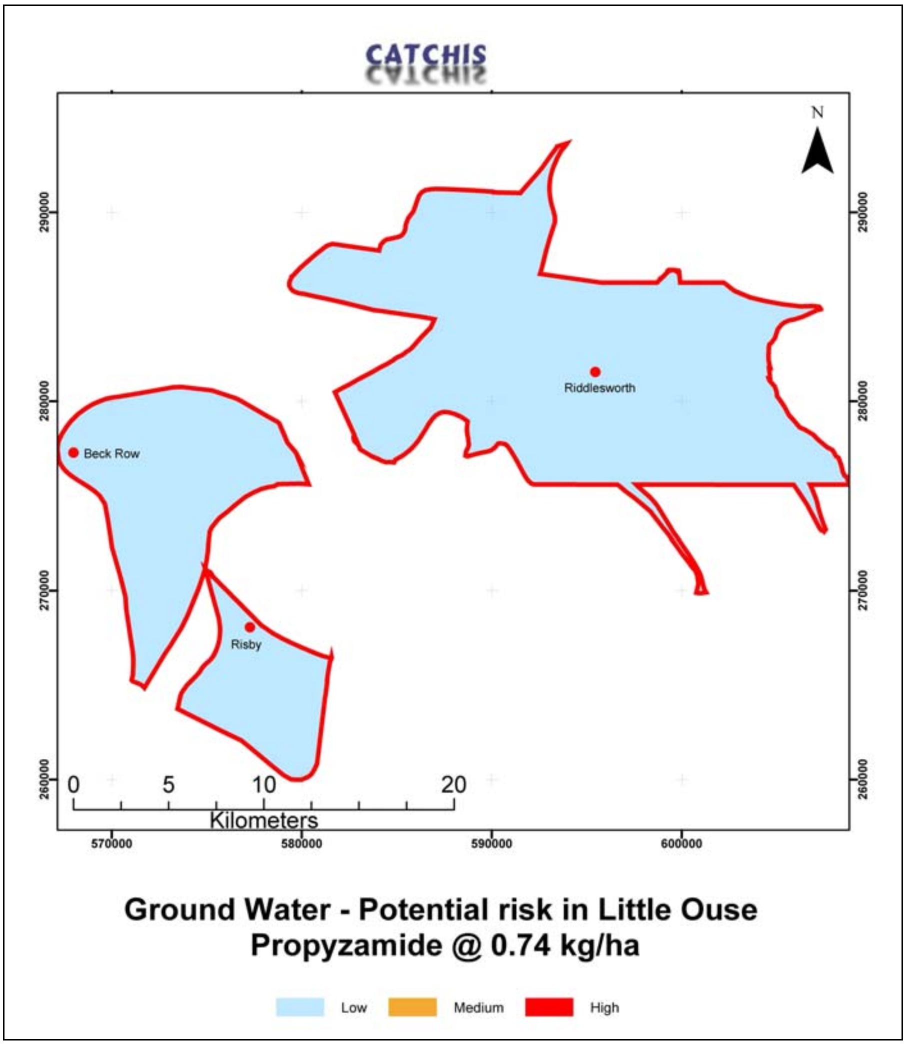
Pesticide risk maps for targeting advice activity in Little Ouse catchment

March 2007



CATCHIS

developed by:

Cranfield UNIVERSITY using GIS by ESRI technology

Executive summary

- The vulnerability of diffuse agricultural pesticides leaching to groundwater in the SPZs of Beck Row, Risby and Riddlesworth is low.
- The majority of soils within the SPZs have low to moderate leaching potentials with limited to moderate connectivity to groundwater sources.
- The region is dry (small excess rain in the winter) which may also reduce vulnerability to leaching
- Point and non-agricultural sources are likely to be important, particularly in close proximity to the borehole.

Background groundwater model

The vulnerability maps indicate 'hot-spot' areas in the catchment where the combination of soil and climate create vulnerable areas that are particularly 'leaky' and have rapid connectivity to groundwater. The vulnerability classes are based on the concentration of pesticide in recharge reaching the local groundwater surface, taking into account attenuation in the soil profile and the unsaturated zone.

The soils data

The soil data used are the National Soil Map (NatMap) and spatial polygons of soil associations and the proportion of specific soil series that comprise the polygon. Mapping is at a scale of 1:250,000. Data from soil properties are used to derive a 'soil leaching potential' class based on soil adsorption/retention potential, permeability and susceptibility to by-pass flow and depth to rock, gravel or rubble. The methods are based on the national groundwater vulnerability classification developed for the Policy and Practice for the Protection of Groundwater (Environment Agency, 1998). However, further subdivision of some classes is made to ensure that they contain a limited range of physical characteristics consistent with the derivation of input parameters required for the soil leaching model. The characteristics of the general classes are as follows:

Class H1

Soils of high leaching potential, because of their shallowness or susceptibility to by-rapid pass flow. Such soils readily transmit liquid discharges directly to rock, gravel or groundwater.

