Implementation of the Nitrates Directive (91/676/EEC)

Description of the methodology applied in identifying waters and designating Nitrates Vulnerable Zones in England (2008)

Water Quality Division, Defra
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1 Introduction

The Nitrates Directive (91/676/EEC) is designed to protect waters against nitrate pollution from agricultural sources. It requires member states to identify waters which are or could become polluted by nitrates and to designate as Nitrate Vulnerable Zones (NVZs) all land draining to those waters and contributing to the pollution. The Directive establishes the criteria for identifying waters as polluted (described in section 1.1 below) and sets down certain monitoring requirements. There is an obligation on member states to review NVZ designations at least every four years.

This document describes the methodology applied in England during the most recent review (undertaken in 2006), which resulted in the designation of approximately 70% of England as an NVZ (see figure 1). The legal basis for designation of these NVZs is set out in The Nitrate Pollution Prevention Regulations 2008 SI 2349.

Figure 1: Outcome of the 2006 review
Sections 2 - 5 of this paper provide a summary of the methodology used in the recent review. The Annexes provide a more detailed description of some of the more technical elements of the process. Figure 2 shows the structure of this document.

**Figure 2:** Simplified illustration of the sections of this document

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<th>Annexes</th>
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</tr>
<tr>
<td><strong>Section 3</strong> Groundwater</td>
<td>Identifying groundwaters which contain or could contain, if preventative action is not taken, more than 50mg of nitrate per litre. <strong>Steps 1 to 6</strong></td>
</tr>
<tr>
<td><strong>Section 4</strong> Eutrophication</td>
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1.1 The Nitrates Directive criteria for identifying polluted waters

The Directive sets the following criteria for identifying polluted waters:

- Surface freshwaters which contain or could contain, if preventative action is not taken (i.e. Action Programme measures), more than 50 mg/litre nitrate.
- Groundwaters which contain or could contain, if preventative action is not taken, more than 50 mg/litre nitrate.
- Natural freshwater lakes, or other freshwater bodies, estuaries, coastal waters and marine waters which are eutrophic or may become so in the near future if preventative action is not taken.

The Directive specifies that the following considerations must be taken into account when applying these criteria:

- The physical and environmental characteristics of the water and land;
- Current (scientific) understanding of the behaviour of nitrogen compounds in the environment (water and soil); and
- Current understanding of the impact of preventative action.

The Directive requires that at each NVZ review, changes and factors unforeseen at the previous review must be taken into account. The periodic nature of reviewing NVZs means that each review necessarily presents a ‘snapshot’ assessment of nitrate pollution up to the time of the review. The latest review was undertaken in 2006 and used data up to and including 2005.

1.2 Surface and Groundwaters assessment methodology (other than Eutrophic Waters)

The methodology used to identify the NVZs designated in 2002 has been refined and improved to form the new methodology described in this paper. It encompasses developments in scientific understanding and modelling techniques and uses a combination of water quality monitoring data and modelling techniques to provide a consistent, statistically valid approach that can be applied in the whole of England.

It represents a robust and practical approach to the identification of polluted waters and NVZs, consistent with assessment approaches adopted for the Water Framework Directive (2000/60/EC) requirements and Groundwater protection.

The methodology was developed by the Environment Agency, and the development was advised by a Defra Steering Group external to the Environment Agency which included Government officials, stakeholders and independent academic experts. It has been peer reviewed and accepted by leaders in the field of surface and groundwater management. The methodology has been applied by the Environment Agency for the most recent review, in close consultation with Defra.

1.3 Eutrophic Waters Assessment Methodology

The methodology for designating nitrate vulnerable zones on the basis of eutrophic waters was originally published in 1993. This has been updated over time to include

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1 'eutrophication': means the enrichment of water by nitrogen compounds, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned
assessment criteria which reflect a better understanding of the science and the processes involved in eutrophication.

Eutrophication is complex and describes a process of change rather than a state. The assessment of whether a water is, or may become, eutrophic is therefore not possible simply by reference to absolute numeric criteria. It is necessary to consider the current condition of the water body and whether undesirable effects due to nitrogen inputs and the growth of algae or plants have occurred, and to predict whether such effects may occur if preventative action is not taken. All these elements are included in the methodology used for the most recent review.
2 Surface freshwaters

2.1 Identifying surface freshwaters which contain, or could contain if preventative action is not taken, more than 50 mg of nitrate per litre (50 mg/l)

Step 1 – Identifying surface freshwaters for analysis
In 2006, England was divided into 4755 surface water catchments for purposes of implementing the Water Framework Directive (see figure 3). In most cases, the catchment contains only a part of the larger river or rivers flowing through it. In keeping with the Nitrates Directive’s role as a basic measure under the Water Framework Directive, these catchments have been used for this assessment.

All watercourses within each catchment were deemed to be ‘the surface water’.

41% of the surface water catchments had one or more monitoring points within them from which regular samples were taken to measure water quality. These were termed type 1 catchments. Those surface water catchments without monitoring points were termed type 2 catchments.

Figure 3: Water Framework Directive surface water catchments
Step 2 – Statistical analysis of surface water quality monitoring data

For all type 1 catchments, the water quality monitoring data from each monitoring point was analysed using statistics to determine:

- if more than 5% of the nitrate concentrations observed at each monitoring point exceeded 50mg/l, or
- if more than 5% of the nitrate concentrations at each monitoring point were predicted to exceed 50mg/l in 2010 based on trends (assuming preventative action was not taken).

If either of these criteria were met the surface water was considered to have ‘failed’ the statistical test. The level of confidence in the assessment was recorded as one of six classes (confident pass, marginal pass, face value pass, face value fail, marginal fail, or confident fail), and the results were taken forward to Step 4. Figure 4 shows the results.

Further information on the monitoring datasets and statistics used in this analysis is provided in Annex A.

Figure 4: Results of the statistical analysis of monitoring data for (a) observed and (b) predicted nitrate concentrations in surface waters – pass or fail and level of confidence

Step 3 – Modelling assessment of nitrate pollution in surface waters

In addition to the statistical analysis of monitored data, a regression model was used to predict the nitrate concentration in every surface water, taking account of nitrate pollution, for example, from atmospheric, agricultural, urban and point source inputs.

This provided an additional assessment of the risk of nitrate pollution and improved on an assessment based on monitoring data alone by:

- enabling an assessment of pollution in surface waters without any monitoring points,
• identifying the significance of agriculture’s contribution to any pollution identified, and
• providing further confidence in the conclusions of the statistical analysis of monitoring data.

If the modelled assessment predicted that 5% of the surface water nitrate concentrations would be greater than 50mg/l, then the surface water was deemed to have ‘failed’ the modelling test. The level of confidence in the modelling assessment was recorded as one of six classes (confident pass, marginal pass, face value pass, face value fail, marginal fail, or confident fail), and the results were taken forward to Step 4. Figure 5 shows the results of the modelling assessment for the surface water within each catchment in England.

Further information on the development, data inputs and workings of the regression model is provided in Annex A.

Figure 5: Results of modelling assessment for each surface water in England - pass or fail and level of confidence (note – for visual clarity, the results have been mapped using catchments rather than surface water networks).
Step 4 – Combining the outputs of the statistical analysis and modelling assessment

For those surface water catchments which did not have any water quality monitoring points (i.e. type 2 catchments) it was not possible to undertake the statistical analysis described in Step 2 above. In these instances the assessment of pollution was limited to evidence from the modelling assessment described in Step 3. If the surface water failed the modelling assessment with at least 75% confidence then it was identified as ‘polluted’ (see final row in figure 6).

For each surface water with monitored data (i.e. type 1 catchment), evidence from the modelling was combined with evidence from the results of the statistical analysis to determine if the surface water should be identified as ‘polluted’. For catchments with multiple monitoring points, the point with the highest nitrate concentration was used. Greater weight was given to monitored results over modelling data. As highlighted in figure 6, waters were only identified as ‘polluted’ if:

• the surface water failed both types of analysis, or
• the surface water failed the statistical analysis with the highest confidence, but passed the modelling assessment.

If the surface water passed the statistical analysis but failed the modelling assessment, it was not identified as polluted.

Figure 6: Combining evidence from the monitoring and modelling analyses to identify polluted waters

<table>
<thead>
<tr>
<th>Modelling</th>
<th>Pass (High conf.)</th>
<th>Pass (Marginal)</th>
<th>Pass (Face Value)</th>
<th>Fail (Face Value)</th>
<th>Fail (Marginal)</th>
<th>Fail (High conf.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Pass (High conf.)</td>
<td>Pass (Marginal)</td>
<td>Pass (Face Value)</td>
<td>Fail (Face Value)</td>
<td>Fail (Marginal)</td>
<td>Fail (High conf.)</td>
</tr>
<tr>
<td></td>
<td>Pass (High conf.)</td>
<td>Pass (Marginal)</td>
<td>Pass (Face Value)</td>
<td>Fail (Face Value)</td>
<td>Fail (Marginal)</td>
<td>Fail (High conf.)</td>
</tr>
<tr>
<td></td>
<td>Pass (Face Value)</td>
<td>Pass (Marginal)</td>
<td>Fail (Face Value)</td>
<td>Fail (Face Value)</td>
<td>Fail (Marginal)</td>
<td>Fail (High conf.)</td>
</tr>
<tr>
<td></td>
<td>Fail (Marginal)</td>
<td>Fail (Face Value)</td>
<td>Fail (Marginal)</td>
<td>Fail (High conf.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 2</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key
Monitoring: current or trend-predicted nitrate concentration
Modelling: prediction of current nitrate concentration
High confidence 95 per cent confidence
Marginal 75 per cent confidence
Face value 50 per cent confidence

Step 5 – Ground truthing for type 1 catchments

As described in step 4, model predictions were compared with the statistical analysis of the monitoring data. The difference between the model predictions and the monitoring is referred to as the model residual and is an indication that either the model or the monitoring are not what we would expect for the local landuse.

