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THE WATER RESOURCES OF ZIELONA GÓRA AS AN ELEMENT OF ITS SUSTAINABLE DEVELOPMENT

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Motto:

„There should be a natural abundance of springs and fountains in the town, or, if there is a deficiency *of them, great reservoirs may be established for the collection of rain-water, such as will not fail when the inhabitants are cut off from the country by war. (...) in all wise states, if there is a want of pure water, and the supply is not all equally good, the drinking water ought to be separated from that which is used for other purposes"*

Arystoteles (384-322 BC)

The subject of this paper is the presentation the water resources and water management as an example of Zielona Góra. In the paper it is shown that the water management should be recognized as the element of the sustainable development of the city. Economic activities in the city should be subordinated to the possibilities of the natural environment and should not disturb both the natural and the water balance.

Keywords: water resources, underground water, water table, sustainable development

1. INTRODUCTION

The quoted words of a wise and great Greek philosopher are still valid and very much applicable to Zielona Góra. The city slightly resembles ancient Athens with its mild climate, the varied lie of the land and large forest areas around the city. Specific physical- geographical conditions are characteristic of each region on our planet. The conditions consists of basic environmental elements, such as climate, area of land and its form, soils, areas of flora and life-giving resources of surface and underground water. The resources of environment are not finite. They have a definite area of occurrence and the quality of particular components of the environment is specified by nature. Regular water called fresh is the sub-

stance of life. Such water used to be called the blood circulation of the Earth. Researchers of ancient civilizations say: "Rivers are the cradle of civilization. Civilizations can come into existence only in places with rivers and streams rich in water (for example, the civilization of China, Harappa, Egypt, Mesopotamia and others)". Zielona Góra also had its cradle – the stream of Złota Łącza (see Fig. 1). The stream was the source of fresh and household water. At the time, it flowed through Zielona Góra and was an element enriching the beauty of landscape. In the middle of the fourteenth century, the growing rich burgesses built an earth – wooden embankment in order to increase their safety. Inside, the embankment was reinforced with solid defensive walls, which the channel of Złota Łącza was driven to (see Fig.2).

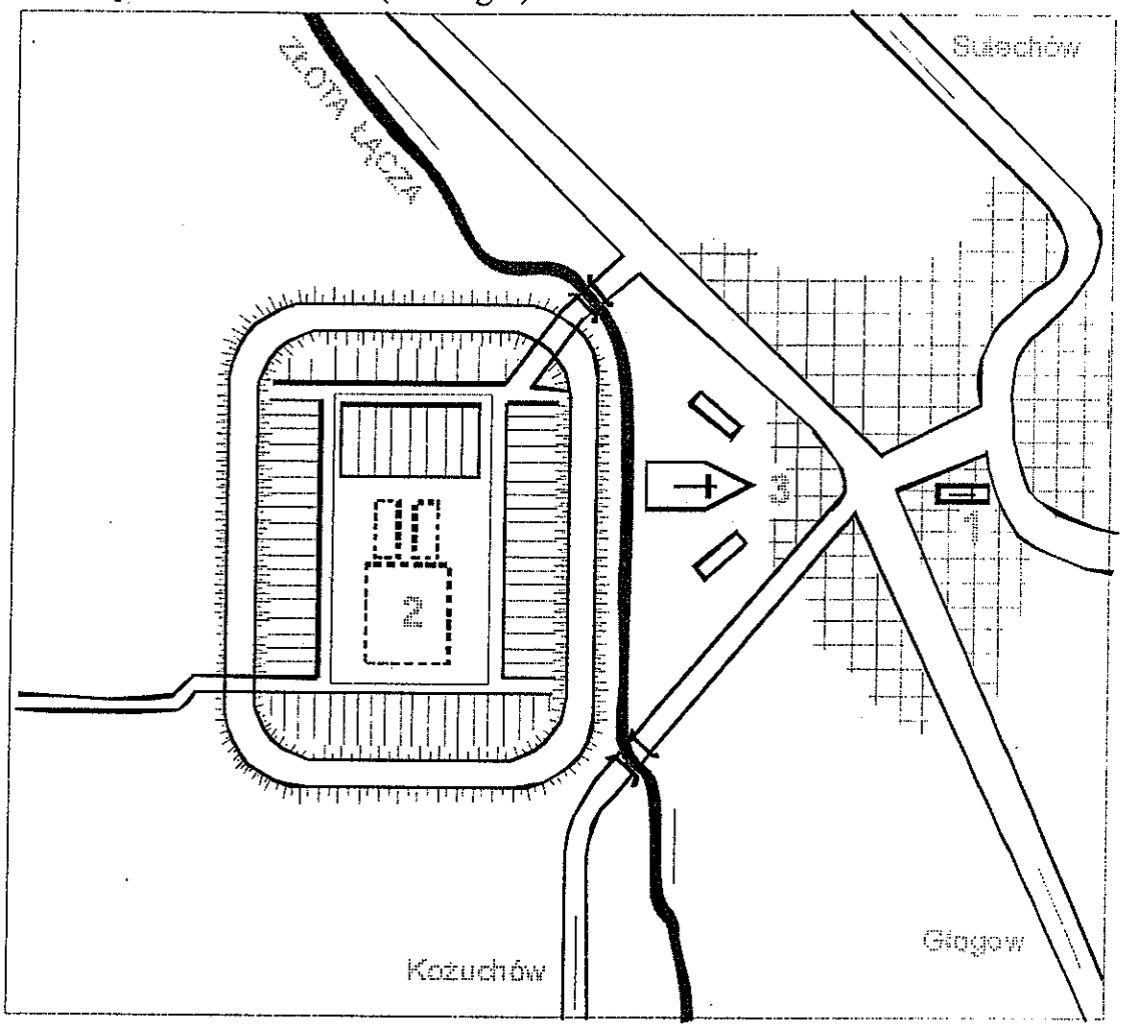


Fig. 1. Zielona Góra- space layout after 1400 year; 1-Church of Saint John, 2 – Town Hall, 3 – Parish Church of Saint Claus; according to Posadza [1].

