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Catchment Risk Assessment of Steroid Oestrogens from Sewage Treatment Works

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Steve Killeen

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Executive summary

This project has developed a regional catchment-based risk assessment for steroid oestrogens in England and Wales. Using the Low Flows 2000 water quality (LF2000-WQX) model, which can predict river concentrations of contaminants discharged through sewage treatment plants (STPs), the project has focussed on predicting concentrations of the three most potent steroid oestrogens in rivers and the associated risk of endocrine disruption in fish. The model could equally well be applied to any other chemical of concern found in treated sewage effluent, where loading can be estimated on a per capita basis.

The model, believed to be the first of its kind, covers the inland waters of England and Wales in unprecedented detail. It includes 357 catchments covering 122,000km^2 and incorporates more than 2,000 STPs serving over 29 million people (STPs discharging to estuaries and coastal waters and those serving very small communities are excluded). The model predicts the concentrations of three steroid oestrogens – oestradiol (E2), oestrone (E1) and ethinyloestradiol (EE2) – and the associated risk of endocrine disruption for 10,313 individual river reaches (21,452 km). The scale of this assessment underlines the usefulness of computer-based risk assessment methods. Developing this regional model was only possible due to the remarkable cooperation of different groups within the Environment Agency and the UK water industry in establishing the underlying database.

The model calculates how much of each of the three oestrogens would be discharged into the receiving waters from data on the flow of the STPs and the populations they serve. The in-stream concentrations are then calculated based on dilutions down through the river network, including the effects of the natural attenuation rate. During the development of the model, refinements were added to allow one of the oestrogens, oestradiol, to be converted in-stream into its first degradation product, oestrone, which is another oestrogen. This simulates what has been observed in the field and allows a more accurate prediction of overall oestrogenicity. In addition, an approach has been developed that allows users to identify and calculate what additional levels of improvement are required for the most polluting STPs in order for there to be no predicted risk of endocrine disruption in their catchment.

Three specific tasks were required to generate the factors underpinning the model. First, the most recent literature and data on STP oestrogen removal efficiencies were reviewed. Primary treatment plants, activated sludge plants (with and without tertiary treatment) and biological filter plants (with and without tertiary treatment) were all considered. The latest UK data indicated that the removal efficiency for E1 in biological filter plants without tertiary treatment was significantly different to that previously determined, being reduced by around 30 per cent. For all other types of STP, the new data indicated that a slightly improved removal efficiency of 69 per cent should be used. In the cases of E2 and EE2, only a slight modification was necessary, increasing the removal efficiency to 83 per cent for all treatment types.

Second, recent scientific studies measuring the effects of steroid oestrogens were reviewed. This allowed PNECs (predicted no effect concentrations) of 0.1ngL^{-1}, 1ngL^{-1} and 3ngL^{-1} to be established for EE2, E2 and E1 respectively. A method for calculating the E2 equivalent concentrations was also developed. This divides each steroid by its respective PNEC to produce a measure of relative potency and these values are then summed, as the effects of steroids have been shown to be additive. Thus the [E2 equivalent] = [EE2]/0.1 + [E2]/1 + [E1]/3 (with the square brackets denoting concentrations).

Finally, the risk class boundaries were also reviewed and it was established that the currently proposed total steroid oestrogen PNEC (1ngL^{-1} E2 equivalent) remained valid for distinguishing 'no risk' sites from 'at risk' sites. The review also determined that the boundary between 'at risk' and 'high risk' sites should be set at 10ngL^{-1} E2 equivalent. This was estimated to be equivalent to the lowest measured population effect end-point for E2 in published literature.

Overall, the majority of the reaches in England and Wales (61 per cent using mean concentrations and expressed as a percentage of the total river length modelled) are predicted not to be ‘at risk’ from endocrine disruptive effects in fish (< $1ngL^{-1}$ E2 equivalent). However, a significant proportion remains ‘at risk’ (>1 ngL^{-1} E2 equivalent; 39 per cent of length of the modelled reaches under mean conditions). These risk proportions are not evenly distributed throughout England and Wales. The lowest proportions predicted to be ‘at risk’ are in Wales and the South West (5 per cent and 16 per cent respectively). In the Southern, North East, and North West regions, 34 per cent, 38 per cent, and 34 per cent of the reach lengths are predicted to be ‘at risk’ respectively. The highest proportions of reaches predicted to be ‘at risk’ are in the Thames, Midlands and Anglian regions, with 67 per cent, 55 per cent, and 50 per cent respectively. Key factors influencing the proportion of river reaches classified as being ‘at risk’ are the location of densely populated areas and the available dilution (which is a function of rainfall, evaporation and upstream water use). The proportion of lengths predicted to be ‘at risk’ seems rather high, but the high proportion of intersex individuals reported in wild roach in two national surveys (Environment Agency 1995 and 2003) suggests the predicted risk is reasonable, at least for this species.

A very small proportion of reaches, around 1–2 per cent, were predicted to be at ‘high risk’ (>$10ngL^{-1}$ E2 equivalent). However, many of these ‘high risk’ reaches were short stretches of headwaters or ditches composed almost entirely of sewage effluent. For this reason, consideration will need to be given to the most appropriate use of this model in determining which options for improving the removal of oestrogens from the environment will provide the greatest benefit for fish populations and their habitats.

A more detailed risk assessment was carried out using these same methods for 12 sites defined as Special Areas of Conservation (SACs). A simpler ‘no risk’ (<$1ngL^{-1}$ E2 equivalent) or ‘at risk’ (E2 equivalent >$1ngL^{-1}$) assessment was used, which incorporated a lower predicted no effect concentration for EE2 of $0.06ngL^{-1}$. Four of these sites were predicted to have at least one reach ‘at risk’ under mean concentrations, rising to seven sites under 90th percentile concentrations (Chapter 8).

This risk assessment was based on readily available data sets and due diligence has been taken in the quality control of these data. However, there are limitations associated with the data and certain outstanding issues that will need to be addressed in the longer term, which both contribute uncertainty to the model. For instance, a correct association needs to be made between each STP and its receiving water course and it would be advantageous to use measured dry weather flows rather than estimated values. Further improvements would include having more detailed estimates of STP steroid removal efficiencies, or even measured values for individual STPs, and refining the PNEC, which may alter the risk category thresholds and the calculation of E2 equivalent concentrations. Also, it is recommended that the predicted environmental concentrations produced by the model should be compared with measured data in water bodies. Furthermore, the predicted risk for fish should be compared to observed effect data, so that the risk assessment can be refined accordingly.

This model gives a detailed and comprehensive picture of the likely levels of exposure of freshwater fish populations to steroid oestrogens. It should therefore help in the development of a rational and cost effective strategy to reduce the risk of population decline, by targeting areas where steroid oestrogen reduction would prove of greatest benefit to fish stocks and to the wider environment.

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We would like to thank Jude Nutter of Wallingford Hydrosolutions for her role in preparing and delivering the underlying databases for the risk assessment. These databases related to sewage treatment plant characteristics, water quality, river flows and artificial influences.

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Contents

1 Introduction

1.1 Background

The Environment Agency has reviewed the evidence for the feminising effects of natural (oestradiol, oestrone) and synthetic (ethinyloestradiol) steroid oestrogens in fish (Environment Agency 2004). British and European surveys of intersex fish (feminised males) have demonstrated that the widespread occurrence of these fish is associated with effluent discharges from domestic sewage treatment plants (STPs). It has also demonstrated that the incidence and severity of intersex fish is positively correlated with the proportion of treated effluent from human sources in receiving waters. In addition, these datasets show that the reproductive success of moderately to severely intersex fish is adversely affected (Environment Agency 2004).

The Environment Agency has been working collaboratively with the water industry, the Water Services Regulation Authority (Ofwat) and the Department for Environment, Food and Rural Affairs (Defra) to design an Endocrine Disrupters Demonstration Programme (EDDP). This programme will investigate the options available to the water industry for removing steroid oestrogens from STP effluents and will be undertaken as part of the current Price Review of the water companies (PR'04) between 2005 and 2010. The EDDP will evaluate the efficacy and cost effectiveness of existing and improved STP treatment processes for reducing steroid oestrogen emissions, in order to inform future decisions (PR'09 and beyond) on an appropriate regulatory strategy for oestrogenic domestic STP effluents.

In addition to the EDDP, the Environment Agency is committed to carrying out a national, catchment-based environmental risk assessment of the steroid oestrogen emissions from domestic STPs in England and Wales. The aim of this assessment is to identify river reaches at risk of exceeding steroid oestrogen concentrations indicative of adverse biological effect under both low and mean flow conditions. This assessment needs to run alongside the EDDP so that STPs that may require improvement in future water industry investment rounds (2010 and beyond) can be identified and prioritised.

An additional need for this risk assessment has arisen as part of the EU Habitat Regulations, which require that 'favourable conservation status' be maintained or restored on river reaches within European Sites[1] in England and Wales. For consistency, it was envisaged that both assessments should be undertaken concurrently as part of this project. The risk assessment conducted for the Habitat Regulations is reported in Chapter 8.

Previously, risk assessments for steroid oestrogens were undertaken by the Environment Agency on a case-by-case basis, with each STP modelled in isolation. However, it is important that the influence of other STP inputs within a catchment, particularly those upstream of a reach of interest, should be incorporated into the risk assessment. This is particularly necessary when choosing STPs to target for the greatest degree of environmental improvement. The Habitat Regulations also require permissions that could adversely affect a European site to be risk assessed both alone and 'in-combination' with other permissions. A catchment-based modelling approach, as described within this report, implicitly evaluates the combined effect of all STPs within a catchment whilst also identifying those STPs that contribute most significantly to the steroid oestrogen load

[1] 'European sites' is used to mean designated Special Areas of Conservation (SACs).

within a particular area. An additional benefit of a catchment approach to modelling is that the removal of steroid oestrogens from the receiving water by natural processes can also be taken into account.

The Environment Agency's Environmental Protection Science Group has evaluated the available catchment models and concluded that the Low Flows 2000 Water Quality model (hereafter referred to as LF2000-WQX) is the best available option. It therefore suggested that this model be used as the basis for the further development of a model to identify which river reaches within England and Wales are at risk from steroid oestrogens.

1.2 Scope of the report

The objective of this project was to undertake a regional, catchment-based risk assessment of steroid discharges from STPs to the aquatic environment using a LF2000-WQX model, which first needed to be developed and populated. The project was split into a number of separate but related tasks (Table 1.1). In order to conduct the risk assessments (Tasks 3 and 4), preliminary activities had to be undertaken (Tasks 1 and 2) and these are also reported where they were directly relevant to the risk assessments. The application of the risk assessment exercise to the European sites (Task 5) is reported in Chapter 8.

Table 1.1 Summary of the main project tasks reported in this document

Task number	Task summary
Task 1.3	In-stream transformation (conversion of oestradiol to oestrone)
Task 1.4	Dissimilar STP steroid oestrogen removal efficiencies as determined by STP class
Task 1.5	Dissimilar STP steroid oestrogen removal rates as determined by sanitary determinands/consent conditions
Task 1.6	Steroid oestrogen PNEC[1] and calculation of oestrogen equivalents
Task 2.1	Oestrogen equivalents calculation methods and their effect on risk assessment
Task 2.2	Sensitivity of the risk assessment to determining STP removal of oestrogens by STP class or sanitary determinands
Task 2.3	Demonstrating management options for improving river risk classes
Task 3	Setting up LF2000-WQX for four Environment Agency regions with existing data (assembled for a previous Environment Agency project, but updated in this project) and performing the risk assessments
Task 4	Extension of LF2000-WQX for four Environment Agency regions without existing data, setting up the model and performing the risk assessments
Task 5	Further detailed assessment of the European (SAC) sites

Notes: 1. PNEC = Predicted no effect concentration.

1.3 Overview of the risk assessment method

This was a chemical concentration-based risk assessment in which a predicted environmental concentration was compared with threshold levels relating to environmental effect levels (see Chapter 4). The steps followed in conducting the risk assessment are given below. Within this overview, references are given to chapters where more detail can be found. Modifications made to this method for SAC (Special Area of Conservation) sites are detailed in Chapter 8.

Step 1: For each STP, obtain the location of the plants, the domestic population served, the dry weather flow (DWF) and the type of treatment. This information was provided by the water companies.

Step 2: From the population data determine the influent loads of oestrone (E1), oestradiol (E2) and ethinyloestradiol (EE2) using a model adapted from one developed previously at the Centre for Ecology and Hydrology (CEH; Johnson and Williams 2004).

Step 3: Run the LF2000-WQX model for each river within the hydrometric area of interest (Chapter 2). This model accounts for the removal of steroid oestrogens by the STP process (Chapter 3), dilution in the receiving water and biodegradation of the steroid oestrogens (including the transformation of oestradiol to oestrone).

Step 4: For each river reach modelled, combine oestrone, oestradiol and ethinyloestradiol to give a concentration in terms of E2 equivalents (Chapter 4).

Step 5: Use the E2 equivalent value to place the river reach into a risk category (no risk, at risk, high risk; see Chapter 4).

Step 6: Repeat steps 1–5 above for each hydrometric area within an Environment Agency region and display the results in the form of a map and table.

Step 7: Produce a map and a table for each Environment Agency region.

2 Description of the LF2000-WQX model

This chapter briefly describes the details of the LF2000-WQX model used to generate the risk assessment maps described in later chapters of this report.

2.1 Hydrological model

LF2000-WQX is an enhancement of the Low Flows 2000 software system. This is a decision support tool designed to estimate river flows at ungauged sites and to aid the development of catchment and regional water resources (Young *et al.* 2003). The development of both the scientific techniques for estimating river flow and the software system were undertaken as part of a CEH project jointly funded by CEH Wallingford (formerly the Institute of Hydrology) and the Environment Agency. Low Flows 2000 was licensed to Wallingford HydroSolutions (WHS) in 2004 and WHS continues to further develop the software and the underpinning science base.

The Low Flows 2000 software system consists of a map-based user interface, an underlying universal database and a low flow estimation module. The system allows natural flow estimates to be derived for any river reach in the UK and for the impact of artificial influences on the flow regime to be modelled.

The estimates of mean flow are generated from a gridded (1kmx1km) dataset of average annual runoff derived from a daily time-step, generalised soil moisture accounting model calibrated with flow data from over 500 gauged catchments within the UK (Holmes *et al*. 2002a). Annual and monthly natural flow duration curves are produced for ungauged catchments using a Region of Influence proximity model. This makes flow predictions based on the flow regimes of gauged catchments that are identified as hydrologically similar to the ungauged catchment (Holmes *et al.* 2002b, Holmes and Young 2002). The impacts of artificial influence features (abstractions, impounding reservoirs and discharges) are incorporated on a river reach basis. Within this database, the impact of each individual influence feature is represented by an array of 12 monthly influence volumes. These are then incorporated into the monthly flow duration curve estimates to yield 12 influenced monthly flow duration curves, which are re-combined to yield an estimate of the influenced (or actual) long-term flow duration curve. The structure of the river network also facilitates the aggregation of reach-scale impacts to the catchment scale and the derivation of residual flow diagrams.

2.2 Water quality extension

The original water quality extension was called the GREAT-ER module and was written to emulate the 'Mode 0' functionality of the GREAT-ER 1 simulator (ECETOC 1999) within the LF2000 software, together with its pre- and post-processing facilities.

The Mode 0 GREAT-ER methodology can be subdivided into the following steps.

- Estimating point source load data for a chemical.
- Simulating in-stream removal and transport processes using a first order decay coupled with a Monte-Carlo dynamic mass balance of inputs, which are described probabilistically.

- Post-processing of the simulation results to provide both tabulated values of predicted environmental concentrations (PECs) and a graphical interpretation of the PECs.

With the implementation of this methodology in LF2000-WQX, the functionality has been extended to model conservative and non-conservative determinands based on measured data and model dissolved oxygen concentrations using a modified Streeter-Phelps model. This functionality was added so that any conceptual representation of the river system and the point source discharges to that system can be evaluated by modelling general quality assessment (GQA)-measured water quality determinands.

The full functionality as implemented within the software is presented in the *LF2000-WQX user guide* (CEH 2003).

2.2.1 Estimation of point source load data for a chemical

The estimation of STP point source load data for a new or existing chemical requires market data on the projected or actual per capita mass of the chemical that is sold. As well as data on the fractions removed within a sewer system and during primary and secondary treatment within the STP. At its most basic, the load discharged from the STP is the product of the removal fractions, the population served by the STP and the per capita mass figure. The estimate of the load can be placed in a probabilistic framework by assigning variation and/or uncertainty to each of the elements within the product using frequency distributions and evaluating the product within a Monte-Carlo framework.

The resultant load is combined, again within a Monte-Carlo framework, with the effluent flow data for the discharge to give a frequency distribution for the effluent concentration. This frequency distribution, together with the probabilistic description of effluent flow, forms the input to the river model for the point source.

Obviously, if measured data for the chemical or GQA determinands of interest are available for the consent compliance monitoring point associated with the STP, these data should form the input into the river model. In this case, no data were available for steroid oestrogens, but measured data for GQA determinands were supplied. These were used as a surrogate for the steroids in a simulation to ensure that the model predictions were reasonably accurate.

The river model can simulate in-stream removal and transport processes using a first-order decay coupled with a Monte-Carlo dynamic mass balance of inputs that are described probabilistically. The user defines the number of runs, or shots, for the Monte-Carlo analysis.

As discussed, the river model can simulate the in-stream removal and/or transport of:

- an unlimited number of conservative determinands;
- an unlimited number of degradable determinands, which can be represented by a first order decay (it is possible to chain determinands such that determinand A can degrade to form determinand B);
- Biochemical Oxygen Demand (BOD) and dissolved oxygen.

The whole catchment is modelled as a network of interconnected model reaches, defined as the river stretches between model features. These features comprise:

- upstream boundary limits, which are usually closed by a freshwater monitoring point;

- significant tributaries, defined within the software using the methodology described in the development of the GREAT-ER datasets;
- nodes defining the confluence of model reaches;
- STPs, as defined by the consent effluent sample point and the estimation of loads for specific, non-monitored chemicals;
- freshwater river quality monitoring points;
- and the downstream limit for the model, which is commonly the tidal limit as defined within LF2000.

Several determinands can be simulated simultaneously. These determinands can either be conservative (no in-stream removal) or degradable (in-stream removal). Dissolved oxygen and BOD can also be modelled.

Flows and quality data can be described using a single value or through the use of a frequency distribution. These distributions can be correlated; for example, temperature and river flow. Full details are provided within the *LF2000-WQX user guide*. Three types of distribution are available for use:

- normal
- log-normal
- uniform.

The inputs into the reach model are: the flow and quality data for the upstream reach; the STPs (if any) associated with the reach; significant tributaries (if any); and the seepage lateral inflows to the reach. The reach model is then applied sequentially to each reach within the model network, with the initial reaches being the first order reaches. The results are summarised as tabulated values of PEC distributions and also graphically, as colour-coded reach maps and down-network concentration profiles.

3 Predicted no effect concentration review and risk classes

The aims of this work were twofold.

1. To review recently published scientific studies involving steroid oestrogens in order to determine whether the Environment Agency's current steroid oestrogen PNEC (predicted no effect concentration) remains valid for the purposes of risk assessment and for determining the threshold between 'no risk' and 'at risk' sites.

2. To set the threshold value used in the risk assessment for distinguishing between the 'at risk' and 'high risk' sites.

3.1 Steroid PNEC review

Journal papers investigating the toxicological effects of E1, E2 and EE2 that had been published since (and not included in) the Environment Agency review (2002) were collated. These papers were critically assessed based upon the five key criteria outlined in the Environment Agency review (2002). These stated that:

- the study should use sensitive taxa;
- these taxa should be at a sensitive life stage;
- exposure concentrations should be measured, rather than expressed as nominal values,
- the biological significance of the endpoints should be directly relevant to population level effects;
- and the exposure duration should be relevant to setting a long-term PNEC expressed as an annual average.

In particular, papers where the exposure concentrations were only expressed as nominal values were excluded, as were studies that only reported sub-individual endpoints, such as vitellogenin induction. This was done because although sub-individual endpoints may be useful biomarkers of exposure to oestrogenic compounds, their relationship with regard to fecundity is currently unclear. In addition, studies that did not use aqueous exposures were also excluded, as recommended in the Environment Agency review (2002).

For each compound, the relevant studies and the endpoints within them are detailed below. These data are then compared with the key studies used to set the existing PNEC to determine whether there is any evidence to suggest that the PNECs should be amended.

3.1.1 17ß-Oestradiol (E2)

Four relevant studies conducted since the Environment Agency review (2002) were identified for E2. These were Brion *et al*. (2004), Kang *et al*. (2002), Nash *et al*. (2004) and

Seki *et al*. (2005). The papers by Brion *et al*. and Nash *et al*. are the full publications of two platform presentations that were cited in the review.

The study by Brion *et al*. (2004) involved exposing zebrafish to E2 for three weeks during the embryo-larval, juvenile or adult stage. A wide range of endpoints was measured, from vitellogenin induction to survival and development of the F1 generation. A number of adverse reactions were reported down to concentrations of ≤25ngL^{-1} nominal (16.5ngL^{-1} measured mean). The No Observed Effect Concentration (NOEC), the Lowest Observed Effect Concentration (LOEC) and the concentration causing 100 per cent effect (EC_{100}) for each of these reported end points are detailed in Table 3.1. No significant effects on the fertilisation and hatching rates of the F1 generation were seen at any exposure concentration.

Table 3.1 Endpoints reported in studies investigating E2

Endpoint	**NOEC (ngL^{-1})**	**LOEC (ngL^{-1})**	**EC_{100} (ngL^{-1})**
Brion *et al*. 2004			
Adult male VTG induction	5	16.5[1]	
Embryo-larval and juvenile VTG induction	25	100	
Adult female VTG induction	5	16.5[1]	
Juvenile retrogonadal cavity development	25	100	100
Embryo-larval sex ratio (skew to female)	25	100	
Adult male uro-genital papillae induction	5	16.5[1]	
Juvenile reduced egg production		25[2]	
Adult reduced egg production		16.5[1,2]	
Kang *et al*. 2002			
Reduced egg production and fertility	250	500	
Male reduced GSI	250	500	
No spermatogenosis			500
VTG induction	31.3	62.5	
Nash *et al*. 2004			
F1 reduced egg viability		5[3]	
Seki *et al*. 2005			
F0 sex ratio (skew to female)	9.77	31.3	100
F0 reduced fecundity	9.77	31.3	
F0 reduced fertility	3.05	9.77	
Male VTG induction	3.05	9.77	
Male reduced GSI	9.77	31.3	

Concentrations reported as nominal, as all measured concentrations were within ±20 per cent of nominal. VTG = vitellogenin; GSI = gonadosomatic index.

Notes: 1. Measured concentration was outside ±20 per cent nominal, so measured is reported.
2. Although decreased egg production was noted, there was only one replicate for each life stage exposed so this cannot be tested statistically. This data point should be used as supporting data only.
3. Only one concentration was tested so low confidence that this is the true LOEC.

Kang *et al*. (2002) investigated the effect of a three-week exposure of adult medaka to E2. Again a range of endpoints was monitored: from vitellogenin induction to survival and development of the F1 generation. All endpoints reported are listed in Table 3.1. Again, no significant effects were seen on the F1 generation at any test concentration.

Nash *et al*. (2004) conducted a multi-generation test with continuous exposure. Adult zebrafish were exposed to E2, and then their reproductive success and the reproductive success of the F1 generation were measured. The main limitation of this study was that only one exposure concentration of E2 was used: 5ngL^{-1} nominal (4.8ngL^{-1} measured mean). This concentration resulted in a significant increase in the egg mortality of the F1 generation. However, as there was only one concentration tested we cannot be confident that this is the true LOEC.

A two generation, continuous exposure experiment was conducted by Seki *et al*. (2005) on medaka. A full range of endpoints was measured and these are reported in Table 3.1. Adverse effects were seen down to concentrations of 9.77ngL^{-1} nominal (8.66ngL^{-1} measured mean) for vitellogenin induction and reduced fertility. The F1 generation was exposed to concentrations up to 9.77ngL^{-1} nominal for 59 days post-hatch. No significant effects were reported.

For comparison, the endpoints reported in the key studies identified in the Environment Agency review (2002) are shown in Table 3.2. The PNEC is based upon an endpoint of 100 per cent feminisation of medaka at 10ngL^{-1} (Nimrod and Benson 1998) with a safety factor of 10 applied, resulting in a PNEC of 1ngL^{-1}.

Table 3.2 Endpoints reported in key studies identified by the Environment Agency review (2002) for E2

Endpoint	NOEC (ngL^{-1})	MATC (ngL^{-1})	LOEC (ngL^{-1})	EC_{100} (ngL^{-1})
Brion *et al*., 2002				
Effects on egg production, male secondary sexual characteristics and gonad histology	5	11.1	25	
Nash and Kime, 2000				
Increased F1 egg mortality			5[1]	
Nimrod and Benson, 1998				
Sex ratio (skew to female)			10[2]	10
Shioda and Wakabayashi, 2000				
Reduced hatching success	2.7	8.5	27	

Concentrations reported as nominal. MATC = Maximum Acceptable Toxicant Concentration
Notes: 1. Only one concentration tested, so low confidence that this is the true LOEC.
2. Lowest concentration tested, so low confidence that this is the true LOEC.

The new data do not indicate that the PNEC needs to be lowered and no effects are reported below the PNEC of 1ngL^{-1}. Other than the LOEC of 5ngL^{-1}reported by Nash *et al*. (2004), which is discussed in the Environment Agency review (2002), the next lowest endpoint is the LOEC for reduced fertility and increased vitellogenin induction at 9.77ngL^{-1} in Seki *et al*. (2005).

Of the newly reported endpoints, two would be predicted to result in population failure. These are the 100 per cent feminisation of medaka at 100ngL^{-1} (Seki *et al*. 2005) and the lack of spermatogenesis in medaka at 500ngL^{-1} (Kang *et al*. 2002). The PNEC of 1ngL^{-1} provides a large margin of safety for these two endpoints.

3.1.2 Oestrone (E1)

No studies were identified that had been published since the original steroid oestrogen PNEC report (Environment Agency 2002) and met the required criteria.

The data evaluated in the Environment Agency review (2002) were also inadequate to derive a PNEC for E1. However, studies investigating the relative potency of steroid oestrogens on vitellogenin induction indicated that E1 is 3–5 times less potent than E2 (Routledge *et al*. 1998, Thorpe *et al*. 2001). For the purposes of risk assessment and adopting a precautionary approach, a PNEC value of 3ngL^{-1} was proposed for calculating total steroid equivalents. As no further data of sufficient quality were available, no revision to this value was proposed.

Only one other recent paper investigating the relative potencies of E1, E2 and EE2 on vitellogenin induction in zebrafish was identified (Van den Belt *et al*. 2004). Although exposure concentrations were measured, the results showed that the actual conditions were very different from the nominal (20–100 per cent). It is unclear whether nominal or measured concentrations were used to calculate the endpoints noted in the paper. The relative potencies of E1 and EE2 compared to E2 are reported as 0.85 (range 0.69–1.1) and 30.6 (range 26.4–33.7) respectively. Although this paper suggests that E1 and E2 are equipotent, and therefore that the current PNEC may be underestimating risk, the concern over the data quality means that this should not be considered a key study.

3.1.3 17α-Ethinyloestradiol (EE2)

Ten relevant studies conducted since the Environment Agency review (2002) were identified for EE2. These were Anderson *et al*. (2003), Fenske *et al*. (2005), Kristensen *et al*. (2005), Maack and Segner (2004), Nash *et al*. (2004), Orn *et al*. (2003), Parrott and Blunt (2005), Schulz *et al*. (2003), Seki *et al*. (2002) and Zillioux *et al*. (2001). Again, the paper by Nash *et al*. (2004) is the full publication of a platform presentation referred to in the review.

Andersen *et al*. (2003) exposed zebrafish to EE2 for periods of up to 60 days over differing life stages. Vitellogenin induction and sex ratio were investigated, although only one EE2 concentration was tested. Effect endpoints are reported in Table 4.3. As only one concentration was tested we cannot be confident that the reported value is a true LOEC and therefore this study should be used as supporting data only.

Similarly, Fenske *et al*. (2005) exposed zebrafish over varying time periods of up to 118 days to a single concentration of EE2. Vitellogenin induction, gonad histology, sex ratio and reproductive capabilities were investigated (Table 3.3). Again, as only one concentration was tested, we cannot be confident that the reported value is a true LOEC and therefore this study should be used as supporting data only.

Male guppy were exposed to EE2 from birth to adulthood by Kristensen *et al*. (2005) and their reproductive success tested. Each exposed male was paired with an unexposed male and made to compete to fertilise a receptive female. The successful male was determined by paternity analysis and other endpoints were also recorded (Table 3.3).

Maack and Segner (2004) exposed zebrafish at three different life stages to a single concentration of $10ngL^{-1}$ EE2 for 27 days. From this, it was determined that the gonad transition stage (43–71 days post-hatch) was most susceptible. A second experiment then exposed this life stage to different concentrations of EE2, and reproductive endpoints and sex ratio were assessed (Table 3.3). The effect of depuration after exposure was also investigated. It was found that at the termination of the exposure all fish in the $3ngL^{-1}$ and $10ngL^{-1}$ exposures had ovaries. However, this feminisation effect appeared to be reversible, for after 120 days in clean water fish with either ovaries or testes were found.

Nash *et al*. (2004) conducted a multi-generation test with continuous exposure. Adult zebrafish were exposed to EE2, and then their reproductive success and the reproductive success of the F1 generation were measured (Table 3.3). Although there was reduced F1 egg viability at $0.5ngL^{-1}$, the variability in egg number meant that this did not result in a reduced number of F2 progeny.

The effect of EE2 on zebrafish vitellogenin production and gonad development was studied by Orn *et al*. (2003) by exposing juvenile fish for 40 days. A significant increase in the number of females was seen at $1ngL^{-1}$ and at exposure concentrations of $2ngL^{-1}$, $5ngL^{-1}$ and $10ngL^{-1}$ only females were detected. However, at $25ngL^{-1}$ both female and male fish were identified, disrupting the dose-response relationship.

Parrott and Blunt (2005) exposed fathead minnows to EE2 for their full life cycle, with effects seen at concentrations down to $0.32ngL^{-1}$. However, this concentration and the concentration above ($0.96ngL^{-1}$) were nominal only. Higher concentrations were measured and were found to be 71–111 per cent of nominal. Although the measured concentrations were in reasonable agreement with the nominal concentrations, this finding makes interpretation of this study difficult.

Schultz *et al*. (2003) exposed adult male rainbow trout to EE2 for 62 days before determining various endpoints. The researchers also tested fertility by mixing exposed male sperm with eggs from a non-exposed female. The fertilisation rate was the most sensitive endpoint measured.

Adult medaka were exposed to EE2 for 21 days by Seki *et al*. (2002). Vitellogenin induction, gonadal condition and reproductive success were studied. As adults were only exposed for a short period of time, the exposure concentrations were relatively high.

Zillioux *et al*. (2001) exposed sub-adult sheepshead minnow to EE2 for up to 59 days. After this time, the reproductive success of the fish and the survival of the progeny were recorded. Although higher exposure concentrations were measured, the lowest three concentrations ($0.2–20ngL^{-1}$) were measured as stock solution only. This makes interpretation of this study difficult.

Table 3.3 Endpoints reported in studies investigating EE2

Endpoint	NOEC (ngL^{-1})	LOEC (ngL^{-1})	EC$_{100}$ (ngL^{-1})
Andersen *et al*. 2003			
VTG induction		15.4[1,2]	
Sex ratio (skew to female)		15.4[1,2]	15.4[1,2]
Fenske *et al*. 2005			
Sex ratio (skew to female)		3[2]	3[2]
VTG induction		3[2]	
Decreased reproduction (after depuration)		3[2]	
Kristensen *et al*. 2005			
Sex ratio (skew to female)	50	112[3]	
Reduction in sperm count	50	112[3]	
Change to courtship behaviour	50	112[3]	
Reduced fertility	50	112[3]	
Maack and Segner 2004			
Reduced fertilisation	1.14[3]	3	
Sex ratio (skew to female)		1.14[3,4]	3
Nash *et al*. 2004			
F0 VTG induction		0.5[4]	
F0 reduced egg production	5	50	50
F1 reduced egg production	0.5	5	
F1 increased proportion of non-viable eggs		0.5[4]	5
F1 sex ratio (skew to female)			5
Orn *et al*. 2003			
VTG induction	<0.6[3]	1.5[3]	
Sex ratio (skew to female)		<0.6[3,4]	
Parrott and Blunt 2005			
Reduced fertilisation		0.32[4,5]	
Reduced egg production	0.96[5]	3.5	3.5
Sex ratio (skew to female)		0.32[e]	3.5
Reduced female GSI	0.96[5]	3.5	
Reduced male secondary sexual characteristics	0.32[5]	0.96[5]	
Increased female ovipositor index	0.96[5]	3.5	
Schultz *et al*. 2003			
Lethality	131[3]	750[3]	750[3]
Increased HSI	15.6[3]	131[3]	
Reduced GSI	15.6[3]	131[3]	
Reduced fertilisation		15.6[3,4]	
Seki *et al*. 2002			
Reduced fecundity	250	500	
VTG induction	31.3	62.5	
Zillioux *et al*. 2001			
Lethality	117[3]	400	
Reduced egg production	20[6]	117[3]	
Reduced hatching	20[6]	117[3]	

Concentrations reported as nominal, as all measured concentrations were within ±20 per cent of nominal. VTG = vitellogenin; GSI = gonadosomatic index.

Notes:
1. Nominal concentration was not given in paper. Measured concentration is therefore reported.
2. Only one concentration was tested, so low confidence that this is the true LOEC.
3. Measured concentration was outside ±20 per cent nominal, so measured concentration is reported.
4. Lowest concentration was tested, so low confidence that this is the true LOEC.
5. Nominal concentrations of 0.32ngL^{-1} and 0.96ngL^{-1} were not measured. However, higher concentrations were measured and means were 71–111 per cent of nominal.
6. Nominal concentration of 20ngL^{-1} was measured as stock, rather than aqueous exposure concentration. Mean concentration was 92 per cent of nominal.

For comparison, the endpoints reported in the key studies identified in the Environment Agency (2002) review are shown in Table 3.4. The PNEC is based upon a Maximum Acceptable Toxicant Concentration (MATC) for reduced fertilisation success in zebrafish of $0.57ngL^{-1}$ (Wenzel *et al*. 2001) with a safety factor of five applied, resulting in a PNEC of $0.1ngL^{-1}$. A MATC is calculated as the geometric mean between the NOEC and LOEC.

Table 3.4 Endpoints reported in key studies identified by the Environment Agency review (2002) for EE2

Endpoint	NOEC (ngL^{-1})	MATC (ngL^{-1})	LOEC (ngL^{-1})	EC_{100} (ngL^{-1})
Länge *et al*. 2001				
Sex ratio	1		4	4
Nash and Kime 2000				
F1 egg production	0.5		5	
Wenzel *et al*. 2001				
Fertilisation success	0.3	0.57	1.1	

Concentrations reported as nominal.

The new data do not suggest that the PNEC needs to be lowered, as no effects are reported below the PNEC of $0.1ngL^{-1}$. The reported LOECs falling below those used to set the current PNEC are discounted for the following reasons.

The lowest endpoint is reported in Parrott and Blunt (2005). This is a LOEC for reduced fertilisation success and altered sex ratio of $0.32ngL^{-1}$. Unfortunately, this was the lowest test concentration, which means that there is no NOEC. Although higher concentrations were measured and were in reasonable agreement with the nominal values, this concentration was not measured. This LOEC should therefore be used as supporting data only. Around a 23 per cent reduction in fertility, compared to controls, was seen at $0.32ngL^{-1}$ and a 56 per cent reduction was seen at $0.96ngL^{-1}$ (both concentrations were nominal only). As the reported effects in terms of EC_{50} are broadly similar to those reported by Wenzel *et al*. (2001; EC_{50} of $1.1ngL^{-1}$ for fertilisation success), this study supports the fact that the current PNEC is representative of other fish species.

The next lowest endpoints are reported in Nash *et al*. (2004). These are a LOEC for vitellogenin induction and increased proportion of non-viable eggs of $0.5ngL^{-1}$. These effects were seen at the lowest test concentration, so again there is no NOEC. As discussed in the Environment Agency review (2002), it was not felt appropriate to base the PNEC on an endpoint that did not have direct demographic relevance. Thus the LOEC for vitellogenin induction should be used as supporting data only. The LOEC for increased non-viable eggs is of demographic relevance, as this could result in reduced population sizes or population failure. However, the authors note that, despite the statistically significant increase in egg failure, the variation in egg numbers meant that the resulting F2 generation was the same size as that of the controls.

Orn *et al*. (2003) report a LOEC for altered sex ratio of $<0.6ngL^{-1}$. This was the lowest concentration tested, so once again there is no NOEC. As the analytical method was unable to quantify the test concentration, because it was below the $0.6ngL^{-1}$ limit of detection, this data point should be used as supporting evidence only.

Five studies reported a change in the sex ratio, such that all individuals were female (Andersen *et al*. 2003, Fenske *et al*. 2005, Maack and Segner 2004, Nash *et al*. 2004, Parrot and Blunt 2005). The effect concentrations (EC_{100}) for this ranged from $3ngL^{-1}$ to $15.4ngL^{-1}$. In addition to this, a complete failure of the next generation, due either to no egg production or no viability, was reported in two studies. This was seen for concentrations of EE2 ranging from $3.5ngL^{-1}$ to $5ngL^{-1}$ for fish exposed for their entire life cycles and $50ngL^{-1}$ for exposed adult fish (Nash *et al*. 2004, Parrott and Blunt 2005). The PNEC of $0.1ngL^{-1}$ provides a margin of safety for these endpoints.

3.2 Risk class threshold review

Previous work has indicated that the effects of E1, E2 and EE2 in mixtures are additive and that the total effect is greater than would be expected from the most potent steroid present (Thorpe *et al*. 2003). It is therefore important that we are able to consider the total steroid loading in a discharge and that the threshold values are set in terms of total steroid concentrations.

There are two main methods for combining concentrations of individual steroids into a total loading. Both are based on the classic mixtures approach known as concentration addition (Backhaus *et al*. 2000). This method is based on the concept that the mixture components act on similar physiological systems within the exposed organism and that the effects are therefore additive. If the relative potencies of the mixture components are known then the effect can be predicted.

The first method assumes that the relative potencies of the steroids remain fixed at all concentrations. Various endpoints and methods have been used to judge the relative potency of the steroids before they are summed. The current steroid PNEC is an example of this approach (Environment Agency 2002). The concentration of each steroid is divided by its respective PNEC and then these values are added. The resulting number is in toxic units; if this number is greater than one then the total PNEC is exceeded. The ratios of the PNECs also allow the individual concentrations to be converted into E2 equivalents for any of the steroids. In this example, as the PNEC for E2 is one, the result for E2 equivalents and toxic units are identical.

This method assumes a linear response, whereby at half the concentration you see half the response. This effect is not, however, normally seen; rather there is a sigmoidal dose response. This is taken into account by the second method, which replaces the constant PNEC or endpoint value with a dose response equation. This method allows the relative potency of the three steroids to vary depending on the concentration. However, at present, the main limitation to this method is that we do not have dose response curves for the endpoints of interest for each of the steroids. Dose response equations may be available for vitellogenin induction, but it is unclear how these could be related to thresholds for population level effects. Consequently, the first approach is currently the most suitable method to use.

The regional risk assessment described in this report aims to categorise all catchments in England and Wales into three groups based on potential steroid oestrogen impacts. These three groups are referred to as ‘no risk’, ‘at risk’ and ‘high risk’. The total steroid oestrogen PNEC (Environment Agency 2002) forms the threshold between ‘no risk’ and ‘at risk’ sites (Equation 1). This boundary therefore represents a distinction between sites where we would predict no impacts (‘no risk’) and sites where impacts may occur (‘at risk’).

$$\frac{[\boldsymbol{EE}2]}{\boldsymbol{PNEC}(\boldsymbol{EE}2)}+\frac{[\boldsymbol{E}2]}{\boldsymbol{PNEC}(\boldsymbol{E}2)}+\frac{[\boldsymbol{E}1]}{\boldsymbol{PNEC}(\boldsymbol{E}1)}<1 \qquad \text{Equation 1}$$

It is also desirable to distinguish between ‘high risk’ sites, so that the catchments of most concern can be identified. This threshold should relate to a concentration above which a population level effect is predicted. In the absence of population level effect data, other endpoints with direct relevance to the population level should be substituted. Of the endpoint concentrations reported in the literature, only 100 per cent feminisation would indicate a definite ‘population level’ effect.

The threshold could be devised along similar lines to the total steroid PNEC (Equation 2), where EC is the effect concentration at which 100 per cent feminisation is seen for each compound respectively.

$$\frac{[\boldsymbol{EE}2]}{\boldsymbol{EC}(\boldsymbol{EE}2)}+\frac{[\boldsymbol{E}2]}{\boldsymbol{EC}(\boldsymbol{E}2)}+\frac{[\boldsymbol{E}1]}{\boldsymbol{EC}(\boldsymbol{E}1)}<1 \qquad \text{Equation 2}$$

If the value calculated in Equation 2 is greater than one, a population level effect would be expected and the site would be categorised as 'high risk'. If the value is less than one but the total steroid PNEC is exceeded, impacts on fish would be expected. However, these may not lead to population level effects and the site would be categorised as 'at risk'.

The lowest endpoints for 100 per cent feminisation are 10ngL^{-1} E2 (Nimrod and Benson 1998) and 3ngL^{-1} EE2 (Fenske *et al*. 2005, Maack and Segner 2004). Unfortunately, there is no data available for E1 in those studies that meet the criteria for inclusion. Metcalfe *et al*. (2001) investigated the effect of exposing medaka to E1 for 100 days from hatch on the sex ratio. At concentrations of 1000ngL^{-1} E1 and above, the sex ratio was significantly skewed towards females and all males were intersex. However, these concentrations are nominal and the exposure concentrations were widely spaced (LOEC = 1000ngL^{-1}, NOEC = 100 ngL^{-1}). Concentrations were measured in duplicate tanks to investigate the persistence of the test compounds. E1 concentrations were found to be relatively stable over time, with a mean measured concentration that was 77.8 per cent of nominal. This would suggest that the measured LOEC would have been around 778ngL^{-1} E1. However, this approach was not accepted in the Environment Agency review (2002) and there is no other data with which to compare this result.

There are two other alternative approaches that could be followed. The first is to exclude E1 from the calculation of the 'high risk' threshold. However, as E1 is often present at the highest concentrations in water bodies, this may mean excluding an important source of oestrogenic potential. The second approach would be to follow the approach used to derive the total steroid PNEC (Environment Agency 2002). This would involve basing the E1 effect concentration on the relative potency of E1 to E2, producing an effect concentration of 30 ngL^{-1} E1. Although not ideal, in view of the lack of suitable data for E1, this presents a conservative option that is preferred to excluding E1. The resulting categories and their associated thresholds are listed in Table 3.5.

Table 3.5 Risk categories and thresholds based on PNEC and 100 per cent feminisation

Risk category	Thresholds
No risk	$\frac{[EE2]}{0.1}+\frac{[E2]}{1}+\frac{[E1]}{3}<1$
At risk	$\frac{[EE2]}{0.1}+\frac{[E2]}{1}+\frac{[E1]}{3}>1$ and $\frac{[EE2]}{3}+\frac{[E2]}{10}+\frac{[E1]}{30}<1$
High risk	$\frac{[EE2]}{3}+\frac{[E2]}{10}+\frac{[E1]}{30}>1$

It is possible that a threshold based on 100 per cent feminisation may be too high given that the conceptual outcome is a population crash. Alternative endpoints to 100 per cent feminisation, which may still result in population level effects, could be chosen. The lowest endpoints for population level-related parameters are 1.1ngL^{-1} EE2 (reduced fertilisation success; Wenzel *et al*., 2001) and 9.77ngL^{-1} E2 (reduced fertility; Seki *et al*. 2005). Again there is no data for E1, so the E1 endpoint would be based on its relative potency to E2, resulting in a value of 30ngL^{-1} for E1. If this approach is followed then the resulting categories and their associated thresholds are listed in Table 3.6. This threshold is based on the same data as the total PNEC, but without safety factors applied. A comparison of the risk ranking obtained using these two methods was undertaken as part of the preliminary modelling (Chapter 5).

Table 3.6 Risk categories and thresholds based on PNEC and the lowest population level-related endpoints

Risk category	Thresholds
No risk	$\frac{[EE2]}{0.1}+\frac{[E2]}{1}+\frac{[E1]}{3}<1$
At risk	$\frac{[EE2]}{0.1}+\frac{[E2]}{1}+\frac{[E1]}{3}>1$ and $\frac{[EE2]}{1}+\frac{[E2]}{10}+\frac{[E1]}{30}<1$
High risk	$\frac{[EE2]}{1}+\frac{[E2]}{10}+\frac{[E1]}{30}>1$

3.3 Summary

Papers published since the steroid oestrogen PNEC review (Environment Agency 2002) support keeping the E2 and EE2 PNECs constant. No further data was identified for E1. Therefore, the existing PNECs require no revision.

The existing total steroid PNEC is an appropriate threshold for distinguishing ‘no risk’ from ‘at risk’ catchments. To clarify, ‘no risk’ should be interpreted as an indication that no concentration of steroids sufficient to cause endocrine disruptive effects (feminisation) in fish will occur, based on the data inputted into the model.

‘High risk’ sites are distinguished by dividing the measured/predicted concentration of each steroid oestrogen by its corresponding LOEC value (without the corresponding safety factors used to derive the PNEC) and the resulting three values summed. If the resulting value is greater than one, a site is categorised as ‘high risk’. If the value is less than one, but the steroid PNEC is exceeded, then the site is categorised as ‘at risk’.

In the absence of population level data, the LOEC defining the threshold between the ‘at risk’ and ‘high risk’ catchments could be based on either 100 per cent feminisation or some other less severe population-related endpoints.

There is a lack of suitable LOEC data for E1 to use this approach to determine the threshold between ‘at risk’ and ‘high risk’ for this steroid. Although not ideal, but in view of the paucity of data, deriving the E1 LOEC based on its relative potency to E2 is the preferred option. This mirrors the approach used to derive the E1 PNEC in the total steroid PNEC equation (Environment Agency 2002).

4 Removal of steroid oestrogens in sewage treatment plants

Two methods for estimating the removal efficiency of steroid oestrogens in STPs were investigated. The first was based on data available from the literature supplemented with analysis of measured data. The second tried to establish a relationship between removal efficiency and the concentration of BOD or ammonium in STP effluents. But no such relationship could be established. Only the results of the first method are reported here.

We distinguished differential oestrogen removal rates for three types of sewage treatment processes (activated sludge, biological trickling filters and primary treatment) in the catchment-based risk assessment of steroid oestrogens[2]. A preliminary examination of the consequence of this approach was carried out for two catchments.

4.1 Activated sludge plants

The previous literature review by Johnson and Williams (2004) covered a number of studies that included details of 31–90 activated sludge plants (ASPs). These studies gave the following removal fractions: 82 per cent for E2, 65 per cent for E1 and 85 per cent for EE2 (the number of STPs for which data are reported is different for each of the steroids). An updated literature review revealed a further eight studies covering 12–44 ASPs. Of these, seven studies contained sufficient information (6–18 plants) to calculate ASP removal fractions relevant to England and Wales. This new dataset gave removals of 95 per cent, 86 per cent and 77 per cent for E2, E1 and EE2 respectively (Table 4.1). Combining these new datasets with the data used to derive the original removal fractions (Johnson and Williams 2004) gave new mean removal values of 83 per cent, 69 per cent and 83 per cent for E2, E1 and EE2 respectively[3]. These values are therefore used in the model.

There is an argument that ASPs with a tertiary biological process or charcoal sorption process (some of the options within Ofwat classes TA1, TA2, TB1, and TB2; see Appendix A) would prove better at removing oestrogens than ASPs conducting straight activated sludge treatment. There are, however, two problems in making such a possible refinement further at this stage. Firstly, the Ofwat designations are not sufficiently specific about the tertiary biological processes. Secondly, there is insufficient scientific evidence on the efficacy of the different treatments with regard to oestrogens.

Some data on the ability of membrane bioreactors[4] and sequencing batch reactors[5] to remove oestrogens can be found in the literature (Clara *et al.* 2004, Kreuzinger *et al*. 2004, Joss *et al*., 2004). However, these data are insufficient (not enough of the reactors have been examined) to come to robust conclusions about their specific merits. Information on the oestrogen removal performance of other sewage treatment types is

[2] It should be noted that the software will be able to distinguish between all seven types of STP defined in the Ofwat scheme, but we only have enough evidence to separate out these three processes at the present time.

[3] The overall value is assessed as the mean of the mean values reported in each paper weighted by the number of STPs used to derive the individually-reported means.

[4] Membrane bioreactors are a combination of activated sludge plants with a micro- or ultrafiltration membrane system that rejects particles. The membrane system replaces the traditional gravity sedimentation unit (clarifier) in the activated sludge process.

[5] Unit processes of sequence batch reactors (SBR) and conventional activated sludge systems are the same. The difference between the two is that SBRs perform equalisation, biological treatment and secondary clarification in a single tank using a timed sequence. In conventional secondary activated sludge systems, these processes would be conducted in separate tanks.

almost non-existent. Therefore, all STPs using ASP with tertiary treatment are modelled as for ASP alone.

Table 4.1 Recent studies on steroid oestrogen removal values for different STPs

Plant	Reference	E2 % removal[1]	E1 % removal[1]	EE2 % removal[1]
Current performance settings used in model (31–90 plants)[2]	Johnson and Williams 2004	82 (+/- 11)	65 (+/- 6)	85 (+/- 5)
ASP (6–18 separate plants studied)[2]	Onda *et al*. 2003, Clara *et al.* 2004, Kreuzinger *et al*. 2004, Andersen *et al.* 2003, Williams *et al*. 2003, Joss *et al.* 2004, Johnson *et al.* 2005	95 (+/- 2)	86 (+/- 10)	77 (+/- 9)
Overall removal		**83 (+/- 8)**	**69 (+/- 8)**	**83 (+/- 6)**
MBR 5 separate plants studied	Clara *et al.* 2004, Kreuzinger *et al*. 2004, Joss *et al.* 2004	98	97	66
SBR 1 plant studied	Kreuzinger *et al.* 2004	33	33	NC[3]
BFP 2 separate plants studied	Ternes *et al.* 1999b, Joss *et al.* 2004	93	78	66

ASP = activated sludge plant; MBR = membrane bioreactor; SBR = sequencing batch reactor; BFP = biological filter plant.
Notes: 1. Standard errors for some new studies cannot be given due to insufficient data in original papers.
2. Number of plants varies for each of the steroids because authors did not always report values for E1, E2 and EE2.
3. Data problems, could not be calculated;

4.2 Biological trickling filters

There are very few studies in the literature on the performance of biological (trickling) filters (BFPs) with respect to oestrogens (Ternes *et al.* 1999b, Joss *et al.* 2004). The Ternes *et al.* (1999b) work refers to a Brazilian BFP sampled in Rio de Janeiro in June 1997. No specific process details were given. In the Joss *et al.* (2004) study, the Swiss BFP was a high performance model with a fixed bed comprising 3.6mm styrofoam balls rather than the 50mm-type clinker normally associated with British BFPs. Thus, neither of these studies would appear to offer the best guide to likely BFP performance for the UK scenario.

To address this knowledge gap, the Environment Agency commissioned CEH to reassess the data from the 2003 survey of steroid oestrogens, (anti-) oestrogenic and (anti-) androgenic activity in the effluents of a wide range of STPs in England and Wales (Environment Agency 2006). The water companies whose plants were involved in the original survey were asked to provide detailed information on the treatment type and practices of these STPs. The 10 BFPs in the survey (Table 4.2) displayed a low mean E1 removal of 30 per cent (SD 31, n=18). When the E1 removal efficiencies of the simple BFP were compared against those of the other STP types (n=25) in the original survey they were found to be significantly lower ($p < 0.001$). There was insufficient evidence to indicate that the BFPs perform worse than ASPs with regard to the removal of E2 and EE2 and so the same removal efficiencies were used. However, it is assumed in the model that simple biological filters will only remove 30 per cent of E1. This is unless they are combined with tertiary treatment, when the removal rate of E1 will be the same as for ASPs (see Johnson *et al.* 2007 for full details of the analysis).

Table 4.2 Summary of oestrone removal performance by different STPs using the original 2003 Environment Agency survey data

Treatment type	Mean oestrone removal (%)
Current performance settings used in model	65 (+/- 6)
ASP	72 (SD 48, n=8)
BFP with tertiary treatment	74 (SD 29, n=17)
BFP	30 (SD 31 n=18)

ASP = activated sludge plant; BFP = biological filter plant

4.3 Primary treatment

STPs that have primary treatment without secondary treatment (sedimentation or sedimentation with chemical precipitation to remove phosphate) manage little or no removal of steroid oestrogens/endocrine disrupting chemicals (Desbrow *et al.* 1998, Svensen *et al.* 2003, Johnson *et al.* 2005). As the major loss mechanism for oestrogens in sewage treatment is deemed to be due to biodegradation (Ternes *et al.* 1999a, Andersen *et al.* 2003), it might be reasonable to equate removal solely with biological treatment. However, recent data has emerged from the primary treatment component of a STP in the Anglian region, which details steroid oestrogen removals of 23–29 per cent for the major oestrogens. Given the background literature of no removal, and the occasional absence of any E1 removal from the BFPs examined in the Environment Agency 2003 survey (all of which contained a primary treatment component), it would be unwise to assume that primary treatment consistently removes any proportion of oestrogens across the UK. Thus, bearing in mind the principle of conservative risk assessment, treatment plants with primary treatment only should be modelled as having no oestrogen removal ability, unless measured data is available. In fact, of the around 2000 STPs in the model contributing to 95 per cent of the DWF, only 16 are of this treatment type.

4.4 Conclusions

The approach used in this risk assessment for modelling oestrogens in effluents was based on a number of pragmatic decisions.

- Reliance was placed on those removal rates influenced by the large, robust datasets for STP performance (rather than individual examples).
- The approach was precautionary in order to ensure that the possible risks from oestrogens released from treatments with potential to be poor performers were not under-represented.
- The need to work within the limitations of the readily available Ofwat STP class designations.

To summarise:

- Ofwat class P are assumed to provide no oestrogen removal;
- Ofwat class SB are assumed to be simple biological filters with only 30 per cent E1 removal (but with removal of other steroid oestrogens as for activated sludge);
- Ofwat classes SAS, TA1, TA2, TB1 and TB2 are assumed to perform as traditional activated sludge, with existing model steroid oestrogen removal settings but a slightly lower EE2 removal, as discussed above.

Table 4.3 Percentage oestrogen removal (standard error) settings per sewage treatment Ofwat class proposed for Tasks 1.4 and 2.2

Ofwat class	Oestradiol	Oestrone	Ethinyloestradiol
P	0	0	0
SB	83 (+/-8)	30 (+/-15)	83 (+/-6)
SAS, TA1, TA2, TB1, TB2	83 (+/-8)	69 (+/-8)	83 (+/-6)

5 Preliminary analysis

This chapter describes the preliminary analysis that was carried out to test the use of three options or capabilities in the final LF2000-WQX model for producing the steroid oestrogen risk maps. These options were:

- to compare two risk categorisation schemes based on the principles of concentration addition (see Chapter 3);
- to compare the effects of using a lower E1 removal efficiency for secondary biological filters than for other secondary treatments (see Chapter 4);
- to demonstrate the levels of treatment required for STPs with discharges resulting in an ‘at risk’ classification to achieve a ‘no risk’ classification.

These options were investigated in two contrasting catchments: the River Exe and the River Aire/Calder. Data sets already existed for both these regions, derived from previous work carried out by CEH during the development of the GREAT-ER model. This allowed the task to progress without needing to wait for new data from the water companies.

In the following sections, where an STP is known by two names the Environment Agency’s Water Information Management System (WIMS) record is followed by the water company designation in brackets.

5.1 Brief description of the pilot catchments

5.1.1 The Exe catchment

The Exe catchment is located in Devon and drains an area of 1190km^2 to the tidal limit at UK national grid reference (NGR) SX917920. It is a fairly rural catchment with mixed agricultural land use dominated by grassland. The geology comprises mainly sandstones. The population density of the catchment is approximately 140 inhabitants per km^2, which reflects the low level of urbanisation of this catchment. The estimated annual mean flow and Q_{95} flow (flow exceeded 95 per cent of the time) at the tidal limit are 23.5m^{3}s^{-1} and 3.7m^{3}s^{-1} respectively (Holmes *et al.* 2005, Young *et al.* 2003; estimated using the LF2000 software because there is no gauging station at the tidal limit).

Referring to the Environment Agency database of consented discharges across England and Wales, 27 STPs were identified in the catchment. The total consented DWF is 0.21m^{3}s^{-1}. In fact, 95 per cent of the DWF from all of these discharges is contributed by only 17 STPs. A description of these major plants is presented in Table 5.1 and their location is provided in Figure 5.1.

Table 5.1 Major STPs in the Exe catchment

STP name	Population served	DWF ($m^3 s^{-1}$) mean (SD)	Type of plant
Lords Meadow (Yeo)	6929	0.047 (0.012)	TA2
Yeoford	1475	0.005 (0.001)	SB
Tedburn St. Mary	1188	0.002 (0.0004)	TA1
Cheriton Bishop	432	0.002 (0.0004)	TB1
Cullompton	7974	0.017 (0.004)	SB
Uffculme	2086	0.006 (0.002)	SAS
Hemyock	1372	0.005 (0.001)	SAS
Bulescombe	618	0.002 (0.0005)	TB1
Halberton	843	0.002 (0.0005)	SB
Silverton	1516	0.007 (0.002)	SAS
Badninch	1685	0.004 (0.001)	SAS
Dunkeswell	1447	0.002 (0.0004)	SB
Thoverton	596	0.002 (0.0006)	SB
Tiverton	17282	0.08 (0.02)	SB
Bampton	1170	0.002 (0.0006)	SB

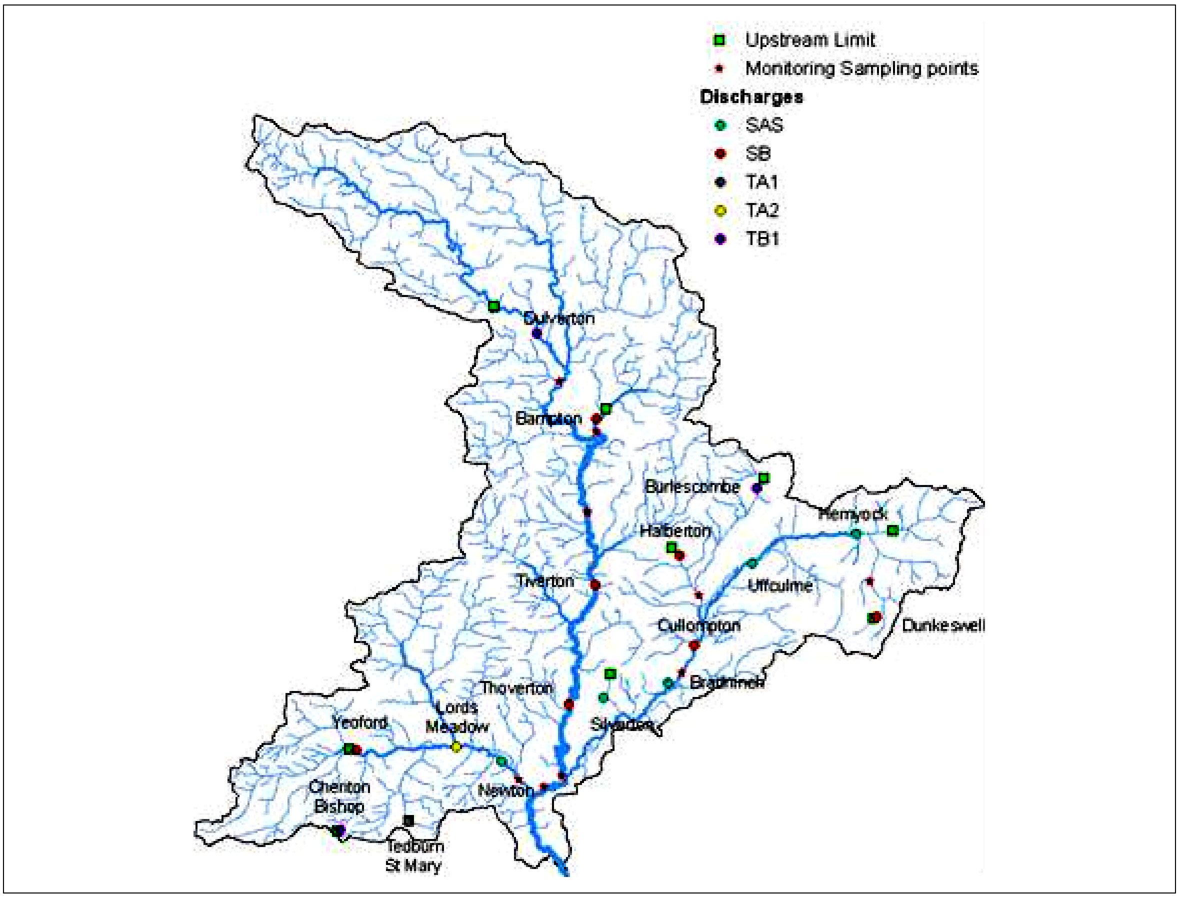

Figure 5.1 Network configuration of the Exe catchment model selected for preliminary modelling

5.1.2 The Aire and Calder catchment

The catchment drained by the rivers Aire and Calder (West Yorkshire) covers an area of approximately 1960km^2 at its tidal limit (Beal Weir). The catchment geology is dominated by Carboniferous limestone and millstone grit in the headwaters (Marsh and Lees 2003). The catchment is fairly densely populated (approximately 925 inhabitants per km^2) and incorporates many industrialised urban areas including the cities of Leeds and Bradford. Average annual flow at Beal Weir (close to the tidal limit) is 35.72m^3s^{-1} and the annual average Q_{95} flow is 8.9 m^3s^{-1} (Marsh and Lees 2003).

