

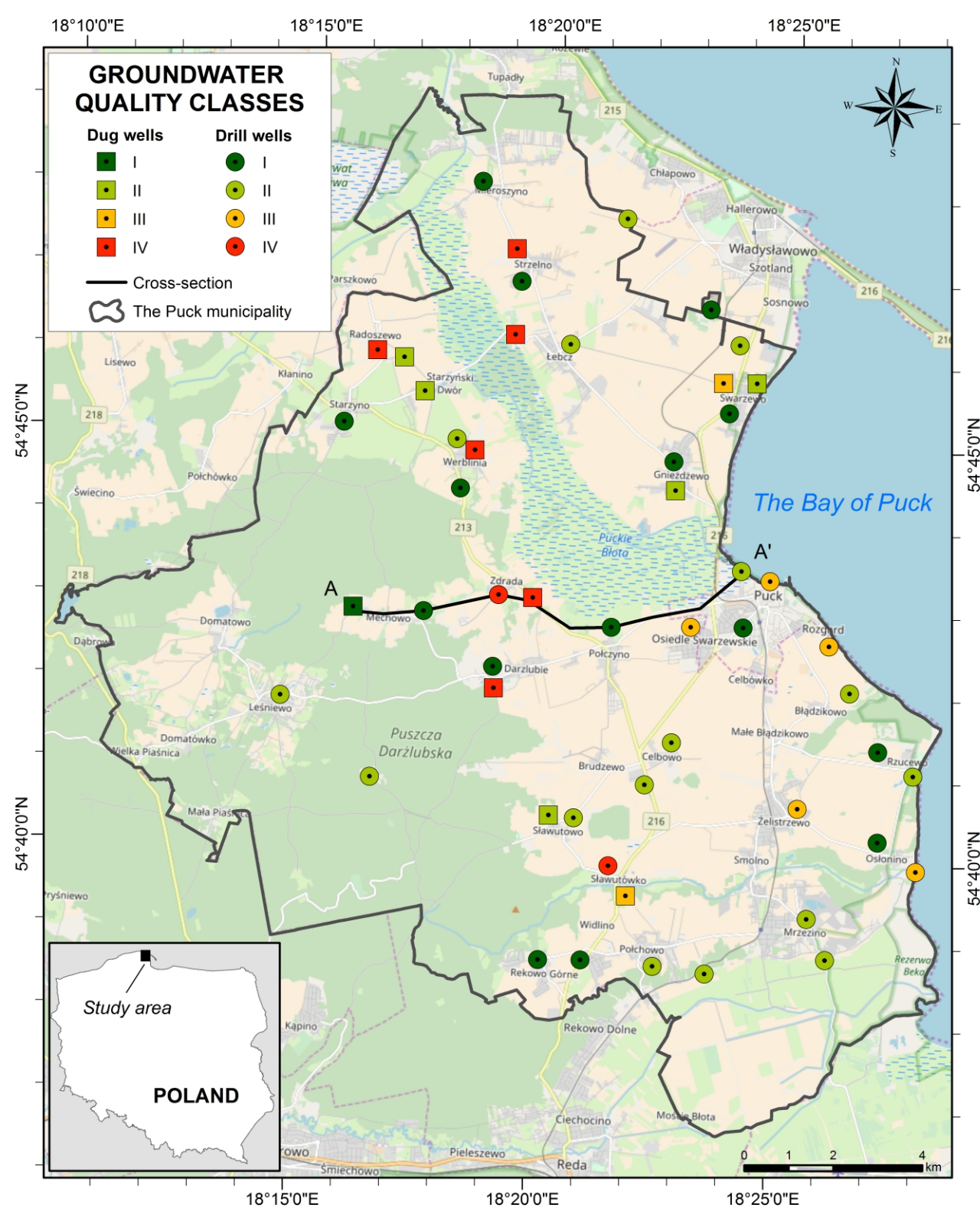
INTRODUCTION

The issue of groundwater quality degradation is one of the most significant problem for water supply and environmental condition. Presented study shows the preliminary assessment of groundwater pollution in the Puck Municipality area. The particular role was paid to the classification of groundwater quality, which was estimated on field surveys and archival data. The composition of basic pollutant indicator in groundwater exploited with dug wells and drill wells have been compared.

