



DIRECT GROUNDWATER DISCHARGE TO THE BALTIC SEA IN GDAŃSK REGION

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Abstract. In Gdańsk region groundwater discharge into the Baltic Sea varies largely along the coast. This is due to variability in lithology, permeability and morphology of different formation (sediments of Quaternary, Tertiary and Cretaceous). About 95% of groundwater is drained by hydrographic system (rivers, polders). Only a small part of this water, participating in circulation system, flows directly to the Baltic Sea in Gdańsk Region. Largest flow is observed in the area of Coastal Terrace, western part of Vistula Delta Plain and Kaszuby ice-marginal valley.

Key words: groundwater, dynamics of groundwater, aquifers.

Abstrakt. Odpływ wód podziemnych do Morza Bałtyckiego wzdłuż linii brzegowej jest w regionie gdańskim znacznie zróżnicowany. Decyduje o tym litologia, przepuszczalność i morfologia różnych osadów: czwartorzędowych, trzeciorzędowych i kredowych. Około 95% wód podziemnych jest drenowana przez system hydrograficzny (rzeki, poldery). Tylko niewielka część tych wód bierze udział w bezpośrednim odpływie do Morza Bałtyckiego. Największe przepływy obserwuje się w obrębie tarasu nadmorskiego, zachodniej części Żuław Wiślanych i pradoliny Kaszubskiej.

Słowa kluczowe: Wody podziemne, dynamika wód podziemnych, poziomy wodonośność.

INTRODUCTION

This paper presents groundwater conditions in Gdańsk region, a general scheme of groundwater circulation, and directions and areas of groundwater flow to the Baltic Sea. The study area included several geographical regions: lake districts, zone of coastal plains including Żuławki Wiślane, zone of coastal uplands and Reda–Łeba ice-marginal valley (Fig. 1). Highest elevations occur in the lake districts, with the highest point — 329 m a.s.l. located in the Kaszuby Lakeland. In the uplands, elevations vary from 40 to 150 m a.s.l. The Reda–Łeba ice-marginal valley, the coastal terrace, and the sandbars show elevations from several to 50 m a.s.l. Lowest elevations are known from the Żuławki Wiślane area: 2 to 10 m b.s.l. Thus, a part of the Żuławki Wiślane area is a depression.

The study area is covered with dense river system. Rivers are generally short, rarely exceeding the length of 150 km. The most important rivers are: Łupawa, Łeba, Piaśnica, Reda, Radunia, Motława, Nogat–Liwa and Elbląg. Attention should be paid to the Żuławki Wiślane area where the Vistula River shows a transitional character. The Żuławki Wiślane area is drained by the polder system. The Hel Peninsula and the Vistula Sandbar do not belong to the drainage basins considered in this project. Therefore, this paper concerns groundwater flow in coastal zone from Ustka City to Vistula Lagoon, only. This is more or less 200 km distance. Total area drained by rivers to the Baltic Sea is 10,000 km².

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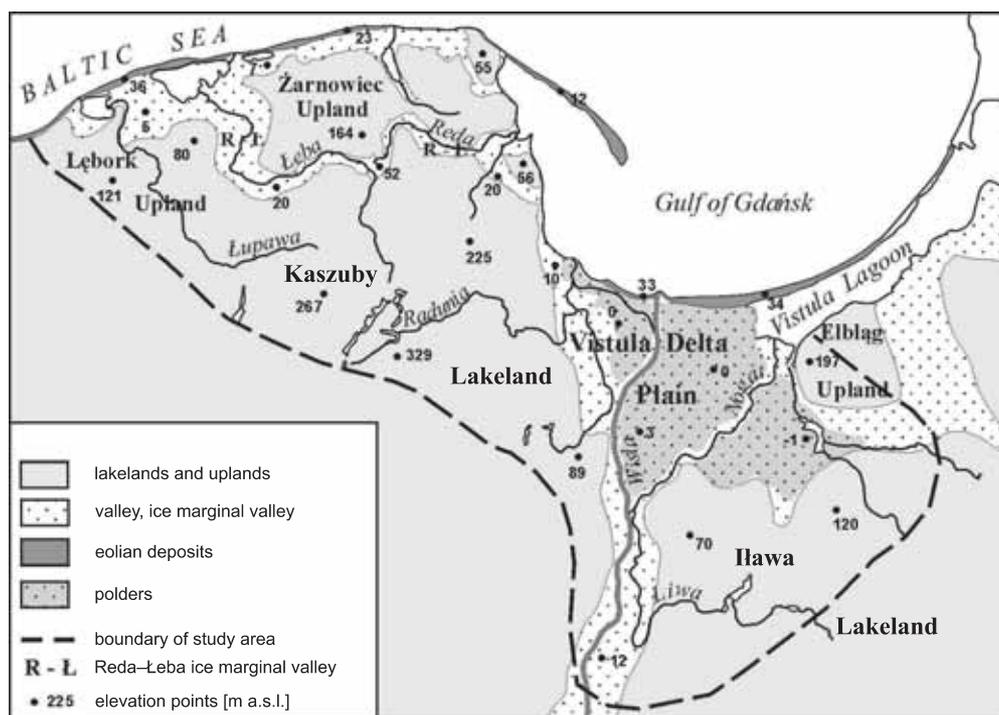