Class H2

Deep, permeable coarse textured soils of high leaching potential, which readily transmit a wide range of pollutants because of their large drainable porosity, small water retention and small adsorption potential. They do not normally have groundwater within 1m depth for significant periods.

Class H3

Coarse textured or moderately shallow soils of high leaching potential, which readily transmit non-sorbed pollutants and liquid discharges but have some ability to attenuate adsorbed pollutants such as organic chemicals because of their moderate adsorption potential.

Class I1

Deep, permeable to slowly permeable soils of intermediate leaching potential, which have a moderate ability to attenuate a wide range of diffuse-source pollutants but in which it is possible that some non-adsorbed diffuse-source pollutants and liquid discharges could penetrate the soil layer.

Class I2

Deep, artificially-drained organic soils of intermediate leaching potential. They are unlikely to transmit adsorbed pollutants because of their large adsorption potential but could possibly transmit some non-adsorbed pollutants or liquid discharges. Such soils normally have groundwater within 2m depth, usually maintained by regional pumping networks.

Class L

Slowly permeable, seasonally wet soils in which pollutants are unlikely to penetrate the soil layer, either because excess water movement is largely horizontal or because they have a large ability to attenuate diffuse source pollutants.

The climatic data

The climatic parameter used by the model is the average annual hydrologically effective rainfall (AAHER). This is the amount of rainfall available to subsurface stores after losses from evapotranspiration and is hence greatest in the winter months. Excess winter rainfall (XWR) is also used to determine agroclimatic regions as part of the parameterisation of the soil leaching model. The climatic classes were based on the spatial distribution of XWR and the following ranges were differentiated:

< 100   100 – 150   150 – 250   250 – 300   300 – 500   500 – 700 mm

It is assumed that areas with XWR of more than 700 mm are not suitable for agriculture.

The pesticide data

The pesticide fate model used requires information on how quickly the compound breaks down in the soil (the pesticide half life in soil, or $T_{1/2}$) and how strongly it is held within the soil against drainage (the soil sorption coefficient, normalised for organic carbon content, or Koc). Realistic 'best-case' values for Koc (maximum sorption) and $T_{1/2}$ (minimum half life) were derived from data held within the NSRI – Severn-Trent Water Catchment Information System (CatchIS, Breach *et al*, 1994). These data comprise a realistic range of values for the Koc and half life of individual compounds compiled from various published sources and verified with the companies who registered the compounds for use in the UK.

Chemical	Koc	$T_{1/2}$
Atrazine	174	17
Chlorotoluron	384	30
Diuron	534	30
Isoproturon	235	13
MCPA	60	6
Mecoprop-P	40	7
Propyzamide	990	16
Simazine	377	20
Trietazine	400	50

The groundwater pesticide fate model

The groundwater model comprises a 'meta-model' version of the dual-porosity soil leaching model, MACRO (Jarvis, 1994) coupled to a simple Attenuation Factor model to simulate pesticide dissipation in the unsaturated zone of the soil substrate material.

Soil Leaching: The MACRO Meta-model

MACRO is a complex mechanistic, dual-porosity pesticide leaching model capable of simulating daily pesticide leaching losses resulting from 'preferential flow' within soils, as well as from bulk matrix flow and convection / dispersion. The model is widely used, especially within Europe and has had a limited amount of validation using local field, plot and lysimeter studies. MACRO is the only preferential flow model that is used for national regulatory purposes (in Denmark and Sweden) and is one of the models recommended by both the Groundwater and Surface water working groups of FOCUS (European Commission 1995, 1996). A comprehensive evaluation of MACRO version 4.0 is given by Beulke *et al* (1998). In order to avoid parameterization and run-time problems whilst capitalizing on the 'state-of-the art' nature of MACRO for predicting soil leaching, a meta-version was developed based on results from 4,704 model runs representing a realistic range of soil / climate scenario derived from the soil leaching classes and the climatic regions differentiated by XWR. These produced 48 soil-climate combinations.

The 4,704 predicted maximum annual average soil leachate concentrations resulting from the MACRO model runs have been compiled into a ‘look-up table’ with a fixed structure based on soil leaching potential class and average annual hydrologically effective rainfall (AAHER). Using this look-up table, the MACRO meta-model estimates the maximum annual average soil leachate concentration by interpolation between appropriate predicted values within the table. The identification of appropriate predicted values in the look-up table and the interpolation between them uses the pesticide Koc and soil half-life values from the Module input file together with computed values for the soil leaching potential class, average annual hydrologically effective rainfall (AAHER) and average seasonal pesticide loading.

