a) natural autonomous ecosystems in the surrounding; (b) maintenance and creation of semi-autonomous ecosystems in the inner urban area in the form of green areas of different size and purpose and (c) maintenance of semi-autonomous agro-ecosystems by the use of the contemporary measures in agriculture, based on the preservation of biological diversity of such ecosystems.

4.6. Minerals

Relatively diverse and economically very significant mineral wealth has been concentrated on the territory of the city of Belgrade. The lignite reserves in the mining basin of Kolubara are the most valuable. A group of non-metaliferous minerals is considerably less significant: fireproof, brick-ceramic and other clays, quartz sands, gravel, pebbles and gravel of alluvial quartz, diatomites, alevrites and some sorts of building and architecture stones (limestone, marble breccias, granodiorites and other siliceous rocks, sandstones). Deposits of metalliferous minerals were exploited in the nearer and more distant past - mercury, lead, zinc, silver and gold. None of these minerals was exploited for a long period of time. Large reserves of iron are well known (oolitic ores of "Šumadija"), but they cannot be used profitably due to their unfavourable technological characteristics. Lead and zinc deposits of "Kosmaj-Babe" might have the economic significance in the perspective, but they are explored insufficiently due to lack of the financial means, which is to a certain degree justified from the point of view of the ecological entirety of this area.

The degree of exploitation of mineral resources is low, except lignite and partly non-metals, which makes the optimal valorisation of the space and the appliance of planned postulates and criteria of using the natural resources and protection of the environment difficult.

Disregarding the existence of certain non-metalliferous and metalliferous mineral deposits and the potential increase of the existing reserves, the ore production should not be maintained and developed on the area of the City of Belgrade with wider surrounding up to 20 km on the south. The reason is the closeness of the City and densely populated parts, i.e. the protection of the environment which has already been greatly endangered due to combined influence of many negative factors.

Besides all problems which exist and which are expected, the mineral lignite base of the Kolubara mining basin has still been the basis of the dominant part of the power production not only of the City of Belgrade but of the republic of Serbia as a whole. However, it has to be approached to a multi-variation estimation of what can be the substitution for lignite when its exploitation becomes exhausted.

All other minerals which are exploited or can be the subject of the exploitation in the near future, have only satisfied partly the needs of the area and they have to be provided from other regions (sometimes 100 km away) or by import. That is particularly characteristic for raw materials used in civil engineering such as cement, sand, gravel, building and architecture stone, etc.

4.7. Natural hazards as limiting factor of the spatial development of the city of Belgrade

The natural hazards, as well as measures which are needed to be overtaken in the prevention of their harmful effects, should be taken into consideration while defining the basic aims of the development of an area. Natural disasters cause smaller or larger changes in the environment, considerable material damages, and, most importantly, they can greatly endanger people's lives and health.

In dependence on the physical - geographic conditions of the environment and man's activity, each area has the characteristics and predispositions for a disaster to occur. Their origin, scope and time of lasting cannot be predicted in most of the cases, but it can be supposed that certain phenomena are going to occur on the basis of the experience, statistical data and methods of modelling and prognostication. The measures of protection can be defined by the analysis of these phenomena, whereas the spatial and urban planning plays the significant role in the prevention of harmful impacts and their reduction to the least possible extent.

The endangerment of the area by natural disasters has been an important factor while choosing the location and planning the land use, as well as while defining the degree of the concentration of physical structures and infrastructural facilities. The city of Belgrade, with its population, material and other natural and created resources, has been exposed to natural hazards, but the degree of its endangerment is not extremely high and still it is enough that it can cause considerable consequences, endanger people's health and lives and damage material goods. In order to avoid and diminish the risk these hazards bear, it is necessary to estimate the endangerment of the area by some disasters.

In regard of the most important physical-geographic limitations, i.e. the possibilities of natural hazards to occur, the area of the City of Belgrade belongs to the mean zone of seismic endangerment, it is permanently exposed to the harmful influence of floods and there are locations of active landslides.

The research of the complex and specific problem of the protection from natural disasters was undertaken according to the unique system. On the basis of analysis of the condition, the potentially endangered localities were identified and their classification was done according to four degrees of endangerment, i.e. the consequences that may occur.

Table 5: Degree of consequences caused by natural disasters.

	Floods	**Seismicity**	**Landslides**
Without consequences	Conditions for floods do not exist	Not endangered areas (<5 MCS)	Favourable terrains
Limited consequences	Rarely flooded areas	Mean endangered areas (6 MCS)	Conditionally favourable terrains
Significant consequences	Frequently flooded areas	Considerably endangered areas (7 MCS)	Unfavourable terrains
Large consequences	Annually flooded areas	Very endangered areas (8 MCS)	Extremely unfavourable terrains

Source: Filipović D, 2002; Filipović D. and Obradović D., 2004.

4.7.1. Earthquakes

The city of Belgrade is situated on very safe constitution of the ground and it belongs to the mean zone of seismic endangerment. It lies on the moderate quivering area where there have not been any catastrophic earthquakes there, but the possibility of their occurring is not excluded.

