ESTIMATION OF GROUNDWATER DISCHARGE AND N-NO_3 LOADS TO PUCK BAY USING SWAT-MODFLOW/MT3D COMBINATION

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Presented study focuses on the integration of surface water and groundwater models to evaluate the quantity and quality of the submarine groundwater discharge (SGD) in the Puck Bay (northern Poland). The main goal was to investigate how the current land use and agricultural practices may affect groundwater recharge, SGD and the associated N-NO_3 fluxes [1, 2].

The study area is located in northern Poland on the southern coast of the Baltic Sea (Puck region). The use of land for agriculture dominates (60%), in addition to forests (29%) and urban areas (11%). The land represents a typical young glacial landscape with relatively high relief shaped by isolated fragments of a moraine plateau and deeply cut ice marginal valleys. Groundwater forms a complex multi-aquifer system drained mainly by the Baltic Sea (Bay of Puck), either directly via SGD or indirectly via streams and rivers. Two Quaternary aquifers span most of the area: the upper aquifer (Q1) and the lower aquifer (Q2). They were formed in fluvioglacial deposits (sand and gravel) separated by moraine till [1].

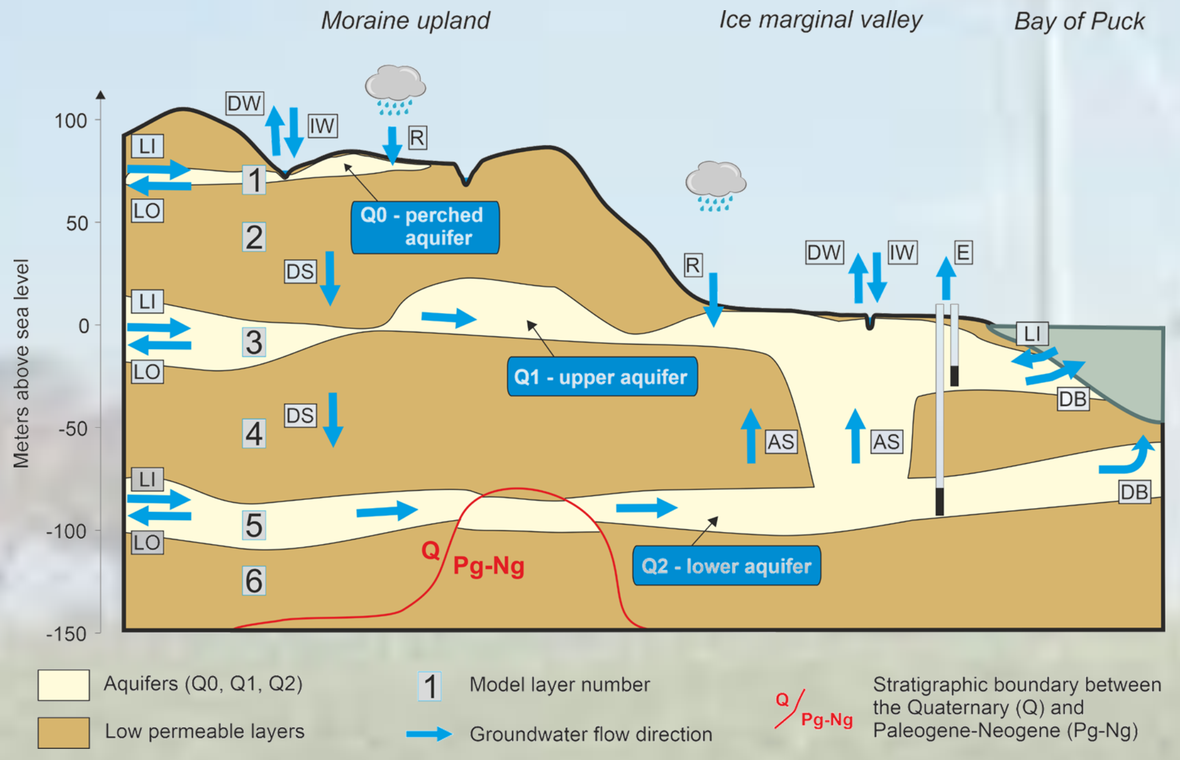

Fig. Conceptual model of groundwater flow in Puck area. Explanation of abbreviations: R - groundwater recharge, IW - infiltration from surface water, DW - drainage to surface water, E - groundwater exploitation, DS - descent seepage, AS - ascent seepage, LI - lateral inflow, LO - lateral outflow, DB - discharge to the Bay of Puck.

