GDAŃSK UNIVERSITY OF TECHNOLOGY

Prediction tool for nitrate transport in groundwater in Puck region (northern Poland) based on SWAT, MODFLOW and MT3D

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Puck region (northern Poland, Baltic Sea coast)

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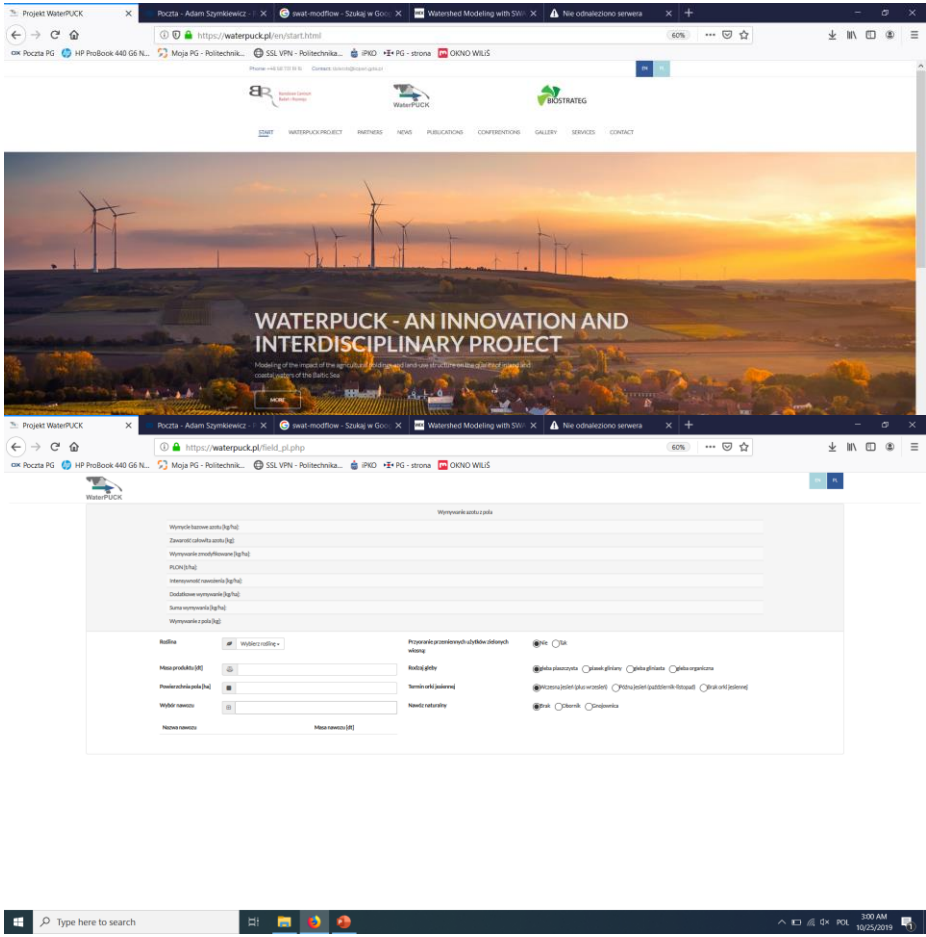
- Puck Bay – shallow brackish water bay, partly isolated from the sea
- unique ecosystem, protected areas, nature reserve
- danger of eutrophication and water hypoxia
- unclear role of submarine groundwater discharge (SGD) to Puck Bay: nutrients, pesticides