It was an undertaking ill- considered from the viewpoint of protecting of water resources. The flow of Złota Łącza was decreased and its water was so polluted that it became oppressive to town dwellers. With time, what gave life to

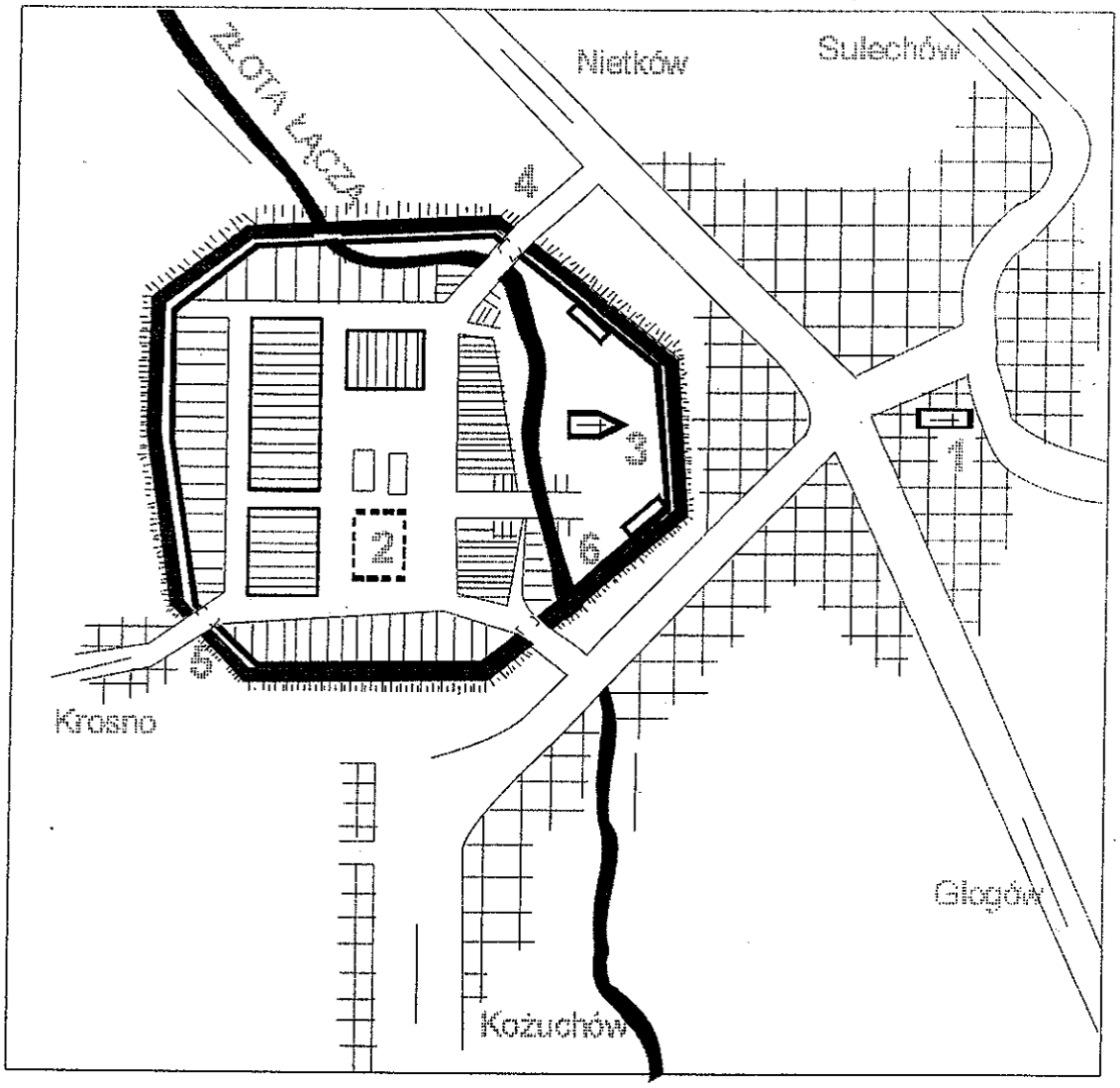


Fig. 2. Zielona Góra – after defensive walls and moat constructed, about year 1487; 1 – Church of Saint John, 2 – Town Hall, 3 – Parish Church of Saint Jadwiga; 4 – Down Gate, 5 – Top Gate, 6 – New Gate; according to Posadza [1].

Zielona Góra, was turned into a sewer. Today, only from the town chronicles do we know that a rapid, mountain type stream flowed through the centre of Zielona Góra. This damage can not be repaired any longer. Under the circumstances, dwellers had to resort to alternative forms of water resources so vital for human existence. The resources of surface and underground waters, which are not in excess, should be the subject of an utmost attention and protection. Water is a very important part of human natural environment. Its proper usage prevents disadvantageous phenomena, such as: draught, fresh water deficiency or its poor quality, unfavorable microclimate or flooding of residential areas. Water resources from the so called communicating tubes, however their range of communication does only relate to the matter of water. Propel management of resources is the part of ***sustainable development*** of the whole city system. The

water management should be discussed in a wide social context of Zielona Góra, namely the environment, economy, life and recreation of town inhabitants. This paper aims at proving the thesis advanced in the title: *the water resources of Zielona Góra as an element of its sustainable development.* The subject of water resources – a significant part of the natural environment of Zielona Góra- concerns its all inhabitants, and, in particular, their living conditions. It is a very important social issue.

2. THE PHYSICAL AND GEOGRAPHICAL LOCATION OF ZIELONA GÓRA

The lie of the land of Zielona Góra is highly varied and when one is looking at the city from a hill or a watchtower, the landscape resembles the Sudetian Foothills (see Fig. 3). The area of Zielona Góra occupies a central part of the highland named the Zielonogórski Bar, being a sub-region of the Zielonogórska Highland.