Attenuation Factor in the unsaturated zone

Calculation of the attenuation factor is based on the work of Rao *et al*. (1985) and Leonard and Knisel (1988). It takes the *pesticide half-life* ($T_{1/2}$) in the substrate and, assuming a first-order rate constant for degradation (*i.e.* that there is an exponential decrease in pesticide concentration with time and that this rate of decrease remains constant with time), calculates the amount of attenuation that will occur during the estimated *time taken* (Td) by the pesticide to leach out of the substrate. The model calculates the attenuation by integrating:

1. Pesticide half life- based on topsoil half life values that are increased in relation to the lower organic matter contents in the substrate and consequently decreased degradation through microbial activity.

2. Substrate leaching time- calculated from a) thickness of the substrate b) water flux (based on AAHER) c) substrate retardation factor (based on water retention characteristics of porous substrates).

Data is derived from the lowest soil layer in the input file as representative of substrate conditions.

Output from the model

Using the two models described above, leachate concentrations are predicted for each soil series / substrate in the grid and a weighted average grid concentration is calculated based on the percentage cover of each component soil series. The model is independent of land use and assumes the pesticide is applied over the whole area of interest. The outputs provide an indication of the concentration of pesticide impacting on the local groundwater source at the grid and do not take into account concentrations at the abstraction source or historical accumulation in the aquifer system. The predicted concentrations are not treated as absolute values but are translated into one of three relative risk categories: Low, Medium or High. The range of concentrations associated with each class is as follows:

Low 0 – 0.1 μg l^{-1}

Medium 0.11 – 0.4 μg l^{-1}

High 0.4 – 1 μg l^{-1}

Interpretation of the map

When interpreting the maps it is important to remember certain assumptions on which the risk assessment is based.

1. The mapped areas are independent of land use and crop data. The map represents the combination of soil and climate characteristics that produce vulnerable situations with leaching potential. Therefore, the model assumes that the pesticide is applied over the whole area (unless it non-agricultural eg ‘urban’ or ‘upland peat’) and gives vulnerability should the pesticide be applied to the specific area. Assessment of actual cropping and land use should be sought from agronomists in the catchment and used in association with the vulnerability maps.
2. As the maps are based on the National Soil Map at 1; 250,000, care should be taken when extrapolating the assessment to specific smaller scale areas (eg. fields) within the map units displayed on the map. For smaller scale areas more detailed characterisation of soil types within certain fields, particularly those close to the borehole, would need to be undertaken.
3. As climate data is indicative of meteorological conditions over long-term periods it represents areas of agroclimatic significance that determine appropriate cropping and land use. The climatic data used to in the model to determine events that contribute to leaching is representative of ‘average’ conditions determined from long-term data. Consideration of weather patterns in a specific timeframe within the catchment should also be taken into account. There are likely to be some years when leaching is greater (eg. because of a particularly

wet late summer and early autumn- greater HER) than the period used in the model, which would give higher concentrations.

4. The assessment only takes into account diffuse agricultural sources and assumes best practice. It does not take into account point sources, non-agricultural sources or inputs from bad practice.

The map is thus simply a generalised vulnerability assessment that attempts to integrate the inherent local environmental risk factors (soil and climate) with the risks attached to the pesticide characteristics.

Interpretation of differences in the vulnerability maps

All compounds in all three source protection zones show low vulnerability for pesticide impacting on groundwater sources from diffuse agricultural inputs. Soils in the Risby SPZ are dominated by I class soils which tend to be deep argillic brown earths and soils with slowly permeable clayey subsoils (Stagnogleyic brown earths and calcareous Pelosols). These have intermediate leaching potentials. Some areas of H2 and H3 class soils are also present in the SPZ which are typified by well drained brown sands and loamy brown earths, respectively. Riddlesworth and Beck Row SPZs are dominated by H2 class soils which are well drained brown sands. Some areas of H1 class soils are present in the SPZ and these are shallow calcareous rendzinas over chalk. The climate may be a limiting factor for leachability because the region is typified by low excess winter rainfall (<100mm) and may limit the potential for leaching.

Other issues:

The model does not take into account non-agricultural sources. This is particularly pertinent to pesticides that are commonly (either at present or historically) applied on hard surfaces (Diuron, Simazine - historically), horticultural/ornamental cultivations (Atrizine, Simazine) and Forestry (Simazine). These may be dominant sources for specific pesticides that have been detected in boreholes. By-pass flow through fissures in sandstone and chalk aquifers may provide further complications in the discrepancy between calculations based on likely pesticide attenuation from diffuse sources and concentrations appearing in the groundwater source.