WaterPUCK project

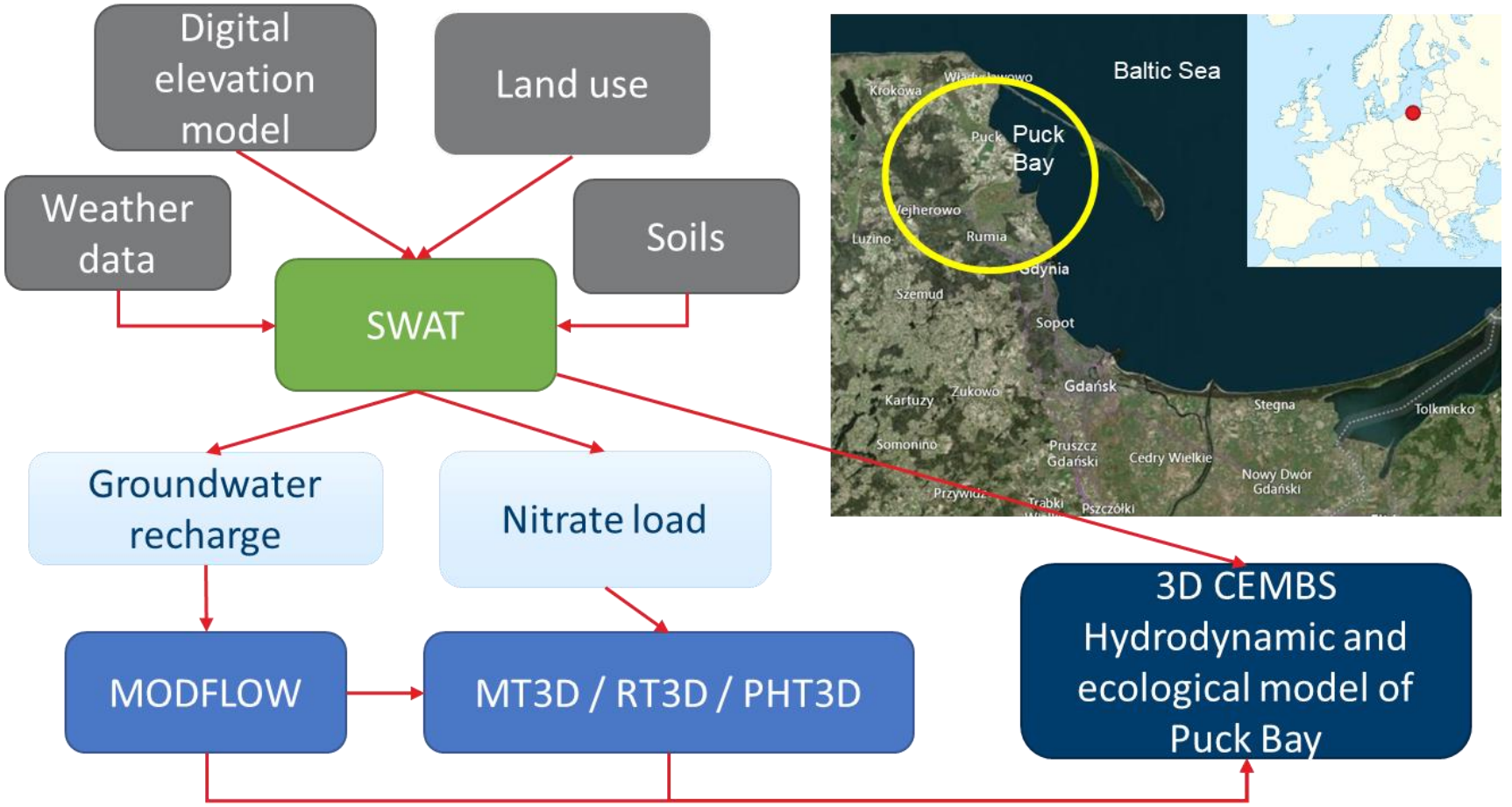
- modeling the impact of agricultural holdings and land-use structure on the quality of inland and coastal waters in Puck Region
- financed by Polish National Centre for Research and Development (NBiR): (BIOSTRATEG3/343927/3/NCBR/2017)
- https://waterpuck.pl/en/



WaterPUCK project

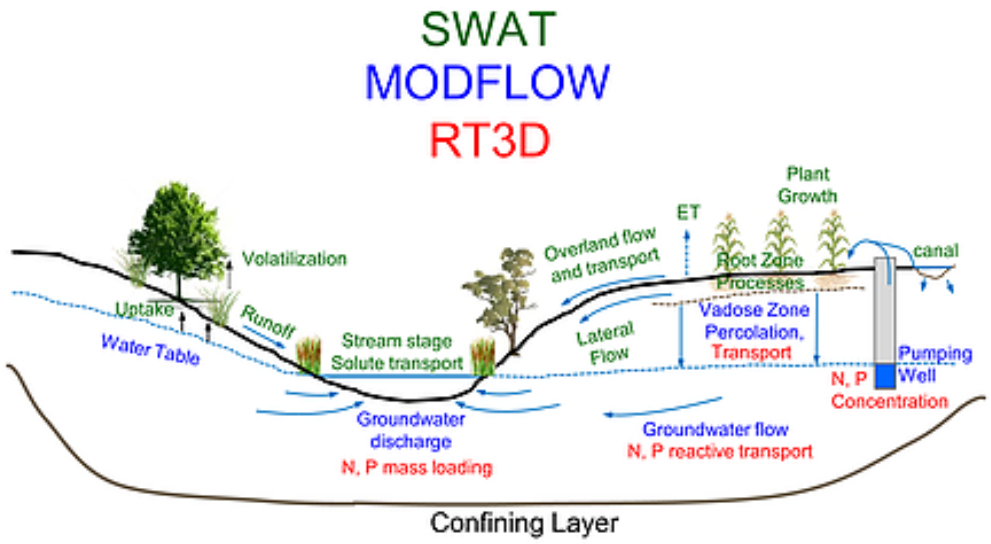
- Institute of Oceanology of the Polish Academy of Science (leader, coastal water model)
- **Gdańsk University of Technology (models for inland water flow: surface and subsurface)**
- Institute of Technology and Life Sciences (collecting and analysing data on agricultural activity, development of simple tools for farmers – nutrient loss calculation)
- Maritime Institute (sampling and chemical analyses)
- Puck municipality (stakeholder, data preparation)