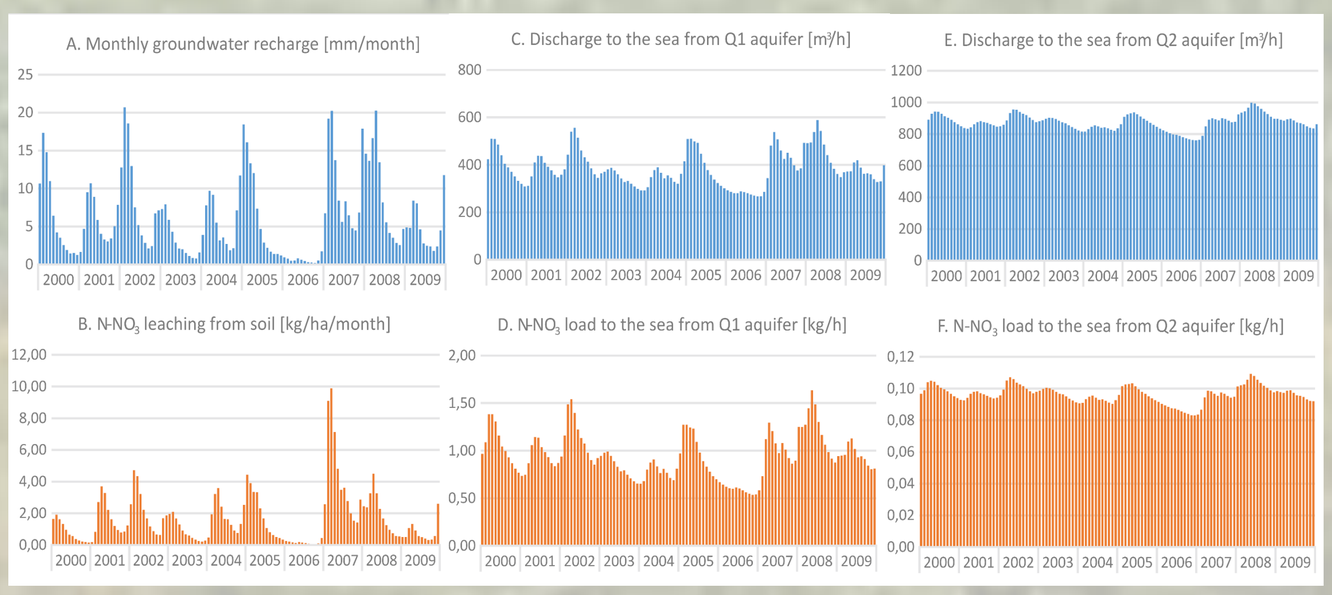

Fig. Time variation of groundwater and N-NO_3 discharge to Bay of Puck

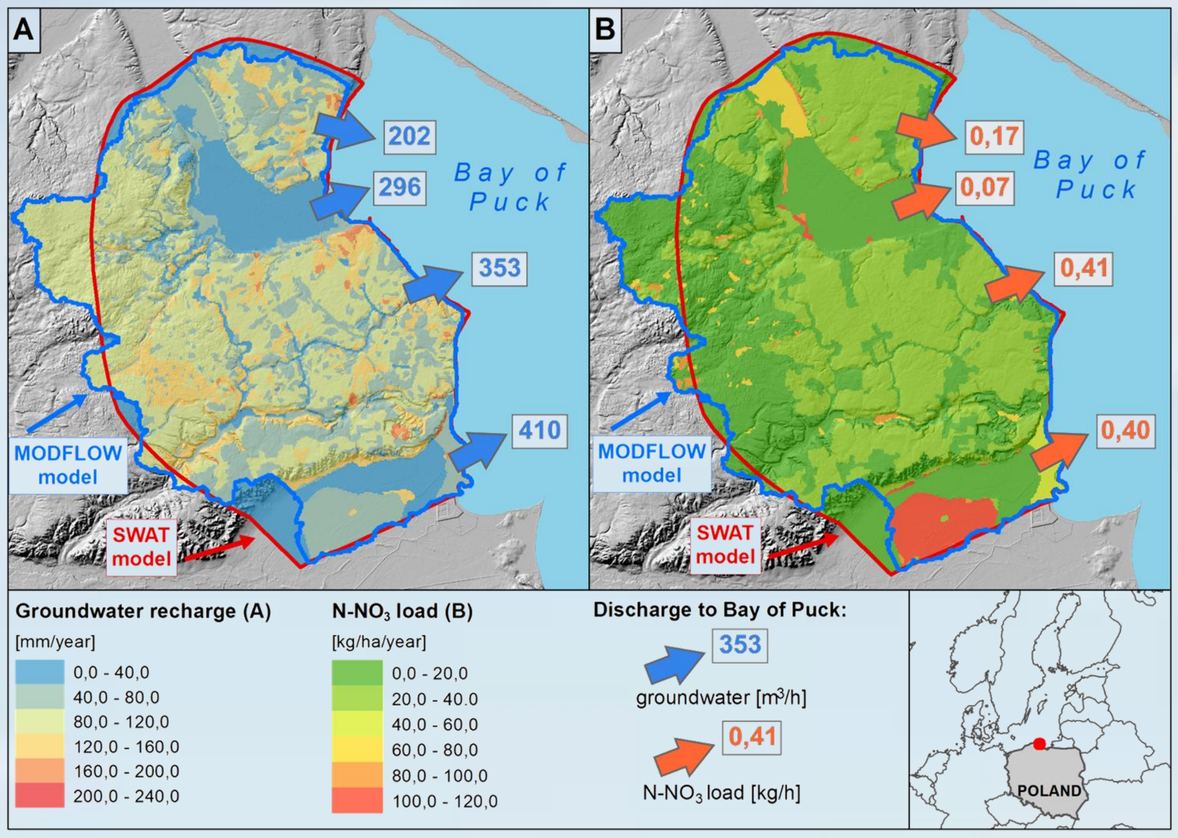

Fig. Spatial variation of groundwater and N-NO_3 discharge to Bay of Puck

The simulations results show significant spatial and time variability of groundwater recharge, SGD and the associated N-NO_3 loads. The amount of recharge depends on the soil type and land use. Larger values are observed in sandy soils and lowest values occur predominantly in peat-covered river valleys. However, there is no simple spatial relationship between recharge and nitrate load. A pattern of seasonal changes were distinguished, with maximum values in late winter/early spring and minimum values in early autumn. Seasonal changes in SGD correspond approximately to seasonal changes in groundwater recharge. The relative fluctuations of SGD from Q1 reach 120% of the lowest value, while in Q2, they do not exceed 31% of the lowest value. A similar dependence is observed in the case of N-NO_3 load to the Puck Bay that is strongly limited by groundwater discharge variability.

The average values of flow rates and nitrate loads from simulations were: 73 mm/y for groundwater recharge, 19.7 kg/ha/y for N-NO_3 leaching from soil, 386 m^3/h from Q1 and 875 m^3/h from Q2 for discharge to Puck Bay and 0.95 kg/h from Q1 and 0.10 kg/h from Q2 for N-NO_3 load to Puck Bay.

The integration of SWAT, MODFLOW-NWT and MT3DMS models were used to develop an innovative and interdisciplinary online toolkit for modelling the impact of the agricultural holdings and land-use structure on the quality of inland and coastal waters [3].

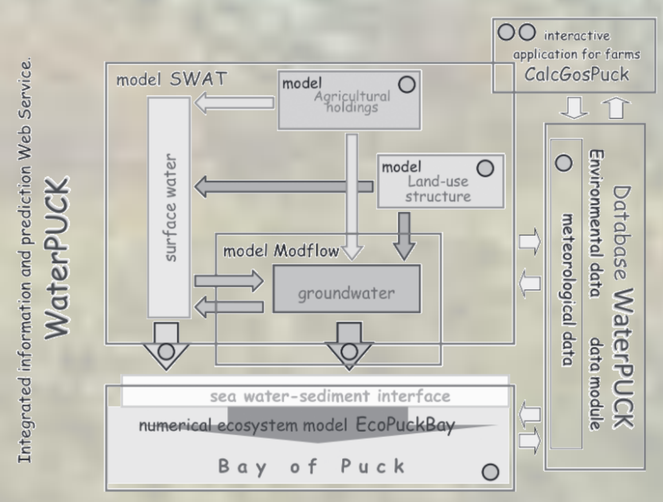

Fig. Schematic flowchart of the modelling system (*www.waterpuck.pl/en*)

CONCLUSIONS

