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Integrated information and prediction Web Service
WaterPUCK - General concept

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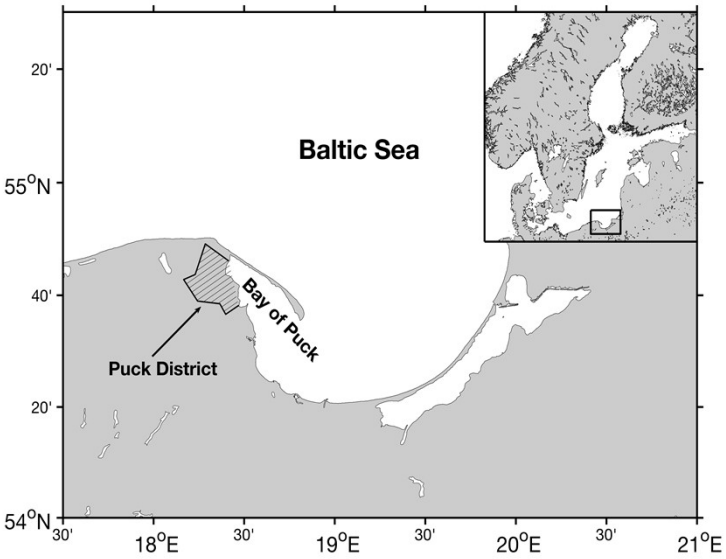
General concept of a new method as ‘Integrated information and prediction Web Service WaterPUCK’ for investigation influence of agricultural holdings and land-use structures on coastal waters of the southern Baltic Sea is presented.

The WaterPUCK Service is constructed as part of the project with the same name ‘WaterPUCK’.



Map of the Puck District and the Buy of Puck.

WaterPUCK Service is focused on determination of the current and future environmental status of the surface water and groundwater located in the Puck District (Poland) and its impact on the Bay of Puck (the southern Baltic Sea) environment. It will highly desired tool for land-use and environment management. WaterPUCK combines several different components and methods such as retrospective analyses of existing monitoring data sets, in situ measures and the application of various models to estimate main mechanisms and threats responsible for the pollution transport from the agricultural holdings and land-use structure to the surface and groundwater and potential predictability of environment change of the Puck District and the Bay of Puck ecosystem.

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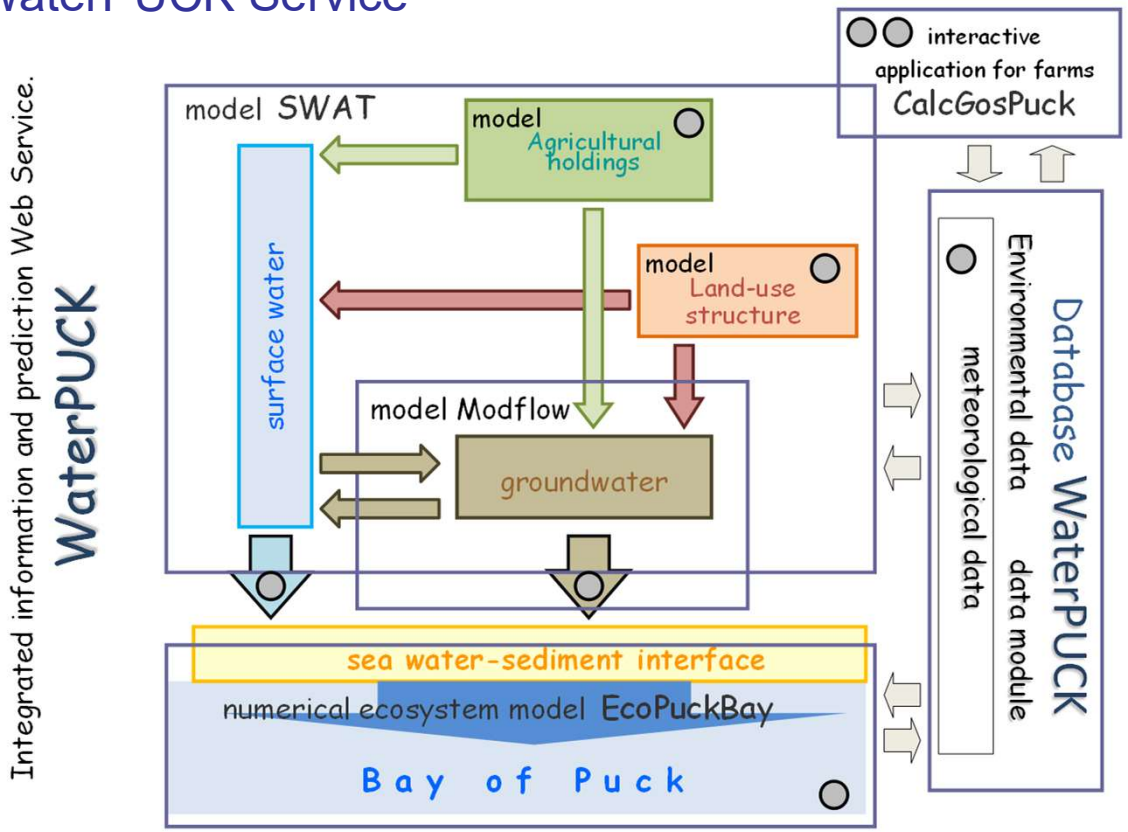
WaterPUCK Service

