Appendix A

The Quarles van Ufford model

An integrated water and nutrient transport model was used to describe the water and nutrient fluxes in Quarles van Ufford. The model was set-up within the 'Monitoring Catchments' programme, funded by the Dutch government, which ran from 2003 till 2011. Quarles van Ufford was one of four catchments for which the impact of Dutch agricultural policies on surface water quality was assessed. The model consists of four coupled modules:

- SWAP (Kroes et al., 2008), a one-dimensional physically based model for simulating the vertical transport of water, heat and solutes in the saturated and unsaturated top-soil compartments, solving the full Richards' equation;
- SWQN (Smit et al., 2009), ahydraulic model for describingwater flow in the surface water system, solving a simplified version of the Saint-Venant equations;
- ANIMO (Groenendijk et al., 2005), aone-dimensional solute transport model describing the complete organic matter, nitrogen and phosphorus cycles in the subsurface, using water fluxes from SWAP;
- NUSWALITE(Siderius et al., 2009),a lumped-process model with simplified description of the phosphorus and nitrogen cycles in the surface water system with the interaction between water and sediment described by an equilibrium equation, using water fluxes from SWQN.

The model was constantly improved over a period of 7 years, step-wise adding more regional information and increasing the spatial resolution of input data and temporal resolution of calculations. In the final version water fluxes through the soil and into the surface water were calculated with a daily time-step for a period of 15 years. The SWAP and ANIMO land surface modules were schematized at a 25m resolution using gridded maps of soil (1:50000 soil map of the Netherlands), land use (National Land use map of the Netherlands - LGN4) and groundwater level (REF). Using the overlay of these gridded maps and ignoring the area-wise smallest 5%resulted in58 unique soil-landuse-groundwater combinations. Water and nutrient loads to the surface water model were estimated for each of these and allocated to the nearest surface water node, based on their area-wise representation within the upstream area of each node.

The surface water modules SWQN and NUSWALITE were schematized based on design and maintenance data from Waterboard 'Rivierenland'. These consisted of dimensions of each watercourse within the area, slope of the watercourses, location and size of weirs and divers and location of inlets and outlets and their design characteristics and rules of operation. The schematization of the Quarles van Ufford surface water system consisted of 1021 sections with an average length of 350m and a maximum length of 1000 m 188 weirs and 3 pumps.

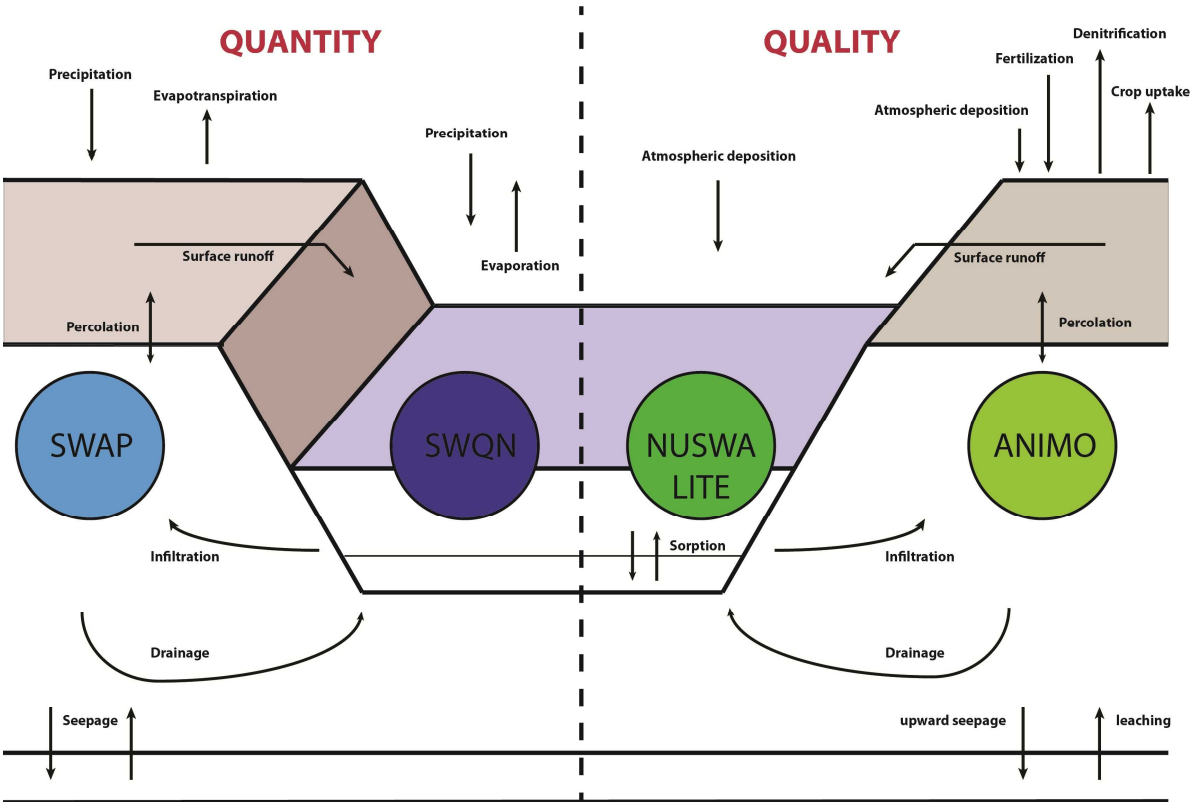

Figure A1: Visual schematisation of the four coupled modules in the Quarles van Ufford model.

Daily input into both the soil and surface water model consisted of rain and evapotranspiration (derived from the KNMI stations De Bilt for evapotranspiration and Megen for precipitation). Manure and fertilizer loads were taken from the STONE model framework(Wolf et al., 2003).Another important boundary condition of the surface water system in Quarles van Ufford was the inlet of river water during the spring and summer months. Daily waterfluxes and concentrations were imposed on each of the five inlets based on measured fluxes and concentrations for each of the inlets over the periods 2002 and 2010, excluding 2003.

To calibrate the model system a dataset with daily to monthly water quality measurements for up to 23 locations, spanning the period 1990-2011, was used. Automatically adjusting 9 parameters, identified as critical, using Latin-Hypercube sampling (McKay et al., 1979) resulted in Nash and Sutcliffe (1970) Model Efficiencies of 0.51 for Nitrogen concentrations and 0.43 for Phosphor concentrations at the outlet. In Siderius et al. (2011) the integrated model calibration and validation for Quarles van Ufford is described in further detail.

To visualise water fluxes through the surface water system, originating from inlets, a tracer method was applied using the NUSWALITE module. By eliminating all processes within the model either any added N or P input behaves as a non-reactive compound. To each of the inlets a load of 1 mg/l was attributed, while all drainage and runoff from the land surface was given a concentration of 0 mg/l. The (lack of) dilution of the 1 mg/l through the surface water system gave an indication of the influence of inlet water in the various surface water sections.

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