The conducted research is a part of a project which main aim is a development of groundwater contaminant transport model and detailed identification of potential agriculture pollutant sources in the selected watersheds of the Puck Bay.

AREA OF STUDY

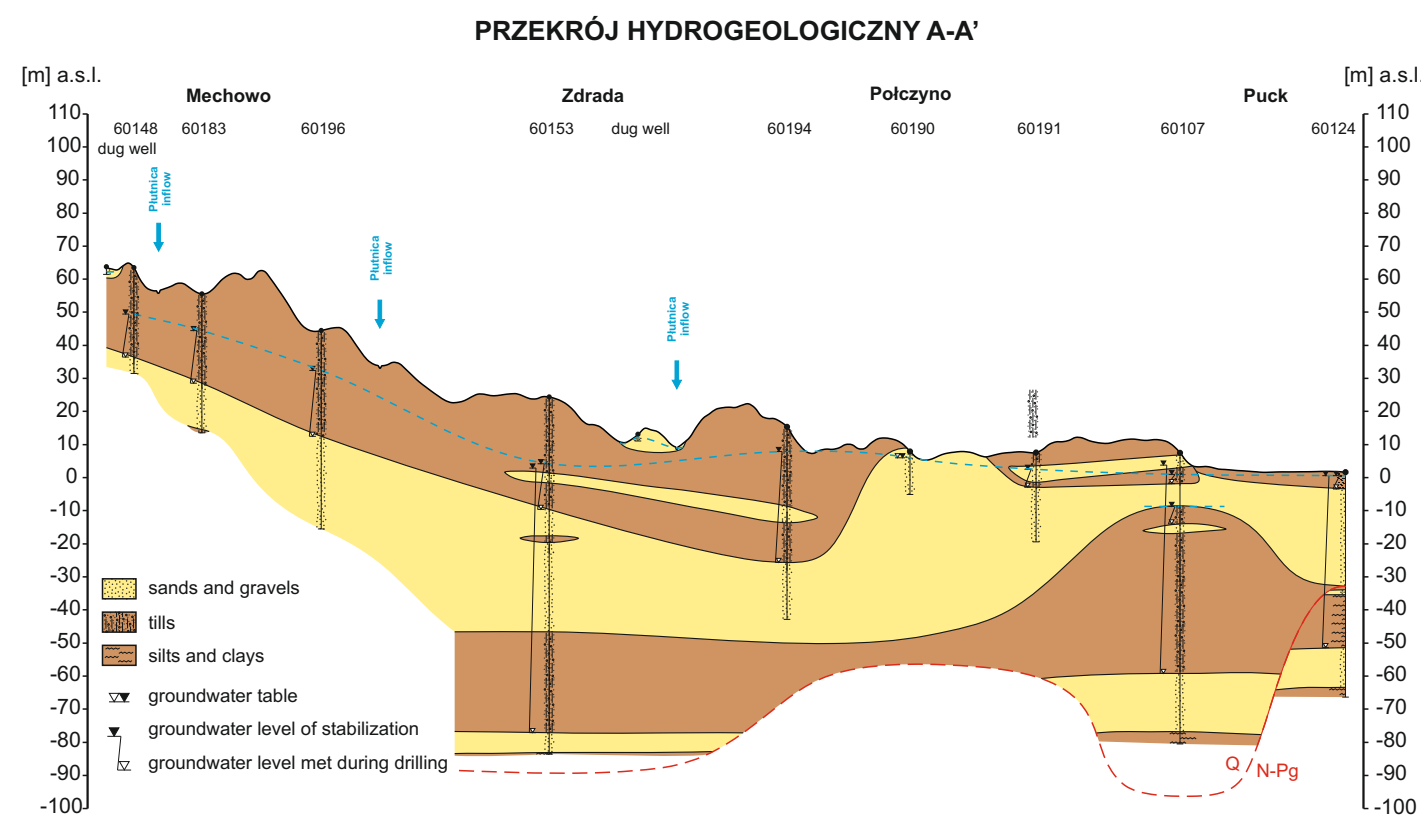
The Puck Municipality is situated in Pomeranian Voivodeship (northern part of Poland), at the western coast of the Bay of Puck (southern Baltic Sea) (Fig. 1). The vicinity of Baltic Sea creates a specific marine climate in this region, which characteristic features are moderate winters and mild summers. The income of local inhabitants comes mainly from agriculture, fishery and tourism, related to the seaside location and unique environmental values of this region. The Puck region together with the Bay of Puck is an example of area that sustainable growth and management is challenging task due to its complex structure (Korzeniewski, 1993).