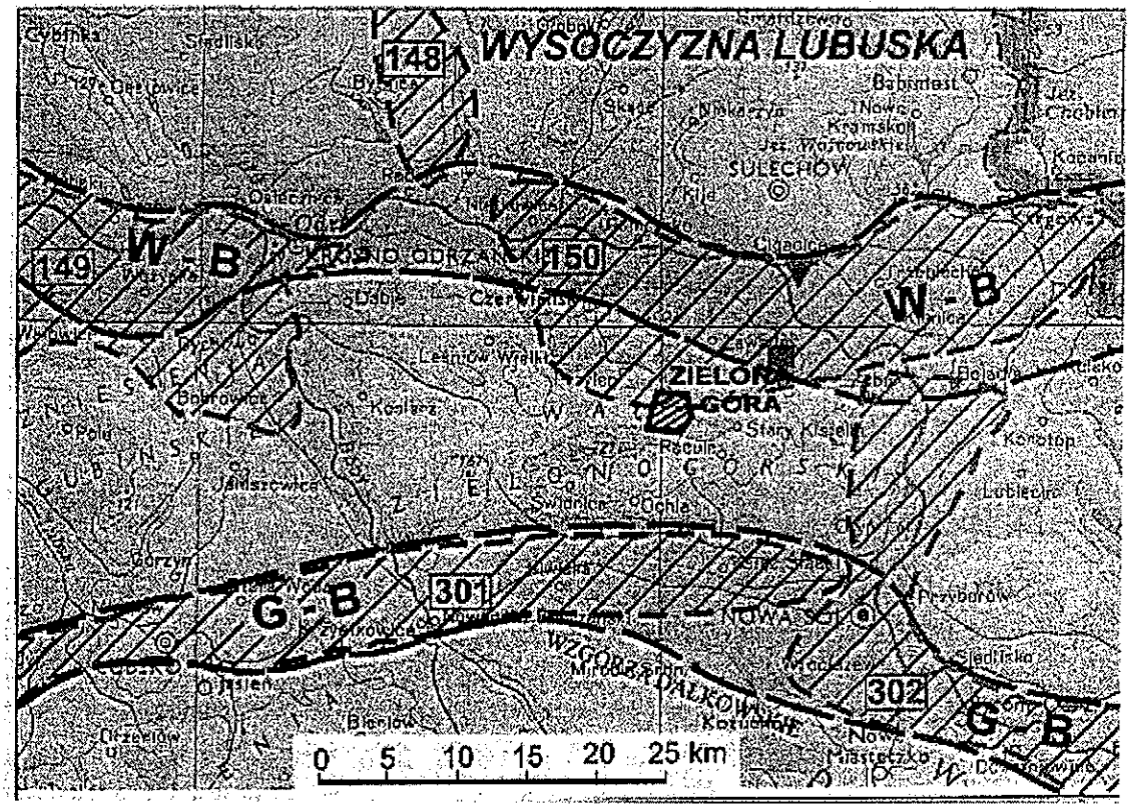


Fig. 3. Physical and geographical location of Zielona Góra. Progracial valleys: Warsaw-Berlin (W-B) and Głogów-Baryth (G-B); main underground water reservoirs: Sandr Pliszka river (148), Sandr Krosno-Gubin (149), Progracial valley Warsaw-Berlin (Koło-Oder) (150), Progracial valley Zasieki-Nowa Sól (301), Progracial valley Barycz-Głogów (302). ■ - underground water intake in Zawada for water supply of Zielona Góra, ▼ - surface water from Obrzyca river intake in Sadowa for water supply of Zielona Góra

The sub-region is surrounded by proglacial valleys: the Warsaw-Berlin in the north with the bottom located at approximately 50-55 metres above sea level and Głogów-Baruth in the south shaped on the level of 55-80 metres above sea level. Zielona Górą is varied in terms of altitude - from 80-100 metres to over 200 metres above sea level. The highest elevation is located west of the Zielona Góra and reaches the altitude of 221 metres above sea level - the Wilkanow Hill.

Large variation of hypsometry in small areas creates considerable slopes of land, which, in consequence, favours a rapid outflow of rainwater. Besides, buildings in the city area are flooded during torrential rain storms. The afforestation of slopes of the Zielonogórski Bar favours the limitation of natural outflow of rainwater and facilitates its the infiltration to the ground and the renewal of underground waters.

The climate of Zielona Góra according to Prawdzic and Koźmiński [3] was divided into a separate Climatic Region because of its slightly lower temperatures in comparison to surrounding proglacial valleys and the highest precipitation in the Lubuski region (mean yearly value amounts to 625-690 mm). The oceanic climate influences predominate in Zielona Góra.

The hydrographical network: Zielona Góra is located on the slopes of the Zielonogórski Bar, (see Fig. 3 and 4), along which runs the watershed in the directions SW - NE. The watershed divides the area of Zielona Góra into two drainage basins: the northern basin of the Oder River with the tributaries of the Złota Łączą and Gęśnik and the southern basin of the Silesian Ochla (also a tributary of the Oder River). The hydrographical network of Zielona Góra is very poor. In comparison to the prelocation period, a large number of small streams and numerous springs, which used to be the source of fresh water for town dwellers in the early medieval period, were damaged or simply disappeared.

The following water-courses originate in the southern slopes of the Zielonogórski Bar within the city limits:

• The Dłubnia (formerly the Brzeźniak) forms two small streams. The western stream flows out of its source area south of the Piastowskie Estate on the level of approximately 150 metres above see level. The water-course is 3,6 km long. In the past, the eastern stream consisted of two short water-courses, one of which flowed out near the Nowa street. The water-course entirely disappeared after the extension of the underground water intake. The second water-course originates in the area of the Ugory street on the ordinate of approximately 144,0 metres above sea level at the foot of the hill with the height of 170,3 metres above sea level. The length of the eastern stream amounts to approximately 3,40 km. The eastern and western streams join south-east of Jędrzychów and form the Dłubnia stream (formerly the Brzeźniak), which is the left tributary of the Silesian Ochla.