References

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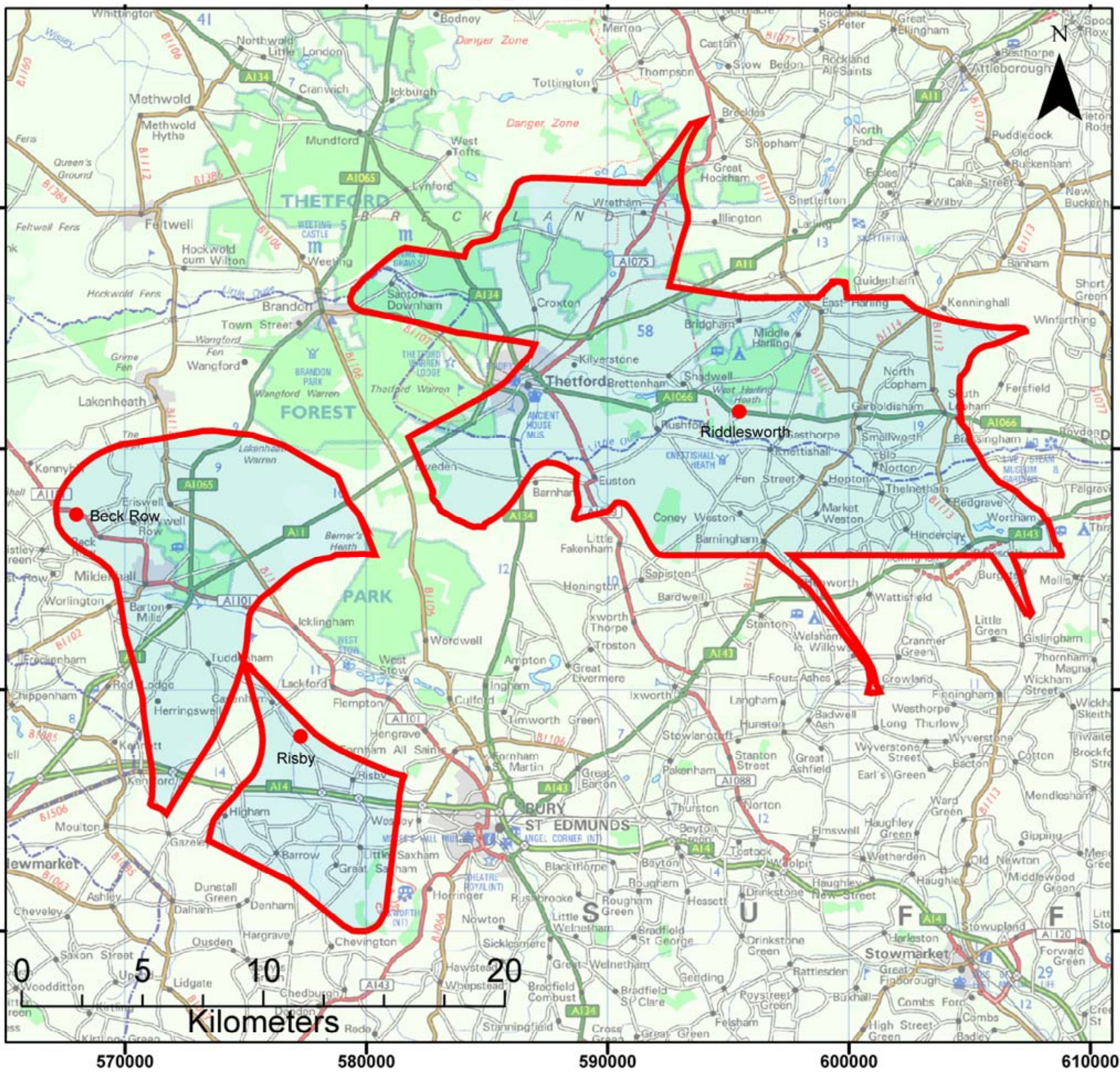
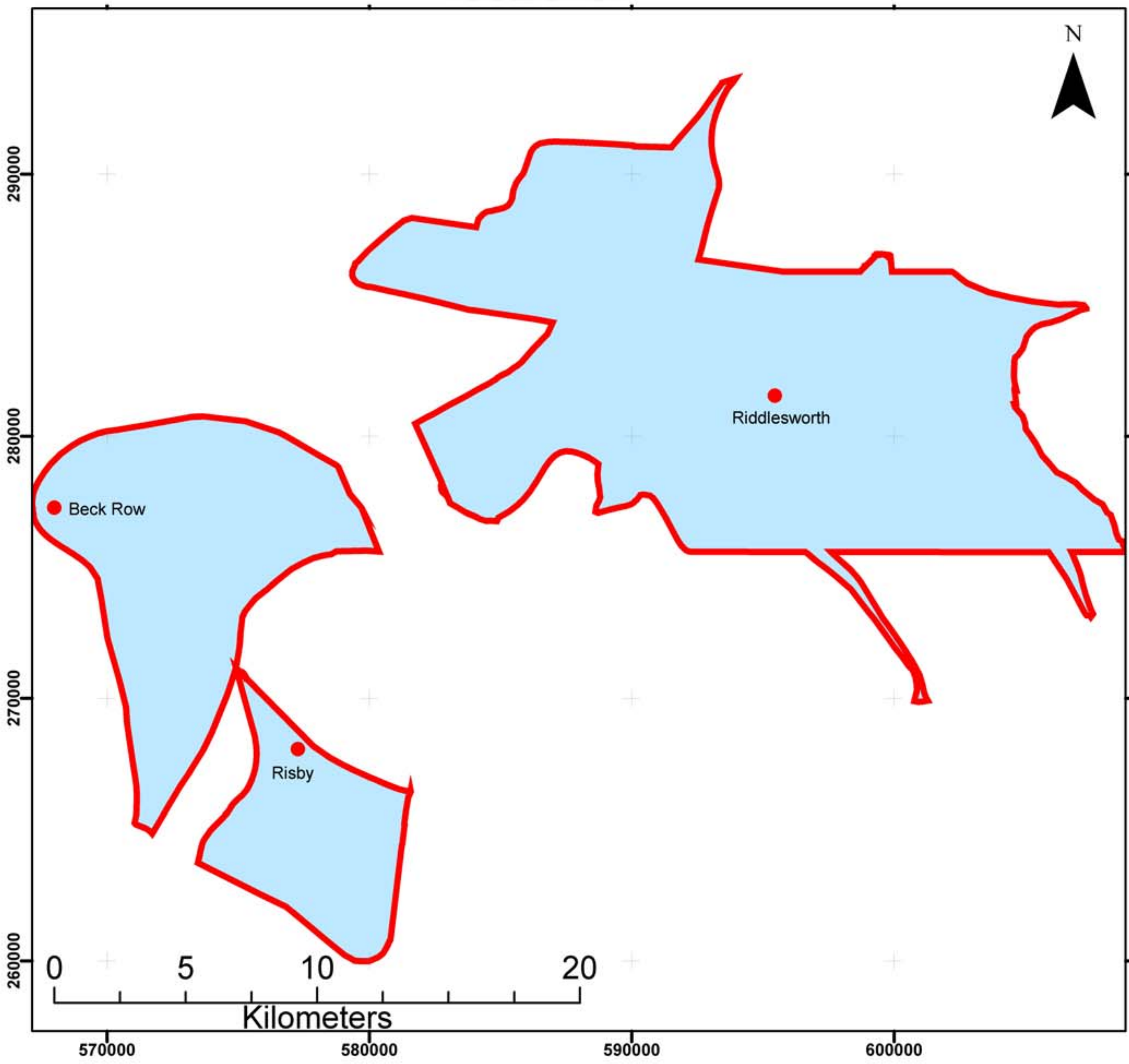