Research area is situated in the eastern part of the Kashubian Coastland mesoregion, which is a type of young glacial area with significant differences in a terrain. The landscape of this region creates a network of isolated morainic uplands separated by deeply cut ice marginal valleys of which the two largest ones are now used by Plutnica and Reda rivers. The geological structure of quaternary has mosaic character, making this region distinct from other parts of Polish Lowlands areas (Sokolowski [ed.], 2014). Moraine uplands mainly consist of till deposits, which are divided by series of fluvio-glacial sediments (sands and gravels). Glacial valleys are covered by extensive peat wetlands and consist of fluvio-glacial sediments.

OCCURRENCE OF GROUNDWATER

The analyzed region is an instance of a hydrogeological diversified region where various groundwater occurrence is observed (Fig.2). Locally, at depths up to 5–10 m below surface, groundwater occurs in subsurface sands (a type of perched aquifer) laying on till deposits. In the Puck Municipality area, two quaternary aquifers adequate for water supplies have been identified (Frączek 1998). They consist of fluvio-glacial sediments series (sands and gravels) which separate till deposits. The upper aquifer has discontinuous character with significant thickness variations, which exceed 100 m. The lower aquifer locally stays in contact with paleogene-neogene sediments and together create continuous aquifer with a thickness about 10-20 m. Both aquifers are hydraulically connected, especially in deeply cut ice marginal valleys. Aquifers are mainly confined on morainic upland areas (Pucka and Swarzewska), on glacial valleys (Reda and Plutnica) its unconfined and locally confined by peat appearing on the surface.



Groundwater recharge of the aquifers takes place on moraine uplands. However, direct infiltration is difficult due to low permeable till sediments laying on the surface, therefore great importance is assigned to lateral inflow. Locally, the perched aquifers can fulfill a significant role in indirect recharge of the lower aquifer by slow seepage. The main discharge areas of quaternary aquifers are deeply cut ice marginal valleys. Both aquifers are also drained by the Bay of Puck, the shallow one has direct contact with the seaside, while the deeper aquifer has an outcrop in the sea bottom, where submarine discharge predominates.

GROUNDWATER QUALITY

Initial assessment of groundwater pollution in the Puck Municipality area was estimated on groundwater quality recognition. The groundwater quality in dug and drill wells have been compared. The hydrogeochemical data have been obtained from field surveys and archival data.

The scope of field studies includes measurements of physicochemical parameters, such as temperature, pH, redox potential and mineralization (TDS). The investigations were carried out in selected wells during the summer and autumn of 2017. The results of field studies were presented in table 1.

Tab.1. Preliminary results of groundwater physicochemical parameters.

Type of well	Temperature	pH	Redox potential	Total dissolved solids (TDS)
	[°C]	[-]	[mV]	[mg/dm³]
Dug wells	10.8 – 16.5	6.8 – 8.1	-20 – 300	165 – 1155
Drill wells	9.1 – 15.1	7.5 – 8.4	-170 – 250	324 – 763

Preliminary recognition of groundwater quality was based on archival chemical analyses of major pollutant indicators – NH_4^+ , NO_2^- , NO_3^- , SO_4^{2-} and Cl^- . The data has been obtained from the Central Hydrogeological Data Bank – The HYDRO Bank of Polish Geological Institute – National Research Institute and chemical analysis taken by The Municipality of Puck. The data has been analyzed for the period between 1965 and 2017. The results were summarized in table 2.