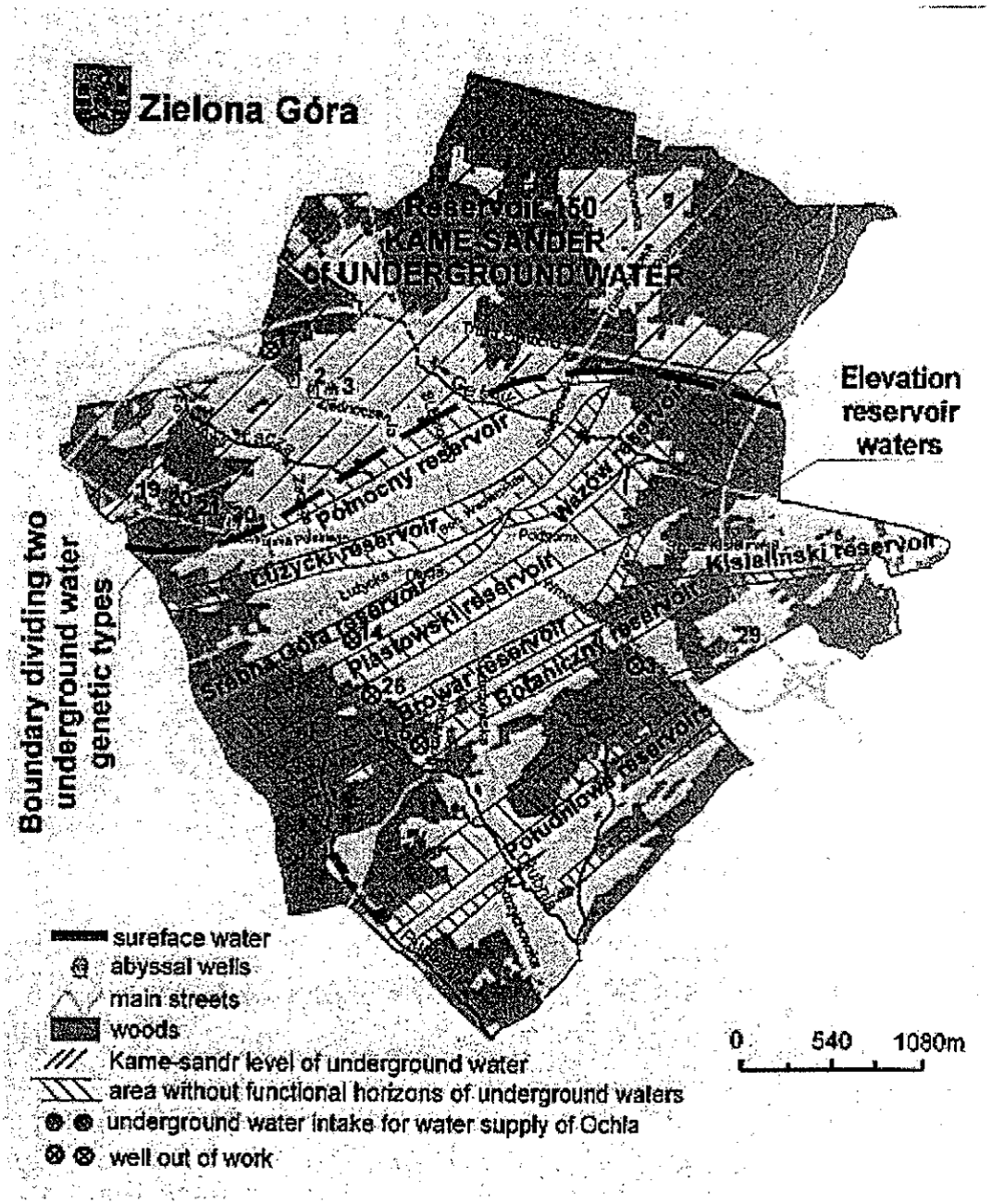


Fig. 4. Functional horizons of underground waters in Zielona Góra

• The Pustelnik (formerly the Srebrzanka or Sącznik) originates south-east of the Piastowskie Estate on the altitude of 140,0 metres above sea level and flows in the yalley of 20 metres in depth in relation to the surrounding areas. In its course, the stream feeds:

- the fire reservoir Leśników,
- the city bathing resort,
- the fishing pond,
- the recreation - fishing pond with the area of 4,4 ha, on the south side of the road (see Fig. 5).

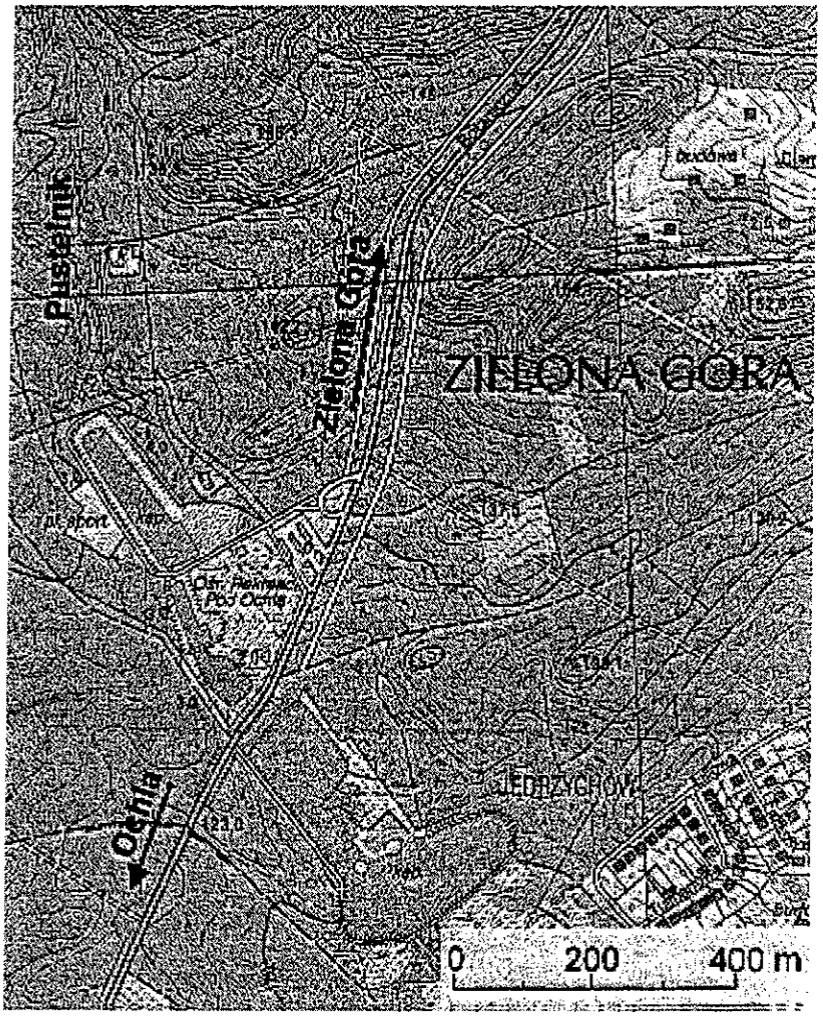


Fig. 5. Recreational and tourism area near Botaniczna street

The development of existing swimming pools in the 1970s and the building of additional pools changed the natural water regime of the Pustelnik. According to the measurements taken in September of 1970 by Przedsiębiorstwo Hydrogeologiczne in Gdańsk [2], 10,04 dm^3/s (36,15 m^3/h) of water flowed into the reservoirs, while 2,12 dm^3/s (7,64m^3/h) flowed out of them. The length of the stream within the city limits amounts to 3,5 km. The Pustelnik periodically disappears in the sands on the distance of 3,2 km. The Pustelnik together with the reservoirs constitutes a very attractive area for tourism and recreation irrespective of the season of the year.