Overview of Ground Water Catchments in Little Ouse

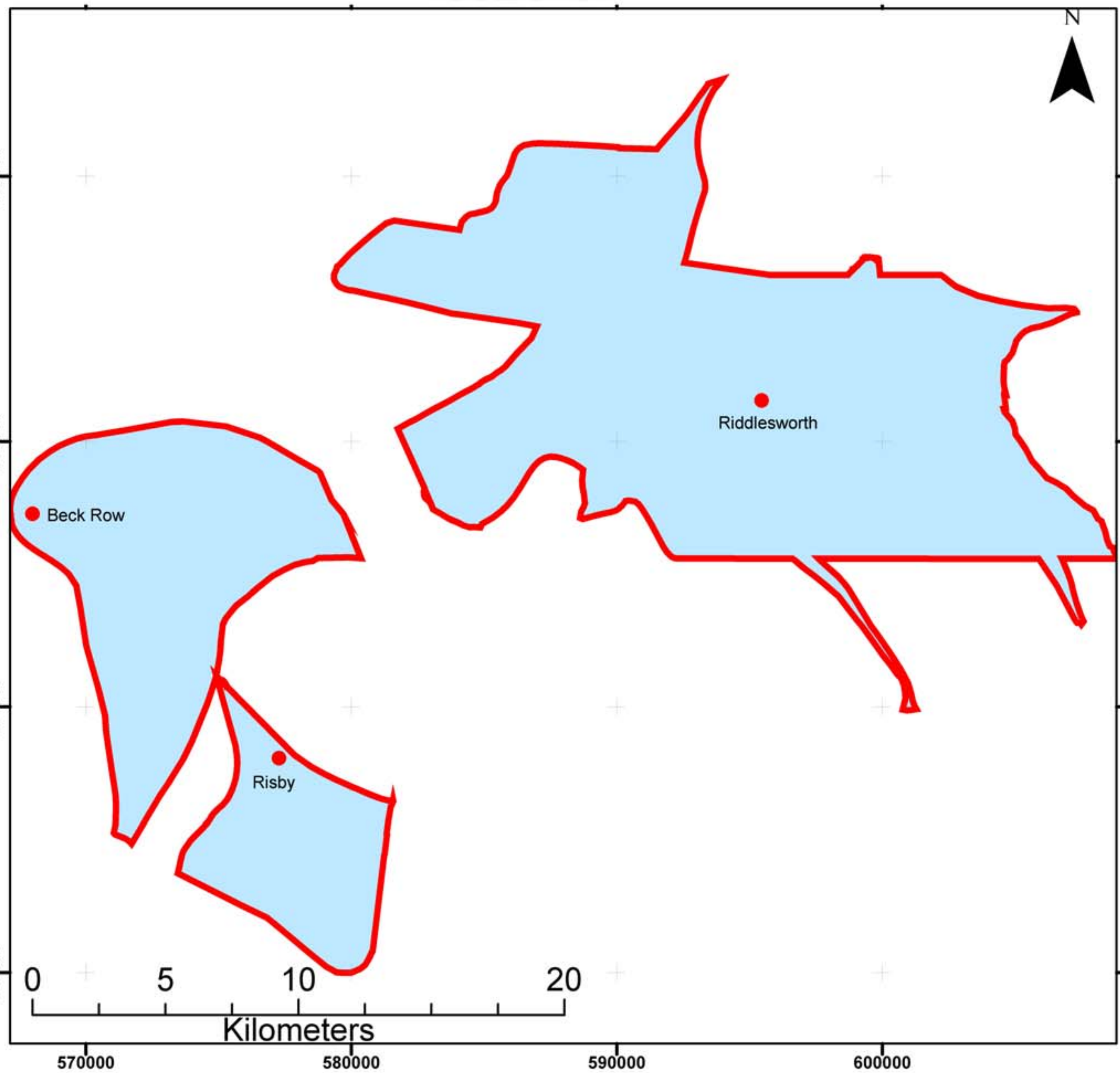
Source Protections Zones

Ground Water Locations



Ground Water - Potential risk in Little Ouse
Atrazine @ 1.5 kg/ha