There are 50 STPs in the catchment for which DWF data are reported in the database of consented discharges. The total consented DWF for these plants is about 9m^3s^{-1}, with 95 per cent of the DWF from all these discharges contributed by just 20 STPs. A description of these major plants is presented in Table 5.2 and their location is provided in Figure 5.2.

Table 5.2 Major STPs in the Aire and Calder catchment

STP name	Population served	DWF (m^3s^{-1}) mean (SD)	Type of plant
Brighouse	48116	0.23 (0.058)	SAS
Byram Park (Sutton)	43526	0.13 (0.032)	SB
Caldervale (Wakefield)	94134	0.37 (0.092)	SAS
Castleford (Wheldale)	27928	0.10 (0.024)	SB
Dowley Gap (Bingley)	34650	0.14 (0.034)	SB
Esholt (Bradford)	315758	1.50 (0.376)	TB2
Halifax	115808	0.67[1] (0.167)	TA1
Huddersfield (Cooper Bridge)	174999	0.97 (0.243)	TB2
Knopstrop High Level	320359	1.15 (0.287)[1]	SB
Knopstrop Low Level	232490	1.28 (0.320)[1]	SAS
Lemonroyd (Rothwell)	28900	0.09 (0.022)	TA1
Marley (Keighley)	79846	0.27 (0.068)	SB
Mitchell Laithes (Dewsbury)	158765	0.67 (0.168)	SB
Neiley	17870	0.09 (0.022)	TB2
Normanton (Mill Lane)	38151	0.12 (0.029)	SB
North Bierley	37703	0.38 (0.096)	TB2
Owlwood (Garforth)	34999	0.10 (0.025)	TA1
Smalley Bight	18433	0.07 (0.017)	SAS
Spenborough	38165	0.38 (0.095)	SB
Todmorden (Eastwood)	14133	0.12 (0.030)	SB

Notes: 1. Data missing from the water company dataset and the WIMS is therefore taken from GREAT-ER dataset.

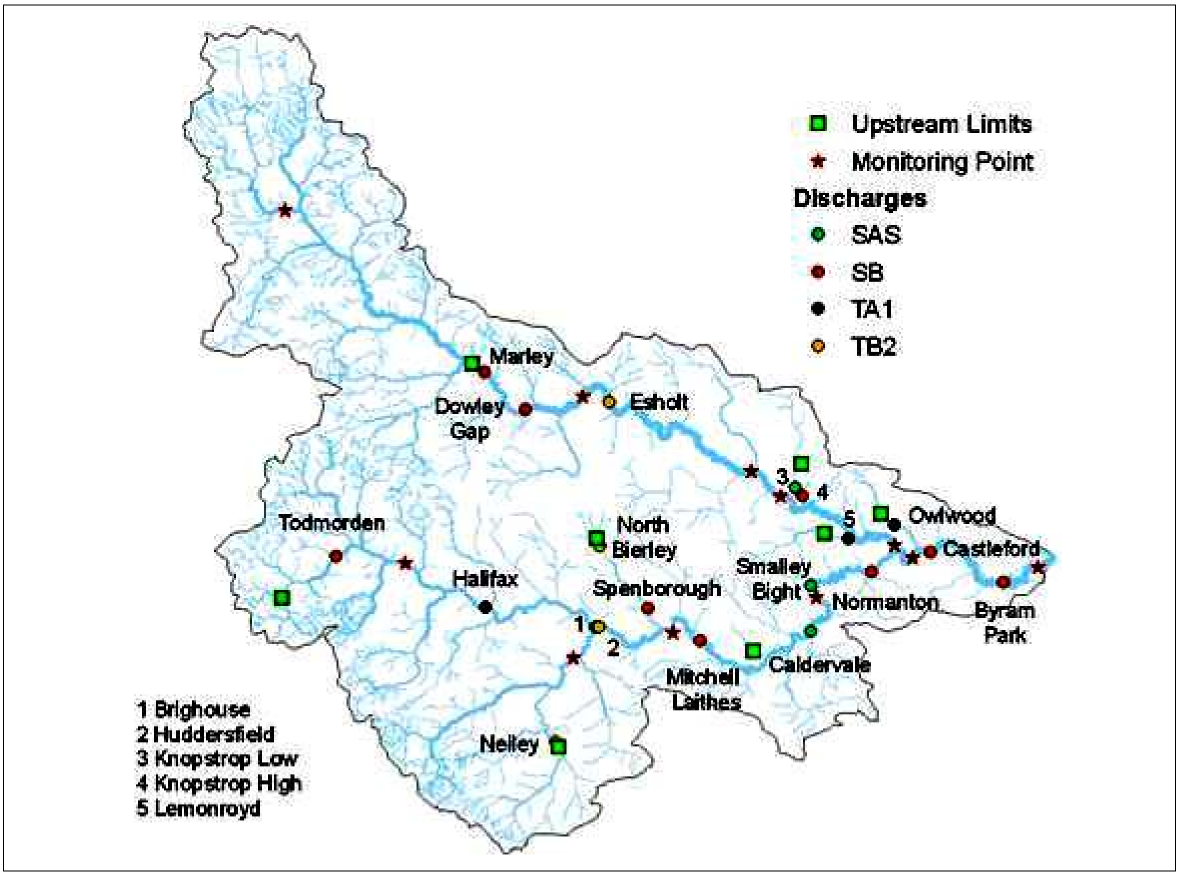

Figure 5.2 Network configuration of the Aire and Calder catchment model selected for preliminary modelling

5.2 Simulation of selected GQA water quality variables and flow rate

Flow rate and GQA determinands were simulated within each of these catchments in order to demonstrate that the model configuration adequately accounts for river flows and significant discharges. Three GQA determinands were selected for modelling: chloride, BOD and orthophosphate (ortho-P). These were chosen because it was expected that their concentrations would be primarily influenced by STP effluent concentrations (although both ortho-P and BOD can also have a significant diffuse agricultural source). In this initial assessment, all the GQA determinands were modelled as conservative and no calibration was attempted (the aim of this simulation was not to model GQA parameters for their own sake, but as a check that the model was configured appropriately). The results of the simulation are summarised here and the full report is given in Appendix B.

The simulations were found to be acceptable, and sufficient to provide confidence that the LF2000-WQX model was appropriately configured to allow the simulations of the steroid oestrogens to proceed. Flow simulations in the Exe were excellent when compared to observed data. Across the five gauging stations in the catchment the modelled flows were within -8 per cent to + 4 per cent of the observed data. The average percentage errors for BOD and ortho-P mean concentrations were -9 per cent and -2 per cent (SD = 19 per cent and 33 per cent) respectively (there were no observed chloride data available).

Flow simulations for the Aire/Calder were also good, although three of the smaller tributaries were simulated poorly. Across the remaining 14 gauging stations in the catchment the modelled flows were within +21 per cent to -5 per cent of the observed data. The percentage error in predictions of BOD, ortho-P and chloride mean concentrations were +4 per cent, -1 per cent and +23 per cent (SD = 19 per cent, -6 per cent and 17 per cent) respectively.

5.3 Prediction of steroid oestrogen concentrations

5.3.1 Comparison of risk thresholds and variable STP removal rates

These two tests were conducted together. This was because variable STP removal rates affect the simulated concentrations and the risk thresholds affect how these concentrations are converted to risk class.

Two different scenarios within each catchment were designed to investigate the impact of variable STP removal rates on oestrogen concentrations and the subsequent associated risks. The scenarios were realised on the same river network structure as used to simulate the GQA determinands (see above). The same chemical properties and influent loads were used for both catchments within both scenarios and these inputs are detailed in Table 5.3. All distributions characterising the oestrogens (properties, removal rates and concentrations) were defined as normal.

Table 5.3 Oestrogen properties including influent load used in the model

Parameter description	Oestrone	Oestradiol	Ethinyloestradiol
Degradation rate (day^{-1})	0.25[1]	0.30[1]	0.04[1]
Change of degradation rate with temperature	1.078[1]	1.075[1]	1.08[3]
Correlation with flow	0 [3]	0[3]	0[3]
Runoff quality	0	0	0
Minimum river quality	0	0	0
Parent to metabolite stochiometry	1[1], conversion to E1	0[4]	0[4]
Influent load mean[5] μg/person/day	3.3[2]	13.8[2]	0.89[2]
Influent load SD	0.3[2]	2[2]	0.01[2]
Degradation rate (day^{-1})	0.25[1]	0.30[1]	0.04[1]
Change of degradation rate with temperature	1.078 [1]	1.075[1]	1.08[3]
Correlation with flow	0[3]	0[3]	0[3]

Notes:
1. Value calculated from Jurgens *et al.* (2002).
2. Value available from Johnson and Williams (2004).
3. No data available and so an arbitrary value was assigned.
4. No metabolite modelled.
5. Converted to an effluent load within the LF2000WQX software.

The two differing STP oestrogen removal scenarios applied to each catchment are hereafter referred to as scenarios A and B. In scenario A, all treatment plant types (with the exception of primary treatment) have the same steroid removal efficiencies (simple trickling filter plants have the same removal rate for E1 as other types of STP). In scenario B, the removal rates used were those developed within Task 1.4, which specified a lower E1 removal rate for BFPs following an update of the literature review of Johnson and Williams (2004). The removal rates used are given in Table 5.4.

Table 5.4 Oestrogen percentage removal rates (mean with standard deviation in brackets) per Ofwat sewage treatment class (Appendix A) for scenarios A and B

Scenario	Ofwat class	Oestradiol	Oestrone	Ethinyloestradiol
A	P	0	0	0
	SB	83 (11.8)	69 (12.7)	83 (8.5)
	SAS, TA1, TA2, TB1, TB2	83 (11.8)	69 (12.7)	83 (8.5)
B	P	0	0	0
	SB	83 (11.8)	30 (31)	83 (8.5)
	SAS, TA1, TA2, TB1, TB2	83 (11.8)	69 (12.7)	83 (8.5)

The two investigated risk thresholds were developed in Chapter 4 (see Tables 4.5 and 4.6). Both risk assessments use the Environment Agency's steroid oestrogen PNECs for the lower threshold (discriminating 'no risk' sites from 'at risk' sites) and use steroid effect concentrations with population effect relevance for the upper thresholds (indicating the 'high risk' sites). The first approach uses a LOEC based on 100 per cent feminisation of male fish for the upper threshold, whereas the second approach uses a more stringent upper threshold based on a LOEC with end-points involving reduced fertilisation success.

The risk categories are defined by combining the concentrations of the three steroids according to their relative potency using the principle of concentration addition (see Task 1.6 for details). For 'no risk', the sum of the concentrations of each steroid divided by its PNEC must be less than one. This means that the mixture has an effect that is less than any one of the steroids at its PNEC and would therefore not be expected to present a risk. For a reach to be categorised as 'at risk' this calculation must give a value greater than one. If this value is very large then the reach could enter the 'high risk' category. How large this value needs to be to become 'high risk' differs between the approaches, because the LOEC for EE2 also differs ($3ngL^{-1}$ in the first approach and $1ngL^{-1}$ in the second approach). Thus, to determine if the concentrations would be 'high risk', the individual steroid concentrations divided by the relevant LOEC are summed and if this value is greater than one then the reach is designated as 'high risk'.

Results and discussion

For the Exe catchment, the predicted concentrations (mean, standard deviation and 90th percentile) for E1, E2 and EE2 in the river reaches immediately downstream of each STP are presented in Appendix C (Table C.1 and Table C.2).

Scenario B gives the same results as scenario A for E2 and EE2, but leads to considerably higher E1 concentrations in various parts of the catchment. These differences are seen in reaches located downstream of plants with secondary biological filters (SB class). For these river reaches, E1 concentrations in scenario B are twice as high as in scenarios A, reflecting the change in E1 removal rates for this type of treatment.

The associated risk levels in the Exe catchment for Scenarios A and B are also presented in Appendix C (Table C.3 and Table C.4) for those reaches immediately downstream of STPs. In scenarios A and B, the risk categories were established using both methods for the mean and 90th percentile (P_{90}; concentration exceeded only 10% of the time) steroid concentrations. The model also gives a representation of the spatial distribution of the risk across the catchment. As an illustrative example, the risk levels obtained for both scenarios using mean concentrations are shown in Figures 5.3 and 5.4. No sites are categorised as ‘high risk’ in either scenario using either of the upper threshold calculations.

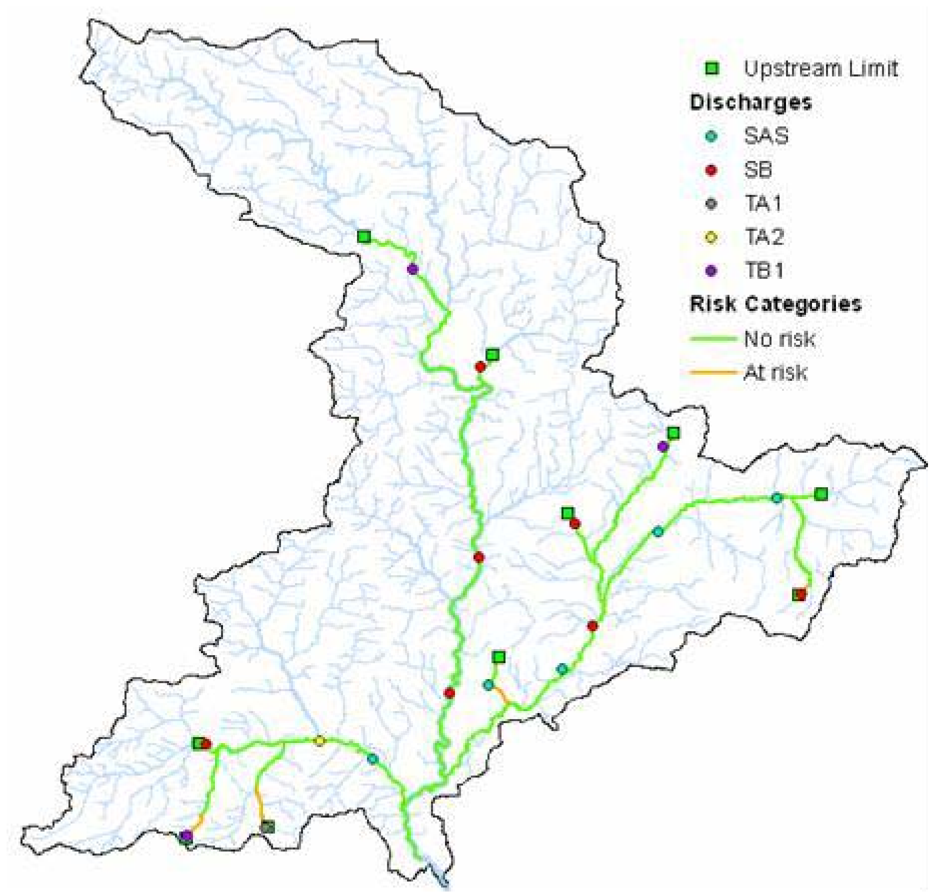

Figure 5.3 Spatial distribution of risk categories in the Exe catchment using scenario A

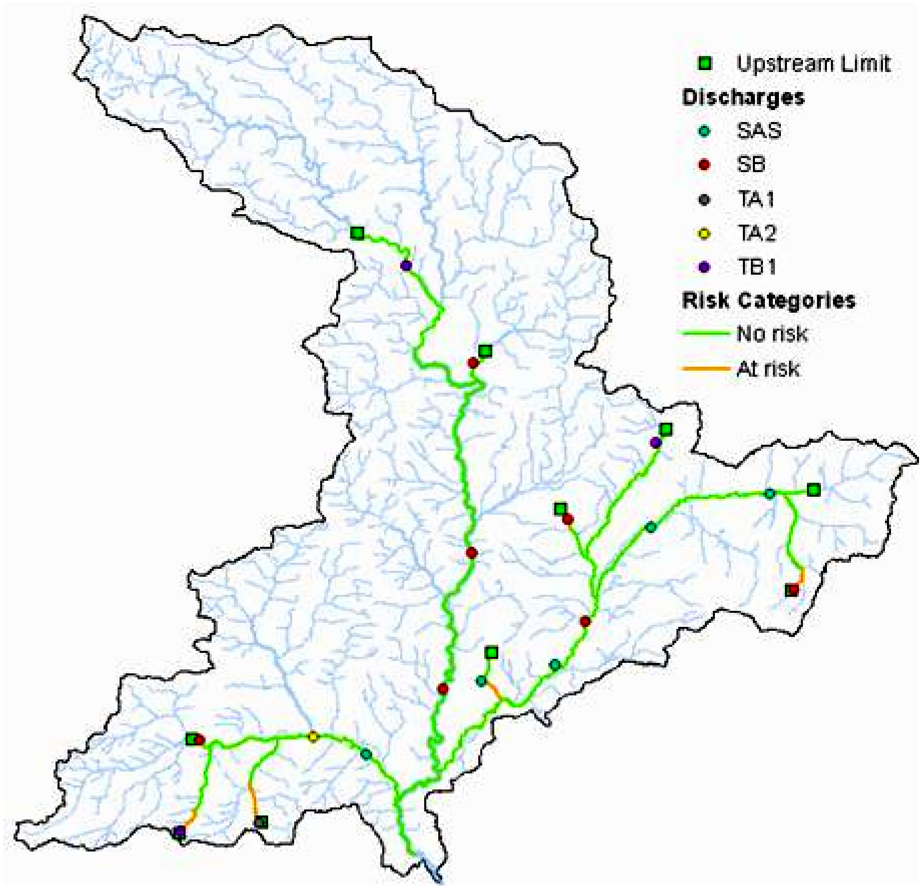

Figure 5.4 Spatial distribution of risk categories in the Exe catchment using scenario B

The choice of threshold specification does not alter the spatial distribution of at risk reaches in the Exe catchment for either of the scenarios under mean concentrations. Between scenarios, there is only one reach immediately downstream of a STP that changes risk class: Halberton STP moves up from 'no risk' to 'at risk' in scenario B. Halberton is a BFP located in the headwaters of one of the tributaries of the Exe (Figure 5.1). At Dunkeswell, which is another SB class plant located high in the headwaters, the 'at risk' category persists downstream for one further river reach in scenario B (Figure 5.3). The total length of the river that is at risk increases from 6.6km to 7.7km (out of a total modelled length of 120km) between scenarios A and B.

The risk classifications based on the P_{90} concentration give rise to more at risk reaches than for the mean concentration if the more stringent threshold is used. For Scenario A, two additional sites fall into the 'at risk' category and one 'at risk' site is re-categorised as 'high risk'. For scenario B, one additional site falls into the 'at risk' category and an 'at risk' site is re-categorised as 'high risk'.

For the Aire/Calder catchment, the predicted concentrations (mean, standard deviation, and P_{90}) for E1, E2 and EE2 in the river reaches immediately downstream of STPs are presented in Appendix C (Table C.5 and Table C.6). Scenario B results in higher E1 concentrations immediately downstream of plants with secondary biological filters than scenario A by a factor of two, reflecting the change in removal rates for this type of treatment.

The associated risk levels in the Aire and Calder catchment are also presented in Appendix C for those reaches immediately downstream of STPs for scenarios A and B respectively (Tables C.7 and C.8). In scenarios A and B, the risk categories were established using both methods for the mean and P_{90} steroid concentrations. When P_{90} concentrations are used all modelled river reaches are categorised as either ‘at risk’ or ‘high risk’. Even when using mean flows, approximately 88km of the 141km reaches modelled downstream of STPs are categorised as ‘at risk’. Maps of the spatial distribution of risk in the Aire and Calder catchment obtained with both scenarios under mean concentrations and derived from the more stringent thresholds are shown in Figures 5.5 and 5.6.

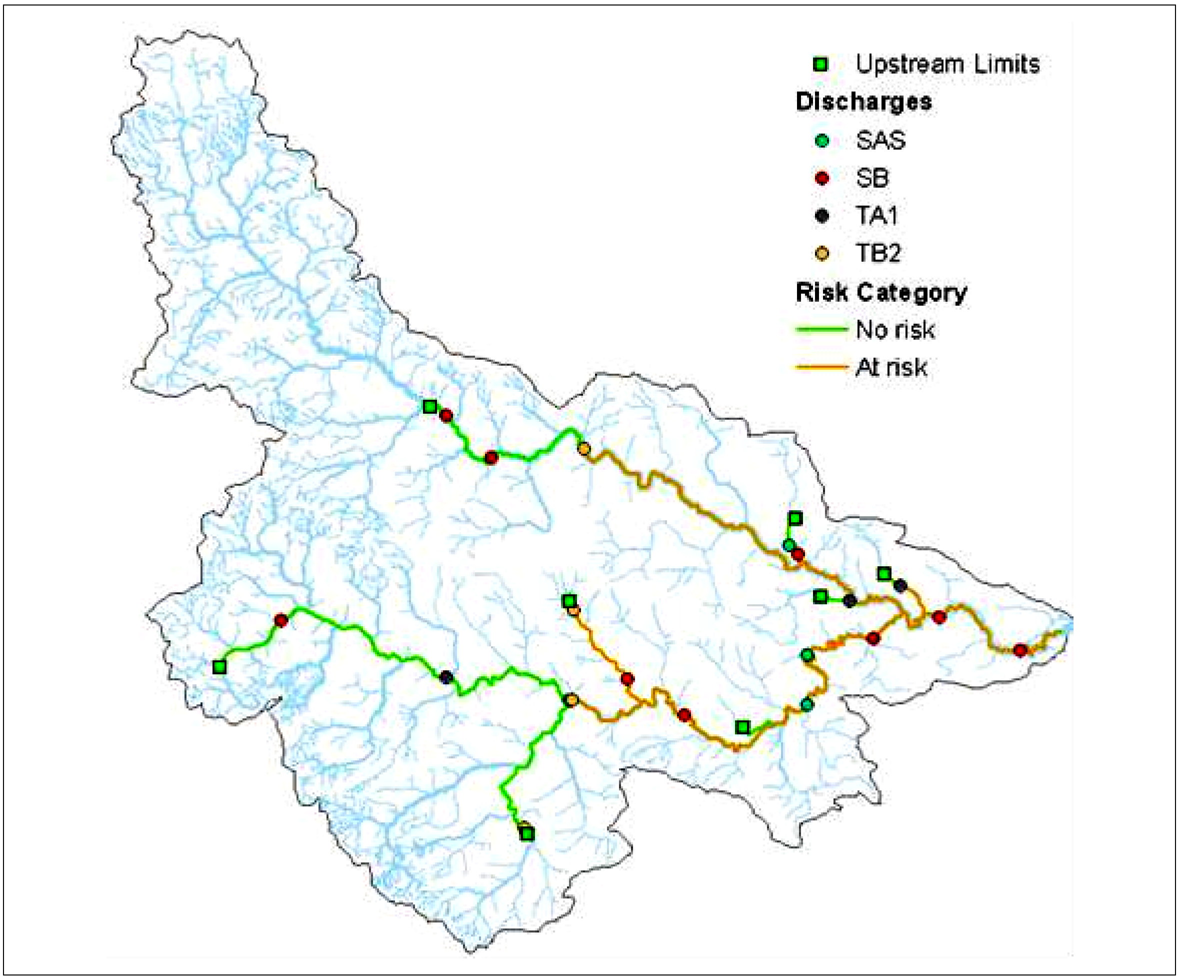

Figure 5.5 Risk assessment in the Aire and Calder catchment using scenario A

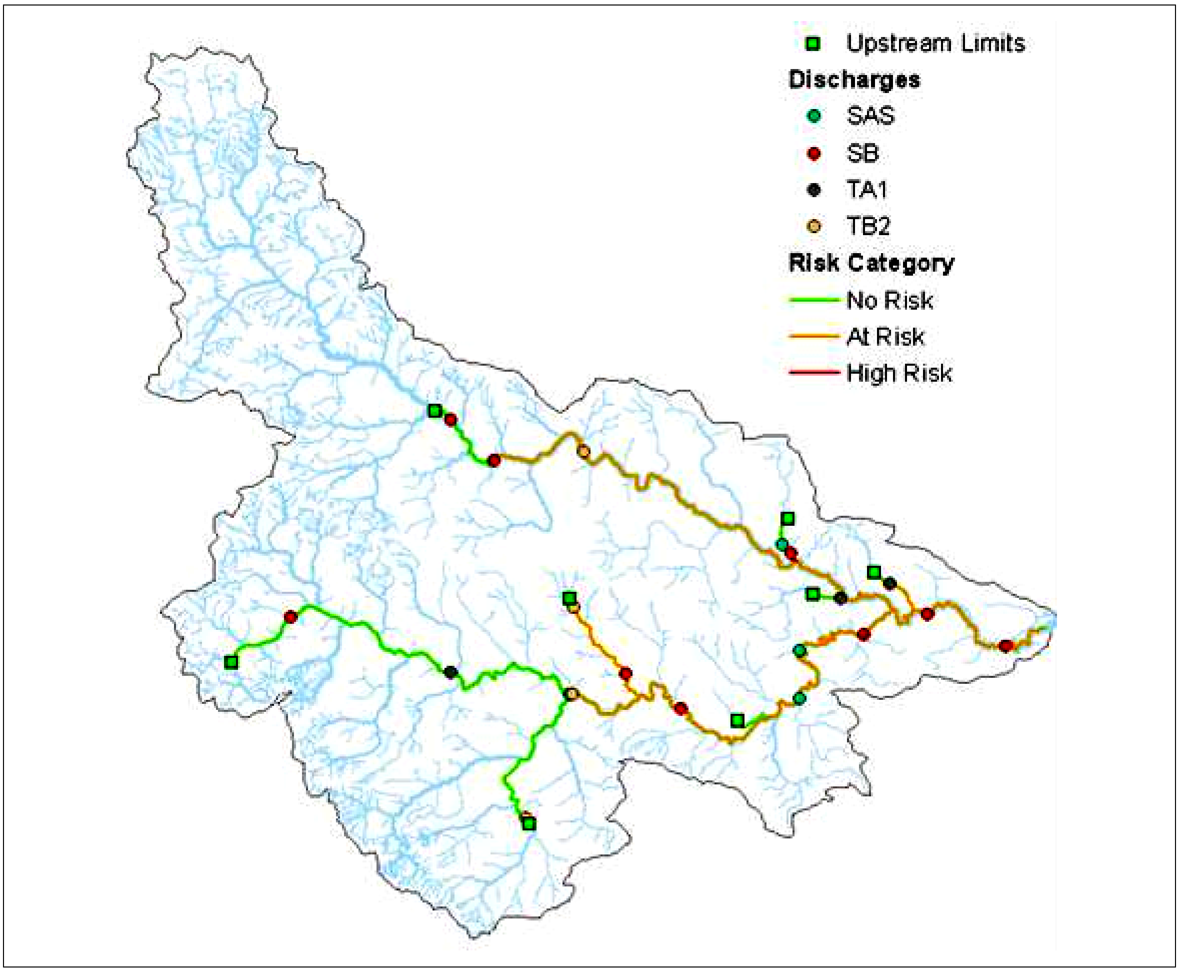

Figure 5.6 Risk assessment in the Aire and Calder catchment using scenario B with high risk sites designated by reduced fertility end-points

Although different removal rates (between scenarios A and B) have significant consequences on E1 concentrations downstream of SB class plants, these changes do not impact greatly on the spatial distribution of risks within the Aire and Calder catchment. The length of the river network categorised as 'at risk' only increases from approximately 81km to 88km. This is because of the balance of STP types within the catchment: only nine of the plants are biological filters. For scenario B, the river reach downstream of Dowley Gap (SB class plant on the upper Aire downstream of Marley STP; see Figure 5.2) moves from 'no risk' to 'at risk' under mean concentrations.

The choice of threshold specification only alters the spatial distribution of risk categories in the case of scenario B for this catchment: the river reach immediately downstream of the Knopstrop High level is moved to 'high risk' when applying the more stringent threshold (the changes described above for Knostrop High STP cannot be seen on Figure 5.5 because the reach involved is very short).

Summary

River Exe

- No ‘high risk’ sites are predicted by any of the tested scenarios under mean concentrations. There is one ‘high risk’ reach downstream of Cheriton Bishop under P_{90} concentrations.
- Changing the removal rate of E1 for SB plants (scenario B) has a significant effect on E1 concentrations, but only has an affect on risk classes in those reaches close to the plant (a 1.1km change in the length of river categorised as ‘at risk’).
- The choice of threshold setting only made a difference to the risk classification for one site (downstream of Cheriton Bishop) using P_{90} concentrations.

River Aire and Calder

- Using P_{90} concentrations, the whole catchment is ‘at risk’ (or ‘high risk’). Even using mean flows, much of the catchment (approximately 88km out of 141km modelled) would be predicted to be ‘at risk’.
- No ‘high risk’ sites are predicted with either E1 removal scenario using an upper threshold based on 100 per cent feminisation of male fish. Using a more stringent threshold for ‘high risk’ (based on reduced fertilisation success) results in just one reach moving into this category.
- Changing the removal rate of E1 in SB class plants (scenario B) has a significant effect on E1 concentrations, but only has an affect on risk classes in those reaches close to one of the STPs (an additional 7km of river becomes ‘at risk’).

5.3.2 Estimating the STP efficacy required to reduce the risk.

When a risk mapping exercise indicates that river reaches downstream of STPs are ‘at risk’ or ‘high risk’, there may be a need to improve treatment. This exercise took the risk maps generated in the previous sections for Scenario B under mean concentrations and estimated what new removal percentages would be required at the plants to reduce ‘at risk’ reaches to ‘no risk’ reaches.

The risk categories for each reach are calculated using the relationships set out in Table 4.5. Mean concentrations of the three steroids must be reduced to a level where equation 1 is satisfied for a reach to be reduced from the ‘at risk’ category to the ‘no risk’ category.

$$\frac{[\boldsymbol{EE}2]}{0.1}+\frac{[\boldsymbol{E}2]}{1}+\frac{[\boldsymbol{EE}2]}{3}<1 \qquad \text{Equation 1}$$

River Exe

In the river Exe, only five STPs caused the down stream river reach to be classified as ‘at risk’: 7.7km of river out of a total modelled length of 120km. Table 5.5 shows the names of the plants, the original removal percentages and the values of the mean concentrations in the downstream reach resulting from this level of removal.

Table 5.5 STPs that give rise to 'at risk' river reaches and the predicted mean concentration of oestrogens in those reaches

		% Removal (SD)			Mean concentration (ngL^{-1})			
STP name	**Type**	**EE2**	**E2**	**E1**	**EE2**	**E2**	**E1**	**E2 eqv**
Cheriton Bishop	TB1	83 (8.5)	83 (11.8)	69 (12.7)	0.22	0.84	6.58	5.26
Silverton	SAS	83 (8.5)	83 (11.8)	69 (12.7)	0.06	0.22	1.82	1.43
Halberton	SB	83 (8.5)	83 (11.8)	30 (31)	0.04	0.13	2.32	1.28
Tedburn St. Mary	TA1	83 (8.5)	83 (11.8)	69 (12.7)	0.10	0.36	2.81	2.29
Dunkeswell	SB	83 (8.5)	83 (11.8)	30 (31)	0.07	0.27	4.49	2.51

To estimate the amount of removal required to achieve a value of around $1ngL^{-1}$ E2 equivalent in those reaches specified in Table 5.5 is straightforward for the River Exe. This is because all the STPs are located in the headwaters and there are no other discharges above any of the plants. The estimation approach used in the model allocates the amount of improvement proportionally across all three steroid oestrogens, although there is an option for targeting a particular steroid oestrogen if the technology is available. Table 5.6 shows the new values calculated by this approach and the resulting E2 equivalent values for each STP. Since it is likely that improving the removal efficiency of a plant will lead to a decrease in the variation of steroid oestrogen concentrations, the standard deviations were arbitrarily set to be half of the difference between the removal required and 100 per cent removal.

Table 5.6 Percentage removals required at target STPs for all reaches in the Exe catchment to be at 'no risk' from oestrogens

STP name	**Type**	% Removal (SD)			Mean concentration (ngL^{-1})			
		EE2	**E2**	**E1**	**EE2**	**E2**	**E1**	**E2 eqv**
Cheriton Bishop	TB1	97 (1.5)	97 (1.5)	95 (2.5)	0.04	0.15	1.04	0.88
Silverton	SAS	89 (5.5)	89 (5.5)	80 (10)	0.04	0.13	1.15	0.90
Halberton	SB	88 (6.0)	88 (6.0)	50 (25)	0.03	0.09	1.72	0.92
Tedburn St. Mary	TA1	93 (3.5)	93 (3.5)	88 (6)	0.04	0.14	1.09	0.91
Dunkeswell	SB	94 (3)	94 (3)	75 (12.5)	0.03	0.09	1.67	0.90

Three of the plants require percentage removals to be improved to around 95 per cent for both E2 and EE2 in order to ensure that all downstream reaches fall into the 'no risk' category. This is because the initial 'at risk' rating was essentially caused by a lack of dilution and the effluents therefore need to be of high quality to avoid this rating. The percentage removal of E1 needs to be increased the most, because the model currently assumes this to be the least well removed steroid oestrogen.

As an additional modelling exercise, the effect of removing all the EE2 (the most potent steroid oestrogen) from the STP effluent while maintaining the default removal efficiencies for E2 and E1 was examined. Table 5.7 shows that two of the STPs in the Exe catchment are no longer predicted to pose a risk. In the other three STPs, the E2 equivalent concentration is reduced considerably (by around 40 per cent) and the moderate amount of improvement required in treatment to remove E1 and E2 can clearly be seen (Table 5.7).

Table 5.7 Predicted mean oestrogen concentrations below STPs that give rise to 'at risk' river reaches when EE2 is completely removed from STP effluents

		% Removal (SD)			Mean concentration (ngL^{-1})			
STP name	**Type**	**EE2**	**E2**	**E1**	**EE2**	**E2**	**E1**	**E2 eqv**
Cheriton Bishop	TB1	100	83 (11.8)	69 (12.7)	0.00	0.86	6.49	3.02
Silverton	SAS	100	83 (11.8)	69 (12.7)	0.00	0.22	1.81	0.82
Halberton	SB	100	83 (11.8)	30 (31)	0.00	0.14	2.31	0.91
Tedburn St. Mary	TA1	100	83 (11.8)	69 (12.7)	0.00	0.36	2.85	1.31
Dunkeswell	SB	100	83 (11.8)	30 (31)	0.00	0.42	3.32	1.53

River Aire/Calder

There were 15 STPs within the catchment that gave rise to 'at risk' status downstream of their discharges (Table 5.8). Because these STPs were nested (some were downstream of others), a stepwise approach was required to assess the improvement in performance required to reclassify all river reaches to 'no risk'. Figure 5.7 shows the sequence in which the STPs were assessed. The process was one of trial and error, in which an initial estimate was made for the required removal using the process outlined above and then the model was run. The results of the model were assessed for risk and if the target was not achieved another larger estimate was made and then the model was re-run. This process was repeated until the reach downstream of each of the plants assessed was categorised as not 'at risk'. Each step in the process was completed in at most four model runs. The results are shown in Table 5.9.

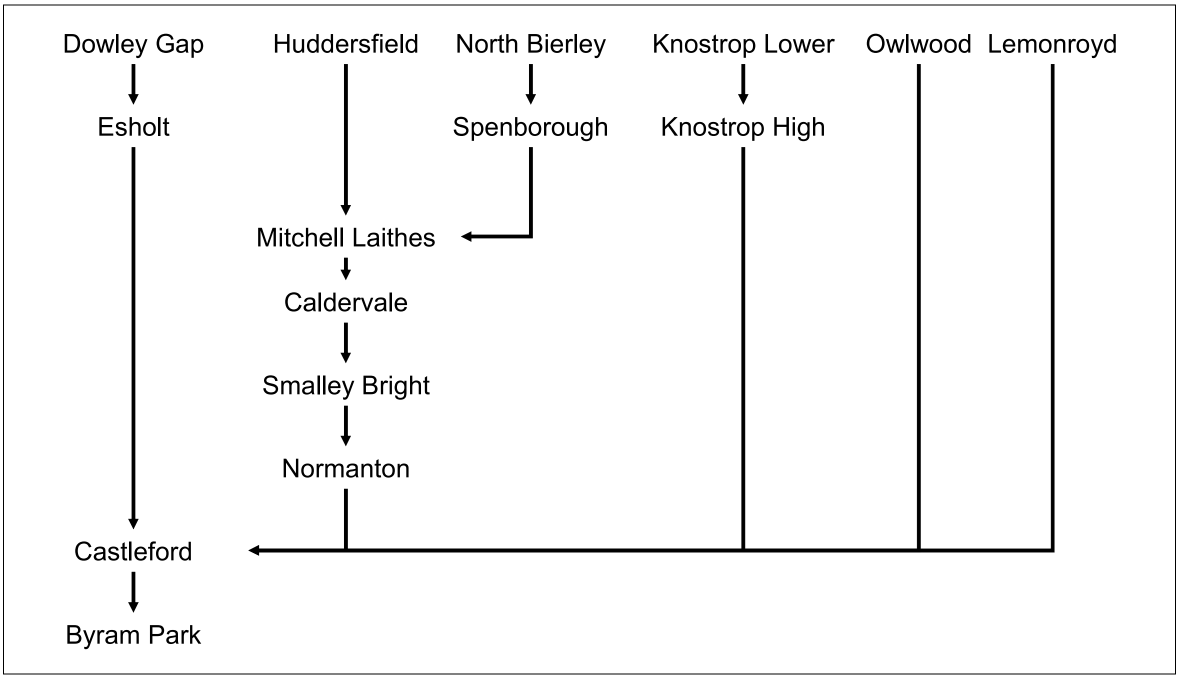

Figure 5.7 Sequence in which each of the STPs in the Aire/Calder catchment were assessed in order to achieve 'no risk' in the downstream reach

STPs on the same level were assessed at the same time.

Table 5.8 STPs that give rise to ‘at risk’ river reaches in the Aire/Calder and the predicted mean concentration of oestrogens in those reaches

		% Removal (SD)			Mean concentration (ngL^{-1})			
STP name[1]	**Type**	**EE2**	**E2**	**E1**	**EE2**	**E2**	**E1**	**E2 eqv**
Dowley Gap	SB	83 (8.5)	83 (11.8)	30 (31)	0.03	0.11	1.89	1.06
Esholt	TB2	83 (8.5)	83 (11.8)	69 (12.7)	0.09	0.30	3.00	2.16
Castleford	SB	83 (8.5)	83 (11.8)	30 (31)	0.11	0.39	4.22	2.93
Byram Park	SB	83 (8.5)	83 (11.8)	30 (31)	0.12	0.39	4.29	2.97
Huddersfield	TB2	83 (8.5)	83 (11.8)	69 (12.7)	0.06	0.21	1.64	1.32
Mitchell Laithes	SB	83 (8.5)	83 (11.8)	30 (31)	0.08	0.28	2.98	2.05
Caldervale	SAS	83 (8.5)	83 (11.8)	69 (12.7)	0.08	0.29	3.03	2.14
Smalley Bight	SAS	83 (8.5)	83 (11.8)	69 (12.7)	0.08	0.29	2.96	2.13
Normanton	SB	83 (8.5)	83 (11.8)	30 (31)	0.09	0.30	3.18	2.24
North Bierley	TB2	83 (8.5)	83 (11.8)	69 (12.7)	0.22	0.83	6.14	5.12
Spenborough	SB	83 (8.5)	83 (11.8)	30 (31)	0.22	0.77	9.43	6.09
Knostrop Low Level	SAS	83 (8.5)	83 (11.8)	69 (12.7)	0.30	1.15	8.45	6.99
Knostrop High Level	SB	83 (8.5)	83 (11.8)	30 (31)	0.42	1.58	19.65	12.30
Owlwood	TA1	83 (8.5)	83 (11.8)	69 (12.7)	0.36	1.34	10.00	8.30
Lemonroyd	TA1	83 (8.5)	83 (11.8)	69 (12.7)	0.22	0.80	6.01	5.01

Notes: 1. STPs are indented to the right to indicate their relative position down the catchment.

Table 5.9 Percentage removals required at target STPs for all reaches in the Aire/Calder catchment to be at ‘no risk’ from steroid oestrogens

		% Removal (SD)			Mean concentration (ngL^{-1})			
STP name[1]	**Type**	**EE2**	**E2**	**E1**	**EE2**	**E2**	**E1**	**E2 eqv**
Dowley Gap	SB	88 (6)	88 (6)	60 (20)	0.03	0.10	1.63	0.93
Esholt	TB2	97 (1.5)	97 (1.5)	92 (4)	0.03	0.11	1.54	0.94
Castleford	SB	96 (2)	96 (2)	85 (7.5)	0.04	0.12	1.20	0.88
Byram Park	SB	85 (7.5)	85 (7)	60 (20)	0.04	0.13	1.27	0.93
Huddersfield	TB2	94 (3)	94 (3)	88 (6)	0.04	0.14	1.17	0.92
Mitchell Laithes	SB	95 (2.5)	95 (2.5)	86 (0.6)	0.04	0.14	1.23	0.96
Caldervale	SAS	96 (2)	96 (2)	94 (3)	0.04	0.14	1.19	0.94
Smalley Bight	SAS	86 (7)	86 (7)	75 (12.5)	0.04	0.14	1.19	0.95
Normanton	SB	95 (2.5)	95 (2.5)	85 (12.5)	0.04	0.14	1.24	0.98
North Bierley	TB2	97 (1.5)	97 (1.5)	94 (3)	0.04	0.14	1.19	0.93
Spenborough	SB	96 (2)	96 (2)	90 (5)	0.03	0.11	1.51	0.92
Knostrop Low Level	SAS	98 (1)	98 (1)	96 (2)	0.04	0.13	1.12	0.87
Knostrop High Level	SB	99 (0.5)	99 (0.5)	98 (1)	0.04	0.13	1.08	0.84
Owlwood	TA1	98 (1)	98 (1)	97 (1.5)	0.04	0.15	0.96	0.89
Lemonroyd	TA1	97 (1.5)	97 (1.5)	94 (3)	0.04	0.14	1.15	0.90

Notes: 1. STPs are indented to the right to indicate their relative position down the catchment.

It can be seen that in the River Aire/Calder catchment STPs that originally had E2 equivalent loads below $3ngL^{-1}$ would require similar removal improvements to those described for the Exe catchment. Where these loads are above $5ngL^{-1}$, however, steroid removal would need to be improved to near 99 per cent for E2 and EE2 and 90 per cent for E1. This approach did not consider the possibility of improving already conforming STPs in order to reduce the task of its downstream neighbours. But it is probable that making modifications to two STPs would be more expensive than modifying one STP, even if the required improvement was more demanding.

The effect of completely removing EE2 from STP effluents was also investigated for the River Aire/Calder (Table 5.10). The results again showed that two STPs should no longer present a risk and that reaches downstream of the remaining STPs had much reduced E2 equivalent concentrations.

Table 5.10 Predicted mean steroid oestrogen concentrations below STPs that give rise to 'at risk' river reaches when EE2 is completely removed from STP effluents

		% Removal (SD)			Mean concentration (ngL^{-1})			
STP name[1]	**Type**	**EE2**	**E2**	**E1**	**EE2**	**E2**	**E1**	**E2 eqv**
Dowley Gap	SB	100	83 (11.8)	30 (31)	0.00	0.11	1.86	0.73
Esholt	TB2	100	83 (11.8)	69 (12.7)	0.00	0.31	2.97	1.30
Castleford	SB	100	83 (11.8)	30 (31)	0.00	0.39	4.19	1.79
Byram Park	SB	100	83 (11.8)	30 (31)	0.00	0.39	4.26	1.81
Huddersfield	TB2	100	83 (11.8)	69 (12.7)	0.00	0.21	1.60	0.74
Mitchell Laithes	SB	100	83 (11.8)	30 (31)	0.00	0.28	2.94	1.26
Caldervale	SAS	100	83 (11.8)	69 (12.7)	0.00	0.29	2.98	1.29
Smalley Bight	SAS	100	83 (11.8)	69 (12.7)	0.00	0.29	2.92	1.27
Normanton	SB	100	83 (11.8)	30 (31)	0.00	0.30	3.13	1.35
North Bierley	TB2	100	83 (11.8)	69 (12.7)	0.00	0.84	6.25	2.92
Spenborough	SB	100	83 (11.8)	30 (31)	0.00	0.78	9.40	3.92
Knostrop Low Level	SAS	100	83 (11.8)	69 (12.7)	0.00	1.16	8.47	3.98
Knostrop High Level	SB	100	83 (11.8)	30 (31)	0.00	1.59	19.75	8.17
Owlwood	TA1	100	83 (11.8)	69 (12.7)	0.00	1.32	9.95	4.63
Lemonroyd	TA1	100	83 (11.8)	69 (12.7)	0.00	0.80	5.89	2.77

Notes: 1. STPs are indented to the right to indicate their relative position down the catchment.

Discussion

In the Exe catchment, considerable additional removal would need to be made at Cheriton Bishop STP because, although it is small (PE = 432), the effluent from it makes up around 47 per cent of the mean stream flow.

In the Aire and Calder catchment, consistently high removal efficiencies are required (Table 5.6). There are two main reasons for this.

- Some STP effluents account for a very large percentage of the mean flow and there is therefore little dilution of the effluents; for example, between them Knostrop Low and Knostrop High make up around 80 per cent of the mean flow.
- The majority of the STPs are located downstream of other STPs and therefore the upstream steroid concentrations are already elevated before the downstream STP effluent joins the river. Thus, even small discharges can elevate the river concentration above the target value; for example, Caldervale (effluent flow is 2 per cent of mean river flow) and Mitchell Laithes (4 per cent of mean river flow).

In general, if the aim is to achieve river concentrations of the three oestrogens that do not give rise to 'at risk' conditions in the receiving waters, the level of removal in the sewage treatments plants would need to be increased. The levels of EE2 and E2 removal need to increase from 83 per cent to 90–99 per cent. For E1, levels of removal need to improve from 69 per cent to 75–99 per cent for ASPs and from 30 per cent to 50–99 per cent for BFPs, depending on the degree of dilution available and the loading from upstream STPs.

The concentrations of the individual steroids showed a fairly consistent pattern across the two catchments. The mean concentrations in the effluents from the STPs in the Exe catchment are 0.038ngL^{-1}, 0.12ngL^{-1} and 1.33ngL^{-1} for EE2, E2 and E1 respectively. The corresponding mean values for STP effluents in the Aire/Calder catchment are 0.037ngL^{-1}, 0.13ngL^{-1} and 1.25ngL^{-1}.

These values indicate that, on average and with a fair degree of consistency, E1 contributes around 41 per cent of the oestrogenicity (measured as E2 equivalents), EE2 contributes 45 per cent and E2 only 14 per cent. Of course, the relative amounts of the three steroids in the effluent are determined by the model used for predicting influents (Johnson and Williams 2004) and the removal efficiencies of the STPs. Since the former are fixed on a per capita basis and the latter are similar for different STPs, it follows that a consistent pattern of concentrations will arise when aiming for the same general target concentrations in the river.

5.4 Summary and conclusions

The model has been applied to two contrasting catchments: the rural Exe and the urban/industrial Aire/Calder. The results for the GQA modelling are satisfactory and give confidence that the LF2000-WQX model was set up appropriately for the proof of concept exercises. The steroid simulations showed that, using mean predicted concentrations, the Exe would be expected to be largely at 'no risk' while the majority of the Aire and Calder would be 'at risk', reflecting the differences in the population densities in these catchments. Another notable difference between the catchments is that the 'at risk' sites in the Exe are located in the headwaters whilst those for the Aire are located downstream. This results from the nature of the catchments. The Exe has a low population density, so problems only occur where there is a lack of dilution in the river reaches receiving effluent. For the Aire and Calder, the high population density means that there is a cumulative build-up of oestrogen loads being discharged to the rivers and hence increasing concentrations downstream. In addition, of course, the large population centres are located towards the bottom of the catchment. Nevertheless, the results of the tests carried out for this task were consistent between the catchments.

- Setting the E1 removal efficiency to be lower in BFPs caused E1 concentrations downstream of BFPs to increase by an expected magnitude. However, in both catchments, these concentration changes only had a small effect on the resultant risk maps. Two main factors account for this; firstly, the smaller number, size and location of BFPs in these catchments; and, secondly, that E1 is the least potent of the steroids.

- The risk classification level of only one river reach in either the Exe or the Aire/Calder changed from 'at risk' to 'high risk' when a more stringent upper classification threshold was used. The risk maps produced by these model applications were not very sensitive to the classification scheme. This was because the estimated concentrations of EE2 were generally low and so E2 equivalent concentrations in excess of $10 ngL^{-1}$ were rare, irrespective of whether EE2 was considered to be 10 times or 3.3 times more potent than E2. However, if the concentrations of EE2 in the STP effluents were reduced to zero, although not removing the need for additional treatment at all the STPs, it did reduce the number where additional treatment was required.

- It is clear that the maps identify which STPs give rise to 'at risk' conditions and the length of the river downstream that is affected. It has been shown that a sequential analysis using the model can suggest new removal efficiencies for these STPs, in order to remove 'at risk' reaches from the river network. The model also has the capability of exploring other management options, such as moving STP discharge points or combining STPs. These options may prove useful in catchment management, but they are not within the scope of the current project.

6 Risk assessment for England and Wales

This chapter presents the results of the catchment-based environmental risk assessment of the steroid oestrogen emissions from domestic STPs in England and Wales. The details of the LF2000-WQX model used to generate the steroid oestrogen concentrations are presented in Chapters 2 and 3, and the risk categorisation that was applied to derive the risk assessment maps is presented in Chapter 3. Where data were available, the configuration of each modelled catchment was checked using GQA data prior to the final risk assessment being made in the manner described in Chapter 5. For reasons of precaution, this risk assessment used the reduced oestrone removal efficiency for BFPs and the more stringent threshold based on reduced fertilisation success to define 'high risk'.

6.1 Brief description of the data collation

The risk assessment for England and Wales was conducted region by region: Anglian, Southern, Thames, Wales, Midlands, North East, North West and South West. The characteristics of these regions are presented in Table 6.1.

Table 6.1 Characteristics of England and Wales regions

Region	Mean annual average runoff (mm)	Surface area modelled (km²)	Population density[1] (cap/km^2)	Number of modelled catchments
Anglian	155	24,239	141	65
Southern	350	8,397	164	37
Thames	245	12,110	447	6
Wales	870	17,235	50	84
Midlands	310	13,324	587	2
North East	420	18,283	219	31
North West	760	12,314	392	43
South West	550	16,366	106	89
England and Wales	448	122,268	241	357

Note: 1. Steroid relevant population – the population served by the STPs included in the model divided by the total modeled area.

Implementing the GREAT-ER module in LF2000-WQX for a specified chemical within a catchment requires the following basic data set.

- Digital data describing the STPs, including location, type of primary and secondary treatment, DWF and domestic population served by the plants.
- Digital data describing the reaches in a river network within the basin and the flows within each reach must be defined by mean and Q_{95} flows. The river networks for the data sets are based on a 1:50,000 digital river network digitised by CEH from the Ordnance Survey (OS) Panorama data set and held within the Low Flows 2000 model. The river flows derived for the reaches are those predicted by the

model. For each reach, mean flow and Q_{95} flow were extracted for the upstream and downstream ends of the reach and held as attributes of the reach.

- Digital data describing chemical characteristics, including type of chemical (conservative/degradable), degradation rate and parent to metabolite stochiometry (if applicable), and background and minimum concentrations. In the absence of measured data, per capita influent load and the removal fraction for sewage treatment must be provided in order to estimate the effluent load for each STP.

The primary objective of the data collection phase of the project was to collate and assess the STP data (location, treatment type, DWF and population served) within all of the regions regulated by the Environment Agency in England and Wales. The STP data were provided by the water companies.

A primary issue with the LF2000-WQX model is the need for an appropriate filter to identify the number of STPs to be considered: too few and major point sources are omitted, too many and the modelling is computationally intractable. The process of identifying STPs was conducted using one filter to select the river basins or catchments constituting 95 per cent of each hydrometric area (a topographical unit) and then another filter to select those municipal STPs consented under the Water Resources Act that constitute 95 per cent of the total DWF discharged to the estuary. STPs that discharged to sea or were within 1km of the coast were also excluded.

Wallingford HydroSolutions undertook the collation and quality control of the data supplied by the water companies and the selection of the STPs to be included in the model. This constituted a major effort within the project and it was essential that it was done rigorously to ensure that the risk assessment could be conducted with some confidence. The procedure is detailed below.

- The STP data submitted by the water companies was checked for missing information relating to location, DWF estimates, population estimates and treatment types (over 6000 STPs in total).
- Following this, any outstanding issues, such as incorrect locations of discharge points, locating multiple discharge points for STPs and designating splits of DWF, complex transfer systems (such as Huddersfield) and STPs discharging to non-freshwater environments, were resolved.
- The resulting data wee then matched with Environment Agency WIMS data by cross-matching the information supplied by the water companies for each of the STPs to be modelled with data stored on WIMS. As consent numbers were not consistently supplied by the water companies, this was a complex process involving detailed checks on various factors, which are detailed below.
    - Consent numbers – full matches, partial matches and dealing with trailing suffixes.
    - Name – full matches and partial matches.
    - Locations – including STP location, discharge point location and sampling point location. Note that grid references for ocean outfalls were often spurious. The receiving water for a STP was sometimes noted by water companies and could therefore be used to cross-check the location.
    - DWF – check of water company-consented DWF with WIMS consented DWF. Cross-checking with population estimates in some cases.
    - Population – WIMS data compared to the water company estimates of population.
- Once a WIMS entry was matched with a water company STP, it was necessary to query the WIMS database to remove duplicate entries. Identifying the true STP data involved reviewing the consent and version number, the effluent type and the presence of a sampling point, assigning a DWF to the data record and manually

inspecting locations on OS maps. Any issues regarding STPs being included in WIMS in the incorrect Environment Agency region were resolved.

The final data set of cross-matched STPs formed the input to the model. The main data fields for each STP and their sources are described below.

- Location of the discharge point: determined using both WIMS data and WC data. OS maps were investigated where any discrepancies arose.
- DWF: selected from the WC data sets where available, otherwise the WIMS value was applied or, where this was lacking, an estimate was made from population figures (in lieu of WIMS data).
- Population (resident): taken from the WC data sets where available, otherwise WIMS data was used.
- Treatment type: available from the WC data sets.
- Discharge sampling point: obtained from the cross-matched WIMS information.

A summary of the number of STPs (total and selected), the amalgamated population served and the number of each type of treatment is shown for each region in Table 6.2.

An internal check on the adequacy of the conceptual representation of the modelled catchments was conducted by modelling three GQA determinands: chloride, BOD and orthophosphate (ortho-P), as detailed in Chapter 5. This was carried out for the major rivers within each modelled hydrometric area, where there were sufficient measured data. In a large majority of cases, the simulations of these water quality variables were acceptable (assessed by plotting observed and modelled data; data not shown). Where there was a discrepancy, the locations of the STPs and the water quality of the discharge data were examined further, and an assessment then made of the reasons for the poor simulations and whether this might affect the risk assessment.

Wallingford HydroSolutions also collated and undertook quality control on the concentrations of chloride, BOD and orthophosphate in the effluent from all the modelled STPs. As well as at upstream and downstream monitoring points plus additional evaluation points within the catchments using the collation procedure previously established by Keller and Young (2004).

Table 6.2 Summary of STPs per region, including population served and type of treatment

	Anglian	Southern	Thames	Wales	Midlands	North East	North West	South West	Total
Total number of STPs	1,072	369	352	872	969	1,056	597	700	5,987
Total population served (10^3)	5,602	3,969	12,625	3,051	8,229	7,211	6,770	3,893	51,350
Number of STPs discharging to sea	76	61	5	175	11	63	55	107	553
Population discharging to sea (10^3)	1,647	2,524	6,566	2,135	41	1,852	1,748	1,329	17,842
Number of STPs modelled	475	167	136	318	257	250	203	331	2,137
Modelled population served (10^3)	3,442	1,376	5,415	864	7,817	4,012	4,828	1,739	29,493
Type P				13		2	1		16
Type SAS	61	14	24	28	43	40	16	35	261
Type SB	177	47	30	202	94	138	109	126	923
Type TA1	33	10	4	11	9	9	11	24	111
Type TA2	39	6	28	2	19	7	26	21	148
Type TB1	116	73	22	57	46	31	16	95	456
Type TB2	49	17	28	5	46	23	24	30	222

6.2 Anglian

The Anglian region has a total area of approximately 27,000km^2 and covers Lincolnshire, Norfolk, Cambridgeshire and Suffolk plus parts of 12 other counties. The region as a whole has a relatively low population density[6] of about 141 inhabitants per km^2. An overview of the principal towns and cities in the Anglian region is presented in Figure 6.1.

Figure 6.1 Map of the Anglian region presenting the main urban centres

The spatial distribution of predicted risk levels in the Anglian region is presented in Figure 6.2. The proportion of each risk level is expressed in terms of the number of reaches and the total length of river in each category, and as a percentage of the total length of rivers modelled. These are provided for both mean and P_{90} concentrations in Table 6.3.

[6] This is the modelled population density – the population served by the modelled STPs divided by the area of the modelled catchments. It is the most relevant measure for explaining oestrogen concentrations and it is used throughout this chapter.

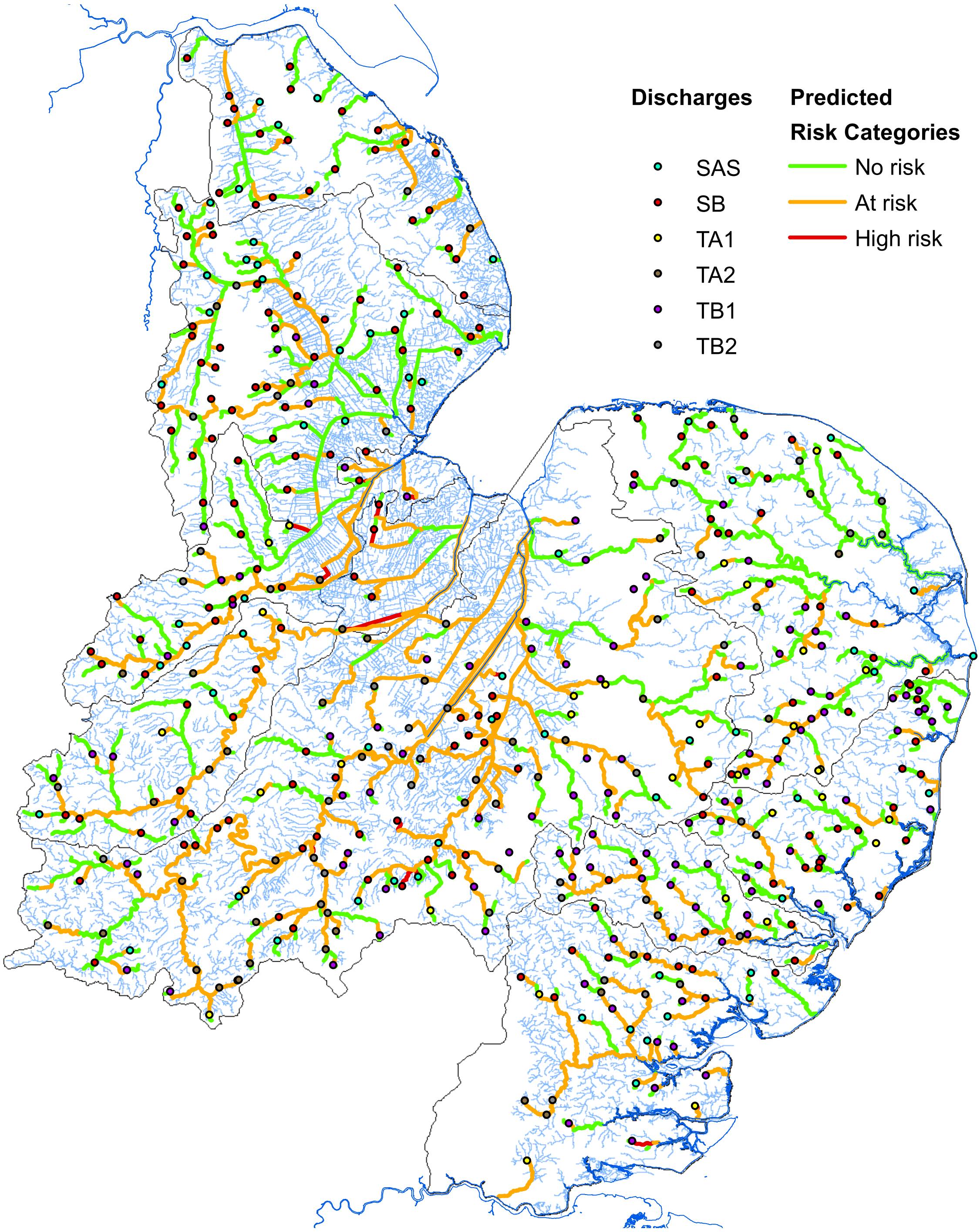

Figure 6.2 Spatial distribution of predicted risk categories in the Anglian region, based on mean concentrations

Table 6.3 Predicted risk categories in the Anglian region

Risk category	Number reaches		Length (km)		% Total length	
	Mean	90th	Mean	90th	Mean	90th
No risk	1,163	834	2,434	1,534	48	30
At risk	1,007	1,177	2,571	3,183	50	63
High risk	70	229	89	377	2	7

Within the Anglian region, 50 per cent of the length of the reaches (2,571km) were predicted to be ‘at risk’ when using mean concentrations, with 2 per cent (89km) at ‘high risk’. In terms of the proportion of the region ‘at risk’ (52 per cent), the Anglian region is similar to the Midlands and Thames regions.