In general these model residuals were small and evenly distributed, a sign that the model is performing well. However, in two distinct geographical areas, the Wash
and North Norfolk, there was a cluster of catchments with high model residuals indicating that the monitored surface water nitrate concentration was significantly below what the model predicted would be expected given the landuse in the area.

The monitoring data in these catchments was examined in detail by the local Environment Agency staff. If the monitoring points were confirmed to be reliable indicators of nitrate pollution from diffuse sources then results of the statistical analysis were upheld and the surface waters were not identified as polluted. If the monitoring data was found to be unrepresentative, the catchment was treated as a Type 2 catchment and assessed in accordance with Step 4.

**Step 6 – Surface waters identified as polluted in 2002, but not in 2006**

Waters that were identified as polluted in 2002, but were not identified as such by the Steps above, retained their identification as polluted waters for the purposes of this review. This was justified on the ground that there was:

- insufficient data to be confident that the improvement in water quality will be sustained, and
- a risk that removal of the Action Programme in these areas could simply lead to an increase in pollution and their re-identification as polluted in the next review.

**2.2 Identifying the land draining to polluted surface waters**

Surface waters in England were identified as polluted in accordance with the steps described in 2.1 above as either type 1 or type 2. The following steps were undertaken to identify the land draining to each type.

**Step 7 – Identifying land draining to type 1 polluted surface waters**

In these catchments the following land was identified for designation as a Nitrate Vulnerable Zone:

- the catchment of the polluted surface water, plus
- the catchments of all those surface waters which are upstream of (and therefore drain into) the polluted surface water. If the failing monitoring point was on a tributary, only catchments upstream of the tributary were designated.

**Step 8 – Identifying land draining to type 2 polluted surface waters**

In these catchments the following land was identified for designation as a Nitrate Vulnerable Zone:

- the catchment of the polluted surface water, plus
- the catchments of those surface waters which are upstream of the polluted surface water, as far as the first upstream catchment with monitoring data.

Catchments of type 2 polluted waters which were less than 30km² were not designated due to insufficient confidence in the spatial accuracy of the modelling results.

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2 This was not part of the peer reviewed methodology
Step 9 – Land draining to surface waters identified as polluted in 2002, but not in 2006⁴

The boundaries of land draining to surface waters identified under Step 6 above were originally drawn in 2002. These were refined in line with the redrawing of catchment boundaries set out in Step 1 above. For the purposes of this review, it was decided that no additional land should be designated as a result of the boundary changes.

The areas of England identified as draining into polluted surface waters are identified in Figure 7 below.

Figure 7: Areas draining to polluted surface waters ("surface water NVZs")

⁴ This was not part of the peer reviewed methodology
3 Groundwaters

3.1 Identifying groundwaters which contain, or could contain if preventative action is not taken, more than 50 mg of nitrate per litre

Most of England is underlain by groundwater in aquifers. A network of 3684 monitoring points was sampled to collect data on the quality of the groundwaters in England. Groundwaters affected by nitrate pollution were identified using the following steps:

Step 1 – Statistical analysis of groundwater quality monitoring data
Water quality monitoring data from each borehole was analysed to determine the mean nitrate concentration in mid 2005 and the predicted mean nitrate concentration in 2021.

If the mean current or predicted nitrate concentration of a groundwater exceeded 45mg/l, it was deemed to have ‘failed’ the statistical test.

Further information on the monitoring datasets and statistics used in this assessment, and why a lower threshold of 45mg/l nitrate was used, is provided in Annex B.

Step 2 – Identifying pollution in areas between boreholes
Step 1 (statistical analysis of monitoring data from boreholes) only enabled the assessment of groundwater nitrate concentrations at specific points within aquifers. To assess whole areas of groundwater, it was necessary to estimate nitrate concentrations between the boreholes.

Kriging, a recognised statistical method for interpolating spatial data, was used to determine current (mid 2005) and predicted (2021) nitrate concentrations for all areas of groundwater in England. Figure 8 shows the results of the interpolation of analysed monitoring data.
Step 3 – Modelling assessment of nitrate leaching to groundwaters

The same landuse data that was used in the regression modelling assessment for surface waters (i.e. atmospheric, agricultural and urban diffuse inputs as described in Annex A, sections 2.2.1 – 2.2.3) was used to predict the amount and source of nitrate leaching to groundwater.

This was done to give a more balanced assessment of the risk of nitrate pollution from agriculture than that which would have come from an assessment of monitoring data alone. The principle purposes of using the landuse data were to:

- identify the significance of the agricultural contribution to any nitrate pollution identified,
- provide further confidence in the conclusions of the statistical analysis of monitoring data, and
- minimise the possibility that the long travel times for nitrate at the surface to reach deep groundwater and become apparent in monitoring data, could lead to the borehole failing due to historic landuse.

The model output was an estimate of the concentration of leached nitrate at the base of the soil zone, for each 1km square in England.

Step 4 – Combining the monitoring and modelling assessments

A risk model was used to overlay the results from Step 3 (nitrate leaching from base of the soil zone) with those from Step 2 (kriged groundwater nitrate concentrations). To note, greater weight was given to monitored results over modelling data.
For every 1km square in England, the risk model assessed the confidence with which it could be determined that the nitrate concentration in the groundwater exceeded, or is likely to exceed (by 2021), 50mg/l and that the source of nitrate includes agriculture. One of three levels of confidence was assigned to each kilometre square:

- **High confidence** – both the monitoring and modelling assessments agreed that nitrate concentrations exceeded or were likely to exceed 50mg/l, and that agriculture was a significant source of the pollution identified (i.e. the modelling assessment identified that at least 30mg/l of the nitrate in the leachate was from agriculture).
- **Medium confidence** – either the monitoring or modelling assessments show that nitrate concentrations exceeded or were likely to exceed 50mg/l, but were not in agreement.
- **Low confidence** – both the monitoring and modelling assessments show that nitrate concentrations were not likely to exceed 50mg/l

Further information on the risk model used to combine the monitoring and modelling assessments is provided in Environment Agency, 2008c.

**Step 5 – Ground-truthing**

To incorporate local knowledge and understanding, the output from Step 4 was reviewed and modified by groundwater quality teams within the Environment Agency. The following national datasets were used to inform this ground-truthing process; solid geology, drift geology, drift thickness, drift permeability, risk of solution features, depth of unsaturated zone, groundwater head, available water and mean surface water nitrate concentration estimated by the regression model (see Annex A).

Modifications to the level of confidence in the output from Step 4 were made on the basis of the following:

- **De-nitrification or mixing** – if these processes act in an area to reduce nitrate concentrations before it reaches the groundwater then the level of confidence could be downgraded.
- **Point source pollution** – if monitoring from a borehole is representative of point source pollution then the level of confidence could be downgraded. Nitrate inputs from point sources and urban sources were considered to help support any modification that was made to the level of confidence.
- **Monitoring is unrepresentative of diffuse nitrate pollution from agriculture** – then the level of confidence could be either downgraded or upgraded dependent on the hydrogeological setting. For example:
  - if a monitoring point takes samples from a deep confined aquifer it would not be representative of shallow unconfined groundwater quality above it.
  - if the monitoring data is from a deep unconfined aquifer, with long delays between pollution leaving the surface and being monitored.
- **Surface water monitoring is available in areas with infrequent groundwater monitoring** – this could be used to upgrade the level of confidence where the data is representative of groundwater quality.

Each 1 km square identified as exceeding 50mg/l with high confidence was taken to represent ‘polluted’ groundwaters. All changes to the level of confidence were based on sound evidence and were recorded within the risk model to provide an audit trail. Once all the modifications had been made the risk model was re-run.
Full details of the modifications permitted and how these changed the risk model are described in Environment Agency, 2008c.

3.2 Identifying the land draining to polluted groundwaters

The following steps were undertaken to identify the land draining to those groundwaters in England which were identified as polluted in accordance with the steps described in 3.1 above.

Step 6 – Using hydrogeological features to identify land draining into polluted groundwaters

Land that is directly above a polluted groundwater does not necessarily drain into it. There are a number of factors affecting the course of water from the surface downwards into a groundwater body including, for example, the presence of a layer of impermeable rock. Similarly, land that is not directly above a polluted groundwater may drain into it, possibly due to lateral flow within the soil.

With professional judgement, the following hydrogeological boundaries were used, in reducing order of preference, to delineate the catchments of the ‘polluted’ groundwaters:

- **Solid or drift geology** (1:50,000)
- **Risk of solution features** (1:50,000) – where solution features are present it can be more appropriate to use this layer than solid geology. This is because the solution feature layer includes a three dimensional aspect at the edge of an aquifer. If the rock at the surface is non aquifer but it is prone to solution features then it is important that the NVZ is extended to include this area
- **Surface water outflow feature** (e.g. river, lake) – these features often define a groundwater divide. Where nitrate risk is high on one side of such a feature they can be used to define catchments.
- **Urban areas** – whilst they do not represent a hydraulic boundary, they can be useful as a boundary beyond which there is no agricultural nitrate contributing to the high risk area.
- **Groundwater flow lines** – used to delineate within an aquifer. Flow lines represent a line across which groundwater does not flow and are drawn perpendicular to groundwater head contours. This type of boundary is subject to professional judgement and has only been used when none of the other boundaries are appropriate.

Step 7 – Groundwater NVZs designated in 2002, but not identified for designation in 2006

Improvements in the network of boreholes for monitoring the quality of groundwaters, and the use of hydrogeological knowledge and data, meant that it was possible to identify polluted groundwaters and their catchments more accurately in this review.

