Environment Agency

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Climate change impacts and water temperature

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Steve Killeen
Head of Science

Executive Summary

Global average surface temperature has increased by 0.6°C during the twentieth century, providing clear evidence that climate change is occurring. It is likely that an increase in air temperature will result in a corresponding increase in the water temperature of rivers and lakes. However, there is an overall lack of good quality, long-term water temperature monitoring data with which to investigate such warming trends. This project aims to identify the available water temperature datasets in England and Wales, and to compile a database containing all ongoing water temperature monitoring. Statistical analysis of the database has been undertaken in order to identify any recent annual or seasonal warming trends that might be attributed to climate change. It was agreed by the project board that two examples of each Water Framework Directive (WFD) river type should be selected in each region in addition to one large river which had multiple sampling sites covering a range of WFD types between its upper and lower reaches.

In the first stage of the project, both Environment Agency and external sources of river and lake water temperature data were investigated and all freely available records obtained where possible. These were audited for length, frequency and completeness of monitoring, before selection of sites for analysis. Some quality assurance procedures were also applied, such as the removal of outlying data points. Six types of statistical analysis were performed on the selected river temperature datasets as follows:

1. *Regional analysis*. This analysis aims to uncover regional differences in river water temperature. One main river in each of the eight Environment Agency regions was selected to be included in the analysis.
2. *Water Framework Directive (WFD) river type analysis within regions*. This analysis aims to uncover type-related differences in river water temperature within each region. Where possible, temperature records from two of each river type within each region were included in the analysis.
3. *WFD river type analysis between regions*. This analysis aims to uncover region-related differences in river water temperature within types. Where possible, two temperature records from each region were included in each analysis.
4. *Moving average analysis*. This analysis was designed to look at any trends in mean monthly and annual temperature over time for a number of sites on the same river.
5. *Annual mean trend analysis.* Assessment of the annual mean temperature series for the best water temperature record in each region, including calculation of the rate of river water temperature change.
6. *Seasonal analysis.* Monthly temperature data, from a representative river in each region (with the exception of Anglian Region where two rivers were used), was split into winter, spring, summer and autumn seasons and moving average trend analysis performed to assess any changes in seasonal temperatures over time.

Significant differences in river water temperature between regions were revealed, with the highest mean monthly water temperatures being found in the Thames Region (11.98°C) and Anglian Region (11.87°C) and the lowest in the North East Region (9.51°C). Within each region, river water temperatures also differ according to the WFD river typology. However, the water temperature of all the river types included in the analysis differs between regions, suggesting that the influence of region (geographic location) on water temperature is often stronger than the influence of river type in England and Wales.

Moving average analysis and annual and decadal mean trend analysis have revealed an increase in river water temperature over the last 20–30 years. This trend is particularly apparent in the Anglian, Thames and South West Regions, but is also seen in the lower reaches of main rivers analysed in all regions. The highest water temperatures are nearly always seen in the later

part of the record, from 1990 to the present date. From the data available the analysis suggests that increases in river water temperature will be more noticeable in the south and east of the UK and in the lower reaches of rivers where increases in air temperature will be greater. However, it should be noted that no upland rivers were represented in this analysis as there was no temperature data available for them.

Seasonal analysis revealed that winter river water temperatures in the northeast and northwest of England were lower than those in the south, southeast and southwest of England. It also identified a generally upward trend in river water temperatures in all seasons. There is some evidence that upper reaches of rivers (headwaters) are warming in winter and spring, whereas lower reaches are warming in summer.

There is an overall lack of long-term, continuous, quality-assured water temperature datasets throughout England and Wales particularly for upland rivers. It is therefore recommended that existing Environment Agency water temperature monitoring be improved, with emphasis on targeted, automated, long-term monitoring at a selected number of sites in each region. The costs of setting up, maintaining and updating a water temperature database are estimated to be reasonably low. Other recommendations from the project include more detailed seasonal analysis of river water temperatures and extension of the analysis to lake and estuarine sites. The potential for the air–water temperature relationship to be used both to reproduce historical water temperatures and to predict future water temperatures under a climate change scenario should also be investigated further.