The relatively high risk predictions for this region can be attributed to a particularly low dilution due to a low runoff of 150mm per annum (Table 6.1). This is a region of low precipitation and high evaporation.

The reaches predicted to be at ‘high risk’ within the Anglian region were further investigated, in order to locate the source STPs and identify the possible causes of the risk. The results of this investigation are presented in Table 6.4 (with the entries ranked according to the oestrogen concentration expressed as E2 equivalents for these particular reaches at mean flow).

Within most of the reaches classified as ‘high risk’ in the Anglian region, the E2 equivalent average concentration ranges between 10ngL^{-1} and 15ngL^{-1}. The highest predicted E2 equivalent concentration is approximately 26ngL^{-1}. It is important to note that most of the reaches categorised as ‘at risk’ are in fact drains, which constitute a predominant part of the river network in the Anglian region.

Table 6.4 Estimated oestrogen concentrations for the predicted 'high risk' reaches in the Anglian region

Location	Length (m)	E1 (ngL^{-1})			E2 (ngL^{-1})			EE2 ngL^{-1})			E2 Eqv (ngL^{-1})			Comments
		Mean	SD	90th	Mean	SD	90th	Mean	SD	90th	Mean	SD	90th	
Old Hurst STP (TB1), Bury Brook	1169	12.31	7.89	22.54	1.59	1.32	3.33	0.43	0.30	0.83	10.00	19.14	6.96	Low dilution/ headwater
Freethorpe STP (SAS), tributary of River Yare	430	12.38	9.25	24.53	1.65	1.57	3.60	0.43	0.36	0.87	10.09	20.43	8.29	Drain
Needingworth STP (TB1), small tributary of the River Great Ouse	351	12.39	7.49	21.91	1.63	1.28	3.24	0.44	0.28	0.80	10.12	18.50	6.57	Drain
Tevesham STP (TB1), Quy Water Bottisham Load	697	12.57	6.87	21.62	1.68	1.27	3.37	0.44	0.26	0.78	10.26	18.43	6.21	Drain
Over STP (TB2), Dockerell Brook	367	12.35	7.10	21.09	1.68	1.28	3.25	0.46	0.28	0.78	10.35	18.06	6.44	Drain
Little Port STP (SAS), Mare Fen Drain	2268	12.62	7.70	22.86	1.62	1.36	3.46	0.46	0.30	0.84	10.40	19.53	6.95	Drain
Caistor STP (SB), Nettleton Beck	1978	18.78	11.71	33.72	1.09	0.90	2.30	0.31	0.21	0.58	10.41	19.39	6.90	Low dilution/ headwater
Holbeach STP (TB1), Old River (Drain)	618	12.68	7.41	21.95	1.69	1.30	3.36	0.45	0.29	0.83	10.46	18.98	6.69	Drain
Donnington STP (SB), Mill Drain	38	26.85	18.94	52.25	1.62	1.42	3.55	0.00	0.00	0.00	10.57	20.97	7.74	Drain
Bourn STP (SB), tributary of Born Brook	1679	19.15	14.68	38.91	1.13	1.09	2.53	0.32	0.26	0.67	10.68	22.16	8.61	Drain
Woodhall Spa STP (SB), Swine Syke Drain	1252	27.09	14.73	45.30	1.69	1.27	3.29	0.00	0.00	0.00	10.72	18.38	6.18	Drain
East Burgholt STP (TB1), Gosnall Brook (River Stour)	1599	13.41	6.56	21.64	1.65	1.17	3.21	0.46	0.27	0.81	10.74	18.53	6.02	Low dilution
Flag Fen STP (TA2), River Nene Counter Drain	7748	12.88	6.95	21.60	1.70	1.22	3.19	0.49	0.28	0.85	10.85	18.88	6.34	Low dilution/ large works
Holbeach STP (TB1), Old River (Drain)	728	13.27	7.70	22.63	1.78	1.35	3.53	0.47	0.30	0.86	10.94	19.63	6.95	Drain
Over STP (TB2), Dockerell Brook	754	13.11	7.47	22.28	1.78	1.35	3.43	0.48	0.29	0.82	10.98	19.02	6.77	Drain
Bottisham STP (TB2), Mill Stream	1336	13.60	7.18	23.34	1.74	1.27	3.39	0.48	0.28	0.85	11.10	19.67	6.44	Drain
Donnington STP (SB), Mill Drain	882	28.31	19.53	54.40	1.71	1.47	3.75	0.00	0.00	0.00	11.15	21.88	7.98	Drain
Deepings STP (TA1), tributary of South Drove Drain	871	13.50	7.56	23.46	1.71	1.30	3.46	0.50	0.31	0.92	11.18	20.49	6.87	Drain
Melbourne STP (SAS), River Mel	2185	13.95	7.87	23.11	1.78	1.32	3.40	0.50	0.29	0.86	11.39	19.66	6.84	Low dilution
Great Cornard STP (TB2), Black Brook	104	13.82	7.94	23.13	1.91	1.58	3.67	0.49	0.34	0.84	11.40	19.73	7.59	STP Drain

Great Easton STP (SB), tributary of River Chelmer	37	20.46	12.99	37.90	1.27	1.04	2.54	0.34	0.23	0.65	11.45	21.68	7.71	Low dilution/ headwater
Elmswell STP (SB), tributary of River Sapiston	698	21.14	13.18	38.54	1.26	1.00	2.61	0.33	0.23	0.61	11.65	21.57	7.68	Low dilution/ headwater
Royston STP (SB), Whaddon Brook	1460	21.35	10.76	35.93	1.19	0.90	2.45	0.34	0.21	0.61	11.67	20.53	6.56	Low dilution/ headwater
Alford STP (SB), Holme Fen Drain	169	20.84	13.38	38.69	1.29	1.13	2.77	0.35	0.26	0.68	11.69	22.47	8.16	Drain
Ramsay STP (TB2), tributary of High Lode (old course River Nene)	915	14.33	8.34	24.71	1.89	1.48	3.68	0.50	0.31	0.89	11.69	20.86	7.36	Drain
Holbeach STP (TB1), Old River (Drain)	459	14.24	8.22	24.24	1.93	1.45	3.74	0.51	0.32	0.90	11.73	20.77	7.41	Drain
Haddenham STP (SB), Catchwater Drain	1496	21.40	13.38	38.65	1.24	1.00	2.59	0.34	0.23	0.66	11.78	22.08	7.78	Drain
Southminster New STP (TB1), Pannel's Brook	1179	14.67	8.72	25.92	1.89	1.48	3.86	0.50	0.32	0.93	11.79	21.82	7.61	Drain
Moulton STP (SB), Moulton Mere Drains	2819	21.26	14.29	40.78	1.27	1.16	2.79	0.35	0.27	0.70	11.84	23.35	8.63	Drain
Rayleigh East STP (TB1), Nobles Green Drain	649	14.54	9.71	26.48	1.83	1.54	3.89	0.53	0.38	1.02	11.94	22.96	8.56	Drain
Cowbit STP (SB), Moulton Mere Drain	3160	21.35	17.64	45.97	1.26	1.36	2.99	0.36	0.32	0.81	11.95	26.44	10.43	Drain
Sudbury STP (TA2), tributary of River Stour	456	14.83	7.76	24.78	1.92	1.39	3.75	0.52	0.31	0.90	12.03	21.03	7.03	Drain
Huntingdon STP (TA2), Cooks Stream	1055	14.73	7.94	24.35	1.95	1.40	3.72	0.52	0.32	0.91	12.08	20.94	7.21	Low dilution
Great Billing S (TA2), Ecton Brook	1638	15.09	7.85	25.09	2.09	1.61	4.16	0.53	0.30	0.90	12.41	21.56	7.23	Large works/ small stream
Royston STP (SB), Whaddon Brook	3775	23.30	11.24	38.39	1.31	0.96	2.65	0.36	0.22	0.65	12.70	21.90	6.87	Low dilution /headwater
Doddington STP (TB1), tributary of Ransonmoor Drain	874	16.58	10.04	29.21	2.01	1.63	4.15	0.54	0.36	0.99	12.96	23.79	8.61	Drain
Sandy STP (TB2), arm of River Ivel	4397	15.96	8.43	26.72	2.03	1.54	3.99	0.57	0.34	1.01	13.02	22.99	7.78	Low dilution/ river representation
Great Wenham STP (TB2), tributary of Strutton Brook	964	16.21	8.36	27.02	2.09	1.54	4.21	0.56	0.33	1.01	13.13	23.32	7.67	Low dilution/ headwater
Surfleet STP (SB), Latham Lode Seasend	1753	24.24	16.60	46.32	1.33	1.32	3.07	0.37	0.31	0.77	13.14	26.24	9.91	Drain
Holbeach STP (TB1), Old River (Drain)	301	16.30	9.59	27.45	2.21	1.65	4.20	0.58	0.38	1.00	13.41	23.34	8.60	Drain

Silverstone STP (SB), tributary of River Tove	353	24.13	15.29	44.02	1.48	1.28	3.25	0.39	0.27	0.76	13.42	25.50	9.08	Low dilution/ headwater
Holton Le Claey STP (SB), Holton Beck	764	24.36	14.43	42.97	1.50	1.19	3.04	0.40	0.27	0.72	13.61	24.57	8.66	Low dilution/ headwater
Ulcerby STP (SB), tributary of Skitter Beck	898	24.45	17.05	46.81	1.55	1.38	3.34	0.41	0.30	0.80	13.76	26.97	10.06	Drain
Deepings STP (TA1), tributary of South Drove Drain	1385	16.65	8.96	28.50	2.12	1.56	4.24	0.61	0.36	1.09	13.77	24.60	8.17	Drain
Flag Fen STP (TA2), River Nene Counter Drain	325	16.56	9.63	27.71	2.23	1.66	4.16	0.60	0.37	1.07	13.80	24.11	8.53	Low dilution/ large works
Flag Fen STP (TA2), River Nene Counter Drain	5032	16.61	9.67	27.79	2.23	1.67	4.18	0.61	0.37	1.07	13.83	24.17	8.56	Low dilution/ large works
Bedford STP (TA2), tributary of River Great Ouse	201	17.11	9.51	28.35	2.27	1.74	4.38	0.61	0.36	1.06	14.05	24.42	8.48	Low dilution/ large works
Cambridge STP (TA2), drainage channel to River Cam	69	17.25	9.67	28.70	2.27	1.71	4.48	0.60	0.37	1.02	14.05	24.22	8.61	Low dilution/ large works
Westleton STP (SB), tributary of the Minsmere New Cut	47	25.56	14.64	45.23	1.53	1.23	3.10	0.41	0.26	0.74	14.12	25.58	8.67	Low dilution
Holbeach STP (TB1), Old River (Drain)	311	17.22	10.41	28.67	2.34	1.76	4.48	0.61	0.41	1.05	14.16	24.50	9.29	Drain
Cambridge STP (TA2), drainage channel to River Cam	2699	17.83	10.21	29.90	2.34	1.79	4.60	0.62	0.38	1.05	14.53	25.08	9.04	Low dilution/ large works
Little Port STP (SAS), Mare Fen Drain	1	17.91	9.89	30.53	2.38	1.85	4.81	0.65	0.38	1.13	14.80	26.26	8.92	Drain
Tevesham STP (TB1), Quy Water Bottisham Load	893	18.50	9.55	30.83	2.49	1.81	4.90	0.64	0.36	1.11	15.07	26.32	8.62	Drain
Bourn STP (SB), tributary of Bourn Brook	436	27.35	18.53	52.56	1.65	1.45	3.58	0.44	0.33	0.89	15.21	30.00	10.90	Drain
Hibstow STP (SB), drains into Scawby Catchwater	811	28.06	16.88	51.05	1.65	1.35	3.41	0.44	0.29	0.82	15.45	28.65	9.88	Drain
Witcham STP (SB), Witcham Catchwater Drain	1241	27.86	17.25	50.10	1.68	1.35	3.52	0.47	0.32	0.88	15.62	29.07	10.27	Drain
Deepings STP (TA1), tributary of South Drove Drain	1500	19.32	10.24	32.41	2.50	1.81	4.99	0.70	0.41	1.22	15.95	28.00	9.29	Drain
Hempnell STP (TB1), Hempnell Beck	140	19.93	11.03	33.85	2.68	2.05	5.21	0.71	0.44	1.25	16.46	28.98	10.15	Drain
Worlijngham Ashtree STP (SB), tributary of River Waveny	436	29.76	19.78	56.73	1.79	1.53	3.87	0.48	0.35	0.93	16.51	32.11	11.66	Drain
Rayleigh East STP (TB1), Nobles Green Drain	4223	21.17	12.17	35.33	2.66	2.03	5.44	0.76	0.48	1.40	17.36	31.25	10.93	Drain

Kirkby le Thorpe STP (SB), the Beck, Heckington Eau	854	46.32	27.37	81.47	2.76	2.28	5.78	0.00	0.00	0.00	18.20	32.94	11.41	Drain
Reepham STP (SB), Blackwater Drain	622	32.68	17.83	54.99	1.96	1.50	3.91	0.54	0.33	0.95	18.23	31.77	10.73	Drain
Little Port STP (SAS), Mare Fen Drain	196	22.18	11.88	36.71	2.94	2.23	5.75	0.80	0.45	1.34	18.32	31.43	10.72	Drain
Olney STP (SB), tributary of River Great Ouse	915	33.95	19.13	58.06	2.03	1.57	4.11	0.55	0.35	1.01	18.82	33.54	11.44	Low dilution / headwater
Freethorpe STP (SAS), the Fleet Drain	226	24.07	14.99	43.42	3.20	2.60	6.56	0.83	0.59	1.54	19.53	36.45	13.45	Drain
Deepings STP (TA1), tributary of South Drove Drain	895	23.89	12.85	39.48	3.13	2.26	6.08	0.86	0.50	1.48	19.70	34.02	11.54	Drain
Bourn STP (SB), tributary of Bourn Brook	440	38.27	22.64	67.67	2.32	1.86	4.68	0.62	0.40	1.17	21.26	38.95	13.43	Drain
Clifton STP (TB2), Henlow Brook	1835	27.16	13.88	44.44	3.54	2.57	6.78	0.94	0.53	1.60	21.96	37.60	12.49	Low dilution
Bourne STP (TA1), Bourne Eau	4988	48.40	1071.65	55.38	1.53	5.03	4.16	0.51	1.58	1.66	22.72	39.21	378.02	STP drain
Burwell STP (SB), Catchwater Drain	1253	45.98	25.20	77.78	2.82	2.10	5.58	0.75	0.46	1.35	25.64	45.04	15.08	Drain

6.3 Southern

The Southern region encompasses the Isle of Wight and the majority of the counties of Hampshire, East Sussex, West Sussex and Kent. The Southern region has an area of approximately 11,000km^2 and a population density of about 164 inhabitants per km^2. An overview of the principal towns and cities in the Southern region is presented in Figure 6.3.

Figure 6.3 Map of the Southern region presenting the main urban centres

The spatial distribution of predicted risk levels in the Southern region is presented in Figure 6.4. The proportion of each risk level is expressed in terms of the number of reaches and the total length of river in each category, and as a percentage of the total length of all rivers modelled. These are provided for both mean and P_{90} concentrations in Table 6.5.

The length of reaches predicted to be 'at risk' under mean concentrations in the Southern region represent 34 per cent of the total length of rivers modelled (508km), while about 1 per cent of the total river length is predicted to be at 'high risk' (representing around 10km of river reaches scattered across the region). The total percentage of reaches 'at risk' in this region is therefore 35 per cent, which is a similar percentage to that in the North East and North West regions.

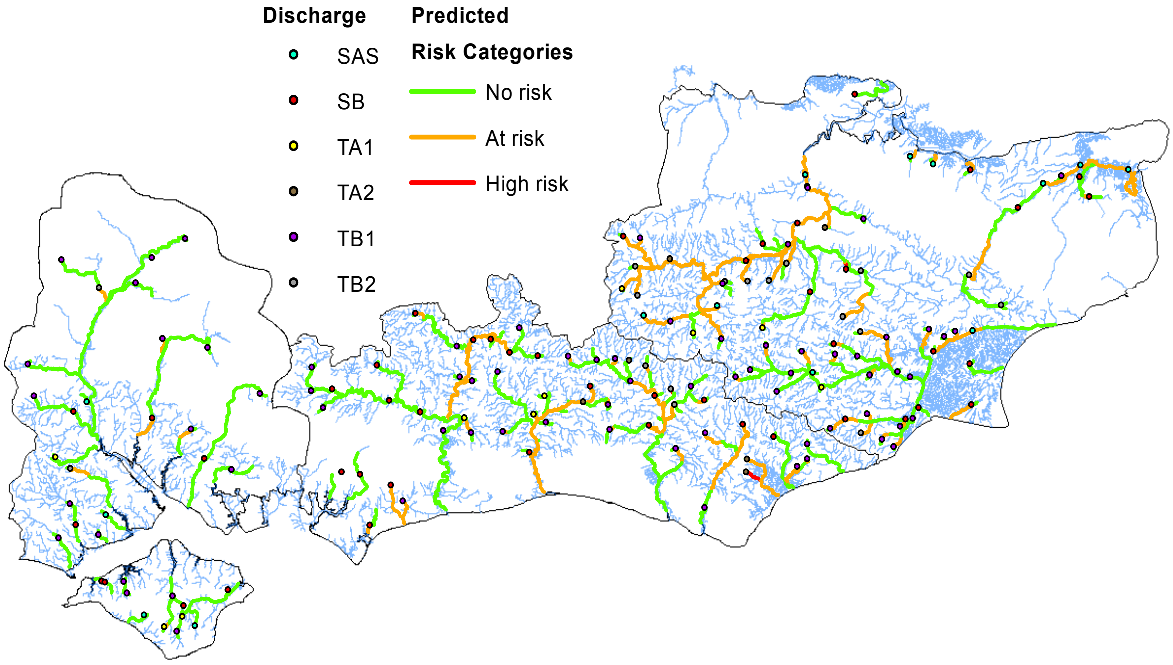

Figure 6.4 Spatial distribution of predicted risk categories in the Southern region, based on mean concentrations

Table 6.5 Predicted risk categories in the Southern region

	Number reaches		Length (km)		% Total length	
Risk category	**Mean**	**90th**	**Mean**	**90th**	**Mean**	**90th**
No risk	546	392	981	793	65	53
At risk	353	444	508	652	34	43
High risk	21	84	10	54	1	4

The reaches classified as 'high risk' are detailed in Table 6.6. This table includes the location of the source STPs, which are ranked according to their mean oestrogen concentrations. The possible causes of the risk are indicated.

As within the Anglian region, the E2 equivalent average concentration ranges between 10ngL^{-1} and 15ngL^{-1} for most reaches classified as 'high risk'. The highest predicted E2 equivalent concentration is approximately 24ngL^{-1}. These E2 equivalent concentrations are again related to low dilution in the Southern region and most of the problematic STPs are within the headwaters of the river network.

Table 6.6 Estimated oestrogen concentrations for the predicted 'high risk' reaches in the Southern region

Location	Length (m)	E1 (ngL^{-1})			E2 (ngL^{-1})			EE2 (ngL^{-1})			E2 Eqv (ngL^{-1})			Comments
		Mean	SD	90th	Mean	SD	90th	Mean	SD	90th	Mean	SD	90th	
Hailsham South STP (TA2), the Horse eye sewer (Pevensey Haven)	120	12.44	7.74	22.71	1.60	1.31	3.38	0.43	0.30	0.82	10.09	19.16	6.85	STP drain
Tunbridge Wells South STP (SAS), drain (River Grom)	240	12.26	6.80	20.63	1.63	1.24	3.16	0.44	0.26	0.75	10.11	17.55	6.15	Low dilution
Hailsham North STP (TA2), Hurst Haven	145	12.49	7.63	22.10	1.64	1.35	3.38	0.44	0.28	0.81	10.24	18.85	6.71	Low dilution
Tunbridge Wells North STP (TB2), tributary River Medway	134	12.85	7.83	23.24	1.68	1.32	3.37	0.45	0.30	0.82	10.47	19.30	6.91	Low dilution
Marefield STP (TB2), tributary of Batt's bridge stream	786	13.20	7.42	23.25	1.65	1.31	3.44	0.44	0.29	0.82	10.49	19.43	6.70	STP drain
Hailsham South STP (TA2), the Horse eye sewer (Pevensey Haven)	1575	13.13	7.98	23.57	1.69	1.36	3.51	0.46	0.31	0.85	10.64	19.85	7.07	STP drain
Lydd STP (SB), Lydd Petty Sewer	310	20.34	12.01	35.63	1.25	0.98	2.47	0.34	0.22	0.63	11.44	20.65	7.19	STP drain
Fernhurst STP (SB), tributary River Lod	40	21.03	13.28	38.93	1.32	1.11	2.77	0.34	0.23	0.65	11.73	22.24	7.83	Low dilution
Hailsham South STP (TA2), The Horse eye sewer (Pevensey Haven)	1211	14.56	8.73	25.81	1.90	1.51	3.89	0.51	0.33	0.93	11.81	21.80	7.73	Sewage drain
Tangmere STP (SB), Addingbourne Rife	327	21.97	11.70	37.23	1.32	1.03	2.64	0.36	0.23	0.66	12.26	21.65	7.19	Low dilution
Cuckfield STP (SB), tributary River Adur	116	22.97	14.23	41.63	1.44	1.15	3.00	0.38	0.26	0.71	12.91	24.02	8.46	Low dilution
Hailsham South STP (TA2), the Horse eye sewer (Pevensey Haven)	680	16.02	9.38	27.72	2.11	1.65	4.24	0.55	0.35	1.00	12.99	23.53	8.30	STP drain
Penbury STP (TB2), tributary Tudeley brook	185	16.08	8.93	27.61	2.11	1.61	4.24	0.56	0.35	1.01	13.10	23.53	8.06	Low dilution
Staplehurst STP (SB), STP Drain (River Beult)	1608	24.24	15.39	45.06	1.44	1.23	3.17	0.40	0.28	0.76	13.50	25.79	9.13	STP drain
Eden Vale STP (TB2), Eden Vale stream	477	16.98	9.16	29.25	2.19	1.61	4.29	0.59	0.34	1.04	13.79	24.42	8.06	Low dilution
Newham STP (SB), drain (Little Stour)	153	31.55	16.72	53.43	0.00	0.00	0.00	0.52	0.32	0.94	15.75	27.16	8.75	Low dilution
Newham STP (SB), drain (Little Stour)	504	32.52	17.15	54.34	0.00	0.00	0.00	0.54	0.32	0.96	16.21	27.68	8.96	Low dilution
Hailsham South STP (TA2), the Horse eye sewer (Pevensey Haven)	221	20.26	11.30	34.51	2.69	2.04	5.35	0.70	0.43	1.24	16.41	29.24	10.11	STP drain
Tonbridge STP (SB), Botary stream	321	40.03	21.05	66.02	2.49	1.93	4.80	0.65	0.41	1.13	22.35	38.08	13.06	Low dilution
Tonbridge STP (SB), Botary stream		40.33	21.16	66.37	2.51	1.94	4.83	0.65	0.41	1.13	22.50	38.24	13.13	Low dilution
Tonbridge STP (SB), Botary stream		41.67	21.80	68.59	2.60	2.02	4.94	0.67	0.43	1.15	23.24	39.31	13.53	Low dilution

6.4 Thames

The Thames region has an approximate surface area of 12,900km^2, and ranges from the Cotswolds, Chilterns, Berkshire Downs, North Downs and the Weald to the highly urbanised Thames Valley and Greater London. The Thames region has a high population density of about 447 inhabitants per km^2 and is therefore the second most populace region in England and Wales. An overview of the principal towns and cities in the Thames region is presented in Figure 6.5.

Figure 6.5 Map of the Thames region presenting the main urban centres

The spatial distribution of predicted risk levels in the Thames Region is presented in Figure 6.6. The proportion of each risk level is expressed in terms of the number of reaches and the total length of river in each category, and as a percentage of the total length of all rivers modelled. These are provided for both mean and P_{90} concentrations in Table 6.7.

Within the Thames region, around 1107km of river are predicted to be ‘at risk’ under mean concentrations, representing 67 per cent of the total length of rivers modelled. Around 44km of river reaches fall into the ‘high risk’ category, representing 3 per cent of the total length modelled. In terms of the proportion of the region ‘at risk’ (70 per cent), the Thames region is similar to the Midlands and Anglian regions.

The major cause of ‘high risk’ predictions for this region is the high level of urbanisation in London and the Home Counties, along with the moderate degree of dilution available in Southern England.

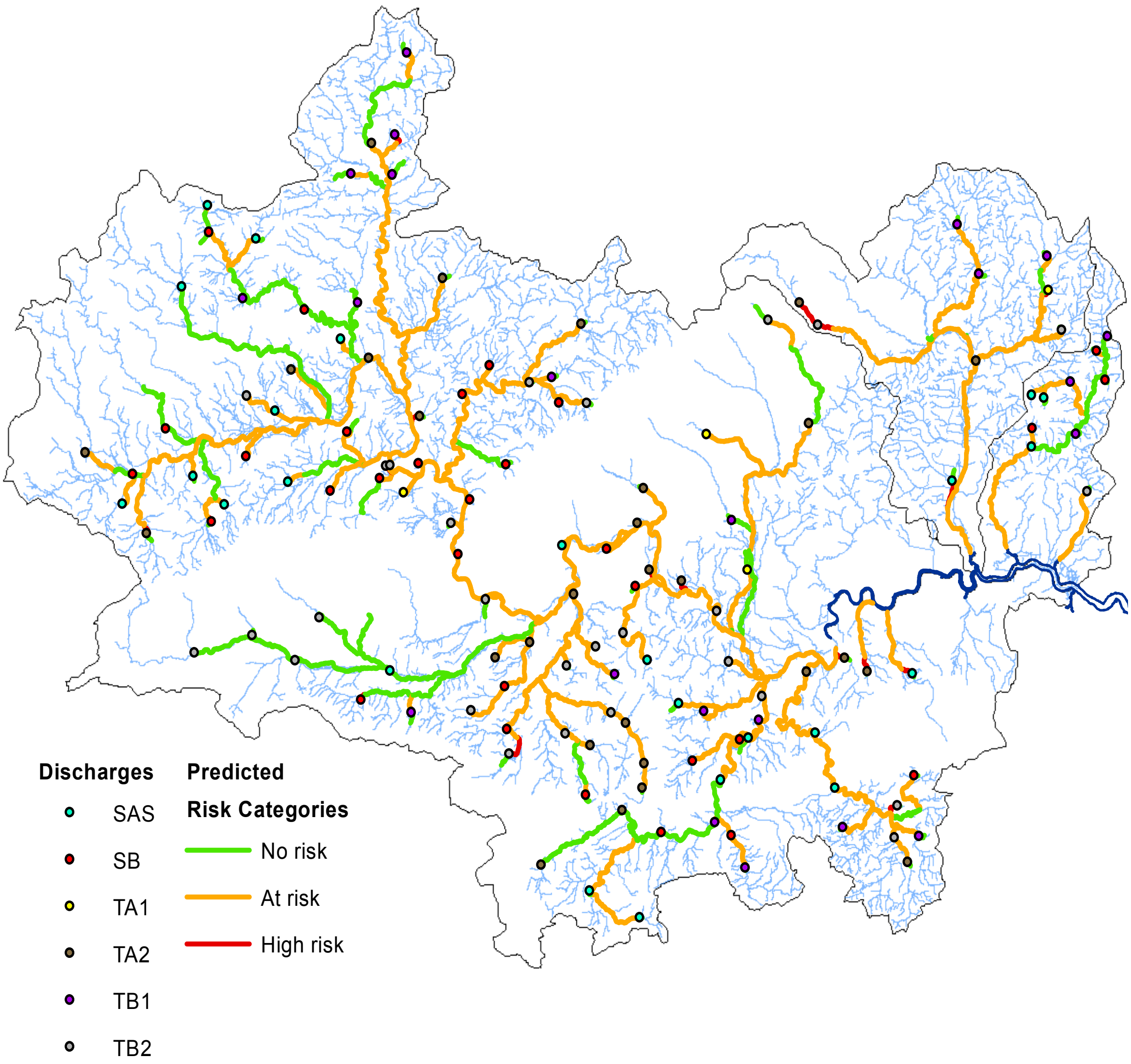

Figure 6.6 Spatial distribution of predicted risk categories in the Thames region, based on mean concentrations

Table 6.7 Predicted risk categories in the Thames region

Risk category	Number reaches		Length (km)		% Total length	
	Mean	90th	Mean	90th	Mean	90th
No risk	196	149	509	311	30	19
At risk	328	300	1,107	1,127	67	68
High risk	52	127	44	222	3	13

The reaches at 'high risk' within the Thames region were further investigated, in order to locate the source STPs across the region and to identify the possible causes of the risk. The results of this investigation are presented in Table 6.8 (ranked according to the oestrogen concentration for these particular reaches).

Table 6.8 Estimated oestrogen concentrations for the predicted 'high risk' reaches in the Thames region

Location	Length	E1 (ng.l⁻¹)			E2 (ng.l⁻¹)			EE2 (ng.l⁻¹)			E2 Eqv (ng.l⁻¹)			Comments
	(m)	Mean	SD	90th	Mean	SD	90th	Mean	SD	90th	Mean	SD	90th	
Washwater STP (SB), Pound Streetbrook (River Enborne)	1220	18.33	10.70	32.14	1.09	0.89	2.25	0.30	0.20	0.55	10.22	6.43	18.51	Low dilution
Luton STP (TA2), River Lee	3631	12.37	7.06	21.75	1.63	1.27	3.31	0.45	0.28	0.81	10.29	6.47	18.66	Low dilution
Harpenden STP (TB2), River Lee	2651	12.43	5.97	20.35	1.62	1.06	3.10	0.46	0.24	0.77	10.33	5.46	17.60	Combined effect STPs
Middleton Cheney STP (TB1), Washle Brook	1741	13.41	8.14	23.69	1.63	1.37	3.38	0.44	0.31	0.87	10.54	7.15	19.94	Low dilution
Chinnor STP (SB), STP drain (Badger brook)	903	18.99	11.60	34.52	1.17	0.94	2.43	0.31	0.20	0.59	10.63	6.83	19.84	Low dilution
Swindon STP (TA2), River Ray	1475	13.11	7.58	22.37	1.76	1.35	3.57	0.47	0.29	0.84	10.85	6.81	19.46	Low dilution
Witney STP (TA2), Colwell Brook	816	13.18	7.40	22.30	1.75	1.37	3.40	0.47	0.30	0.85	10.86	6.80	19.32	Low dilution
Farnham STP (TA2), tributary of River Wey	210	13.26	7.23	22.38	1.79	1.32	3.49	0.47	0.28	0.81	10.86	6.52	19.08	Low dilution
Bishop Stortford STP (TA1), Great Hellingbury Brook	739	13.23	7.95	22.29	1.79	1.39	3.55	0.48	0.33	0.88	11.02	7.29	19.80	Low dilution
Bishop Stortford STP (TA1), Great Hellingbury Brook	753	13.47	8.12	22.61	1.82	1.41	3.61	0.49	0.33	0.89	11.18	7.42	20.04	Low dilution
Hogsmill Valley STP (TA2), Hogsmill River	1727	13.99	7.97	24.10	1.88	1.48	3.64	0.50	0.30	0.90	11.55	7.18	20.63	Low dilution
Culham STP (SB), Clifton Hampden ditch	688	21.16	11.65	36.83	1.23	0.97	2.47	0.33	0.21	0.59	11.60	6.98	20.65	STP drain
Luton STP (TA2), River Lee	808	14.15	8.10	24.90	1.85	1.45	3.72	0.51	0.32	0.90	11.63	7.31	21.06	Low dilution
Lightwater STP (SAS), Halebourne	53	14.28	8.53	25.31	1.89	1.47	3.89	0.50	0.33	0.91	11.65	7.61	21.46	Low dilution
Basingstoke STP (TB2), River Loddon	4361	14.72	9.39	25.70	1.89	1.64	3.93	0.50	0.35	0.94	11.81	8.32	21.86	Low dilution
Abbingdon STP (TB2), Oldhay Hill ditch	433	14.65	7.76	24.27	1.89	1.36	3.70	0.52	0.30	0.90	11.97	6.95	20.75	Sewage drain
Deephams STP (SAS), Salmon Brook	945	14.47	8.16	24.95	1.98	1.48	3.90	0.52	0.32	0.92	12.01	7.39	21.42	Low dilution
Standon STP (TB1), STP drain (River Rib)	508	15.07	8.87	26.44	2.01	1.60	4.14	0.54	0.34	0.99	12.41	7.95	22.90	STP drain
Hogsmill STP (TA2), Beverley Brook	1375	15.40	8.81	26.40	2.00	1.59	3.96	0.55	0.36	1.02	12.62	8.11	23.00	Low dilution
Deephams STP (SAS), Salmon Brook	1621	15.31	8.55	26.37	2.09	1.55	4.11	0.55	0.33	0.97	12.69	7.72	22.56	Low dilution
Witney STP (TA2), Colwell Brook	50	15.81	9.12	26.77	2.11	1.68	4.12	0.56	0.36	1.01	13.02	8.36	23.11	Low dilution
Reigate STP (TB2), Earlswood Brook	1725	15.92	8.81	27.64	2.11	1.62	4.27	0.56	0.35	1.00	13.07	8.08	23.52	Low dilution
Oxford STP (TA2), Pottery Stream	2113	15.81	8.67	26.90	2.14	1.60	4.23	0.57	0.35	1.00	13.13	7.99	23.16	Low dilution
Hogsmill STP (TA2), Beverley Brook	994	16.21	9.06	27.30	2.12	1.66	4.15	0.57	0.36	1.05	13.26	8.33	23.75	Low dilution
Ascot STP (SAS), STP Drain (Bullbrook)	527	16.11	8.99	27.16	2.19	1.58	4.31	0.60	0.34	1.04	13.53	8.02	23.75	STP drain
Abbingdon STP (TB2), Oldhay Hill ditch	1220	16.97	9.13	28.36	2.19	1.59	4.30	0.60	0.35	1.03	13.84	8.14	24.10	STP drain

Maidenhead STP (TA2), Maidenhead ditch	1540	17.45	9.13	28.50	2.21	1.62	4.37	0.60	0.36	1.04	14.04	8.25	24.31	Low dilution
Beddington STP (SAS), STP drain (River Wandle)	673	17.60	9.66	29.39	2.34	1.66	4.56	0.62	0.36	1.07	14.40	8.47	25.03	STP drain
Deephams STP (SAS), Salmon Brook	497	17.60	9.78	29.97	2.40	1.77	4.69	0.63	0.37	1.08	14.54	8.76	25.51	Low dilution
Deephams STP (SAS), Salmon Brook	805	17.66	9.82	30.06	2.41	1.77	4.70	0.63	0.37	1.08	14.57	8.78	25.56	Low dilution
Beddington STP (SAS), STP drain (River Wandle)	403	18.02	9.96	29.90	2.40	1.71	4.64	0.63	0.37	1.10	14.73	8.71	25.62	STP drain
Beddington STP (SAS), STP drain (River Wandle)	410	18.21	10.11	30.22	2.43	1.73	4.70	0.64	0.37	1.12	14.88	8.82	25.95	STP drain
Beddington STP (SAS), STP drain (River Wandle)	536	18.76	10.57	31.30	2.50	1.79	4.85	0.66	0.39	1.16	15.32	9.20	26.91	STP drain
Kingsclere STP (TB1), Kingsclere ditch	256	18.93	10.15	32.22	2.44	1.78	4.65	0.66	0.40	1.14	15.40	9.14	26.78	Low dilution
Beddington STP (SAS), STP drain (River Wandle)	98	18.94	10.73	31.71	2.53	1.82	4.89	0.66	0.39	1.17	15.46	9.31	27.21	STP drain
Abbingdon STP (TB2), Oldhay Hill ditch	196	19.36	10.71	32.74	2.51	1.85	4.93	0.68	0.40	1.17	15.75	9.46	27.52	STP drain
Reigate STP (TB2), Earlswood Brook	383	19.26	10.12	32.44	2.59	1.89	5.10	0.68	0.41	1.18	15.84	9.34	27.68	Low dilution
Oxford STP (TA2), Pottery Stream	210	19.17	11.87	32.09	2.62	2.29	5.12	0.69	0.54	1.19	15.95	11.64	27.70	Low dilution
Worminghall STP (SB), Worminghall Brook	304	28.69	16.79	50.82	1.78	1.43	3.57	0.47	0.31	0.86	16.06	10.14	29.14	Low dilution
Slough STP (TA2), Roundmoor ditch	1058	19.56	10.59	32.25	2.64	1.96	5.14	0.70	0.40	1.21	16.19	9.53	27.99	Low dilution
Thame STP (TB2), Lashlake stream	270	19.98	11.15	33.34	2.64	1.90	5.14	0.70	0.40	1.20	16.30	9.63	28.22	Low dilution
Ascot STP (SAS), STP drain (Bullbrook)	39	20.28	11.33	34.15	2.77	1.99	5.39	0.75	0.43	1.28	17.04	10.06	29.58	STP drain
Slough STP (TA2), Roundmoor ditch	838	20.64	11.35	34.11	2.79	2.09	5.48	0.74	0.43	1.28	17.06	10.18	29.65	Low dilution
Basingstoke STP (TB2), River Loddon	39	20.95	12.77	34.90	2.79	2.20	5.38	0.74	0.46	1.28	17.18	11.09	29.86	Low dilution
Benson STP (SB), Howberry ditch	230	31.29	15.45	51.63	1.93	1.36	3.73	0.52	0.30	0.92	17.53	9.53	30.12	Low dilution
Wargrave STP (TA2), STP drain (River Loddon)	268	21.85	13.32	37.07	2.98	2.34	5.73	0.77	0.47	1.34	17.93	11.46	31.44	STP drain
Wheatley STP (SB), Wheatley ditch	32	34.98	19.57	58.42	2.10	1.57	4.14	0.56	0.35	1.02	19.39	11.59	33.86	STP drain
Hurley STP (SB), Bisham brook	185	35.82	19.04	59.43	2.16	1.58	4.20	0.58	0.33	1.01	19.92	11.26	34.06	STP drain
Chinor STP (SB), STP drain (Badger brook)	252	37.81	21.82	64.34	2.34	1.78	4.73	0.62	0.37	1.11	21.12	12.73	37.26	STP drain
Hatfield Heath STP (TB2), the Pincey Brook	483	34.40	19.32	59.29	4.71	3.68	9.31	1.22	0.76	2.16	28.39	17.68	50.68	STP drain
Chinor STP (SB), STP drain (Badger brook)	104	53.48	30.03	88.27	3.33	2.46	6.45	0.87	0.50	1.50	29.88	17.51	50.85	STP drain
Bourton STP (SB), Lenta Brook	1069	81.13	92.15	186.08	4.65	6.07	11.26	1.32	1.60	3.12	44.90	52.77	104.43	Low dilution

Within most of the reaches classified as 'high risk' in the Thames region, the E2 equivalent average concentration ranges between $10ngL^{-1}$ and $17ngL^{-1}$. A few reaches have concentrations ranging between $20ngL^{-1}$ and $30ngL^{-1}$, but these are final effluent drains. The highest predicted E2 equivalent concentration is approximately $45ngL^{-1}$, which is exceptional and occurs downstream of the Bourton STP. Such a high concentration appears to be due to the low dilution and the fact that Bourton is a BFP with a lower removal efficiency for E1.

6.5 Wales

The Wales region comprises most of Wales and also parts of the Dee and Wye river catchments lying in England. This region covers approximately $21,300km^2$ and has a relatively low population density of about 50 inhabitants per km^2. An overview of the principal towns and cities in the Wales region is presented in Figure 6.7.

Figure 6.7 Map of the Wales region presenting the main urban centres

The spatial distribution of predicted risk levels in the Wales region is presented in Figure 6.8. The proportion of each risk level is expressed in terms of the number of reaches and the total length of river in each category, and as a percentage of the total length of all rivers modelled. These are provided for both mean and P_{90} concentrations in Table 6.9.

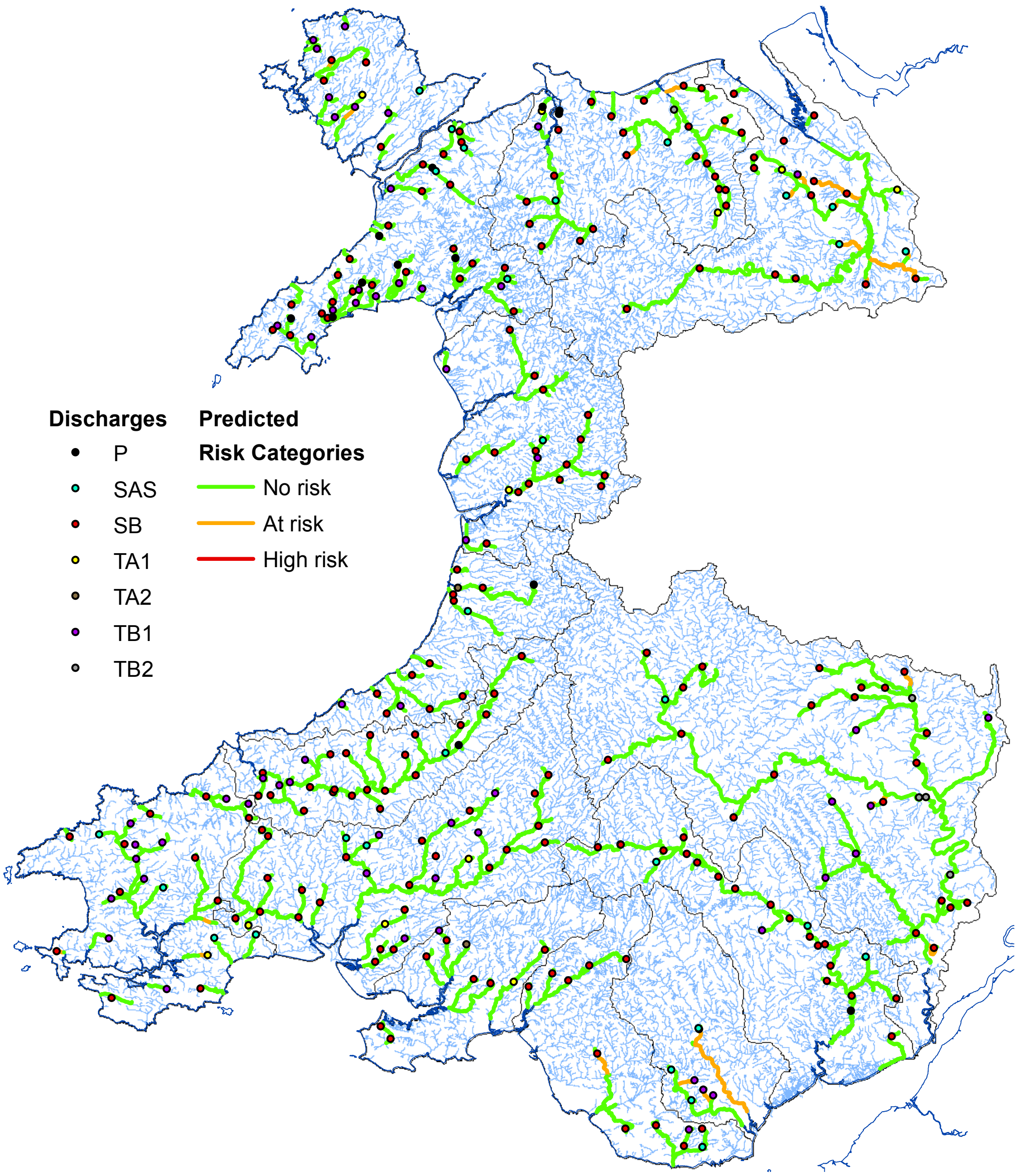

Figure 6.8 Spatial distribution of predicted risk categories in the Wales region, based on mean concentrations

Table 6.9 Predicted risk categories in the Wales region

Risk category	Number reaches		Length (km)		% Total length	
	Mean	90th	Mean	90th	Mean	90th
No risk	1447	1323	2,597	2,415	95	88
At risk	105	225	133	312	5	11
High risk	3	7	1	4	> 1	1

Within Wales, 5 per cent of the length of the reaches (133km) were predicted to be ‘at risk’ under mean concentrations, while less than 1 per cent (1km) were predicted to be at ‘high risk’. The proportion categorised as ‘at risk’ (<6 per cent) is much lower in Wales than in any other region. Most of Wales falls into the ‘no risk’ category due to the combined effects of low population density and high surface water runoff (Table 6.1).

The reaches categorised as at ‘high risk’ within the Wales region are presented in more detail in Table 6.10 (ranked according to the estimated oestrogen concentrations). Within the Wales region, only three river reaches are categorised as ‘high risk’, with a total river length of less than 500m. The highest predicted E2 equivalent concentration is around $26ngL^{-1}$, and occurs downstream of Ross on Wye STP in what appears to be an effluent drain.

Table 6.10 Estimated oestrogen concentrations for the predicted 'high risk' reaches in the Wales region

Location	Length (m)	E1 ($ng.l^{-1}$)			E2 ($ng.l^{-1}$)			EE2 ($ng.l^{-1}$)			E2 Eqv ($ng.l^{-1}$)			Comments
		Mean	SD	90th	Mean	SD	90th	Mean	SD	90th	Mean	SD	90th	
Luston and Yarpole STP (SB), tributary of River Lugg	102	18.35	15.33	38.95	1.11	1.18	2.65	0.30	0.27	0.65	10.19	8.96	22.12	Low dilution
Downstream Mold STP (TA1), tributary of river Alyn (Afon Alun)	96	22.27	11.55	37.00	2.96	2.06	5.63	0.78	0.46	1.37	18.19	10.49	31.68	Low dilution
Ross on Wye STP (TB2), STP drain (River Avon)	79	32.29	18.98	57.98	4.28	3.43	8.75	1.13	0.73	2.10	26.29	17.09	49.04	STP drain

6.6 Midlands

The Midlands region has a total area of approximately 21,600km^2 and covers many counties, including Shropshire, Warwickshire, Staffordshire, Nottinghamshire and Leicestershire. The region has the highest population density of all the regions, at around 587 inhabitants per km^2. An overview of the principal towns and cities in the Midlands region is presented in Figure 6.9.

Figure 6.9 Map of the Midlands region presenting the main urban centres

Table 6.11 Predicted risk categories in the Midlands region

	Number reaches		Length (km)		% Total length	
Risk category	**Mean**	**90th**	**Mean**	**90th**	**Mean**	**90th**
No risk	453	352	1,329	865	43	28
At risk	537	501	1,691	1,850	55	60
High risk	52	189	50	355	2	12

The spatial distribution of predicted risk levels in the Midlands region is presented in Figure 6.10. The proportion of each risk level is expressed in terms of the number of reaches and the total length of river in each category, and as a percentage of the total length of all rivers modelled. These are provided for both mean and P_{90} concentrations in Table 6.12.

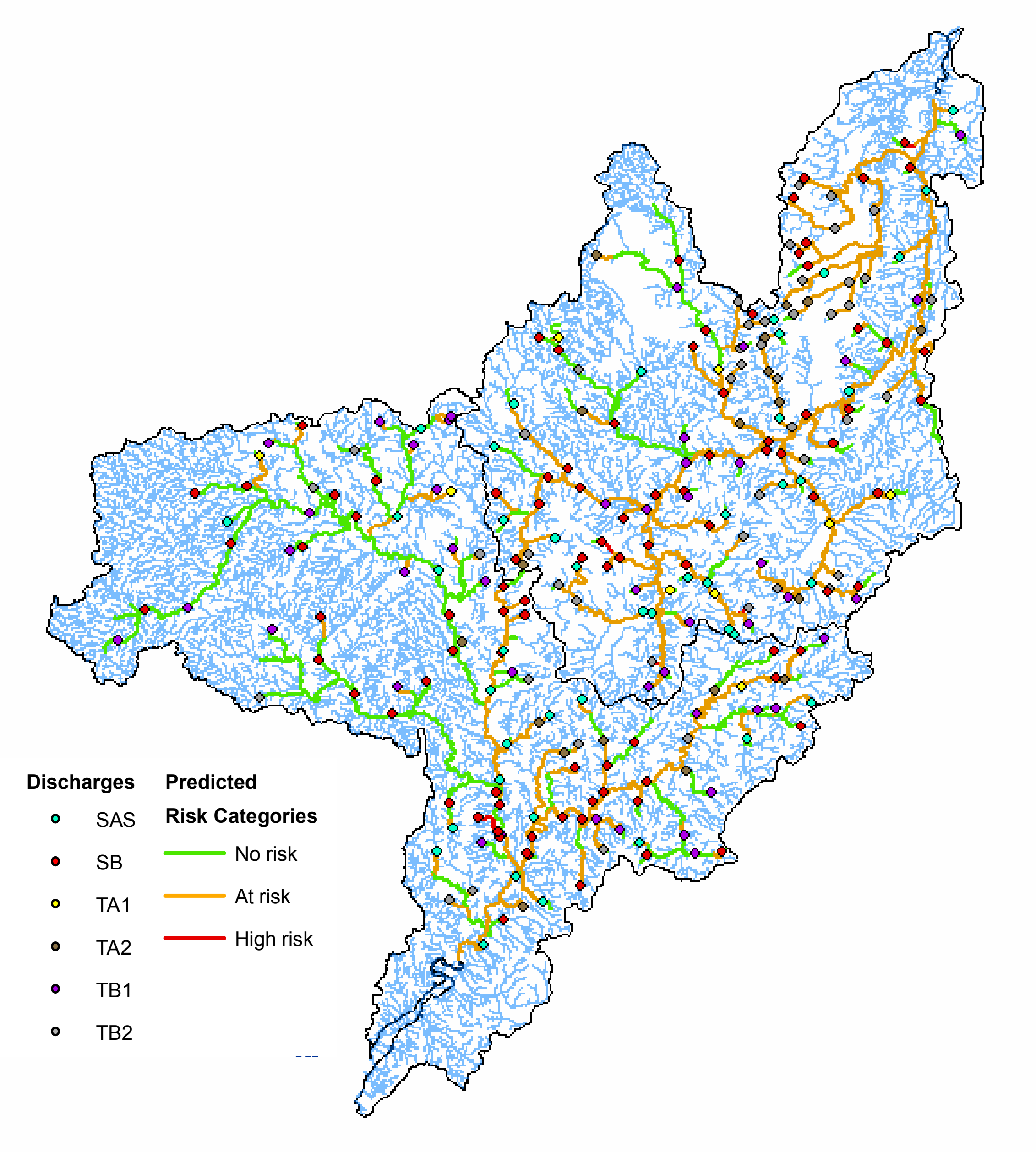

Figure 6.10 Spatial distribution of predicted risk categories in the Midlands region, based on mean concentrations

Within the Midlands region, around 1700km of river are predicted to be 'at risk', representing 55 per cent of the total length of rivers modelled. Around 50km of river reaches are predicted to be at 'high risk' under mean concentrations, representing 2 per cent of the total length modelled. In terms of the proportion of the region 'at risk' (57 per cent), the Midlands region is similar to the Thames and Anglian regions.

The major cause of the large number of 'high risk' predictions for this region is the high population density and the lack of dilution – the estimated annual runoff for this region is 310mm (Table 6.1).

The reaches at 'high risk' within the Midlands region were further investigated in order to locate the source STPs across the region and to identify the possible causes of the risk. The results of this investigation are presented in Table 6.12 (ranked according to the oestrogen concentration for these particular reaches).

Within the Midlands region, the E2 equivalent average concentration ranges between 10ngL^{-1} and 21ngL^{-1} for the reaches predicted to be at 'high risk'. These reaches are mainly located within the headwaters of the river network where the dilution availability is restricted. Furthermore, in many cases the STPs lying upstream of predicted 'high risk' reaches are BFPs, which have low oestrone removal efficiencies (

Table 5.4).

Table 6.12 Estimated oestrogen concentrations for the predicted 'high risk' reaches in the Midlands region

Location	Length (m)	E1 (ng.l⁻¹) Mean	E1 SD	E1 90th	E2 (ng.l⁻¹) Mean	E2 SD	E2 90th	EE2 (ng.l⁻¹) Mean	EE2 SD	EE2 90th	E2 Eqv (ng.l⁻¹) Mean	E2 Eqv SD	E2 Eqv 90th	Comments
Milton STP (SB), tributary of River Trent	211	17.88	9.44	30.23	1.11	0.80	2.18	0.29	0.17	0.51	10.01	5.69	17.39	Low dilution/ headwater
Dunchurch STP (TB1), tributary of River Leam	1823	12.57	7.74	22.74	1.59	1.29	3.28	0.43	0.29	0.82	10.12	6.82	19.10	Low dilution/ headwater
Langley STP (TB1), Langley Brook	56	12.46	7.93	22.56	1.67	1.33	3.49	0.45	0.32	0.86	10.29	7.22	19.57	Low dilution
Maltby Abby Lathe STP (SB), Maltby Dyke	954	18.46	11.06	33.27	1.15	0.92	2.34	0.30	0.20	0.56	10.33	6.62	19.04	Low dilution
Hinkley STP (TB2), Sketchley Brook	2681	12.51	6.75	20.95	1.66	1.17	3.22	0.45	0.27	0.79	10.34	6.07	18.06	Low dilution
Brockhampton (New) STP (SAS), Hyde Brook	1086	18.28	12.11	33.79	1.17	0.98	2.47	0.31	0.23	0.61	10.40	7.28	19.79	Low dilution/ headwater
Quay Lane STP (SB), Pool Brook	3020	18.41	11.34	33.23	1.09	0.88	2.25	0.32	0.22	0.62	10.40	6.87	19.51	Low dilution
Bredon STP (SB)	206	18.72	11.19	33.95	1.17	0.96	2.41	0.30	0.21	0.57	10.45	6.78	19.47	Drain
Stanton STP (SB), tributary of River Trent	1340	18.08	10.24	31.84	1.19	0.86	2.36	0.32	0.20	0.60	10.46	6.24	18.96	Low dilution
Radcliffe on Trent STP (SB), tributary of Polster Brook	2382	19.20	13.77	37.70	1.13	1.04	2.55	0.32	0.25	0.62	10.70	8.11	21.32	Low dilution/ headwater
Kegworth STP (SB), tributary of River Soar	838	19.62	11.90	35.15	1.14	0.94	2.38	0.31	0.21	0.59	10.75	7.04	20.02	Low dilution/ headwater
Haxely STP (SB), Ferry drain	2325	19.66	13.54	37.93	1.18	1.06	2.65	0.32	0.25	0.65	10.96	8.06	21.76	Drain
Walsall Wood STP (SB), Ford Brook	3199	19.73	12.39	36.12	1.16	1.00	2.47	0.33	0.23	0.64	11.01	7.47	20.94	Low dilution/ headwater
Arlewas STP (TB1), tributary of River Trent	657	13.70	7.91	23.15	1.79	1.34	3.54	0.47	0.30	0.83	11.03	6.93	19.52	Low dilution/ headwater
Hixon STP (SB), tributary of River Trent	399	19.74	13.29	37.40	1.23	1.05	2.64	0.32	0.24	0.63	11.05	7.84	21.36	Drain
Aslockton New STP (TB2), tributary of Car Dyke	251	13.73	8.00	24.33	1.82	1.46	3.70	0.49	0.32	0.88	11.26	7.29	20.61	Low dilution/ headwater
Pire Hill STP (TB2), tributary of River Trent	899	13.81	7.85	24.25	1.87	1.43	3.68	0.50	0.32	0.90	11.48	7.22	20.72	Low dilution/ headwater
Loggerheads Sanitorium STP (TB1), tributary of River Tern	90	14.17	7.57	24.19	1.91	1.35	3.73	0.50	0.30	0.87	11.60	6.85	20.52	Low dilution/ headwater
Blockley STP (SB), Blockley Brook	34	20.80	34.78	35.09	1.28	2.36	2.46	0.34	0.67	0.60	11.63	20.65	20.18	Low dilution
Barnards Green STP, Malvern (SB), Pool Brook	874	20.99	12.58	37.14	1.26	0.99	2.58	0.35	0.24	0.68	11.80	7.60	21.76	Low dilution other upsteam works
Barnhurst STP (TA2), Penk Brook	717	14.44	8.26	24.45	1.91	1.42	3.74	0.52	0.31	0.90	11.88	7.30	20.90	Low dilution/ headwater

Dinnington STP (SB), Cramfit Brook	1513	21.55	13.51	38.66	1.32	1.11	2.75	0.36	0.24	0.67	12.08	8.01	22.35	Low dilution/ headwater
Stoney Stanton (TB1), tributary of River Soar	818	15.17	9.11	26.71	1.89	1.52	3.76	0.52	0.33	0.95	12.14	7.90	22.18	Drain
Bromsgrove Fringe Green STP (SB), Sugar Brook	167	14.99	7.98	25.34	1.98	1.45	3.80	0.54	0.32	0.94	12.34	7.30	21.68	Low dilution
Church Stretton STP (SB), Quinney Brook	64	22.20	12.76	38.22	1.40	1.08	2.77	0.36	0.24	0.66	12.43	7.72	22.15	Ditch
Aslockton New STP (TB2), tributary of Car Dyke	501	15.28	8.60	26.21	2.03	1.59	4.11	0.54	0.34	0.95	12.51	7.85	22.30	Low dilution/ headwater
Cotgrave STP (TB2), Thirlbeck Dyke	697	15.30	8.27	25.94	2.00	1.52	3.90	0.55	0.34	0.98	12.64	7.70	22.37	STP ditch
Pire Hill STP (TB2), tributary of River Trent	510	15.33	8.56	26.56	2.09	1.56	4.05	0.55	0.35	0.96	12.72	7.87	22.55	Low dilution/ headwater
Goscote STP, Walsall (SAS), tributary of River Tame	1302	16.19	8.79	27.41	2.05	1.54	3.98	0.56	0.33	0.98	13.10	7.82	22.90	Low dilution/ headwater
Stanton STP (SB), tributary of River Trent	467	22.96	12.08	38.33	1.52	1.04	2.97	0.41	0.23	0.72	13.25	7.38	23.00	Low dilution
Barnards Green STP, Malvern (SB), Pool Brook	2386	24.08	13.77	41.59	1.44	1.11	2.94	0.40	0.26	0.75	13.51	8.35	24.30	Low dilution other U/S works
Burntwood STP (SB), Crane Brook	2936	24.15	13.53	41.66	1.44	1.12	2.85	0.41	0.26	0.73	13.58	8.23	24.01	Low dilution/ headwater
Pire Hill STP (TB2), tributary of River Trent	175	16.48	9.19	28.27	2.25	1.67	4.32	0.59	0.37	1.04	13.67	8.44	24.10	Low dilution/ headwater
Earl Shilton STP (TB2), tributary of Thurlaston Brook	1827	16.79	9.47	27.63	2.25	1.72	4.51	0.59	0.35	1.04	13.75	8.38	24.15	Ditch
Stoke Bardolph STP (SAS), tributary of River Trent	596	16.79	9.48	28.06	2.28	1.71	4.44	0.59	0.37	1.03	13.81	8.58	24.05	Ditch
Castle Donnington (SB)), tributary of River Trent	709	25.82	14.56	44.54	1.51	1.15	2.99	0.42	0.27	0.76	14.30	8.66	25.46	Ditch
Cotgrave STP (TB2), Thirlbeck Dyke	516	17.42	9.31	29.07	2.29	1.75	4.34	0.63	0.39	1.09	14.36	8.71	24.93	Ditch
Barnhurst STP (TA2), Penk Brook	858	18.13	10.00	30.36	2.39	1.74	4.69	0.64	0.37	1.11	14.87	8.81	25.93	Low dilution/ headwater
Duffield STP (SB), tributary of River Derwent	29	27.11	14.98	45.50	1.64	1.22	3.25	0.44	0.25	0.77	15.04	8.76	26.08	Ditch
Barston STP (TB2), tributary of River Blyth	2104	18.89	10.64	31.43	2.46	1.83	4.75	0.65	0.40	1.17	15.25	9.39	26.89	Low dilution/ headwater
Stanton STP (SB), tributary of River Trent	104	27.23	15.33	46.90	1.71	1.29	3.44	0.46	0.28	0.84	15.36	9.24	27.48	Low dilution
Cotgrave STP (TB2), Thirlbeck Dyke	684	18.68	10.12	30.73	2.47	1.96	4.67	0.67	0.42	1.15	15.39	9.53	26.42	Ditch
Lower Gornal STP (SB), tributary of River Stour	378	28.33	16.52	49.50	1.74	1.42	3.49	0.47	0.30	0.87	15.87	9.92	28.71	Low dilution
Litchfirld STP (SB), Full Brook	219	28.96	16.24	47.47	1.79	1.45	3.37	0.47	0.29	0.82	16.14	9.80	27.38	Low dilution
Hixon STP (SB), tributary of River Trent	398	29.95	18.18	53.38	1.88	1.50	3.85	0.49	0.32	0.90	16.76	10.79	30.70	Drain

Shardlow STP (SB), tributary of River Derwent	399	30.55	16.50	50.26	1.84	1.37	3.51	0.50	0.29	0.86	16.99	9.75	28.89	Drain
Barnards Green STP, Malvern (SB), Pool Brook	2234	30.40	16.48	51.10	1.84	1.36	3.66	0.50	0.31	0.91	16.99	9.98	29.77	Low dilution
Castle Donnington (SB)), tributary of River Trent	1549	31.81	17.36	53.75	1.87	1.38	3.68	0.51	0.31	0.89	17.57	10.29	30.54	Ditch
Brancote STP (SB), tributary of River Penk	132	35.31	18.96	58.32	2.24	1.66	4.38	0.57	0.37	1.02	19.75	11.67	33.98	Low dilution/ headwater
Beeston (Lilac Grove) STP (SB), River Trent	1004	36.24	19.25	59.91	2.16	1.67	4.29	0.59	0.36	1.05	20.15	11.71	34.76	Ditch
Burntwood STP (SB), Crane Brook	877	35.77	18.71	60.14	2.23	1.66	4.30	0.60	0.36	1.04	20.18	11.52	34.79	Low dilution/ headwater
Barnards Green STP, Malvern (SB), Pool Brook	226	37.91	20.00	61.62	2.31	1.69	4.49	0.62	0.37	1.09	21.11	12.07	35.93	Low dilution

6.7 North East

The North East region has a total area of approximately 22,700km^2 and comprises Northumberland, Durham and Yorkshire. The region has a population density of about 219 inhabitants per km^2. An overview of the principal towns and cities in the North East region is presented in Figure 6.11.

