# Description of “mixing method”

This short note provides a more detailed description of the “mixing method” used to estimate groundwater quality changes at Catfield Fen in the “Report on the Assessment of Abstraction within the Ludham-Catfield Area in the Vicinity of Ant Broads and Marshes SSSI”. A key issue is the proportion of groundwater (as opposed to water derived from rainfall) present within the fen, and how that might change with time and with alternative abstraction scenarios.

An overview is given in section 8.3.8 of that report, with additional information on thresholds in section 9.2.

The method uses groundwater balance component information generated by the NEAC groundwater model to calculate a water quality ‘index’ which can be viewed as a representation of the proportion of water in the peat derived from rainfall and from upwelling groundwater.

For a given cell of the groundwater model, the following components, which are output at monthly intervals from the model, are used:

- Recharge
- Evaporation from groundwater
- Upflow of groundwater from the Crag below the peat
- Discharge of water to surface drains

Note that groundwater abstraction is not included directly, since there is no abstraction from the peat itself. However, abstraction from the Crag intercepts some water that might otherwise have flowed to the site, and therefore affects the quantity of upflow from below.

Note that lateral transfers of groundwater within the peat are ignored in these calculations, as the volumes involved are very small. Each component is output as a rate (in $m^3$/d) at the end of each month. By assigning “concentrations” to inputs and outputs, these rates can be converted to a calculation of volume and mass, enabling a time series of mixed “concentration” to be derived. If the “concentration” in rainfall is assigned a value of 0 and the “concentration” in Crag groundwater is assigned a value of 1, then the resulting calculation simply gives the proportion of Crag groundwater present in the peat at the location of the model cell.

A step-by-step description of the calculation is given below:

1) Initialise the process

   a) Calculate volume of water from water level, base of peat and specific yield (using the value form the groundwater model). Note that specific yield is used, and not total porosity: this effectively assumes that the ‘active’ mixing takes place only in the ‘readily accessible’ pore space of the peat. This is an approximation, but does not have an important effect on the calculations: using a higher porosity value results in less seasonal fluctuation in the calculated proportions of water, but hardly any difference in the magnitude.

b) Assign an initial concentration value (between 0 and 1). The calculation is not sensitive to the value chosen after an initial period of adjustment.

c) Calculate initial mass in place

2) Input processes

a) If recharge > evaporation, assign a concentration of 0 to (recharge – evaporation)

b) Assign leakage from streams to groundwater a concentration of 0

c) Assign upflow of groundwater from below a concentration of 1

3) Calculate interim volume and concentration

a) Multiply rates (i.e. of processes in $m^3/d$) by length of month to calculate volume input

b) Multiply volume inputs by concentration to give mass input

c) Add volume and mass to existing calculated volume and mass (i.e. from previous time of calculation)

d) Divide volume by mass to give an interim concentration value

4) Output processes

a) If evaporation > recharge, assign the interim concentration to (evaporation-recharge)

b) Assign the interim concentration to "discharge to streams"

5) Calculate volume and concentration

a) As above, multiply rate by length of month to give volume output

b) As above, multiply volume by concentration to give mass output

c) Calculate remaining volume and mass

d) Divide remaining volume by remaining mass to give concentration for this month

6) Repeat for next time

By doing these calculations for model scenarios with different abstraction regimes, estimates of change in the proportion of Crag groundwater present in the peat may be obtained.

As noted in the report, it should be stressed that this is not intended to be a complete hydrochemical model of the fen: it is purely a mixing calculation, with no chemical reactions or other influences that may affect the chemistry. There are many simplifications, approximations and uncertainties within the method. It is intended as a simple method to help understand the effect of relative changes in the magnitude of the water balance components arising from changes to the abstraction/groundwater regime. The results should not be interpreted as representing the concentration of any specific determinand.

For one location (cell H), the method has been extended to give an estimate of pH change. Using concentrations of major ions from typical rainfall and Crag groundwater samples, the widely used chemical model Phreeqc has been used to estimate pH for the spectrum of mixing proportions of rainfall and Crag groundwater. These calculations are used as a "lookup table" for each point in the time series of rainfall: Crag groundwater proportions estimated by the mixing method. This then gives an estimate of a pH time series. It is again important to note, as acknowledged in the report, that this calculation considers mixing only: no other chemical reactions or influences are taken into consideration.

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