Modeling approach



Modeling approach

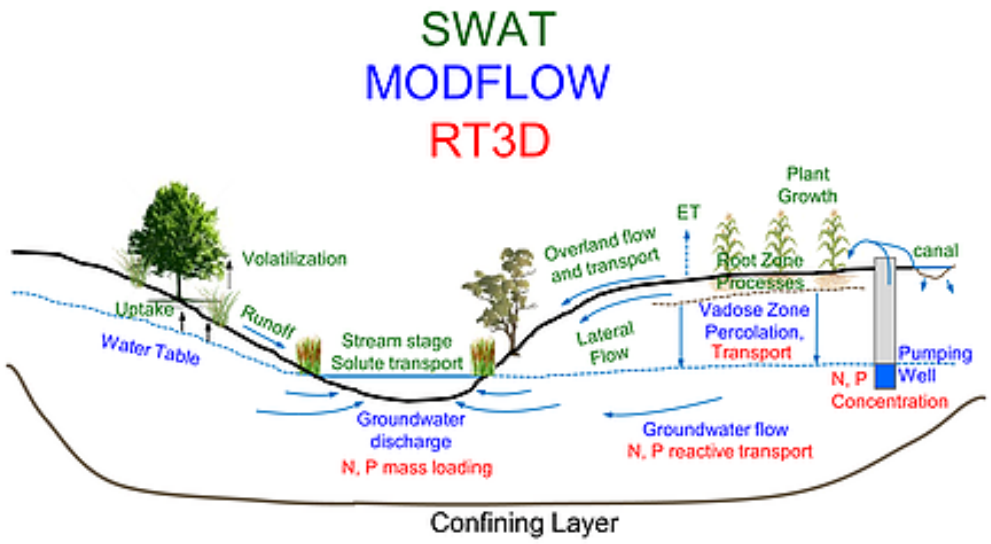
- difficulties in using the coupled SWAT-MODFLOW code (Bailey et al. 2016)
- RIV boundary condition implemented only in the first layer of MODFLOW model
- information on stream water stage from SWAT not detailed enough (too large subbasins)
- calibration ???



Bailey et al. 2016

Modeling approach

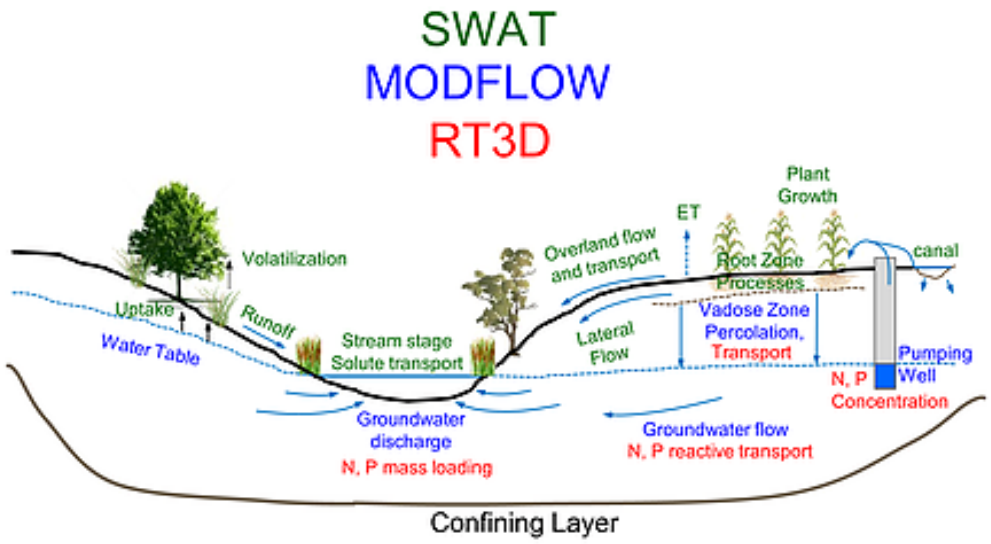
- current approach: one-way data transfer from SWAT to MODFLOW
- groundwater recharge
- nitrate loads
- simultaneous calibration of both models