Figure 6.11 Map of the North East region presenting the main urban centres

The spatial distribution of predicted risk levels in the North East region is presented in Figure 6.12. The proportion of each risk level is expressed in terms of the number of reaches and the total length of river in each category, and as a percentage of the total length of all rivers modelled. These are provided for both mean and P_{90} concentrations in Table 6.13.

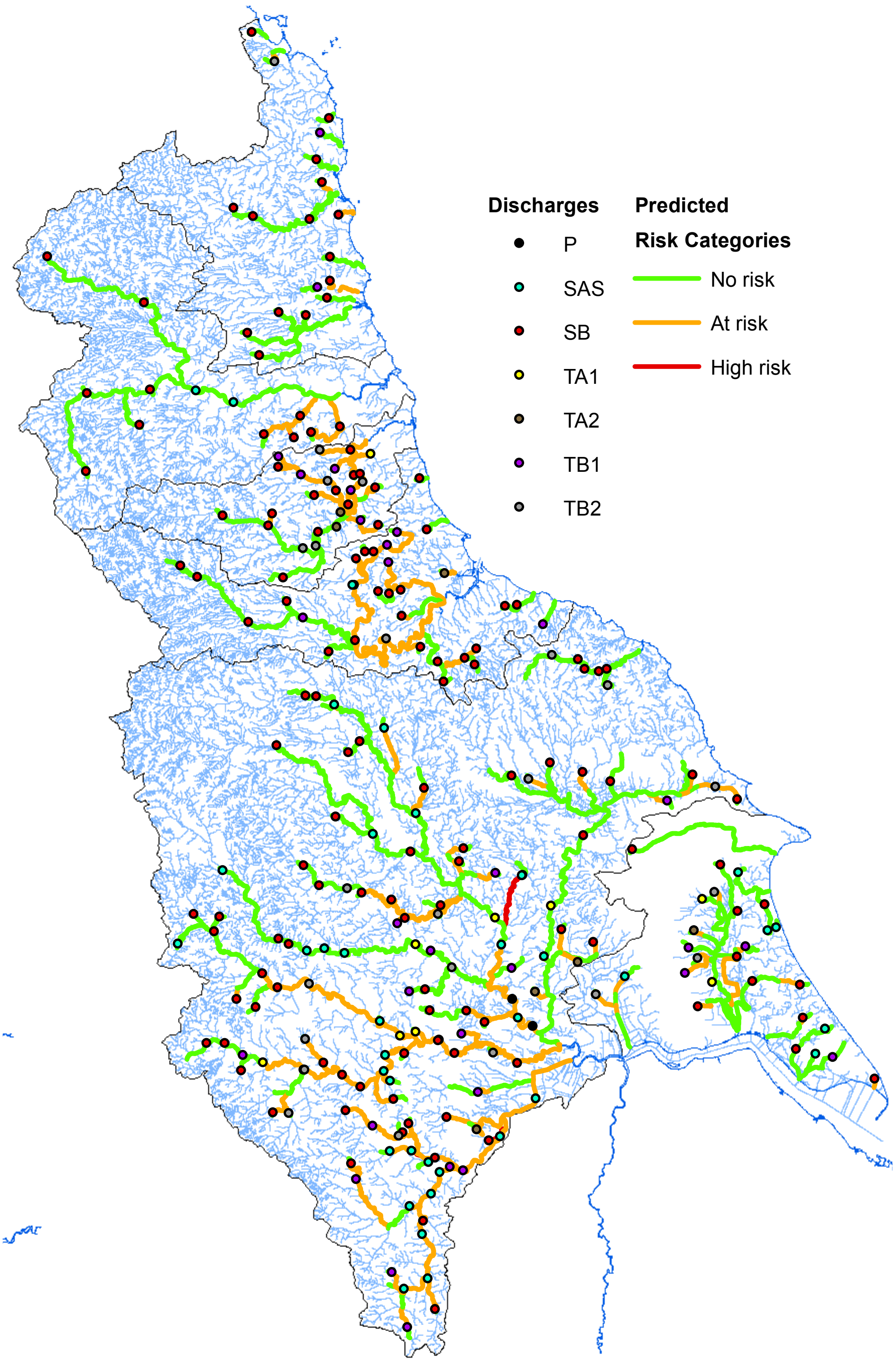

Figure 6.12 **Spatial distribution of predicted risk categories in the North East region, based on mean concentrations**

Table 6.13 Predicted risk categories in the North East region

Risk category	Number reaches		Length (km)		% Total length	
	Mean	90th	Mean	90th	Mean	90th
No risk	604	462	1,646	1,186	61	44
At risk	437	496	1,004	1,358	38	51
High risk	31	114	33	139	1	5

The length of reaches predicted to be 'at risk' under mean concentrations in the North East region represent 38 per cent of the total length of rivers modelled (1004km). Around 1 per cent of the total regional length is predicted to be at 'high risk' (about 33km of river reaches scattered across the region). The total proportion of 'at risk' reaches (39 per cent) in this region is similar to the Southern and North West regions.

The reaches at 'high risk' within the North East region were further investigated in order to locate the source STPs across the region and to identify the possible causes of the risk. The results of this investigation are presented in Table 6.14 (ranked according to the oestrogen concentration for these particular reaches).

The moderate runoff in the North East region (420mm per annum; Table 6.1), combined with the densely populated areas of Leeds, Sheffield, Middlesbrough and Newcastle, is the main cause of the high proportion of reaches predicted to be 'at risk' or at 'high risk'.

Within most of the reaches classified as 'high risk' within the North East region, the E2 equivalent average concentration ranges between 10ngL^{-1} and 15ngL^{-1}, with the highest predicted concentration at around 21ngL^{-1}. All reaches with E2 equivalent concentrations higher than 15ngL^{-1} are located downstream of BFPs with low oestrone removal efficiencies (

Table 5.4).

Table 6.14 Estimated oestrogen concentrations for the predicted 'high risk' reaches in the North East region

Location	Length (m)	E1 ($ng.l^{-1}$) Mean	E1 SD	E1 90th	E2 ($ng.l^{-1}$) Mean	E2 SD	E2 90th	EE2 ($ng.l^{-1}$) Mean	EE2 SD	EE2 90th	E2 Eqv ($ng.l^{-1}$) Mean	E2 Eqv SD	E2 Eqv 90th	Comments
Adwick STP (SB), Mill Dike	49	12.26	6.81	19.87	1.63	1.22	3.16	0.43	0.25	0.76	10.01	6.00	17.41	Low dilution
Knopstrop STP (SAS), STP drain	573	12.43	7.60	20.44	1.63	1.42	3.03	0.44	0.31	0.75	10.14	7.07	17.31	STP drain
Normanton STP (SB), Choke Churl Beck (River Calder)	93	18.32	12.01	33.67	1.15	0.96	2.38	0.30	0.21	0.57	10.26	7.02	19.31	Low dilution
Grimethorpe STP (SB), tributary River Deame	328	18.47	11.04	31.99	1.14	0.93	2.30	0.30	0.21	0.56	10.34	6.72	18.54	Low dilution
Melbourne STP (TA2), Hopplecare drain	404	13.17	7.38	22.30	1.67	1.31	3.44	0.43	0.28	0.80	10.39	6.55	18.87	STP drain
Leyburn STP (SB), Mill Beck (River Ure)	432	18.82	10.84	33.86	1.13	0.94	2.37	0.30	0.19	0.57	10.44	6.49	19.35	Low dilution
Aycliffe STP (SAS), STP drain	201	12.68	4.60	18.73	1.71	0.86	2.85	0.45	0.18	0.69	10.47	4.23	15.95	STP drain
Seamer STP (SB), tributary Seamer Drain	171	19.16	11.06	32.54	1.18	0.87	2.27	0.31	0.18	0.54	10.64	6.38	18.53	Low dilution
Aycliffe STP (SAS), STP drain	259	13.05	7.24	21.47	1.77	1.34	3.46	0.47	0.28	0.81	10.81	6.55	18.68	STP drain
Wombwell STP (SAS), Bulling Dyke (River Deame)	2271	13.59	7.49	22.70	1.79	1.45	3.55	0.49	0.31	0.86	11.19	7.02	19.71	Low dilution
Sedgeletch STP (SB), Herrington Burn	226	13.77	7.69	23.94	1.83	1.36	3.56	0.49	0.30	0.87	11.29	6.95	20.26	Low dilution
Ripponden Wood STP (SB), River Ryburn	726	20.68	12.26	36.63	1.17	0.96	2.37	0.32	0.22	0.60	11.30	7.20	20.60	Low dilution
Dipton STP (SB), Dipton Burn	33	13.67	8.62	24.80	1.83	1.55	3.85	0.50	0.33	0.91	11.38	7.75	21.24	Low dilution
Rawcliffe STP (SB), Rawcliffe Ings drain (River Ouse)	1873	20.48	12.33	35.65	1.20	1.00	2.46	0.34	0.23	0.63	11.38	7.39	20.66	Low dilution
Barwick STP (TB1), tributary Cock Beck	547	14.53	7.61	24.36	1.85	1.35	3.57	0.49	0.30	0.86	11.61	6.85	20.31	Low dilution
Normanton STP (SB), Choke Churl Beck (River Calder)	712	21.30	13.16	37.82	1.34	1.06	2.70	0.35	0.23	0.65	11.93	7.71	21.83	Low dilution
Eggborough STP (TB2), tributary River Aire	471	14.80	7.71	24.16	1.93	1.37	3.70	0.51	0.30	0.89	11.95	6.96	20.68	Low dilution
Morpeth STP (TB1), Wansbeck River	174	14.98	8.56	24.82	1.97	1.39	3.74	0.51	0.29	0.87	12.05	7.16	20.75	Low dilution
Hambleton STP (SB), Town Dike	463	23.26	12.63	39.25	1.41	1.08	2.86	0.37	0.23	0.68	12.91	7.63	22.73	Low dilution
Grimethorpe STP (SB), tributary River Deame	701	24.04	13.59	40.21	1.48	1.18	2.88	0.40	0.27	0.70	13.45	8.37	23.29	Low dilution
Bentley STP (SB), Mill Goit	5119	25.66	14.04	44.39	1.55	1.17	3.06	0.43	0.27	0.78	14.41	8.52	25.69	Low dilution
Lundwood STP (TB2), Cliff Bridge Dyke (River Deame)	167	18.20	10.14	29.99	2.43	1.83	4.75	0.65	0.40	1.14	15.03	9.20	26.12	STP drain
Walbutts – Lagoon1 STP (SB), River Foss	937	18.01	17.30	39.58	2.28	2.53	4.98	0.69	0.71	1.51	15.15	15.37	33.23	Combined effect STPs
Walbutts – Lagoon2 STP (SB), River Foss	24	18.49	20.47	43.56	2.56	3.46	6.11	0.66	0.78	1.49	15.34	18.12	35.57	Low dilution

Pocklington STP (SB), STP drain (Pocklington Beck)	617	28.48	15.94	47.21	1.70	1.28	3.28	0.46	0.28	0.81	15.84	9.39	27.15	STP drain
Normanton STP (SB), Choke Churl Beck (River Calder)	48	31.59	17.43	51.65	1.98	1.42	3.76	0.52	0.31	0.92	17.69	10.34	30.13	Low dilution
Chilton & Windlestone STP (SB), tributary Rushyford Beck	441	33.45	19.33	58.80	2.05	1.57	4.11	0.56	0.36	1.01	18.76	11.65	33.78	Low dilution
Bentley STP (SB), STP drain (Mill Goit)	449	33.88	17.99	56.16	2.12	1.54	4.08	0.55	0.32	0.96	18.89	10.72	32.38	STP drain
Leven STP (SB), drain	219	35.35	20.85	59.77	2.19	1.71	4.19	0.57	0.37	1.01	19.72	12.36	34.23	Drain
Walbutts – Lagoon2 STP (SB), River Foss	132	24.34	25.61	57.02	3.37	4.31	7.96	0.87	0.98	1.98	20.19	22.67	46.78	Low dilution
Walbutts – Lagoon1 STP (SB), River Foss	14380	25.05	23.22	55.05	3.18	3.38	7.00	0.95	0.95	2.11	21.03	20.59	46.47	Combined effect STPs

6.8 North West

The North West region comprises several counties, including Lancashire, Cheshire, Grater Manchester and Cumbria. This region covers approximately 14,500km^2 and has a relatively high population density of about 392 inhabitants per km^2. An overview of the principal towns and cities in the North West region is presented in Figure 6.13.

Figure 6.13 Map of the North West region presenting the main urban centres

The spatial distribution of predicted risk levels in the North West region is presented in Figure 6.14. The proportion of each risk level is expressed in terms of the number of reaches and the total length of river in each category, and as a percentage of the total length of all rivers modelled. These are provided for both mean and P_{90} concentrations in Table 6.16.

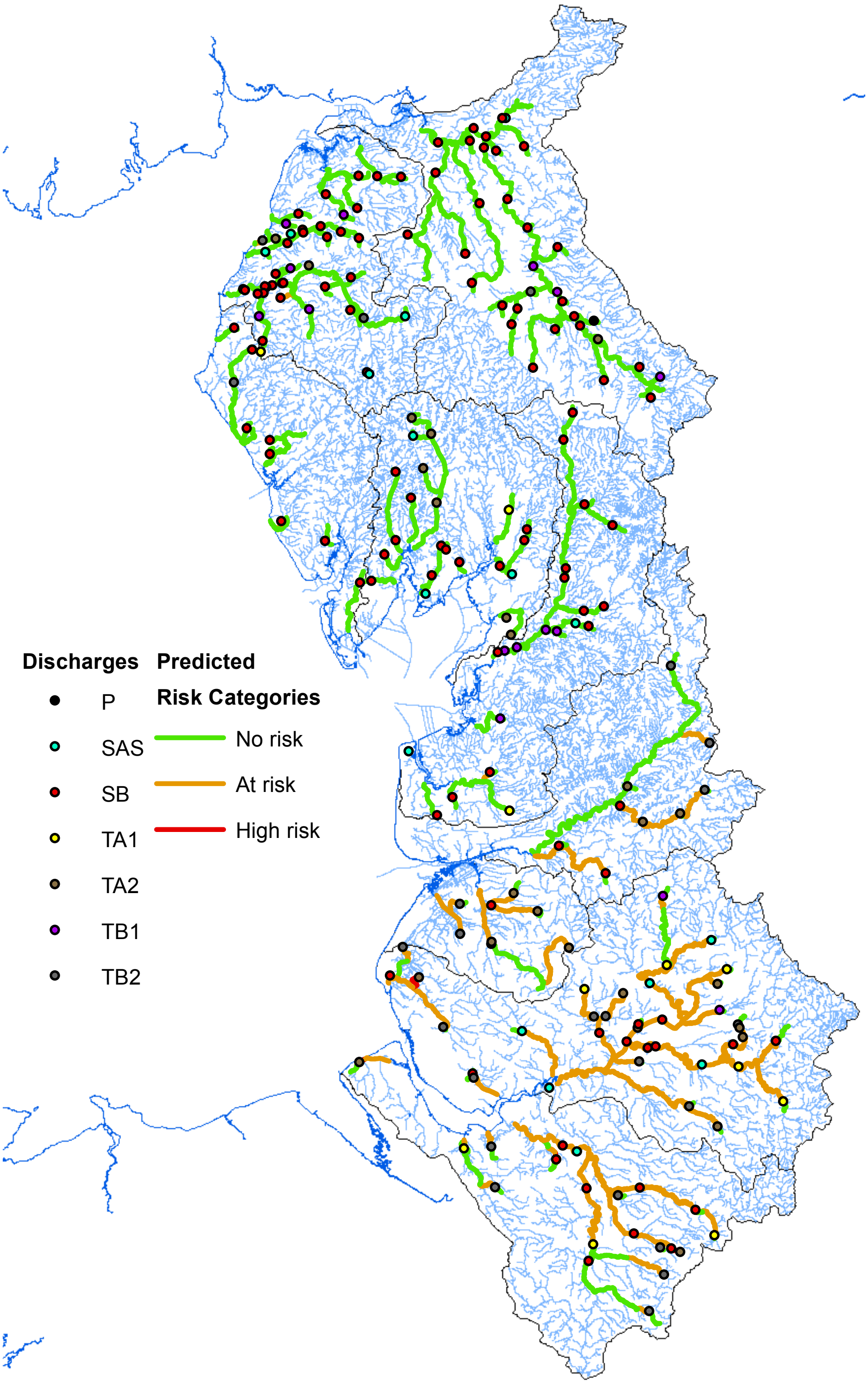

Figure 6.14 **Spatial distribution of predicted risk categories in the North West region, based on mean concentrations**

Table 6.15 Predicted risk categories in the North West region

Risk category	Number reaches		Length (km)		% Total length	
	Mean	90th	Mean	90^{th}	Mean	90th
No risk	593	540	1,169	1,026	65	57
At risk	226	238	601	82	34	5
High risk	19	60	16	678	1	38

Within the North West region, around 601km of river are predicted to be 'at risk' under mean concentrations, representing 34 per cent of the total length of rivers modelled. Around 16km of river reaches are predicted to be at 'high risk', representing 1 per cent of the total length modelled. In terms of the proportion of the region 'at risk' (35 per cent), the North West region is similar to the North East and Southern regions.

The reaches classified as 'high risk' are detailed in Table 6.16 (ranked according to the oestrogen content of each reach). This table includes the location of the 'high risk' reaches in relation to source STPs and the possible causes of the risk.

The relatively high population density in the North West region, particularly around Manchester and Merseyside (470 inhabitants per km^2; Table 6.1), is the main reason for the high proportion of reaches predicted to be 'at risk' or at 'high risk'.

Within the reaches classified as 'high risk' in the North West region, the E2 equivalent average concentration ranges from $10ngL^{-1}$ to $20ngL^{-1}$. The highest predicted E2 equivalent concentration (around $20ngL^{-1}$) is downstream of Sale STP, in an effluent drain prior to merging with the River Mersey.

Table 6.16 Estimated oestrogen concentrations for the predicted 'high risk' reaches in the North West region

	Length	E1 ($ng.l^{-1}$)			E2 ($ng.l^{-1}$)			EE2 ($ng.l^{-1}$)			E2 Eqv ($ng.l^{-1}$)			
Location	**(m)**	**Mean**	**SD**	**90th**	**Mean**	**SD**	**90th**	**Mean**	**SD**	**90th**	**Mean**	**SD**	**90th**	**Comments**
Middlewich STP (TB2), River Croco	504	12.24	7.42	21.57	1.62	1.28	3.30	0.43	0.29	0.79	10.01	6.61	18.34	Low dilution
Woolton STP (TB2), tributary of Netherley Brook	1281	12.21	6.69	20.64	1.59	1.23	3.15	0.44	0.26	0.77	10.03	6.11	17.76	Low dilution
North Wirral STP (TA2), the Birke	1222	12.42	6.97	20.90	1.60	1.18	3.21	0.44	0.26	0.78	10.14	6.12	17.96	Low dilution
Eccles STP (SB), Salt Eye Brook	961	18.80	12.33	35.30	1.20	1.08	2.51	0.31	0.24	0.61	10.61	7.56	20.39	Low dilution
Kidsgrove STP (TA2), Kidsgrove Stream	2503	12.99	6.99	21.51	1.69	1.25	3.29	0.46	0.28	0.79	10.62	6.35	18.37	Low dilution
Hillhouse STP (TA2), Hey cop drain (River Alt)	870	13.12	7.22	21.77	1.75	1.31	3.40	0.47	0.28	0.80	10.82	6.48	18.71	STP drain
Oldham STP (TA2), tributary of Wince Brook	556	13.43	7.72	23.29	1.78	1.30	3.43	0.46	0.28	0.82	10.89	6.72	19.43	Low dilution
Cuddington STP (SB), Cuddington Brook	1972	20.31	10.58	34.45	1.20	0.86	2.35	0.32	0.19	0.58	11.18	6.29	19.58	Low dilution
Burscough STP (TB2), Sewage drain (Boat House Sluice)	39	14.18	7.94	23.13	1.83	1.43	3.59	0.48	0.28	0.84	11.39	6.92	19.71	STP drain
Huyton STP (SB), Netherley Brook	446	20.76	12.73	36.89	1.25	1.01	2.57	0.33	0.22	0.60	11.47	7.44	20.88	Low dilution
Burscough STP (TB2), sewage drain (Boat House Sluice)	546	14.42	8.10	23.40	1.86	1.45	3.66	0.49	0.29	0.85	11.58	7.04	20.00	STP drain
Hillhouse STP (TA2), Hey cop drain (River Alt)	1181	14.09	7.72	23.31	1.88	1.41	3.60	0.50	0.29	0.86	11.60	6.91	19.94	STP drain
Ashton under Lyne STP (TB2), River Tame	1270	14.40	8.09	24.44	1.84	1.37	3.63	0.50	0.31	0.88	11.62	7.19	20.61	Low dilution
Blackburn STP (SB), Hole Brook (River Darwen)	125	21.27	12.94	37.46	1.29	1.03	2.62	0.34	0.22	0.61	11.75	7.55	21.21	Low dilution
Huyton STP (SB), Netherley Brook	236	21.00	11.49	35.22	1.30	0.99	2.56	0.35	0.21	0.61	11.75	6.92	20.42	Low dilution
Hillhouse STP (TA2), Hey cop drain (River Alt)	355	14.80	8.13	24.77	2.00	1.49	3.80	0.53	0.31	0.90	12.18	7.26	21.04	STP drain
Hillhouse STP (TA2), Hey cop drain (River Alt)	1472	15.57	8.60	26.10	2.10	1.57	4.00	0.55	0.32	0.94	12.81	7.66	22.06	STP drain
Westoughton STP (SB), Hall Lee Brook	134	16.44	9.13	27.56	2.13	1.62	4.10	0.58	0.38	1.01	13.40	8.49	23.39	Low dilution
Sale STP (SB), sewage drain (River Mersey)	444	35.46	21.11	58.48	2.23	1.73	4.34	0.59	0.46	1.01	19.99	13.36	33.92	STP drain

6.9 South West

The South West region stretches from Gloucestershire to Cornwall, spanning the South Peninsula and including the counties of Dorset, Somerset, Devon and Wiltshire. This region covers approximately 20,800km^2 and has a relatively low population density of around 106 inhabitants per km^2. An overview of the principal towns and cities in the South West region is presented in Figure 6.15.

Figure 6.15 **Map of the South West region presenting the main urban centres**

The spatial distribution of predicted risk levels in the South West region is presented in Figure 6.16. The proportion of each risk level is expressed in terms of the number of reaches and the total length of river in each category, and as a percentage of the total length of all rivers modelled. These are provided for both mean and P_{90} concentrations in Table 6.17.

Within the South West region, 16 per cent of the length of the reaches (461km) was predicted to be 'at risk' under mean concentrations, with less than 1 per cent (6 km) predicted to be at 'high risk'. In terms of the total proportion of the region 'at risk' (17 per cent), the South West has a markedly lower risk than any region other than Wales.

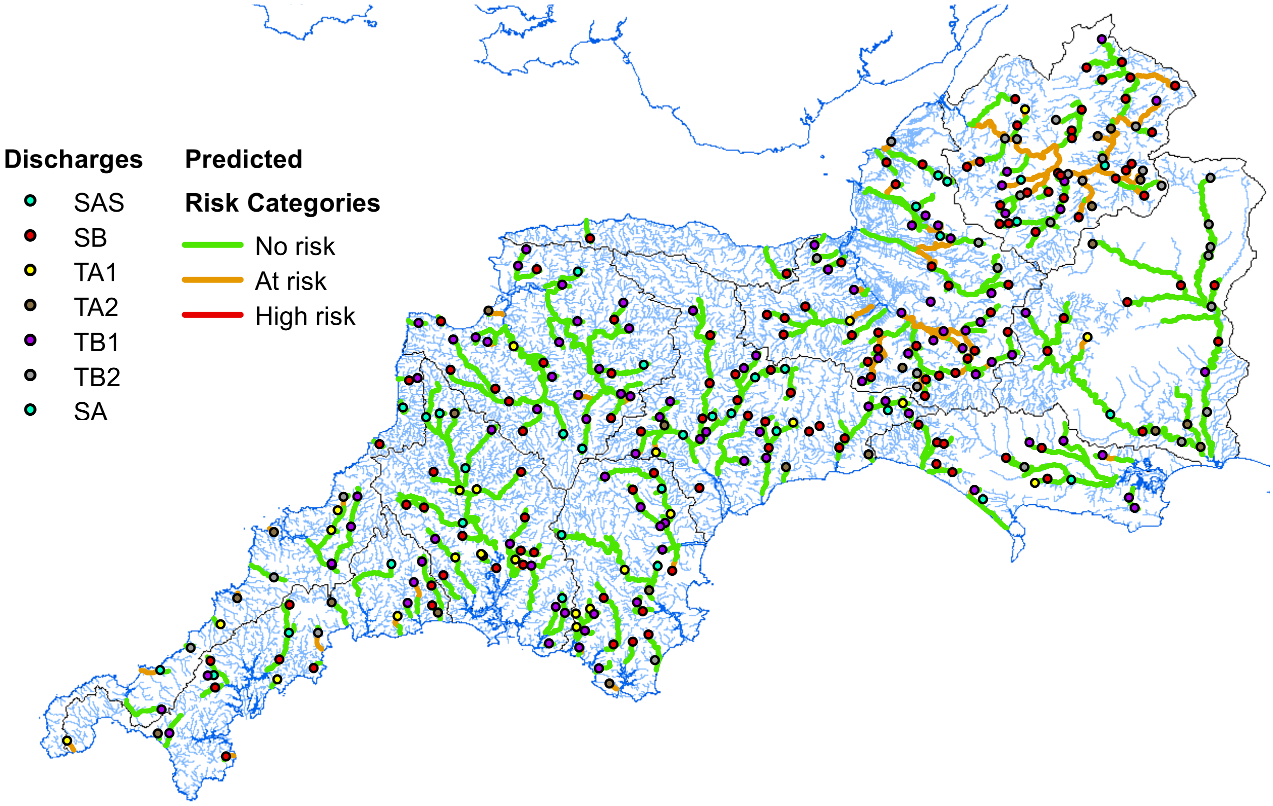

Figure 6.16 **Spatial distribution of predicted risk categories in the South West region, based on mean concentrations**

Table 6.17 Predicted risk categories in the South West region

	Number reaches		Length (km)		% Total length	
Risk category	**Mean**	**90th**	**Mean**	**90th**	**Mean**	**90th**
No risk	1216	998	2,462	2,059	84	70
At risk	316	489	461	821	16	28
High risk	16	61	6	49	> 1	2

The reaches at 'high risk' within the South West region were further investigated in order to locate the source STPs across the region and to identify the possible causes of the risk. The results of this investigation are presented in Table 6.14 (ranked according to the oestrogen concentration for these particular reaches).

The low risk predictions for this region are mainly due to the relatively high runoff and the low levels of urbanisation (the population density is estimated at around 190 inhabitants per km^2; Table 6.1).

Within most of the reaches classified as 'high risk' in the South West region, the E2 equivalent average concentration ranges between 10ngL^{-1} and 15ngL^{-1}. All reaches with E2 equivalent concentrations between 15ngL^{-1} and 20ngL^{-1} appear to be effluent drains downstream of BFPs with low oestrone removal efficiencies (

Table 5.4).The highest predicted E2 equivalent concentration is approximately 29ngL^{-1} in the River Chew, downstream of Chew Stoke STP.

Table 6.18 Estimated oestrogen concentrations for the predicted 'high risk' reaches in the South West region

Location	Length (m)	E1 (ng.l^{-1})			E2 (ng.l^{-1})			EE2 (ng.l^{-1})			E2 Eqv (ng.l^{-1})			Comments
		Mean	SD	90th	Mean	SD	90th	Mean	SD	90th	Mean	SD	90th	
Kingston Seymoor STP (TB2), drain		13.25	7.64	22.41	1.75	1.29	3.35	0.47	0.28	0.80	10.89	6.66	18.87	Low dilution
Sutton Benger STP (SB), ditch draining into River Avon		19.89	10.35	32.69	1.17	0.85	2.27	0.31	0.19	0.55	10.95	6.17	18.64	Low dilution
Kingston Seymoor STP (TB2), drain		13.84	8.01	23.33	1.83	1.34	3.52	0.49	0.30	0.83	11.37	6.98	19.65	Low dilution
Kingston Seymoor STP (TB2), drain		14.00	8.13	23.60	1.86	1.36	3.58	0.50	0.30	0.84	11.50	7.08	19.90	Low dilution
Kingston Seymoor STP (TB2), drain		14.48	8.50	24.54	1.93	1.41	3.75	0.51	0.32	0.87	11.88	7.41	20.65	Low dilution
Chudleigh STP (TA1), STP drain (River Teign)		15.13	10.72	28.89	1.94	1.77	4.29	0.52	0.38	1.02	12.15	9.13	24.15	STP drain
Draycott STP (TB1), Dolmead Rhyne		15.48	9.90	28.52	1.87	1.55	3.99	0.51	0.37	1.02	12.17	8.60	23.72	Low dilution
Chard STP (SB), tributary of River Isle		22.90	11.81	38.21	1.40	1.01	2.71	0.38	0.22	0.65	12.82	7.13	21.95	Low dilution
Martock STP (SB), Hinton Meads Brook (Parrett River)		23.41	14.22	41.69	1.43	1.17	3.02	0.38	0.26	0.71	13.01	8.47	24.07	Low dilution
Potterne STP (TA2), tributary of Semington Brook		16.69	9.19	28.37	2.18	1.61	4.22	0.58	0.34	0.99	13.51	8.09	23.58	Low dilution
Ringwood STP (TB2), canal diversion of River Avon		17.51	9.41	29.18	2.38	1.74	4.65	0.63	0.36	1.09	14.54	8.51	25.29	Flow representation
Ringwood STP (TB2), canal diversion of River Avon		17.77	9.55	29.53	2.42	1.77	4.74	0.64	0.37	1.10	14.75	8.63	25.57	Flow representation
Ratfin STP (SB), STP drain (River Avon)		18.78	10.63	31.44	2.52	1.80	4.88	0.67	0.40	1.15	15.44	9.31	26.81	STP drain
Wootton Bassett STP (SB), STP drain (Brinkworth Brook)		30.11	16.50	51.09	1.82	1.39	3.62	0.49	0.31	0.88	16.74	9.98	29.47	STP drain
Wellington STP (SB), STP drain (River Tone)		33.83	19.18	54.99	2.13	1.59	4.00	0.55	0.32	0.95	18.96	11.22	31.87	STP drain
Chew Stoke STP (SB), River Chew		52.45	26.46	84.49	3.21	2.31	6.30	0.85	0.50	1.47	29.23	16.13	49.14	Low dilution

6.10 Evaluation of the model outputs

In this project, the model simulated BOD, chloride and ortho-phosphate concentrations, in addition to steroid oestrogen concentrations. This was done to test the model against observed data derived from the Environment Agency GQA sampling programme. These three compounds are known to be highly dependent on STP discharges and therefore give an indication as to whether all the main discharges have been included in a catchment model. In each hydrometric area, where there were sufficient data available, the predicted and observed mean concentrations of these three compounds were plotted and compared along the river profiles. In a large majority of cases, the agreement between the observed and predicted values was judged to be acceptable, thereby giving reasonable confidence that the model predictions incorporate the effects of the influential STPs on water quality. By extension, this finding provides increased confidence in the model predictions for the steroid oestrogens.

There are some examples in the literature of modelling the fate of oestrogen, and also of GIS (geographical information systems) models being used to predict contaminants from STPs. The first step in predicting concentrations throughout a catchment is to make an accurate prediction of either the effluent or the immediate receiving water concentration downstream of the point source. Vermeirssen *et al.* (2006) used the oestrogen excretion and effluent model (Johnson and Williams 2004) and found that it routinely overestimated effluent concentrations in one Swiss STP by a factor of two over a 48-day period. Using the same model, Johnson *et al.* (2007) compared modelled effluent E1 concentrations with observed values for 22 STPs listed in an Environment Agency monitoring study (2003). The original sampling data were from spot samples rather than composite samples, so were not ideal for this comparison. When comparing predicted versus observed data, every time a real measurement was recorded (39 data points) the mean predictive accuracy was within a factor of 3.9 (median 2.1) for E1 and a factor of 4.3 (median 3.2) for E2, with standard deviations of 4.9–5. This means that there was a general tendency to overestimate effluent concentration.

Unfortunately, there has not yet been any corroboration of oestrogen predictions with oestrogen measurements at a catchment scale. However, a number of tests have been carried out using GREAT-ER, a model that is very similar to LF2000-WQX. Schulze and Matthies (2001) reviewed the ability of GREAT-ER to predict the concentrations of linear alkyl sulfonate (LAS) in the Rur catchment in Germany. The LAS concentrations had been measured over a number of years by Henkel, a major chemical producer, with values ranging from 0.5–12μgL^{-1}. The model predicted flows well (within a factor of two) using boron measurements (as a conservative tracer) taken by the local environment agency and, overall, the LAS predictions were within a factor of three of the measured values. A comprehensive test of the ability of the GREAT-ER model to predict concentrations of four different xenobiotic chemicals was carried out along 19km of the urbanised River Itter in Germany (Wind *et al.* 2004). The predicted values were within a factor of 1.5 of measurements obtained from 24-hour composite samples for the observed boron concentrations, and within a factor of 2.9 for LAS, 1.4 for EDTA, and 1.2 for triclosan.

The best example of testing in a real way how close a model prediction is to reality can be found in Jobling *et al.* (2006). In this study, combined oestrogen predictions expressed as oestradiol equivalents (E1 + E2 +EE2/0.2) for around 40 STP effluents and their receiving waters were divided into three risk classes according to their potential to cause endocrine disruption in fish. These predictions were found to fit well with the incidence and severity of intersex in fish found downstream of the STPs. This study provides a rare example of model predictions of chemicals being validated against observed biological effects in aquatic wildlife.

In summary, not many studies correlating predicted to measured concentrations of chemicals have yet been conducted for either sewage effluent or receiving waters/catchments. However, the examples that do exist are encouraging, particularly because chemical measurements of oestrogens in environmental samples can themselves vary by a factor of two or more when inter-laboratory comparisons are carried out (Johnson *et al.* 2005).

7 Conclusions of the regional risk assessment

A summary of the results obtained from modelling the predicted risk of oestrogen exposure in the Environment Agency regions is presented in Table 7.1. The total length of reaches falling into each category is given in kilometres and is also expressed as a percentage of the total modelled length (in brackets).

Table 7.1 Summary of the distribution of reaches across risk categories based on mean concentrations, expressed in total km and as a percentage of total river length modelled (in brackets) for each region

	Anglian	Southern	Thames	Wales	Midlands	North East	North West	South West	Total
No risk	2,434 (48)	981 (65)	509 (30)	2,597 (95)	1,329 (43)	1,646 (61)	1,169 (65)	2,462 (84)	13,127
At risk	2,571 (50)	508 (34)	1,107 (67)	133 (5)	1,691 (55)	1,004 (38)	601 (34)	461 (16)	8,076
High risk	89 (2)	10 (1)	44 (3)	1 (>1)	50 (2)	33 (1)	16 (1)	6 (>1)	249
Total	5,094	1,499	1,660	2,731	3,070	2,683	1,786	2,929	21,452

Overall, the majority of the reaches in England and Wales (61 per cent of the total length of rivers modelled) were predicted to be at 'no risk' from the effects of endocrine disruption under mean concentrations (PEC/PNEC< 1). However, this means that 39 per cent of reaches remain at risk (PEC/PNEC>1). The 'at risk' proportion is not evenly distributed around the country, with the lowest proportions predicted for Wales and the South West (5 per cent and 16 per cent respectively). The Southern, North East, and North West regions have approximately average proportions of reach lengths predicted to be at risk, with 34 per cent, 38 per cent and 34 per cent respectively. The highest proportion of reaches predicted to be at risk were found in the Thames, Midlands, and Anglian regions, with 67 per cent, 55 per cent and 50 per cent respectively. Key factors influencing the proportion of river reaches being at risk are their location and aggregation, the population density, and the available dilution (a combination of rainfall, runoff and evaporation). As might be expected, 'at risk' predictions are most prevalent where these factors occur in combination, such as areas of high conurbation with little rainfall and high evaporation (Thames region). However, risk still occurs in populace areas with reasonable run-off (North West region) and in dry areas with fewer inhabitants (Southern region).

A very small proportion of reaches – around 1 per cent (expressed as a percentage of the total length of river modelled) – were predicted to be at 'high risk' (>10 ngL^{-1} E2 equivalent), equating to approximately 250km in total. However, many of these 'high risk' reaches were either drains from STPs or natural ditches/headwater streams that were composed almost entirely of sewage effluent.

The high proportion of reported intersex in wild roach in two Environment Agency national surveys (1995 and 2003; male intersex fish were found at almost all the 47 sites sampled across England) suggests that the risk levels predicted here may not be unreasonable, at least for roach. Given this prevalence of intersex fish and the high population density in parts of England and Wales, it is not unexpected that the model should predict a considerable proportion of river reaches to be ‘at risk’.

In summary

- The majority of reaches (61 per cent) in England and Wales are not predicted to be at risk of endocrine disruption.
- A significant minority (39 per cent) are predicted to be at risk of endocrine disruption, based on a PEC/PNEC comparison equating to $1 ngL^{-1}$ E2 equivalents.
- All regions have some locations ‘at risk’, although this category is more widespread in the Thames, Anglian and Midlands regions. The frequency of occurrence is higher in areas of high conurbation or low run-off, and is most prevalent where these factors combine.
- A very small proportion of river reaches are predicted to be in the ‘high risk’ category (having >10ng/L E2 equivalents), but many of these locations are drains or ditches comprising close to 100 per cent effluent.
- A methodology for identifying the degree of improvement required at STPs to produce an acceptable environmental concentration ($<1 ngL^{-1}$) has been developed.

This risk assessment has been based on readily available data sets and due diligence has been taken in ensuring that these data are quality controlled. However, there are limitations associated with the underlying data and outstanding issues that will contribute to an unknown part of the model uncertainty. These include: the assumption that a correct association has been made between each STP and it’s receiving water course; the use of estimated DWFs rather than measured values; the use of a universal removal efficiency for STPs (except for biological filters); and any further refinement of the PNEC that would change the calculated E2 equivalent concentrations and the risk thresholds. For these reasons, it will be necessary to revisit the underpinning dataset to improve and refine the risk assessment in accordance with developments in the scientific understanding of steroid effects in the species of concern and any new treatment possibilities/efficiencies. The specific objectives of any strategy for environmental improvement or risk reduction will also need to be considered.
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8 Risk assessments for European (SAC) sites

8.1 Introduction

An important part of the regional risk assessment model for potential endocrine disruption is the need to ensure that European sites (SACs) and their associated upstream catchments are considered in detail. The riverine SAC sites for England and Wales are listed in Table 8.1.

Table 8.1 Riverine SAC sites in England and Wales

SAC code	SAC name	
UK0013016	River Avon	England
UK0030248	River Axe	England
UK0030056	River Camel	England
UK0030074	Afonydd Cleddau/Cleddau Rivers	Wales
UK0030250	River Clun	England
UK0030252	River Dee and Bala Lake/Afon Dyfrdwy a Llyn Tegid[1]	Wales
UK0030253	River Derwent	England
UK0030032	River Derwent and Bassenthwaite Lake[1]	England
UK0012643	River Eden	England
UK0012599	River Itchen	England
UK030256	River Kent	England
UK0030257	River Lambourn	England
UK0030258	River Mease	England
UK0012691	River Tweed	England
UK0012647	River Wensum	England
UK0012642	River Wye/Afon Gwy	Wales/England
UK0030075	Afon Eden – Cors Goch Trawsfynydd	Wales
UK0030046	Afon Gwyrfai a Llyn Cwellyn	Wales
UK0012670	Afon Teifi	Wales
UK0013010	Afon Tywi	Wales
UK0013007	River Usk/Afon Wysg	Wales

Notes: 1. Modelling steroid oestrogens in lakes is outside of the scope of this project; however, the riverine component of the SAC will be modelled.

The risk assessment approach for SAC sites was developed in conjunction with English Nature and the Countryside Council for Wales. The initial aim was to determine which reaches within each SAC fell into ‘no risk’, ‘at risk’ and ‘high risk’ categories, in the same manner as for the regional risk assessment. However, while it is desirable to distinguish 'high risk' sites from 'at risk' sites (so that the catchments of most concern can be identified), it is important to be aware that SACs are afforded special protection in law and thus it is imperative that the integrity of such sites be preserved. Competent Authorities can only authorise a plan or project if they are certain that it will not adversely affect the integrity of a SAC. Obviously, the level of concern associated with oestrogenic exposure at a site is influenced by its ecological value and the level of protection afforded. Thus, a SAC or SSSI (site of special scientific interest) categorised as 'at risk' may still be a high priority for remedial action.

This consideration led to an additional risk categorisation method being applied to the SAC sites, alongside the one used in the regional risk assessment. This method uses a more stringent PNEC for EE2 of 0.06ngL^{-1}, applying some of the supporting data from the literature review to the equations that calculate the E2 equivalent concentrations and define the boundary between 'no risk' and 'at risk' sites (see section 8.2.3). There was no threshold set for 'high risk' sites, as all sites at risk within a SAC are considered a priority.

There were three specific objectives for this risk assessment.

- A map comparison exercise to ensure that the catchments included in the regional model provided coverage for the habitat (SAC) sites.
- Additional modelling of all STPs falling within SAC sites, plus modelling those upstream STPs that contribute to 98 per cent of the DWF.
- Predicting the receiving water concentrations of steroid oestrogens throughout the SAC sites and the associated risk categories using both the regional risk assessment approach and the approach designed for SAC sites for each river reach modelled.

8.2 Methods

This section describes the methods adopted to address the three objectives detailed above:

8.2.1 Assessing suitable coverage

An ArcGIS shape file[7] showing the locations of all the SAC sites in England and Wales was used to identify the boundaries of the riverine SAC sites given in Table 8.1. Of the 21 riverine sites, 12 were then selected for modelling (on the basis that resources were not available to model all 21). Following this, two new shapefiles were created representing the 12 riverine SAC sites to be modelled (Figure 8.1). The model setup procedure involves displaying all the information available using ArcGIS for each area and utilising the software to edit the input files used by the model to ensure that all the necessary data are available. The SAC shapefiles are then displayed to ensure that the area modelled includes the whole of the SAC.

[7] ArcView is a GIS that provides a platform for viewing and manipulating spatial data. A shapefile is a particular set of files containing the information required to display the spatial information.

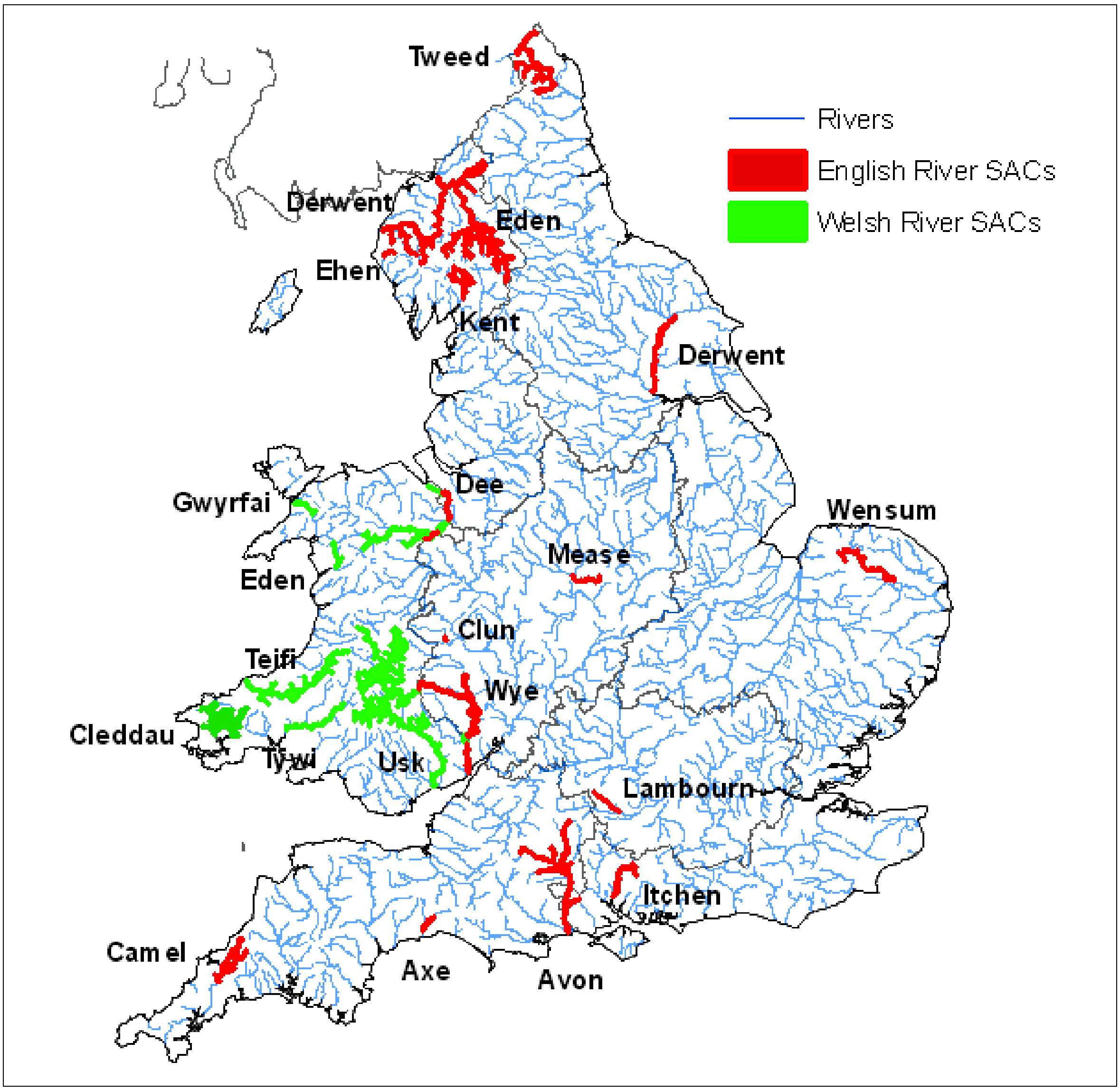

Figure 8.1 Location map showing the SACs to be included in the steroid oestrogen risk assessment

8.2.2 Inclusion of additional STPs

An estimate of individual steroid oestrogen concentrations, total E2 equivalent concentrations and risk was calculated for all reaches within SAC sites as a part of the regional risk assessment. This regional assessment included discharges accounting for 95 per cent of the DWF in the catchment. For SAC sites, discharges from more of the STPs contributing to the DWF were included. These comprised:

- all municipal STP discharges consented under the Water Resources Act that fall within the SAC;
- and those municipal STP discharges consented under the Water Resources Act that account for 98 per cent of the DWF for the catchment draining to the upstream point of the SAC.

8.2.3 Predicted environmental concentrations of steroid oestrogens and risk level

The outputs of the risk assessment take two forms for each SAC.

1. A table comprising data for every reach within the catchment containing the SAC. The reaches within the SAC are highlighted, as are those that receive a STP discharge. The table has the following columns.
   a) Reach identifier.
   b) NGR top of reach, NGR bottom of reach.
   c) Length of reach.
   d) Predicted concentrations of E1, E2 and EE2 for mean flow and P_{90} flow (and standard deviation).
   e) Predicted E2 equivalent concentrations for mean flow and P_{90} flow conditions, calculated using the relative potencies for the steroids as described in the regional risk assessment.
   f) Risk class ('no risk', 'at risk', 'high risk') for the mean and P_{90} concentrations using the same categories as those used for the regional risk assessment (see left hand side of Table 8.2).
   g) Risk class ('no risk', 'at risk') for the mean and P_{90} concentrations. This is derived by comparing an E2 equivalent concentration calculated using a PNEC of $0.06 ngL^{-1}$ for EE2 (instead of $0.1 ngL^{-1}$) with a threshold between 'no risk' and 'at risk' calculated in the same manner (see right hand side of Table 8.2).

2 A colour coded map showing the risk categories for the river basin in which the SAC resides. The extent of the SAC and the STPs that were included in the risk assessment are also shown. These maps are drilled down from the regional risk assessment and therefore use the same categories (see left hand side of Table 8.2)

Table 8.2 Risk categories and threshold

Risk category	Classification criteria	
	Regional risk assessment	**SAC site risk assessment**
No risk	$\frac{[EE2]}{0.1}+\frac{[E2]}{1}+\frac{[E1]}{3}<1$	$\frac{[EE2]}{0.06}+\frac{[E2]}{1}+\frac{[E1]}{3}<1$
At risk	$\frac{[EE2]}{0.1}+\frac{[E2]}{1}+\frac{E1}{3}>1$ and $\frac{[EE2]}{1}+\frac{[E2]}{10}+\frac{[E1]}{30}<1$	$\frac{[EE2]}{0.06}+\frac{[E2]}{1}+\frac{[E1]}{3}>1$
High risk	$\frac{[EE2]}{1}+\frac{[E2]}{10}+\frac{[E1]}{30}>1$	Not Used

8.3 Results

This section presents the results that have been obtained for the 12 riverine SAC sites listed below (for convenience, the Afonydd Cleddau SAC has been modelled as two sites). Due to the constraints of the project, nine English sites have not been modelled (see Table 8.1).

- River Lambourn
- Afon Tywi
- River Wye/Afon Gwy
- Afon Teifi
- Afon Eden – Cors Goch Trawsfynydd
- Afon Wysg/River Usk
- Afon Gwyrfai a Llyn Cwellyn
- River Dee and Bala Lake/Afon Dyfrdwy a Llyn Tegid
- River Wensum
- River Itchen
- River Avon
- Afonydd Cleddau (Eastern)
- Afonydd Cleddau (Western)

The risk maps for all of the SACs are presented in the main text, while the tables of results are presented in Appendix D.

8.3.1 River Lambourn

The SAC area follows the River Lambourn from just north of the village of Lambourn to its confluence with the River Kennet. The SAC also includes the lower reaches of the Winterbourne (a tributary of the Lambourn), where the two rivers run parallel. Two STPs treating a population of ~5,200 discharge directly into the Lambourn SAC (types TB2 and SB) and two STPs treating a population of ~4,300 discharge into the Winterbourne (types TB1 and SA). There are four other STPs in the catchment (all type SB) treating effluent from ~600 people, but these discharge to the Chalk and have not been included in the risk assessment. A map of the River Lambourn with the SAC stretches highlighted is presented in Figure 8.2, showing the location and type of treatment of the STPs.

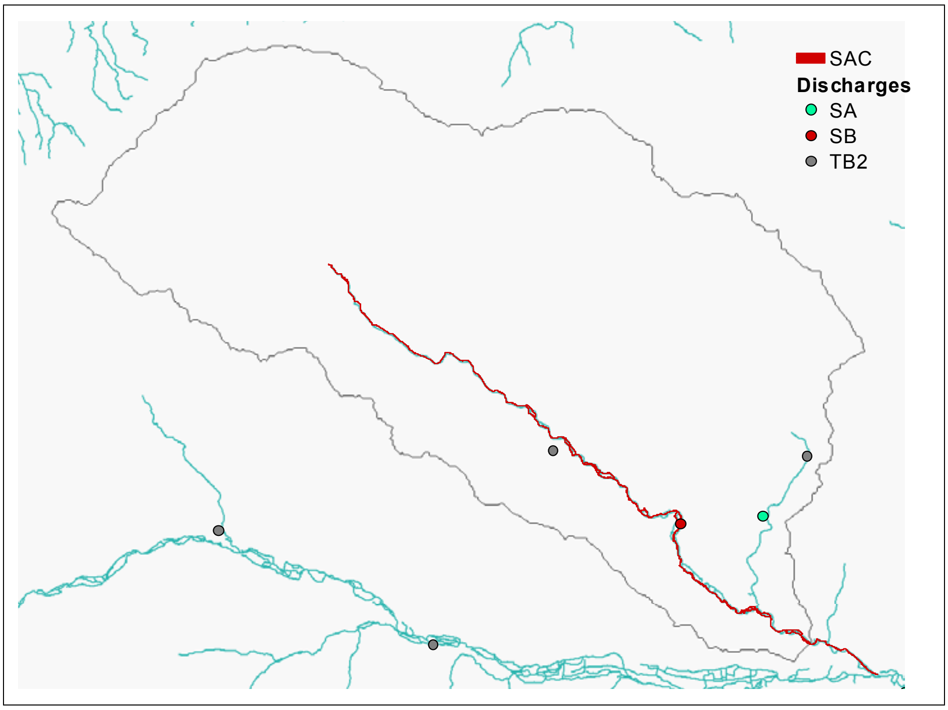

Figure 8.2 Map of the River Lambourn showing the SAC and the STPs to be included in the steroid oestrogen risk assessment

The results of the risk assessment are shown in Figure 8.3 and Table D.1. No reaches within the SAC are predicted to be 'at risk' using either the regional risk assessment approach or the risk assessment designed for SAC sites under mean flow conditions. If P_{90} concentrations are used then both risk assessment classifications predict that the lower reaches of the Winterbourne, just upstream of the confluence with the Lambourn, will be 'at risk'.

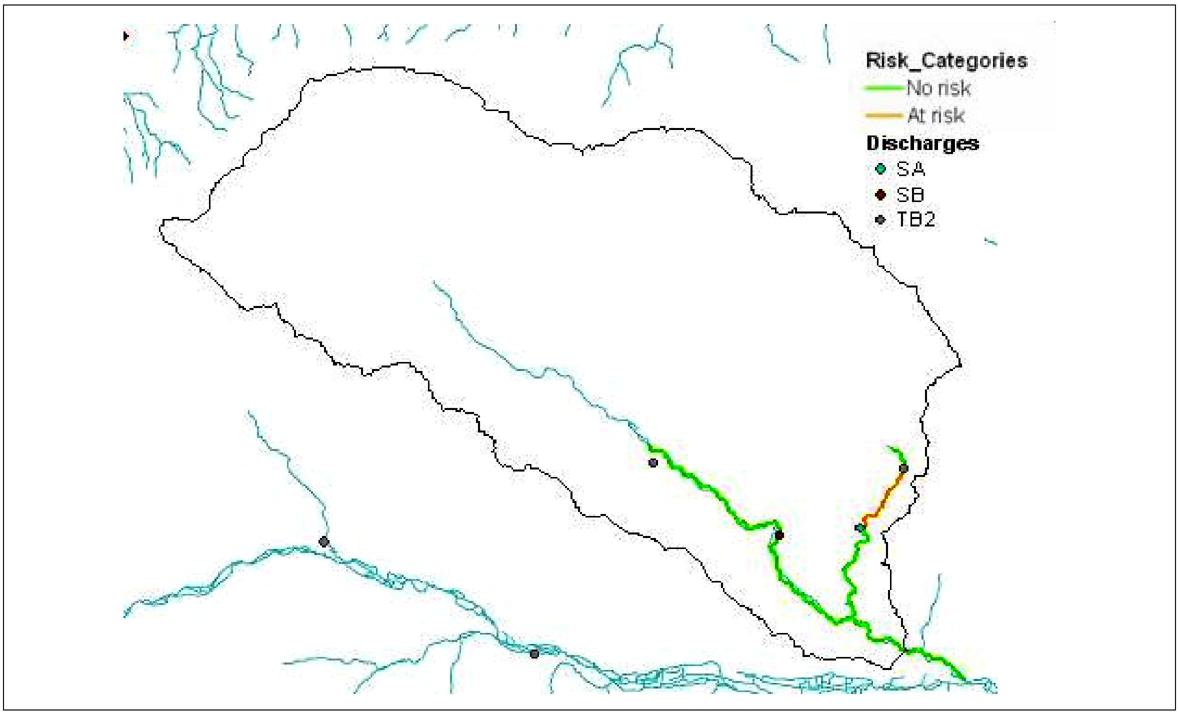

Figure 8.3 Map of the River Lambourn showing the oestrogen-associated risk derived from mean concentrations and applying the regional risk assessment approach

Outside of the SAC boundary, the reach below Chievely STP is 'at risk' using either risk assessment classification under mean concentrations. Under P_{90} concentrations, all of the Winterbourne below Chievely STP is predicted to be 'at risk', regardless of the risk assessment used.

8.3.2 Afon Tywi

The SAC follows the River Tywi from Llandovery down to Carmarthen. There are 33 STPs treating the effluent from ~11,000 people that drain into the SAC. Two of these STPs only conduct primary treatment (Ofwat Class P), 22 are BFPs (Ofwat Class SB), two are activated sludge (Ofwat Class SAS) and three conduct tertiary treatment (Ofwat class TB1 and TB2). A map of the River Tywi with the SAC stretches highlighted is presented in Figure 8.4, showing the location and type of treatment of the STPs.

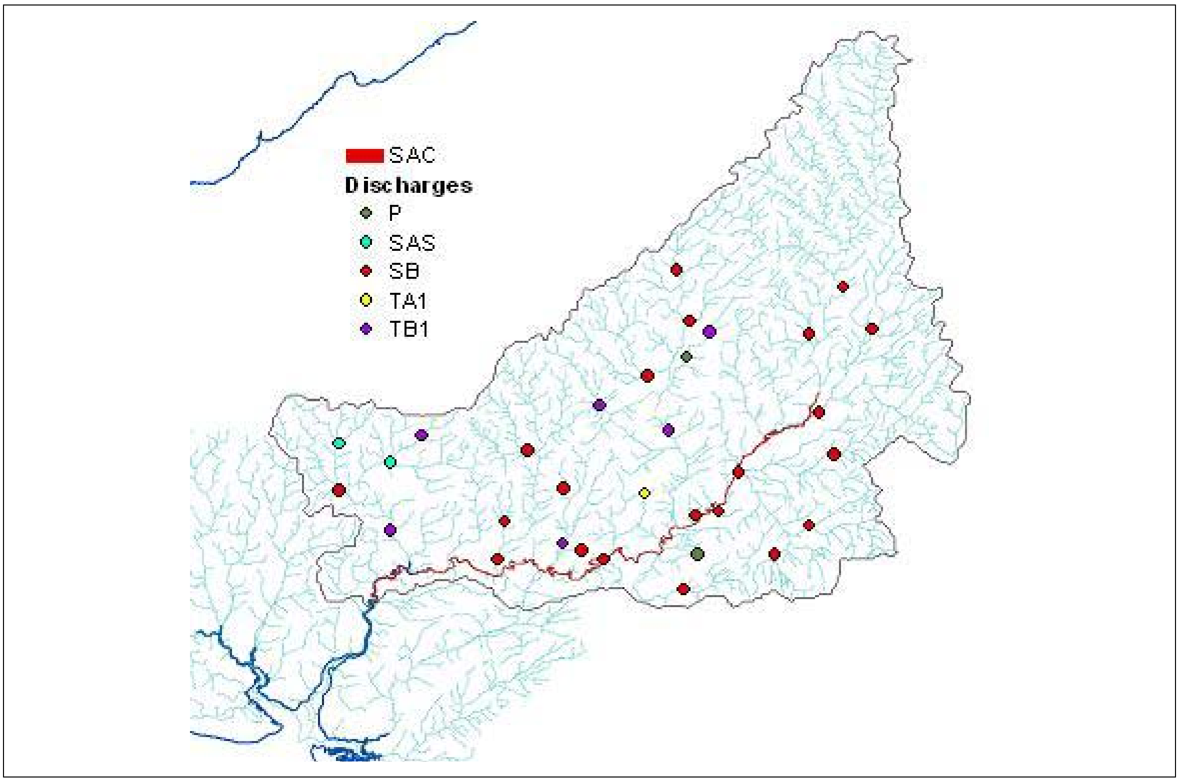

Figure 8.4 Map of the River Tywi showing the SAC and the STPs to be included in the steroid oestrogen risk assessment

The results of the risk assessment are shown in Figure 8.5 and Table D.2. These show that no stretches of the SAC would be ‘at risk’ from steroid oestrogens under mean or P_{90} conditions, even using the risk assessment categories designed for SAC sites. There is just one stretch within the wider catchment (downstream of Bryngwyn STP) that would be classified as ‘at risk’ under P_{90} conditions using this risk assessment approach.