Therefore, where groundwater NVZs designated in 2002 were not identified for designation under the preceding Steps 1 – 5, their designation status was removed for the purposes of this review.

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4 This was not part of the peer reviewed methodology
Step 8 - Further checks

Before making a final determination of the land draining to a polluted groundwater, further checks were undertaken for those waters which had been identified by limited monitoring data to confirm that:

- it had more than one monitoring point that was exhibiting high nitrate concentrations. If there was only one monitoring point it must have data over a reasonable period (at least a 12 months).
- a significant proportion of the land had an agricultural loading (from the modelling assessment) greater than 30mg/l. This figure was taken to be a reasonable indication that nitrate leaching from the land is significant. This check confirmed that the high confidence criteria of Step 4 were met.

These checks were made to prevent any unsupportable designations being made as a result of the greater weight given by the risk model to monitoring data. If the land failed either of these checks it was not designated as an NVZ.

The areas of England identified as draining to polluted groundwaters are identified in Figure 9 below.

Figure 9: Areas draining to polluted groundwaters (“groundwater NVZs”)
4 Waters Subject to Eutrophication

4.1 Identifying water bodies that are eutrophic or could become eutrophic

Eutrophication describes a process of change rather than a state and studies have shown that it is controlled by a number of factors. These include nutrients, flow rate of waters, shading and turbidity, depth, temperature and turbulence. The precise influence of many of these factors in the process is not easily quantified.

From the definition in the Nitrates Directive and the Regulations, eutrophication has three sequential elements:

a) enrichment of water by nitrogen;

b) causing an accelerated growth of algae and higher forms of plant life; and

c) producing an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned.

The requirement is to identify waters which are eutrophic, or in the near future may become eutrophic if preventative action is not taken, following reviews at least every four years. To do this, it is necessary to consider the current condition of the water body (ideally compared to a reference condition) and whether undesirable effects due to nitrogen inputs and the growth of algae or plants had occurred, and to predict whether such effects may occur if preventative action is not taken. The current or future eutrophic state of a water body can only be assessed by the consideration of evidence collected against each of the above three elements.

Water bodies in England were assessed for eutrophication using the following three steps:

Step 1 – Focusing in on water bodies of concern

The Environment Agency (EA) has adopted a risk-based approach to monitoring for eutrophication. Information from national monitoring programmes (e.g. the General Quality Assessment monitoring network for rivers), operational investigations and local knowledge was used to identify specific water bodies which warranted a more detailed investigation. Information was considered for different water body types – rivers, lakes, transitional (estuarine) and coastal.

For the 2006 review, a number of lakes and transitional waters were identified for more detailed assessment.

Step 2 – Detailed investigation of individual water bodies

For the lakes and transitional waters identified under Step 1, further more focused evidence was collected by Environment Agency staff to determine whether the waters were eutrophic or at risk of becoming eutrophic in the near future.

Evidence collected was compared against suites of criteria for the different types of water under investigation. The criteria are both quantitative and qualitative and reflect the three elements of eutrophication. They are broken down as follows:-

Nutrients (category I) – nitrogen and phosphorus are termed causative parameters. Both can contribute to eutrophication, but for the Nitrates Directive we only identify polluted waters if sufficient nitrate is present to promote
eutrophication. Thresholds have been established for the relevant water types to decide whether waters are enriched by nutrients.

Plants/algae (category II) – elevated nutrient concentrations can have a range of impacts on the plant life in waters. These are termed response parameters. The changes assessed include:
- increased abundance and biomass of algae (phytoplankton, macroalgae, benthic diatoms) and/or higher plants
- changes to species composition
- exceptional algal blooms

Secondary and other effects (category III) – water quality and adverse ecological impacts resulting from excessive plant/algal growth including changes to dissolved oxygen, occurrence of toxic/harmful algal blooms and the effects on other flora and fauna.

Information on the impact on water use (e.g. recreation or conservation value) was also considered.

Further detail of the criteria for identifying lakes and transitional waters is set out in Annex C. Although national guidance and criteria for each water body type is provided, the importance of particular symptoms depends upon local circumstances and water body type.

The criteria described above are based on an understanding of the relevant science. The assessment of whether a water is eutrophic or may become eutrophic is not possible simply by reference to absolute numeric criteria. A number of symptoms are considered in order to come to a rounded judgement, taking into account the weight of evidence, as to whether an individual water is suffering an “undesirable disturbance” or may do so without preventative action.

A case for identification was considered to exist where it was found that the Category I (causative) criteria were exceeded and some (or all) of the Category II (response) and Category III (secondary and others effects) criteria were exceeded, or may be exceeded, taking into account the influence of relevant environmental factors and considering the overall weight of evidence.

To promote consistency in collating, vetting and making decisions on the data/information gathered, a proforma was completed for all waters assessed. An example pro-forma for one type of water is given in Annex D. These summarised the condition of each water body in terms of data gathered for comparison to the relevant chemical, biological and other criteria, plus supporting information.

Step 3 - Quality assurance and submission of data to a national panel
Eutrophication is complex, and in recognition of the subjective nature of certain of the criteria, a national Environment Agency panel was used to ensure consistency in the assessment procedure. 73 proformas for lakes and 9 proformas for transitional waters were put forward to the national panel for consideration.

The national panel reviewed the proformas for each water body and formed the view that the criteria for eutrophication were met in relation to 26 lakes and 8 estuaries in England. The national panel reviewed the proformas for each water
body and formed the view that the criteria for eutrophication were met in relation to 26 lakes and 8 estuaries in England. These recommendations were put to Defra for approval and identification as polluted waters (eutrophic).

4.2 Identifying the land draining to eutrophic water bodies

The following step was undertaken to identify the land draining to those surface waters in England which were identified as polluted in accordance with the steps described in 4.1 above.

Step 4 – Identification of land

The land draining to the polluted waters (eutrophic) was defined as:

• land draining directly to the eutrophic water, for which specific hydrological boundaries were drawn within the WFD catchment boundaries described in 2.1 above, plus
• the WFD catchments of all those surface waters which are upstream of (and therefore drain into) the eutrophic water.

Figure 10 below identifies areas of England identified as draining to polluted waters (eutrophic).
Figure 10: Areas draining to polluted waters (eutrophic) ("eutrophic NVZs")
5 Identification of final NVZ boundaries

5.1 Matching the soft boundaries to identifiable features on the landscape

The boundaries identified by implementing the earlier parts of the methodology are based upon hydrological and hydrogeological features, and as such do not follow any landscape features such as hedges, fences, roads etc. It is therefore quite common for these boundaries to dissect a field. To make these ‘soft’ boundaries more practical and workable, they are adjusted to follow field boundaries. This ‘hard’ boundary forms the basis for designating NVZs.

Converting the soft boundaries into hard boundaries can be achieved by laying the soft boundary areas over large scale, detailed, Ordnance Survey (OS) digital map data (Landline) and matching the soft boundaries to the most appropriate mapped boundary features.

The detailed rules and supporting guidelines by which the outer soft boundaries are converted into hard boundaries are as follows. In these rules, references to waters should be taken to mean waters that are polluted or could become polluted.

Rules for the inclusion/exclusion of individual fields

Rule 1 - For land draining within a surface water NVZ and eutrophic NVZ, individual fields with 50% or more area within the outer soft boundary are to be wholly included in the final NVZ area.

Rule 2 - For land within a groundwater NVZ, if any part of the field falls within the soft boundary, the whole field is to be included in the final NVZ area.

In situations where part of a field drains into a surface water or eutrophic water and partly drains into groundwater, rule 2 takes priority over rule 1. If the field is partially covered by a NVZ, which is a combination of a surface water/eutrophic NVZ and a groundwater NVZ, then rule 2 must be applied.

When applying rules 1 and 2, this may, in some situations lead to designation of isolated fields. Where Rule 1 or 2 creates isolated areas outside the main boundary:

Rule 3 - Individual, isolated single fields outside the main boundary are removed. This does not extend to clusters of fields or very large land areas.

Defining boundaries at heads of watersheds can be difficult, especially in more extensive agricultural areas where no field boundary runs close to the catchment boundary. An additional problem is that the nearest field boundary may be into the next catchment and is therefore an inappropriate boundary to use in hydrological terms.

Rule 4 - Fix boundary of heads of watersheds as the nearest field boundary on the inside of the watershed, where this lies within a reasonable distance (e.g. up to 400m) from the soft boundary.

Rule 5 - For watersheds where there is no field boundary on the inside of the watershed within a reasonable distance, the NVZ boundary will remain as shown on the soft map and will not be linked to the nearest Landline feature. In such
cases the hard boundary will effectively follow the natural watershed boundary of the designated catchment.

Rule 5 above is likely to be workable in most cases because such areas with no field boundaries are unlikely to be in intensive agriculture and therefore unlikely to have difficulty complying with the Action Programme rules.

**General guidelines in support of the Rules**

- Only solid (identifiable) features on the ground as identified on the O.S. Landline data are to be used for hard boundary definition. In most instances this will be represented by a continuous line on the Landline data. (E.g. wall, fence, hedge, road edge, byway)

- Areas of woodland, copse and plantation that are unfenced can be used in forming the hard boundary, providing they are depicted as such on the OS Landline data.

- Areas of commercial woodland will be included within the NVZ hard boundary to ensure all isolated parcels of agricultural land, as appears on the Rural Land Register, are included.

- When interpreting the aim should be to keep to the true hydrological boundary.