Low Medium High



Ground Water - Potential Risk in Little Ouse
Diuron @ 5.4 kg/ha

Low Medium High

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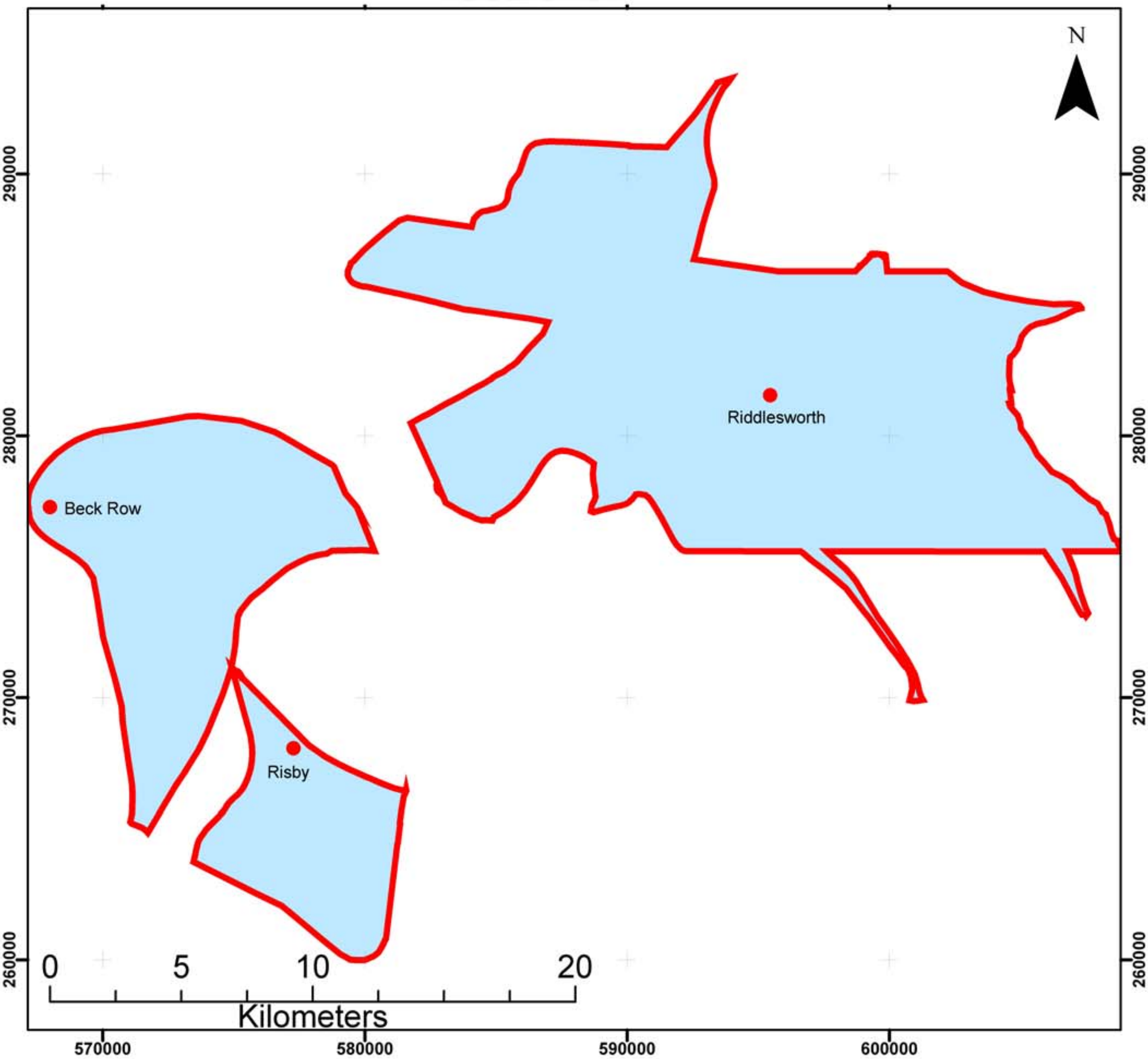