WaterPUCK Service will integrate several models, such as:

- a surface water model based on SWAT,
- a groundwater flow model based on MODFLOW,
- a 3D-ecohydrodynamic model of the Bay of Puck called EcoPuckBay and
- an agriculture calculator called CalcGosPuck.



The shame of water and contaminant fluxes covered in WaterPUCK.

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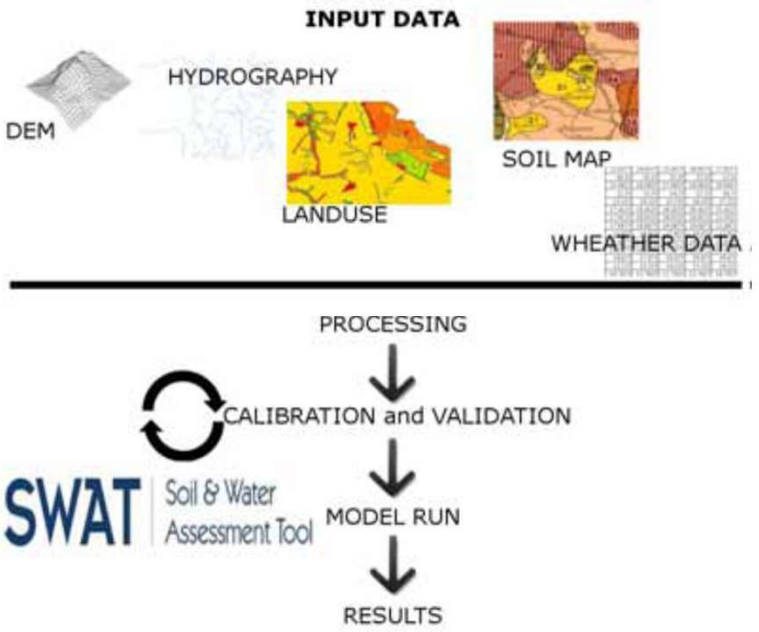
SWAT model (Soil and Water Assessment Tool)

SWAT model (Soil and Water Assessment Tool) has a river basin structure and will be use to predict the influence of changes in the way of farming for: water balance, erosion degree, nitrogen and phosphorus compounds pollution, pesticides, bacteria and heavy metals.