3. THE FUNCTIONAL RANGES OF THE UNDERGROUND WATERS OF ZIELONA GÓRA

Within the limits of the city of Zielona Góra, since at least fiftieth century, the underground waters of the Quaternary period were utilized by means of natural springs and the building of shallow wells. With time, people reached for

waters located much deeper. The demand for water increased along the development of industry and the increase of the population .

The Quaternary sediments are mostly of river, hydro-glacial, glacial and dune origins, and their depth reaches 100 meters. The above mentioned sediments are not deposited horizontally - they were dislocated by Continental glaciers, which moved south through the Lubuskie region in the Pleistocene period. Encountering irregularities of surface, the Continental glaciers deformed older geological sediments on their way by means of their pressure. Folding and dislocation of older subsoil blocks of different size occurred in this way. The youngest, the last continental glacier, called the Baltic glacier, stopped on the highland of Zielona Góra and never crossed it. This border separates two types of geological structures:

- the kame - sandr structure with horizontally undislocated deposited geological strata,
- the elevation area (high) with strongly dislocated, above all, folded strata with numerous accidental inclusion of sediments of older geological deposit, frequently occurring among younger sediments.

This style of geological structure was decisive in the division of water-bearing structures within the limits of Zielona Góra into two types of underground water reservoirs, which differ in the conditions, in which the water occurs, and in the size of geological structures.

The kame-sandr level of underground water was formed in sandy and sandy - gravel hydro-glacial sediments, deposited horizontally and wrapping glaciotectonically dislocated sediments of the Zielonogórski Bar from the north, east and south sides. The thickness of the water-bearing, kame-sandr stratum is variable and ranges from several to 25-35 meters. The sediments are characterized by high filtration coefficients and very favourable specific capacity amounting to 10-20 $m^3/h/l$ meter of depression. The underground waters of the horizon are characterized by excellent quality parameters. There is no need for water conditioning of many intakes of underground water of the horizon in question. In the north, waters of the kame-sandr level join underground waters of the Warsaw - Berlin proglacial valley, which have been separated into the Main Underground Water Reservoir No. 150, which is the object of special protection (see Fig. 3 and Fig. 4).

The elevation reservoir of underground waters within the limits of Zielona Góra occurs in the highest areas of the city. Elevation reservoirs formed in glaciotectonical synclines filled with sandy - gravel sediments. They are separated by glaciotectonical anticlines built with Tertiary clay and argillaceous glacial sediments of the older Pleistocene. The thickness of the sandy - gravel sediments in the axial segments of the synclines reaches 100 meters. Additional

distortions in the form of blocks moved from other places frequently appear in the area of elevation reservoirs. A number of elevation reservoirs with the dimensions of from several tens to over 150 meters in width and from several hundred to several thousand meters in length have been marked off within the city limits. Elevation reservoirs of underground water stretch in parallel to the axis of the Zielonogórski Bar and have limited spread. The yield of water intakes located in the area in question is very high: 10-30 m^3/h. Because of limited spread of water-bearing structures with unregulated exploitation of wells, water resources were often drained and water surface were lowered in large areas.

In 1970s, it was assumed that the elevation reservoir of underground water was a uniform structure. Research made in 1970 showed that the amount of exploitation resources of underground water is limited and should not exceed [2]:

a) for elevation horizons - 4 644 m^3 /day,

b) for kame-sandr horizons - 9 904 m3 /day,

with specified renew ability of the above mentioned horizons ranging:

a) 6192 m^3/d - for elevation horizons,

b) 12 494 m^3/d - for kame-sandr horizons.

If one compares the increase of population and the water requirement starting from the 1860s, it is obvious that the local underground water resources within the limits of Zielona Góra cannot satisfy the still growing requirements without any negative effects to the soil - water environment. Apart from water-bearing Quaternary horizons within the limits of Zielona Góra, intensively hydrated Miocene sediments on the depth of 199,5-355,0 meters were found (exploratory bore-hole made by the Fabryczna street on the premises of the former winery in 1980). The exploration found sub-artesian water resources. However, the technological possibilities of exploitation of the stratum have not been established.

4. WATER SUPPLY AND QUALITY OF DRINKING WATER

The development of the city based on the social and economical developed coordinated with the preservation of natural environment is called the sustainable development. The care for advantages for the city inhabitants: new jobs, aspirations to raise their living level, with the preservation of natural environment belong to the main tasks of the self-governmental authorities. The development of the city should be ordered and well-thought out. The water resources of the city and its vicinity should be the subject of special protection and wise management.

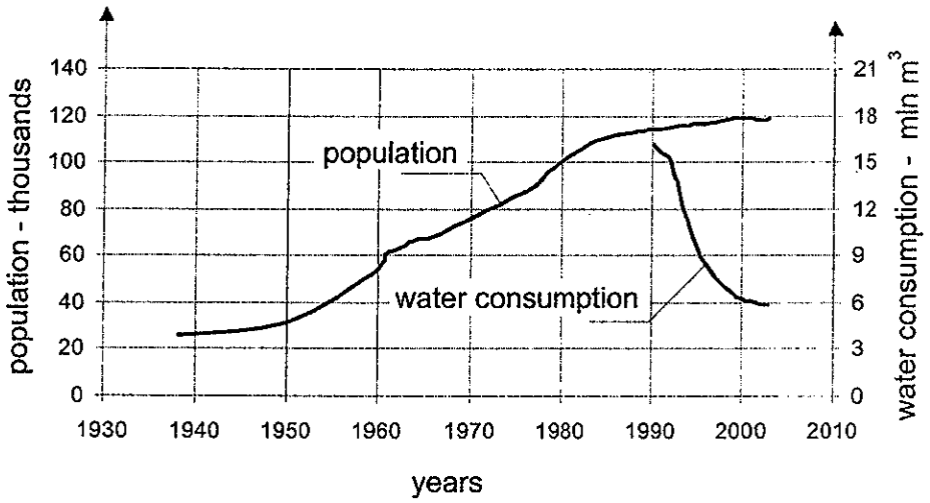


Fig. 6. Population and water consumption in Zielona Góra [Zielona Góra Water Supply and Sewage Management]