Fig. 1. Map of Gdańsk region

HYDROGEOLOGICAL STRUCTURE

The groundwater system includes three multi-aquifer formations which correspond to three stratigraphic units: Quaternary, Tertiary and Cretaceous (Kozerski, 2001). The groundwater horizons in Quaternary formation are related to intermoraine sediments, river valleys, ice-marginal valleys, and also to Holocene deposits in Vistula delta and in the sand bars. The Tertiary formation is comprised of Oligocene and Miocene groundwater horizons. The Miocene horizon commonly

shows hydraulic connection with the intermoraine aquifers. The Oligocene horizon is very well recognised in the coastal zone, only. The Cretaceous formation includes vast aquifer known as “Gdańsk Sub-trough” — sand series. The aquifers are separated by aquitard layers of clay, silt, and glacial till of varying thickness. Fresh water appears to the depth of about 200–400 m in pore space in Quaternary, Tertiary and Upper Cretaceous.

RESULTS

Morphology of piezometric surface of the Quaternary groundwater formation is very diversified. Drainage areas related to main rivers, their tributaries, and lakes can be identified together with boundaries of groundwater basins which reflect the topographic divides of coastal rivers (Paczyński, 1995). Only small part of the study area participates in the direct groundwater recharge of the Baltic Sea. Direct groundwater flow occurs only in small basins of poorly developed rivers system as well as in the direct Baltic Sea drainage basin which is marked by the culminations of dune ridges. This area is generally limited. Groundwater flow within the Tertiary formation (Oligocene horizon) is also directed towards the Baltic Sea. However, the main drainage bases are related to the main coastal rivers valleys, to the ice-marginal valleys, to the coastal plain in the vicinity of the Łebsko Lake, and to the Żuławy Wiślane area. As a result, only a part of these waters reaches the sea shore and is drained to the Baltic Sea (Lidzbarski, Kordalski, 2003).

The largest area of groundwater flow towards the Baltic Sea is related to the Cretaceous groundwater formation. Its boundaries reflect roughly the topographic divides of coastal rivers. A part of groundwater from this formation is also drained into the deeply cut ice-marginal valleys and into the Żuławy Wiślane area.

Figure 2 summarised areas of direct groundwater discharge to the Baltic Sea in comparison with study area. Attention should be paid to area of Cretaceous aquifer which is exceeding the referred area.

Region of Gdańsk includes local, indirect and regional groundwater circulation systems. Groundwater from local circulation systems does not contribute to the recharge of the Baltic Sea except for the coastal areas. Groundwater belonging to indirect circulation system participates partly in the recharge of the Baltic Sea but the one belonging to regional circulation system — Cretaceous sand series — participates fully in the discussed recharge.