SWAT model is a physically based, time continuous simulation model that operates on a daily time step at catchment scale



SWAT model schema; source: own elaboration

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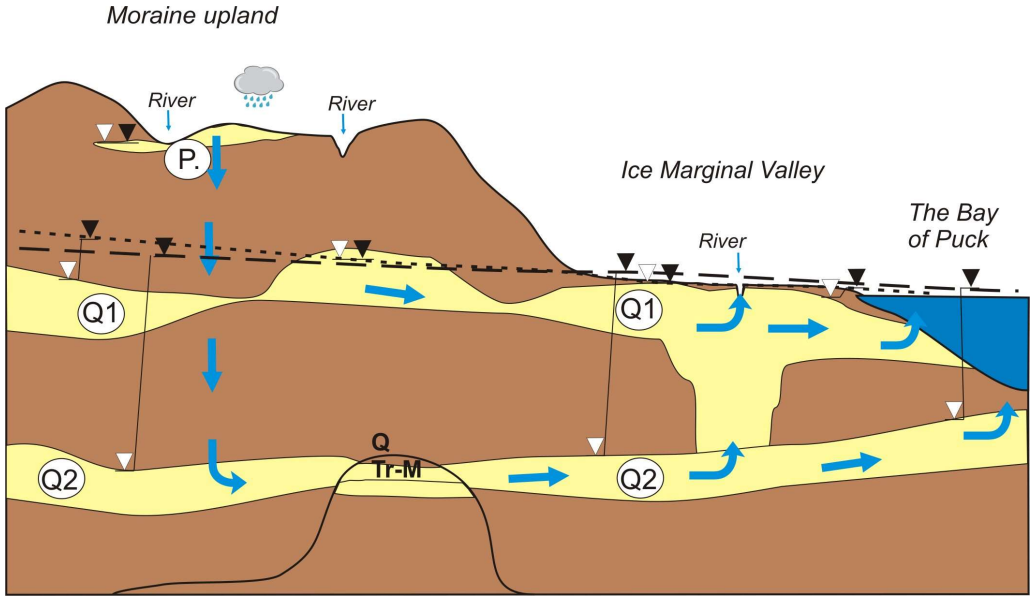
MODFLOW model

Based on the knowledge of the hydrogeological system, a steady-state mathematical model of the Puck multi-aquifer system is developed. The extent of the multi-aquifer system is limited by the rivers watersheds and the drainage area of the Puck Bay. The mathematical modelling is based on the finite difference solution of the MODFLOW program, which is the most commonly used code for simulating groundwater flow.



Simplified diagram of groundwater flow, Q1 and Q2 upper and lower Quaternary aquifers, P – local perched groundwater.

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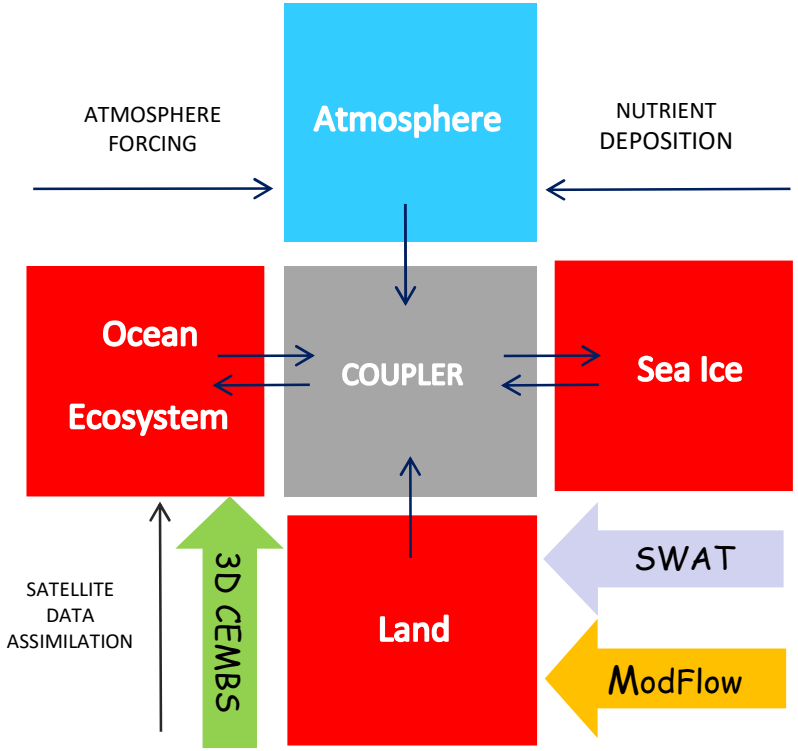
EcoPuckBay model

EcoPuckBay model consists of active ocean, ecosystem and ice modules, coupled together with active land module (SWAT plus ModFlow) which provide data, such as freshwater inflow and nutrient discharge from rivers and ground, and passive atmospheric module which provide data such as weather forecasts from external sources (UM ICM).
From the side of the open sea, boundary conditions will be fed from the three-dimensional model of the ecosystem for the Baltic Sea 3D CEMBS (www.cembs.pl).