Contents

List of Figures

List of tables

1 Introduction

1.1 Aims and objectives

Eleven of the last twelve years (1995–2006) are ranked among the 12 warmest years since instrumental records of global surface temperature began in 1850 (IPCC 2007). In addition, Karoly and Stott (2006) consider that the observed warming in annual mean central England air temperature (CET) of approximately 1°C since 1950 is very unlikely to have been caused by natural variations in climate. This provides clear evidence that climate change is occurring. The UKCIP02 Climate Change scenarios indicate that, by the 2080s, the annual average temperature across the UK may rise between 1 and
5°C depending on region and emissions scenario, with the greatest warming predicted in the southeast of the country in summer and autumn (Hulme *et al.* 2002). Changes to other climate variables, such as precipitation, cloud cover, solar radiation, relative humidity and wind speed, are also predicted to occur. As a result, the Environment Agency needs to consider climate change impacts and adaptation as part of all its activities.

Although the Environment Agency holds a considerable amount of long-term hydrometric, physicochemical and biological data for air, water and land, little analysis has been undertaken to determine whether or not trends in environmental parameters can be attributed to climate change. A report commissioned by the Environment Agency and published in 2003 described an initial audit of Environment Agency datasets, listed key datasets external to the Environment Agency with the potential to detect climate change impacts, and identified gaps in the availability of monitoring data (Codling *et al*. 2003). Water temperature was identified as being an important climate change indicator, with datasets that include water temperature measurements being held both within the Environment Agency and externally.

This project aimed to identify all of the available water temperature datasets in England and Wales, and to compile a database containing all ongoing water temperature monitoring. It was not intended to be a detailed review of the effects of water temperature on ecology. The 'best' records in each Environment Agency region (generally the longest, the most frequently monitored and the most complete) were subjected to statistical analysis to detect any long-term trends in water temperature. Although water temperature datasets for both rivers and lakes are identified, freshwater river sites (excluding estuaries) are the main focus of the analysis.

The Countryside Council for Wales (CCW) has contributed both financially and practically to this project, and we thank them for their contribution.

1.2 Literature review

1.2.1 Introduction

Water temperature regimes in streams and rivers are influenced by changes in air and ground temperatures as well as by alterations to the hydrological regime, all of which occur as a result of both natural and human modification. Water temperature has a strong influence on the physical characteristics of streams and rivers, such as surface tension, density and viscosity, solubility of gases and chemical reaction rates (Webb 1996, Webb and Nobilis 2007). Changes in water temperature are therefore linked to changes in water quality (e.g. dissolved oxygen concentrations and nitrogen levels). Statistical analysis of the effects of air temperature on river water quality have shown that biological oxygen demand and suspended solids increase and dissolved oxygen concentrations decrease in response to an increase in air temperature (Ozaki *et al.* 2003). Lake water quality is also likely to be influenced by changes in water temperature. A mathematical lake water temperature model developed by Hassan *et al.* (1998a) showed that water temperature profiles change in response to higher air temperatures, which may lead to earlier stratification and corresponding changes in lake water quality. Deterioration of the water quality in Lake Kasumigaura, Japan, has been found to correlate to increases in air temperature (Fukushima *et al.* 2000).

The ecological effects of changes in water temperature are outside the scope of this project, but should be considered briefly here. Thermal regime influences aquatic organisms in terms of growth rate, metabolism, reproduction and life history, distribution, behaviour and tolerance to parasites/diseases and pollution (Alabaster and Lloyd, 1980, Crisp 1996, Webb 1996, Caissie 2006). Most communities and species in freshwater ecosystems are cold-blooded and will therefore be sensitive to changes in the water temperature regime (Conlan *et al.* 2005). The effects of temperature change on the distribution, abundance and diversity, growth and reproduction of freshwater fishes have been particularly well documented. Davidson and Hazlewood (2005) predict that future temperature increases are likely to have significant effects on the growth rate of freshwater fish, such as trout and salmon, in UK rivers. Similarly, Webb and Walsh (2004) have predicted that higher river temperatures as a result of climate change will be detrimental to the habitat of cold water fish species such as Atlantic salmon, brown trout and grayling, although warm water species may benefit.