Tab. 2. Range of selected pollutant indicators in groundwater from 1965-2017.

		NH_4^+	NO_2^-	NO_3^-	SO_4^{2-}	Cl^-
		mg/dm³				
Dug wells	MAX concentration	0.71	0.31	95.3	56.9	63.6
	MIN concentration	<0.05	<0.01	<0.1	<1.0	4.4
	Range of the most often occurring concentrations 25-75%	0.09 – 0.24	0.03 – 0.11	0.9 – 15.0	1.0 – 29.3	10.2 – 16.5
Drill wells	MAX concentration	3.32	0.16	19.6	290.0	92.0
	MIN concentration	<0.05	<0.01	<0.1	16.2	5.9
	Range of the most often occurring concentrations 25-75%	0.05 – 0.50	0.01 – 0.08	0.1 – 7.7	22.8 – 56.0	11.4 – 22.3

The differences of groundwater quality exploited with dug wells and drill wells are noticeable. In drilled wells, the values of measured physicochemical parameters are typical for natural groundwater. However, the observed redox potential indicates reducing environment in the majority part of the analyzed area where aquifer occurs at great depths and its isolated by a thick layer of low permeable till material. This conditions can be associated with an increased content of NH_4^+ in the groundwater (Macioszczyk and Dobrzyński, 2007). Raised concentrations of ammonium, nitrite, nitrate, sulphates and chlorides were observed locally in the shallow aquifer. The drilled wells are mainly located on morainic upland areas, where anthropopressure is negligible due to a thick layer of low permeable till sediments, deeply situated groundwater table and not strongly urbanization.

Inferior quality of groundwater was observed in dug wells, which captures shallow and perched aquifers. These wells are mostly situated in the edge zone of morainic upland or area of river valleys and were built mainly for farm needs. Shallow water table observed in dug wells and lack of low permeable sediments on the surface create good conditions of pollutant infiltration. Increased mineralization (TDS) and concentrations of nitrate and nitrite were more frequent in groundwater exploited with dug wells.

The concentrations of selected pollutant indicators in groundwater were compared with groundwater quality classification (RMŚ, Dz.U. 2016 poz. 85). The results are shown on the map (Fig. 1). The map was prepared on the basis of point assessment. The assignment of the groundwater quality class was dictated by the least favorable value of the indicator taken into account (NH_4^+ , NO_2^- , NO_3^- , SO_4^{2-} , Cl^-). The major classes of groundwater quality are III and IV (polluted water) in dug wells as well as I and II in drill wells.

SUMMARY

The preliminary recognition of groundwater quality in the Puck Municipality area shows noticeable differences in degree of groundwater pollution. Shallow aquifers, exploited by dug wells, characterizes worse quality than deeper aquifers, captured by drill wells. The hydrogeological conditions of analyzed area indicate that glacial valleys are more vulnerable to pollution than moraine upland areas.

Agricultural land use of the Puck municipality area can be potential serious source of a contaminated groundwater. However, actual recognition of basic pollutant indicators composition in groundwater shows a local impact of agriculture. To determine the reliability of agriculture influence on aquifers in the Puck municipality, detailed groundwater quality studies are necessary.

REFERENCES

- Frączek E., 1998. *Hydrogeological Map of Poland 1:50 000 – Puck sheet explanations* [in Polish].
- Korzeniewski K. [ed.], 1993. *Climate of the Bay and its catchment: Puck Bay* [in Polish].
- Macioszczyk A. and Dobrzyński D., 2007. *Hydrogeochemistry of* [in Polish].
- Rozporządzenie Ministra Środowiska (Dz.U. 2016 poz. 85) [in Polish].
- Sokolowski R. J. [ed.], 2014. *Sediment environments evolution of the Kashubian Coastland* [in Polish].

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