Bailey et al. 2016

Modeling approach

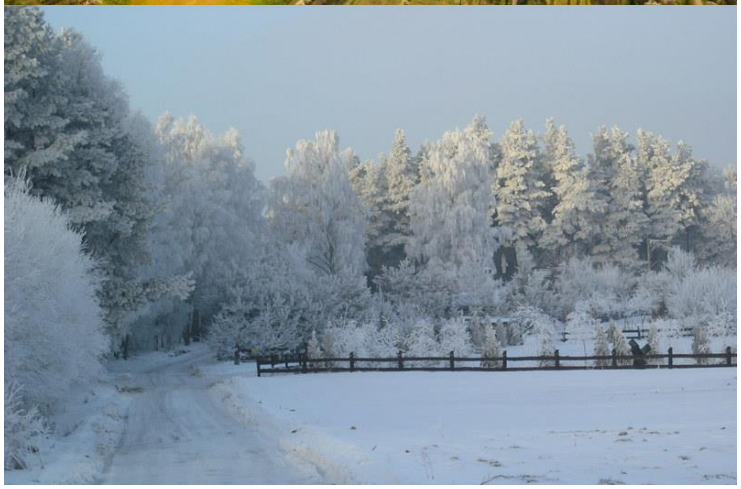
- SWAT model calibration based on 2000-2009 period, validation for 2017-19 period
- MODFLOW model calibration based on steady-state solution, with average recharge values obtained from SWAT
- transient simulations with both models to assess the impact of land use changes (in progress)



Bailey et al. 2016

Climate

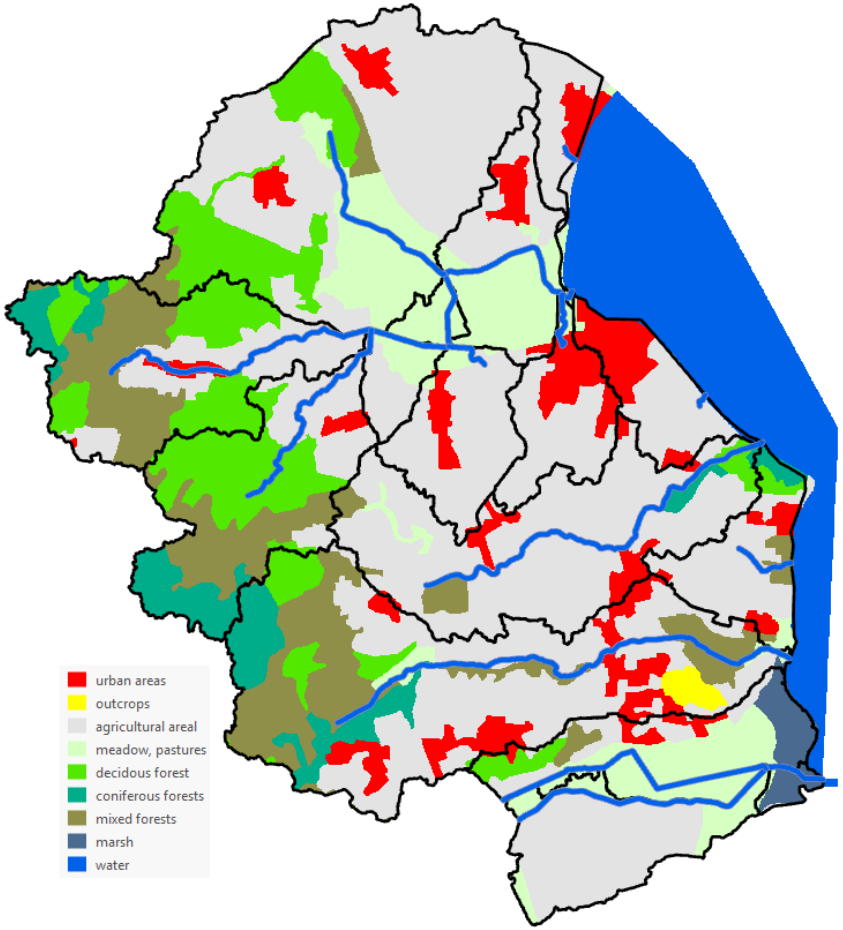
- precipitation data from local rain gauge, other data from forecast reanalysis
- average precipitation 620 mm/year (2000-2009)
- average temperature:
- yearly: 7°C
- January: -1°C
- July: 17°C