- Decisions can only be based on the representation of features on the ground as mapped within OS Landline data, but can be helped by using Rural Land Registry data, UK Perspectives (UKP) aerial photography data and other recognised datasets such as the Moorland Line. However, there will be occasions where the boundary has to cross a feature such as a road, railway line or airfield, to link the hard boundary between two land parcels. In this situation the procedure is to cross the feature in a straight line, at the same time as minimising the amount of the feature to be included within the hard boundary.

- Areas of urban conurbation can be omitted where they fall on the boundary. The NVZ hard boundary can cut across an urban area by the road system in order to ensure that isolated parcels of agricultural land, as identified on the Rural Land Register, are captured if appropriate to the soft boundary. The Urban area should be identified within OS Landline, but it can be confirmed by using OS 1:10,000 mapping, the Rural Land Register mapping and UKP aerial photography.

- Where the soft boundary crosses the coastline the hard boundary must follow the Mean High Water Line. At estuaries the hard boundary can cross the water course where the width of the channel between the high water marks becomes less than 750m. This is a practical solution which captures the appropriate agricultural land, whilst avoiding the creation of an unnecessarily long and complex perimeter to the NVZ.

- Interpretation must be driven by a clear combination of the basic Rules above, the supporting guidelines and the OS data. In some instances implementation of the rules and guidelines will not result in a definitive location for the hard boundary. In such instances, the digital map data is interpreted to include land draining into waters that are polluted or could become polluted. In the case of a discrepancy
between OS maps and features on the ground, the features on the ground must prevail.

Specific guidelines in support of Rules

- Tracks and other features clearly splitting a field can be used to define the hard boundary. (E.g. ditches, hedges, fences, walls, byways – but not footpaths / nominal public rights of way).
- Internal redundant field boundaries (pecked) are to be ignored.
- If an area is clearly labelled such as a wood and is clearly defined, this can be used to identify smaller fields than would be possible without the named area.
- In tidal areas the mean high water line can be used as a defining line, if no other feature is available.
- The existing NVZ boundary (designated in 2002) was digitised using Landline mapping, with revisions made following an appeal process. This line is not to be re-interpreted using current mapping or any other supporting datasets.

5.2 Filling in gaps

Where gaps were left within the area of new NVZs these were filled in if their area was less than 100 hectares. This only applied to gaps that were completely within an NVZ, not to gaps between NVZs.

The final NVZ boundaries are shown in figure 1. More detailed, interactive maps are available via the Defra website.
Annexes

Detailed description of some of the more technical elements of the methodology
Annex A  Surface freshwaters

1.  Statistical analysis of water quality monitoring data (section 2, step 2)

As described in section 2, step 2, water quality monitoring data was analysed to determine:

- if the observed nitrate concentration exceeded 50mg/l in 2004, or
- if the nitrate concentration was predicted to exceed 50mg/l in by 2010.

This section describes the datasets and statistics used in the above analysis.

1.1  Surface water quality datasets

The General Quality Assessment (GQA) surface water monitoring network comprises approximately 6878 sampling sites. Approximately 12 samples have been taken from each site each year for more than 30 years. The samples are analysed and their nitrate concentration recorded (among many other water quality parameters).

The following datasets were compiled from the GQA network:

- All nitrate concentrations recorded during 1999 – 2004 (6 years).
- All nitrate concentrations recorded during 1990 – 2004 (15 years).

The dataset comprising 6 years monitoring data was used in both the regression modelling (see section 2 below) and the non-parametric Weibull method (see section 1.2.1 below). The dataset comprising 15 years monitoring data was used in the trend analysis (see section 1.2.2 below) as more data was required for this analysis.

The following quality assurance (QA) checks were applied to these datasets to ensure that misleading data were not included in any of the analyses:

- For each monitoring site, outliers in the data were excluded using the standard Environment Agency approach, the Multiple Outlier Test (Environment Agency, 1992)
- Each monitoring site was identified and recorded as being located on either a main river (i.e. one extending beyond the upper limit of a catchment) or a tributary (i.e. a stream or river not extending beyond the boundary of the catchment). Distinguishing between “main river” and “tributary” monitoring points is necessary to ensure that upstream catchments are only designated as NVZs if they are hydrologically connected to a downstream, failing monitoring point (see section 2, step 7). In other words, land upstream of a surface water catchment, draining via the main river, will not be designated on the basis of a polluted tributary that is only draining land within the boundary of the local catchment.

1.2  Statistics

1.2.1  Non-parametric Weibull method

The non-parametric Weibull method (see Information Box 1) was used to estimate the 95 percentile nitrate concentration at each monitoring point and whether this exceeded 50mg/l nitrate (i.e. it identified if more than 5% of the nitrate concentrations observed at each monitoring point exceeded 50mg/l).
The method requires a sufficient number of observations, hence 6 years monitoring data, providing a maximum of 72 observations per monitoring site, were used. The method was applied to the most recent 6 years data available at the time of analysis. These data were collected over the period 1999-2004.

The results of the assessment were recorded at three levels of confidence:

- high confidence where we have a greater than or equal to 95% confidence that the annual 95th percentile nitrate exceeds 50 mg/l;
- marginal at 75-95% confidence that the annual 95 percentile nitrate exceeds 50 mg/l; and
- face value at 50 - 75% confidence that the annual 95 percentile nitrate exceeds 50 mg/l.

The calculations were carried out using statistical routines taken from ZEBRA, the DOS-based package that WRc developed for the NRA in the early 1990s.

1.2.2 Trend analysis

The statistical model AntB (Environment Agency, 2008a) was used to undertake trend analysis and consequently determine whether the 95th percentile nitrate concentration at each monitoring point was predicted to exceed 50mg/l by 2010.5

AntB was used to distinguish distinct periods within the 15 years of data that are each well represented by a local linear trend. To do this linear splines were fitted to the data after removing the influence of within year seasonal variation in concentrations.

To determine the 95 percentile concentrations during the prediction year (2010), 500 Monte Carlo simulations of the fitted trend model and residual error were conducted.

The trend model component linear splines were treated as equally likely to occur in the future, making this approach similar to that for the groundwater trend analysis (see Annex B). Nitrate concentrations (both the 95 percentile and 2-sided confidence intervals on this value) were simulated and predicted for 2010. The confidence intervals from this assessment are the same as described in 1.2.1.

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Information Box 1. Percentile estimation by the Weibull convention

The r-th ranked value within the observation dataset is used to provide an estimate of the 95%ile, where $r = 0.95(N + 1)$ and N is the number of samples. When r is not an integer, linear interpolation is used between the values for ranks Int(r) and Int(r+1). Conservative 50%ile 75% and 90% confidence intervals are calculated using binomial distribution theory, as described in the Environment Agency’s Codes of Practice for Data Handling (Summary Statistics). These were used to determine whether the 95%ile nitrate concentration exceed (or not) 50 mg/l using the lower limit (or upper) of the 2-sided confidence intervals on the 95 percentile value.

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5 It should be noted that 2010 is not coincident with the trend date for the groundwater analysis, because groundwater takes longer to recover and therefore trends need to be identified earlier to make action plans most effective.
2. Modelling assessment of nitrate pollution in surface waters (section 2, step 3)

As described in section 2, step 3, a regression model was used to estimate the nitrate concentration in each surface water based upon information regarding sources of nitrate inputs within the associated catchment.

2.1 Multivariate Regression Modelling

The following sections briefly summarise the following four steps of the regression modelling assessment:
- Step 1 – Collation of input data (sections 2.1.1 and 2.1.2 below)
- Step 2 – Constructing the regression model (section 2.1.3)
- Step 3 – Testing the performance of the regression model (section 2.1.4)
- Step 4 – Using the regression model to estimate surface water nitrate concentrations (section 2.1.5)
Information Box 2: Introducing multivariate regression analysis

Data collected on two variables (where one is a response (or dependent) variable, Y, and the other is an explanatory (or independent) variable, X) can be plotted on a scatterplot (see diagram below). The data collected must be representative of the population from which it is collected.

In its simplest form (i.e. bivariate, with just two variables), the goal of regression analysis is to fit a line through the points on the scatterplot in order to quantify the relationship between the two variables. Specifically, the chosen line should ensure that the squared vertical deviations of the observed points from the regression line are minimised – this general procedure is sometimes also referred to as least sum of squares estimation or least squares regression.

When fitting the regression line it is necessary to estimate where it intercepts the Y axis (a) and also its gradient (b). As can be seen from the diagram above, the scatter of points about the line suggests that it does not perfectly predict a value of Y for a given value of X – there is an error (e) about the fitted regression line indicating other unknown factors affect the values of Y. The following equation (the regression model) can be used to summarise the relationship between the two variables:

\[ Y = a + bX + e \]

In reality it is rare to find an environmental situation in which a response variable, Y, is solely dependent on a single explanatory variable, X (on a scatterplot, all the data points would fall exactly in a straight line and would be perfectly matched by the regression line). Therefore, it is desirable to consider more than one explanatory variable within the regression model. This reduces the size of the error and thereby improve the predictive ability of the model. Consideration of more than one explanatory variable in the regression model is referred to as multivariate regression analysis.

In cases where we consider two explanatory variables, rather than fitting a line to a two dimensional graph, we use regression to fit a flat plane through a three dimensional scatterplot. In cases where there is more than two explanatory variables, the regression line cannot be visualized in the three dimensional space, but it can still be computed just as easily.

In cases with \( n \) number of explanatory variables, the regression model is expressed as:

\[ Y = a + b_1X_1 + b_2X_2 + ... + b_nX_n + e \]

More complex models can include explanatory variables called factors. These are non-continuous variables represented by two or more discrete levels.
2.1.1 Data inputs to the regression model

The response (or dependent) variable (Y) was the Weibull estimate of the 95 percentile of the observed surface water nitrate concentration (NO3), expressed as total oxidisable N (TON) (section 1.2). This data was available in just over 40% of the 4755 surface water catchments in England.