The question whether the localization of Zielona Góra corresponds to its size is very important. The localization and natural resources, water resources in particular, so vital for the development of the city, are limited, thus, so is the city expansion. Tracing the development of the city and the drinking water supply for the city inhabitants in the last period, one can see clearly that its condition is on the edge of balance. The demographic development of the city in the last 60 years has been very dynamic. Just before the Second World War, Zielona Góra was a small German town with the population of several thousand inhabitants (see Fig 6), to reach almost 120 thousand inhabitants in the third millennium. The increase of population in the city has been caused by growing birth-rate and the inclusion of surrounding villages in the administrative borders of the city: Chynów and Jedrzychów. The villages had their own underground water intakes in the moment of inclusion. Currently, the population growth is scarce, and even there is the downward trend in the number of inhabitants, which is caused by low birth-rate.

Political decisions of both city and province authorities in the recent past of the PRL (Polish People's Republic) forced the city development without any care for life-giving properties of natural environment of the city, whose capacities, especially water resources, were limited. The water deficiency in Zielona Góra, because of its hilly location, was particularly sensed in the 1960s. Abyssal wells in the city limits were not capable of supplying amount of water sufficient for the needs of the city inhabitants and rapidly growing industry. The situation was even more deteriorated, when the wells had been partly shut down.

Due to lack of water, sources of water began to be searched for outside the city. In 1966, 22 exploitation drill-holes were made in the Zawada area, located in the valley of the Oder river, 7 kilometers from the city. The intake con-

sists of a set of wells of the length of 2200 meters formed in the shape of an arch. The water resources accumulated there are estimated at approximately 48.000 m^3/day, and stem from tributaries of the Zielonogórski Bar and infiltrating waters of the Oder river. At the beginning, the exploitation amounted to 12-16.000 m^3/day. The quality of water was consistent with the norms, apart from the slightly exceeded content of iron. The excessive consumption of water caused the hydro - chemical catastrophe, which occurred in 1971. The catastrophe consisted in the rapid increase of iron and sulphur contents in water, which threatened the health of inhabitants. When the urgent search for solutions was carried out, a new source of water was taken into consideration, namely, the surface water of the Obrzyca river in the town of Sadowa, which was then considered the first class of purity. The raw water from the intake contained organic compounds and its temperature was not stable. *New* problems of water conditioning and its transport to the distant Zielona Góra arose. From this moment, the city system of water supply required extensive reconstruction. The quality of water in the drainage area of the Obrzyca river worsened with time and, in consequence, so did the quality of drinking water in the city. The content of trihalomethane was increased and the organoleptic properties of the drinking water were diminished. The organic halogens were generated in the applied process of water conditioning and passed to the drinking water. In order to eliminate these inconveniences, the Water Supply Board of Zielona Góra kept on searching for new technologies of water conditioning and kept improving the existing solutions.

The liberation transformations taken place in the country made the discussion more open and probably more aggressive. The City Council of Zielona Góra energetically joined the actions related to the improvement of water quality. The result of the above mentions actions was the passing of the resolution, which obligated the City Board to develop a study concerning the drinking water supply for the city. The State Geological Institute in Wrocław (Państwowy Instytut Geologiczny) on the order of the City Hall of Zielona Góra developed in 1998 *the study of water supply for the city of in perspective and directional periods* [7]. The study critically assessed the present system of water supply for the city; however, in the difficult situation of Zielona Góra, the study recommends to continue the usage of surface water from the water intake in Sadowa. It was deemed very important to prepare the documentation of development of abyssal wells and the method of exploitation of underground water in the city area.

The regulated intake of water should prevent the excessive exploitation of underground water, which does not take into account the amount of renewable resources. The study recommended the usage of *"high quality"* water from the Gryżyna structure in the directional period.

Currently, the quality of drinking water in the city has considerably improved. This happened mainly owing to the decrease of water consumption (see

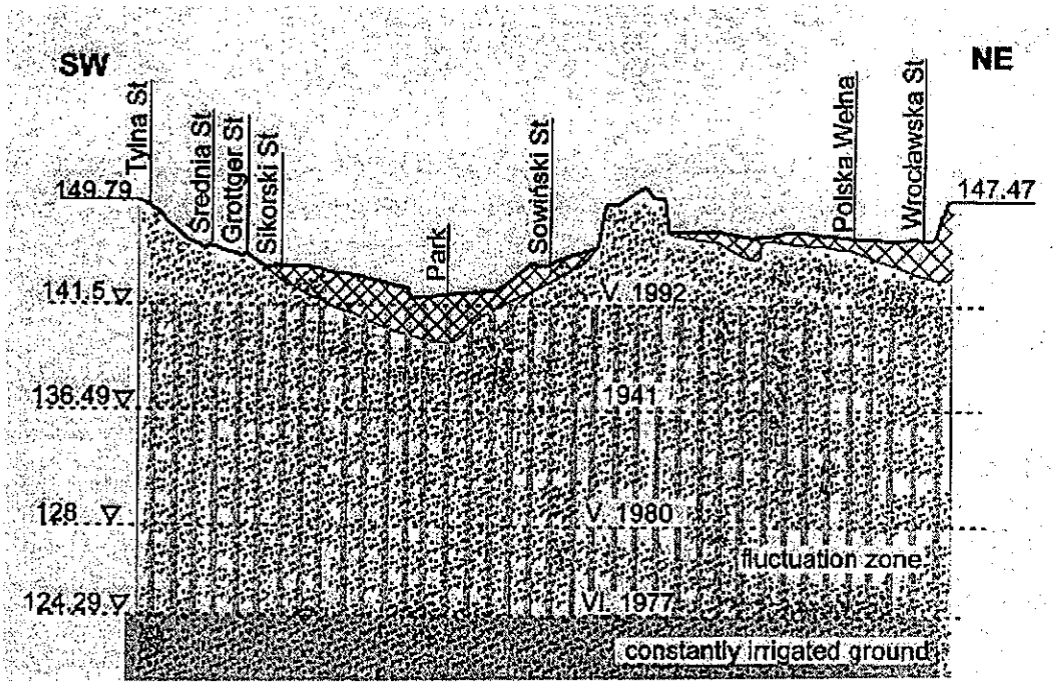
Fig. 6) and the increase of amount of abyssal water in the general mass of water supplied to the city. *„The Report on influence on the Environment of the undertaking: The ordering of the water - sewage management of the city of Zielona Góra and the commune of Zielona Góra and Świdnica"* [9] provides the percentage shares of individual water intakes: Obrzyca (surface water) - 46,7%, abyssal wells in the city area - 15,9% and the siphon type intake in Zawada - 37,4%. Water from the abyssal wells does not require any conditioning, unless its iron content is increased. The elimination of iron does not require too complicated technologies, which consists mainly in the aeration of water. The stable temperature of abyssal water in comparison with variable temperature of surface water, which is dependant on the weather, is very important. It has to be pointed out that the water intakes of a siphon type, in Zawada are not exactly of abyssal type, because of the presence of organic compounds [8,10]. In this case, the process of conditioning should be similar to the conditioning process of surface water.