1.2.2 Thermal regime

Streams and rivers show both temporal and spatial variations in water temperature. Temperature at the source of a stream is generally close to that of groundwater temperature, and mean daily water temperature increases with distance downstream or with increasing stream order. This rate of increase is greater for small streams than for large rivers. Smaller scale temperature variations can be seen below the confluence with tributaries and in seepage areas in pools.

Water temperature also varies temporally on a daily and annual cycle. Over a 24-hour period, temperature is usually at a maximum in the late afternoon/early evening and at a minimum in the early morning. Figure 1.1 shows an example of the daily cycle at a site on the River Tyne, plotted from hourly measurements taken on 3 June 2005, which broadly fits this pattern. Such variations are generally smaller in cold headwater streams than in larger streams, as the groundwater influence decreases. In terms of an annual cycle, the temperature of rivers in colder regions is generally close to freezing during the winter, with a sinusoidal annual temperature cycle from spring to autumn (Caissie *et al.* 1998).

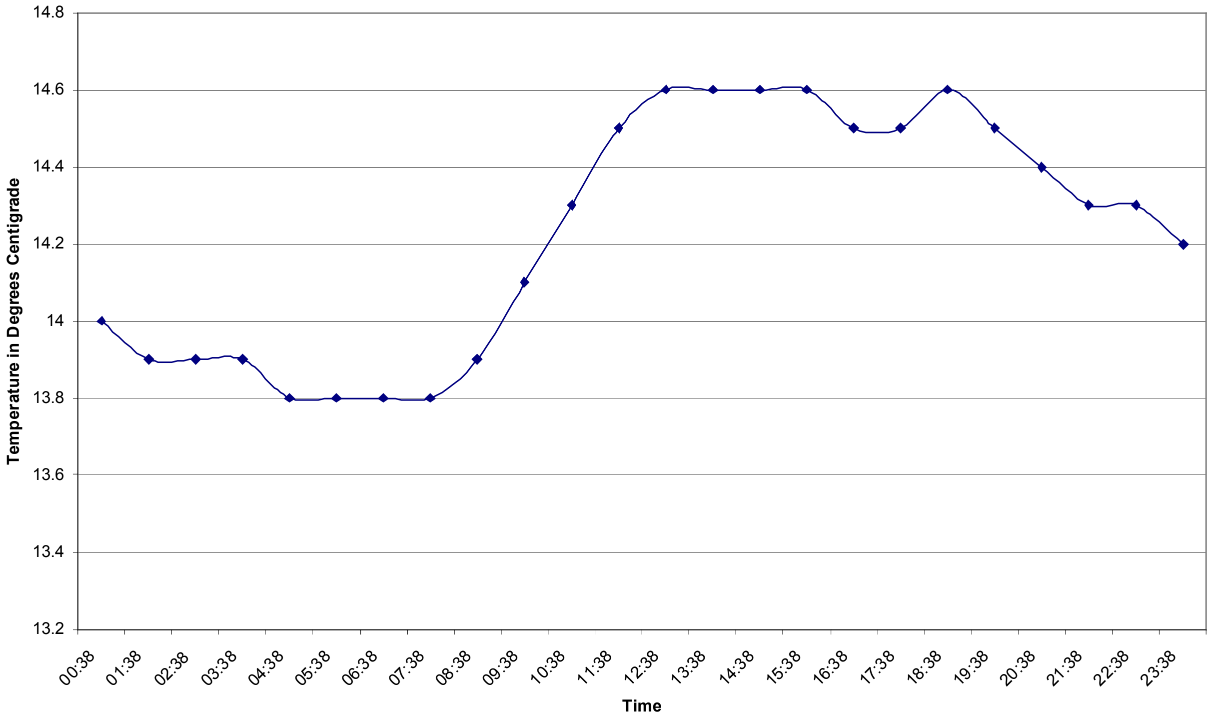


Figure 1.1 Daily water temperature variations on the River Tyne

When modelling river water temperature, heat exchange processes in the river environment should be taken into account (Caissie 2006). Changes in the water temperature of a watercourse occur as a result of changes to the energy budget and/or thermal capacity. The energy or heat budget of a stream or river reach can be expressed in terms of the following major components:

$$Qn = \pm Qr \pm Qe \pm Qh \pm Qhb + Qfc \pm Qa$$

where Q_n = total net heat exchange, Q_r = heat flux due to net radiation, Q_e = heat flux due to evaporation and condensation, Q_h = heat flux due to sensible transfer between air and water, Q_{hb} = heat flux due to bed conduction, Q_{fc} = heat flux due to friction, and Q_a = heat flux due to advective transfer in precipitation, groundwater, tributary inflows, streamflow and effluent discharge. This equation represents the amount of energy available to modify the water temperature of a stream or river. The thermal capacity of a watercourse depends on the volume of water present, with heat storage capacity increasing and sensitivity to alterations in energy budget decreasing as the water volume increases (Webb 1996).