Land use

- area: about 170 km^2
- population: about 25 000
- main town: Puck (11 000)

	[ha]	[%]
URBAN	1336.50	7.95
WETLAND	260.25	1.55
AGRICULTURAL	8563.50	50.95
GRASSLAND	1978.25	11.77
FOREST	4647.50	27.65
WATER	11.25	0.07



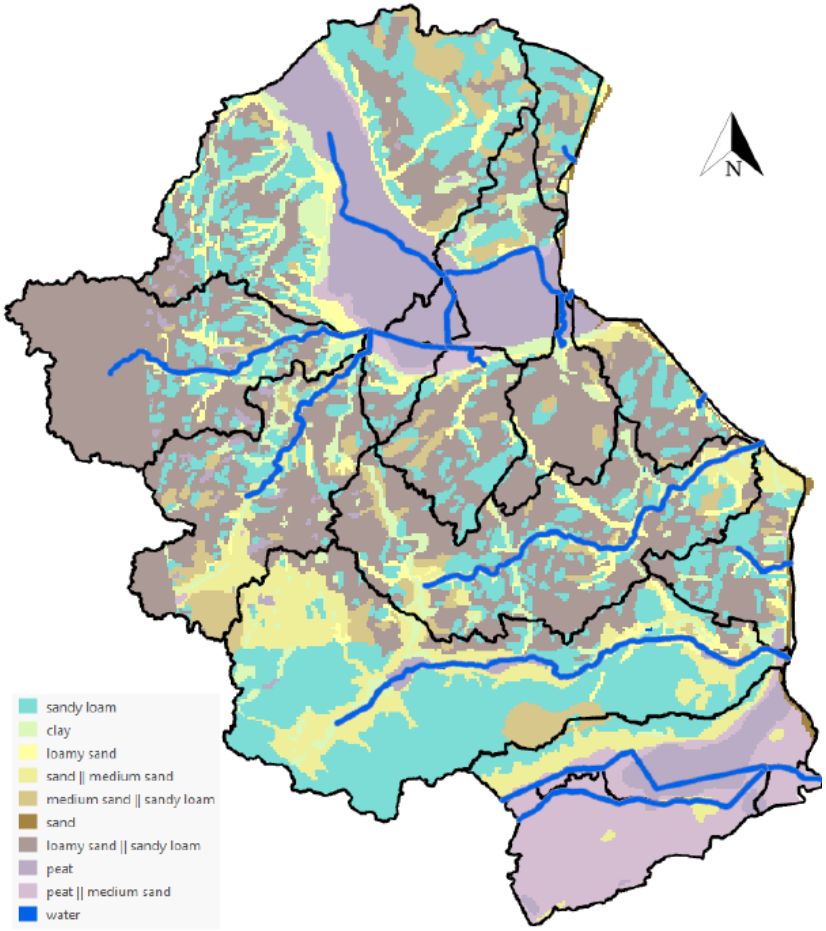
Agriculture

- wheat (winter and summer)
- triticale (wheat-rye cross-over)
- fodder corn
- canola
- potatoe
- permanent meadows (hay)