Ground Water - Potential risk in Little Ouse
Propyzamide @ 0.74 kg/ha

Low Medium High

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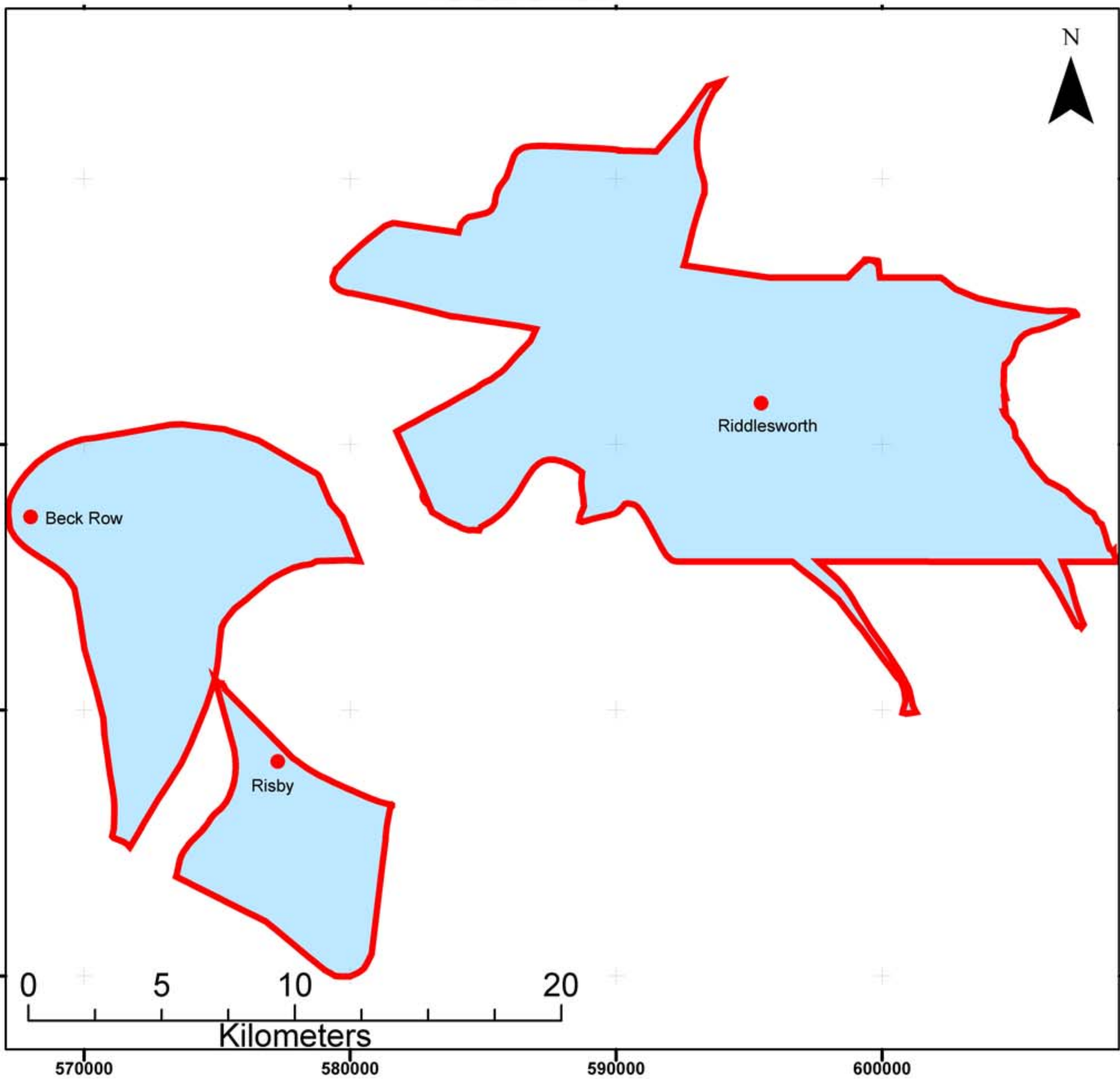