The territory of the City of Belgrade does not have its autochthonous epicentres of strong earthquakes. The earthquake can strike the City with the maximum force of 5 on the Mercali Scale. The seismic waves from the epicentres of the surroundings can cause stronger earthquakes on the territory of Belgrade. Therefore, Belgrade is endangered most by the Mionica epicentre, measuring 8 on the Mercali Scale, as well as by the epicentre from the direction of Rudnik Mt., measuring 7 on the Mercali Scale, then Kosmaj, Svilajnac, Golubac, Fruška Gora and Kopaonik epicentres (6 on the Mercali Scale). The subsequent strikes of stronger intensity cannot be felt on the area of Belgrade.

On the basis of the Seismic Map of the SFRY (1987), the City of Belgrade lies in the area of 7 on the Mercali Scale. On the map of detailed micro-seismic regionalisation, it can be seen that the seismic endangerment of the area ranges from 6 to 9 on the Mercali Scale, as well as that the seismic activity increases from the north towards the south of the territory of the City of Belgrade, so that the region of Lazarevac is the most endangered region (Fig. 12).

In accordance with the seismic plans, all structures are built in such a way that they can withstand one degree stronger earthquakes than predicted.

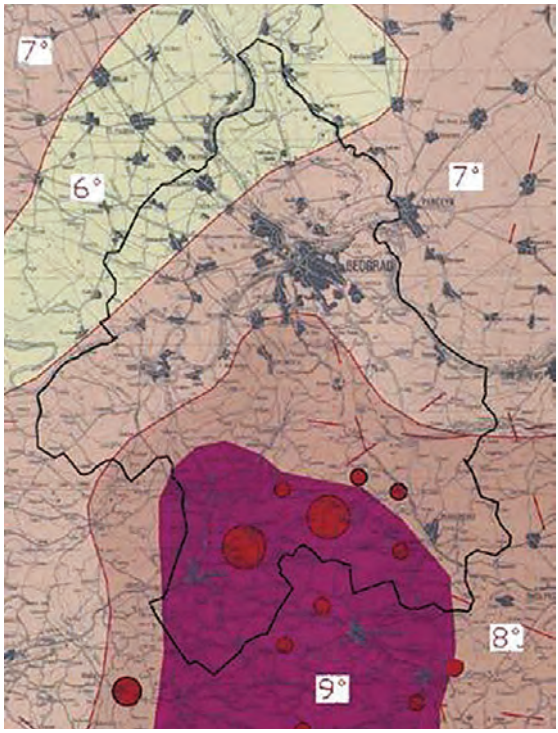


Figure 12:

Seismic activity of Belgrade and wider surrounding with isolines and zones of basic degree of seismicity (Mercali Scale).

Source: "Ecological Atlas of Belgrade", 2002.

From the aspect of seismology, the stony complexes with stable, mean and unstable characteristics build the area of Belgrade. The most stable terrains are built of limestone, sandstones, serpentinites and other compact stony masses with weakly expressed ability of decomposition. The terrains of seismically mean stability conditions comprise the greatest area on the territory of Belgrade, built of sands, clay, clayey sands, loess and other similar sediments with more expressive ability of decomposition.

Seismically the most unstable terrains are the terrains built mainly of gravels, sandy clays, mud, as well as all incompact soils and the soils where the level of underground water is relatively high. These terrains are situated on alluvial plateaus of the Sava and the Danube on the Srem and Banat side, as well as in the valleys of the Kolubara and other smaller water currents on the territory of the Šumadija part.

4.7.2. Floods

The area of the City of Belgrade is exposed to the harmful effect of floods. They may have extremely negative influence on the total development of this area, as on people's lives and health, so on material and natural resources.

The risk from floods on the area of Belgrade is planned out on the basis of Waterpower Base of Serbia and many studies done by various institutions (Faculty of Civil Engineering, "Jaroslav Černi" Institute, PS "Srbijavode" – Waterpower Centre "Sava", etc.).

There are several endangered zones on the territory of the City of Belgrade:

- part next to the Sava and the Danube, endangered by high waters of these two rivers;
- area around smaller streams of torrential character. There are about 160 smaller torrential streams on the area of Belgrade which endanger the parts of the city by short, but very dangerous floods;
- underground waters which coincide with high levels of the Sava and the Danube are endangered by low valley zones in the northern part of the territory of the city of Belgrade;
- low parts of old city core (on the right bank of the Sava, especially the zone around the railroad station), are endangered by the breakthrough of drainage waters under the high levels of the Sava and the Danube.

The terrain is zoned on extremely unfavourable and unfavourable terrains. Extremely unfavourable terrains on the territory of the city of Belgrade include the flooding parts of alluvial plateaus. Surface waters in the plain part of the City (alluvium of the Sava and the Danube) and high level of underground waters, characterised for those areas, represent the significant limitation of the normal development and construction and they can cause material damage. Unfavourable terrains include narrow pro-alluvial plateaus and sources, the parts of alluvial plateaus below the peak elevation of 72 a.s.l., as well as oxbows, swamps and meander scars.