The improvement of the water quality is also the result of continuous efforts of the Water Board of Zielona Góra to refine the conditioning technology by using better and better chemical compounds, constant monitoring of water and precise dosing of chemical agents used for water conditioning.

The process of water conditioning produces considerate quantities of post-production waste in the form of deposits collected in lagoons [Zielona Góra Water Supply and Sewage Management]. The deposits are derived from washings on microsieves and high-rate filters and form an excessive deposit from the process of water clarification. In the last 5 years, the waste quantities amounted to respectively: 2000 - 475,4 t, 2001 - 447,6 t, 2003 - 407,11, 2004 - 416,8 t. The iron hydroxide makes up over 50% of the waste, while aluminium hydroxide, phosphates, manganese dioxide and other organic suspended matter make up the remaining part. The waste is not toxic, however it is not neutral to the environment, because it forms an additional burden and requires a storage space. The formation of waste products in the process of water conditioning is yet another argument for the usage of abyssal water to supply the city with drinking water.

The sustainable development of Zielona Góra should provide sufficient amounts of good drinkable water for the city. The prudent water management consists in the creation of conditions for the storage of water. The hilly lie of the land, on which the city is situated, is disadvantageous and does not favour the storage of water, which flows towards the forests owing to the gravity. In turn, large stretches of forests in our province favour the storage of water. For example, the area of "burnt forest", which is now considered an investment area, used to play a useful role of the fresh water reservoir. Taking a care of forests is the main task of a good manager.

5. THE SUSTAINABLE MANAGEMENT OF WATER RESOURCES IN ZIELONA GÓRA



Furthermore, we do not seem to notice that water is the matter, which can occur in different physical forms in the same conditions of pressure and temperature. This is the reason why it was in the past, as it is even now difficult to manage water resources. Many mistakes and errors have been made in the management of water resources of Zielona Góra, which, inconsequence, have led to:

- the destruction of the largest stream, the Złota Łącza, and a number of smaller streams and springs in the area of Zielona Góra,
- the excessive exploitation of underground water in the higher parts of the city has led to the lowering of the level of surface water by approximately 20 meters (Fig. 7). As a result, many old trees in the centre of Zielona Góra have dried up and old lime trees at the Niepodległości Avenue have died.

Various components of the water balance have to be recognized and the strategy of water management has to be established on that basis in order to conduct a sustainable management of water resources in a selected area. It has to be pointed out that ***the quantity of water in nature is constant.*** The water is continuously circulating and it is continually changing its form of occurrence. Assuming that, in a long specified period of time, the quantity of water resources in a selected drainage area or in its sections is constant, then, it is

best to use the water balance equation in order to make a sustainable water management decision.

The mutual relations of precipitation P, run-offs H, area evaporation S and retention changes R is defined by the curtate Penck formula for water balance:

$$P = H + S \pm R \tag{1}$$

In the hydrology, the practical determination of the size of both underground and surface run-off is very important for the determination of the feed size of the underground water level.

The amplitudes of the underground water level calculated for the Highland of Zielona Góra (Wysoczyzna Zielonogórska) in the years of 1968 - 1970 on the basis of measurements in the network of piezometres have made it possible to estimate the water balance for the area. The basic elements of the water balance have been shown in the table below:

Table 1.

Water balance components	in mm	%
Area evaporation - S	305.0	67.6
Underground run-off - H_{und}	105.0	18.4
Surface run-off - H_{sur}	80.0	14.0
Total mean annual precipitation - P	570.0	100.0

The obtained quantity of the underground run-off in the amount of 105 mm annually should be considered dynamically renewable, variable resources from the first Quaternary level of the underground waters for the Highland of Zielona Góra (Wysoczyzna Zielonogórska) [4]. The value of 105 mm of the underground run-off for the elevation area of Zielona Góra should be treated as disposable resources, with the necessity to systematically monitor the water surface and the intake quantity of the underground water intakes in the area.

The hydro - geological situation in the so called kame-sandr area, which covers the northern parts of Zielona Góra, and which was included in the Main Reservoir of Underground Waters no. 150 - the Warsaw - Berlin Post-glacial Valley, is characterized by very favourable resources and incomparably good quality of water. The area located among Zielona Góra, Płoty and Czerwieńsk should be treated as perspective areas for supplying water to Zielona Góra.

The surface water resources of Zielona Góra are very sparse. The stream ***Pustelnik*** (formerly the Srebrzanka), on which the biggest recreational resort in Zielona Góra was built, should be given special attention. However,

even here some hydrological errors have been made, because too large reservoir areas have increased the evaporation. This, in turn, has led to the lack of water in many reservoirs down the recreational reservoir. The balance analysis has not been carried out to guarantee the flow necessary to maintain the biological life.

The streams Gęśnik and Dłubnia require the making of complete hydrological inventory and the preparation of their valley space development plan.

The atmospheric precipitation in the amount of over 600 *mm* a year (mean value of the last 40 years) makes Zielona Góra relatively affluent in this type of waters. According to the climate ariolity meter based the mean precipitation value for a given area, Zielona Góra is ranked as the low humidity climate of $500\ mm < P < 700\ mm$. The Zielonogórski Bar forms „an island" among the mild dry climate areas of $250\ mm < P < 500\ mm$. The practice of collecting precipitation water for drinking and industrial purposes has not been developed in our conditions. In the 1980s, The Institute of Environmental Science And Technology in Zielona Góra carried out an analysis and research on the possibilities for collecting roof water and supplying to households, greenhouses and other facilities. The research results were very encouraging. 50-70% of all annual water needs for 4-5-person family can be obtained from a *150 - 200* m^2 roof area. If we take into account that there over 12 million single-family houses, then, we contribute to gathering a considerable amount of water by collecting roof water, which irretrievably flows to the sea. Thus, we can contribute to even more sustainable management of underground and surface waters.