Configuration of the 3D EcoPuckBay model

EcoPuckBay model

The model horizontal resolution is 1/960°, which corresponds to ca. 115 m grid. Vertically model is divided into 19 layers. The first of 5 layers is 0.4 meters thick. 3D EcoPuckBay model will generate 72-hour forecast which include currents, temperature, salinity and ice parameters.
In addition, the model will forecast ecological parameters i.e. nutrients, pesticides, dissolved oxygen concentration and biomass of phytoplankton and zooplankton in the entire water column.
Each of these variables will be calculated with a second-order advection-diffusion, partial differential equation:

$$\frac{\partial C}{\partial t}+(V+w_s)\nabla C=\frac{\partial}{\partial z}\left(D_z\frac{\partial C}{\partial z}\right)+\sum_{i=1}^{2}\frac{\partial}{\partial x_i}\left(D_{x_i}\frac{\partial C}{\partial x_i}\right)+Q_C \qquad (1)$$

where C is each model variable, V (u, v, w) is the velocity vector, ws is the sinking velocity of pelagic detritus, Dz and Dx are vertical and horizontal turbulent diffusion coefficients and QC is the biogeochemical source-sink term. EcoPuckBay model will also determine the spatiotemporal changes in the quality of marine waters in respect to specific pollution indicators.

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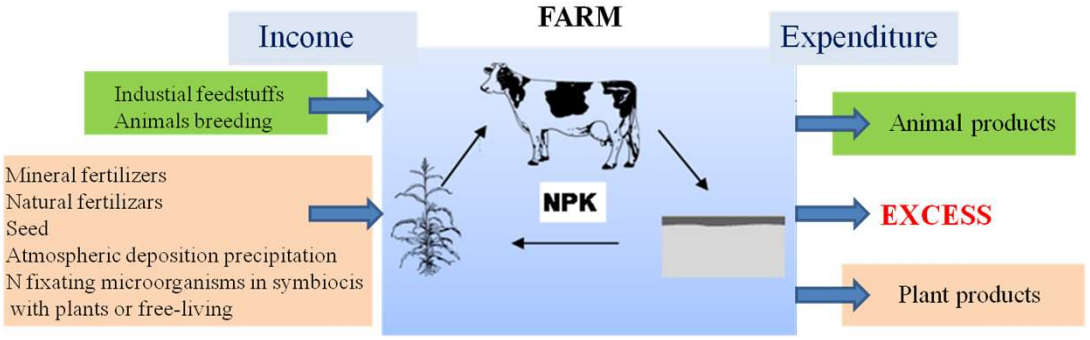
CalcGosPuck calculator

The CalcGosPuck calculator will be working as an independent application by which will can be to plan the fertiliser usage by farmers in order to obtain the best harvest policy. Preparation of the nutrient balance at farm level by the "at farm gate" method involves determination of input and output streams on the farm.

Inputs are the masses of nutrients brought onto the farm in the form of:
1) Purchased materials:
– mineral fertilisers
– commercial feedstuffs
– breeding and replacement animals
– other agricultural inputs, for example, manure, straw, seed
2) Biological fixation by plant material (legumes and nitrogen)
3) Atmospheric deposition
4) Biological fixation in soil by non-symbiotic microorganisms (nitrogen).



Components of the "at farm gate" nutrient balance method CalcGosPuck

Outputs are the masses of nutrients leaving the farm in the form of:
1) Products sold:
– plant products (e.g. cereals, potatoes, sugar beet, oilseed, fruits, vegetables etc.)
– animal products (live animal, milk, eggs, wool, etc.);
2) Random events, such as fallen animals, accidental crop destruction (e.g. by fire or flooding).