The following seven land-use based sources of nitrate, plus an index of catchment hydrological response (BFI), were identified as potential explanatory (or independent) variables (X1, X2...Xn):

- Agricultural sources by land-use:
  - managed arable crops (CropN)
  - managed grassland (GrassN)
  - spreading of animal manures (AnimalN)
- Atmospheric inputs (AtmosN)
- Urban sources (UrbanN)
- Base flow index (BFI)
- Point source inputs associated with consented discharges (PointN)
- Groundwaters associated with surface waters (GroundN)

A value for each of the above variables was calculated for each of the 4755 surface water catchments in England using a variety of data sources. More information on these sources of data and the derivation of the land-use variables used to construct the regression model is described under ‘Deriving the data inputs’ (section 2.2) below.

2.1.2 Regression model assumptions and data transformation

There are certain conditions and assumptions that should be met for regression analysis to provide a reliable synthesis of relationships within data. In order to help meet these conditions a number of supporting analyses were undertaken. These are not described in detail here. However it is worth noting that, because of the hierarchical nature of catchments, monitoring points distributed along rivers sample water derived from an increasing proportion of the total river basin draining land area (and hence sources of nitrate). Because of this the model assumption that estimates of nitrate concentration are independent could not be given the disposition of monitoring points. Likewise, for each predictor variable, the individual estimates cannot satisfy this assumption. In addition, the values of some of the independent variables were correlated across the population of catchments, that is the independent variables showed collinearity.

The distribution of sample data relating to the Weibull estimates of the 95%ile nitrate concentration was significantly skewed and did not have a normal distribution. Furthermore, many of the independent or predictor land use variables had distributions that were non-regular, skewed or highly skewed. Hence a variety of transformations were applied to help normalise the data and meet the required assumptions of regression analysis. These were as follows:

- A square root transformation \( \sqrt{X} \) was used in order to help normalise the Weibull estimate of the 95 percentile observed nitrate concentration. This helped the distribution of regression model residuals to approach a normal distribution.
- Spreading of animal wastes (AnimalN), urban sources (UrbanN) and atmospheric inputs (AtmosN) were transformed by \( \log_{10}(X+c) \), where c is a small constant necessary to transform zero values.
- Managed grassland (GrassN) and groundwater (GroundN) variables were transformed by \( \sqrt{X} \).
- The count of the number of upstream point source discharges (PointN) was highly skewed. This was transformed into a factor variable with 6 levels. The levels were
chosen to represent different numbers of sewage treatment inputs (0, 1-3, etc). The levels were chosen such that each represented a large number of catchments.

2.1.3 Constructing the regression model
Only 40% of the surface water catchments contained one or more monitoring points and hence values for the response variable (Y). But all catchments had values of the predictor variables (the X_i’s). In those catchments with both sets of variables, the ‘sources of nitrate’ data (X_i’s) for all catchments upstream of a surface water catchment with at least one monitoring point were plotted against the ‘observed surface water nitrate concentration’ within that catchment (Y). Multivariate regression analysis was then used to describe and quantify the relationship between the plotted data. All analyses were undertaken using S-plus statistical software (http://www.insightful.com).

There are several different approaches to fitting a multivariate regression model. Both forward and backward stepwise least squares regression were used to identify those potential predictors (suitably transformed X_i’s) that could explain a significant increment in the spatial variation in the observed 95%ile nitrate concentration (Y, as √TON). Only those variables explaining a statistically significant part of the observed variation in surface water quality and identified using both forward or backward approaches, were included in the final regression model.

Applying this approach, it was concluded that groundwater nitrate concentration (GroundN) should be excluded from the model.

The final regression model, based on the remaining 7 explanatory variables, was fitted using robust regression methods rather than least squares estimation, because of the issues identified in Section 2.1.2. Robust statistical methods (see Draper and Smith, 1988) help control bias in regression model coefficients in cases where the assumptions of least squares regression may not be satisfied. Using robust methods, Wald’s test is used to determine whether independent variables, added sequentially, might be included in the final regression model (see Table 1).
Table 1. Robust regression results, model terms added sequentially.

<table>
<thead>
<tr>
<th>Variable name (X_i)</th>
<th>Variable Transform or Factor level</th>
<th>Chi Squared</th>
<th>Degrees of Freedom</th>
<th>Wald test statistic</th>
<th>Pr (&gt;Wald)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td></td>
<td>1658.8</td>
<td>1</td>
<td>0.0000</td>
<td></td>
</tr>
<tr>
<td>CropN</td>
<td>None</td>
<td>1082.1</td>
<td>1</td>
<td>0.0000</td>
<td></td>
</tr>
<tr>
<td>UrbanN</td>
<td>Log_{10}(X+0.1)</td>
<td>978.7</td>
<td>1</td>
<td>0.0000</td>
<td></td>
</tr>
<tr>
<td>GrassN</td>
<td>√X</td>
<td>7.2</td>
<td>6</td>
<td>0.0071</td>
<td></td>
</tr>
<tr>
<td>PointN</td>
<td>Factor</td>
<td>22.1</td>
<td>1</td>
<td>0.0000</td>
<td></td>
</tr>
<tr>
<td>BFI</td>
<td>None</td>
<td>33.0</td>
<td>1</td>
<td>0.0000</td>
<td></td>
</tr>
<tr>
<td>AtmosN</td>
<td>Log_{10}(X+0.1)</td>
<td>27.7</td>
<td>1</td>
<td>0.0000</td>
<td></td>
</tr>
</tbody>
</table>

2.1.4 Testing the performance of the regression model

Before using the regression model to provide predictive estimates of the nitrate concentration of all surface waters in England based on the associated land-use, it was necessary to undertake a number of tests to check how well the regression model might perform.

Firstly we measured the goodness of fit of the model to the observed 95% ile nitrate (Y as √TON) using the coefficient of determination \( r^2 \). \( r^2 \times 100 \) can be interpreted as the % of variation in Y that can be explained by the regression model. The nearer it is to 100% the more powerful the model. The final model, fitted using robust regression methods, explained 85% of the variation in 95 percentile nitrate concentration (Y, as √TON). The uncertainty on predictions based on the model (i.e. predictions of untransformed 95% ile TON) will be large. Hence the stated \( r^2 \) overstates the predictive skill of the model in untransformed space. The use of predictive confidence limits attached to the model predictions (section 2.1.4) make allowance for this.

Table 2 below shows the details of robust regression model fit provided by S-plus. The relative importance of the variables is crudely indicated by the magnitude of the value of student’s t. The most important sources of nitrate are indicated to be arable crops (CropN), urban land use (UrbanN), Managed grassland (GrassN) and point sources (PointN).

The performance of the final robust regression model was evaluated using standard regression diagnostics, based on the residual differences between the fitted model and monitoring data. Examined spatially, the residuals were generally distributed evenly across catchments; this is a positive indication that the model is performing satisfactorily. In a small number of areas high positive or negative residuals were clustered together, indicating the possibility of some spatial bias in the data or model fit. These catchments may be atypical; hence the water quality monitoring in these catchments was investigated and ground-truthed to identify if it was representative. Consultation with local Environment Agency staff provided explanations for some of these cases. Where monitoring data was identified to be unreliable, the catchment was treated as a Type 2 catchment. Full details of the data used to support this ground truthing are described in Environment Agency, 2008c.

\( r^2 \) measures how much of the total variation in Y is explained by the linear model. Usually there is substantial residual variation of the observed datapoints around the fitted regression line (as in the scatterplot shown earlier). The deviation of a particular datapoint from the regression line (its predicted value) is called it’s residual value. If all the datapoints were to lie exactly on the line (i.e. this would be a perfect fit) then the regression model is clearly describing the scatter better than in the case where the data are scattered widely about the line.
Table 2. Results of the final robust regression model fit. \( \Pr(>|t|) \) indicates the probability of finding a value of student’s \( t \) equal or higher than the absolute value indicated in the previous column. Note that the variables BFI and AtmosN do not contribute to a statistically significant component to the overall model fit, but contribute to a significant reduction in the residual variation when added stepwise (see Table 1).

| Variable name (\( X_i \)) | Variable Transform or Factor level | Estimate of regression model coefficient | Standard error of estimate | Student \( t \) value | \( \Pr(>|t|) \) |
|-----------------------------|-----------------------------------|------------------------------------------|---------------------------|---------------------|----------------|
| Intercept                   |                                   | 1.569                                    | 0.065                     | 24.09               | 0.000          |
| CropN                       | None                              | 0.260                                    | 0.006                     | 40.68               | 0.000          |
| UrbanN                      | \( \log_{10}(X+0.1) \)           | 0.795                                    | 0.028                     | 28.63               | 0.000          |
| GrassN                      | \( \sqrt{X} \)                   | 0.781                                    | 0.025                     | 31.26               | 0.000          |
| PointN                      |                                    |                                          |                           |                     |                |
| Level 1                     |                                   | 0.037                                    | 0.016                     | 2.27                | 0.023          |
| Level 2                     |                                   | 0.016                                    | 0.009                     | 1.76                | 0.079          |
| Level 3                     |                                   | 0.014                                    | 0.008                     | 1.78                | 0.075          |
| Level 4                     |                                   | 0.029                                    | 0.007                     | 4.18                | 0.000          |
| Level 5                     |                                   | 0.022                                    | 0.014                     | 1.57                | 0.118          |
| Level 6                     |                                   | 0.060                                    | 0.011                     | 5.37                | 0.000          |
| AnimalN                     | \( \log_{10}(X+0.1) \)           | 0.096                                    | 0.048                     | 2.25                | 0.024          |
| BFI                         | None                              | -0.124                                   | 0.083                     | -1.49               | 0.138          |
| AtmosN                      | \( \log_{10}(X+0.1) \)           | -0.055                                   | 0.085                     | -0.65               | 0.518          |

2.1.5 Using the regression model to estimate surface water nitrate concentrations

The regression model summarises the evidence of the influence of different land-use based sources of nitrate on observed river water quality. It does this by, in effect, recognising patterns in the relationships between water quality and land-use across a large and varied population of catchments with a diversity of land-uses. Catchment specific values for each of the six land-use based sources of nitrate, plus BFI (i.e. the explanatory variables, see Section 2 below) were input into the fitted regression model. Using these data, the model was used to predict the 95 percentile nitrate concentration for each of the 4755 surface water catchments in England. The predictions are based on the land-use based explanatory variables, calculated as average values over the upstream drainage basin, or on the factorised count of upstream point source discharges (see section 2.2).