- crop rotation in SWAT model:
  winter wheat, canola, oats

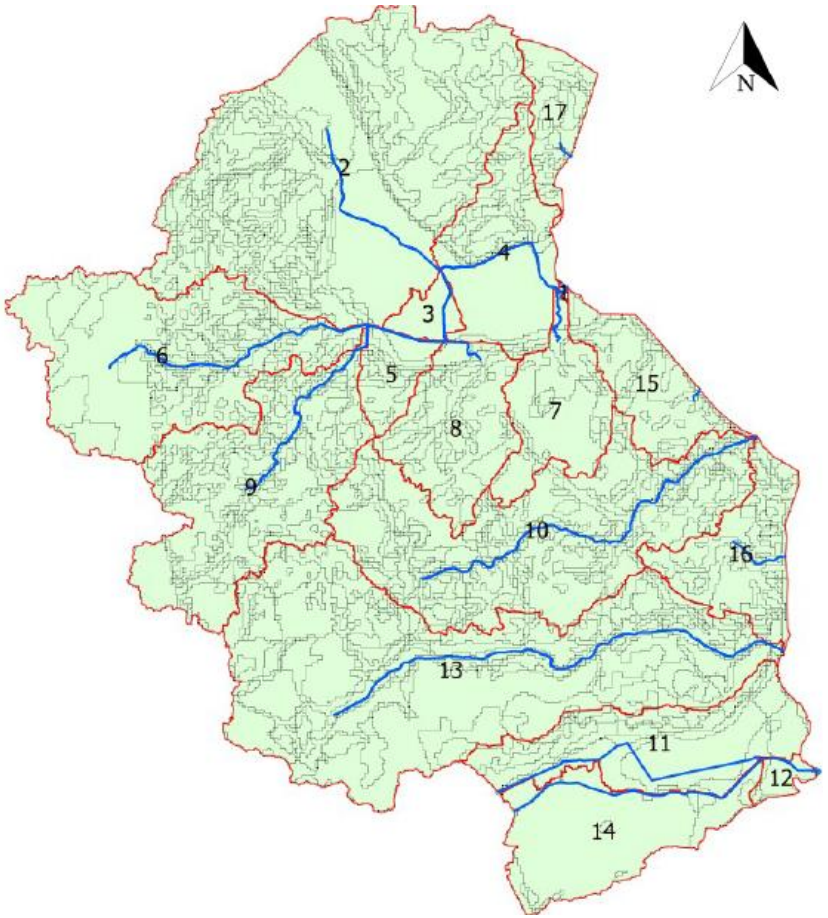
Soils

- area dominated by post-glacial sedimentary soils
- glacial till:
  - sandy loam
  - sandy loam covered by loamy sands
- sand
- peat (in valleys)
- parameters taken from earlier studies on Polish soils



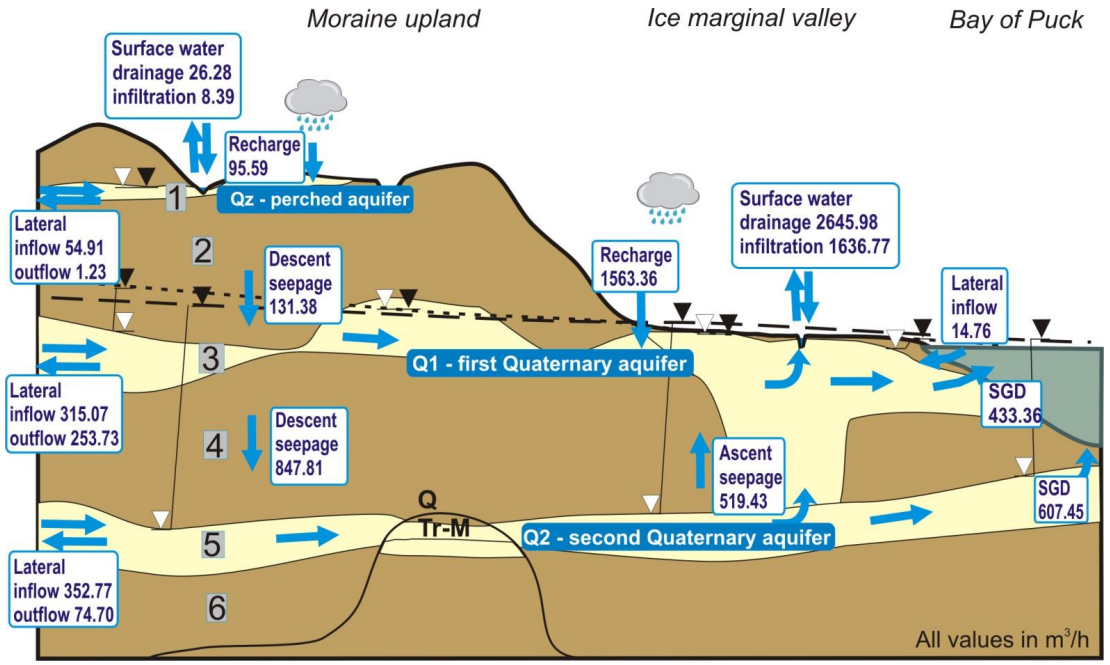
Subbasins and HRU's

- catchments of 3 streams and the lower part of Reda river catchment
- HRU delineation using standard procedure in QGIS, based on land use and soil type
- slope not taken into account (negligible effect on the results)
- 17 subbasins, 353 HRUs