The difference between inputs and outputs is defined as the balance (surplus or deficit).

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Examples of preliminary results presenting the work of individual modules of the WaterPUCK Service

The input GIS data for the SWAT model has been prepared. The basis is 10 meter resolution Digital Elevation Model (DEM). Files in a regular grid with an interval of 1 m, have been obtained from the Head Office of Geodesy and Cartography in Poland. To cover the area of Puck District 254 LAS sheets have been used, creating merged numeric terrain model. This data has been used for automatic catchment delineation and its division into 23 sub-catchments (areas from 5 to 38 km2), of which 3 discharge rainwater directly to the Puck Bay.

Table 1 shows the obtained values of the highest peak discharge with the probability of exceeding 1% for main watercourses.

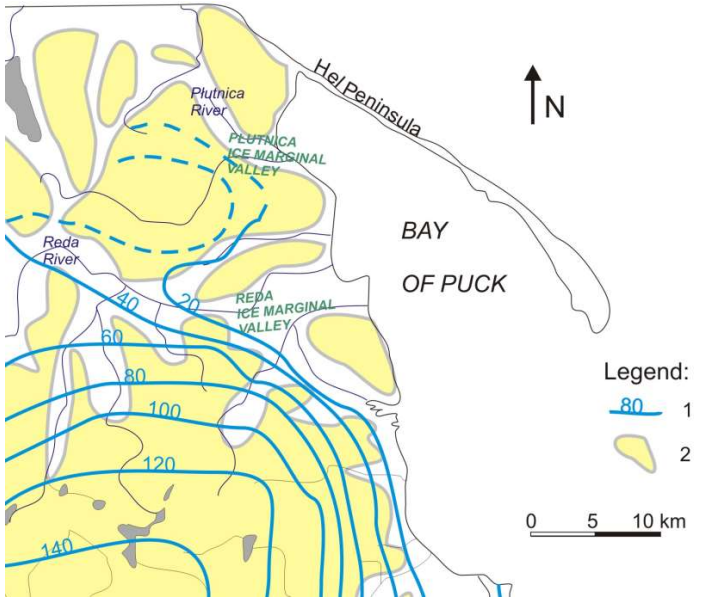
Highest peak discharge with the probability of exceeding 1% (Qmax1%) for the main watercourses in the Puck District.

Object	$Q_{max1\%}$ [m^3/s]
Plutnica	14.74
Bladzikowski	3.53
Gizdepka	6.49
Reda River	41.33

Examples of preliminary results presenting the work of individual modules of the WaterPUCK Service

These fluvioglacial aquifers, built of sands and gravels, are separate by till deposits. Both aquifers are hydraulically connected and confined, except areas where till cover was eroded. These aquifer system is drained mainly by the Bay of Puck, however river valleys and ice marginal valleys also play a significant role.

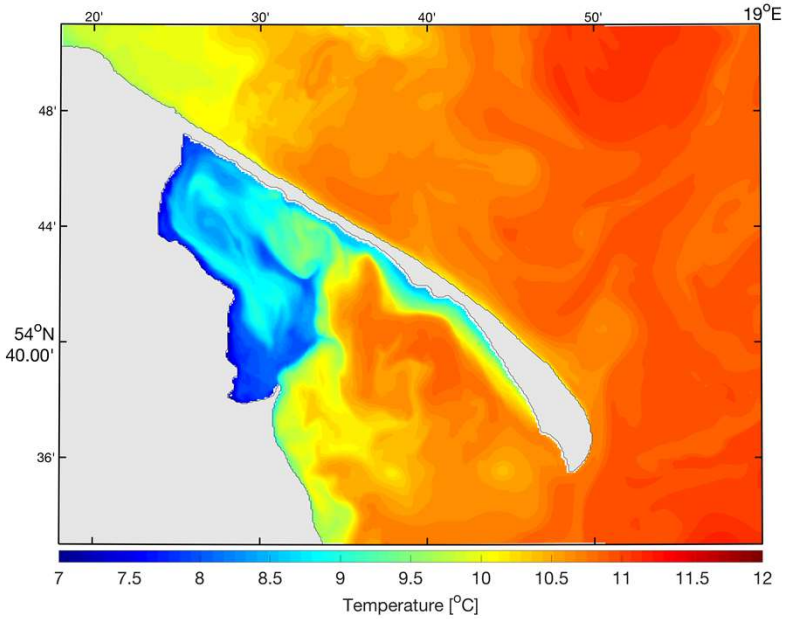
An example of preliminary results of hydraulic head distribution for the main Quaternary aquifer is shown in Figure