To allow for the considerable residual uncertainty associated with the fitted regression model, 90% and 50% predictive confidence intervals were used to classify water bodies into 6 classes. These determine whether the land-use predicted 95 percentile nitrate concentration in each surface water might exceed (or not) the 50 mg/l (11.3 mg.L\(^{-1}\) TON equivalent) target for nitrate with greater (or lesser) than 95%, 75% or 50% confidence. This was identical to the approach used for the surface water quality data (section 1.1) and trend analysis data (section 1.2.1). Figure 5 in the main document illustrates the mapped output from the regression model.

2.2 Deriving the data inputs

As described in section 2.1.1, the following sources of nitrate inputs were the explanatory (\( X \)) variables:

- Agricultural sources by land-use:
  - managed arable crops (CropN)
  - managed grassland (GrassN)
  - spreading of animal manures (AnimalN)
• Atmospheric inputs (AtmosN)
• Urban sources (UrbanN)
• Base flow index (BFI)
• Point source inputs associated with consented discharges (PointN)
• Groundwaters associated with surface waters (GroundN) (note – GroundN was dropped from the final regression model).

These data were used:
• in the first instance for the purpose of constructing the regression model.
• in the second instance for estimating the nitrate concentration in each surface water in England

This section provides further information on how the data input into the regression model in relation to each of the above variables was derived.

2.2.1 Atmospheric Deposition
The most recent available set of spatial atmospheric deposition data for the UK was used. The data is based on a spatial interpolation of monitoring data. Total annual area averaged estimates of nitrogen (N) deposition (kg ha\(^{-1}\) yr\(^{-1}\)) were input to the MAGPIE soil leaching model (Lord, E. and Anthony, S. 2000). Between year variation of total N emissions is believed to be relatively small, hence the data used should be representative of the last five years. This data was supplied to ADAS as an input for their NEAP-N model (Anthony et al., 1996; Lord and Anthony, 2000; Silgram et al., 2001).

The results from the addition of atmospheric deposition into the NEAP-N model were compared to SUNDIAL, a more detailed model from Rothamsted Research, and were found to be similar with no significant discrepancies observed.

2.2.2 Agricultural inputs
Diffuse nitrate loads from agriculture and atmospheric deposition for all surface water and groundwater bodies were predicted by using the results derived above in the NEAP-N model within the MAGPIE decision support system.

The model provides GIS layers containing predictions for average annual soil drainage, nitrate flux and concentrations from diffuse sources at 1 km\(^2\) resolution. The model has been run using current climate conditions (1971-2000) and data on agricultural land use derived from the ADAS National Land Use database which is populated for each 1 km\(^2\) cell. This database incorporates the ADAS National Land Cover Map and information collated from the Defra Agricultural Census for the year 2000, which was the most recent complete census. It should be noted that the agricultural census data are a snapshot of the crop areas and numbers of animals on farms on June 4th each year and do not reflect seasonality of animal numbers. The predicted loads aggregated nitrate loads from diffuse input sources (agricultural and atmospheric) and explicitly excluded any point source or urban contributions.

NEAP-N models nitrogen loss for a variety of categories of crop and livestock. For each category, it provides a single maximum potential nitrogen loss coefficient. This value is then modified according to spatially distributed information on soil type and hydrologically effective rainfall.

The NEAP-N model provides a summary of inputs and processes that act to affect the annual amount of nitrate lost through leaching on a 1 km\(^2\) scale grid. Information on nitrate inputs due to a variety of categories of crop and livestock is used. These include typical nitrate loads associated with applications of nitrogen fertilisers to each crop, crop
uptake and harvest removal, animal manures and excreta, nitrogen fixation, nitrification and denitrification, etc. Nitrate loss values are modified according to spatially distributed information on soil type and hydrologically effective rainfall, the latter based on estimates of annual average rainfall.

Nitrate losses for crops and animals can be aggregated to provide estimates of nitrate leaching by land-use class. For this analysis, nitrate leaching per 1 km² was calculated for the following three “land-uses”: arable crops, managed grassland and for land subject to the spreading of animal manures.

Baseline data for the nitrogen loading of manure from grazing livestock were derived from research under-pinning the N-CYCLE model. Maximum potential nitrogen losses have been modified by ADAS data under-pinning the MANNER model (Chambers et al., 1999) to consider only the leachable component of the manure nitrogen, and the timing of manure applications. These modifications assume that around half the manure is applied in autumn and half the following spring (Lord, 1995; Smith et al., 2001a; Smith et al., 2001b).

The NEAP-N simulation of nitrate leaching uses a series of regressions to simplify the UK Meteorological Office's MORECS hydrological model. The simplification considers long-term winter soil drainage (Hydrologically Effective Rainfall, HER) as a function of long-term mean annual rainfall and potential evapotranspiration for different crop and soil combinations. For each spatial calculation, the dominant soil series within each spatial unit is placed into one of three classes based on Available Water Capacity (AWC), the water held between field capacity and permanent wilting point.

The proportion of nitrogen vulnerable to leaching is calculated from a simple leaching function that relates soil drainage to soil water content at field capacity (Anthony et al., 1996). The model is a simplification of the SLIM model (Addiscott and Whitmore 1991).

Hence, based on outputs from NEAP-N, estimates of nitrate loading (kg.ha⁻¹.yr⁻¹) from atmospheric deposition and each of the three agricultural land-use sources were available for each 1 km² over England. Totals for each NEAP-N output variable (V, generically) were calculated for each WFD surface water body catchment (i) based on the number of 1km² cells (mᵢ) contained within the area of the catchment (aᵢ)².

\[
V_i = 100 \sum_{k=m_i}^{k=m_i} v_k \quad \text{(kg.yr}^{-1}\text{)}
\]

Each variable (Vᵢ) was converted into an increment in effective concentration, by dividing by the catchment total hydrologically effective rainfall, HERᵢ.

\[
HER_i = \sum_{k=m_i}^{k=m_i} HER_k \quad \text{(mm.yr}^{-1}\text{)}
\]

An area-weighted average, effective concentration was then estimated based on the data included within the upstream drainage basin of the catchment, based on each (j) of the

\[\text{Values of variables for grid squares spanning 2 or more surface water body catchment boundaries were allocated pro rata based on their estimates of area contained within each catchment.}\]
(n) upstream water body catchments \((j = 1\ldots n)\) draining to the water body contained within catchment \(i\), including the catchment \(i\) (i.e. \(j=i=1\)).

Hence, for CropN for catchment \(i\),

\[
\text{e.g. } \quad \text{Crop}N_i = \left( \sum_{j=1}^{\text{num}} V_j \frac{a_j}{\sum_{j=1}^{\text{num}} a_j} \right) \left/ \left( \sum_{j=1}^{\text{num}} \text{HER}_j \frac{a_j}{\sum_{j=1}^{\text{num}} a_j} \right) \right) \quad \text{(kg.mm}^{-1}\text{)}
\]

2.2.3 Urban sources of diffuse nitrate

Urban nitrate leaching to groundwater was estimated using the component model (Lerner, 2000). This model summarises evidence from a study of recharge components in the city of Nottingham and expert assumptions in the form of export coefficient models for each type of urban land cover. The model identifies 14 different components of nitrate loss, ranging from leaking sewers to runoff from highways. In this current assessment, certain of these components could not be calculated, as they would require access to fine scale data on the urban environment. The components that have been modelled are as follows, and have been numbered according to Lerner's component approach:

*Parks and gardens (1)*
Nitrogen loss from parks and gardens was calculated as an average rate of 4.6kg N ha\(^{-1}\) per year. This loss rate excludes any contribution from atmospheric deposition because this component is already taken into account in the calculations of nitrate loss from rough grassland in the NEAP-N model above. The park and gardens areas were mapped by category 10 (Urban Green Spaces) from the CORINE 2000 land cover dataset (Centre for Ecology and Hydrology, NERC).

*Recreational grassland and golf courses (3)*
Nitrogen loss from grassland and golf courses was calculated as an average rate of 9.2kg N ha\(^{-1}\) per year. This loss rate also excludes any contribution due to atmospheric deposition (see above). The recreational grassland areas were mapped by category 11 (Sport and Leisure Facilities) from the CORINE 2000 land cover dataset.

*Construction activities (5)*
Nitrogen loss from construction activities was calculated as an average annual rate of 400kg N ha\(^{-1}\) per year. The loss rate represents the total that will be released over several years following site disturbance. Hence, the annual rate assumes that the mapped area of construction activity represents an annual average. The construction areas were mapped by category 9 (Construction Sites) from the CORINE 2000 land cover dataset.

*Spills and leaks in industry (6)*
Nitrogen loss from spills and leaks in industry was calculated as an average rate of 175kg N ha\(^{-1}\) per year. The industrial areas were mapped by category 3 (Industrial or Commercial Units) from the CORINE 2000 land cover dataset.
Leaking sewers (9)
A loss estimate was calculated using an average rate of 0.06kg N per capita and a 1km² population map derived by ADAS from the Office of Population Census & Surveys (OPCS) 2001 census and Address Point data on the location of individual properties.