4.7.3. Landslides

Landslides represent the greatest limiting factor for the area usage. Besides landslides, there are also areas affected by erosion and rockslide. By "Cadastre of landslides and unstable slopes of the territory of Belgrade" (1988), the rolling-hilly parts of the terrain south from the Sava and the Danube were included. Thus, all the landslide phenomena were noted and defined spatially (2341 phenomena of different forms of instability), by which the precise and complete image on the spreading and the state of landslides and unstable slopes was provided for each registered phenomenon on the area of Belgrade.

Figure 13: A part from the map of the territory of Belgrade for which the cadastre of landslides and unstable slopes is made.

Source: Gojgić D. et al., 1995.

On the basis of "Cadastre of landslides and unstable slopes of the territory of Belgrade", out of the total area comprised by the Cadastre (1693 km2), the unstable terrains include the area of 377 km2 (22.27 %), whereof the active landslides include the area of 41 km2 (2.42 %), calmed landslides comprise 87 km2 (5.14 %), reclaimed ones include 1 km2 (0.06 %), while 248 km2 (14.65 %) represent the conditionally stable terrains.

The sliding of land is the characteristic of areas built of the Neogene sediments. The terrain is zoned on absolutely unfavourable and unfavourable terrains. The absolutely unfavourable terrains are the terrains with active landslides, being present on several locations, on the area south from the Sava and the Danube. The unfavourable terrains include the areas with the potentially unstable slopes, the terrains where calmed landslides appear and loess scarps with the phenomenon of rockslides. The engineering-geological characteristics of these terrains in the natural conditions are the limiting factor.

4.7.4. Atmospheric disasters

The City of Belgrade is in the area of frequent and intensive phenomena of hail, electrical discharge and downpour of rain. According to mean radar observations, in the summer half of the year, the stormy clouds pass over Belgrade every fourth day, whereof 3-4 per year bear the scales of elemental catastrophes. Generally, the territory of Belgrade is not considerably endangered by atmospheric disasters. The endangerment is manifested through a few (isolated) phenomena without greater consequences except the eventual material damages.

4.8. Zoning of the City according to the limitations of area usage

On the basis of the characteristics of the natural factors, the zones can be selected according to the degree of suitability, i.e. the limitation for construction and area usage (Table 6) on the territory of Belgrade. The zoning is done on the basis of:

- engineering-geological conditions and the suitability of the terrain for the construction (landslides, unstable slopes and inclinations),
- hydrological characteristics of the terrain (areas endangered by floods),
- hydro-geological conditions of the terrain (the level of underground waters),
- micro-seismic endangerment of the terrain (endangerment by earthquakes).

Table 6: Characteristics of natural conditions (limitations in the City of Belgrade according to the degree of the sustainability for construction).

Natural conditions/ limitations	**TERRITORY**		
	Floods	**Seismicity**	**Landslides**
Floods	Areas which are not flooded or they are flooded less than once in 100 years	Areas flooded once in 100–10 years	Areas flooded more than once in 10 years
Hydro-geological conditions	Horizons full of water on depth larger than 3m	Horizons full of water on depth of 1–3m with necessary hydro-isolation works	Horizons full of water on depth less than 1m
Landslides	None	Partially stabilized landslides,calmed	Intensive process of sliding, active landslides
Eroding of shores of water currents	None	Endangered zone less than 10 m wide	Endangered zone more than 10 m wide
Seismicity	Areas to 7 MCS	Areas over 7 MCS	Areas over 8 MCS
Relief	Inclination of areas to 0,10	Inclination of areas from 0,1 to 0,2	Inclination of areas higher than 0,2

Source: Filipović D, 2002; Filipović D. and Pavlović D., 2003.

4.9. Strategic determinations of protection from natural disasters

When defining the basic aims of the development of Belgrade, the endangerment of some parts of the City by natural disasters and other hazards must be taken into consideration, as well as the security measures which are taken for their prevention. The contemporary way of planning the measures of protection from disasters has been based on the valorisation of area, on the basis of which the criteria are defined for selecting the most suitable solutions for the protection of people, material goods and environment from the effect of natural disasters and other hazards.

The protection of the area from endangerment by disasters has to be proportional to the significance and the function of the area. This means that the emphasis is put on the protection of the priorities such as: large urban agglomerations, capital strategic structures (larger industrial structures, steam power plants, hydroelectric power stations, etc.) and structures of the special purpose.

Considering the significance and the function of the area, the protection of Belgrade from endangerment by natural disasters must be of the first rank. That means that the optimal organisation of the urban area will be provided by certain measures and even distribution of structures of urban equipment, as well as adapting the communal and infrastructural facilities for possible extraordinary conditions.

The contemporary concept of the protection proceeds from the fact that it is necessary to define an acceptable level of risk from natural disasters on all levels and in all phases, and to act with an aim of their prevention by the system of preventive, organisational and other measures and instruments.