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Zdzisław Mikulski

THE NOTION OF WATER RESOURCES — THEIR TYPES AND CHARACTERISTICS

The notion of water resources has not been precisely defined. According to L'vovich (1979) this notion refers to the "waters which can be used, thus almost all waters of the globe (rivers, lakes and seas, underground and soil water, glacier and polar cap water, vapour in the atmosphere), with exception of water bound in minerals and biomass". This is certainly the most general formulation of this notion, as expressed in the title of the book *Water Resources of the World* (Polish translation). A similar title bears the UNESCO monograph *World Water Balance and Water Resources of the Earth* (Paris 1978). The latter monograph deals, in principle, with the quantity of water on the globe. In this monograph, a comparison of the volumes of all waters on the Earth is entitled "World water reserves". Similarly, when considering individual hydrographic objects, the notion of "water reserves" (stored in ice and glaciers, in the great lakes of the world and in the upper layer of the lithosphere) is used. When, however, the book deals with the annual renewal of water volumes, the notion of "resources" is used, as in the case of the annual renewal of the underground waters. Thus in Russian, a distinction is made between the terms "resources" and "reserves".

According to Chebotarev (1978) the notion of "water resources" denotes the "resources of surface and underground waters of any given area". Furthermore: "Taking into account the relatively small volumes of utilized underground and lake water, the notion of water resources of larger areas is usually understood as annual river runoff. With respect to separate economic regions the assessment of water resources is made with consideration of underground and lake waters". Unfortunately, this definition is neither clear nor unambiguous. The same author expands it with regard to underground waters: "In hydrogeology, 'reserves' are distinguished from 'resources', with the notion of 'resources' being applied to the characterization of these volumes of underground waters, which are recharged in the water cycle of the globe (natural resources of underground waters), and the notion of 'reserves', to the characterization of the general volume of underground waters in the earth's crust, within the limits of a given region".

The most recent German handbook of hydrology (Baumgartner, Liebscher, 1990), in the chapter on the waters of the Earth's hydrosphere, treats separately the amount of water on the globe (*Wasservorkommen,* called in other German publications *Wasservorraete*) and water in the hydrological cycle on the earth (*Wasserumsatz*), that is, the amount which is generally understood under the notion of water "resources". Similarly, in the English-language literature a distinction is made between the amount of water (water reserves) and water in the hydrological cycle (water resources). Taking this into account, one should consider both the overall amount of water on the globe (either direct volumes or water layer) and the amount of water circulating on the Earth, expressed in volume per unit of time (e.g., in cubic km/annum in the case of the globe, or in cubic m in the case of a river basin).

A very concise definition is provided by the *International Glossary of Hydrology* (1992): "Water available, or capable of being made available, for use in sufficient quantity and quality at a location and over a period of time appropriate for an identifiable demand". Additionally, the notion of "water resources assessment" is also defined: "Determination of the sources, extent, dependability and quality of water resources for their utilization and control".

Let us now try to define more precisely the notion of water resources of a specific area. Shiklomanov (1988) gives the following definition: "Water resources of any administrative region are defined through the listing of the following flow characteristics: total flow in the region, river inflow and outflow [of the transit rivers — Z.M]. The total flow in the region equals the flow of all the rivers and temporary water flows of the region; the river inflow is the volume of water brought to the region from the outside; the river outflow, the volume of water flowing out of the region through all the rivers and temporary water flows. The sum of the values of the regional flow and the river inflow represents the totality of the river water resources of an administrative region." In our case this will refer to the areas of the majority of Polish provinces (voivodships), through which larger rivers often flow.

The definition proposed by Kaczmarek (1978) is relatively precise: "Water resources of a country or a region are usually measured by the volume of water produced within a given area within a definite interval of time, due to atmospheric processes." The same author indicates then the magnitude of atmospheric precipitation, major part of which returns to the atmosphere through evaporation, with the remaining part feeding rivers, lakes and underground water reservoirs, i.e., the waters which are treated as water resources of the country. Thus we arrive at the notion of the river runoff, whose magnitude determines water resources of an area (of a catchment area or a country). This more precise notion of the surface water resources has become officially accepted in Poland. It is, however, somewhat oversimplified and not sufficiently precise when we consider simultaneously the underground water resources, which are, after all, linked with the surface waters; at the same time it is closely dependent upon precipitation.