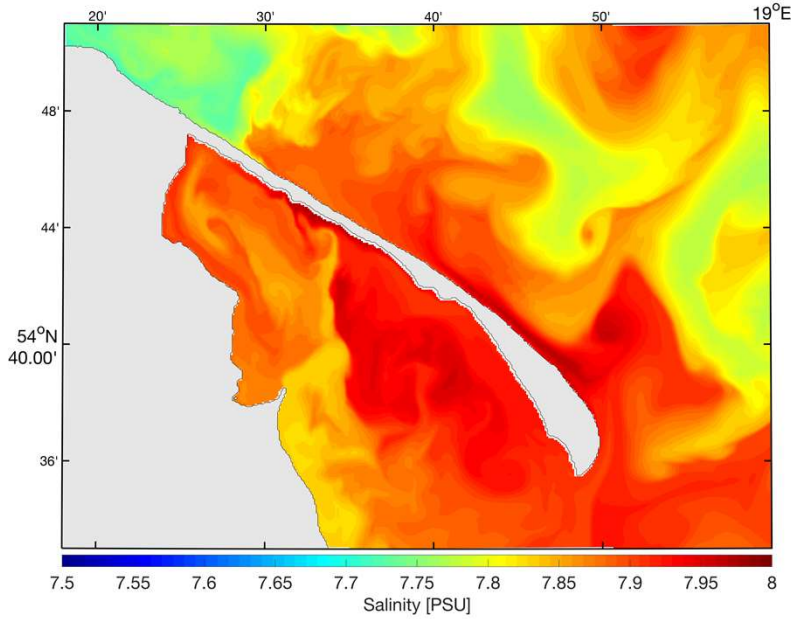
Hydraulic head distribution for the Quaternary (Q1) aquifer (m a.s.l.). 1 - head contour line, 2 – moraine upland

Examples of preliminary results presenting the work of individual modules of the WaterPUCK Service

Figures show the modelled results from the 3D EcoPuckBay model. For example, distributions of the temperature and salinity in the upper layer sea in Bay of Puck in November are presented.



Distribution of the sea surface temperature in Bay of Puck in November (3D EcoPuckBay).



Salinity distribution in the surface layer in Bay of Puck in November (3D EcoPuckBay).

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Conclusion

The WaterPUCK service will enable to:

- **calculate the sufficient amount of fertilizers that should be used (CalcGosPuck),**
- **investigate the nutrients and pesticides sources,**
- **model the fate and distribution of pollutants such as nutrients and pesticides in the surface water and groundwater,**
- **model loads of pollution to surface water and groundwater,**
- **model fluxes of nutrients via submarine groundwater discharge to the Baltic Sea coastal environment (Bay of Puck, Southern Baltic Sea),**
- **model the processes and mechanisms influencing the persistence of nutrients in the environment such as denitrification,**
- **predict the changes in land use and climate change influence on the ecosystem,**
- **calculate the sufficient amount of fertilizers that should be used (CalcGosPuck).**

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Conclusion

The social and economic perspective of WaterPUCK aims to increase the environmental quality of the Puck Bay ecosystems under different scenarios of economic development.

The growing pressure of agriculture, industry and tourism on the environment increases costs of maintaining biodiversity of the Baltic Sea and mitigation of eutrophic processes. What is more, the tourist attractiveness of the Baltic Sea decreases and the amount and variety of species of fish caught, give additional cost to coastal regions and municipalities. Therefore proposed solution and improvement is desired by both national and international communities.

The implementation of WaterPUCK and its possible transfer outside the pilot region, will require segmentation of the end-users and assessment of their readiness to use and further expand the functionality of the proposed system.

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Thank you for your attention

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