Leaking water mains (11)
A loss estimate was calculated using an average rate of 0.3kg N per capita and a 1km² population map derived by ADAS from the OPCS 2001 census and Address Point data on the location of individual properties.

The above data provide an estimate of total annual average nitrate loading per 1km² from urban sources. These data were combined with a GIS data layer within NEAP-N showing areas (km²) of urbanised land in order to estimate the total urban loadings (kgN.yr⁻¹) within the catchment boundary of each surface water catchment. Estimates of the increment in area-weighted effective concentration, due to urban areas, was calculated for each catchment draining to each surface water in the same way as described above for atmospheric and agricultural land use sources.

2.2.4 Point sources of nitrate
The regression model used a count of the number of upstream point discharges derived from EA’s consents for discharges data. Estimates of point source loads, adjusted for estimates of river flow (hence dilution) were investigated but were found to be a less successful predictor of observed river nitrate concentration.

2.2.5 Groundwater nitrate
Where groundwaters discharge into surface waters they will impact on the quality of that surface water. Groundwaters that could be associated with particular surface waters were identified. Estimates of the average concentration of nitrate in the associated groundwaters used to provide a potential predictor of surface water nitrate. The data was found to have little predictive power and hence was not used in the final regression model.

2.2.6 Base flow index
The base flow index represents an estimate of the ratio of a river’s base flow to its total flow. The base flow is maintained by rainfall following below-surface flow paths. Base flow index is available as 1 km² mapped values. A small number of catchments lacked values for ‘base flow index’ variable. In these cases the national average value for base flow index was used.
Annex B  Groundwaters

1.  Statistical analysis of water quality monitoring data (section 3, step 2)

As described in section 3, step 2, water quality monitoring data was analysed to determine:

- if the observed nitrate concentration exceeded 50mg/l in mid 2005, or
- if the nitrate concentration was predicted to exceed 50mg/l in by 2021.

This section describes the datasets and statistics used in the above analysis.

1.1  Datasets

The national groundwater quality monitoring network comprises 3684 sampling sites. Sampling at each site is normally carried out 4 times per year, or less. The network is still in development and therefore many of the sites have a limited period of data record. As a result, there will always be significantly less groundwater monitoring data available for analysis, compared to surface water.

The full data record from each sampling site was used in the statistical analysis.

The following quality assurance (QA) checks were applied to the datasets to ensure the best possible quality of data for the statistical analysis:

- Remove duplicate data by keeping only the maximum monitored value on any given day at each borehole location.
- Remove zero readings that have occurred due to problems at the laboratories, usually because nitrate is below the limit of detection.
- Identify any records where nitrate has been recorded as nitrogen (15 affected records were found and corrected).
- Ensure that the boreholes were all situated in the correct region (by plotting spatially).

1.2  Statistics

1.2.1  Justification for using the mean statistic and a threshold nitrate concentration of 45mg/l

As described in section 3, step 2, if the mean current (mid 2005) or predicted (2021) nitrate concentration of a groundwater sampling site exceeded 45mg/l, it was deemed to have ‘failed’ the statistical test. The justification for using the mean statistic and a threshold of 45mg/l is provided below.

Using the ‘mean’

The ‘mean’ statistic was used because:

- It is the most readily understood statistical measure.
- Well over 50% of the sampling points have insufficient records to reliably use any statistical test other than the mean.
- Variability in groundwater nitrate concentrations is low compared to surface water. The lower 90% confidence interval of the 95 percentile is approximately equal to the mean for data with low standard deviations.
Using a threshold of 45mg/l

A threshold of 50mg/l is set by the Nitrates Directive for identifying polluted waters (both surface waters and groundwaters). As described in Annex A, when analysing surface water monitoring data to determine if this threshold was exceeded, the statistic used was the lower 90% confidence interval about the 95th percentile. If this statistic exceeded the 50mg/l threshold then the surface water was deemed to have ‘failed’ the statistical test.

As described above, when analysing groundwater monitoring data, it was not possible to use this statistic and instead the mean was used. However, the lower 90% confidence interval of the 95 percentile was estimated for all groundwater sampling sites (note – the error in this estimate is potentially large for many of the sites). The difference between this estimate and the mean for the entire population was then averaged.

This showed that using the lower 90% confidence interval of the 95 percentile compared to the mean nitrate concentration for groundwater sampling sites is equivalent to tightening the threshold from 50mg/l to 45mg/l. We have therefore used 45mg/l as the threshold to give a comparable level of protection to that achieved by the statistical test for surface waters (Annex A). Full details of the approach followed are described in Environment Agency, 2008b.

1.2.2 Estimating the observed nitrate concentration

To determine whether the mean nitrate concentration at each groundwater sampling site was greater than 45mg/l in mid 2005 one of the following three tests was used as appropriate:

- For sampling sites with sufficient data, the observed mean nitrate concentration was taken to be the value predicted by the appropriate trend analysis method for mid 2005 (see 1.2.3 below).
- For data deficient sites with greater than ten years data a linear trend, where one is significant, was used.
- For sites with less than 10 years data the mean value for the entire dataset was used.

1.2.3 Trend analysis

To determine whether the mean nitrate concentration at each groundwater sampling site was predicted to be greater than 45mg/l in 2021 the appropriate trend analysis method from the following options (Environment Agency, 2008a) was adopted according to the length and quality of data record:

- AntB – Used to assess monitoring sites with at least 6 years of good quality data with more than one reading per year. This method removes the seasonal component from the dataset and then fits a series of linear splines through the historic data. 500 possible futures, based on the historic splines, were generated and used to estimate the mean nitrate concentration in 2021.
- AntC (simple version of AntB) – Used to assess monitoring sites with at least one sample per year over a 6 year period. This method was applied using annual mean values. 500 possible futures, based on the historic splines, were generated and used to estimate the mean nitrate concentration in 2021.
- AntC2 (simple version of AntC) – Used to assess monitoring sites with at least 20 measurements. This package was applied using bi-annual means. The software then runs 500 possible futures based on the historic splines and estimates the mean nitrate concentration in 2021.
- For data-deficient monitoring sites, no meaningful trend could be predicted. Therefore the current mean value was used as the prediction for 2021.

This is different to that used for the surface water trend analysis, because groundwater takes longer to respond to changes in nitrate inputs at the soil surface.
1.2.4 Checking for a significant change in the historic trend
An elbow function test, which fits two linear splines to the data to identify if there has been a change in trend over the historic record, was done in response to a request from stakeholders advising the Environment Agency on the Technical Review Group.

The elbow function test was fitted to all the historic data. A statistically significant elbow could only be fitted to 12% of the records, and so it was not possible to draw any meaningful conclusions from this test. It should be noted that the AntB analysis package fits an elbow function, if this is the best fit to the historic data.

This work demonstrated that the change in agricultural practice that has occurred over the last 30 years, since nitrate application rates peaking in the late 1970s, is not generally detectable in the groundwater monitoring data. Note – the test was conducted to provide a better understanding of trends in groundwater nitrate concentrations and the results of the test were not specifically used to identify polluted groundwaters or designate NVZs.
Annex C  Waters subject to eutrophication

The criteria for identifying eutrophication in lakes and transitional waters are set out below.

1.  Lakes

1.1  Focusing in on water bodies of concern (section 4, step 1)

Using the EA national lake database, 5157 lakes were screened to identify lakes of potential concern with regard to eutrophication for the purposes of the Nitrate Directive and Regulations. The final screening criteria used were:

- Chlorophyll levels equal or greater than 8 µg/l as an annual mean and/or
- Winter Total Oxidised Nitrogen levels greater than 1mg/l (as nitrogen)

1.2  Criteria used to identify eutrophication in lakes (section 4, step 2)

The lakes were assessed based on their specific typology. The typology was taken from the national GB Inventory and is derived from the Water Framework Directive typology. Lakes are divided into 3 types based on alkalinity (High, Medium, Low). Peat and Marl lakes are considered separately. Peat lakes contain > 75% peat in catchment and Marl lakes are found on Limestone and are characterised by very low natural P levels.

The lakes are also divided into 3 depth types, very Shallow (<3.0m mean depth) which should be dominated by submerged vegetation; shallow (3-15m) lakes where prolonged stratification is unlikely and deep (>15m) lakes where stratification occurs. The geological type of the lake can be based on the alkalinity data, on conductivity information or on geological maps.

The assessments undertaken and criteria considered are described below. Not all elements of criteria have to be available:

1.2.1  Nutrients (category I)

The chemical status of each lake was determined by measured phosphorus concentration, measured nitrogen concentration and predicted nitrogen concentration.

1.2.2  Plants/ algae (category II)

The biological status of each lake was determined by the concentration of chlorophyll a, the macrophyte status and by paleolimnology:

- Chlorophyll a data were assessed on the mean concentration at face value and as a 95% confidence limit. Chlorophyll a greater than 8 µg/l as an annual mean was considered indicative of accelerated growth.

- Assessment of macrophyte status was based on data collected during the summers of 2003 and 2004 for the Water Framework Directive for a classification method based on the difference between taxa typical of reference conditions and those typical of impacted conditions. Values < -0.22 indicated a site at less than Good status.
Paleolimnology provides an indication of the change in diatom taxa from the bottom to the surface of a sediment core and thus gives a direct indication of ecological change. This was measured as “square of chord distance” and a value > 0.5 was used for the Water Framework Directive river basin characterisation as not at Reference status. A value > 0.8 was considered to be at risk of not achieving Good status.