Water resources should be treated in the perspective of their use. The needs of agriculture, forestry and vegetation in general are satisfied primarily by precipitation. Therefore, in our geographical zone the notions of excess or, more often, of shortage of precipitation have been in use for a long time. Maps of precipitation shortage are made for agriculture. This constitutes the motivation for the assessment of the magnitude of water vapour resources in the atmosphere, moving over the given area. Today, thanks to meteorological observations, we can evaluate with a definite precision the resources of water vapour in the atmosphere over a country. These resources are decisive for the magnitude of precipitation, that is, for the quantity of water reaching the area of a country (region, catchment area). In this way we obtain the magnitude of (gross) water resources, which can be used in such important sectors of national economy as agriculture and forestry.

A systematic attempt at the evaluation of the vapour transport over the territory of Poland was undertaken by Lenart (1983). It is to be hoped that further efforts will bring positive effects and will make it possible in the future to evaluate the quantity of water vapour transported over Poland.

The evaluation of the magnitude of precipitation in Poland has been conducted for many years, resulting in increasingly longer observation series, including most recent observations. *The Hydrological Atlas of Poland* (1986, 1987), contains tables and maps of precipitation from the period 1951-1970. The values of precipitation are given for selected catchment areas. Recently, the tables and maps for the period of 1961-1990 have been also prepared. Unfortunately, these tables and maps present directly measured, uncorrected, values of precipitation. For many years it has already been known that the values of precipitation measured with standard devices (Hallmann's rain-gauges, pluviographs) are charged with a significant error, especially in the case of the so-called solid precipitation (snow, hail, granular snow). In the geographical conditions of Poland the measurement error, averaged over a year, is approximately -20%. Thus the true magnitude of precipitation, and therefore the magnitude of water resources in this group, are systematically underestimated. Consequently, the calculations of water balances significantly diverge from reality, and this is in particular true of the systematic calculations conducted in the experimental catchment areas.

First efforts to correct the measured precipitation were made in the hydrometeorological service during 1970s (Chomicz, 1976, 1977). Studies in this field were initiated in 1980s at the Mazovian Geographical Observatory of the University of Warsaw. Data from the meteorological service were