SWAT, MODFLOW-NWT, and MT3DMS computer codes were sequentially coupled, in order to develop a model of transient groundwater flow and nitrate transport in a coastal multi-aquifer hydrosystem. The SWAT model allowed the capture of effects of hypothetical changes in land use and crop type on groundwater fluxes (including SGD) and the associated nitrate loads. The main findings can be summarized as follows:

- Groundwater recharge, SGD, and the corresponding nitrate loads show a distinct time variable pattern, with maximum recharge rates and NO3 leaching in late winter/early spring.
- The average values of recharge and SGD fluxes are influenced more significantly by crop type grown on farmlands than by the changes in land use. The maximum relative difference between the 10 y average of SGD flux between different scenarios did not exceed 12%. In contrast, nitrate leaching from soil and nitrate transport via SGD shows a larger variability, strongly depending on crop type and land use.
- The lowest N-NO_3 load in SGD occurred for the hypothetical scenario with all land converted to grassland, and it was three times smaller than the largest load, corresponding to converting all land to growing crops.

REFERENCES

[1] Szymkiewicz, A. et al. (2020). Evaluation of the Influence of Farming Practices and Land Use on Groundwater Resources in a Coastal Multi-Aquifer System in Puck Region (Northern Poland). Water, 12, 1042.
[2] Wielgat P. et al. (2021). Towards a multi-basin SWAT model for the migration of nutrients and pesticides to Puck Bay (Southern Baltic Sea). PeerJ, PeerJ 9, e10938.
[3]Dzierzbicka-Głowacka et al. (2022). Modelling the impact of the agricultural holdings and land-use structure on the quality of inland and coastal waters with an innovative and interdisciplinary toolkit. Agricultural Water Management, 263, 107438.

ACKNOWLEDGEMENTS

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