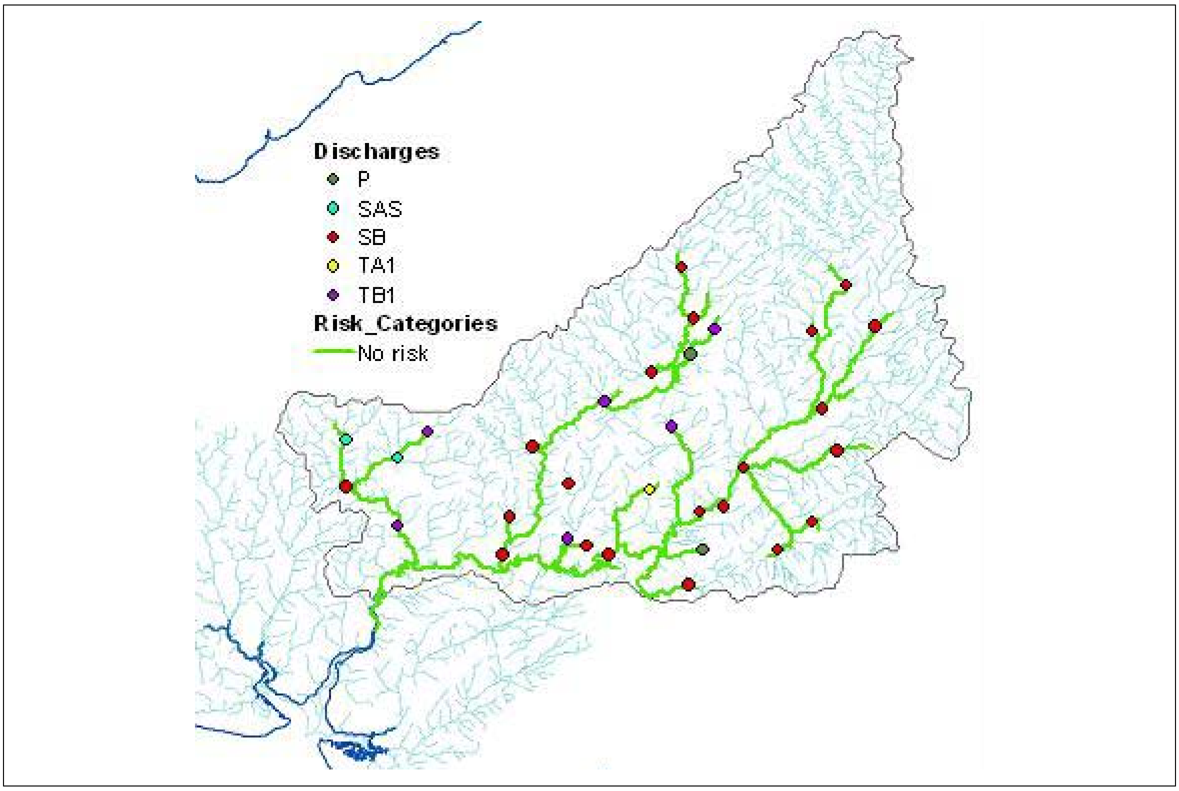

Figure 8.5 Map of the River Tywi showing the oestrogen-associated risk derived from mean concentrations and applying the regional risk assessment approach

8.3.3 River Wye/Afon Gwy

Most of the river Wye, from Pant Mawr (north of Llanguig) down to Chepstow, is classified as a SAC, including tributaries such as the rivers Lugg, Ithon and Monnow. The tidal limit of the river Wye (south of Monmouth) is the defined outlet of the catchment. The modelled area covers approximately 4100km^2 and includes 70 STPs treating the effluent from about 189,300 people. The majority of the STPs included in this risk assessment are Ofwat class SB (50 STPs), but there are also two STPs that only conduct primary treatment (Ofwat class P), two with activated sludge (Ofwat class SAS) and 16 that conduct tertiary treatment (Ofwat classes TA and TB). A map of the River Wye with the SAC stretches highlighted is presented in Figure 8.6, showing the location and type of treatment of the STPs.

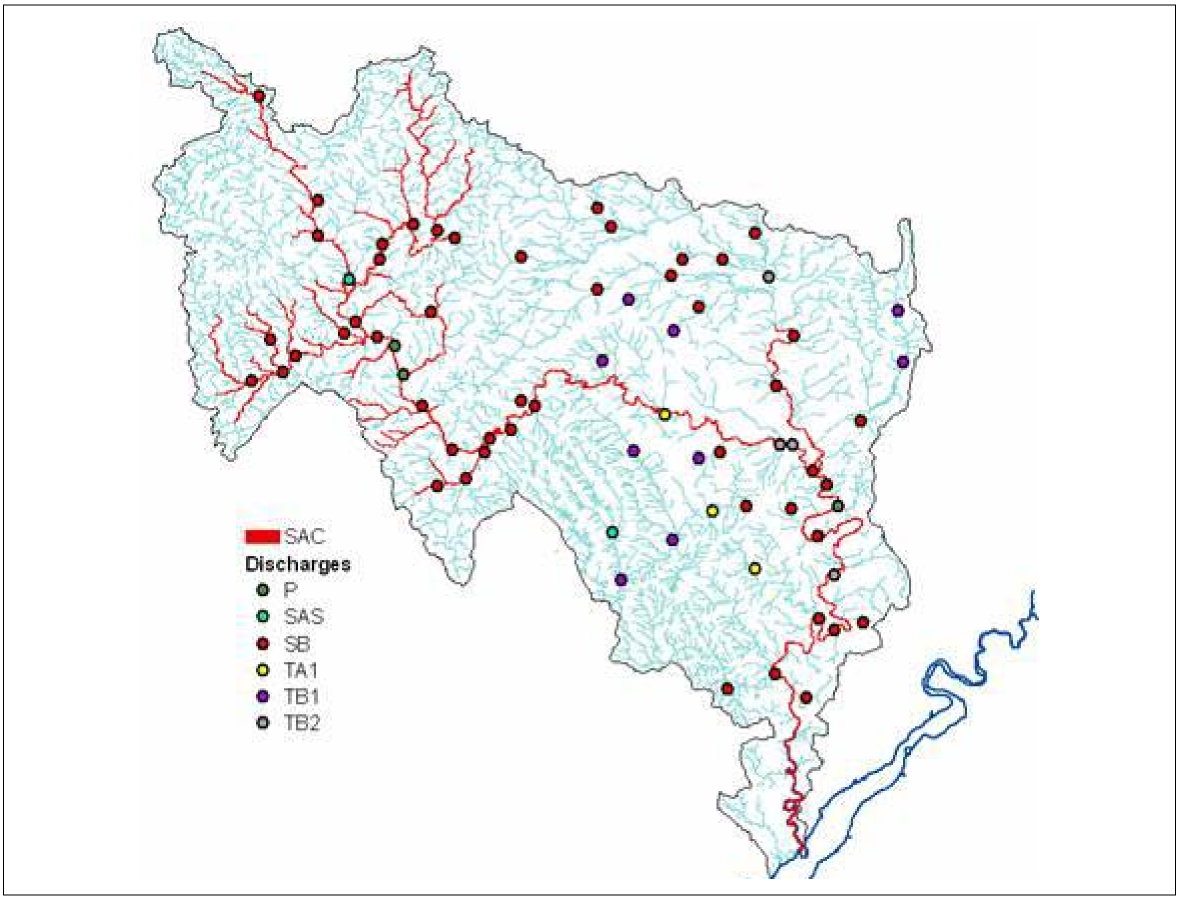

Figure 8.6 Map of the River Wye showing the SAC and the STPs to be included in the steroid oestrogen risk assessment

The results of the risk assessment are shown in Figure 8.7 and Table D.3. Within the SAC boundary, only one reach immediately downstream of Hereford STP is classified as 'at risk' when using the risk assessment designed for SAC sites and the P_{90} concentrations. Within the wider catchment, a further 20 stretches immediately below STPs are 'at risk' under these conditions (some comprising several river reaches), with 13 of these STPs also 'at risk' under mean flow conditions. If the regional risk assessment is used, three of these downstream stretches are classified as 'high risk' (Dilwyn STP, Ross STP and Luston and Yarpole STP). A further 16 are classified as 'at risk' under P_{90} conditions, with two remaining as 'high risk' (Ross STP and Luston and Yarpole STP) and eight as 'at risk' even under mean flow conditions.

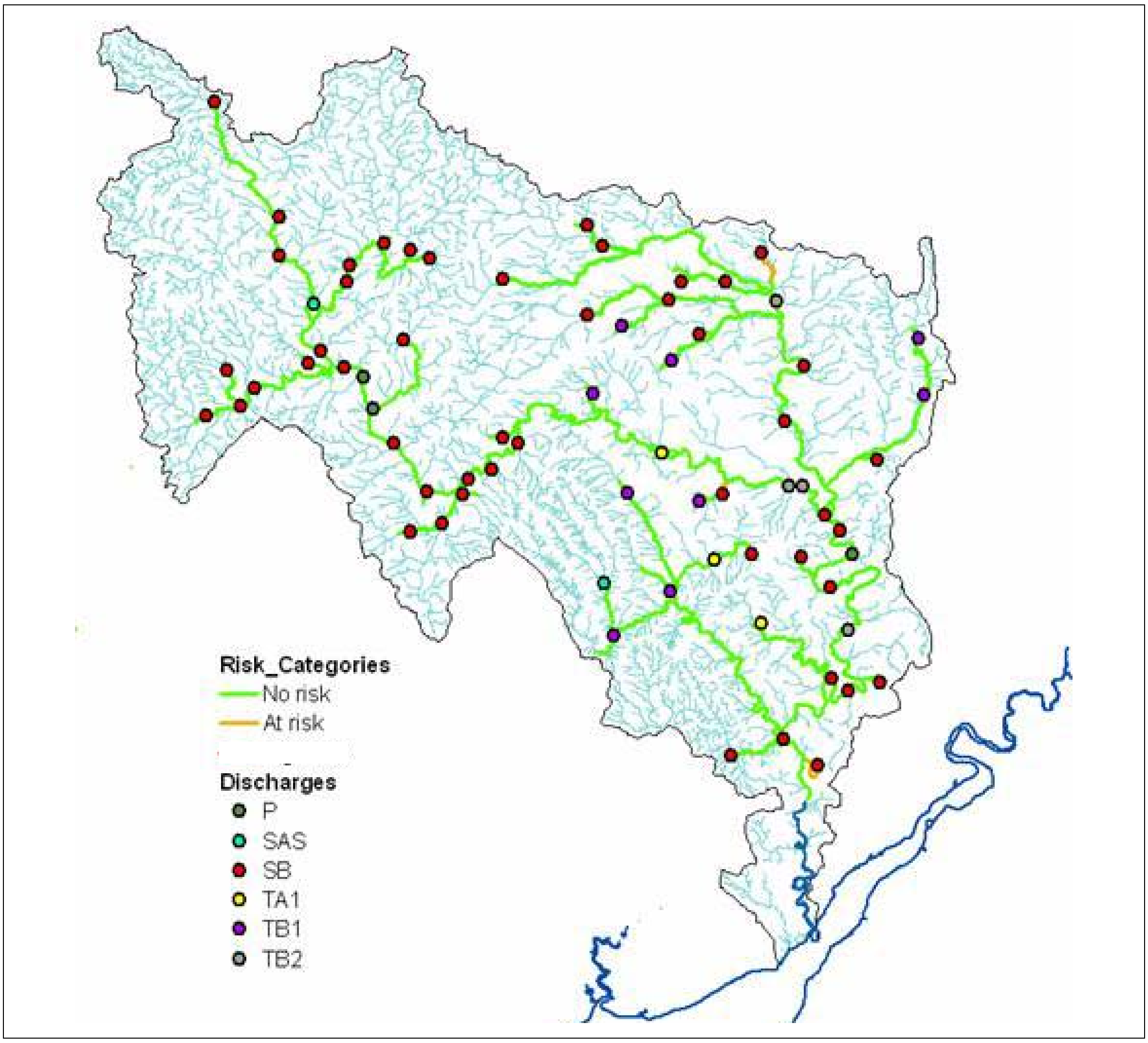

Figure 8.7 Map of the River Wye showing the oestrogen-associated risk derived from mean concentrations and applying the regional risk assessment approach

8.3.4 Afon Teifi

The SAC follows the River Teifi from Llyn Teifi down to its tidal limit near Cilgerran. The following tributaries of the river Teifi are included within the SAC: the River Cych, the River Ceri, the River Tyweli, the River Clettwr, the River Grannell, the River Dulas and the River Groes. This SAC covers a basin area of approximately 1010km^2 and comprises 27 STPs treating the effluent from ~18,800 people. Amongst these STPs, 21 are BFPs (Ofwat class SB), one only conducts primary treatment (Ofwat class P), one has activated sludge (Ofwat class SAS) and four conduct tertiary treatment (Ofwat class TB1). A map of the River Teifi with the SAC stretches highlighted is presented in Figure 8.8, showing the location and type of treatment of the STPs.

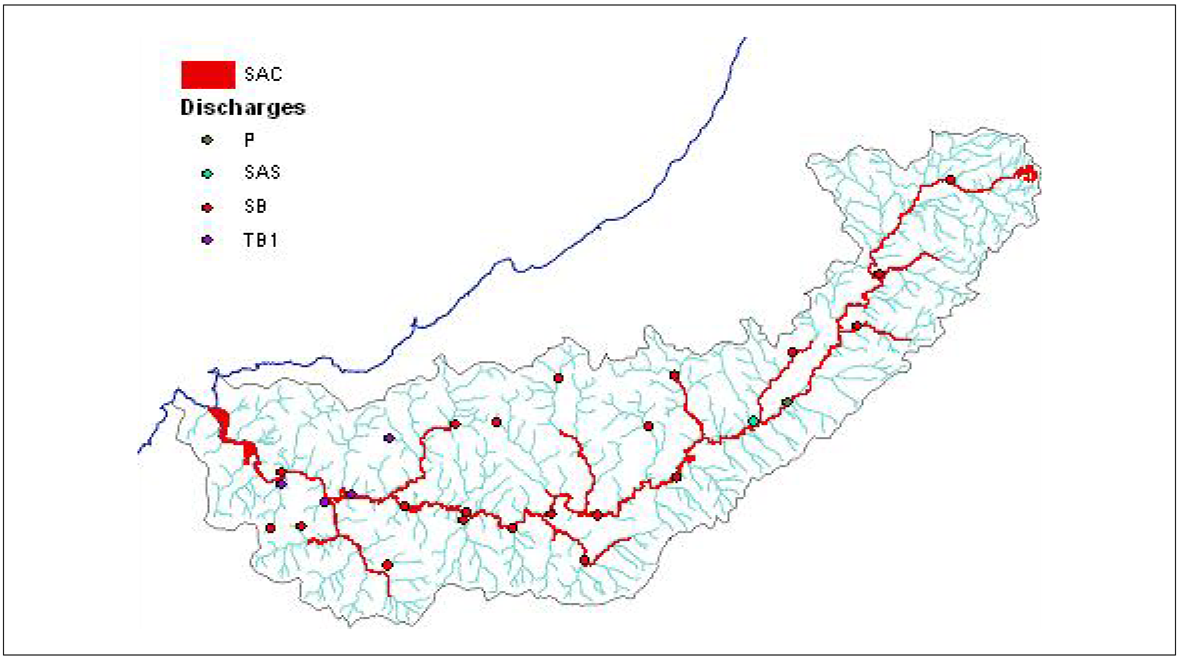

Figure 8.8 Map of the River Teifi showing the SAC and the STPs to be included in the steroid oestrogen risk assessment

The results of the risk assessment are shown in Figure 8.9 and Table D.4. Within the River Teifi SAC boundary, there are no river reaches 'at risk' under mean or P_{90} conditions regardless of the risk assessment approach used. Within the wider catchment, seven STPs are considered to put the immediate downstream reaches 'at risk' using the assessment approach designed for SAC sites under P_{90} concentrations, with four of these remaining 'at risk' under mean concentrations. Similarly, six STPs are upstream of 'at risk' reaches using the regional risk assessment approach under P_{90} concentrations, but only two (Beulah STP and Cellan STP) remain so under mean concentrations.

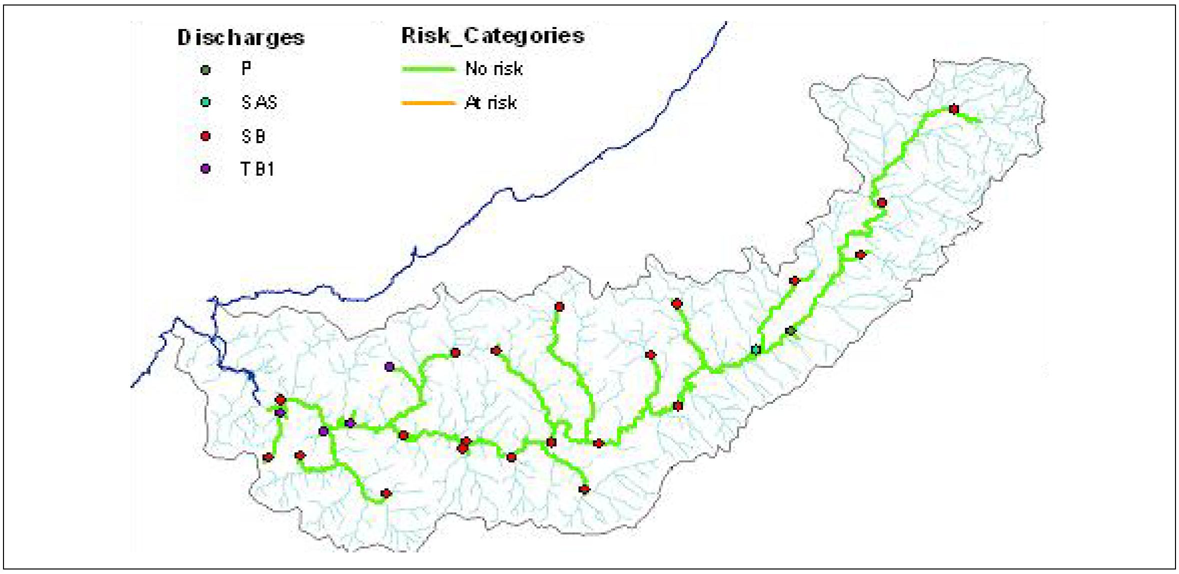

Figure 8.9 Map of the River Teifi showing the oestrogen-associated risk derived from mean concentrations and applying the regional risk assessment approach

8.3.5 Afon Eden – Cors Coch Trawsfynydd

The SAC follows the River Eden from Bron Aber down to its tidal limit near Llanelly and also includes the River Wen. This SAC covers a basin area of approximately 160km^2 and contains two STPs, both of type SB, treating the effluent from ~900 people. A map of the River Eden with the SAC stretches highlighted is presented in Figure 8.10, showing the location and type of treatment of the STPs.

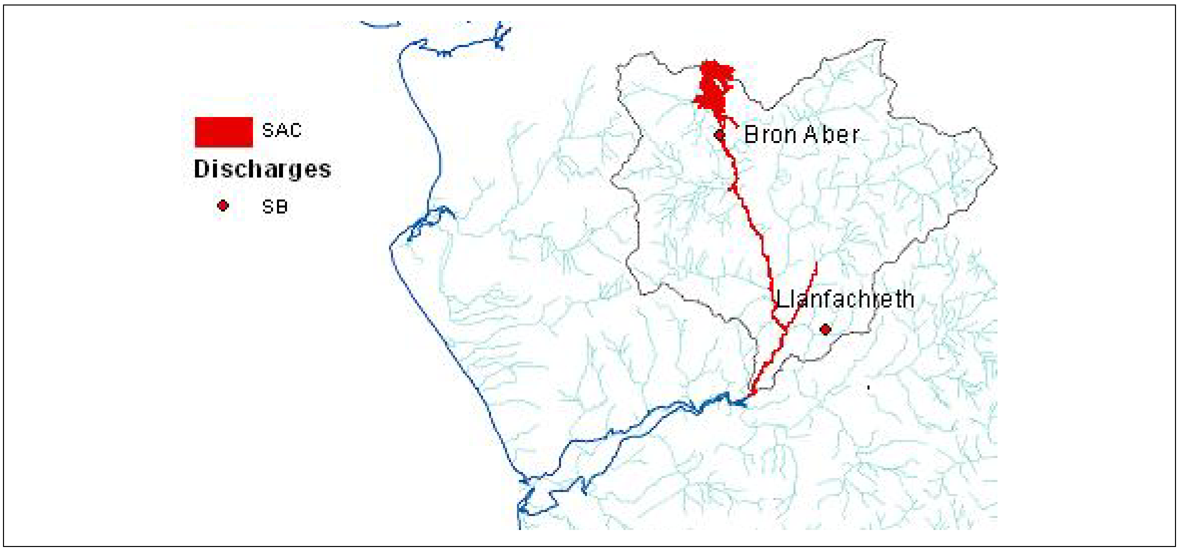

Figure 8.10 Map of the River Eden – Cors Goch Trawsfynydd showing the SAC and the STPs to be included in the steroid oestrogen risk assessment

The results of the risk assessment are shown in Figure 8.11 and Table D.5. These show that no reaches of the SAC or the wider catchment would be 'at risk' from steroid oestrogens, even using the assessment designed for SAC sites under P_{90} conditions.

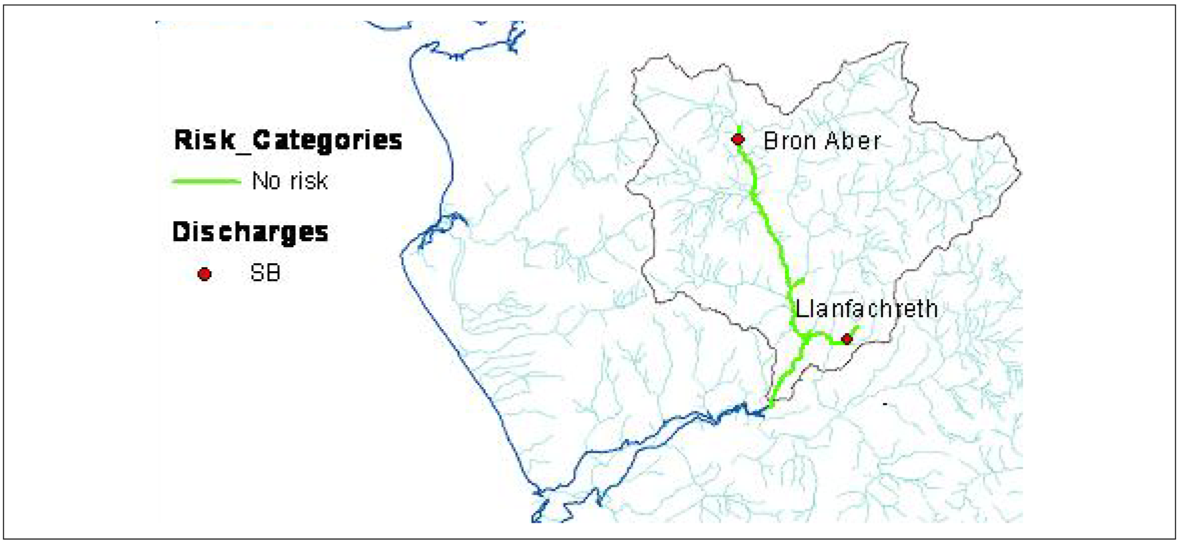

Figure 8.11 Map of the River Eden – Cors Goch Trawsfynydd showing the oestrogen-associated risk derived from mean concentrations and applying the regional risk assessment approach

8.3.6 Afon Wysg/River Usk

The SAC follows the River Usk from the Usk reservoir down to Newport. However, the risk assessment only considered the section of the SAC upstream of the River Usk tidal limit, located near the town of Caellion. The present SAC also includes several tributaries of the River Usk, such as the River Ysair and the River Honddu. This SAC covers a basin area of approximately 1300km^2 and comprises 31 STPs treating the effluent from ~48,600 people. The majority of these STPs are Ofwat class SB (25 STPs), but four are activated sludge (Ofwat class SAS), one only conducts primary treatment (Ofwat class P) and one conducts tertiary treatment (Ofwat class TB1). A map of the River Usk with the SAC stretches highlighted is presented in Figure 8.12, showing the location and type of treatment of the STPs.

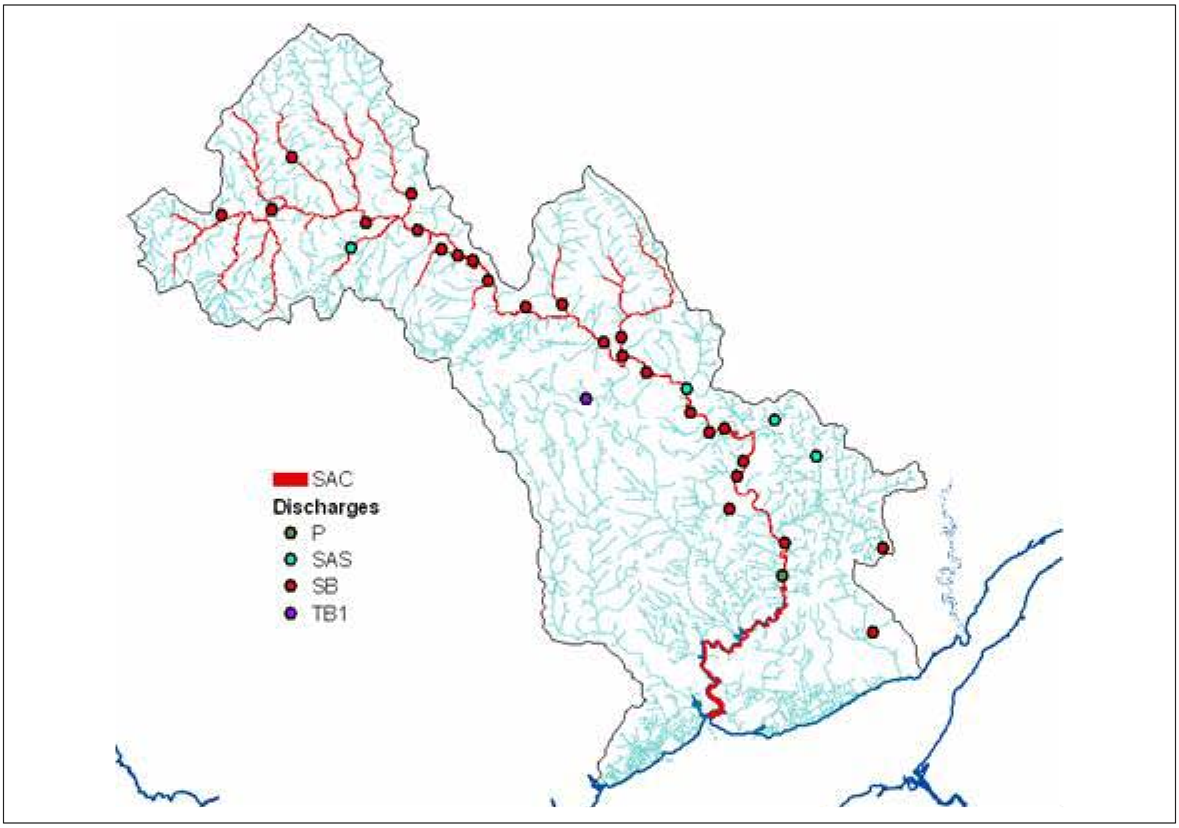

Figure 8.12 Map of the River Usk showing the SAC and the STPs to be included in the steroid oestrogen risk assessment

The results of the risk assessment are shown in Figure 8.13 and Table D.6. Within the River Usk SAC boundary, there are no river reaches at risk under mean or P_{90} concentrations using either of the risk assessment approaches. Outside the boundary of the SAC, the risk assessment designed for SAC sites shows that six STPs are considered to put the immediate downstream reaches 'at risk' under P_{90} concentrations and that three of these (Llanspyddid, Brynmwar and Devauden STPs) remain 'at risk' under mean concentrations. If the regional risk assessment approach is used, the outcome is the same except that there is one less STP associated with 'at risk' reaches under P_{90} concentrations.

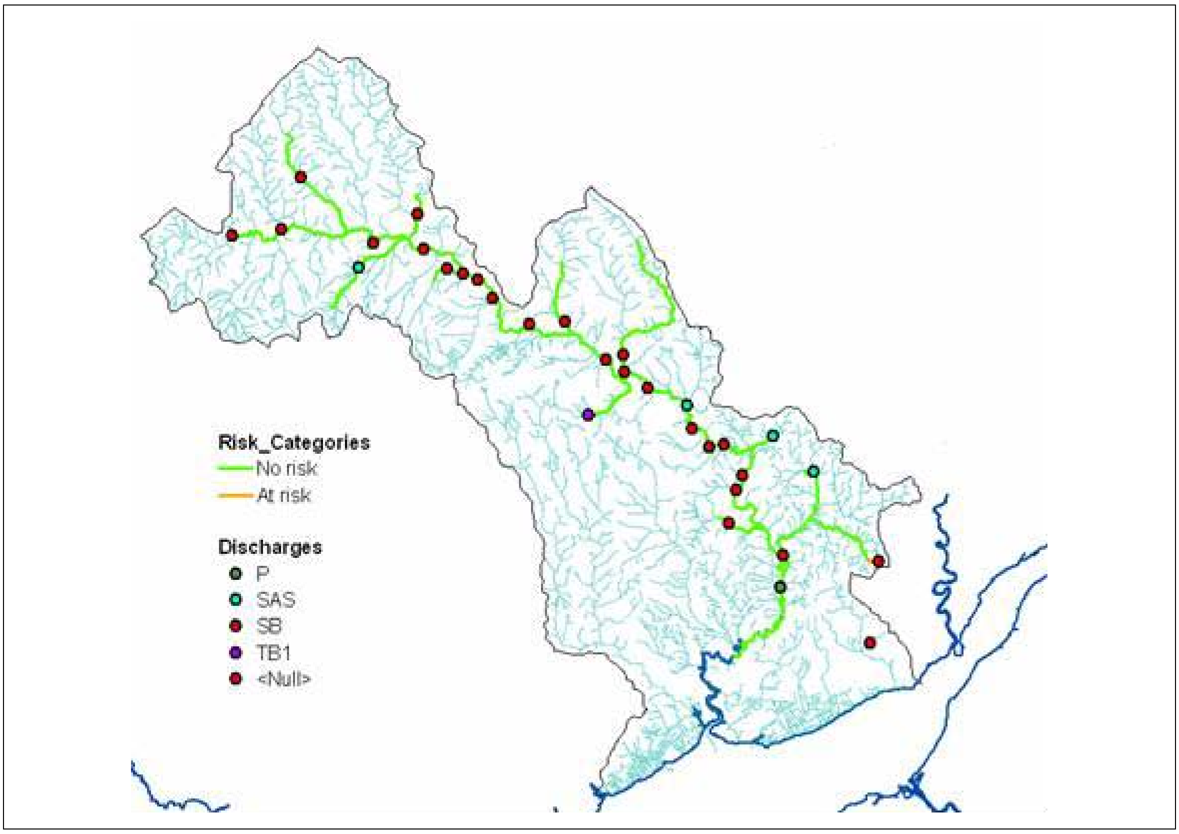

Figure 8.13 Map of the River Usk showing the oestrogen-associated risk derived from mean concentrations and applying the regional risk assessment approach

8.3.7 Afon Gwyrfai a Llyn Cwellyn

The SAC starts above Llyn Cwellyn and includes the Afon Treweunydd tributary and the lake itself. Below the lake, the SAC follows the river Gwyfrai to the point where it enters Foryd Bay. However, the modelled watercourse stops at the limit of tidal influence and does not include the lake (although the effect of the lake on the hydrological statistics is included). The SAC covers a basin area of about 53km^2, within which there are three STPs (Ofwat class P, SB and TB1) treating effluent from ~4,800 people. A map of the Afon Gwyrfai with the SAC stretches highlighted is presented in figure 8.14, showing the location and type of treatment of the STPs.

The results of the risk assessment are shown in Figure 8.15 and Table D.7. Within the SAC, under either mean or P_{90} concentrations, the reach below Llanfaglan STP is 'at risk' using either risk assessment approach. In the wider catchment, the small reach below Waunfawr STP would also considered to be 'at risk' using both risk assessment thresholds under P_{90} concentrations.

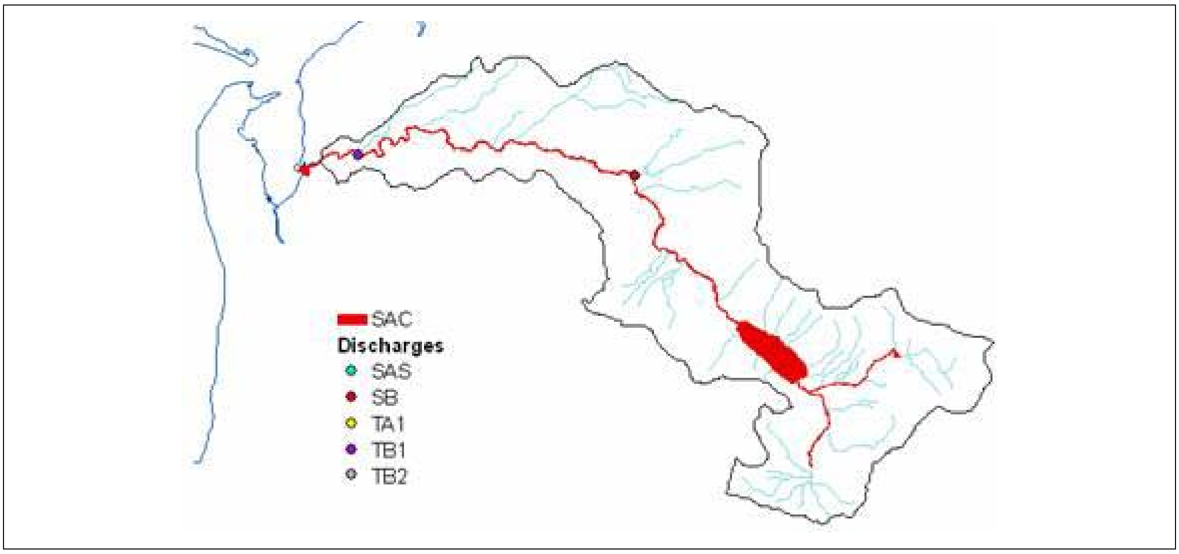

Figure 8.14 Map of the River Gwyrfai showing the SAC and the STPs to be included in the steroid oestrogen risk assessment

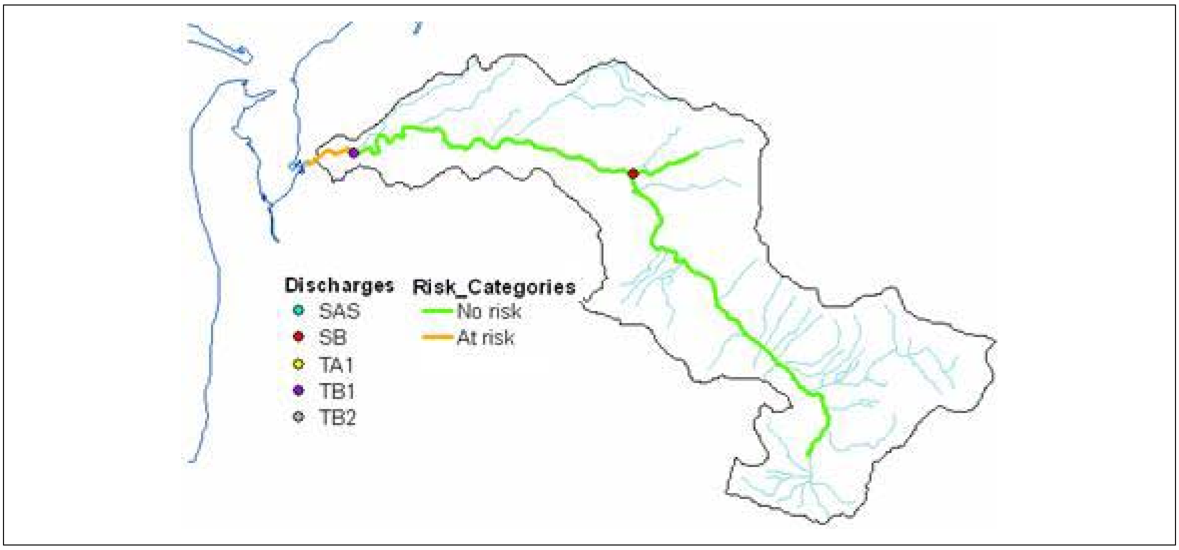

Figure 8.15 Map of the River Gwyrfai showing the oestrogen associated risk derived from mean concentrations and applying the regional risk assessment approach

8.3.8 River Dee and Bala Lake / Afon Dyfrdwy a Llyn Tegid

The SAC follows the River Dee from Llyn Celyn and Llyn Tegid down to its tidal limit near the town of Connah's Quay. The SAC also includes the River Ceirig, a tributary of the River Dee. This SAC covers a basin area of approximately 1,930km^2 and comprises 44 STPs treating the effluent from ~187,000 people. The majority of the STPs (28) are BFPs (Ofwat class SB), while five have activated sludge (Ofwat class SAS), five conduct tertiary treatment (Ofwat classes TA1 and TB1) and six conduct only primary treatment. A map of the River Dee with the SAC stretches highlighted is presented in Figure 8.16, showing the location and type of treatment of the STPs.

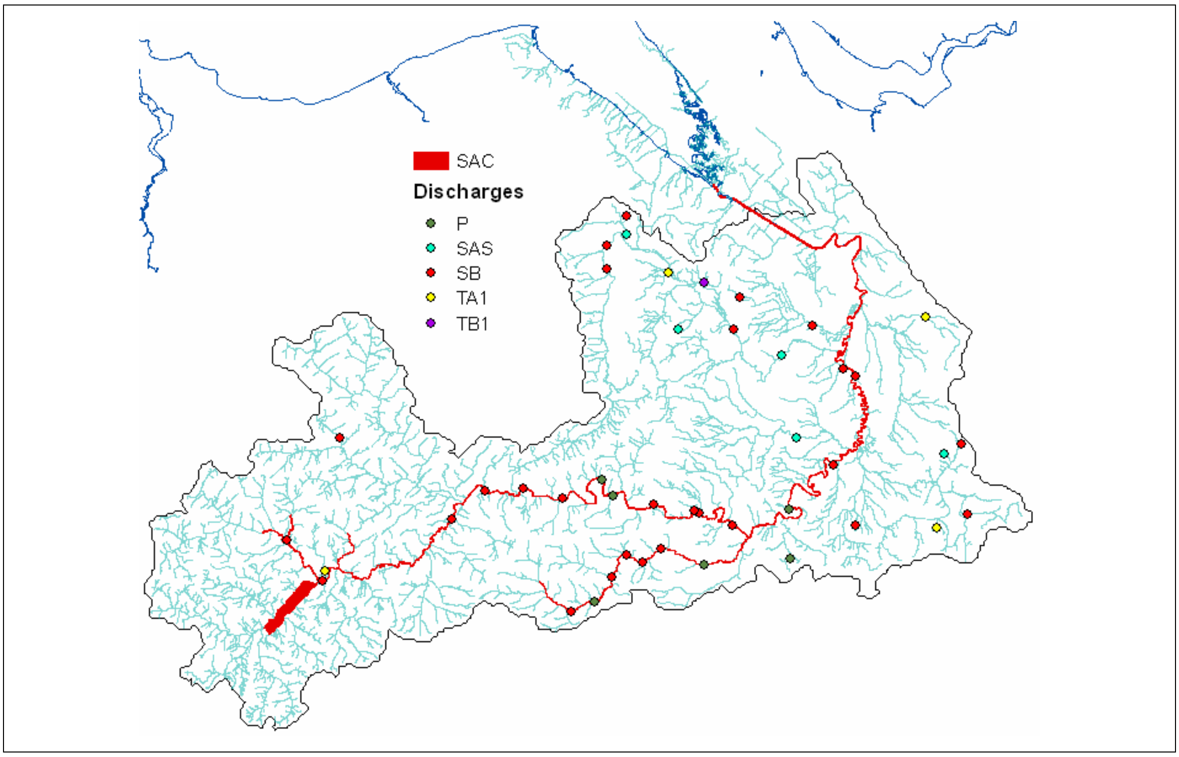

Figure 8.16 Map of the River Dee showing the SAC and the STPs to be included in the steroid oestrogen risk assessment

The results of the risk assessment are shown in Figure 8.17 and Table D.8. Within the River Dee and Bala Lake SAC boundary, there are no river reaches at risk under mean or P_{90} conditions using either risk assessment approach. In the wider catchment, there are reaches downstream of 17 STPs that are 'at risk' using the risk assessment designed for SAC sites and P_{90} concentrations, with 15 of these STPs still 'at risk' under mean concentrations. These 'at risk' sections sometimes extend to several reaches and cover considerable distances. If the regional risk assessment approach is considered, Mold STP poses a 'high risk' under mean concentrations and another three STPs (Overton STP, Nomansheath STP and Penyffordd STP) are associated with 'high risk' under P_{90} conditions. A further nine STPs are upstream of 'at risk' sites under P_{90} concentrations, rising to 12 under mean concentrations.

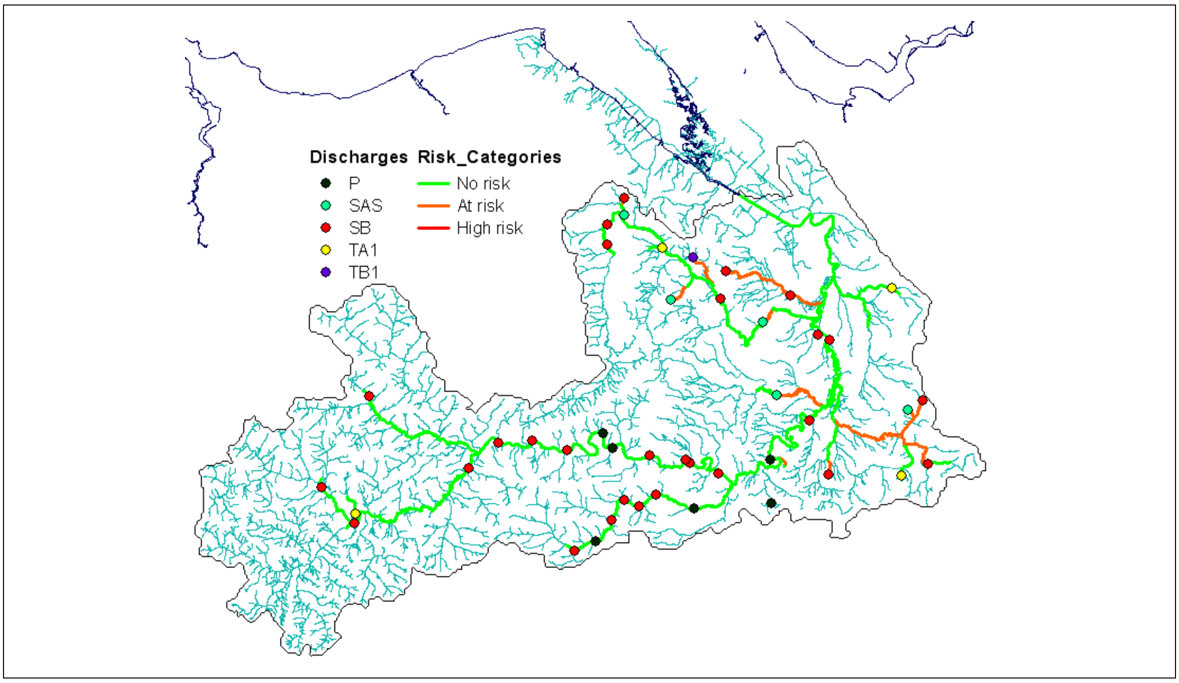

Figure 8.17 Map of the River Dee showing the oestrogen-associated risk derived from mean concentrations and applying the regional risk assessment approach

8.3.9 River Wensum

The SAC follows the River Wensum from its headwaters near Whissonsett down to the city of Norwich, upstream of the River Tud confluence. This SAC covers a basin area of approximately 570km^2 and contains 12 STPs treating the effluent from ~44,400 people. Seven of the STPs are BFPs (Ofwat class SB), one is activated sludge (Ofwat class SAS) and four STPs conduct tertiary treatment (Ofwat classes TB). A map of the River Wensum with the SAC stretches highlighted is presented in Figure 8.18, showing the location and type of treatment of the STPs.

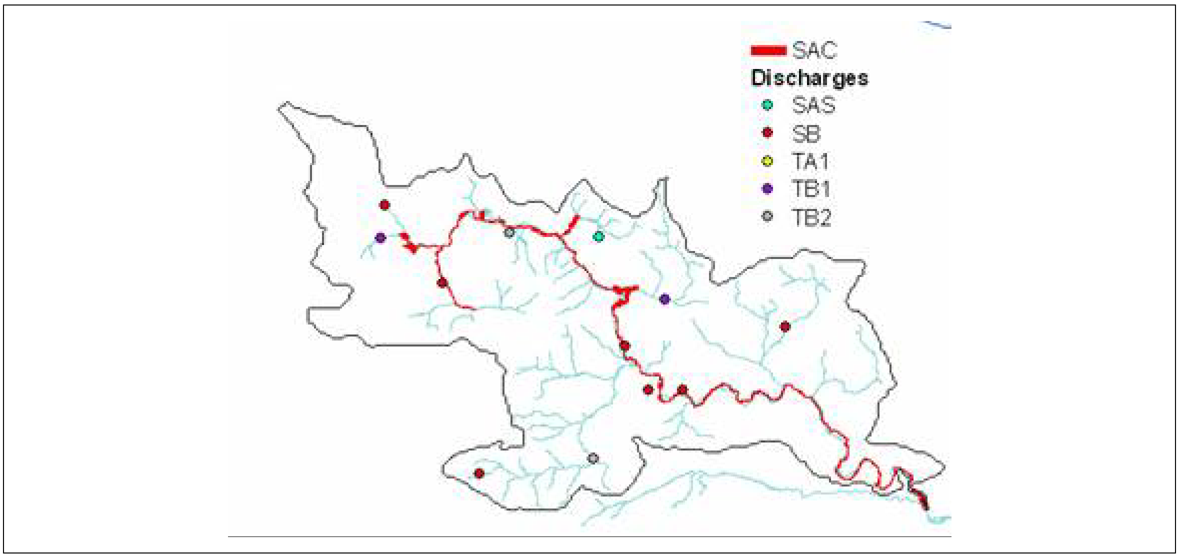

Figure 8.18 Map of the River Wensum showing the SAC and the STPs to be included in the steroid oestrogen risk assessment

The results of the risk assessment are shown in Figure 8.19 and Table D.9.

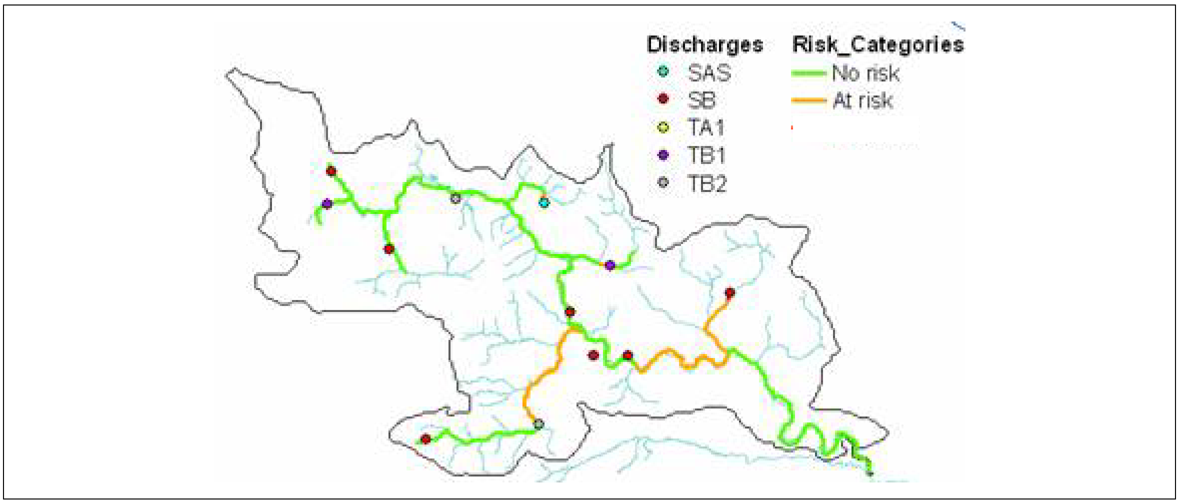

Figure 8.19 Map of the River Wensun showing the oestrogen associated risk derived from mean concentrations and applying the regional risk assessment approach

Within the SAC, the reach below Bylaugh STP is 'at risk' in the risk assessment designed for SAC sites under mean concentrations. Under P_{90} concentrations, the reaches below Fakenham STP, Nelmham STP and Swanmor STP would also be 'at risk' using both risk assessment approaches. In the wider catchment, a further six STPs are upstream of 'at risk' stretches under P_{90} concentrations, with four of these remaining 'at risk' under mean concentrations. When the regional risk assessment approach is used, the same six STPs are associated with risk under P_{90} concentrations, but Reepham STP poses a 'high risk' and Dereham STP is 'at risk' even under mean concentrations.

8.3.10 River Itchen

The SAC starts from the River Itchen at Titchbourne and the headwaters include the River Alre from New Alresford and an un-named tributary that rises in a series of springs to the north. The SAC then follows the River Itchen to its tidal limit. There are three STPs treating effluent from ~ 100,000 people that discharge within the catchment of the SAC (two of type TB1 and one SB). A map of the River Itchen with the SAC stretches highlighted is presented in Figure 8.20, showing the location and type of treatment of the STPs.

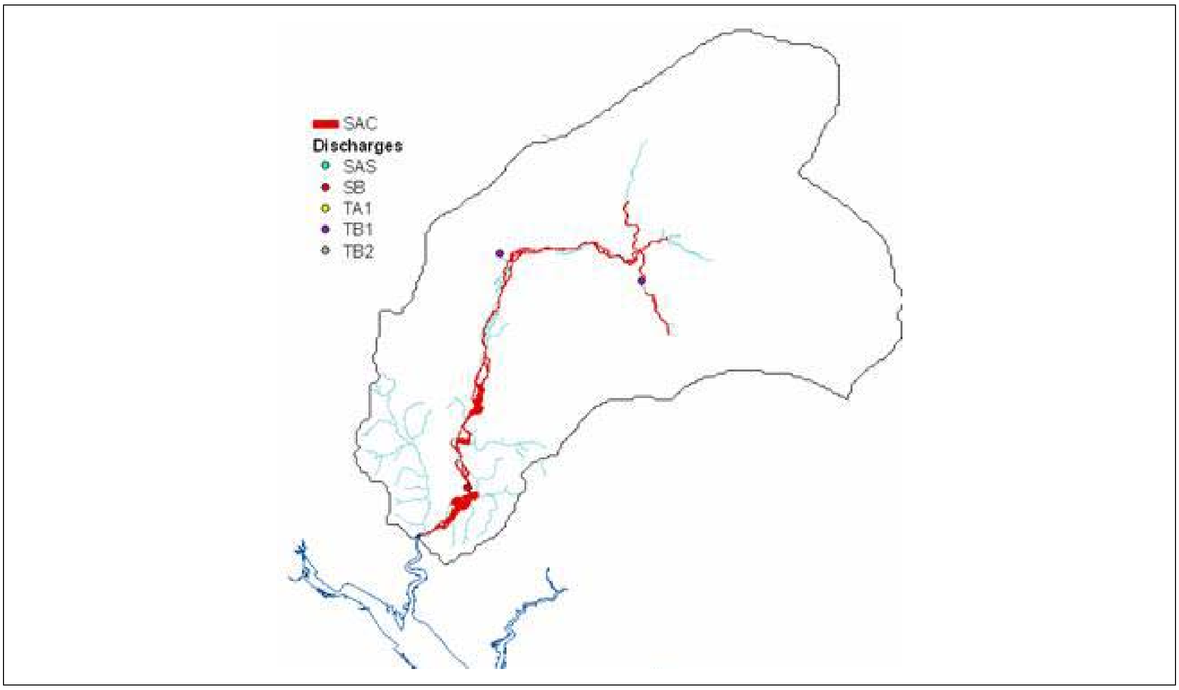

Figure 8.20 Map of the River Itchen showing the SAC and the STPs to be included in the steroid oestrogen risk assessment

The results of the risk assessment are shown in Figure 8.21 and Table D.10. Within the SAC, all of the river below Chickenhall STP is predicted to be 'at risk' under either mean or P_{90} conditions, using either risk assessment approach. In the wider catchment, the tributary of the Itchen downstream of Harestock STP would also be 'at risk' in the same manner.

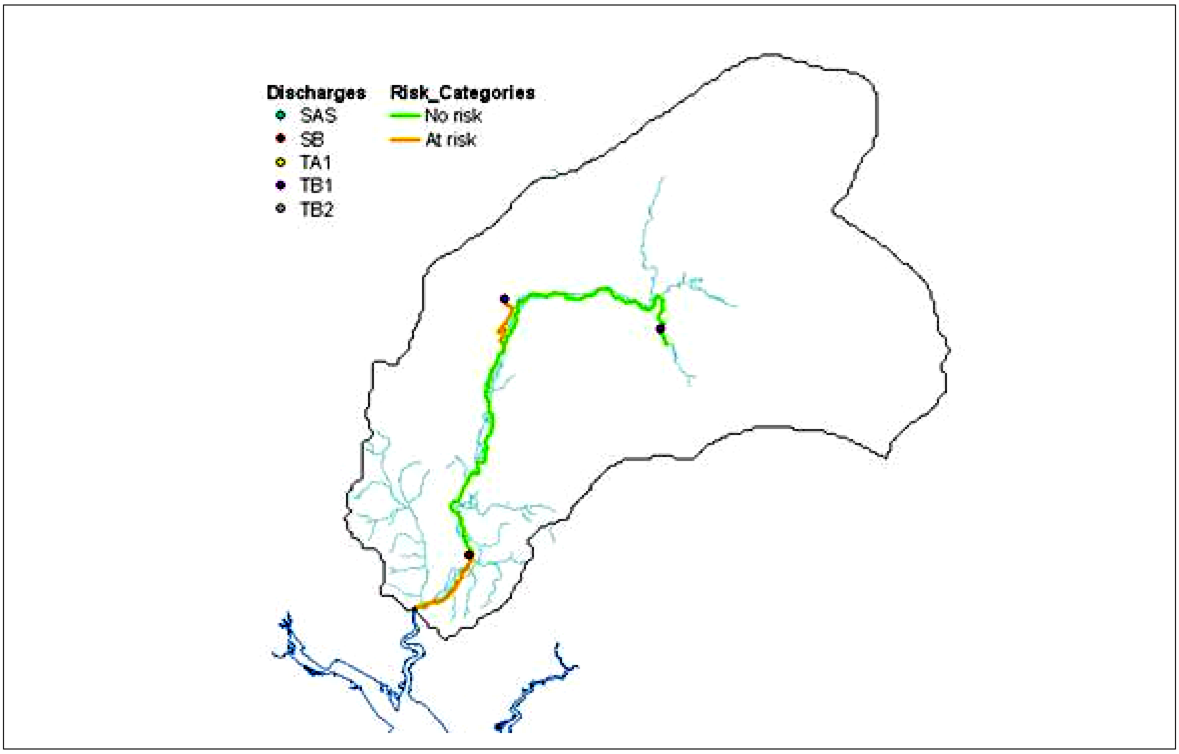

Figure 8.21 Map of the River Itchen showing the oestrogen-associated risk derived from mean concentrations and applying the regional risk assessment approach

8.3.11 River Avon

The SAC follows the River Avon from upstream of Upavon down to the tidal limit at Christchurch/Newport. The SAC also includes the River Wylye, the River Nadder, the downstream end of the River Bourne and the Dockens Waters. It covers a basin area of approximately 1,700km^2 and contains 20 STPs treating the effluent from ~149,600 people. The majority of the STPs (13) conduct tertiary treatment (Ofwat classes TA and TB), while the rest are BFPs (Ofwat class SB). A map of the River Avon with the SAC stretches highlighted is presented in Figure 8.22, showing the location and type of treatment of the STPs.

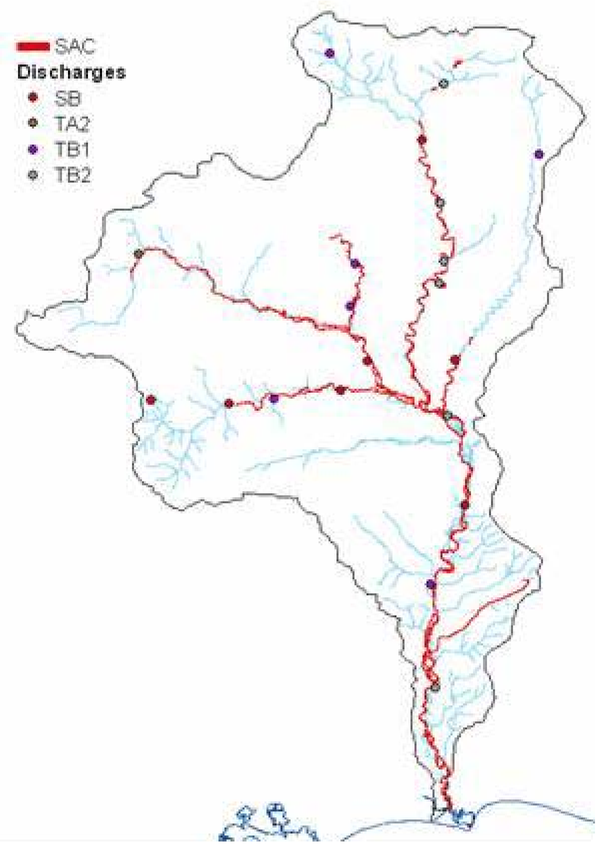

Figure 8.22 Map of the River Avon showing the SAC and the STPs to be included in the steroid oestrogen risk assessment

The results of the risk assessment are shown in Figure 8.23 and Table D.11. Within the SAC, the reaches predicted to be 'at risk' comprise those below Salisbury STP under mean concentrations and those below Pewsey under P_{90} concentrations using either risk assessment approach. Under P_{90} conditions, the reaches below Amesbury STP and Downton STP are also 'at risk' when using the risk assessment designed for SAC sites. In the wider catchment, a further seven STPs are upstream of reaches predicted to be 'at risk' using this approach, with four of them remaining 'at risk' under mean concentrations. The same outcome arises if the regional risk assessment is used, except that two of the STPs are on reaches considered to be at 'high risk' under mean concentrations. This rises to three STPs under P_{90} concentrations.

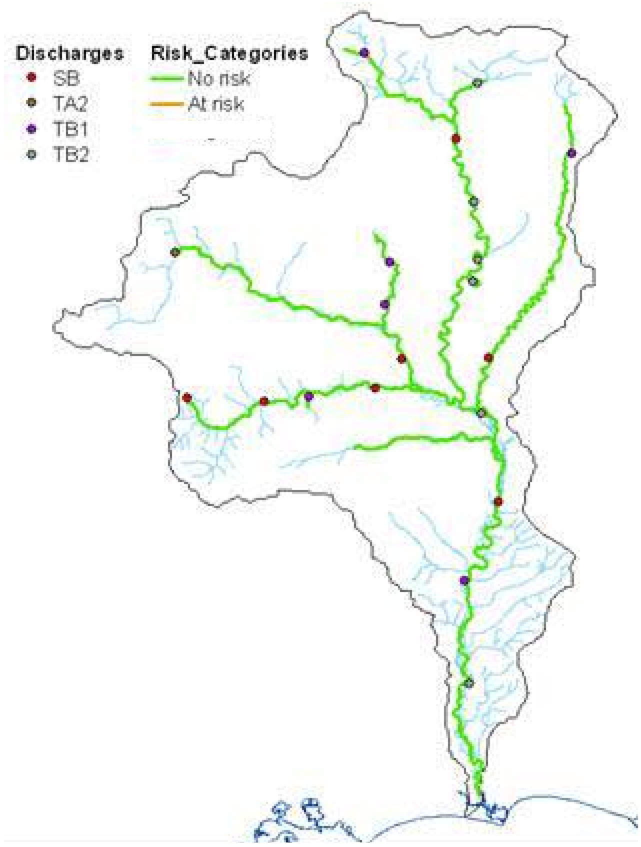

Figure 8.23 Map of the River Avon showing the oestrogen-associated risk derived from mean concentrations and applying the regional risk assessment approach

8.3.12 Afonydd Cleddau (Eastern)

The SAC follows the Eastern River Cleddau from the headwaters down to the tidal limit near Narberth. It also includes many tributaries, amongst which are the River Wern, the River Rhyd and the River Syfni. This SAC covers a basin area of approximately 210km^2 and comprises three STPs, all of type SB, treating the effluent from ~1,300 people (Figure 8.24). A map of the Eastern River Cleddau with the SAC stretches highlighted is presented in Figure 8.24, showing the location and type of treatment of the STPs.

The results of the risk assessment are shown in Figure 8.25 and Table D.12. Within the SAC, the reaches downstream of Maencholog STP and Clynderwen STP are classified as 'at risk' under P_{90} concentrations using the risk assessment designed for SAC sites, but not under mean concentrations and not using the regional risk assessment approach. In the wider catchment, the reach immediately downstream of Clynderwen is predicted to be 'at risk' under mean conditions when using the risk assessment designed for SAC sites. This site and the reaches downstream of Llandewi are also predicted to be 'at risk' in both risk assessment approaches under P_{90} concentrations.