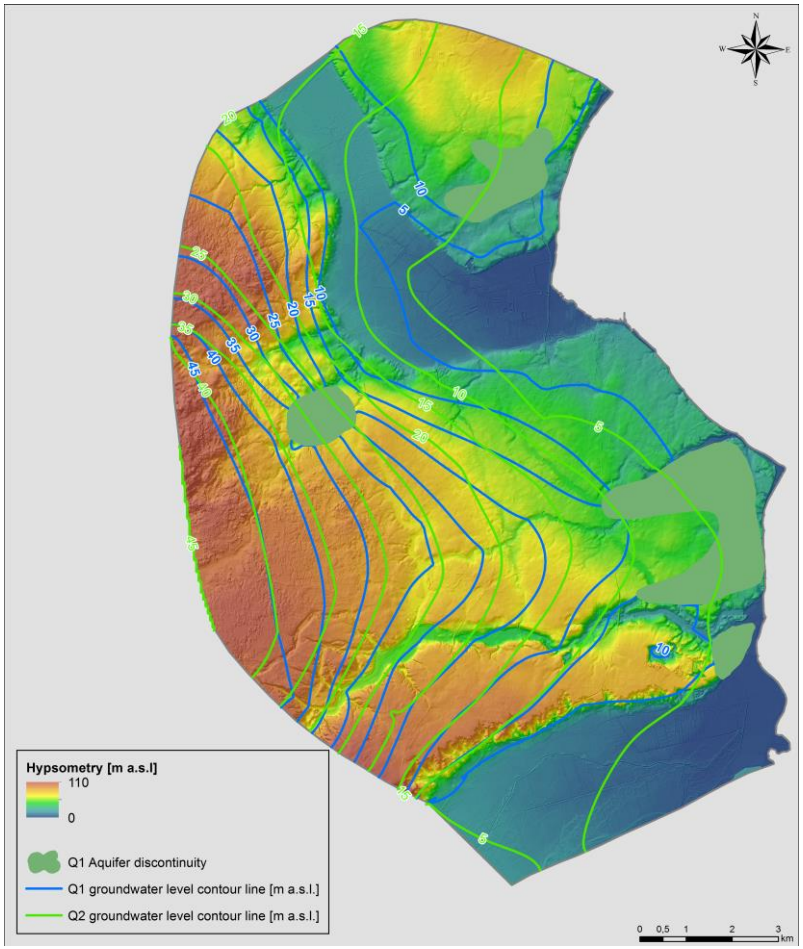
Groundwater

- complex multi-aquifer system
- 2 main aquifers in sandy deposits, mostly confined by till and peat layers
- several small shallow aquifers (perched on till)
- need to use state-of-the art groundwater model



Groundwater

- MODFLOW-NWT (with GMS and ModelMuse interfaces)
- 50m x 50m horizontal gridblock size
- 6 layers for vertical discretization
- steady-state and transient simulations



Calibration: SWAT

- lack of good quality calibration data for SWAT
- very limited data on stream discharges in 2000-2009 period
- manual „soft” calibration
- groundwater recharge values consistent with MODFLOW model (steady state groundwater flow with average recharge from 2000-2009 period)
- crop yield consistent with the information obtained from the local farmers

Calibration: SWAT

- realistic management schedules, based on information from farmers
- realistic values of soil hydraulic conductivity
- parameters calibrated:
  - SCS curve numbers (generally increased),
  - REVAP and interception capacity (increased in forests),
  - plant characteristics for forests (default values from QGIS preprocessor describe forests as being planted each year anew)

Calibration: SWAT

- problems:
- perennial grasslands have much lower crop yield than reported by farmers
- high loads of leached nitrate in peat soils, not confirmed by measurements