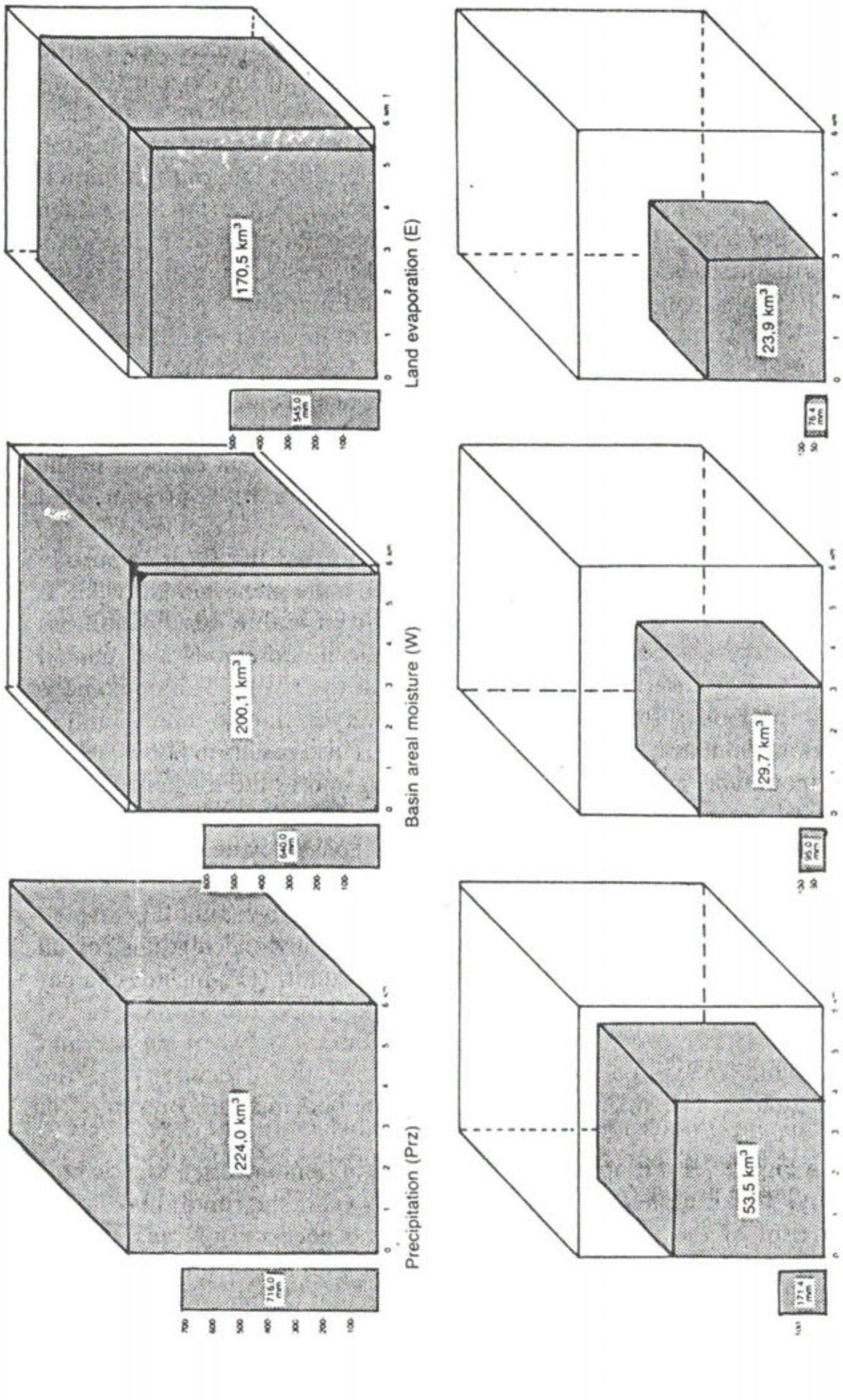

Fig. 1. Elements of water balance in Poland (after Gutry-Korycka, 1985, and Mikulski, 1990)

used by Gutry-Korycka (1985) for the new calculation of the water balance of Poland. For the first time the water balance of Poland was calculated using the so-called true precipitation values (Fig.1). These calculations, though, apply to an already distant period of 1931- 1960, the new period still not having been thus analysed. A concise information on the state of water resources in Poland has been recently provided by Mikulski (1990).

Yet, the basis for the water resources of an area is the river runoff during a year, this quantity being subject to cyclical renewal; these are the gross resources. The net resources (also called effective resources) are the "maximum values of the runoff from a given area, which can be, in principle, used by the economy without disturbing the biological equilibrium of the waters, with consideration of their quality" (*Environmental Protection*, 1991). The net resources constitute therefore the difference between the gross resource value and the biological minimum, the latter being usually calculated on the basis of multiannual average flows. The criteria of definition of the biological minimum flows of rivers constitute, of course, a subject of separate discussion.

In the assessment of gross water resources on the basis of river runoff it is necessary to account for its random character. It should namely be "treated as a non-stationary stochastic process, with parameters subject to annual periodicity". Due to this, "the net resources, meant for use, are much lower than the previously given nominal values" (Kaczmarek, 1978). The magnitude of the net resources defined this way depends upon the adopted probability of their availability to the users (e.g., 90%-95%), these being the so-called guaranteed resources.

We have thus come to the issue which is essential for the evaluation of the total (summary) water resources, surface and underground. Thus, namely, according to the most recent calculations of the water balance of Poland (Gutry-Korycka, 1985), the surface component of the river outflow constitutes only 45% of its value, while the underground component, as much as 55%. This means that rivers are primarily fed from the (shallow) groundwaters, which are simultaneously referred to as an essential part of the underground water resources. Thus, we are witnessing here an alarming phenomenon of "amplification" of a part of water resources of an area through their double accounting.

It is therefore imperative to establish which of the underground waters feed the rivers (the so called shallow, or potamic, groundwaters) and are therefore also included in the calculation of surface waters. This question has to be resolved by the hydrologists and hydrogeologists working in cooperation. It is also necessary to introduce corrections to the magnitude of the underground water resources, calculated and announced by the state geological service.

The resources of the underground waters of deeper horizons require further, more precise assessment, based upon the increasingly better hydrogeological survey of the country. A separate matter, given inadequate attention until now, is the recharged intensity of these waters. Knowledge of resources renewal is necessary for preservation of the constant level of availability of these waters.

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