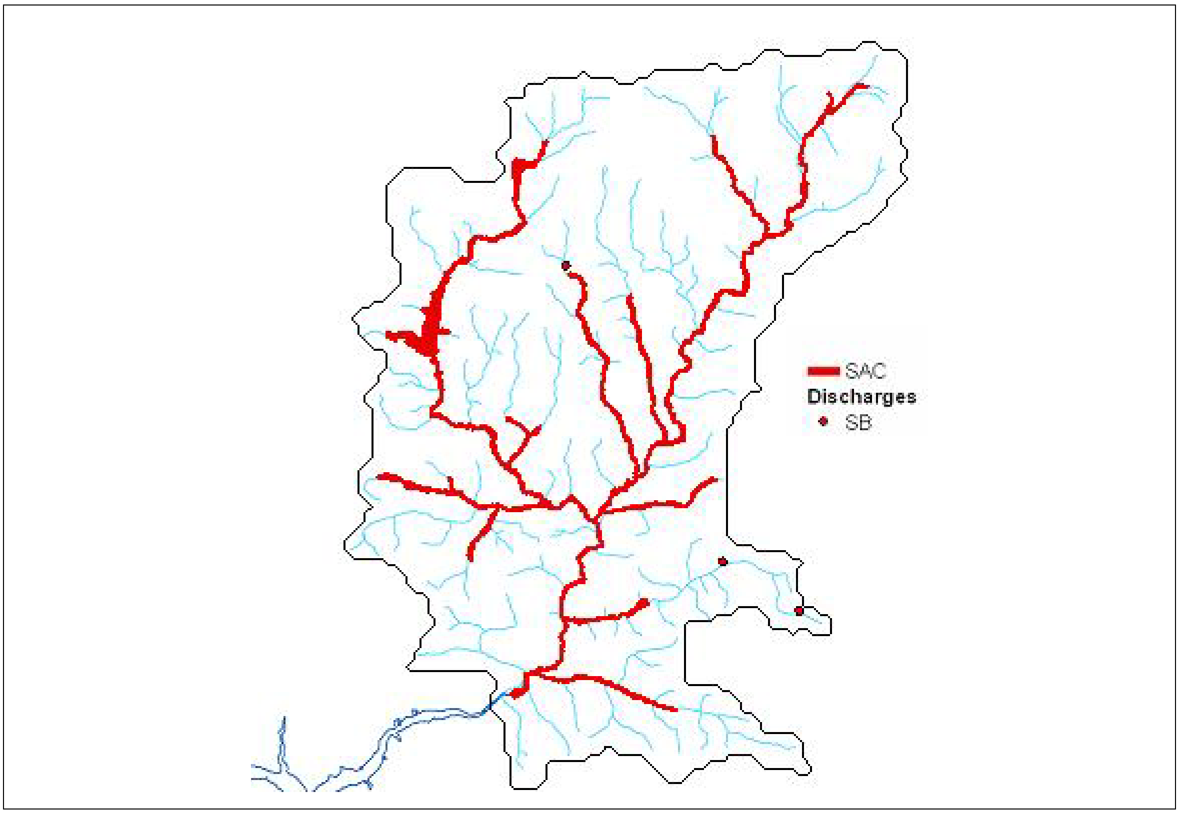

Figure 8.24 Map of the Eastern River Cleddau showing the SAC and the STPs to be included in the steroid oestrogen risk assessment

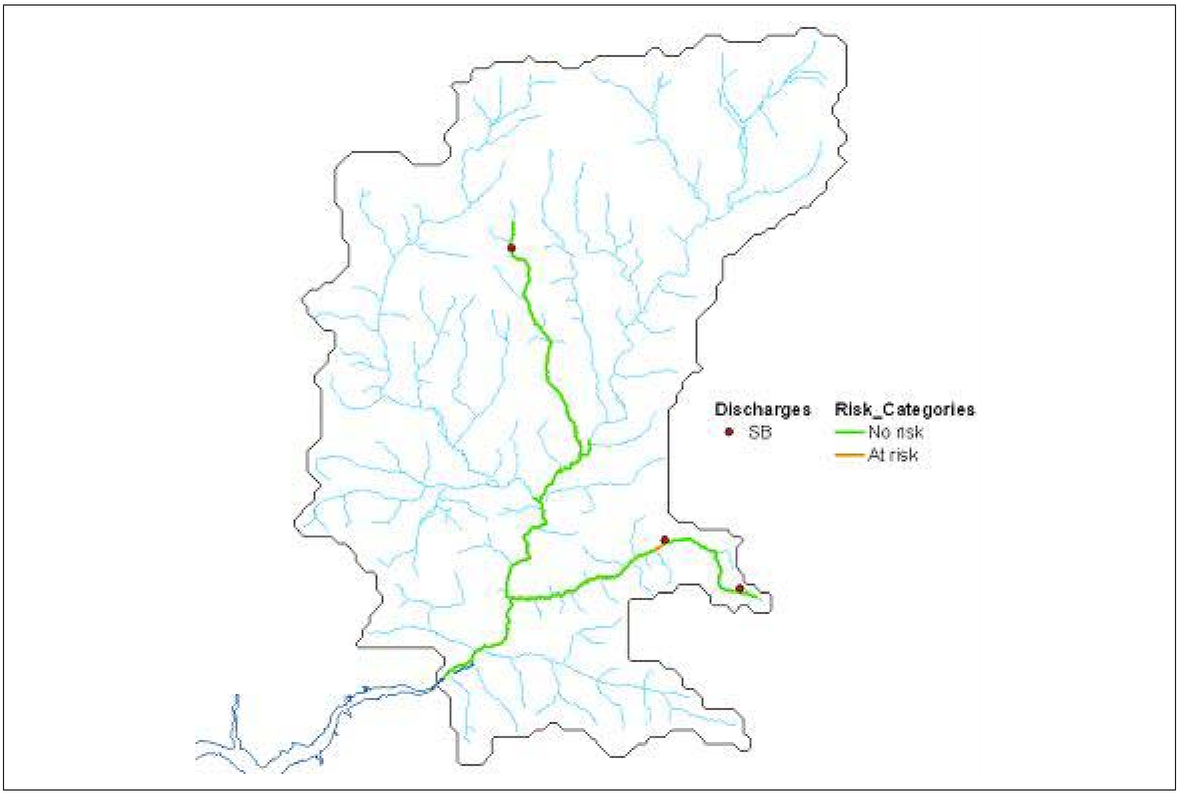

Figure 8.25 Map of the Eastern River Cleddau showing the oestrogen-associated risk derived from mean concentrations and applying the regional risk assessment approach

8.3.13 Afonydd Cleddau (Western)

The SAC follows the Western River Cleddau from the headwaters down to the tidal limit near Haverford West. The SAC also includes many tributaries, including Afon Anghof, Cortlett Brook, Spittet Brook and Rudbaxton Water. This SAC covers a basin area of approximately 250km^2 and comprises 14 STPs treating the effluent from around 3,400 people. Seven STPs are of the Ofwat class TB1 (tertiary treatment), five are BFPs (Ofwat class SB) and two have activated sludge treatment (Ofwat class SAS). A map of the Western River Cleddau with the SAC stretches highlighted is presented in Figure 8.26, showing the location and type of treatment of the STPs.

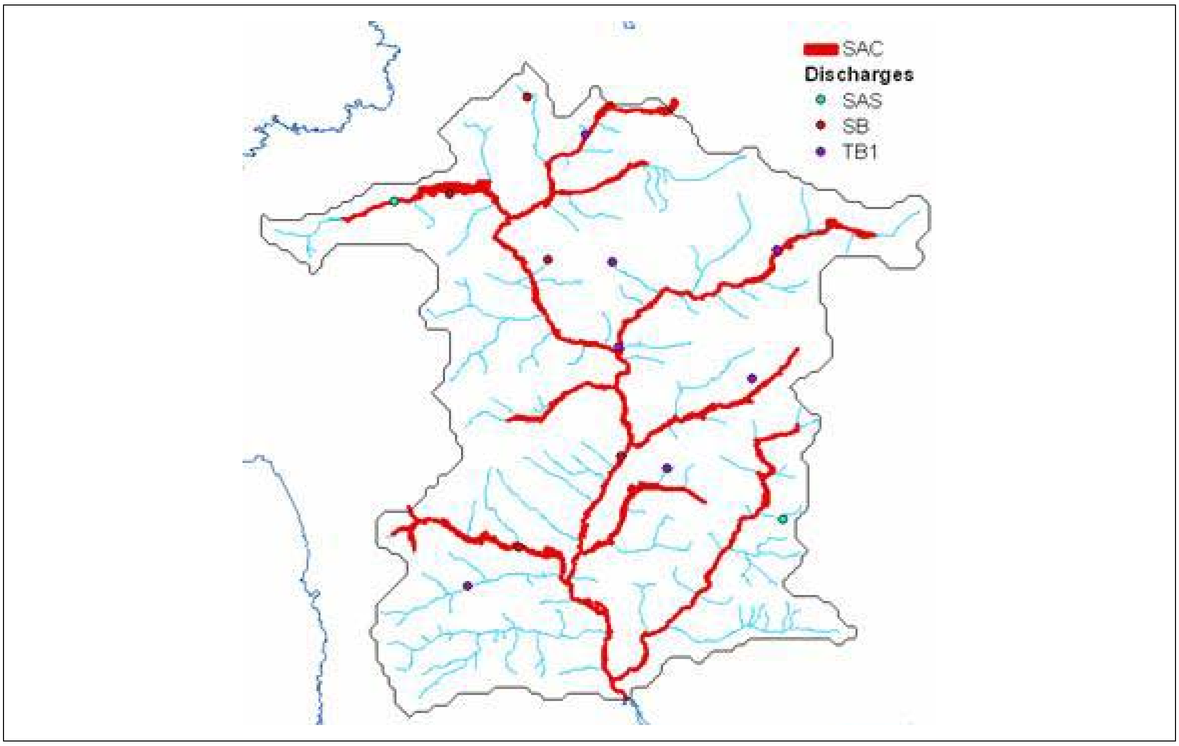

Figure 8.26 Map of the Western River Cleddau showing the SAC and the STPs to be included in the steroid oestrogen risk assessment

The results of the risk assessment are shown in Figure 8.27 and Table D.13. Within the Western River Cleddau SAC boundary, there are no river reaches at risk under mean or P_{90} conditions using either risk assessment approach. In the wider catchment, the reaches immediately downstream of Spittal STP and Letterston West STP are predicted to be 'at risk' under mean conditions when applying either risk assessment approach. This is also the case for Clarebeston STW, but only when applying the risk assessment designed for SAC sites. The reaches downstream of Letterston East and Clarbeston Road STP are also predicted to be 'at risk' under P_{90} concentrations using either risk assessment approach.

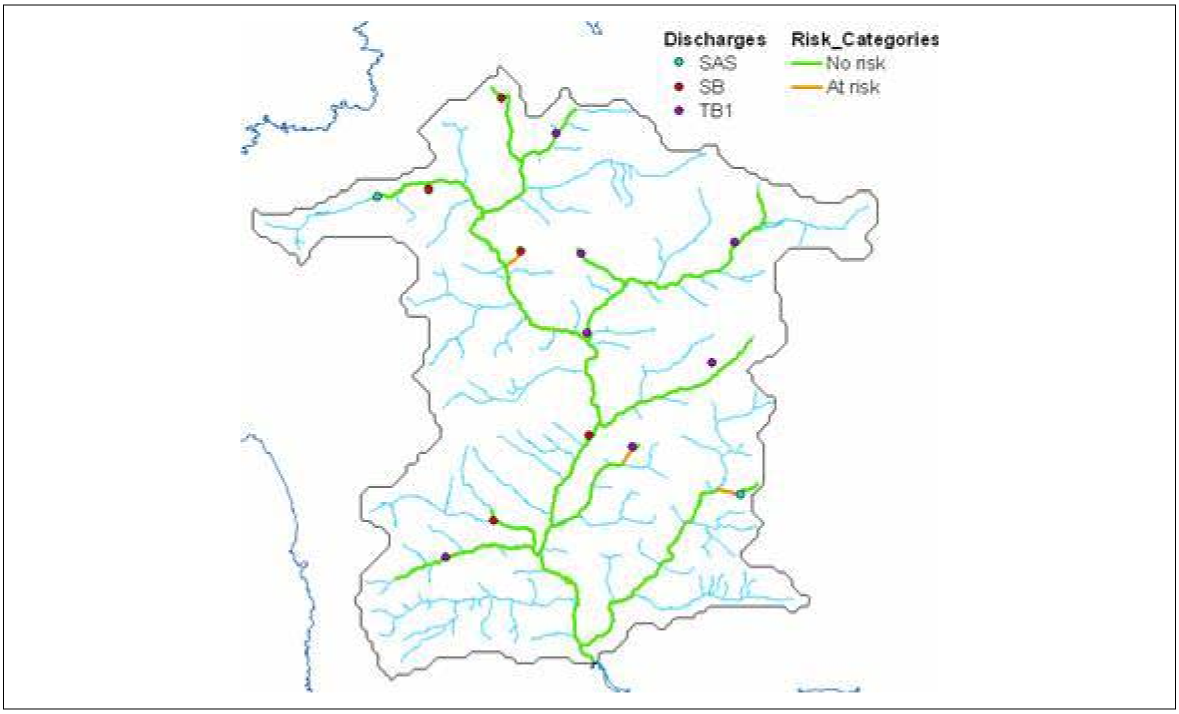

Figure 8.27 Map of the Western River Cleddau showing the oestrogen-associated risk derived from mean concentrations and applying the regional risk assessment approach

8.4 Summary

All SAC river reaches downstream of the selected STPs are predicted to contain very small concentrations of steroid oestrogens. However, in many of the cases examined so far, these concentrations would be below those predicted to have any effect on fish. The exceptions are detailed below. More river reaches outside the SAC boundaries but within the wider catchment were also predicted to be at risk but are not included in this summary.

- River Lambourn SAC – one reach on the lower Winterbourne is 'at risk' (caused by the combined effects of Chieveley STP and Winterbourne STP) under P_{90} conditions when using either the regional risk assessment or the risk assessment designed for SAC sites.
- River Wye/Afon Gwy SAC – one reach immediately downstream of Hereford STP is 'at risk' under P_{90} conditions when using the risk assessment designed for SAC sites.
- Afon Gwyrfai SAC – one reach immediately below Llanfaglan STP is 'at risk' under both mean and P_{90} conditions when using either the regional risk assessment or the risk assessment designed for SAC sites.
- River Wensum SAC – one reach immediately below Bylaugh STP is predicted to be 'at risk' under mean conditions when applying the risk assessment designed for SAC sites. Under P_{90} conditions, one further reach downstream of this site, and several more downstream of Fakenham STP, Nelmham STP and Swanmor STP, would also be 'at risk' when using either the regional risk assessment or the risk assessment designed for SAC sites.
- River Itchen SAC – three reaches immediately below Chickenhall STP, constituting all of the river to the tidal limit, are predicted to be 'at risk' under both mean and P_{90}

conditions using either the regional risk assessment or the risk assessment designed for SAC sites.

- River Avon SAC – two reaches below Salisbury STP are predicted to be 'at risk' under mean conditions and two reaches below Pewsey STP are predicted to be 'at risk' under P_{90} conditions using either the regional risk assessment or the risk assessment designed for SAC sites. In the latter case, the reaches immediately downstream of both Amesbury STP and Downton STP are also 'at risk' under P_{90} conditions.
- Afonydd Cleddau (Eastern) SAC – one reach immediately downstream of Maencholog STP and a reach downstream of Clynderwen STP where it crosses the boundary of the SAC are predicted to be 'at risk' under P_{90} conditions when using the risk assessment designed for SAC sites.

8.5 Further work

Nine of the riverine SACs in England have not been assessed for risk from steroid oestrogens in this project due to the constraints of time and budget. However, almost 1000 river reaches within the 12 catchments containing SACs that have been modelled to date have been risk assessed. Of these, only 24 reaches on top of those already identified by the regional risk assessment were predicted to be at risk under P_{90} conditions. A further 25 reaches identified by the regional models as being at risk under P_{90} conditions were reclassified as also being at risk under mean conditions. This implicates an additional 13 STPs – one of which falls within a SAC (Bylaugh STP on the River Wensum) – as sources of the risk under mean conditions. A further eight STPs are implicated as sources of risk under P_{90} conditions: six of these either discharge into or influence reaches within SACs (Hereford STP on the River Wye, Amesbury, Ratfyn and Downton STPs on the River Avon and Maencholog and Clynderwen STPs on the Eastern Afonydd Cleddau). There is only a small percentage increase in the reaches predicted to be at risk when using the risk assessment approach designed for SACs rather than the regional risk assessment. However, the former approach does identify additional STPs as potential sources of risk and so there is a clear need to model the remaining SACs in a similar manner.

9 Future work

This project has produced a detailed reach-by-reach risk assessment of rivers in England and Wales. It involved undertaking PEC/PNEC comparisons for the three major steroid oestrogens arising from STP discharges, which allowed predictions to be made of the likely exposure and consequences for fish populations. However, a number of further areas of research are recommended to test the predicted environmental concentrations and to refine the risk assessment.

9.1 Testing the model predictions

- The risk assessment method has predicted whether reaches across England and Wales are at ‘no risk’, ‘risk’ or ‘high risk’ of causing intersex effects in fish. Previous surveys of the incidence and severity of a number of intersex endpoints in wild roach have been carried out at selected river sites (Environment Agency 2008). It is recommended that the locations of these survey points be located on the risk maps produced by this model, thereby allowing the predicted risk of intersex to be compared with the actual level of intersex observed in wild fish (Jobling *et al.* 2006).
- The risk assessment model operates on the basis of river catchments, predicting concentrations of the three steroid oestrogens arising from the accumulated STP discharges down the river network to the tidal limit. We recommend that the PECs generated by the model are tested against measured steroid concentrations along selected river catchments. Collected samples will need to cover a sufficiently long time period to allow a reasonable estimate of the mean concentration in the river, which can then be compared with the mean concentrations predicted by the model.

9.2 Refining the risk assessment

- In the current risk assessment, each STP was assumed to be discharging into the nearest river reach according to the regional grid reference supplied by the water company. This is likely to be the correct reach in most cases. However, in the case of reaches determined to be at ‘high risk’, it would be wise to establish whether a discharge had been wrongly attributed to that reach. This could occur where an STP actually discharges into the main river, but where the closest river point in the model was a small tributary or drainage channel. However, if this type of error has occurred, the length of river involved is likely to be very short and therefore it would not greatly affect the overall risk assessment for the catchment.
- The removal efficiencies for different types of STP have been distinguished in this risk assessment in a fairly limited manner, with only E1 removal by BFPs assigned a lower value. Should data become available that allow for a better assessment of the removal efficiencies of different types of STP, such as that being generated by the Endocrine Disruption Demonstration Programme, it is recommended that the model should be re-run to produce a new set of predicted steroid oestrogen concentrations and risk maps. This may also be necessary if further information on the effects of steroids in fish become available. This information could be used to

refine the individual steroid PNEC, which may alter the relative potencies used to establish the E2 equivalent valuation on which the risk assessment is based.

- A method has been presented for calculating the additional percentage of steroid removal required at individual STPs within a catchment to ensure that no reaches are predicted to be at risk. Before this kind of exercise is undertaken, it is recommended that the underlying data sets are validated in terms of population served, DWF and treatment type. Early confirmation of these more recently acquired parameters would require relatively little effort at a catchment scale, but would return more reliable estimates for the required removal efficiencies.
- An alternative approach for selecting STPs to be modelled is to filter out STPs with effluent streams that are highly diluted by the receiving water, rather than filtering out those that do not contribute to 95 per cent of the DWF. A comparison of these two filter methods may be undertaken for a selection of basins in order to quantify the impact of those small STPs not modelled in this study.
- The potential for animal husbandry and septic tanks in rural locations to contaminate small streams and ditches with oestrogenic compounds has yet to be assessed. Matthiessen *et al.* (2007) has shown that oestrogens can be detected in streams associated with animal farms and Swartz *et al.* (2006) has shown that septic tanks are poor at removing oestrogens. A targeted field monitoring study could help to identify the extent and potential significance of such discharges.
- An underlying assumption of the model is that all steroid oestrogens in glucuronide form are rapidly deconjugated in the sewers, but this may not be the case for EE2. Levels of free EE2 may continue to increase during secondary biological treatment and in the river itself. Further investigation using mesocosm studies could lead to a better understanding of the processes involved.

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List of abbreviations

ASP	Activated Sludge Plant
BFP	Biological (Trickling) Filter Plant
BOD	Biochemical Oxygen Demand
CEH	Centre for Ecology and Hydrology
COD	Chemical Oxygen Demand
Defra	Department for Environment, Food and Rural Affairs
DWF	Dry Weather Flow (from STPs)
EC_{100}	Concentration causing 100 per cent effect
EC_{50}	Concentration causing 50 per cent effect
EDDP	Endocrine Disruptors Demonstration Programme
E1	Oestrone
E2	Oestradiol
E2 eqv	Oestradiol equivalent
EE2	Ethinyloestradiol
GIS	Geographical information systems
GQA	General Quality Assessment
GSI	Gonadosomatic index
HSI	Histosomatic index
LAS	Linear alkyl sulfonate
LF2000	Low Flows 2000
LF2000-WQX	Low Flows 2000 water quality
Ofwat	Water Services Regulation Authority
Ortho-P	Orthophosphate
PNEC	Predicted no effect concentration
LOEC	Lowest observed effect concentration
MATC	Maximum acceptable toxicant concentration
MBR	Membrane bioreactor
NGR	National Grid Reference
NOEC	No observed effect concentration
OS	Ordnance Survey
PEC	Predicted environmental concentration
SAC	Special Area of Conservation

SAS	Secondary Activated Sludge (sewage treatment, Ofwat class)
SB	Secondary Biological (sewage treatment, Ofwat class)
SBR	Sequencing batch reactor
SSSI	Site of special scientific interest
STP	Sewage Treatment Plant
TA1	Tertiary (sewage treatment, Ofwat class) of type A1 (see Appendix A)
TA2	Tertiary (sewage treatment, Ofwat class) of type A2 (see Appendix A)
TB1	Tertiary (sewage treatment, Ofwat class) of type B1 (see Appendix A)
TB2	Tertiary (sewage treatment, Ofwat class) of type B2 (see Appendix A)
VTG	Vitellogenin
WHS	Wallingford HydroSolutions
WIMS	Water Information Management System (Environment Agency)

Appendix A: Ofwat sewage treatment classification

The Ofwat classification scheme is primarily a tool to allow the analysis of a water service company's financial performance as part of the 'June returns, Chapter 17'. However, the classification scheme is also suitable for discriminating between different treatment processes in terms of their pollutant removal efficiency.

The 2005 scheme classifies STPs into seven different categories.

P (Primary): Includes STPs whose treatment methods are restricted to preliminary and primary treatment (screening, comminution, maceration, grit and detritus removal, pre-aeration and grease removal and storm tanks, plus primary sedimentation, including where assisted by the addition of chemicals such as Clariflow).

SAS (Secondary activated sludge): As primary, plus STPs whose treatment methods include activated sludge (including diffused air aeration, coarse bubble aeration, mechanical aeration, oxygen injection, submerged filters) and other equivalent techniques including deep shaft process, extended aeration (single, double and triple ditches) and biological aerated filters as secondary treatment.

SB (Secondary biological): As primary, plus STPs whose treatment methods include rotating biological contactors and biological filtration (including conventional filtration, high rate filtration, alternating double filtration and double filtration) and root zone treatment (where used as a secondary treatment stage).

TA1 (Tertiary A1): STPs with a secondary activated sludge process whose treatment methods include prolonged settlement in conventional lagoons or raft lagoons, irrigation over grassland, constructed wetlands, root zone treatment (where used as a tertiary stage), drum filters, microstrainers, slow sand filters, tertiary nitrifying filters, wedge wire clarifiers or Clariflow installed in humus tanks, where used as a tertiary treatment stage.

TA2 (Tertiary A2): STPs with a secondary activated sludge process whose treatment methods include rapid-gravity sand filters, moving bed filters, pressure filters, nutrient control using physico-chemical and biological methods, disinfection, hard chemical oxygen demand (COD) and colour removal, where used as a tertiary treatment stage.

TB1 (Tertiary B1): STPs with a secondary stage biological process whose treatment methods include prolonged settlement in conventional lagoons or raft lagoons, irrigation over grassland, constructed wetlands, root zone treatment (where used as a tertiary stage), drum filters, microstrainers, slow sand filters, tertiary nitrifying filters, wedge wire clarifiers or Clariflow installed in humus tanks, where used as a tertiary treatment stage.

TB2 (Tertiary B2): STPs with a secondary biological process whose treatment methods include rapid gravity sand filters, moving bed filters, pressure filters, nutrient control using physico-chemical and biological methods, disinfection, hard COD and colour removal, where used as a tertiary treatment stage.

Where a STP's load is split into two treatment streams, the STP should be classified according to the stream with the higher proportion. For example, a STP with a split of 60 per cent secondary activated sludge and 40 per cent secondary biological should be classed as secondary activated sludge. Where a STP conducts tertiary treatment in both categories 1 and 2, it should be classified as category 2.

Appendix B: Simulation of flow and GQA determinand concentrations

GQA determinands were simulated within each of the catchments in order to demonstrate that the model configuration adequately accounts for river flows and significant discharges. Three GQA determinands were selected for modelling: chloride, BOD and ortho-P. These were chosen because it was expected that their concentration would be primarily influenced by the STP effluent concentration (although ortho-P can also have a diffuse agricultural source). In this initial assessment, all the GQA determinands were modelled as conservative and no calibration was attempted (the aim of this project was not to model GQA parameters for their own sake, but as a check that the model was configured appropriately).

The GREAT-ER method, as adapted within LF2000-WQX (Keller and Young 2004), is based on Monte Carlo simulations where the user defines the input data as distributions. Within all the simulation undertaken for this proof of concept, the flows are represented using log-normal distributions defined by the mean flow and the flow exceeded 95 per cent of the time (Q_{95}). The GQA input data for STPs and at river monitoring sites are represented by mean, standard deviation and distribution type (normal and log normal). These data for the Exe and Aire and Calder catchments were derived from spot samples collected during the period 1990 to 2000 and recorded in the Environment Agency's WIMS database. Also, across all the simulations, 2000 Monte Carlo shots were used to ensure that the results were repeatable.

To investigate the estimates of GQA concentrations, two scenarios were considered within each catchment.

- The normal scenario: within this scenario, all the distributions used to define the GQA concentrations were defined as normal.
- The log-normal scenario: within this scenario, all the distributions used to define the GQA concentrations were defined as log-normal.

The method of flow estimation for any ungauged catchment within this model was calibrated as part of the development of LF2000. Within LF2000-WQX, the impact of artificial influences (discharges, abstractions and impounding reservoirs) on the natural flow regime can be accounted for while estimating the flows provided that data are available. The artificial influence data were all available for the Exe catchment and the Aire and Calder catchment.

B.1 The Exe catchment

B1.1 Input data

For this catchment, there were no measured data for chloride, thus only BOD and ortho-P were modelled. Tributaries receiving discharges from the large STPs were modelled from a monitoring point upstream of the discharge. The boundary conditions are held in the database, with measured data at all the upstream limits defined within Figure 5.1 Details of the measured data for each upstream limit are presented in Table B.1

Table B.1 Observed mean (standard deviation) BOD and ortho-P concentrations (mgL^{-1}) at upstream limits in the Exe catchment

	BOD	Ortho-P
(S) Stream Silverton[2]	1.5 (0.8)	0.05 (0.03)
Lilly Brook u/s Tedburn St Mary STP [1]	1.7 (0.8)	0.04 (0.03)
Crosse stream u/s Cheriton Bishop STP	1.7 (1.0)	0.12 (0.40)
River Troney at Yeoford	1.7 (1.0)	0.08 (0.06)
River Culm at Bridgehouse bridge	1.7 (0.9)	0.05 (0.02)
Halberton stream u/s Halberton STP	2.2 (2.5)	0.18 (0.11)
Dunkeswell stream u/s Dunkeswell STP	1.4 (0.8)	0.04 (0.05)
Tiverton canal at Fencare bridge	1.8 (1.6)	0.07 (0.11)
River Batherm at Kersdown Barton	1.4 (0.5)	0.05 (0.03)
Danes Brook at Castle Bridge	1.1 (0.3)	0.02 (0.01)

Notes: 1. Revised value, original sample set for BOD was recorded as mean = 2.914, stdev = 9.168.
2. Dummy point with default determinand concentrations, which were also used for any runoff and tributaries that were not modelled.

In one instance, there was no upstream Environment Agency monitoring point available and a dummy point had to be inserted in the network (Table B.1). A set of default determinand values was associated with this point, with these default values also attributed to tributaries that were not modelled and to lateral runoff entering a reach. These values were derived by inspecting sampled data from monitoring sites that did not receive any effluent inputs.

B1.2 Results and discussion of the GQA simulation

The validity of the modelled flows was assessed by comparing them with measured flow data for several gauging stations across the catchment (Marsh and Lees 2003). The outcome of this comparison is presented in Table B.2.

Table B.2 Comparison of observed and estimated mean and Q_{95} flows (m^3s^{-1}) for five stations in the Exe catchment

	Observed	Estimated	Error (%)[1]
River Creedy at Cowley	3.8 (0.3)	3.9 (0.4)	4
River Exe at Thorverton	16.2 (2.0)	14.8 (1.2)	-8
River Exe at Stoodleigh	12.7 (1.7)	11.9 (1.1)	-6
River Culm at Wood Mill	3.8 (1.0)	3.9 (1.1)	3
River Barle at Brushford	4.7 (0.6)	4.7 (0.6)	1

Notes: 1. The error was calculated using Equation B.1.

The agreement between the estimated flows and the gauged flow in the Exe catchment was excellent, with the percentage error ranging from -8 per cent to 4 per cent across the five gauging stations considered.

The results of the simulations for BOD and ortho-P are presented in Table B.3. The results are presented for both the log-normal and the normal scenarios, alongside the observed data for comparison purposes. The error between the predicted and the observed concentrations are shown in Table B.4. The error was calculated using the following formula:

$$Error = \frac{(C_{Est} - C_{Obs})}{C_{Obs}} \times 100 \qquad \text{Equation B.1}$$

where C_{obs} is the observed/measured concentration and C_{est} is the estimated concentration.

The estimated concentrations (for both scenarios) are in good agreement with the measured data: the estimates for both BOD and ortho-P are within a factor of two at the maximum (Table B.4). Although there is no clear tendency to under- or over-predict the ortho-P concentrations, the model seems to slightly under-predict the BOD concentrations across the river network in the Exe catchment (mean error ~ -8 per cent). It should be noted that diffuse sources of both BOD and ortho-P would be expected in the river Exe catchment, which flows through predominantly agricultural land.

This modelling exercise was carried out to try to test the performance of the model in accounting for point loads (the main source of steroid oestrogens). Some diffuse sources were accounted for implicitly by using measured data for upstream tributary inputs. However, for many tributaries, a default, catchment value was used, which could under- (or possibly over-) estimate the actual local values.

The estimated concentrations are very similar for both log-normal and normal distributions (Table B.3). Although, no clear pattern arises when examining the errors generated within both scenarios, it is common practice to represent chemical and determinand concentrations using log-normal distributions. Thus, from the results obtained in this catchment, we would recommend using log-normal distributions to represent the GQA concentrations.

Table B.3 Observed and estimated BOD and ortho-P concentrations (standard deviations) at a number of sites in the Exe catchment

	BOD concentrations (mgL^{-1})			Ortho-P concentrations (mgL^{-1})		
	Observed	**Normal scenario**	**Log-normal scenario**	**Observed**	**Normal scenario**	**Log-normal scenario**
Madford River at Dunkeswell Abbey	1.6 (0.7)	1.8 (0.7)	1.7 (0.7)	0.10 (0.04)	0.17 (0.15)	0.16 (0.14)
River Batherm at Bowbierhill Wood	1.6 (0.8)	1.5 (0.5)	1.5 (0.5)	0.09 (0.06)	0.08 (0.05)	0.08 (0.05)
River Creedy at Oakford Farm	2.0 (1.5)	1.7 (0.6)	1.7 (0.6)	0.37 (0.36)	0.28 (0.30)	0.22 (0.29)
River Culm at Merry Harriers Inn	2.8 (1.4)	1.7 (0.4)	1.7 (0.5)	0.25 (0.08)	0.15 (0.10)	0.14 (0.09)
River Exe at Lythecourt	1.3 (0.3)	1.5 (0.6)	1.5 (0.6)	0.04 (0.02)	0.06 (0.02)	0.06 (0.02)
River Exe at Pynes Leat	1.9 (1.4)	1.6 (0.6)	1.6 (0.6)	0.13 (0.08)	0.08 (0.05)	0.08 (0.04)
River Exe d/s Exe Valley Fishery	1.3 (0.4)	1.5 (0.6)	1.5 (0.7)	0.03 (0.01)	0.05 (0.02)	0.05 (0.03)
River Exe u/s Brampford Speke STP	1.6 (0.7)	1.6 (0.6)	1.6 (0.6)	0.08 (0.04)	0.08 (0.05)	0.07 (0.04)
Spratford Stream at Five Bridges	2.3 (1.4)	1.7 (0.6)	1.7 (0.6)	0.32 (0.20)	0.12 (0.10)	0.11 (0.06)

Table B.4 Error (%) in mean BOD and ortho-P concentrations at a number of sites in the Exe catchment

	BOD error (%)		Ortho-P error (%)	
	Normal scenario	**Log-normal scenario**	**Normal scenario**	**Log-normal scenario**
Madford River at Dunkeswell Abbey	11	7	70	61
River Batherm at Bowbierhill Wood	-10	-10	-7	-9
River Creedy at Oakford Farm	-14	-16	-25	-41
River Culm at Merry Harriers Inn	-38	-40	-39	-45
River Exe at Lythecourt	15	15	47	46
River Exe at Pynes Leat	-20	-19	-36	-39
River Exe d/s Exe Valley Fishery	17	18	77	76
River Exe u/s Brampford Speke STP	-5	-5	3	-3
Spratford Stream at Five Bridges	-26	-27	-62	-64
Mean error	***-8***	***-9***	3	-2

B.2 The Aire and Calder catchment

B.2.1 Input data

Within the Aire and Calder catchment, BOD, chloride and ortho-P were modelled. Tributaries receiving discharges from the large STPs were modelled from a monitoring point upstream of the discharge. The boundary conditions are held in the database, with measured data available at all the upstream limits defined within Figure 5.2. Details of the measured data for each upstream limit are presented in Table B.5.

Table B.5 Observed mean (standard deviation) BOD, chloride and ortho-P concentrations (mgL^{-1}) at upstream limits in the Aire and Calder catchment

	BOD	Chloride	Ortho-P
Hunsworth bk u/s North Bierley STP	6.5 (13.0)	131.7 (141.4)	0.27 (1.35)
Kippax Stream[1]	2.9 (12.5)	93.7 (51.0)	0.26 (0.55)
Lupsett Beck at Horbury	3.6 (4.5)	141.4 (140.3)	0.34 (0.98)
Midgelden Brook at Bacup Road end	1.5 (0.7)	18.0 (15.1)	0.04 (0.03)
Oulton Bck at Oulton	2.9 (2.2)	153.0 (246.0)	0.05 (0.04)
River Aire at East Riddlesden Hall	2.2 (1.0)	29.4 (16.6)	0.22 (0.15)
River Holme at Brockholes	2.1 (1.5)	45.5 (25.9)	0.04 (0.03)
Wyke Beck above Knopstrop STP	3.3 (4.1)	84.1 (53.6)	0.11 (0.12)

Notes: 1. Dummy point with default determinand concentrations, which were also used for runoff and tributaries that were not modelled.

In one instance, there was no upstream Environment Agency monitoring point available and a dummy point had to be inserted in the network (Table B.5). A set of default determinand values was associated with this point, with these default values also attributed to tributaries that were not modelled and to lateral runoff entering a reach. These values were derived by inspecting sampled data from monitoring sites that did not receive any effluent inputs.

B.2.2 Results and discussion of the GQA simulation

The validity of the modelled flows was assessed by comparing them with measured flow data for several gauging stations across the catchment (Marsh and Lees 2003). The outcomes of this comparison are presented in Table B.6.

The average percentage error was around 9 per cent across the 17 gauging stations that were considered within the Aire and Calder catchment. Three of the small tributaries are not well predicted, but the main rivers are predicted very well, although the model has a general tendency to overestimate the flows.

Table B.6 Comparison of observed and estimated mean and Q_{95} flows (m^3s^{-1}) for 17 stations in the Aire and Calder catchment

	Observed	Estimated	Error (%)[1]
River Aire at Armley	15.1 (3.3)	14.6 (3.3)	- 3
River Aire at Beal Weir	35.8 (8.9)	38.3 (10.0)	7
River Calder at Caldene Bridge	4.1 (0.7)	4.4 (0.9)	7
River Colne at Colne Bidge	4.4 (0.6)	5.1 (0.9)	16
Eastburn Beck at Crosshills	0.9 (0.1)	1.0 (0.1)	11
River Calder at Elland	8.5 (2.1)	8.6 (1.7)	1
Outlon Beck at Farrer Lane	0.1 (0.0)	0.2 (0.0)	100
River Worth at Keighley	1.4 (0.3)	1.6 (0.4)	14
River Aire at Kildwick Bridge	6.3 (0.6)	6.3 (0.6)	0
River Aire at Lemonroyd	18.0 (5.0)	18.0 (5.4)	0
River Colne at Longroyd Bridge	1.4 (0.3)	1.7 (0.1)	21
River Calder at Methley	20.4 (5.8)	19.3 (5.2)	- 5
Spen Beck at Northorpe	0.8 (0.3)	0.8 (0.3)	0
River Holmes at Queens Mill	2.2 (0.5)	2.3 (0.6)	5
River Ryburn at Ripponden	0.6 (0.2)	0.6 (0.1)	0
Bradford Beck at Shipley	0.7 (0.2)	1.0 (0.2)	43
Eller Beck at Skipton	1.7 (0.1)	0.6 (0.1)	- 65

Notes: 1. The error was calculated using equation B.1.

The results of the simulations for BOD, ortho-P and chloride in the Aire and Calder catchment are shown in Table B.7, Table B.9 and Table B.8 respectively. The results for both the log-normal and the normal scenario are presented alongside the observed data. Also, for comparison purposes, the error for both scenarios was calculated using Equation 1.

Table B.7 Observed and estimated BOD concentrations at a number of sites in the Aire and Calder catchment

	BOD concentrations (mgL^{-1})			BOD error (%)	
	Observed	**Normal scenario**	**Log-normal scenario**	**Normal scenario**	**Log-normal scenario**
River Aire u/s Hickson fine chemicals	5.5 (2.2)	6.8 (2.7)	6.3 (2.8)	24	15
River Aire above Thwaite mill weir	4.7 (2.3)	4.4 (2.1)	4.2 (2.2)	-7	-11
River Aire at Allerton Bywater	5.9 (3.0)	6.6 (3.0)	6.4 (2.9)	12	8
River Aire at Beal	5.2 (2.0)	6.9 (2.7)	6.4 (2.8)	32	23
River Aire at Leeds Bridge	4.6 (2.1)	4.4 (2.2)	4.2 (2.3)	-4	-7
River Aire at Buck Bridge	4.0 (2.2)	3.7 (1.9)	3.6 (2.0)	-7	-10
River Calder at Stanley Ferry	5.6 (2.4)	7.0 (3.2)	6.3 (3.5)	24	11
River Calder at Brearley Weir	2.2 (0.9)	2.9 (1.3)	2.8 (1.4)	30	26
River Calder at Dewsbury	6.4 (3.0)	6.6 (3.4)	5.8 (3.9)	3	-8
River Colne at top weir (Ashgrove Road)	3.7 (2.0)	3.3 (1.6)	3.2 (1.9)	-6	-7
			Mean error	***10***	***4***

Table B.8 Observed and estimated ortho-P concentrations at a number of sites in the Aire and Calder catchment

	Ortho-P concentrations (mgL^{-1})			Ortho-P error (%)	
	Observed	**Normal scenario**	**Log-normal scenario**	**Normal scenario**	**Log-normal scenario**
River Aire u/s Hickson fine chemicals	0.91 (0.51)	0.96 (0.49)	0.92 (0.51)	5	1
River Aire above Thwaite mill weir	0.62 (0.44)	0.54 (0.31)	0.52 (0.32)	-13	-16
River Aire at Allerton Bywater	0.92 (0.49)	0.91 (0.57)	0.87 (0.59)	0	-5
River Aire at Beal	0.94 (0.54)	1.01 (0.51)	0.97 (0.52)	8	3
River Aire at Leeds Bridge	0.65 (0.46)	0.55 (0.31)	0.53 (0.32)	-15	-17
River Aire at Buck Bridge	0.42 (0.35)	0.42 (0.25)	0.41 (0.28)	-2	-4
River Calder at Stanley Ferry	0.92 (0.58)	0.95 (0.50)	0.91 (0.51)	4	-1
River Calder at Brearley Weir	0.16 (0.14)	0.19 (0.12)	0.17 (0.14)	19	12
River Calder at Dewsbury	0.67 (0.48)	0.75 (0.44)	0.71 (0.45)	12	7
River Colne at top weir (Ashgrove Road)	0.16 (0.13)	0.20 (0.13)	0.18 (0.16)	23	16
			Mean error	***4***	***-1***

Table B.9 Observed and estimated chloride concentrations at a number of sites in the Aire and Calder catchment

	Chloride concentrations (mgL^{-1})			Chloride error (%)	
	Observed	**Normal scenario**	**Log-normal scenario**	**Normal scenario**	**Log-normal scenario**
River Aire u/s Hickson fine chemicals	104.9 (34.5)	115.3 (38.0)	112.1 (38.3)	10	7
River Aire above Thwaite mill weir	73.6 (37.6)	94.5 (39.6)	92.1 (40.4)	28	25
River Aire at Allerton Bywater	99.8 (37.1)	105.5 (37.7)	102.8 (38.5)	6	3
River Aire at Beal	120.6 (46.6)	116.4 (38.0)	113.4 (38.6)	-3	-6
River Aire at Leeds Bridge	71.9 (28.8)	95.3 (40.6)	92.9 (41.4)	33	29
River Aire at Buck Bridge	43.1 (18.3)	45.4 (15.7)	44.6 (16.3)	5	3
River Calder at Stanley Ferry	117.1 (51.6)	127.0 (46.0)	123.4 (45.0)	8	5
River Calder at Brearley Weir	24.5 (12.1)	57.1 (23.8)	56.1 (26.0)	133	128
River Calder at Dewsbury	103.9 (52.7)	133.8 (57.1)	129.7 (55.0)	29	25
River Colne at top weir (Ashgrove Road)	58.4 (28.1)	66.6 (32.0)	66 (35.3)	14	13
			Mean error	***26***	***23***

When comparing the results obtained from both scenarios in this catchment, it can be seen that the estimated concentrations of all three determinands are very similar for both log-normal and normal distributions (Table B.7, Table B.8 and Table B.9, respectively). However, comparing the mean error for both BOD and chloride shows that the log-normal scenario provides less biased results (Table B.7 and Table B.9). Therefore, as for the Exe, we can recommend using log-normal distributions to represent GQA concentrations.

The estimated BOD concentrations (for both scenarios) are in agreement with the measured data: the error ranges between 26 per cent and -11 per cent for the log-normal scenario (Table B.7). The mean error suggests there is a tendency for the model to slightly over-predict BOD values, but this was expected because BOD degradation was not included in the model for these runs.

For ortho-P concentrations, the estimates from both scenarios are also in agreement with the measured data: the error ranges between 16 per cent and -17 per cent (Table B.8). There is no clear tendency to under-predict ortho-P concentrations.

The estimated chloride concentrations are clearly over-predicted compared to the measured data, with a mean error of 23 per cent for the log-normal scenario. This over-prediction is mainly caused by a poor simulation at one site (Table B.9). For this monitoring site (Brearley Weir on the River Calder, situated downstream of Todmorden STP), the estimated and measured concentrations are out by a factor of two. The measured chloride concentrations in the final effluent for this particular STP are not particularly high or abnormal in terms of distribution, therefore such a discrepancy can only be a consequence of a background concentration that is too high.

B.3 Conclusions of flow and GQA simulations

- Flow simulations in the Exe were excellent when compared with observed data.
- Flow simulation in the Aire/Calder was acceptable, but some small tributaries were not simulated well.
- The model simulated observed GQA determinands reasonably well in both the Exe and the Aire/Calder. However, the high level of agricultural activity in the Exe catchment gives rise to diffuse sources of both ortho-P and BOD, which are not explicitly accounted for in the model simulations.
- The simulations of both catchments showed that the model configurations were acceptable for steroid modelling and for completing the second task.

Appendix C: Tabulated concentrations and associated risks for oestrogens in the Exe catchment and the Aire and Calder catchment

Table C.1 Scenario A: estimated oestrogen concentrations in the Exe catchment immediately downstream of STPs

	EE2 ($ng.l^{-1}$)			E2 ($ng.l^{-1}$)			E1 ($ng.l^{-1}$)		
STP name	**Mean**	**SD**	**90th**	**Mean**	**SD**	**90th**	**Mean**	**SD**	**90th**
Bampton	0.004	0.005	0.009	0.019	0.030	0.044	0.147	0.194	0.325
Bradninch	0.010	0.009	0.021	0.045	0.043	0.092	0.374	0.315	0.743
Burlescombe	0.008	0.008	0.017	0.037	0.047	0.084	0.298	0.295	0.603
Cheriton Bishop	0.201	0.146	0.387	0.927	0.777	1.957	7.583	4.753	13.523
Cullompton	0.010	0.009	0.020	0.045	0.043	0.090	0.372	0.310	0.730
Dulverton	0.001	0.001	0.002	0.005	0.007	0.010	0.036	0.049	0.077
Dunkeswell	0.066	0.084	0.146	0.304	0.458	0.711	2.545	3.049	5.688
Halberton	0.033	0.028	0.064	0.150	0.146	0.325	1.348	1.052	2.673
Hemyock	0.005	0.004	0.010	0.021	0.021	0.044	0.185	0.163	0.389
Lords Meadow	0.019	0.020	0.040	0.083	0.095	0.192	0.679	0.679	1.469
Newton St Cyres	0.010	0.012	0.022	0.045	0.054	0.104	0.373	0.395	0.804
Silverton	0.053	0.038	0.103	0.234	0.202	0.498	2.098	1.311	3.842
Tedburn St Mary	0.092	0.129	0.222	0.405	0.629	0.981	3.384	4.310	7.838
Thoverton	0.002	0.003	0.005	0.010	0.013	0.022	0.078	0.089	0.162
Tiverton	0.002	0.002	0.005	0.010	0.013	0.022	0.077	0.087	0.160
Uffculme	0.006	0.006	0.012	0.026	0.025	0.052	0.219	0.188	0.437
Yeoford	0.004	0.005	0.009	0.020	0.025	0.043	0.156	0.160	0.326

Table C.2 Scenario B: estimated oestrogen concentrations in the Exe catchment immediately downstream of STPs

	EE2 ($ng.l^{-1}$)			E2 ($ng.l^{-1}$)			E1 ($ng.l^{-1}$)		
	Mean	**SD**	**90th**	**Mean**	**SD**	**90th**	**Mean**	**SD**	**90th**
Bampton	0.004	0.006	0.010	0.017	0.025	0.040	0.266	0.362	0.615
Bradninch	0.012	0.010	0.023	0.041	0.036	0.088	0.561	0.474	1.161
Burlescombe	0.009	0.009	0.020	0.033	0.039	0.075	0.254	0.269	0.567
Cheriton Bishop	0.225	0.170	0.462	0.830	0.788	1.846	6.522	4.629	12.646
Cullompton	0.011	0.009	0.023	0.040	0.036	0.085	0.592	0.501	1.229
Dulverton	0.001	0.001	0.002	0.004	0.006	0.010	0.029	0.038	0.067
Dunkeswell	0.074	0.099	0.177	0.278	0.377	0.662	4.529	5.539	10.607
Halberton	0.037	0.035	0.078	0.139	0.145	0.308	2.374	1.936	4.846
Hemyock	0.005	0.005	0.012	0.019	0.018	0.042	0.245	0.214	0.508
Lords Meadow	0.021	0.022	0.047	0.077	0.085	0.179	0.670	0.661	1.498
Newton St Cyres	0.012	0.013	0.026	0.042	0.047	0.098	0.363	0.371	0.827
Silverton	0.060	0.048	0.124	0.224	0.212	0.494	1.825	1.297	3.590
Tedburn St Mary	0.099	0.139	0.258	0.372	0.574	0.912	2.901	3.727	7.299
Thoverton	0.002	0.003	0.005	0.009	0.010	0.019	0.118	0.120	0.250

	EE2 ($ng.l^{-1}$)			E2 ($ng.l^{-1}$)			E1 ($ng.l^{-1}$)		
Tiverton	0.002	0.003	0.005	0.009	0.010	0.019	0.119	0.122	0.252
Uffculme	0.007	0.006	0.014	0.024	0.022	0.050	0.247	0.207	0.506
Yeoford	0.005	0.006	0.011	0.018	0.023	0.043	0.290	0.316	0.652

Table C.3 Oestrogen-associated risk derived from mean concentrations in the Exe catchment immediately downstream of STPs

	Scenario A		Scenario B	
	RA1	RA2	RA1	RA2
Bampton	No risk	No risk	No risk	No risk
Bradninch	No risk	No risk	No risk	No risk
Burlescombe	No risk	No risk	No risk	No risk
Cheriton Bishop	At risk	At risk	At risk	At risk
Cullompton	No risk	No risk	No risk	No risk
Dulverton	No risk	No risk	No risk	No risk
Dunkeswell	At risk	At risk	At risk	At risk
Halberton	No risk	No risk	At risk	At risk
Hemyock	No risk	No risk	No risk	No risk
Lords Meadow	No risk	No risk	No risk	No risk
Newton St Cyres	No risk	No risk	No risk	No risk
Silverton	At risk	At risk	At risk	At risk
Tedburn St Mary	At risk	At risk	At risk	At risk
Thoverton	No risk	No risk	No risk	No risk
Tiverton	No risk	No risk	No risk	No risk
Uffculme	No risk	No risk	No risk	No risk
Yeoford	No risk	No risk	No risk	No risk

Table C.4 Oestrogen-associated risk derived from P_{90} concentrations in the Exe catchment immediately downstream of STPs

	Scenario A		Scenario B	
	RA1	RA2	RA1	RA2
Bampton	No risk	No risk	No risk	No risk
Bradninch	No risk	No risk	No risk	No risk
Burlescombe	No risk	No risk	No risk	No risk
Cheriton Bishop	At risk	High Risk	At risk	High Risk
Cullompton	No risk	No risk	No risk	No risk
Dulverton	No risk	No risk	No risk	No risk
Dunkeswell	At risk	At risk	At risk	At risk
Halberton	At risk	At risk	At risk	At risk
Hemyock	No risk	No risk	No risk	No risk
Lords Meadow	At risk	At risk	At risk	At risk
Newton St Cyres	No risk	No risk	No risk	No risk
Silverton	At risk	At risk	At risk	At risk
Tedburn St Mary	At risk	At risk	At risk	At risk
Thoverton	No risk	No risk	No risk	No risk
Tiverton	No risk	No risk	No risk	No risk
Uffculme	No risk	No risk	No risk	No risk
Yeoford	No risk	No risk	No risk	No risk

Table C.5 Scenario A: estimated oestrogen concentrations in the Aire and Calder catchment immediately downstream of STPs

	EE2 (ng.l^{-1})			E2 (ng.l^{-1})			E1 (ng.l^{-1})		
STP name	**Mean**	**SD**	**90th**	**Mean**	**SD**	**90th**	**Mean**	**SD**	**90th**
Brighouse	0.036	0.031	0.075	0.129	0.118	0.268	1.002	0.817	2.056
Byram Park	0.117	0.070	0.215	0.397	0.242	0.728	2.970	1.715	5.390
Caldervale	0.086	0.056	0.161	0.301	0.196	0.561	2.267	1.379	4.128
Castleford	0.116	0.070	0.213	0.396	0.244	0.730	2.956	1.724	5.379
Dowley Gap	0.032	0.033	0.070	0.115	0.130	0.257	0.907	0.930	1.996
Esholt	0.086	0.075	0.177	0.307	0.305	0.668	2.356	1.977	4.895
Halifax	0.039	0.036	0.084	0.137	0.146	0.306	1.068	0.917	2.260
Huddersfield	0.058	0.044	0.115	0.211	0.164	0.426	1.597	1.142	3.127
Knopstrop High Level	0.418	0.157	0.621	1.586	0.743	2.553	11.754	3.996	17.004
Knopstrop Low Level	0.306	0.160	0.514	1.143	0.776	2.230	8.595	4.062	13.970
Lemonroyd	0.218	0.159	0.425	0.812	0.709	1.765	6.038	4.207	11.742
Marley	0.027	0.034	0.063	0.100	0.134	0.232	0.784	0.949	1.789
Mitchell Laithes	0.081	0.054	0.152	0.285	0.193	0.539	2.138	1.358	3.907
Neiley	0.030	0.031	0.064	0.108	0.124	0.243	0.815	0.782	1.706
Normanton	0.091	0.057	0.168	0.310	0.196	0.572	2.318	1.378	4.162
North Bierley	0.222	0.145	0.412	0.837	0.677	1.726	6.190	3.689	11.067
Owlwood	0.361	0.250	0.689	1.328	1.078	2.818	10.171	6.353	19.026
Smalley Bight	0.087	0.056	0.162	0.298	0.191	0.551	2.236	1.345	4.038
Spenborough	0.216	0.126	0.383	0.792	0.535	1.524	5.941	3.151	10.156
Todmorden	0.021	0.023	0.048	0.082	0.103	0.191	0.597	0.614	1.357

Table C.6 Scenario B: estimated oestrogen concentrations in the Aire and Calder catchment immediately downstream of STPs

	EE2 (ng.l^{-1})			E2 (ng.l^{-1})			E1 (ng.l^{-1})		
STP name	**Mean**	**SD**	**90th**	**Mean**	**SD**	**90th**	**Mean**	**SD**	**90th**
Brighouse	0.035	0.030	0.073	0.126	0.116	0.262	1.067	0.901	2.149
Byram Park	0.116	0.070	0.212	0.391	0.244	0.721	4.313	2.554	7.732
Caldervale	0.085	0.054	0.160	0.297	0.202	0.564	3.021	1.918	5.693
Castleford	0.114	0.070	0.210	0.389	0.245	0.717	4.241	2.541	7.668
Dowley Gap	0.032	0.032	0.069	0.115	0.124	0.246	1.934	1.882	4.126
Esholt	0.087	0.077	0.183	0.303	0.289	0.657	3.025	2.434	6.264
Halifax	0.038	0.035	0.080	0.131	0.136	0.296	1.184	1.050	2.453
Huddersfield	0.057	0.043	0.113	0.206	0.169	0.414	1.624	1.167	3.179
Knopstrop High Level	0.417	0.153	0.615	1.561	0.761	2.570	19.690	6.913	28.374
Knopstrop Low Level	0.305	0.160	0.518	1.138	0.803	2.194	8.618	4.062	13.800
Lemonroyd	0.216	0.155	0.424	0.828	0.719	1.775	5.996	4.085	11.701
Marley	0.028	0.033	0.063	0.099	0.130	0.243	1.689	1.916	3.882
Mitchell Laithes	0.079	0.052	0.149	0.280	0.201	0.557	2.978	1.967	5.714
Neiley	0.028	0.029	0.060	0.110	0.129	0.256	0.818	0.771	1.695
Normanton	0.089	0.056	0.166	0.305	0.201	0.578	3.168	1.960	5.961
North Bierley	0.217	0.142	0.417	0.802	0.659	1.686	6.195	3.807	11.336
Owlwood	0.352	0.243	0.684	1.320	1.109	2.746	9.965	6.299	18.684
Smalley Bight	0.086	0.054	0.161	0.294	0.198	0.553	2.958	1.857	5.541
Spenborough	0.213	0.124	0.384	0.771	0.521	1.494	9.475	5.349	16.893
Todmorden	0.021	0.024	0.048	0.078	0.095	0.185	1.281	1.326	2.812

Table C.7 Oestrogen-associated risk derived from mean concentrations in the Aire and Calder catchment immediately downstream of STPs

	Scenario A		Scenario B	
STP name	**RA1**	**RA2**	**RA1**	**RA2**
Brighouse	No risk	No risk	No Risk	No Risk
Byram Park	At risk	At risk	At Risk	At Risk
Caldervale	At risk	At risk	At Risk	At Risk
Castleford	At risk	At risk	At Risk	At Risk
Dowley Gap	No risk	No risk	At Risk	At Risk
Esholt	At risk	At risk	At Risk	At Risk
Halifax	No risk	No risk	No Risk	No Risk
Huddersfield	At risk	At risk	At Risk	At Risk
Knopstrop High Level	At risk	At risk	At Risk	High Risk
Knopstrop Low Level	At risk	At risk	At Risk	At Risk
Lemonroyd	At risk	At risk	At Risk	At Risk
Marley	No risk	No risk	No Risk	No Risk
Mitchell Laithes	At risk	At risk	At Risk	At Risk
Neiley	No risk	No risk	No Risk	No Risk
Normanton	At risk	At risk	At Risk	At Risk
North Bierley	At risk	At risk	At Risk	At Risk
Owlwood	At risk	At risk	At Risk	At Risk
Smalley Bight	At risk	At risk	At Risk	At Risk
Spenborough	At risk	At risk	At Risk	At Risk
Todmorden	No risk	No risk	No Risk	No Risk

Table C.8 Oestrogen-associated risk derived from P_{90} concentrations in the Aire and Calder catchment immediately downstream of STPs

	Scenario A		Scenario B	
STP name	**RA1**	**RA2**	**RA1**	**RA2**
Brighouse	At risk	At risk	At Risk	At Risk
Byram Park	At risk	At risk	At Risk	At Risk
Caldervale	At risk	At risk	At Risk	At Risk
Castleford	At risk	At risk	At Risk	At Risk
Dowley Gap	At risk	At risk	At Risk	At Risk
Esholt	At risk	At risk	At Risk	At Risk
Halifax	At risk	At risk	At Risk	At Risk
Huddersfield	At risk	At risk	At Risk	At Risk
Knopstrop High Level	High Risk	High Risk	High Risk	High Risk
Knopstrop Low Level	At risk	High Risk	At Risk	High Risk
Lemonroyd	At risk	At risk	At Risk	At Risk
Marley	At risk	At risk	At Risk	At Risk
Mitchell Laithes	At risk	At risk	At Risk	At Risk
Neiley	At risk	At risk	At Risk	At Risk
Normanton	At risk	At risk	At Risk	At Risk
North Bierley	At risk	At risk	At Risk	At Risk
Owlwood	High Risk	High Risk	High Risk	High Risk
Smalley Bight	At risk	At risk	At Risk	At Risk
Spenborough	At risk	At risk	At Risk	High Risk
Todmorden	At risk	At risk	At Risk	At Risk

Appendix D: Tabulated concentrations and associated risks for oestrogens in SAC catchments

Note: Units in tables are $10^{-3}ngL^{-1}$ (picogrammes/L) for clearer formatting.

The reaches within the SAC are highlighted in grey; those that receive a STP discharge are shown in bold.