Calibration: MODFLOW

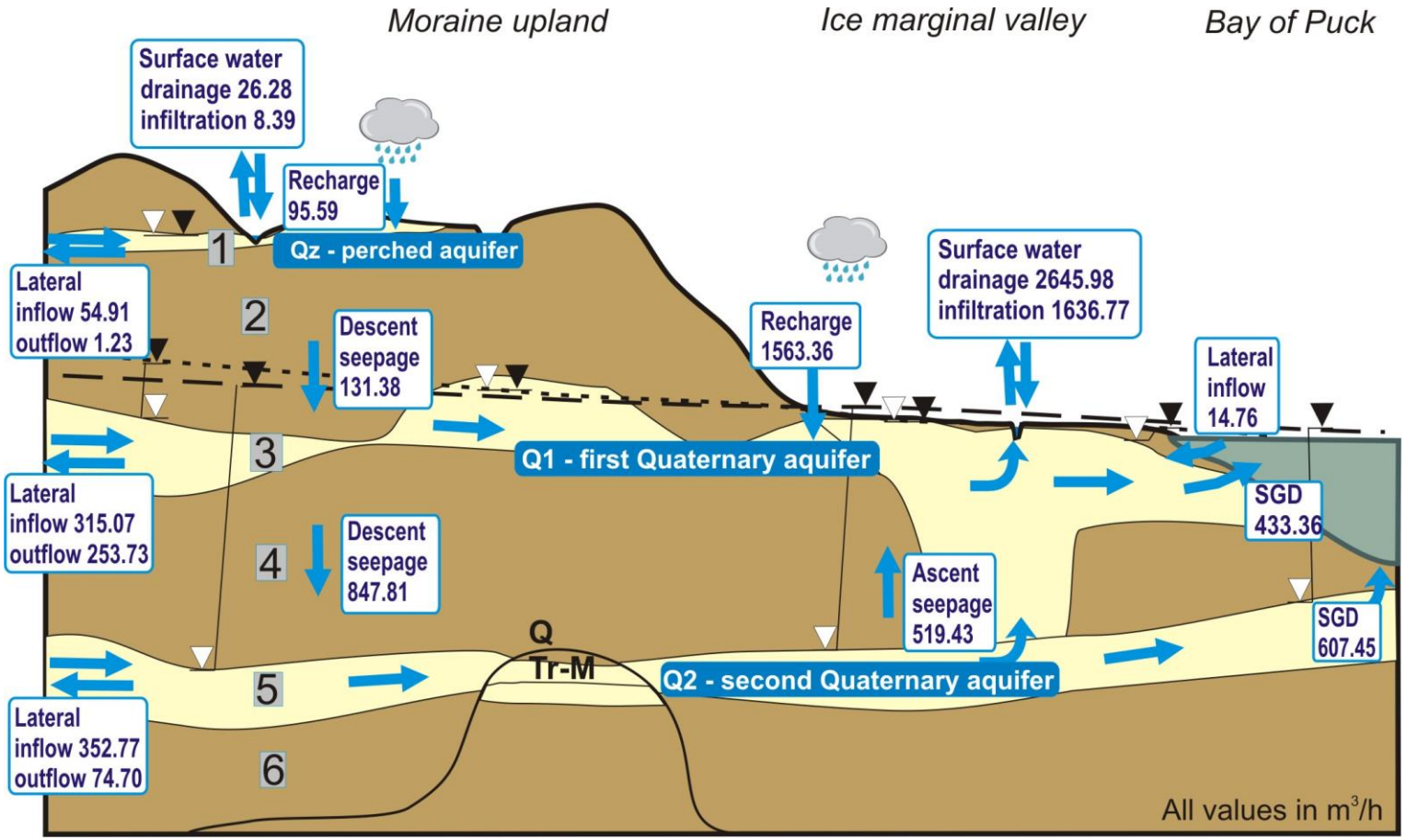
- steady state solution using average recharge values calculated by SWAT
- comparison with average groundwater levels measured in wells and piezometers (data for all 3 aquifers)
- pumping rates of groundwater intakes

Groundwater recharge (from SWAT)

- recharge / precipitation ratio for different soils and land covers is comparable with published data for Poland

	Crops	Grassland	Forests
Peat	0.08	0.05	0.08
Peat / Sand	0.08	0.04	0.08
Clay	0.07	0.04	0.06
Sandy Loam	0.11	0.11	0.10
Loamy Sand / Sandy Loam	0.15	0.15	0.13
Sand	0.22	0.22	0.16

Groundwater budget (from MODFLOW)



Nitrate leached to groundwater (from SWAT)

- average values in kg/ha/year

	Crops	Grassland	Forest
Peat	6.74	0.51	7.16
Peat / Sand	8.70	0.72	8.45
Clay	1.30	0.11	0.46
Sandy Loam	3.29	0.75	0.86
Loamy Sand / Sandy Loam	4.58	1.10	1.04
Sand	5.84	1.23	0.94

Conclusions

- prediction of the fate of contaminants at land-sea interface requires coupling of several models describing flow and transport in various hydrological compartments
- SWAT is the computer model of choice for water flow and nutrient transport in the shallow subsurface
- need of a comprehensive approach to calibration: cross-checking recharge with groundwater model and with the known crop yield and biomass