1.2.3 Secondary and other effects (category III)
Evidence of undesirable disturbance was also based on:

- Dissolved oxygen levels showing excessive supersaturation of surface layers and decreased saturation in deeper stratified layers attributable to nutrient enrichment.

- Evidence of blue green algal blooms. The national reports of cyanobacteria from 1990 – 2002 were summarised into a risk category where 1 reported bloom in 13 yrs =1, 2 to 4 blooms in 13 yrs = 2 and greater than 5 blooms in 13 yrs = 3. This was confirmed at a local level. (NB. Blooms are not necessarily routinely monitored once they have occurred at a site as they are likely to recur in subsequent years).

Supporting information on the waterbody, its uses and catchment were also included.

2. Estuaries

2.1 Focusing in on water bodies of concern (section 4, step 1)
Estuarine waters are those waters where freshwater and saline waters mix and, as a result present a greater challenge than either in terms of deriving a robust assessment of trophic state. Estuarine waters are of a more individual nature than coastal waters of being heavily influenced by local factors.

The factors influencing primary production in estuaries are numerous and complex and there is no simple trigger parameter by which sites of potential concern can be highlighted. Sites that warrant further investigation were therefore highlighted through monitoring programmes such as OSPAR, Habitats Directive or Water Framework Directive studies, or through specific screening studies carried out in previous eutrophication reviews for the Urban Waste Water Treatment and Nitrates Directives.

2.2 Criteria used to identify eutrophication in estuaries (section 4, step 2)
Given the individual nature of estuaries it is not feasible to outline the precise information requirements which were relevant to each estuary. The list below outlines the general considerations.

1.2.1 Nutrients (category I)
The chemical status of each transitional water was measured by collecting winter nutrient data to determine the degree of hypernutrification, analysing for Total Oxidised Nitrogen (TON), Ammonia, and Nitrite to establish levels of Dissolved Available Inorganic Nitrogen (DAIN) and orthophosphate to establish levels of Dissolved Available Inorganic Phosphorus (DAIP). Hypernutrification (elevated nutrient concentrations) was considered
in the context on the thresholds for DAIN and DAIP defined in the UK Comprehensive Studies Task Team report, 1997.

1.2.2 Plants/ algae (category II)
The biological status of the transitional water was determined by assessing a combination of the concentration of chlorophyll a, the phytoplankton status or the macroalgal status:

- Where phytoplankton growth was considered significant, summer sampling for cell counts and chlorophyll a was undertaken. It is considered exceptional if the normal pattern of growth (a spring bloom with increased light levels) has changed as a result of nutrient enrichment. Attention was given to blooms of unusual scale and duration, species or toxicity or changes in algal species or abundance. Elevated chlorophyll a was considered in the context of thresholds of 25 µg/l mean and 100 µg/l maximum at the freshwater limit of the estuary, decreasing proportionately with salinity through to the 10 µg/l threshold which is considered relevant for open coastal waters. In many estuaries the fast flushing times and/or high suspended solids means that excessive phytoplankton biomass does not have time and/or sufficient light to develop.

- Macroalgal growth was examined in the summer and for sites with excessive growth quantitative information on % cover was collected. A substantiated trend of increasing cover of nuisance species was a cause for concern where changes could reflect a species shift from long lived to short lived nuisance species with dense and widespread growth e.g. of enteromorpha and ulva species. Excessive growth was considered when there were areas of greater than 10 hectares (and greater than 25% of available intertidal area) in which the average algal cover exceeded 25%. Assessments may also have been made using a method proposed for the Habitats Directive illustrated below:

<table>
<thead>
<tr>
<th>% Cover</th>
<th>Density</th>
<th>Evidence of ecological impact?</th>
<th>Do further (habitats directive) Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5%</td>
<td></td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>5-15%</td>
<td>&lt; 100 gm m-2</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>5-15%</td>
<td>100-1,000 gm m-2</td>
<td>no</td>
<td>No</td>
</tr>
<tr>
<td>5-15%</td>
<td>100-1,000 gm m-2</td>
<td>yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5-15%</td>
<td>&gt; 1,000 gm m-2</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>&gt;15%</td>
<td></td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

Concern was focussed on the consequences of the excess algal coverage on the function of the ecosystem.

1.2.3 Secondary and other effects (category III)
Evidence of undesirable disturbance was also based, where relevant, on:

- Decreased dissolved oxygen concentration at the surface as well as in deeper layers. Median values of less than 7mg/l during the growing season would indicate a cause for concern.
- Changes in fauna such as substantial increases or decreases in zoobenthic biomass, shifts in species composition
• Formation of algal scums on beaches
• Occurrence of paralytic shellfish poisoning, although this could be due to a variety of natural causes.

Supporting information on the waterbody, its uses and catchment were included.
Annex D  Example proforma for Still Freshwaters

Lake Name:

<table>
<thead>
<tr>
<th>Water Body ID:</th>
<th>Region:</th>
<th>Area:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location:</td>
<td>Easting:</td>
<td>North:</td>
</tr>
<tr>
<td>Surface Area (ha):</td>
<td>Conf:</td>
<td></td>
</tr>
<tr>
<td>Lake Type:</td>
<td>Data source: EA(LA &lt; 200, MA 200-1000, HA &gt;1000)</td>
<td></td>
</tr>
<tr>
<td>Alkalinity (ueq/L):</td>
<td>Conf:</td>
<td></td>
</tr>
<tr>
<td>Mean Depth (m):</td>
<td>Conf:</td>
<td></td>
</tr>
</tbody>
</table>

Typology was derived from GB Inventory and is derived from the WFD typology. Lakes are divided into 3 types based on alkalinity, Peat lakes contain > 75% peat in catchment and Marl lakes are found on Limestone and are characterised by very low natural P levels. Lakes are divided into 3 depth types, very Shallow (<3.0m mean depth) which should be dominated by submerged vegetation; Shallow (3-15m) lakes where prolonged stratification is unlikely and Deep (>15m) lakes where stratification occurs.

**For geological type a confidence of 3 indicates data type based on alkalinity data, 2 on conductivity and 1 on geology maps. For depth a value of 1 indicates modelled depth and 3 measured depth.**

---

**Is typology consistent with local knowledge?**

If No, indicate correct typology and source of evidence to support

**Does stratification occur?** Frequently (most years), Occasionally (c 1 year in 5), No (<1 year in 5 or never)

**Catchment**

Estimated Catchment Area (ha)

Is lake fed by natural surface water catchment as shown on map

And is it a pump storage reservoir.

If catchment on map is substantially incorrect please mark and provide information about source of water to lake.

Is there evidence that lake is fed by ground water with a substantially different catchment from that shown on map.

**Summary of main uses and designations:**

Within Conservation Site

Natura 2000 site and designated for Aquatic Interest

SAC (1 if Yes, else 0): Name:

SPA (1 if Yes, else 0): Name:

SSSI site (0.5 if yes & aquatic interest, 0.25 if yes no aquatic interest)

Name:

Public Water Supply (1 if identified as a Drinking Water Protected Area for WFD)

UWWTD Sensitive Area Y/N

Other Uses

- Angling Y/N
- Recreation and tourism Y/N
- Water Contact Sports Y/N
- Amenity Y/N
- Irrigation Y/N
- Fish Farm Y/N
- Industrial water supply Y/N
Lake Name:

*Data available to summarise impact of Eutrophication.*
(All WQ data below collected during 2003 – 2005)

### Lake Data

<table>
<thead>
<tr>
<th></th>
<th>Annual Mean</th>
<th>N</th>
<th>Lower 95% Confidence Limit</th>
<th>Status Is TP double Reference ? Is Chl &gt; 8.0 ug/L ?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total P (ug/L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type Ref</td>
<td></td>
<td></td>
<td>FV</td>
<td></td>
</tr>
<tr>
<td>Chlorophyll (ug/L)</td>
<td></td>
<td></td>
<td>FV</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>95%</td>
<td></td>
</tr>
<tr>
<td>Total oxidised nitrogen (mg/L)</td>
<td>75th percentile Is lake TON &gt; 1.0 mg/L</td>
<td></td>
<td>95%</td>
<td></td>
</tr>
</tbody>
</table>

### Other Data

<table>
<thead>
<tr>
<th></th>
<th>Modelled lake 75th percentile TON (mg/L)</th>
<th>If inflow TON is &gt; 5.0 mg/L then it is likely that the 75th percentile of lake TON will be &gt; 1.0 mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual mean TON (GQA 2002/03 survey) (mg/L)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Other evidence

Assessment of macrophyte status is based on data collected during summers of 2003 and 2004, and uses a draft classification method. This is based on the difference between taxa typical of reference conditions and those typical of impacted conditions. Values < -0.22 currently indicate a site at less than Good status.

Palaeolimnology provides an indication of the change in diatom taxa from the bottom to the surface of a sediment core and thus gives a direct indication of ecological change. This is measured as “square of chord distance” and a value > 0.5 was used for the WFD river basin characterisation as not at Reference status. A value > 0.8 was considered to be at risk of not achieving Good status.

<table>
<thead>
<tr>
<th>Macrophyte status (Non Impact – Impact Taxa)</th>
<th>Palaeolimnology</th>
</tr>
</thead>
</table>
| Reports of cyanobacteria 1990 – 2002  
1 = 1 in 13 yr, 2=2-4 in 13 yr, 3 = > 5 in 13 yr | Mean DO of Hypolimnion (summer 2004) |
| Mean Dissolved Oxygen (DO) of whole water column (summer 2004) | |

### Summary of Evidence:
References


Environment Agency (2008a) Technical Note 2: Statistical Methodology used in AntB and AntC


Environment Agency (2008c) Technical Note 5: The groundwater risk model and how it was used to support designation of NVZs