Table D.1 Estimated oestrogen concentrations and associated risk derived from mean and P_{90} concentrations in the River Lambourn

				Concentrations ($10^{-3}ngL^{-1}$)											Risk classes			
Reach	Upstream NGR	Downstream NGR	Length (m)	EE2			E2			E1			E2 Equivalent		National		SAC	
				Mean	SD	90th	Mean	SD	90th	Mean	SD	90th	Mean	90th	Mean	90th	Mean	90th
1	SU389747	SU391745	282	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
2	**SU391745**	**SU398740**	**1027**	**8**	**6**	**15**	**29**	**28**	**61**	**221**	**153**	**425**	**230**	**449**	**No risk**	**No risk**	**No risk**	**No risk**
3	SU398740	SU410732	1624	7	5	14	28	26	58	212	145	405	221	431	No risk	No risk	No risk	No risk
4	SU410732	SU426722	2407	7	5	13	26	24	53	195	133	371	204	397	No risk	No risk	No risk	No risk
5	SU426722	SU430719	706	7	5	13	24	23	51	186	127	354	195	378	No risk	No risk	No risk	No risk
6	**SU430719**	**SU451693**	**4401**	**7**	**5**	**13**	**25**	**22**	**50**	**202**	**128**	**376**	**202**	**387**	**No risk**	**No risk**	**No risk**	**No risk**
7	SU451693	SU457690	678	7	5	13	24	22	50	201	127	373	201	384	No risk	No risk	No risk	No risk
8	SU465746	SU469739	807	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
9	**SU469739**	**SU456721**	**2443**	**53**	**42**	**109**	**200**	**183**	**449**	**2207**	**1738**	**4516**	**1824**	**3774**	**At risk**	**At risk**	**At risk**	**At risk**
10	**SU456721**	**SU452698**	**3028**	**26**	**18**	**50**	**95**	**77**	**201**	**1132**	**785**	**2246**	**905**	**1781**	**No risk**	**At risk**	**No risk**	**At risk**
11	SU452698	SU453695	286	26	18	49	93	76	198	1116	774	2211	894	1755	No risk	At risk	No risk	At risk
12	SU453695	SU457690	808	25	18	48	91	74	192	1083	752	2154	870	1712	No risk	At risk	No risk	At risk
13	SU457690	SU474683	2337	10	6	18	36	25	66	358	215	653	322	582	No risk	No risk	No risk	No risk
14	SU474683	SU487674	1653	9	6	17	34	24	62	333	204	614	300	547	No risk	No risk	No risk	No risk

Table D.2 Estimated oestrogen concentrations and associated risk derived from mean and P_{90} concentrations in the River Tywi

Reach	Upstream NGR	Downstream NGR	Length (m)	Concentrations (10^{-3}ngL^{-1}) EE2 Mean	EE2 SD	EE2 90th	E2 Mean	E2 SD	E2 90th	E1 Mean	E1 SD	E1 90th	E2 Equivalent Mean	E2 Equivalent 90th	Risk classes National Mean	National 90th	SAC Mean	SAC 90th
1	SN645456	SN648445	1502	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
2	**SN648445**	**SN651439**	**870**	**1**	**1**	**2**	**3**	**5**	**7**	**45**	**75**	**103**	**30**	**70**	**No risk**	**No risk**	**No risk**	**No risk**
3	SN651439	SN652434	709	1	1	1	2	4	5	33	53	75	21	50	No risk	No risk	No risk	No risk
4	SN652434	SN648413	2479	0	1	1	1	2	3	22	34	49	14	33	No risk	No risk	No risk	No risk
5	SN648413	SN655404	1539	0	1	1	1	2	3	17	26	40	12	27	No risk	No risk	No risk	No risk
6	SN670426	SN658405	3119	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
7	**SN658405**	**SN655404**	**322**	**0**	**0**	**0**	**0**	**1**	**1**	**7**	**9**	**16**	**5**	**10**	**No risk**	**No risk**	**No risk**	**No risk**
8	SN759236	SN757241	609	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
9	SN757241	SN754241	411	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
10	**SN754241**	**SN737235**	**2110**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**4**	**7**	**1**	**5**	**No risk**	**No risk**	**No risk**	**No risk**
11	SN718211	SN724215	840	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
12	SN724215	SN727217	418	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
13	**SN727217**	**SN735221**	**1072**	**0**	**0**	**0**	**1**	**1**	**1**	**9**	**11**	**21**	**5**	**13**	**No risk**	**No risk**	**No risk**	**No risk**
14	SN735221	SN738226	628	0	0	0	1	1	1	8	10	18	5	12	No risk	No risk	No risk	No risk
15	SN738226	SN737235	987	0	0	0	0	0	1	5	6	10	2	6	No risk	No risk	No risk	No risk
16	SN660187	SN654189	788	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
17	**SN654189**	**SN632218**	**9879**	**0**	**0**	**0**	**1**	**1**	**1**	**9**	**12**	**22**	**5**	**14**	**No risk**	**No risk**	**No risk**	**No risk**
18	SN575222	SN571221	374	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
19	**SN571221**	**SN550212**	**2691**	**3**	**5**	**7**	**11**	**18**	**25**	**351**	**535**	**864**	**179**	**435**	**No risk**	**No risk**	**No risk**	**No risk**
20	SN597203	SN581204	1830	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
21	SN581204	SN578204	418	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
22	SN511247	SN508245	330	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
23	SN508245	SN508244	127	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
24	**SN508244**	**SN508238**	**605**	**1**	**1**	**2**	**3**	**4**	**6**	**42**	**56**	**97**	**27**	**64**	**No risk**	**No risk**	**No risk**	**No risk**
25	SN508238	SN509225	1478	1	1	1	2	3	5	33	43	76	21	50	No risk	No risk	No risk	No risk
26	SN818409	SN811404	939	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
27	SN811404	SN804398	959	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
28	**SN804398**	**SN796386**	**1919**	**0**	**0**	**0**	**0**	**1**	**1**	**7**	**10**	**17**	**5**	**10**	**No risk**	**No risk**	**No risk**	**No risk**

29	SN796386	SN788371	1922	0	0	0	0	1	1	6	8	14	2	9	No risk	No risk	No risk	No risk
30	SN788371	SN771342	4483	0	0	0	0	0	1	4	5	9	2	5	No risk	No risk	No risk	No risk
31	SN668220	SN665218	396	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
32	**SN665218**	**SN663216**	**273**	**18**	**24**	**40**	**65**	**90**	**145**	**316**	**453**	**701**	**462**	**1038**	**No risk**	**No risk**	**No risk**	**At risk**
33	SN663216	SN645212	2173	5	6	10	16	22	35	90	127	197	121	269	No risk	No risk	No risk	No risk
34	SN645212	SN633218	1847	2	3	5	8	11	19	50	70	110	65	145	No risk	No risk	No risk	No risk
35	SN369319	SN376311	1232	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
36	SN376311	SN378307	447	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
37	**SN378307**	**SN373274**	**3623**	**1**	**1**	**1**	**2**	**3**	**6**	**19**	**24**	**44**	**19**	**44**	**No risk**	**No risk**	**No risk**	**No risk**
38	SN373274	SN377270	718	0	0	1	1	2	3	9	11	20	7	19	No risk	No risk	No risk	No risk
39	**SN377270**	**SN384265**	**919**	**1**	**1**	**2**	**4**	**5**	**8**	**48**	**60**	**111**	**35**	**80**	**No risk**	**No risk**	**No risk**	**No risk**
40	SN629270	SN622266	823	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
41	**SN622266**	**SN607259**	**1965**	**10**	**15**	**23**	**36**	**61**	**89**	**408**	**612**	**981**	**337**	**804**	**No risk**	**No risk**	**No risk**	**No risk**
42	SN607259	SN593245	2477	4	6	9	14	25	34	161	250	393	133	322	No risk	No risk	No risk	No risk
43	SN593245	SN597234	1385	3	5	8	11	19	27	127	195	307	105	254	No risk	No risk	No risk	No risk
44	SN597234	SN597228	745	2	4	6	8	14	20	95	144	228	78	189	No risk	No risk	No risk	No risk
45	SN597228	SN597220	1011	2	3	5	7	12	17	80	123	193	67	161	No risk	No risk	No risk	No risk
46	SN599346	SN587338	1475	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
47	**SN587338**	**SN587338**	**60**	**8**	**12**	**19**	**30**	**47**	**74**	**215**	**301**	**491**	**233**	**555**	**No risk**	**No risk**	**No risk**	**No risk**
48	SN587338	SN586335	321	1	1	1	2	3	5	15	20	34	16	38	No risk	No risk	No risk	No risk
49	SN444313	SN443313	93	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
50	**SN443313**	**SN442312**	**125**	**2**	**2**	**4**	**6**	**10**	**15**	**47**	**65**	**109**	**49**	**113**	**No risk**	**No risk**	**No risk**	**No risk**
51	SN442312	SN420295	3449	1	2	3	4	7	10	32	47	76	33	81	No risk	No risk	No risk	No risk
52	SN420295	SN418292	335	1	1	1	2	4	6	18	25	41	18	43	No risk	No risk	No risk	No risk
53	**SN418292**	**SN384265**	**5554**	**3**	**5**	**7**	**11**	**16**	**27**	**97**	**124**	**228**	**95**	**218**	**No risk**	**No risk**	**No risk**	**No risk**
54	SN524301	SN526302	319	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
55	SN526302	SN529302	258	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
56	**SN529302**	**SN535300**	**812**	**1**	**1**	**2**	**3**	**5**	**7**	**46**	**60**	**104**	**30**	**70**	**No risk**	**No risk**	**No risk**	**No risk**
57	SN619362	SN622361	338	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
58	SN622361	SN624362	183	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
59	**SN624362**	**SN641367**	**2043**	**1**	**1**	**2**	**3**	**4**	**7**	**43**	**61**	**97**	**29**	**67**	**No risk**	**No risk**	**No risk**	**No risk**
60	SN679405	SN675398	1011	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
61	SN675398	SN675396	167	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
62	**SN675396**	**SN656376**	**3472**	**1**	**1**	**2**	**3**	**4**	**8**	**27**	**30**	**59**	**27**	**62**	**No risk**	**No risk**	**No risk**	**No risk**

63	SN656376	SN656376	36	1	1	2	3	4	6	22	25	49	22	51	No risk	No risk	No risk	No risk
64	**SN656376**	**SN652370**	**936**	**2**	**2**	**5**	**9**	**8**	**18**	**46**	**46**	**96**	**62**	**131**	**No risk**	**No risk**	**No risk**	**No risk**
65	SN652370	SN644355	2111	2	2	4	7	7	15	37	39	79	51	109	No risk	No risk	No risk	No risk
66	SN753401	SN755395	692	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
67	**SN755395**	**SN760387**	**931**	**1**	**1**	**2**	**4**	**5**	**8**	**56**	**67**	**121**	**37**	**84**	**No risk**	**No risk**	**No risk**	**No risk**
68	SN767447	SN781432	2219	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
69	**SN781432**	**SN765399**	**4648**	**0**	**0**	**0**	**0**	**0**	**1**	**3**	**4**	**8**	**1**	**5**	**No risk**	**No risk**	**No risk**	**No risk**
70	SN765399	SN760387	1856	0	0	0	0	0	0	3	4	8	1	5	No risk	No risk	No risk	No risk
71	SN786347	SN771342	1979	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
72	SN800300	SN788300	1339	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
73	SN788300	SN786300	166	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
74	SN786300	SN782302	492	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
75	SN782302	SN774297	1010	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
76	SN774297	SN774297	68	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
77	**SN774297**	**SN767299**	**741**	**1**	**1**	**2**	**4**	**6**	**9**	**61**	**79**	**138**	**39**	**91**	**No risk**	**No risk**	**No risk**	**No risk**
78	SN767299	SN749284	2669	1	1	2	3	4	7	45	59	103	29	69	No risk	No risk	No risk	No risk
79	SN749284	SN725291	3096	0	0	1	1	2	3	19	25	44	13	29	No risk	No risk	No risk	No risk
80	SN725291	SN698284	3602	0	0	1	1	1	2	13	18	31	9	20	No risk	No risk	No risk	No risk
81	**SN698284**	**SN696284**	**219**	**6**	**9**	**14**	**21**	**34**	**50**	**348**	**505**	**792**	**235**	**551**	**No risk**	**No risk**	**No risk**	**No risk**
82	SN640319	SN640319	46	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
83	SN640319	SN640318	100	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
84	**SN640318**	**SN647310**	**1149**	**7**	**11**	**17**	**27**	**43**	**68**	**203**	**288**	**500**	**216**	**517**	**No risk**	**No risk**	**No risk**	**No risk**
85	SN647310	SN649304	740	4	6	9	15	24	37	112	161	274	119	284	No risk	No risk	No risk	No risk
86	SN649304	SN647239	8845	1	1	2	3	5	8	28	36	66	28	67	No risk	No risk	No risk	No risk
87	SN557228	SN556227	167	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
88	**SN556227**	**SN550212**	**1948**	**1**	**1**	**2**	**3**	**5**	**8**	**23**	**37**	**53**	**24**	**57**	**No risk**	**No risk**	**No risk**	**No risk**
89	SN655404	SN641367	5291	0	0	0	1	1	1	10	12	21	6	13	No risk	No risk	No risk	No risk
90	SN737235	SN695281	7087	0	0	0	0	0	0	3	3	7	1	4	No risk	No risk	No risk	No risk
91	SN384265	SN418237	6472	2	2	3	6	7	13	57	69	129	51	112	No risk	No risk	No risk	No risk
92	**SN418237**	**SN432204**	**4060**	**2**	**2**	**4**	**6**	**7**	**13**	**59**	**67**	**133**	**54**	**119**	**No risk**	**No risk**	**No risk**	**No risk**
93	SN760387	SN762361	3234	0	0	0	0	0	1	6	7	13	4	8	No risk	No risk	No risk	No risk
94	SN762361	SN761348	1384	0	0	0	0	0	1	6	6	13	2	8	No risk	No risk	No risk	No risk
95	SN761348	SN753327	2402	0	0	0	0	0	1	6	6	13	2	8	No risk	No risk	No risk	No risk
96	SN771342	SN761332	1669	0	0	0	0	0	0	2	2	4	1	2	No risk	No risk	No risk	No risk

97	**SN761332**	**SN753327**	**1575**	**4**	**6**	**8**	**13**	**25**	**31**	**206**	**307**	**493**	**140**	**332**	**No risk**	**No risk**	**No risk**	**No risk**
98	SN550212	SN545207	930	1	2	2	4	5	9	53	82	122	38	88	No risk	No risk	No risk	No risk
99	SN641367	SN644355	1357	0	0	1	1	2	3	19	24	43	13	29	No risk	No risk	No risk	No risk
100	SN753327	SN696284	8944	1	1	2	3	4	6	42	50	95	28	64	No risk	No risk	No risk	No risk
101	SN644355	SN586335	7497	0	1	1	2	2	4	18	21	39	14	32	No risk	No risk	No risk	No risk
102	SN696284	SN695281	328	1	1	3	4	5	9	64	76	141	43	97	No risk	No risk	No risk	No risk
103	SN586335	SN542306	5981	0	1	1	1	2	3	16	18	35	13	30	No risk	No risk	No risk	No risk
104	SN542306	SN535300	993	0	0	1	1	1	3	13	15	29	11	24	No risk	No risk	No risk	No risk
105	SN695281	SN687267	1686	1	1	2	3	4	6	45	51	98	29	69	No risk	No risk	No risk	No risk
106	SN687267	SN663248	4226	1	1	2	3	3	6	43	49	94	29	65	No risk	No risk	No risk	No risk
107	**SN663248**	**SN656240**	**1518**	**1**	**1**	**2**	**3**	**4**	**6**	**46**	**52**	**99**	**31**	**69**	**No risk**	**No risk**	**No risk**	**No risk**
108	SN656240	SN647239	862	1	1	2	3	4	6	45	51	98	31	68	No risk	No risk	No risk	No risk
109	SN535300	SN509225	10194	0	0	1	1	1	3	16	18	34	11	27	No risk	No risk	No risk	No risk
110	SN647239	SN633218	4210	1	1	2	3	3	6	43	48	93	30	67	No risk	No risk	No risk	No risk
111	SN509225	SN505213	1410	0	0	1	1	1	3	16	18	34	11	27	No risk	No risk	No risk	No risk
112	**SN505213**	**SN500200**	**1919**	**1**	**1**	**1**	**2**	**3**	**5**	**33**	**40**	**70**	**23**	**52**	**No risk**	**No risk**	**No risk**	**No risk**
113	SN633218	SN632218	91	1	1	2	3	3	6	43	48	93	30	67	No risk	No risk	No risk	No risk
114	SN632218	SN616215	1764	1	1	2	3	3	6	41	46	90	28	66	No risk	No risk	No risk	No risk
115	**SN616215**	**SN597220**	**3254**	**1**	**2**	**3**	**5**	**6**	**11**	**75**	**87**	**158**	**51**	**112**	**No risk**	**No risk**	**No risk**	**No risk**
116	SN597220	SN590214	965	1	2	3	5	6	11	74	87	159	51	112	No risk	No risk	No risk	No risk
117	SN590214	SN589214	71	1	2	3	5	6	11	74	87	159	51	112	No risk	No risk	No risk	No risk
118	**SN589214**	**SN578204**	**3118**	**1**	**2**	**3**	**5**	**6**	**11**	**73**	**84**	**154**	**51**	**110**	**No risk**	**No risk**	**No risk**	**No risk**
119	SN578204	SN545207	5463	1	2	3	5	5	10	70	80	148	50	106	No risk	No risk	No risk	No risk
120	SN545207	SN500200	7709	1	2	3	4	5	10	66	75	140	46	101	No risk	No risk	No risk	No risk
121	SN500200	SN491204	962	1	1	2	4	4	8	57	65	123	41	89	No risk	No risk	No risk	No risk
122	SN491204	SN432204	8075	1	1	2	4	4	8	55	61	117	40	87	No risk	No risk	No risk	No risk
123	SN432204	SN400152	10870	1	1	2	4	4	8	51	55	107	39	83	No risk	No risk	No risk	No risk

Table D.3 Estimated oestrogen concentrations and associated risk derived from mean and P_{90} concentrations in the River Wye

Reach	Upstream NGR	Downstream NGR	Length (m)	Concentrations ($10^{-3}ngL^{-1}$) EE2 Mean	EE2 SD	EE2 90th	E2 Mean	E2 SD	E2 90th	E1 Mean	E1 SD	E1 90th	E2 Equivalent Mean	E2 Equivalent 90th	Risk classes National Mean	National 90th	SAC Mean	SAC 90th
1	SO131371	SO135380	1275	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
2	**SO135380**	**SO133382**	**261**	**25**	**29**	**57**	**97**	**120**	**230**	**1594**	**1789**	**3489**	**1051**	**2348**	**No risk**	**At risk**	**At risk**	**At risk**
3	SO188378	SO173379	1766	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
4	**SO173379**	**SO170382**	**404**	**9**	**12**	**20**	**33**	**47**	**80**	**546**	**701**	**1238**	**363**	**829**	**No risk**	**No risk**	**No risk**	**No risk**
5	SO530316	SO532311	591	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
6	**SO532311**	**SO532306**	**495**	**70**	**78**	**162**	**259**	**341**	**618**	**4480**	**4988**	**10306**	**2911**	**6757**	**At risk**	**At risk**	**At risk**	**At risk**
7	SO532306	SO534301	661	21	23	47	77	102	183	1334	1460	3007	868	1975	No risk	At risk	No risk	At risk
8	SO534301	SO546291	2043	8	9	18	29	38	67	501	538	1108	329	736	No risk	No risk	No risk	No risk
9	SO546291	SO547289	288	6	7	13	21	27	48	364	392	806	239	535	No risk	No risk	No risk	No risk
10	SO423549	SO426549	254	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
11	**SO426549**	**SO433551**	**755**	**202**	**189**	**442**	**741**	**823**	**1685**	**13214**	**10535**	**27394**	**8507**	**18176**	**At risk**	**High risk**	**At risk**	**At risk**
12	SO433551	SO434552	158	87	93	202	319	400	759	5631	5111	12135	3646	8165	At risk	At risk	At risk	At risk
13	SO434552	SO439552	576	8	10	18	28	41	67	494	518	1073	322	723	No risk	No risk	No risk	No risk
14	SO322287	SO323285	336	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
15	**SO323285**	**SO328281**	**692**	**1**	**1**	**3**	**4**	**5**	**10**	**31**	**34**	**68**	**33**	**74**	**No risk**	**No risk**	**No risk**	**No risk**
16	SO328281	SO335234	6114	0	0	1	1	2	3	10	12	22	10	24	No risk	No risk	No risk	No risk
17	SO376418	SO385423	1054	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
18	**SO385423**	**SO401423**	**2175**	**3**	**3**	**6**	**10**	**15**	**24**	**78**	**88**	**174**	**82**	**185**	**No risk**	**No risk**	**No risk**	**No risk**
19	SN920515	SN921512	399	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
20	**SN921512**	**SN922489**	**3910**	**0**	**1**	**1**	**2**	**2**	**4**	**26**	**35**	**59**	**17**	**40**	**No risk**	**No risk**	**No risk**	**No risk**
21	SN922489	SN934471	3118	0	1	1	1	2	3	22	29	49	13	33	No risk	No risk	No risk	No risk
22	SO000527	SO009518	1342	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
23	**SO009518**	**SO032513**	**2736**	**1**	**1**	**2**	**3**	**5**	**6**	**43**	**66**	**98**	**29**	**65**	**No risk**	**No risk**	**No risk**	**No risk**
24	SO103540	SO110543	938	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
25	**SO110543**	**SO116539**	**810**	**0**	**1**	**1**	**2**	**3**	**4**	**27**	**37**	**62**	**17**	**41**	**No risk**	**No risk**	**No risk**	**No risk**
26	SO116539	SO123518	3179	0	0	0	1	1	2	11	16	24	6	16	No risk	No risk	No risk	No risk
27	SO123518	SO096478	6725	0	0	0	0	0	1	5	5	10	2	6	No risk	No risk	No risk	No risk
28	SO096478	SO077470	2267	0	0	0	0	0	1	4	5	9	2	5	No risk	No risk	No risk	No risk

29	**SO077470**	**SO076469**	**167**	**1**	**2**	**3**	**5**	**6**	**11**	**23**	**29**	**52**	**34**	**76**	**No risk**	**No risk**	**No risk**	**No risk**
30	SO336551	SO342557	1019	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
31	**SO342557**	**SO360564**	**2374**	**14**	**17**	**31**	**50**	**65**	**120**	**399**	**455**	**851**	**416**	**922**	**No risk**	**No risk**	**No risk**	**No risk**
32	SO360564	SO366566	691	12	14	26	42	54	100	334	379	711	350	772	No risk	No risk	No risk	No risk
33	SO366566	SO374579	2094	7	9	16	25	32	60	204	229	433	215	474	No risk	No risk	No risk	No risk
34	SO374579	SO390584	1929	5	5	10	15	19	36	125	132	259	132	287	No risk	No risk	No risk	No risk
35	SO302493	SO308492	676	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
36	SO308492	SO312486	792	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
37	**SO312486**	**SO307478**	**1028**	**10**	**11**	**21**	**36**	**48**	**84**	**261**	**295**	**572**	**281**	**631**	**No risk**	**No risk**	**No risk**	**No risk**
38	SO307478	SO323468	2525	8	9	17	28	37	65	204	229	445	221	497	No risk	No risk	No risk	No risk
39	SO142634	SO140632	292	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
40	SO140632	SO138631	343	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
41	**SO138631**	**SO134632**	**397**	**0**	**1**	**1**	**2**	**3**	**4**	**27**	**39**	**63**	**17**	**41**	**No risk**	**No risk**	**No risk**	**No risk**
42	SO134632	SO115629	2517	0	1	1	1	2	3	20	29	46	13	32	No risk	No risk	No risk	No risk
43	SO481240	SO492241	1666	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
44	**SO492241**	**SO493231**	**1666**	**1**	**1**	**3**	**4**	**6**	**10**	**32**	**37**	**72**	**33**	**75**	**No risk**	**No risk**	**No risk**	**No risk**
45	SO493231	SO502227	1729	1	1	2	3	4	7	25	28	54	25	57	No risk	No risk	No risk	No risk
46	SO502227	SO524225	2755	1	1	1	2	3	5	18	19	39	18	42	No risk	No risk	No risk	No risk
47	SO524225	SO533217	2514	0	0	1	1	1	3	10	10	20	9	21	No risk	No risk	No risk	No risk
48	SO533217	SO560183	11813	0	0	1	1	1	2	6	6	13	6	14	No risk	No risk	No risk	No risk
49	SO485312	SO484312	182	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
50	SO484312	SO483313	57	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
51	SO483313	SO481315	375	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
52	**SO481315**	**SO475326**	**1409**	**30**	**38**	**65**	**112**	**153**	**269**	**1814**	**2162**	**4065**	**1211**	**2707**	**At risk**	**At risk**	**At risk**	**At risk**
53	SO475326	SO464327	1238	21	27	45	76	108	184	1228	1511	2754	827	1847	No risk	At risk	No risk	At risk
54	SO464327	SO461316	1403	8	11	17	28	41	67	448	570	1001	304	676	No risk	No risk	No risk	No risk
55	SO461316	SO441309	2569	5	8	11	18	28	44	301	392	671	205	458	No risk	No risk	No risk	No risk
56	**SO441309**	**SO435304**	**967**	**6**	**8**	**13**	**21**	**30**	**50**	**315**	**396**	**690**	**226**	**502**	**No risk**	**No risk**	**No risk**	**No risk**
57	SO435304	SO419305	2034	5	7	11	18	25	42	260	324	574	189	421	No risk	No risk	No risk	No risk
58	SO419305	SO401282	3376	4	5	8	12	17	29	183	225	405	135	301	No risk	No risk	No risk	No risk
59	SO292667	SO306666	1565	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
60	**SO306666**	**SO307666**	**77**	**23**	**26**	**53**	**84**	**102**	**201**	**1407**	**1515**	**2996**	**938**	**2080**	**No risk**	**At risk**	**No risk**	**At risk**
61	SO307666	SO310650	1982	5	7	13	19	26	46	323	409	706	217	491	No risk	No risk	No risk	No risk
62	SO310650	SO322643	1858	1	1	1	2	3	5	35	46	76	22	52	No risk	No risk	No risk	No risk

63	SO322643	SO352636	4181	5	6	10	17	22	39	260	303	560	178	392	No risk	No risk	No risk	No risk
64	SO208603	SO217607	1171	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
65	SO217607	SO279607	7832	2	2	3	6	7	13	88	102	197	60	134	No risk	No risk	No risk	No risk
66	SO279607	SO352636	10096	1	1	1	2	3	6	38	37	81	25	56	No risk	No risk	No risk	No risk
67	SO210404	SO204405	680	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
68	SO204405	SO198408	711	4	6	9	16	25	36	246	329	560	166	378	No risk	No risk	No risk	No risk
69	SO202440	SO216439	1555	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
70	SO216439	SO223442	873	11	15	25	42	56	96	690	885	1521	459	1024	No risk	No risk	No risk	At risk
71	SO223442	SO232454	1883	8	11	18	29	40	66	477	634	1050	321	719	No risk	No risk	No risk	No risk
72	SO104337	SO117339	1521	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
73	SO117339	SO127343	1189	0	1	1	2	3	4	31	40	68	19	45	No risk	No risk	No risk	No risk
74	SO127343	SO149344	3082	0	0	1	1	1	2	16	20	35	10	24	No risk	No risk	No risk	No risk
75	SO149344	SO150346	278	0	0	0	0	1	1	7	10	16	5	10	No risk	No risk	No risk	No risk
76	SO150346	SO151348	219	0	0	0	0	1	1	6	8	14	4	9	No risk	No risk	No risk	No risk
77	SO151348	SO170382	4396	4	6	10	16	23	41	266	350	593	178	408	No risk	No risk	No risk	No risk
78	SN903798	SN908797	507	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
79	SN908797	SN952715	11218	0	0	0	1	1	2	12	18	27	8	17	No risk	No risk	No risk	No risk
80	SN952715	SN978674	6427	0	0	0	0	1	1	8	12	19	5	12	No risk	No risk	No risk	No risk
81	SN978674	SN967657	2384	2	3	5	8	13	19	125	180	299	85	198	No risk	No risk	No risk	No risk
82	SN967657	SN978633	2773	2	3	4	7	12	17	113	161	270	77	180	No risk	No risk	No risk	No risk
83	SN978633	SO014582	8234	2	3	4	6	10	15	97	133	232	67	159	No risk	No risk	No risk	No risk
84	SO014582	SO013564	3003	2	3	5	7	11	16	102	136	242	74	177	No risk	No risk	No risk	No risk
85	SO587232	SO584234	399	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
86	SO584234	SO583234	79	1133	730	2112	4329	3414	8683	32122	19431	55677	33913	62433	High risk	High risk	At risk	At risk
87	SO616409	SO615415	639	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
88	SO615415	SO615415	40	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
89	SO615415	SO613421	567	26	34	61	96	134	224	1575	1882	3382	1061	2366	No risk	At risk	At risk	At risk
90	SO613421	SO597419	1758	18	24	41	63	91	148	1044	1283	2256	711	1586	No risk	At risk	No risk	At risk
91	SO338394	SO348380	1841	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
92	SO348380	SO349379	128	6	7	13	20	28	49	155	184	362	164	377	No risk	No risk	No risk	No risk
93	SO349379	SO368352	3679	4	5	9	14	19	32	105	125	247	110	256	No risk	No risk	No risk	No risk
94	SO368352	SO401282	8339	3	3	6	8	11	20	67	77	155	72	167	No risk	No risk	No risk	No risk
95	SO095653	SO089647	979	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
96	SO089647	SO087642	606	102	150	258	374	582	965	6143	8441	15029	4128	10271	At risk	At risk	At risk	At risk

97	SO398618	SO399618	121	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
98	**SO399618**	**SO401620**	**280**	**23**	**24**	**50**	**90**	**105**	**211**	**1413**	**1431**	**2963**	**946**	**2036**	**No risk**	**At risk**	**No risk**	**At risk**
99	SO401620	SO415608	2330	16	18	35	62	75	146	969	1016	2054	657	1420	No risk	At risk	No risk	At risk
100	SO415608	SO415608	92	13	14	28	49	59	115	758	811	1603	514	1117	No risk	No risk	No risk	At risk
101	SO415608	SO454605	4530	8	9	18	30	37	70	476	498	995	327	703	No risk	No risk	No risk	No risk
102	**SO454605**	**SO501594**	**6183**	**16**	**16**	**34**	**54**	**58**	**121**	**849**	**808**	**1805**	**595**	**1289**	**No risk**	**At risk**	**No risk**	**At risk**
103	SO491642	SO492636	585	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
104	**SO492636**	**SO492635**	**102**	**305**	**271**	**684**	**1145**	**1178**	**2632**	**18290**	**15589**	**38844**	**12321**	**26987**	**High risk**	**High risk**	**At risk**	**At risk**
105	SO492635	SO503614	2995	72	80	170	255	313	606	4090	4316	9218	2820	6504	At risk	At risk	At risk	At risk
106	SO503614	SO501607	770	48	55	112	166	211	396	2673	2932	6063	1854	4280	At risk	At risk	At risk	At risk
107	SO501607	SO503601	660	31	37	73	107	140	254	1723	1945	3914	1200	2773	No risk	At risk	At risk	At risk
108	SO503601	SO501596	597	9	11	21	31	41	73	493	578	1109	345	788	No risk	No risk	No risk	No risk
109	SO383512	SO396521	1601	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
110	**SO396521**	**SO406534**	**1944**	**35**	**37**	**76**	**124**	**154**	**301**	**993**	**1040**	**2134**	**1032**	**2281**	**No risk**	**At risk**	**At risk**	**At risk**
111	SO406534	SO407533	115	30	33	67	108	135	259	860	916	1857	894	1990	No risk	At risk	No risk	At risk
112	SO407533	SO433543	3327	18	21	41	62	81	150	503	553	1075	530	1185	No risk	No risk	No risk	At risk
113	SO433543	SO439552	1401	16	18	35	53	68	127	427	468	910	453	1012	No risk	No risk	No risk	At risk
114	SN888455	SN893460	687	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
115	SN893460	SN900462	1147	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
116	**SN900462**	**SN916470**	**2199**	**1**	**1**	**2**	**3**	**7**	**8**	**51**	**74**	**121**	**34**	**81**	**No risk**	**No risk**	**No risk**	**No risk**
117	SN916470	SN934471	1898	1	1	1	2	5	6	37	53	88	25	58	No risk	No risk	No risk	No risk
118	SO618178	SO618179	38	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
119	**SO618179**	**SO618184**	**532**	**43**	**37**	**89**	**159**	**160**	**361**	**2804**	**2178**	**5541**	**1809**	**3696**	**At risk**	**At risk**	**At risk**	**At risk**
120	SO618184	SO598181	2152	25	23	53	89	96	207	1575	1333	3241	1024	2173	No risk	At risk	At risk	At risk
121	SO317210	SO335228	3280	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
122	**SO335228**	**SO335234**	**623**	**1**	**1**	**2**	**4**	**5**	**9**	**28**	**31**	**57**	**28**	**63**	**No risk**	**No risk**	**No risk**	**No risk**
123	SO459103	SO459101	229	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
124	**SO459101**	**SO516116**	**9153**	**1**	**1**	**1**	**2**	**3**	**5**	**29**	**42**	**65**	**20**	**45**	**No risk**	**No risk**	**No risk**	**No risk**
125	SO363302	SO363301	98	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
126	SO363301	SO372295	1406	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
127	SO372295	SO388285	2316	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
128	SO388285	SO395276	1222	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
129	**SO395276**	**SO395276**	**66**	**14**	**19**	**33**	**55**	**86**	**127**	**410**	**562**	**913**	**432**	**977**	**No risk**	**No risk**	**No risk**	**No risk**
130	SO556093	SO551090	753	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk

131	**SO551090**	**SO536097**	**4327**	**103**	**89**	**214**	**367**	**368**	**835**	**5991**	**4843**	**12262**	**4076**	**8496**	**At risk**	**At risk**	**At risk**	**At risk**
132	SO421367	SO423370	425	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
133	**SO423370**	**SO430377**	**1120**	**89**	**100**	**208**	**337**	**429**	**828**	**2663**	**2828**	**6036**	**2711**	**6308**	**At risk**	**At risk**	**At risk**	**At risk**
134	SO430377	SO435373	610	52	61	121	193	258	470	1533	1718	3518	1564	3656	At risk	At risk	At risk	At risk
135	SO435373	SO449380	1776	30	36	69	108	146	263	877	998	1980	892	2071	No risk	At risk	No risk	At risk
136	**SO449380**	**SO457394**	**2220**	**44**	**48**	**97**	**158**	**185**	**360**	**1775**	**1841**	**3871**	**1475**	**3265**	**At risk**	**At risk**	**At risk**	**At risk**
137	SO114641	SO116639	395	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
138	**SO116639**	**SO115629**	**1347**	**0**	**0**	**0**	**1**	**1**	**1**	**9**	**15**	**21**	**5**	**13**	**No risk**	**No risk**	**No risk**	**No risk**
139	SN949494	SN951492	285	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
140	**SN951492**	**SN955493**	**854**	**1**	**1**	**1**	**2**	**3**	**5**	**30**	**44**	**69**	**20**	**46**	**No risk**	**No risk**	**No risk**	**No risk**
141	SO650556	SO657550	1139	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
142	SO657550	SO658544	735	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
143	**SO658544**	**SO665485**	**10372**	**34**	**46**	**81**	**119**	**170**	**299**	**905**	**1096**	**2055**	**989**	**2326**	**No risk**	**At risk**	**No risk**	**At risk**
144	**SO665485**	**SO626428**	**8739**	**26**	**32**	**59**	**83**	**106**	**203**	**662**	**719**	**1461**	**734**	**1679**	**No risk**	**At risk**	**No risk**	**At risk**
145	SO626428	SO597419	3421	19	25	45	61	79	149	484	533	1068	545	1250	No risk	No risk	No risk	At risk
146	SO303570	SO306571	365	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
147	**SO306571**	**SO307571**	**98**	**21**	**28**	**46**	**83**	**124**	**203**	**1271**	**1647**	**2813**	**852**	**1911**	**No risk**	**At risk**	**No risk**	**At risk**
148	SO307571	SO390584	12734	4	6	10	16	23	40	251	301	538	173	381	No risk	No risk	No risk	No risk
149	SO023533	SO021531	303	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
150	**SO021531**	**SO021530**	**181**	**2**	**3**	**5**	**8**	**14**	**19**	**132**	**201**	**308**	**87**	**206**	**No risk**	**No risk**	**No risk**	**No risk**
151	SO352636	SO501596	24197	2	3	5	7	9	16	115	118	246	82	182	No risk	No risk	No risk	No risk
152	SO170382	SO178390	1595	5	6	11	17	23	41	279	355	611	188	425	No risk	No risk	No risk	No risk
153	SO401282	SO395276	985	3	4	7	10	12	22	110	126	247	95	213	No risk	No risk	No risk	No risk
154	SO439552	SO468568	3962	12	13	27	40	49	92	427	423	914	382	852	No risk	No risk	No risk	No risk
155	SN934471	SN936472	253	1	1	1	2	4	5	33	45	74	21	49	No risk	No risk	No risk	No risk
156	**SN936472**	**SN955493**	**3851**	**1**	**1**	**2**	**3**	**4**	**6**	**40**	**53**	**93**	**28**	**62**	**No risk**	**No risk**	**No risk**	**No risk**
157	SO335234	SO399264	8915	1	1	1	2	3	5	17	19	37	18	39	No risk	No risk	No risk	No risk
158	SO115629	SO087642	9521	0	0	0	1	1	1	9	13	20	5	13	No risk	No risk	No risk	No risk
159	SO597419	SO560387	5319	18	23	41	55	69	132	477	508	1026	519	1163	No risk	No risk	No risk	At risk
160	SO390584	SO393587	417	4	5	10	16	21	38	236	275	511	168	372	No risk	No risk	No risk	No risk
161	**SO393587**	**SO468568**	**11474**	**5**	**6**	**11**	**16**	**20**	**37**	**241**	**265**	**517**	**177**	**386**	**No risk**	**No risk**	**No risk**	**No risk**
162	SO501596	SO501594	225	3	3	5	8	9	18	129	128	272	93	198	No risk	No risk	No risk	No risk
163	SO395276	SO399264	1603	5	6	10	16	21	35	153	183	335	144	313	No risk	No risk	No risk	No risk
164	SN955493	SO032513	11394	1	1	1	2	3	5	35	44	80	24	55	No risk	No risk	No risk	No risk

165	SO087642	SO077649	1583	1	2	2	4	6	8	58	92	133	38	91	No risk	No risk	No risk	No risk
166	SO077649	SO053623	5091	1	1	2	2	4	6	40	64	93	27	65	No risk	No risk	No risk	No risk
167	SO053623	SO049606	2693	1	2	2	4	6	9	58	90	133	39	93	No risk	No risk	No risk	No risk
168	SO049606	SO013564	8643	8	14	19	29	53	69	478	821	1127	327	768	No risk	No risk	No risk	No risk
169	SO468568	SO512567	5545	6	6	12	18	20	40	245	252	520	191	409	No risk	No risk	No risk	No risk
170	SO501594	SO507585	1274	3	3	7	10	11	22	162	157	336	116	244	No risk	No risk	No risk	No risk
171	SO507585	SO512567	2377	11	13	23	40	45	88	380	387	814	350	742	No risk	No risk	No risk	No risk
172	SO399264	SO512122	30318	2	2	3	5	5	10	44	44	92	46	96	No risk	No risk	No risk	No risk
173	SO032513	SO035516	418	1	1	1	2	3	5	36	45	79	24	55	No risk	No risk	No risk	No risk
174	SO013564	SO021530	5324	4	6	9	14	21	32	218	306	504	155	353	No risk	No risk	No risk	No risk
175	SO512567	SO536515	8509	8	10	18	28	31	61	297	291	618	266	560	No risk	No risk	No risk	No risk
176	SO536515	SO517456	12628	8	9	17	27	28	57	280	267	578	255	536	No risk	No risk	No risk	No risk
177	SO517456	SO560387	12748	9	10	19	28	29	60	318	306	650	281	591	No risk	No risk	No risk	No risk
178	SO021530	SO035516	2087	4	6	9	14	20	31	213	295	489	151	346	No risk	No risk	No risk	No risk
179	SO560387	SO565371	2759	10	11	21	30	30	63	327	312	675	301	630	No risk	No risk	No risk	No risk
180	SO035516	SO045515	1341	3	4	6	9	12	20	136	180	313	97	219	No risk	No risk	No risk	No risk
181	SO045515	SO068504	3178	3	4	7	11	15	24	166	217	378	118	267	No risk	No risk	No risk	No risk
182	SO068504	SO076469	3839	3	4	7	10	14	24	162	208	368	114	261	No risk	No risk	No risk	No risk
183	SO076469	SO100433	5602	3	4	7	10	13	22	144	182	328	104	239	No risk	No risk	No risk	No risk
184	SO100433	SO133382	6609	3	4	6	9	12	21	137	170	311	101	231	No risk	No risk	No risk	No risk
185	SO133382	SO178390	5809	3	4	6	9	12	20	136	167	304	101	228	No risk	No risk	No risk	No risk
186	SO178390	SO179395	547	3	4	7	10	12	22	149	184	344	110	250	No risk	No risk	No risk	No risk
187	SO179395	SO198408	3563	3	4	7	10	12	22	150	183	345	110	252	No risk	No risk	No risk	No risk
188	SO198408	SO232433	5943	3	4	6	9	11	20	138	157	315	102	232	No risk	No risk	No risk	No risk
189	SO232433	SO232454	2244	3	4	7	10	13	24	162	192	361	119	266	No risk	No risk	No risk	No risk
190	SO232454	SO323468	14864	3	4	7	10	11	22	149	169	332	112	251	No risk	No risk	No risk	No risk
191	SO323468	SO401423	13468	3	4	7	9	10	21	135	147	299	106	235	No risk	No risk	No risk	No risk
192	SO401423	SO457394	10433	3	4	7	9	9	19	127	134	279	101	226	No risk	No risk	No risk	No risk
193	SO457394	SO522388	8176	3	4	8	9	10	21	135	142	294	109	244	No risk	No risk	No risk	No risk
194	SO522388	SO535388	1910	12	19	28	44	67	108	386	506	890	379	876	No risk	No risk	No risk	No risk
195	SO535388	SO565371	6691	16	22	37	58	76	142	485	580	1154	492	1143	No risk	No risk	No risk	At risk
196	SO565371	SO563354	2019	14	18	32	50	59	116	433	482	991	432	981	No risk	No risk	No risk	No risk
197	SO563354	SO575340	2611	14	18	32	49	58	115	430	476	974	429	974	No risk	No risk	No risk	No risk
198	SO575340	SO587318	5081	14	18	32	48	57	113	425	466	962	427	967	No risk	No risk	No risk	No risk

199	**SO587318**	**SO547289**	**5397**	**14**	**18**	**32**	**47**	**55**	**110**	**415**	**451**	**941**	**422**	**953**	**No risk**	**No risk**	**No risk**	**No risk**
200	SO547289	SO565280	2745	14	17	32	47	54	108	409	442	930	418	944	No risk	No risk	No risk	No risk
201	**SO565280**	**SO583234**	**17327**	**14**	**16**	**30**	**42**	**47**	**97**	**372**	**385**	**839**	**391**	**878**	**No risk**	**No risk**	**No risk**	**No risk**
202	SO583234	SO598181	9774	14	17	32	45	49	103	388	398	868	414	927	No risk	No risk	No risk	No risk
203	SO598181	SO583170	3883	14	17	32	44	48	101	386	393	866	411	922	No risk	No risk	No risk	No risk
204	**SO583170**	**SO566183**	**4914**	**14**	**17**	**32**	**44**	**48**	**102**	**389**	**395**	**871**	**414**	**929**	**No risk**	**No risk**	**No risk**	**No risk**
205	**SO566183**	**SO560183**	**699**	**15**	**17**	**32**	**44**	**48**	**102**	**395**	**401**	**886**	**418**	**935**	**No risk**	**No risk**	**No risk**	**No risk**
206	SO560183	SO512122	11858	13	15	30	40	40	90	355	337	787	381	851	No risk	No risk	No risk	No risk
207	SO512122	SO515119	447	12	13	26	35	36	79	315	298	695	339	749	No risk	No risk	No risk	No risk
208	**SO515119**	**SO516116**	**307**	**13**	**14**	**28**	**38**	**38**	**86**	**363**	**349**	**793**	**371**	**815**	**No risk**	**No risk**	**No risk**	**No risk**
209	SO516116	SO536097	3145	12	14	27	37	37	82	349	336	766	358	789	No risk	No risk	No risk	No risk
210	SO536097	SO540055	4874	13	14	28	38	38	85	379	367	839	378	836	No risk	No risk	No risk	No risk

Table D.4 Estimated oestrogen concentrations and associated risk derived from mean and P_{90} concentrations in the River Teifi

				Concentrations ($10^{-3}ngL^{-1}$)											Risk classes			
Reach	Upstream	Downstream	Length	EE2			E2			E1			E2 Equivalent		National		SAC	
	NGR	NGR	(m)	Mean	SD	90th	Mean	SD	90th	Mean	SD	90th	Mean	90th	Mean	90th	Mean	90th
1	SN346473	SN345473	83	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
2	**SN345473**	**SN341472**	**505**	**6**	**9**	**13**	**22**	**37**	**52**	**360**	**521**	**811**	**241**	**542**	**No risk**	**No risk**	**No risk**	**No risk**
3	SN341472	SN333471	1044	1	2	3	4	8	10	70	108	158	46	106	No risk	No risk	No risk	No risk
4	SN333471	SN319462	2209	1	2	2	4	7	9	65	98	147	44	99	No risk	No risk	No risk	No risk
5	SN319462	SN318446	2176	1	1	2	3	5	6	44	66	99	29	68	No risk	No risk	No risk	No risk
6	SN446363	SN445363	117	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
7	SN425512	SN425512	118	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
8	SN425512	SN425510	114	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
9	**SN425510**	**SN422498**	**1409**	**1**	**2**	**3**	**4**	**8**	**10**	**73**	**103**	**174**	**49**	**115**	**No risk**	**No risk**	**No risk**	**No risk**
10	SN422498	SN422489	1114	1	1	2	3	4	6	42	57	98	28	65	No risk	No risk	No risk	No risk
11	SN422489	SN438461	5113	1	1	1	2	3	4	28	39	67	19	44	No risk	No risk	No risk	No risk
12	SN438461	SN451427	4603	0	0	1	1	1	2	14	18	33	9	23	No risk	No risk	No risk	No risk
13	SN451427	SN451424	369	0	0	1	1	1	2	12	16	28	8	19	No risk	No risk	No risk	No risk
14	SN451424	SN444403	2484	0	0	0	1	1	2	11	15	26	8	17	No risk	No risk	No risk	No risk
15	SN494472	SN494471	59	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
16	**SN494471**	**SN500460**	**1543**	**3**	**6**	**8**	**12**	**20**	**28**	**210**	**350**	**481**	**137**	**314**	**No risk**	**No risk**	**No risk**	**No risk**
17	SN500460	SN500448	1382	3	5	7	11	18	26	193	314	444	127	291	No risk	No risk	No risk	No risk
18	SN500448	SN493430	2351	2	3	5	7	11	17	129	187	295	85	196	No risk	No risk	No risk	No risk
19	SN663555	SN657552	723	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
20	**SN657552**	**SN656551**	**100**	**3**	**5**	**7**	**11**	**20**	**26**	**176**	**266**	**410**	**118**	**272**	**No risk**	**No risk**	**No risk**	**No risk**
21	SN656551	SN641548	1799	3	4	6	9	17	22	153	229	353	102	237	No risk	No risk	No risk	No risk
22	SN355394	SN351398	1150	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
23	**SN351398**	**SN348405**	**852**	**11**	**17**	**27**	**41**	**70**	**100**	**680**	**914**	**1562**	**458**	**1069**	**No risk**	**No risk**	**No risk**	**At risk**
24	SN444361	SN445363	223	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
25	SN749659	SN739660	1275	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
26	SN739659	SN739660	130	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
27	SN216423	SN211425	614	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
28	**SN211425**	**SN211426**	**86**	**26**	**42**	**63**	**98**	**177**	**232**	**751**	**1165**	**1748**	**785**	**1868**	**No risk**	**At risk**	**No risk**	**At risk**

29	SN292462	SN295461	247	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
30	**SN295461**	**SN296461**	**132**	**138**	**188**	**345**	**523**	**794**	**1372**	**4308**	**5718**	**10762**	**4250**	**10703**	**At risk**	**At risk**	**At risk**	**At risk**
31	SN296461	SN305460	999	30	42	69	110	165	265	1305	1659	3057	1045	2436	No risk	At risk	At risk	At risk
32	SN305460	SN310454	836	13	20	30	47	75	112	560	752	1312	448	1043	No risk	No risk	No risk	At risk
33	SN310454	SN318446	1157	9	14	21	33	52	78	394	528	919	317	734	No risk	No risk	No risk	No risk
34	SN608485	SN602491	925	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
35	**SN602491**	**SN601490**	**209**	**171**	**111**	**308**	**633**	**414**	**1161**	**2780**	**1889**	**5026**	**4414**	**7975**	**At risk**	**At risk**	**At risk**	**At risk**
36	SN620539	SN606531	1921	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
37	**SN606531**	**SN596514**	**2396**	**2**	**3**	**4**	**7**	**11**	**16**	**115**	**173**	**264**	**77**	**176**	**No risk**	**No risk**	**No risk**	**No risk**
38	SN596514	SN587505	1482	1	2	3	4	7	9	67	100	153	44	102	No risk	No risk	No risk	No risk
39	SN587505	SN581479	3089	1	1	2	2	4	5	39	55	89	25	60	No risk	No risk	No risk	No risk
40	SN581479	SN581476	271	1	1	1	2	4	5	38	54	87	25	58	No risk	No risk	No risk	No risk
41	SN510516	SN515512	785	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
42	**SN515512**	**SN516511**	**145**	**4**	**8**	**9**	**15**	**31**	**35**	**236**	**439**	**547**	**157**	**364**	**No risk**	**No risk**	**No risk**	**No risk**
43	SN516511	SN521501	1530	2	4	5	8	15	18	119	207	278	81	185	No risk	No risk	No risk	No risk
44	SN521501	SN524497	695	2	3	4	7	13	15	102	179	238	69	159	No risk	No risk	No risk	No risk
45	SN524497	SN535468	4567	1	2	2	4	7	9	58	92	133	40	91	No risk	No risk	No risk	No risk
46	SN535468	SN535462	920	1	2	2	4	6	8	56	89	129	39	88	No risk	No risk	No risk	No risk
47	SN269428	SN265418	1189	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
48	**SN265418**	**SN266416**	**187**	**36**	**47**	**86**	**146**	**228**	**362**	**1077**	**1422**	**2508**	**1102**	**2633**	**No risk**	**At risk**	**At risk**	**At risk**
49	SN199387	SN202391	504	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
50	**SN202391**	**SN205394**	**428**	**28**	**37**	**67**	**105**	**146**	**263**	**1785**	**2166**	**4260**	**1165**	**2801**	**No risk**	**At risk**	**At risk**	**At risk**
51	SN205394	SN207403	977	11	16	27	42	61	104	737	953	1723	478	1123	No risk	No risk	No risk	At risk
52	SN207403	SN211410	879	7	11	16	25	38	61	441	601	1039	287	678	No risk	No risk	No risk	No risk
53	SN211410	SN209423	1548	5	8	11	17	26	42	306	413	715	199	469	No risk	No risk	No risk	No risk
54	SN209423	SN211426	403	4	7	10	15	23	36	262	364	622	172	407	No risk	No risk	No risk	No risk
55	SN378481	SN378475	576	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
56	**SN378475**	**SN386467**	**1325**	**14**	**21**	**33**	**50**	**74**	**129**	**925**	**1238**	**2169**	**592**	**1404**	**No risk**	**At risk**	**No risk**	**At risk**
57	SN386467	SN392458	1360	4	7	10	15	24	38	272	413	639	175	416	No risk	No risk	No risk	No risk
58	SN392458	SN403450	1567	3	5	7	10	17	27	192	293	453	124	294	No risk	No risk	No risk	No risk
59	SN403450	SN409441	1356	2	4	5	8	13	20	145	219	341	94	224	No risk	No risk	No risk	No risk
60	SN409441	SN415422	2811	2	3	4	6	10	16	111	164	260	73	174	No risk	No risk	No risk	No risk
61	SN415422	SN420416	944	2	3	4	5	8	13	89	131	208	60	140	No risk	No risk	No risk	No risk
62	SN420416	SN422415	236	1	3	4	5	8	12	89	129	206	58	139	No risk	No risk	No risk	No risk

63	SN296363	SN293361	394	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
64	**SN293361**	**SN289356**	**646**	**5**	**7**	**11**	**17**	**28**	**41**	**272**	**361**	**630**	**183**	**431**	**No risk**	**No risk**	**No risk**	**No risk**
65	SN289356	SN282356	770	1	2	3	4	7	10	66	88	153	44	104	No risk	No risk	No risk	No risk
66	SN282356	SN276359	647	1	2	3	4	7	10	65	85	150	42	101	No risk	No risk	No risk	No risk
67	SN276359	SN270372	1656	1	1	2	3	5	7	44	57	101	29	68	No risk	No risk	No risk	No risk
68	SN270372	SN254387	2789	0	1	1	2	3	4	27	35	63	17	43	No risk	No risk	No risk	No risk
69	SN240408	SN244412	583	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
70	**SN244412**	**SN246413**	**276**	**8**	**12**	**19**	**31**	**48**	**77**	**236**	**332**	**507**	**250**	**568**	**No risk**	**No risk**	**No risk**	**No risk**
71	SN223392	SN225391	241	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
72	**SN225391**	**SN232380**	**1431**	**7**	**9**	**16**	**24**	**35**	**59**	**424**	**546**	**979**	**275**	**645**	**No risk**	**No risk**	**No risk**	**No risk**
73	SN232380	SN245381	1934	1	1	2	3	5	8	59	84	137	38	90	No risk	No risk	No risk	No risk
74	SN245381	SN254386	1230	1	1	2	3	4	7	48	68	113	30	74	No risk	No risk	No risk	No risk
75	SN254386	SN254387	131	1	1	2	3	4	7	48	68	113	30	74	No risk	No risk	No risk	No risk
76	SN445363	SN445365	199	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
77	**SN445365**	**SN421391**	**4179**	**3**	**5**	**8**	**12**	**18**	**28**	**203**	**277**	**450**	**136**	**310**	**No risk**	**No risk**	**No risk**	**No risk**
78	SN421391	SN412402	1848	3	4	6	9	14	22	161	216	356	108	246	No risk	No risk	No risk	No risk
79	SN739660	SN728667	1340	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
80	**SN728667**	**SN718667**	**1364**	**2**	**5**	**6**	**9**	**18**	**20**	**146**	**238**	**336**	**98**	**226**	**No risk**	**No risk**	**No risk**	**No risk**
81	SN718667	SN699646	3932	1	2	3	5	9	11	78	117	180	52	121	No risk	No risk	No risk	No risk
82	SN699646	SN677623	4581	1	2	2	4	6	8	58	85	133	39	91	No risk	No risk	No risk	No risk
83	SN677623	SN671614	1336	1	1	2	3	5	6	46	67	106	31	72	No risk	No risk	No risk	No risk
84	SN671614	SN672592	4035	1	1	2	3	4	6	41	58	95	28	66	No risk	No risk	No risk	No risk
85	**SN672592**	**SN673589**	**357**	**2**	**4**	**5**	**8**	**14**	**18**	**137**	**207**	**313**	**92**	**209**	**No risk**	**No risk**	**No risk**	**No risk**
86	SN673589	SN641548	8839	2	3	4	6	9	12	92	136	211	63	144	No risk	No risk	No risk	No risk
87	SN318446	SN295419	5403	2	3	4	6	9	13	80	105	179	61	136	No risk	No risk	No risk	No risk
88	SN211426	SN215429	641	6	9	14	22	32	50	298	406	703	223	525	No risk	No risk	No risk	No risk
89	SN215429	SN214436	798	6	9	14	21	31	48	285	384	674	214	506	No risk	No risk	No risk	No risk
90	SN254387	SN251401	1754	1	1	1	2	3	4	30	36	65	20	44	No risk	No risk	No risk	No risk
91	SN251401	SN246413	1868	0	1	1	2	2	4	29	34	63	18	43	No risk	No risk	No risk	No risk
92	SN641548	SN601490	8508	2	3	3	5	8	11	81	115	182	57	128	No risk	No risk	No risk	No risk
93	SN246413	SN246414	112	1	1	2	3	4	6	36	43	77	26	60	No risk	No risk	No risk	No risk
94	SN601490	SN581476	3276	3	4	6	8	13	19	92	132	208	81	185	No risk	No risk	No risk	No risk
95	SN581476	SN581476	38	2	4	5	8	12	18	87	123	195	75	171	No risk	No risk	No risk	No risk
96	SN581476	SN577476	470	2	4	5	8	12	18	86	122	195	75	171	No risk	No risk	No risk	No risk

97	**SN577476**	**SN535462**	**7843**	**4**	**6**	**9**	**13**	**18**	**28**	**121**	**164**	**268**	**116**	**263**	**No risk**	**No risk**	**No risk**	**No risk**
98	SN535462	SN519441	4653	3	5	8	11	15	24	106	140	235	101	229	No risk	No risk	No risk	No risk
99	SN519441	SN516432	1448	3	5	8	11	15	24	105	138	232	101	228	No risk	No risk	No risk	No risk
100	**SN516432**	**SN513433**	**296**	**4**	**6**	**10**	**14**	**19**	**31**	**159**	**224**	**346**	**137**	**305**	**No risk**	**No risk**	**No risk**	**No risk**
101	SN513433	SN493430	3386	4	6	9	12	16	28	143	193	310	123	275	No risk	No risk	No risk	No risk
102	SN493430	SN472413	3722	4	5	8	12	15	26	137	181	296	117	260	No risk	No risk	No risk	No risk
103	SN472413	SN455401	3333	4	5	8	11	14	25	132	172	285	113	254	No risk	No risk	No risk	No risk
104	**SN455401**	**SN444403**	**1235**	**4**	**5**	**8**	**12**	**15**	**26**	**136**	**176**	**293**	**117**	**258**	**No risk**	**No risk**	**No risk**	**No risk**
105	SN444403	SN422415	4414	3	4	7	10	12	22	116	147	250	100	222	No risk	No risk	No risk	No risk
106	SN422415	SN419403	1408	3	4	7	9	12	21	114	143	245	97	218	No risk	No risk	No risk	No risk
107	**SN419403**	**SN412402**	**809**	**4**	**5**	**8**	**12**	**15**	**26**	**149**	**193**	**324**	**121**	**268**	**No risk**	**No risk**	**No risk**	**No risk**
108	SN412402	SN389391	3672	4	5	8	11	14	25	146	185	313	118	256	No risk	No risk	No risk	No risk
109	**SN389391**	**SN356401**	**4883**	**3**	**5**	**7**	**10**	**13**	**24**	**139**	**171**	**297**	**112**	**244**	**No risk**	**No risk**	**No risk**	**No risk**
110	SN356401	SN353403	446	3	5	7	10	12	24	139	171	296	112	244	No risk	No risk	No risk	No risk
111	**SN353403**	**SN348405**	**813**	**4**	**5**	**8**	**11**	**13**	**25**	**149**	**183**	**319**	**119**	**259**	**No risk**	**No risk**	**No risk**	**No risk**
112	SN348405	SN305408	6990	4	5	8	12	14	26	159	192	340	126	272	No risk	No risk	No risk	No risk
113	**SN305408**	**SN295419**	**1913**	**4**	**6**	**9**	**13**	**16**	**29**	**186**	**224**	**404**	**143**	**315**	**No risk**	**No risk**	**No risk**	**No risk**
114	SN295419	SN266416	3831	4	5	9	12	15	27	174	209	377	135	298	No risk	No risk	No risk	No risk
115	SN266416	SN246414	3719	4	5	9	12	15	27	169	201	366	134	292	No risk	No risk	No risk	No risk
116	SN246414	SN218436	4443	3	5	8	11	13	23	147	171	316	116	255	No risk	No risk	No risk	No risk
117	SN218436	SN214436	412	3	5	8	11	12	23	147	171	316	116	255	No risk	No risk	No risk	No risk
118	SN214436	SN212435	203	3	5	8	11	13	23	148	172	317	117	256	No risk	No risk	No risk	No risk
119	**SN212435**	**SN200429**	**1694**	**4**	**5**	**8**	**11**	**13**	**24**	**154**	**180**	**332**	**122**	**266**	**No risk**	**No risk**	**No risk**	**No risk**

Table D.5 Estimated oestrogen concentrations and associated risk derived from mean and P_{90} concentrations in the River Eden–Cors Goch Trawsfynydd

Reach	Upstream NGR	Downstream NGR	Length (m)	EE2 Mean	EE2 SD	EE2 90th	E2 Mean	E2 SD	E2 90th	E1 Mean	E1 SD	E1 90th	E2 Equivalent Mean	E2 Equivalent 90th	National Mean	National 90th	SAC Mean	SAC 90th
				Concentrations ($10^{-3}ngL^{-1}$)											Risk classes			
1	SH704320	SH705318	253	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
2	SH705318	SH704314	468	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
3	**SH704314**	**SH708305**	**1321**	**4**	**5**	**9**	**13**	**21**	**33**	**221**	**321**	**530**	**145**	**354**	**No risk**	**No risk**	**No risk**	**No risk**
4	SH708305	SH711289	1782	3	4	8	12	18	29	194	276	466	128	316	No risk	No risk	No risk	No risk
5	SH710289	SH711289	113	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
6	SH758230	SH754223	840	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
7	**SH754223**	**SH753221**	**207**	**5**	**8**	**13**	**21**	**33**	**52**	**339**	**479**	**811**	**222**	**540**	**No risk**	**No risk**	**No risk**	**No risk**
8	SH753221	SH747221	633	1	2	3	5	7	12	82	104	189	52	125	No risk	No risk	No risk	No risk
9	SH747221	SH745225	518	1	1	2	4	5	9	60	73	137	39	91	No risk	No risk	No risk	No risk
10	SH745225	SH738225	745	1	1	2	3	4	7	50	59	113	31	75	No risk	No risk	No risk	No risk
11	SH738225	SH735223	401	1	1	2	3	4	7	49	58	110	31	74	No risk	No risk	No risk	No risk
12	SH734251	SH728247	802	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
13	SH726243	SH727243	105	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
14	SH737227	SH734224	500	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
15	SH711289	SH721269	2458	2	2	4	6	9	14	95	133	228	62	155	No risk	No risk	No risk	No risk
16	SH721269	SH727248	2297	1	2	4	5	8	13	88	122	211	58	143	No risk	No risk	No risk	No risk
17	SH727248	SH728247	185	1	2	4	5	8	13	88	121	210	58	143	No risk	No risk	No risk	No risk
18	SH728247	SH727243	427	1	1	2	2	4	6	39	52	92	25	61	No risk	No risk	No risk	No risk
19	SH727243	SH730234	973	1	1	1	2	3	5	33	45	79	21	53	No risk	No risk	No risk	No risk
20	SH730234	SH734224	1181	1	1	1	2	3	5	32	44	78	21	52	No risk	No risk	No risk	No risk
21	SH734224	SH735223	243	1	1	1	2	3	4	30	40	72	20	48	No risk	No risk	No risk	No risk
22	SH735223	SH718193	3732	1	1	1	2	3	4	30	39	71	20	48	No risk	No risk	No risk	No risk

Table D.6 Estimated oestrogen concentrations and associated risk derived from mean and P_{90} concentrations in the River Usk