6. SUMMARY

1. The intensive demographical development of Zielona Góra as well as the development of different water-consuming branches of industry in the 20th century did not permit to fully satisfy the water requirements in the area of Zielona Góra. This has led to the necessity to supply water from outside the city limits. The hydro - chemical catastrophes, which took place of 1966 and 1968, forced both the limitations in water consumption from wells and the search for other sources of water. The bank water intake on the Obrzyca river was built in order to fully cover the water deficiency. However, the water has periodically variable qualitative parameters, and frequently does not meet the chemical and organoleptic requirements of the first purity class. The process of water conditioning is very complicated and does not fully satisfy the requirements.

2. The water resources of Zielona Góra arę not abundant. Over the centuries, the biggest stream of Złoty Potok has lost its character of a natural stream to become a sewage channel. In addition, a number of smaller streams and springs have disappeared in the city area. A petrol station has been built on the last beating spring in the city between the Drzewna street and the Konstytucji 3-go Maja avenue.
3. The further demographic and civilization development of Zielona Góra can be realized provided that the following conditions are met:
   • Supplying water from underground water intakes from outside the city limits from high quality water deposits. The perspective areas for building underground intakes can be:
     • underground water deposits occurring in the area of Gryżyna -GZWP no. 148 (Main Underground Water Reservoirs),
     • water-bearing areas north of Zielona Góra in the area between Przylep and Czerwieńsk on the northern peripheries of GZWP (Main Underground Water Reservoirs) no. 150 (see maps Fig. 3 and Fig. 4).
   • The introduction of rational and regulated water management in the existing resources of underground waters occurring in the administrative limits of the city.
4. The sustainable management of water resources in the city area should consist in:
   A. In terms of underground waters:
      • The exploitation of underground waters in the capacity not exceeding the amount of renewable resources,
      • The systematic monitoring of water table on the piezometres in the city area and on the city wells managed by ZWiK, which are adapted to measurements and currently excluded from exploitation. The measurements should be synchronized with the taking samples of water for laboratory tests in order to determine selected indicators. Reports should be prepared on the basis of measurements taken and their result should be published in the bulletin of the City Hall. This will constitute the material for analysis of underground water states in the city and the data for constructors necessary for proper specification of foundations.
   B. In terms of surface waters, in order to properly use this type of water, it is necessary to:
      • make complete hydrographical inventory and register of hydrotechnical management of the following streams: the Pustelnik (formerly the Srebrzanka), the Dłubnia (formerly the Brzeźniak), the Gęśnik(formerly the Moczydło),
      • the conception of stream valley management can be developed on the basis of the inventory.
   C. In terms of larger utilization of water resources, Zielona Góra has very favourable location on the watershed of the Zielonogórski Bar and increased atmospheric precipitation, amounting to 636 mm (annual mean value).

The precipitation permits to include the area of Zielona Góra in the low humidity climate (500-700 mm/year). The physical and geographical areas surrounding the Zielonogórski Bar are ranked among the mild dry climate areas (250-500 mm/year). More attention should be paid to water from atmospheric precipitation, because of climatic changes occurring on our planet, which influence the arrangement of water resources. According to the Self-governmental authorities, there should be:

- the separation of precipitation water from city sewage,
- a part of the precipitation water should be stored in reservoirs built for that purpose, which apart from aesthetic values could also collect water for emergency situations,
- the usage of precipitation water for the needs of single-family houses.

In the area of Zielona Góra and its vicinity, the precipitation waters should cover even 50% of water requirements of single-family households, farms and greenhouses. Precipitation waters of many countries in the Mediterranean Sea basin satisfy the requirements of their inhabitants. In some of the countries of the European Union, it is obligatory for individual housing development to design installations for storing rain water and its utilization for household needs and maintaining cleanliness.

The above mentioned resources for creating programs of more rational management of water resources occurring in the operational area of the local government contributes to more sustainable management of the very difficult environmental resources. The issues of forecasting and management of water resources should be realized by an administrative unit of the City Hall, which deals with the environment protection.

The water resources and water management in the world is one of the most important issues of humankind. The amount of pure and drinking water, which is the source of life, is decreasing. Therefore, the water supply is the strategic task for the inhabitants of the Earth. In comparison with the World and Europe, Poland has very limited water resources, which are characterized by high instability and irregularity of occurrence [11].

Zielona Góra and its vicinity have very unfavourable conditions for water supply due to its geographical location. The hilly lie of the city favours the water run-off, colloquially speaking, *„water does not hold to the city area".*

The self-governmental authorities should develop a water retention programme and put it in practice. Water should be collected in the city through the building of new water reservoirs and fountains. The cutting down of forests and individual trees should be forbidden. Instead, special attention should be given to their regeneration. Forests create an ecosystem, which is favourable for water retention. Inner sources, such as abyssal wells in the city area should be protected and exploited in a very ecologically-oriented and wise manner.

The city authorities should assess and estimate the water resources and revise the water management, so also the supplying Zielona Góra with drinking water in directional and perspective dimensions. Specialist studies have already been made. Now, it is sufficient to return to the study and analyse it.

The development of industry can not made at the expense of the natural environment, especially in such a naturally sensitive city as Zielona Góra. The quantity of water being sold should not be the criterion for the quality of the Water Board. Economic activities in the city should be subordinated to the possibilities of the natural environment and should not disturb both the natural and water balance. *The water management should be recognized as the element of the sustainable development of the city of Zielona Góra.*

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ZASOBY WODNE ZIELONEJ GÓRY ELEMENTEM JEJ ZRÓWNOWAŻONEGO ROZWOJU

Streszczenie

Przedmiotem pracy jest przedstawienie procesów rozwoju źródeł wód podziemnych i zarządzanie nimi na przykładzie Zielonej Góry. W pracy pokazano, że zarządzanie wodami podziemnymi powinno być elementem zrównoważonego rozwoju miasta. Gospodarka w mieście powinna podlegać możliwościom środowiska naturalnego i nie powinna zakłócać równowagi wodnej.