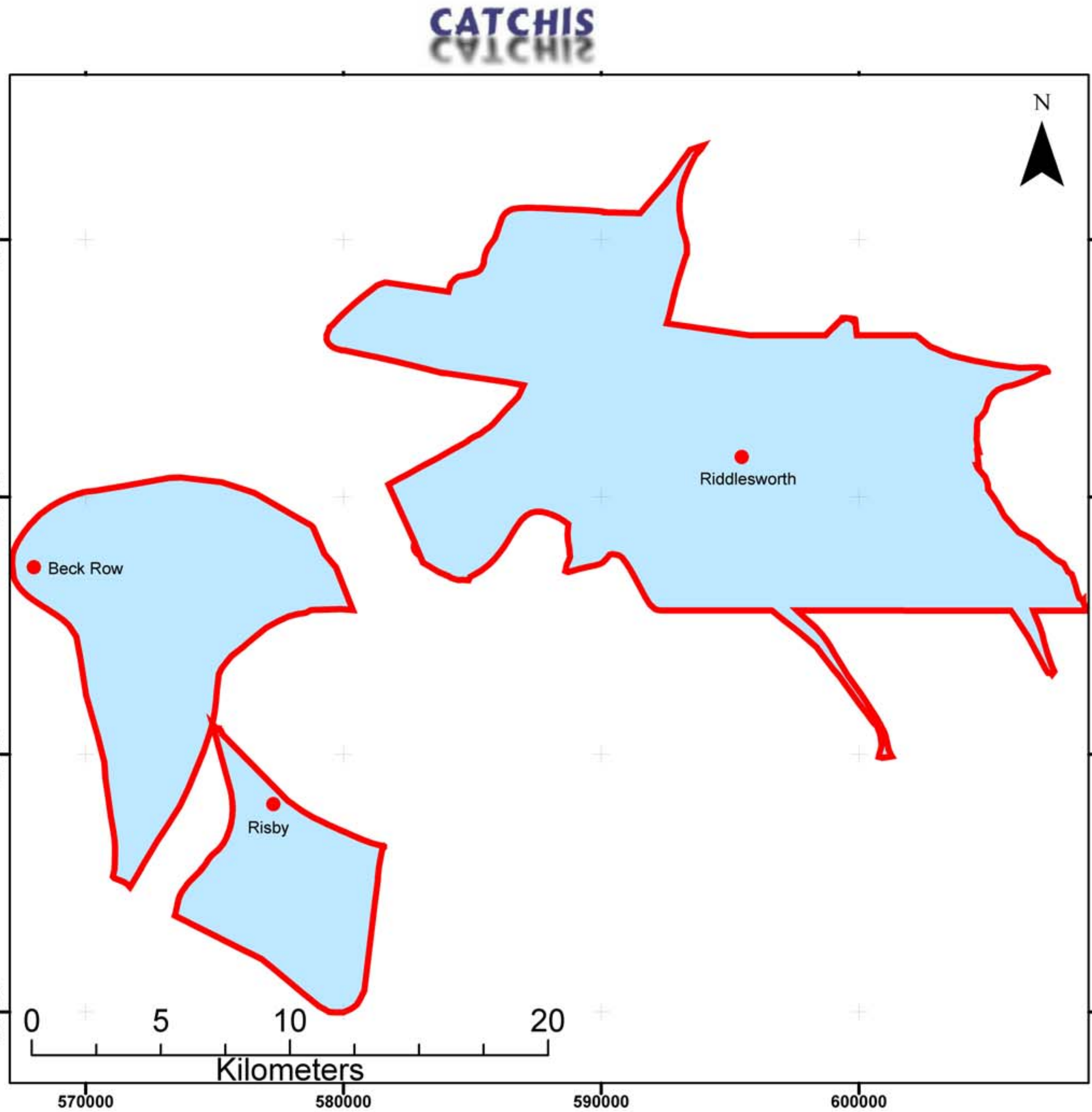


Ground Water - Potential Risk in Liitle Ouse
Simazine @ 0.9 kg/ha

Low Medium High



Ground Water - Potential Risk in Liitle Ouse
Trietazine @ 1.2 kg/ha

Low Medium High