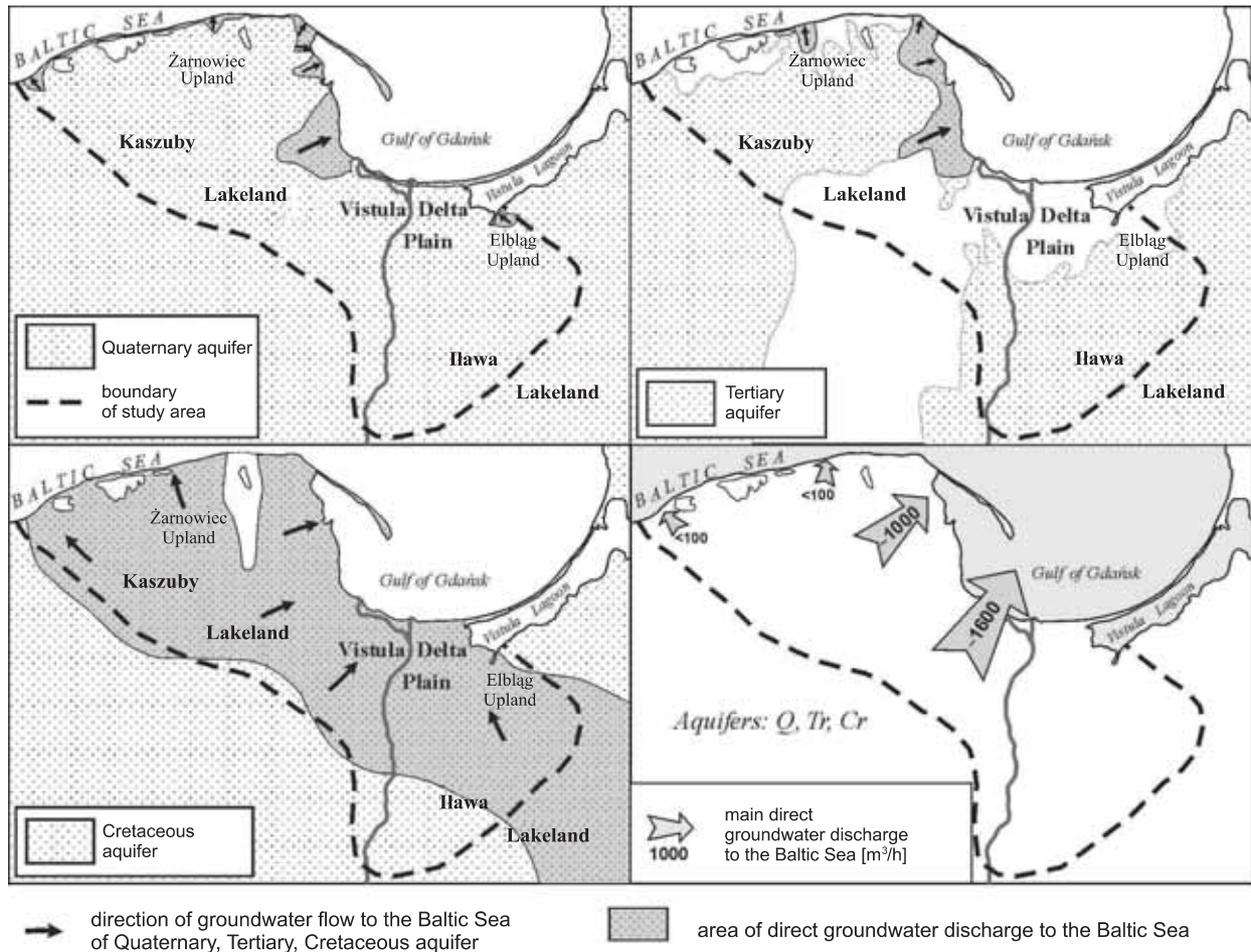


Fig. 2. Areas of direct groundwater discharge to the Baltic Sea

CONCLUSIONS

Concluding, only a small part of groundwater participating in circulation system flows directly to the Baltic Sea. About 80 to 90% of these waters is drained by hydrographic system. This opinion is supported by very high values of specific underground runoff modulus: from 5 to 15 l/s·km² (Pietrucień, 1983). An exception is the Żuławy Wiślane area where low values of specific runoff modulus were indicated. However, the prevailing part of groundwater does not reach the sea, being drained by the polder system (Fig. 2).

Figure 2 illustrates principal directions of underground recharge. Largest flow is observed in the area of Coastal Terrace, western part of Vistula Delta Plain, Kaszuby ice-marginal valley, and the eastern part of Żarnowiec Upland. The flow rate in these places exceeds 1000 m³/h, within Cretaceous and Tertiary aquifers mainly. In another place the groundwater flow rate rarely exceeds 100 m³/h (Kulma *et al.*, 2002; Lidzbarski, Kordalski, 2003).

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