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A concept for estimating depths to the redox interface for catchment scale nitrate modelling in a till area

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A major challenge in Danish water resources management is to reduce the nitrate load to surface waters from agricultural areas. Since the 1980ties, regulation on agricultural management has been introduced in order to reduce the nitrate leaching. However, the efficiency of the present regulation is low, as it is applied uniformly for the whole of Denmark without taking natural transformation of nitrate in the subsurface and the spatially variability of this into account.

Nitrate is transformed naturally under anaerobic conditions. The transition from aerobic to anaerobic conditions in the saturated zone is called the redox interface and nitrate must be transported below this interface for nitrate reduction to occur. About 50% of Denmark is covered by young clay till sediments and the redox interface is normally found close to the surface, resulting in a high degree of nitrate reduction in the saturated zone. However; local variations in the subsurface result in large differences in reduction potential within a catchment.

To identify areas of high and low nitrate reduction potential using distributed models, it requires the models to have predictability on small scales. The major challenges in this respect are to determine the location of the redox interface and the ability to accurately simulate the local scale water flow paths in groundwater. The focus of this study was on the first of these issues.

The redox interface can be easily determined in the field by change in sediment colour, but since a borehole drilling is needed for each data point, redox data are often sparse. Studies from Denmark and North America have shown that the location of the redox interface in tills can vary several meters over short distances. This combination of large variablity in redox depths and small number of data makes it difficult to estimate the location of the redox interface over larger areas. A concept for determining depths to the redox interface on catchment scale is therefore needed which was the objective of this study.

The redox interface concept was based on the hypothesis, that the redox interface has been developing since the beginning of Holocene due to oxidation of reduced compounds in the sediment by oxygen in recharging water. The key principle of the concept was to estimate the spatial pattern of the redox interface from variability in groundwater recharge and reduced compounds in the sediments. The concept was tested for the 101 km2 Norsminde fjord catchment using a catchments scale nitrate model, where two parameters controlling the estimated redox interface was calibrated based on the observed nitrate transport to the fjord. The estimated depths to the redox interface were able to reproduce the cumulative distribution of measured depths across the catchment, but they did not fit well with the observations at individual wells. It is therefore concluded that the concept may be useful for simulation of nitrate transport and reduction in the saturated zone at catchment scale, but that it is not able to correctly predict nitrate reduction at point scale.