Reach	Upstream NGR	Downstream NGR	Length (m)	EE2 Mean	EE2 SD	EE2 90th	E2 Mean	E2 SD	E2 90th	E1 Mean	E1 SD	E1 90th	E2 Equivalent Mean	E2 Equivalent 90th	National Mean	National 90th	SAC Mean	SAC 90th
				Concentrations (10^{-3}ngL^{-1})											Risk classes			
1	SO408072	SO415072	927	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
2	**SO415072**	**SO416071**	**138**	**21**	**27**	**48**	**82**	**124**	**198**	**602**	**702**	**1358**	**638**	**1444**	**No risk**	**At risk**	**No risk**	**At risk**
3	SO416071	SO418049	2496	16	22	36	60	96	146	446	542	1011	477	1088	No risk	No risk	No risk	At risk
4	SO418049	SO417036	1644	13	18	30	50	79	119	365	444	828	394	902	No risk	No risk	No risk	No risk
5	SO417036	SO409026	1269	7	10	15	25	43	60	181	235	415	197	453	No risk	No risk	No risk	No risk
6	SN972223	SN975223	297	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
7	SN975223	SN985241	2697	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
8	SN985241	SN995257	2171	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
9	SN995257	SN996259	295	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
10	**SN996259**	**SO018270**	**2759**	**0**	**0**	**1**	**1**	**1**	**3**	**10**	**8**	**20**	**10**	**20**	**No risk**	**No risk**	**No risk**	**No risk**
11	SO018270	SO028277	1355	0	0	1	1	1	2	8	7	16	7	16	No risk	No risk	No risk	No risk
12	SO028277	SO039288	1677	0	0	0	1	1	2	6	5	13	6	13	No risk	No risk	No risk	No risk
13	SO119230	SO121231	209	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
14	**SO121231**	**SO124231**	**331**	**1**	**1**	**2**	**3**	**4**	**7**	**51**	**56**	**113**	**33**	**75**	**No risk**	**No risk**	**No risk**	**No risk**
15	SN879295	SN880289	676	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
16	**SN880289**	**SN884287**	**401**	**11**	**14**	**25**	**40**	**63**	**96**	**648**	**870**	**1474**	**431**	**1006**	**No risk**	**No risk**	**No risk**	**At risk**
17	SN884287	SN901290	2198	1	2	2	3	8	8	54	103	127	34	87	No risk	No risk	No risk	No risk
18	SN901290	SN920286	2632	0	1	1	2	3	4	26	47	61	17	41	No risk	No risk	No risk	No risk
19	SN920286	SN925294	1078	0	0	1	1	1	2	13	18	29	8	20	No risk	No risk	No risk	No risk
20	**SN925294**	**SN925295**	**82**	**0**	**0**	**1**	**1**	**1**	**2**	**13**	**18**	**29**	**8**	**20**	**No risk**	**No risk**	**No risk**	**No risk**
21	**SN925295**	**SN938298**	**1797**	**1**	**1**	**2**	**3**	**4**	**6**	**41**	**56**	**96**	**26**	**65**	**No risk**	**No risk**	**No risk**	**No risk**
22	SN938298	SN987292	5676	1	1	1	2	3	5	30	41	71	20	48	No risk	No risk	No risk	No risk
23	SO006278	SO011282	720	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
24	**SO011282**	**SO011283**	**53**	**32**	**38**	**69**	**118**	**143**	**272**	**1938**	**2104**	**4236**	**1294**	**2837**	**At risk**	**At risk**	**At risk**	**At risk**
25	SO051326	SO051308	2364	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
26	**SO051308**	**SO049306**	**323**	**4**	**6**	**9**	**15**	**21**	**33**	**245**	**329**	**566**	**163**	**374**	**No risk**	**No risk**	**No risk**	**No risk**
27	SO049306	SO042286	2548	0	1	1	2	3	4	28	39	66	18	43	No risk	No risk	No risk	No risk
28	SO066247	SO079258	2179	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk

29	**SO079258**	**SO089253**	**1425**	**1**	**2**	**3**	**5**	**7**	**12**	**84**	**105**	**186**	**55**	**126**	**No risk**	**No risk**	**No risk**	**No risk**
30	SO089253	SO093254	545	1	1	2	4	5	8	58	68	126	38	85	No risk	No risk	No risk	No risk
31	**SO093254**	**SO095254**	**180**	**1**	**1**	**2**	**4**	**5**	**9**	**69**	**78**	**146**	**46**	**98**	**No risk**	**No risk**	**No risk**	**No risk**
32	SO203123	SO208124	544	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
33	**SO208124**	**SO210124**	**248**	**47**	**45**	**103**	**175**	**195**	**400**	**1335**	**1232**	**2916**	**1399**	**3087**	**At risk**	**At risk**	**At risk**	**At risk**
34	SO210124	SO216125	646	40	39	88	149	168	341	1143	1066	2498	1194	2642	No risk	At risk	At risk	At risk
35	SO216125	SO230134	1735	35	35	78	131	148	301	1012	945	2214	1057	2346	No risk	At risk	At risk	At risk
36	SO230134	SO242155	3185	28	28	63	103	119	237	811	764	1782	846	1881	No risk	At risk	No risk	At risk
37	SO327029	SO337024	1463	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
38	**SO337024**	**SO355016**	**2346**	**4**	**4**	**8**	**13**	**17**	**30**	**206**	**221**	**443**	**140**	**308**	**No risk**	**No risk**	**No risk**	**No risk**
39	SO355016	SO365019	1435	3	4	7	12	15	27	183	198	395	124	275	No risk	No risk	No risk	No risk
40	ST478989	ST476989	179	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
41	**ST476989**	**ST467989**	**1002**	**36**	**39**	**83**	**131**	**160**	**308**	**3001**	**2713**	**6508**	**1738**	**3857**	**At risk**	**At risk**	**At risk**	**At risk**
42	ST467989	ST464993	587	26	30	60	93	119	222	2115	2026	4632	1229	2763	At risk	At risk	At risk	At risk
43	ST464993	ST462998	659	14	18	33	51	68	121	1153	1154	2553	673	1525	No risk	At risk	No risk	At risk
44	ST462998	ST460998	143	11	13	25	38	51	89	852	870	1881	498	1130	No risk	No risk	No risk	At risk
45	ST460998	SO459007	1126	8	10	18	26	38	64	597	638	1341	350	811	No risk	No risk	No risk	No risk
46	SO459007	SO423022	5852	5	7	12	16	24	38	353	398	810	213	499	No risk	No risk	No risk	No risk
47	SO423022	SO409026	1783	3	4	7	9	14	23	212	235	483	128	300	No risk	No risk	No risk	No risk
48	SO184265	SO183262	300	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
49	SO183262	SO184260	195	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
50	SO184260	SO183248	1402	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
51	SO183248	SO181214	3954	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
52	SO181214	SO188209	891	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
53	**SO188209**	**SO193199**	**1308**	**0**	**0**	**1**	**1**	**1**	**2**	**13**	**14**	**30**	**9**	**20**	**No risk**	**No risk**	**No risk**	**No risk**
54	SN931382	SN932381	152	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
55	SN932381	SN942343	4869	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
56	SN942343	SN944341	319	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
57	**SN944341**	**SN987292**	**7368**	**0**	**0**	**0**	**0**	**0**	**1**	**4**	**4**	**8**	**1**	**5**	**No risk**	**No risk**	**No risk**	**No risk**
58	SO252284	SO246198	14668	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
59	SO246198	SO240179	2387	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
60	**SO240179**	**SO235159**	**2308**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**3**	**5**	**1**	**2**	**No risk**	**No risk**	**No risk**	**No risk**
61	SO382109	SO377105	592	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
62	**SO377105**	**SO376103**	**243**	**27**	**28**	**63**	**107**	**130**	**260**	**809**	**828**	**1863**	**833**	**1938**	**No risk**	**At risk**	**No risk**	**At risk**
63	SO376103	SO376101	174	6	8	15	25	35	61	186	229	444	192	455	No risk	No risk	No risk	No risk

64	SO376101	SO370099	604	2	2	4	7	11	18	56	72	133	56	136	No risk	No risk	No risk	No risk
65	SO370099	SO359093	1629	1	2	3	5	7	12	37	47	88	37	89	No risk	No risk	No risk	No risk
66	SO409026	ST388979	7528	5	7	11	16	25	39	169	195	386	153	356	No risk	No risk	No risk	No risk
67	SN987292	SO001295	1470	0	1	1	2	2	4	25	32	58	16	40	No risk	No risk	No risk	No risk
68	SO001295	SO011283	2069	0	0	1	1	2	3	20	25	47	13	32	No risk	No risk	No risk	No risk
69	SO011283	SO039288	3034	0	1	1	1	2	4	24	29	54	16	37	No risk	No risk	No risk	No risk
70	SO039288	SO042286	452	0	0	1	1	1	3	19	20	43	13	31	No risk	No risk	No risk	No risk
71	SO042286	SO058275	2208	0	0	1	1	1	3	20	20	45	13	31	No risk	No risk	No risk	No risk
72	**SO058275**	**SO095254**	**5178**	**3**	**3**	**6**	**10**	**13**	**23**	**155**	**179**	**362**	**105**	**247**	**No risk**	**No risk**	**No risk**	**No risk**
73	SO095254	SO107248	2193	3	3	6	9	12	22	149	169	346	101	236	No risk	No risk	No risk	No risk
74	**SO107248**	**SO124231**	**2648**	**3**	**3**	**6**	**9**	**12**	**22**	**148**	**168**	**345**	**102**	**237**	**No risk**	**No risk**	**No risk**	**No risk**
75	SO124231	SO155203	6106	2	2	5	7	9	17	117	120	265	79	182	No risk	No risk	No risk	No risk
76	**SO155203**	**SO193199**	**4197**	**2**	**3**	**5**	**8**	**9**	**18**	**125**	**126**	**281**	**86**	**193**	**No risk**	**No risk**	**No risk**	**No risk**
77	SO193199	SO225175	4403	2	2	5	7	8	17	114	115	258	79	179	No risk	No risk	No risk	No risk
78	**SO225175**	**SO235159**	**2133**	**3**	**3**	**6**	**9**	**10**	**21**	**146**	**145**	**326**	**101**	**224**	**No risk**	**No risk**	**No risk**	**No risk**
79	SO235159	SO242155	972	2	3	5	8	9	18	132	130	293	91	201	No risk	No risk	No risk	No risk
80	SO242155	SO241163	814	4	4	9	14	15	31	173	164	381	137	299	No risk	No risk	No risk	No risk
81	**SO241163**	**SO263148**	**3115**	**4**	**4**	**8**	**14**	**14**	**30**	**170**	**160**	**374**	**136**	**295**	**No risk**	**No risk**	**No risk**	**No risk**
82	**SO263148**	**SO301132**	**4866**	**4**	**4**	**9**	**15**	**15**	**32**	**196**	**184**	**426**	**151**	**328**	**No risk**	**No risk**	**No risk**	**No risk**
83	**SO301132**	**SO303112**	**2677**	**6**	**6**	**14**	**23**	**24**	**49**	**254**	**242**	**547**	**213**	**458**	**No risk**	**No risk**	**No risk**	**No risk**
84	**SO303112**	**SO320094**	**2989**	**6**	**6**	**14**	**23**	**24**	**48**	**250**	**238**	**538**	**211**	**452**	**No risk**	**No risk**	**No risk**	**No risk**
85	**SO320094**	**SO333097**	**1641**	**6**	**6**	**14**	**23**	**23**	**47**	**250**	**237**	**534**	**211**	**450**	**No risk**	**No risk**	**No risk**	**No risk**
86	**SO333097**	**SO359093**	**4336**	**6**	**6**	**13**	**22**	**23**	**46**	**245**	**232**	**524**	**207**	**444**	**No risk**	**No risk**	**No risk**	**No risk**
87	SO359093	SO350067	2890	6	6	13	22	22	46	240	227	516	205	439	No risk	No risk	No risk	No risk
88	**SO350067**	**SO344054**	**1572**	**6**	**6**	**13**	**22**	**22**	**45**	**239**	**225**	**512**	**205**	**438**	**No risk**	**No risk**	**No risk**	**No risk**
89	**SO344054**	**SO365019**	**6483**	**6**	**6**	**13**	**21**	**22**	**45**	**240**	**225**	**509**	**205**	**438**	**No risk**	**No risk**	**No risk**	**No risk**
90	SO365019	ST387994	4001	6	6	13	21	21	44	234	217	491	200	426	No risk	No risk	No risk	No risk
91	**ST387994**	**ST388979**	**2534**	**6**	**6**	**14**	**22**	**22**	**46**	**251**	**233**	**532**	**212**	**453**	**No risk**	**No risk**	**No risk**	**No risk**
92	ST388979	ST386965	1476	6	6	14	21	22	45	246	229	518	208	446	No risk	No risk	No risk	No risk
93	**ST386965**	**ST342903**	**14030**	**6**	**6**	**12**	**19**	**18**	**39**	**210**	**191**	**440**	**184**	**391**	**No risk**	**No risk**	**No risk**	**No risk**

Table D.7 Estimated oestrogen concentrations and associated risk derived from mean and P_{90} concentrations in the River Gwyrfai

Reach	Upstream NGR	Downstream NGR	Length (m)	EE2 Mean	EE2 SD	EE2 90th	E2 Mean	E2 SD	E2 90th	E1 Mean	E1 SD	E1 90th	E2 Equivalent Mean	E2 Equivalent 90th	National Mean	National 90th	SAC Mean	SAC 90th
				Concentrations ($10^{-3}ngL^{-1}$)											Risk classes			
1	SH568526	SH571531	611	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
2	**SH571531**	**SH572532**	**189**	**2**	**4**	**4**	**7**	**23**	**15**	**105**	**266**	**231**	**70**	**155**	**No risk**	**No risk**	**No risk**	**No risk**
3	SH572532	SH567540	1168	1	2	2	3	9	8	54	115	119	35	79	No risk	No risk	No risk	No risk
4	SH567540	SH535573	5032	0	0	1	1	2	2	14	24	31	9	21	No risk	No risk	No risk	No risk
5	**SH535573**	**SH528589**	**2260**	**4**	**6**	**8**	**13**	**23**	**28**	**142**	**382**	**242**	**119**	**237**	**No risk**	**No risk**	**No risk**	**No risk**
6	SH543594	SH531589	1305	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
7	SH531589	SH528589	310	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
8	**SH528589**	**SH528589**	**50**	**24**	**32**	**55**	**88**	**130**	**217**	**1408**	**1905**	**3145**	**949**	**2174**	**No risk**	**At risk**	**No risk**	**At risk**
9	SH528589	SH466594	7911	3	3	7	13	11	27	263	238	492	157	304	No risk	No risk	No risk	No risk
10	**SH466594**	**SH456591**	**1261**	**57**	**57**	**117**	**211**	**226**	**469**	**1812**	**1623**	**3654**	**1757**	**3642**	**At risk**	**At risk**	**At risk**	**At risk**

Table D.8 Estimated oestrogen concentrations and associated risk derived from mean and P_{90} concentrations in the River Dee

Reach	Upstream NGR	Downstream NGR	Length (m)	Concentrations (10^{-3}ngL^{-1}) EE2 Mean	EE2 SD	EE2 90th	E2 Mean	E2 SD	E2 90th	E1 Mean	E1 SD	E1 90th	E2 Equivalent Mean	E2 Equivalent 90th	Risk classes National Mean	National 90th	SAC Mean	SAC 90th
1	SJ487399	SJ488403	409	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
2	SJ488403	SJ487406	364	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
3	SJ487406	SJ487407	71	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
4	**SJ487407**	**SJ489412**	**552**	**36**	**35**	**76**	**134**	**155**	**315**	**1029**	**990**	**2207**	**1069**	**2324**	**No risk**	**At risk**	**At risk**	**At risk**
5	SJ489412	SJ489412	68	26	27	56	98	118	233	752	764	1635	780	1715	No risk	At risk	No risk	At risk
6	SJ489412	SJ491435	3230	8	9	18	29	36	69	245	251	509	246	532	No risk	No risk	No risk	No risk
7	SJ512479	SJ509478	358	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
8	**SJ509478**	**SJ506474**	**516**	**142**	**137**	**315**	**543**	**604**	**1331**	**9171**	**8467**	**21151**	**5960**	**13630**	**At risk**	**High risk**	**At risk**	**At risk**
9	SJ506474	SJ500462	1579	44	49	101	166	209	400	2822	2973	6639	1845	4293	At risk	At risk	At risk	At risk
10	SJ369412	SJ371415	348	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
11	**SJ371415**	**SJ364421**	**1105**	**186**	**141**	**369**	**678**	**593**	**1425**	**12011**	**8124**	**22589**	**7786**	**15109**	**At risk**	**High risk**	**At risk**	**At risk**
12	SJ210682	SJ210681	99	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
13	**SJ210681**	**SJ205675**	**825**	**84**	**76**	**182**	**323**	**349**	**749**	**6212**	**4901**	**12459**	**3792**	**7936**	**At risk**	**At risk**	**At risk**	**At risk**
14	SJ205675	SJ209665	1142	8	9	18	31	39	72	599	548	1225	368	777	No risk	No risk	No risk	No risk
15	**SJ209665**	**SJ207660**	**550**	**15**	**14**	**30**	**56**	**56**	**122**	**771**	**686**	**1546**	**560**	**1135**	**No risk**	**No risk**	**No risk**	**At risk**
16	SH931383	SH940364	2931	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
17	**SH940364**	**SH943364**	**381**	**2**	**3**	**4**	**7**	**11**	**16**	**47**	**69**	**110**	**51**	**119**	**No risk**	**No risk**	**No risk**	**No risk**
18	SJ151334	SJ157329	771	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
19	SJ157329	SJ177336	2462	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
20	**SJ177336**	**SJ179336**	**277**	**0**	**1**	**1**	**1**	**2**	**3**	**19**	**31**	**44**	**13**	**28**	**No risk**	**No risk**	**No risk**	**No risk**
21	**SJ179336**	**SJ195359**	**3423**	**1**	**2**	**3**	**5**	**7**	**10**	**32**	**49**	**71**	**35**	**81**	**No risk**	**No risk**	**No risk**	**No risk**
22	SJ195359	SJ197359	113	1	2	2	4	6	8	25	39	56	29	64	No risk	No risk	No risk	No risk
23	**SJ197359**	**SJ209378**	**2839**	**1**	**1**	**2**	**3**	**4**	**7**	**25**	**34**	**56**	**25**	**57**	**No risk**	**No risk**	**No risk**	**No risk**
24	**SJ209378**	**SJ224372**	**1788**	**2**	**3**	**5**	**9**	**14**	**19**	**119**	**171**	**268**	**89**	**199**	**No risk**	**No risk**	**No risk**	**No risk**
25	**SJ224372**	**SJ242384**	**2229**	**3**	**4**	**6**	**10**	**15**	**20**	**133**	**187**	**300**	**97**	**217**	**No risk**	**No risk**	**No risk**	**No risk**
26	**SJ242384**	**SJ280370**	**4498**	**3**	**4**	**6**	**10**	**14**	**21**	**138**	**190**	**305**	**101**	**223**	**No risk**	**No risk**	**No risk**	**No risk**
27	**SJ280370**	**SJ318395**	**5806**	**3**	**3**	**6**	**9**	**12**	**19**	**115**	**149**	**254**	**89**	**196**	**No risk**	**No risk**	**No risk**	**No risk**
28	SH905400	SH905392	1003	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk

29	SH905392	SH906391	79	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
30	**SH906391**	**SH906391**	**50**	**1**	**1**	**1**	**2**	**4**	**5**	**34**	**63**	**79**	**22**	**51**	**No risk**	**No risk**	**No risk**	**No risk**
31	SH906391	SH937356	5506	0	0	1	1	2	2	16	25	36	9	22	No risk	No risk	No risk	No risk
32	SH947488	SH951483	878	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
33	**SH951483**	**SH954477**	**970**	**6**	**10**	**15**	**25**	**46**	**59**	**376**	**531**	**896**	**252**	**603**	**No risk**	**No risk**	**No risk**	**No risk**
34	SH954477	SH953475	225	5	8	12	19	37	46	295	420	695	198	470	No risk	No risk	No risk	No risk
35	SH953475	SH978453	4145	1	2	3	5	10	12	80	116	190	54	129	No risk	No risk	No risk	No risk
36	SH978453	SJ006446	4171	1	1	2	3	6	8	48	65	112	32	77	No risk	No risk	No risk	No risk
37	SJ006446	SJ022443	2077	1	1	2	3	5	6	39	53	92	26	63	No risk	No risk	No risk	No risk
38	SJ022443	SJ060425	5109	1	1	1	2	3	5	31	39	72	21	50	No risk	No risk	No risk	No risk
39	SJ485586	SJ480592	928	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
40	SJ480592	SJ478592	170	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
41	**SJ478592**	**SJ443582**	**4424**	**28**	**33**	**63**	**102**	**128**	**232**	**781**	**824**	**1686**	**832**	**1838**	**No risk**	**At risk**	**No risk**	**At risk**
42	SJ453553	SJ443582	3715	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
43	SJ492472	SJ495469	392	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
44	**SJ495469**	**SJ500462**	**931**	**129**	**85**	**241**	**468**	**374**	**953**	**3774**	**2230**	**6777**	**3876**	**7235**	**At risk**	**At risk**	**At risk**	**At risk**
45	SJ537417	SJ515416	2458	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
46	**SJ515416**	**SJ508418**	**820**	**119**	**78**	**221**	**450**	**353**	**904**	**7300**	**4311**	**13123**	**4871**	**8953**	**At risk**	**At risk**	**At risk**	**At risk**
47	SJ508418	SJ507433	2245	85	62	163	315	271	664	5091	3426	9770	3427	6639	At risk	At risk	At risk	At risk
48	SJ507433	SJ491435	1733	66	52	130	243	221	524	3935	2843	7787	2661	5291	At risk	At risk	At risk	At risk
49	SJ414401	SJ415402	153	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
50	SJ415402	SJ415405	271	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
51	**SJ415405**	**SJ416415**	**1099**	**81**	**60**	**157**	**289**	**251**	**618**	**4941**	**3298**	**9245**	**3279**	**6310**	**At risk**	**At risk**	**At risk**	**At risk**
52	SJ416415	SJ413419	605	59	50	122	210	200	474	3596	2719	7193	2397	4900	At risk	At risk	At risk	At risk
53	SJ413419	SJ420438	2419	7	8	16	25	30	60	428	443	917	288	636	No risk	No risk	No risk	No risk
54	SJ420438	SJ419460	2563	4	4	8	13	16	31	216	240	462	146	323	No risk	No risk	No risk	No risk
55	SH929351	SH937356	935	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
56	SJ342488	SJ347491	622	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
57	SJ347491	SJ362484	2352	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
58	**SJ362484**	**SJ409473**	**8005**	**138**	**109**	**282**	**493**	**446**	**1090**	**3724**	**2772**	**7470**	**4035**	**8271**	**At risk**	**At risk**	**At risk**	**At risk**
59	SJ279623	SJ279623	18	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
60	**SJ279623**	**SJ281621**	**271**	**219**	**142**	**401**	**810**	**639**	**1628**	**6083**	**3643**	**10818**	**6487**	**11914**	**At risk**	**At risk**	**At risk**	**At risk**
61	SJ281621	SJ280618	373	189	129	361	698	580	1445	5243	3333	9742	5600	10709	At risk	At risk	At risk	At risk
62	SJ280618	SJ298595	3708	150	109	298	535	472	1151	4084	2721	7755	4396	8697	At risk	At risk	At risk	At risk
63	SJ246633	SJ248631	339	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk

64	SJ199626	SJ192634	1335	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
65	SJ192634	SJ192656	2877	2	2	4	7	10	17	116	131	250	77	172	No risk	No risk	No risk	No risk
66	SJ192656	SJ202668	1830	5	5	10	17	19	38	276	295	575	186	390	No risk	No risk	No risk	No risk
67	SJ202668	SJ207660	1046	5	5	10	17	19	38	272	289	563	182	384	No risk	No risk	No risk	No risk
68	SJ309611	SJ311609	322	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
69	SJ311609	SJ321609	1078	225	191	466	861	867	2032	13460	10785	27982	9096	19124	At risk	High risk	At risk	At risk
70	SJ321609	SJ325602	817	194	173	411	734	770	1751	11493	9616	24610	7796	16809	At risk	High risk	At risk	At risk
71	SJ325602	SJ353600	3540	132	126	287	475	525	1131	7518	6606	16410	5184	11383	At risk	At risk	At risk	At risk
72	SJ353600	SJ356600	327	115	113	252	413	468	986	6526	5907	14351	4510	9968	At risk	At risk	At risk	At risk
73	SJ356600	SJ364595	993	64	71	142	227	286	548	3611	3668	8095	2501	5615	At risk	At risk	At risk	At risk
74	SJ364595	SJ377585	2090	36	42	78	124	161	295	1979	2065	4368	1380	3058	At risk	At risk	At risk	At risk
75	SJ377585	SJ409578	3908	58	49	122	197	185	421	3292	2697	6733	2265	4693	At risk	At risk	At risk	At risk
76	SJ255580	SJ256580	148	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
77	SJ256580	SJ267589	1731	96	90	215	348	372	788	3442	2701	6686	3087	6595	At risk	At risk	At risk	At risk
78	SJ267589	SJ272593	657	60	61	135	215	247	497	2143	1811	4268	1924	4166	At risk	At risk	At risk	At risk
79	SJ272593	SJ278605	1421	34	37	78	121	144	280	1232	1080	2446	1101	2396	No risk	At risk	At risk	At risk
80	SJ234631	SJ238633	440	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
81	SJ238633	SJ247631	1028	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
82	SJ247631	SJ248631	96	795	468	1361	2934	2103	5654	22418	11715	37506	23653	40842	High risk	High risk	At risk	At risk
83	SJ443582	SJ425588	2221	10	12	22	35	46	77	266	299	572	287	626	No risk	No risk	No risk	No risk
84	SJ425588	SJ419602	1631	8	11	18	29	38	64	222	249	475	239	524	No risk	No risk	No risk	No risk
85	SJ500462	SJ498458	477	82	63	166	297	258	642	3035	2082	5840	2674	5357	At risk	At risk	At risk	At risk
86	SJ498458	SJ498458	89	75	59	154	272	241	595	2782	1947	5405	2453	4958	At risk	At risk	At risk	At risk
87	SJ498458	SJ487444	1963	53	47	115	189	188	434	1942	1550	4028	1726	3693	At risk	At risk	At risk	At risk
88	SJ491435	SJ487444	1128	54	44	110	197	185	433	3149	2407	6318	2150	4364	At risk	At risk	At risk	At risk
89	SH937356	SH938355	85	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
90	SH938355	SH943364	1162	0	0	0	1	1	2	15	11	28	9	18	No risk	No risk	No risk	No risk
91	SJ207660	SJ250628	6265	5	6	11	20	19	42	299	287	610	209	432	No risk	No risk	No risk	No risk
92	SJ248631	SJ249629	280	352	248	677	1301	1085	2701	9928	6347	18045	10480	19996	At risk	High risk	At risk	At risk
93	SJ249629	SJ250628	92	194	159	413	716	682	1575	5460	4126	10803	5769	12065	At risk	At risk	At risk	At risk
94	SJ487444	SJ419460	10703	47	39	97	159	143	348	2366	1815	4791	1736	3564	At risk	At risk	At risk	At risk
95	SH943364	SH950367	932	0	0	1	1	1	2	15	11	28	9	19	No risk	No risk	No risk	No risk
96	SH950367	SJ052411	16902	0	0	0	1	1	2	13	9	24	8	16	No risk	No risk	No risk	No risk
97	SJ052411	SJ060425	1981	0	0	0	1	1	2	14	10	27	9	17	No risk	No risk	No risk	No risk
98	SJ250628	SJ265620	2060	35	37	77	126	143	291	1082	1023	2254	1065	2321	No risk	At risk	At risk	At risk

99	SJ265620	SJ278605	2283	29	31	64	104	120	239	893	861	1876	884	1933	No risk	At risk	No risk	At risk
100	SJ419460	SJ423494	4452	29	26	61	95	91	209	1427	1185	2970	1056	2209	No risk	At risk	At risk	At risk
101	SJ060425	SJ083436	3431	0	0	1	1	1	2	15	11	28	9	19	No risk	No risk	No risk	No risk
102	SJ083436	SJ117437	4135	0	0	1	1	1	3	23	16	42	14	28	No risk	No risk	No risk	No risk
103	SJ117437	SJ153429	4213	0	0	1	1	1	3	24	16	44	16	29	No risk	No risk	No risk	No risk
104	SJ153429	SJ188444	7493	0	0	1	2	1	3	24	17	44	16	31	No risk	No risk	No risk	No risk
105	SJ188444	SJ197432	2310	0	0	1	2	1	3	24	17	44	16	31	No risk	No risk	No risk	No risk
106	SJ197432	SJ235424	5143	0	0	1	2	1	3	23	16	43	16	31	No risk	No risk	No risk	No risk
107	SJ235424	SJ271420	5432	1	1	1	2	2	5	38	27	72	25	50	No risk	No risk	No risk	No risk
108	SJ271420	SJ275416	589	1	1	1	3	2	5	41	28	76	28	52	No risk	No risk	No risk	No risk
109	SJ275416	SJ306406	6570	1	1	2	4	3	8	68	49	128	45	87	No risk	No risk	No risk	No risk
110	SJ306406	SJ318395	1708	1	1	2	4	3	8	68	49	128	45	88	No risk	No risk	No risk	No risk
111	SJ278605	SJ298595	2662	29	31	63	102	115	235	882	832	1832	876	1902	No risk	At risk	No risk	At risk
112	SJ318395	SJ364421	7469	1	1	2	4	3	8	68	50	130	47	90	No risk	No risk	No risk	No risk
113	SJ298595	SJ306581	2050	36	31	76	127	120	271	1063	833	2158	1085	2255	No risk	At risk	At risk	At risk
114	SJ306581	SJ313556	3076	39	33	81	138	122	287	1276	958	2532	1216	2479	No risk	At risk	At risk	At risk
115	SJ313556	SJ326543	2409	34	29	71	119	108	248	1099	851	2213	1053	2174	No risk	At risk	At risk	At risk
116	SJ326543	SJ349558	5153	32	27	67	109	97	228	1007	760	1992	980	2005	No risk	At risk	No risk	At risk
117	SJ349558	SJ358570	2027	44	36	91	152	129	310	1325	992	2608	1325	2691	At risk	At risk	At risk	At risk
118	SJ358570	SJ399560	5058	42	34	87	142	120	290	1239	914	2415	1257	2540	No risk	At risk	At risk	At risk
119	SJ364421	SJ355421	1069	1	1	3	5	4	9	73	53	137	51	96	No risk	No risk	No risk	No risk
120	SJ355421	SJ388454	10430	1	1	3	5	3	9	71	51	132	50	94	No risk	No risk	No risk	No risk
121	SJ388454	SJ395460	2301	1	1	3	4	3	8	70	51	131	49	94	No risk	No risk	No risk	No risk
122	SJ395460	SJ409473	2563	1	1	3	5	4	9	74	53	139	51	98	No risk	No risk	No risk	No risk
123	SJ409473	SJ423494	5981	7	6	15	26	25	55	232	184	448	225	448	No risk	No risk	No risk	No risk
124	SJ423494	SJ413539	10652	8	7	16	27	25	56	256	195	483	244	475	No risk	No risk	No risk	No risk
125	SJ413539	SJ406548	1386	8	7	16	27	25	56	262	197	491	248	480	No risk	No risk	No risk	No risk
126	SJ406548	SJ399560	2149	8	7	16	27	25	56	264	199	497	249	484	No risk	No risk	No risk	No risk
127	SJ399560	SJ409578	4420	11	8	21	37	30	72	341	245	635	330	632	No risk	No risk	No risk	No risk
128	SJ409578	SJ408591	1844	11	9	21	38	30	75	362	258	674	345	656	No risk	No risk	No risk	No risk
129	SJ408591	SJ419602	1925	11	9	21	37	30	74	360	256	670	344	654	No risk	No risk	No risk	No risk
130	SJ419602	SJ414634	4381	11	9	21	37	30	73	353	252	657	340	645	No risk	No risk	No risk	No risk
131	SJ414634	SJ326684	15195	11	8	20	34	27	67	329	230	604	322	608	No risk	No risk	No risk	No risk

Table D.9 Estimated oestrogen concentrations and associated risk derived from mean and P_{90} concentrations in the River Wensum

Reach	Upstream NGR	Downstream NGR	Length (m)	Concentrations (10^{-3}ngL^{-1})											Risk classes			
				EE2			E2			E1			E2 Equivalent		National		SAC	
				Mean	SD	90th	Mean	SD	90th	Mean	SD	90th	Mean	90th	Mean	90th	Mean	90th
1	TF981284	TF981285	168	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
2	**TF981285**	**TF980293**	**833**	**35**	**33**	**77**	**129**	**136**	**290**	**1463**	**1196**	**3003**	**1200**	**2567**	**No risk**	**At risk**	**At risk**	**At risk**
3	TF980293	TF979294	117	15	16	33	53	65	124	602	591	1332	495	1116	No risk	No risk	No risk	At risk
4	TF979294	TF968298	1245	11	12	24	38	46	89	442	425	980	364	821	No risk	No risk	No risk	No risk
5	TF968298	TF964298	415	9	10	21	32	39	75	371	358	823	306	691	No risk	No risk	No risk	No risk
6	TF964298	TF965269	4164	5	6	12	17	21	41	210	201	468	174	393	No risk	No risk	No risk	No risk
7	TF894126	TF901127	713	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
8	**TF901127**	**TF915134**	**1621**	**14**	**17**	**33**	**51**	**63**	**125**	**1049**	**1129**	**2364**	**641**	**1459**	**No risk**	**At risk**	**No risk**	**At risk**
9	TF915134	TF926126	1575	7	8	15	23	29	55	469	521	1062	287	657	No risk	No risk	No risk	No risk
10	TF926126	TF933127	808	5	7	12	18	23	43	366	433	847	225	526	No risk	No risk	No risk	No risk
11	TF933127	TF940128	761	4	5	9	14	18	34	291	331	667	179	413	No risk	No risk	No risk	No risk
12	TF940128	TF968132	3130	3	3	6	9	11	22	189	214	431	117	270	No risk	No risk	No risk	No risk
13	TF968132	TF976136	988	2	3	5	7	9	18	160	178	364	99	228	No risk	No risk	No risk	No risk
14	TF976136	TF975137	173	2	2	4	5	7	13	114	125	258	70	162	No risk	No risk	No risk	No risk
15	**TF975137**	**TF969161**	**3062**	**157**	**144**	**329**	**584**	**574**	**1360**	**4416**	**3609**	**9235**	**4678**	**9925**	**At risk**	**At risk**	**At risk**	**At risk**
16	TF969161	TF991192	4485	120	117	260	426	441	1015	3314	2868	7001	3529	7683	At risk	At risk	At risk	At risk
17	TF991192	TG005201	2062	80	77	172	277	286	643	2179	1890	4496	2330	5005	At risk	At risk	At risk	At risk
18	TF887240	TF885242	342	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
19	TF885242	TF878256	1583	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
20	**TF878256**	**TF876280**	**3023**	**1**	**1**	**1**	**3**	**3**	**6**	**43**	**38**	**86**	**28**	**58**	**No risk**	**No risk**	**No risk**	**No risk**
21	TG039253	TG030243	1488	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
22	TG030243	TG024244	534	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
23	**TG024244**	**TG015246**	**932**	**38**	**46**	**92**	**139**	**192**	**339**	**1108**	**1283**	**2650**	**1148**	**2752**	**No risk**	**At risk**	**At risk**	**At risk**
24	TG015246	TF998248	1952	25	30	59	89	120	214	721	813	1691	749	1765	No risk	At risk	No risk	At risk
25	TG105227	TG104226	192	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
26	**TG104226**	**TG103220**	**622**	**530**	**336**	**954**	**1961**	**1470**	**3908**	**32550**	**17962**	**55493**	**21642**	**38301**	**High risk**	**High risk**	**At risk**	**At risk**
27	TG103220	TG091208	1789	48	36	95	170	145	360	2878	1930	5389	1921	3746	At risk	At risk	At risk	At risk
28	TG091208	TG087201	753	33	29	71	118	110	258	2007	1511	3921	1344	2750	At risk	At risk	At risk	At risk

29	TG087201	TG103185	2392	27	24	58	92	90	205	1576	1259	3189	1062	2233	No risk	At risk	At risk	At risk
30	TF830272	TF828281	962	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
31	TF828281	TF835285	875	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
32	**TF835285**	**TF851288**	**1602**	**6**	**5**	**12**	**22**	**22**	**48**	**173**	**137**	**337**	**178**	**361**	**No risk**	**No risk**	**No risk**	**No risk**
33	TF835312	TF837307	595	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
34	**TF837307**	**TF851288**	**2612**	**13**	**11**	**27**	**45**	**44**	**100**	**1479**	**1319**	**3291**	**748**	**1644**	**No risk**	**At risk**	**No risk**	**At risk**
35	TF851288	TF876280	3319	9	7	17	30	25	62	782	663	1699	434	914	No risk	No risk	No risk	No risk
36	TF876280	TF923292	7294	4	4	9	15	12	30	380	325	832	215	454	No risk	No risk	No risk	No risk
37	**TF923292**	**TF965269**	**6143**	**23**	**18**	**44**	**82**	**73**	**170**	**824**	**589**	**1637**	**743**	**1456**	**No risk**	**At risk**	**No risk**	**At risk**
38	TF965269	TF998248	4768	20	16	39	69	62	144	709	512	1418	642	1270	No risk	At risk	No risk	At risk
39	TF998248	TF997213	4998	20	16	39	67	58	140	676	493	1349	625	1243	No risk	No risk	No risk	At risk
40	**TF997213**	**TG005201**	**2202**	**21**	**17**	**41**	**70**	**59**	**144**	**757**	**539**	**1521**	**674**	**1334**	**No risk**	**At risk**	**No risk**	**At risk**
41	TG005201	TG020183	3214	31	22	57	102	74	195	966	631	1819	932	1756	No risk	At risk	No risk	At risk
42	**TG020183**	**TG041178**	**3196**	**31**	**22**	**58**	**102**	**74**	**194**	**985**	**640**	**1836**	**945**	**1772**	**No risk**	**At risk**	**No risk**	**At risk**
43	**TG041178**	**TG103185**	**9886**	**38**	**27**	**71**	**121**	**84**	**234**	**1120**	**732**	**2130**	**1119**	**2134**	**No risk**	**At risk**	**At risk**	**At risk**
44	TG103185	TG198107	21103	31	22	59	91	60	170	963	606	1772	935	1743	No risk	At risk	No risk	At risk

Table D.10 Estimated oestrogen concentrations and associated risk derived from mean and P_{90} concentrations in the River Itchen

Reach	Upstream NGR	Downstream NGR	Length (m)	EE2 Mean	EE2 SD	EE2 90th	E2 Mean	E2 SD	E2 90th	E1 Mean	E1 SD	E1 90th	E2 Equivalent Mean	E2 Equivalent 90th	National Mean	National 90th	SAC Mean	SAC 90th
				Concentrations ($10^{-3}ngL^{-1}$)											Risk classes			
1	SU486323	SU487322	66	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
2	**SU487322**	**SU486307**	**2842**	**98**	**64**	**187**	**361**	**300**	**759**	**3544**	**2040**	**6239**	**3169**	**5959**	**At risk**	**At risk**	**At risk**	**At risk**
3	SU486307	SU486297	1223	78	51	150	286	239	606	2828	1634	4989	2532	4772	At risk	At risk	At risk	At risk
4	SU576298	SU573306	1039	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
5	**SU573306**	**SU572324**	**2213**	**11**	**8**	**21**	**41**	**35**	**81**	**317**	**205**	**587**	**331**	**632**	**No risk**	**No risk**	**No risk**	**No risk**
6	SU572324	SU564317	1410	4	3	8	15	13	29	116	76	218	120	232	No risk	No risk	No risk	No risk
7	SU564317	SU511325	6459	3	2	5	10	8	19	77	50	144	80	154	No risk	No risk	No risk	No risk
8	SU511325	SU486297	4880	2	2	5	8	7	17	68	44	127	69	136	No risk	No risk	No risk	No risk
9	SU486297	SU486296	120	9	6	17	34	26	68	321	190	571	296	546	No risk	No risk	No risk	No risk
10	SU486296	SU468179	14488	7	5	14	25	20	50	251	148	444	232	427	No risk	No risk	No risk	No risk
11	**SU468179**	**SU468178**	**112**	**43**	**31**	**82**	**159**	**137**	**331**	**2453**	**1731**	**4678**	**1688**	**3255**	**At risk**	**At risk**	**At risk**	**At risk**
12	SU468178	SU454156	3333	42	31	81	153	133	320	2375	1690	4533	1640	3172	At risk	At risk	At risk	At risk
13	SU454156	SU438152	1895	38	28	73	138	119	287	2159	1522	4102	1489	2873	At risk	At risk	At risk	At risk

Table D.11 Estimated oestrogen concentrations and associated risk derived from mean and P_{90} concentrations in the River Avon

Reach	Upstream NGR	Downstream NGR	Length (m)	EE2 Mean	EE2 SD	EE2 90th	E2 Mean	E2 SD	E2 90th	E1 Mean	E1 SD	E1 90th	E2 Equivalent Mean	E2 Equivalent 90th	National Mean	National 90th	SAC Mean	SAC 90th
				Concentrations (10^{-3}ngL^{-1})											Risk classes			
1	ST997293	ST998302	937	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
2	**ST998302**	**SU002306**	**645**	**35**	**35**	**76**	**135**	**153**	**307**	**1019**	**997**	**2180**	**1058**	**2299**	**No risk**	**At risk**	**At risk**	**At risk**
3	ST884303	ST886301	307	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
4	**ST886301**	**ST895286**	**2150**	**18**	**16**	**38**	**66**	**64**	**145**	**1626**	**1307**	**3254**	**914**	**1860**	**No risk**	**At risk**	**No risk**	**At risk**
5	ST895286	ST895284	220	7	7	15	26	26	58	648	538	1331	364	755	No risk	No risk	No risk	No risk
6	ST895284	ST897280	454	6	6	14	23	24	52	569	493	1195	319	676	No risk	No risk	No risk	No risk
7	ST897280	ST924274	3271	5	5	10	16	19	37	403	394	902	227	508	No risk	No risk	No risk	No risk
8	ST924274	ST952296	4715	2	2	4	6	7	14	151	140	328	85	186	No risk	No risk	No risk	No risk
9	ST952296	ST952296	61	2	2	3	5	6	11	128	118	278	73	157	No risk	No risk	No risk	No risk
10	ST952296	ST957298	555	1	1	2	4	4	8	90	78	189	50	107	No risk	No risk	No risk	No risk
11	**ST957298**	**ST964297**	**787**	**8**	**7**	**17**	**31**	**31**	**66**	**522**	**430**	**1069**	**340**	**704**	**No risk**	**No risk**	**No risk**	**No risk**
12	ST964297	SU002306	5744	7	6	14	24	24	52	415	339	849	273	567	No risk	No risk	No risk	No risk
13	SU061453	SU074427	3795	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
14	**SU074427**	**SU070387**	**6041**	**4**	**3**	**9**	**16**	**14**	**33**	**126**	**88**	**238**	**130**	**255**	**No risk**	**No risk**	**No risk**	**No risk**
15	**SU070387**	**SU068368**	**2357**	**4**	**3**	**9**	**16**	**14**	**32**	**128**	**86**	**239**	**132**	**255**	**No risk**	**No risk**	**No risk**	**No risk**
16	SU237574	SU244528	5313	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
17	**SU244528**	**SU169338**	**29697**	**2**	**2**	**4**	**5**	**4**	**11**	**198**	**310**	**453**	**108**	**233**	**No risk**	**No risk**	**No risk**	**No risk**
18	**SU169338**	**SU155302**	**5092**	**11**	**9**	**22**	**37**	**38**	**79**	**694**	**639**	**1451**	**450**	**934**	**No risk**	**No risk**	**No risk**	**No risk**
19	SU155302	SU166286	3078	10	8	20	32	32	68	604	529	1243	395	808	No risk	No risk	No risk	No risk
20	SU032626	SU050621	2095	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
21	**SU050621**	**SU056616**	**829**	**45**	**39**	**96**	**162**	**160**	**360**	**1313**	**1064**	**2614**	**1355**	**2837**	**At risk**	**At risk**	**At risk**	**At risk**
22	SU056616	SU059610	724	15	13	33	54	54	120	441	367	879	454	956	No risk	No risk	No risk	No risk
23	SU059610	SU063607	527	12	11	26	43	43	95	351	294	700	361	762	No risk	No risk	No risk	No risk
24	SU063607	SU071582	3215	8	8	18	29	30	65	239	203	483	248	527	No risk	No risk	No risk	No risk
25	SU071582	SU089580	2076	6	5	12	19	19	42	160	132	324	166	352	No risk	No risk	No risk	No risk
26	SU089580	SU134560	7089	3	3	7	10	10	21	87	71	174	89	189	No risk	No risk	No risk	No risk
27	SU149036	SU148035	96	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk

28	SU148035	SU147035	98	625	356	1086	2400	1685	4685	17747	9333	30100	18726	32818	High risk	High risk	At risk	At risk
29	SU147035	SU145034	279	616	352	1072	2359	1658	4594	17453	9197	29631	18446	32339	High risk	High risk	At risk	At risk
30	SU158287	SU159286	148	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
31	SU159286	SU166286	706	351	205	604	1280	953	2502	9711	5226	16279	10364	17989	At risk	High risk	At risk	At risk
32	ST874435	ST874436	87	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
33	ST874436	ST878437	443	29	21	54	107	94	225	802	544	1507	856	1632	No risk	At risk	No risk	At risk
34	ST878437	ST882442	752	29	21	54	106	92	222	791	537	1487	846	1614	No risk	At risk	No risk	At risk
35	ST882442	ST928423	6635	21	15	40	75	66	157	583	393	1083	619	1176	No risk	No risk	No risk	At risk
36	ST928423	ST932422	374	19	14	36	68	60	141	526	357	979	559	1066	No risk	No risk	No risk	At risk
37	ST932422	ST973394	6645	13	10	25	45	40	94	361	241	663	382	725	No risk	No risk	No risk	No risk
38	ST973394	SU068368	12119	9	7	17	30	27	62	248	167	454	264	504	No risk	No risk	No risk	No risk
39	SU040254	SU180241	18833	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
40	SU163596	SU157594	668	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
41	SU157594	SU151592	694	33	27	66	124	119	271	944	715	1854	990	1989	No risk	At risk	No risk	At risk
42	SU151592	SU131574	3591	27	22	54	98	95	214	765	582	1503	803	1621	No risk	At risk	No risk	At risk
43	SU131574	SU134560	2037	22	18	44	78	75	168	611	467	1201	641	1295	No risk	At risk	No risk	At risk
44	SU154433	SU156428	564	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
45	SU156428	SU156427	110	664	430	1130	2554	2169	4912	18705	11807	31157	19849	34123	High risk	High risk	At risk	At risk
46	SU002306	SU060311	7784	7	6	14	24	21	49	363	283	720	256	519	No risk	No risk	No risk	No risk
47	SU060311	SU105308	5791	6	5	13	22	18	44	344	244	664	244	481	No risk	No risk	No risk	No risk
48	SU166286	SU168285	339	92	69	184	334	298	715	2763	1924	5234	2782	5521	At risk	At risk	At risk	At risk
49	SU168285	SU169284	61	92	69	183	334	297	714	2758	1920	5225	2778	5512	At risk	At risk	At risk	At risk
50	SU068368	SU088338	4759	8	6	15	26	21	52	216	140	391	231	429	No risk	No risk	No risk	No risk
51	SU088338	SU088338	28	9	6	16	29	23	57	271	167	480	268	489	No risk	No risk	No risk	No risk
52	SU088338	SU105308	4170	9	6	16	29	22	56	265	164	471	264	483	No risk	No risk	No risk	No risk
53	SU134560	SU136542	2056	14	13	30	49	53	111	396	343	813	415	873	No risk	No risk	No risk	No risk
54	SU136542	SU150485	8371	11	9	22	36	35	76	349	267	685	331	669	No risk	No risk	No risk	No risk
55	SU150485	SU152480	717	11	9	22	36	35	75	344	264	677	327	662	No risk	No risk	No risk	No risk
56	SU152480	SU154479	224	12	10	25	42	37	84	394	287	761	378	746	No risk	No risk	No risk	No risk
57	SU154479	SU162432	7341	12	10	24	39	35	78	364	271	710	357	707	No risk	No risk	No risk	No risk
58	SU162432	SU156427	2025	10	8	21	33	30	67	317	234	614	311	617	No risk	No risk	No risk	No risk
59	SU105308	SU140297	5323	8	5	14	25	18	48	280	170	496	249	448	No risk	No risk	No risk	No risk
60	SU156427	SU151408	4403	19	14	36	66	51	132	561	380	1024	577	1080	No risk	No risk	No risk	At risk
61	SU151408	SU140297	18062	21	14	39	68	47	128	584	363	1038	611	1122	No risk	No risk	No risk	At risk
62	SU140297	SU145291	1075	12	7	21	38	25	69	374	222	664	361	647	No risk	No risk	No risk	No risk

63	SU145291	SU169284	2640	12	7	21	38	25	68	371	220	660	360	645	No risk	No risk	No risk	No risk
64	SU169284	SU180241	5240	21	13	38	69	47	127	620	371	1097	617	1126	No risk	No risk	No risk	At risk
65	SU180241	SU175208	3634	18	11	34	60	41	111	546	325	961	544	990	No risk	No risk	No risk	No risk
66	SU175208	SU174204	423	18	11	34	60	41	111	545	324	960	544	989	No risk	No risk	No risk	No risk
67	**SU174204**	**SU177187**	**2263**	**19**	**12**	**34**	**62**	**41**	**114**	**583**	**341**	**1022**	**568**	**1025**	**No risk**	**No risk**	**No risk**	**At risk**
68	SU177187	SU157144	8766	18	11	32	57	37	104	542	309	936	535	953	No risk	No risk	No risk	No risk
69	SU157144	SU146130	2704	17	10	30	53	35	97	502	289	869	497	890	No risk	No risk	No risk	No risk
70	**SU146130**	**SU146129**	**107**	**18**	**11**	**32**	**58**	**37**	**106**	**535**	**306**	**933**	**531**	**955**	**No risk**	**No risk**	**No risk**	**No risk**
71	SU146129	SU145034	14411	17	10	30	52	33	95	484	277	834	490	876	No risk	No risk	No risk	No risk
72	SU145034	SZ155938	17391	18	11	32	54	34	98	504	285	868	519	915	No risk	No risk	No risk	No risk
73	SZ155938	SZ157932	791	18	11	32	54	34	97	502	284	864	518	912	No risk	No risk	No risk	No risk

Table D.12 Estimated oestrogen concentrations and associated risk derived from mean and P_{90} concentrations in the River Eastern Cleddau

				Concentrations ($10^{-3}ngL^{-1}$)											Risk classes			
Reach	Upstream NGR	Downstream NGR	Length (m)	EE2			E2			E1			E2 Equivalent		National		SAC	
				Mean	SD	90th	Mean	SD	90th	Mean	SD	90th	Mean	90th	Mean	90th	Mean	90th
1	SN076276	SN075269	670	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
2	SN075269	SN076268	154	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
3	**SN076268**	**SN080253**	**1836**	**13**	**19**	**28**	**48**	**72**	**114**	**771**	**1048**	**1745**	**520**	**1169**	**No risk**	**No risk**	**No risk**	**At risk**
4	SN080253	SN096207	5382	5	7	10	15	23	36	267	341	587	179	395	No risk	No risk	No risk	No risk
5	SN099212	SN096207	708	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
6	SN082195	SN084194	194	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
7	SN148167	SN143168	515	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
8	**SN143168**	**SN136180**	**1719**	**12**	**18**	**27**	**42**	**75**	**94**	**834**	**1119**	**1973**	**515**	**1207**	**No risk**	**At risk**	**No risk**	**At risk**
9	SN136180	SN121182	1601	4	5	10	15	20	34	308	326	675	188	417	No risk	No risk	No risk	No risk
10	**SN121182**	**SN117180**	**436**	**26**	**25**	**56**	**99**	**119**	**214**	**1646**	**1493**	**3500**	**1073**	**2318**	**No risk**	**At risk**	**At risk**	**At risk**
11	SN117180	SN112178	617	19	19	41	73	87	156	1212	1102	2569	790	1699	No risk	At risk	No risk	At risk
12	SN112178	SN109175	374	14	15	32	54	69	119	908	865	1972	592	1301	No risk	At risk	No risk	At risk
13	SN109175	SN094168	2012	11	12	26	42	56	94	712	709	1563	466	1040	No risk	No risk	No risk	At risk
14	SN094168	SN076166	2205	9	11	21	35	47	77	576	586	1272	382	858	No risk	No risk	No risk	No risk
15	SN096207	SN092204	617	1	1	1	2	3	4	33	47	73	21	49	No risk	No risk	No risk	No risk
16	SN092204	SN084194	1599	1	1	1	2	3	4	31	45	71	21	46	No risk	No risk	No risk	No risk
17	SN084194	SN075172	3140	0	0	0	1	1	2	12	13	25	8	16	No risk	No risk	No risk	No risk
18	SN075172	SN076166	658	0	0	0	1	1	2	12	13	25	8	16	No risk	No risk	No risk	No risk
19	SN076166	SN072153	1565	1	1	2	3	4	6	49	49	107	33	70	No risk	No risk	No risk	No risk
20	SN072153	SN056143	2035	1	1	2	3	4	6	46	47	102	30	68	No risk	No risk	No risk	No risk

Table D.13 Estimated oestrogen concentrations and associated risk derived from mean and P_{90} concentrations in the Western River Cleddau

				Concentrations ($10^{-3}ngL^{-1}$)											Risk classes			
Reach	Upstream	Downstream	Length	EE2			E2			E1			E2 Equivalent		National		SAC	
	NGR	NGR	(m)	Mean	SD	90th	Mean	SD	90th	Mean	SD	90th	Mean	90th	Mean	90th	Mean	90th
1	SM924352	SM928350	514	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
2	**SM928350**	**SM935327**	**2956**	**2**	**3**	**5**	**6**	**9**	**17**	**217**	**306**	**575**	**112**	**290**	**No risk**	**No risk**	**No risk**	**No risk**
3	SN016264	SN004253	1667	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
4	**SN004253**	**SM985244**	**2393**	**3**	**4**	**6**	**10**	**15**	**23**	**95**	**142**	**229**	**85**	**206**	**No risk**	**No risk**	**No risk**	**No risk**
5	SM985244	SM976242	891	2	3	5	8	13	19	78	116	190	71	173	No risk	No risk	No risk	No risk
6	SM976242	SM962234	1852	1	2	3	4	6	9	39	55	94	35	86	No risk	No risk	No risk	No risk
7	SM954345	SM950340	603	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
8	SM950340	SM947336	583	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
9	**SM947336**	**SM945332**	**434**	**8**	**9**	**18**	**28**	**37**	**69**	**222**	**262**	**511**	**229**	**533**	**No risk**	**No risk**	**No risk**	**No risk**
10	SM945332	SM935327	1261	5	6	12	19	25	47	153	181	353	156	363	No risk	No risk	No risk	No risk
11	SM882314	SM884314	199	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
12	**SM884314**	**SM887315**	**298**	**5**	**6**	**12**	**18**	**26**	**44**	**141**	**162**	**332**	**149**	**354**	**No risk**	**No risk**	**No risk**	**No risk**
13	SM887315	SM890315	460	5	6	11	17	23	40	128	147	300	136	321	No risk	No risk	No risk	No risk
14	SM890315	SM901318	1208	3	4	7	11	16	27	87	99	202	92	217	No risk	No risk	No risk	No risk
15	**SM901318**	**SM914318**	**1488**	**4**	**5**	**10**	**15**	**18**	**32**	**165**	**183**	**376**	**138**	**317**	**No risk**	**No risk**	**No risk**	**No risk**
16	SM914318	SM917313	611	3	4	7	10	13	23	116	132	266	97	224	No risk	No risk	No risk	No risk
17	SM917313	SM921308	790	2	3	6	9	10	19	96	108	219	80	185	No risk	No risk	No risk	No risk
18	SM934297	SM934295	188	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
19	**SM934295**	**SM929289**	**766**	**99**	**111**	**231**	**364**	**442**	**898**	**7590**	**7441**	**16995**	**4542**	**10404**	**At risk**	**At risk**	**At risk**	**At risk**
20	SM954296	SM956294	269	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
21	**SM956294**	**SM971283**	**2026**	**14**	**18**	**33**	**47**	**71**	**115**	**806**	**805**	**1936**	**546**	**1312**	**No risk**	**At risk**	**No risk**	**At risk**
22	SN018316	SN017303	1658	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
23	SN017303	SN011298	829	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
24	**SN011298**	**SN004288**	**1347**	**2**	**3**	**5**	**8**	**14**	**22**	**62**	**81**	**148**	**66**	**159**	**No risk**	**No risk**	**No risk**	**No risk**
25	SN004288	SM982283	2552	1	2	4	6	9	14	42	54	100	43	106	No risk	No risk	No risk	No risk
26	SM982283	SM982284	73	1	2	4	5	9	14	42	53	99	43	105	No risk	No risk	No risk	No risk
27	SM982284	SM971283	1304	1	2	2	4	6	10	29	37	68	30	72	No risk	No risk	No risk	No risk
28	SM976227	SM974225	254	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
29	**SM974225**	**SM970220**	**736**	**72**	**100**	**185**	**264**	**396**	**669**	**2824**	**3282**	**7074**	**2405**	**6112**	**At risk**	**At risk**	**At risk**	**At risk**
30	SM970220	SM959209	1891	9	13	23	33	51	82	367	435	907	309	771	No risk	No risk	No risk	No risk

31	SM959209	SM947199	1777	8	10	19	26	39	65	292	330	710	249	615	No risk	No risk	No risk	No risk
32	SM947199	SM945199	268	5	7	12	17	25	43	192	218	468	165	405	No risk	No risk	No risk	No risk
33	SN017213	SN011210	776	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
34	**SN011210**	**SN003211**	**857**	**34**	**38**	**81**	**125**	**165**	**310**	**1083**	**1186**	**2491**	**1046**	**2482**	**No risk**	**At risk**	**At risk**	**At risk**
35	SN003211	SM994200	1713	5	7	13	19	30	47	169	216	412	162	398	No risk	No risk	No risk	No risk
36	SM994200	SM974174	3862	3	4	7	10	16	25	94	119	229	90	220	No risk	No risk	No risk	No risk
37	SM974174	SM963160	2373	2	3	5	7	10	16	62	78	151	59	147	No risk	No risk	No risk	No risk
38	SM963160	SM955156	935	2	3	5	6	10	16	60	75	146	58	143	No risk	No risk	No risk	No risk
39	SM890180	SM902185	1365	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
40	SM902185	SM903185	144	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
41	SM903185	SM908187	528	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
42	**SM908187**	**SM914189**	**712**	**18**	**27**	**46**	**65**	**108**	**156**	**506**	**699**	**1218**	**541**	**1332**	**No risk**	**At risk**	**No risk**	**At risk**
43	SM914189	SM938190	2814	8	10	19	26	37	61	219	261	508	226	538	No risk	No risk	No risk	No risk
44	SM924204	SM924200	385	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
45	SM924200	SM925200	104	0	0	0	0	0	0	0	0	0	0	0	No risk	No risk	No risk	No risk
46	**SM925200**	**SM938190**	**2193**	**3**	**3**	**6**	**9**	**11**	**21**	**154**	**151**	**339**	**102**	**231**	**No risk**	**No risk**	**No risk**	**No risk**
47	SM935327	SM935316	1181	4	5	9	14	18	33	159	189	383	130	309	No risk	No risk	No risk	No risk
48	SM935316	SM921308	1737	1	2	3	5	7	13	61	72	145	49	117	No risk	No risk	No risk	No risk
49	SM971283	SM959266	2438	2	3	5	7	10	15	88	90	203	68	161	No risk	No risk	No risk	No risk
50	**SM959266**	**SM958263**	**323**	**4**	**5**	**9**	**14**	**19**	**33**	**138**	**147**	**319**	**123**	**289**	**No risk**	**No risk**	**No risk**	**No risk**
51	SM938190	SM941188	340	4	4	10	15	16	33	174	170	391	144	323	No risk	No risk	No risk	No risk
52	SM921308	SM929289	2877	2	2	4	6	7	13	69	76	159	57	133	No risk	No risk	No risk	No risk
53	SM929289	SM933277	1432	4	5	9	14	16	33	243	264	552	160	372	No risk	No risk	No risk	No risk
54	SM933277	SM958263	3329	3	4	8	11	13	26	195	214	445	129	303	No risk	No risk	No risk	No risk
55	SM958263	SM962234	3667	3	3	6	10	10	21	142	139	315	104	233	No risk	No risk	No risk	No risk
56	SM962234	SM959230	600	3	3	6	9	10	20	131	130	293	96	220	No risk	No risk	No risk	No risk
57	SM959230	SM959229	55	3	3	6	9	10	20	131	130	293	96	220	No risk	No risk	No risk	No risk
58	**SM959229**	**SM945199**	**3845**	**3**	**3**	**6**	**9**	**10**	**20**	**131**	**131**	**294**	**98**	**221**	**No risk**	**No risk**	**No risk**	**No risk**
59	SM945199	SM941188	1319	3	3	7	9	10	21	133	133	302	101	230	No risk	No risk	No risk	No risk
60	SM941188	SM955156	4570	3	3	6	9	9	20	124	121	276	95	218	No risk	No risk	No risk	No risk
61	SM955156	SM960151	713	3	3	6	9	9	19	114	113	253	90	203	No risk	No risk	No risk	No risk

Glossary

ECx	The concentration of a chemical in water to which test organisms are exposed that is estimated to be effective in producing a sub-lethal response in x per cent of the test organisms. The ECx (for example, EC_{50} or EC_{100}) is usually expressed as a time-dependent value (96h EC_{50}).
GSI	Gonadosomatic index – the relationship of gonad weight to total body weight.
HSI	Histosomatic index – the relationship of liver weight to total body weight.
LOEC	Lowest observed effect concentration – the lowest concentration of a chemical used in a toxicity test that has a statistically-significant adverse effect on the exposed test organisms compared with controls.
MATC	Maximum allowable toxicant concentration – the hypothetical toxic threshold concentration lying in a range bounded at the lower end by the highest tested concentration having no observed effect (NOEC) and at the higher end by the lowest concentration having a significant toxic effect (LOEC). It is calculated as the geometric mean of the LOEC and NOEC.
NOEC	No observed effect concentration – the highest concentration of a chemical used in a toxicity test that has no statistically-significant adverse effect on the exposed test organisms compared with controls.
PNEC	Predicted no effect concentration – the lowest environmental concentration at which the absence of any adverse effect is expected.
Q_{95}	A low flow statistic: the flow exceeded 95 per cent of the time.
VTG	Vitellogenin is an egg yolk precursor protein usually only expressed in female fish. However, in the presence of estrogenic chemicals, male fish can produce VTG in a dose-dependent manner. VTG induction in male fish is used as a biomarker of exposure to estrogenic substances.

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