Solar radiation is generally thought to be the dominant component of the total energy flux. Net radiation (comprising solar radiation and net longwave radiation) was found to account for 56% of the total heat gain and 49% of the total heat loss for rivers in the Exe Basin, Devon (Webb and Zhang 1997). Similarly, radiative fluxes were found to account for 85% of the total energy input and 27% of the total energy losses to two Dorset chalk watercourses, the Piddle and Bere (Webb and Zhang 1999).

Heat flux at the streambed is largely a function of geothermal heating (derived from the internal heat of the earth) through conduction and advective heat transfer from groundwater and hyporheic exchange. The majority of the total energy exchange within a river is thought to occur at the air/water interface, with a much smaller proportion occurring at the streambed/water interface (Sinokrot and Stefan 1994, Evans *et al.* 1998). Evans *et al.* (1998) found that more than 82% of total energy transfers in the River Blithe, Staffordshire, occurred at the air/water interface whereas only 15% occurred at the channel bed. However, heat exchange at the streambed/water interface has not been extensively studied, and there is uncertainty surrounding the relative importance of these processes (Caissie 2006).

Natural and anthropogenic modifications to the river heat budget can result in changes to the thermal regime. The more common types of modification (predominantly anthropogenic) are as follows:

1. **Land use changes**. Changes in vegetation cover and land management techniques may affect hydrology and water quality and therefore potentially the water temperature of rivers and lakes. These include land drainage, agricultural soil erosion, forestry (considered separately below) and urban development (Robinson *et al.* 2000).

2. **Forestry/removal of cover**. The removal of riparian tree cover will generally result in an increase in river water temperature due to an increase in the amount of shortwave solar radiation reaching the river channel (Sinokrot and Stefan 1993). A study of the effects of afforestation on stream temperatures in southwest Scotland suggests that shading of incoming solar radiation has a strong effect on the water temperature behaviour of a forested stream (Webb and Crisp 2006). With the use of modelling, Bartholow (2000) found a net effect from clearcutting of a 4°C warming, with changes in stream shading being the largest influence on maximum daily water temperature. Over a 30-year period between 1955 and 1984, Beschta and Taylor (1988) found that average daily maximum and minimum stream temperatures have increased by 6 and 2°C, respectively.

3. **Flow and abstraction**. The effect of river flow on water temperature is dependent on channel shape and the surface area of the water. If the surface area remains similar but the flow is reduced, water temperature will increase during hot and sunny weather (Solomon 2005). Similarly, abstraction might alter the volume and/or velocity of water flowing in the channel and cause changes in water temperature by the same mechanisms (Webb 1996). However, the effect of abstraction will vary according to the river type; for example, groundwater abstractions in the upper catchment are likely to have the greatest impact on water temperature in groundwater-fed chalk streams (Solomon 2005).

4. **Flow regulation**. River regulation by upstream dams and reservoirs directly impacts the downstream water temperature regime. If the flow regime of the river is also altered on a daily basis, this might influence water temperature as a result of higher or lower flows (Webb 1996). Webb and Walling (1997) analysed 14 years of water temperature data below a reservoir in southwest England, and concluded that the main effects of regulation were to increase mean water temperature, depress summer maximum values, eliminate freezing conditions, delay the annual cycle and reduce daily fluctuation. However, these effects might vary, with a decrease in water temperature occurring if water is released from deep in the reservoir where it is coldest. Channelisation and other types of flow regulation might also have significant impacts on thermal capacity. For example, augmentation of flows by cold groundwater can bring about a reduction in river water temperature (Cowx 2000).

5. **Heated effluents**. A significant volume of heated effluent is returned to rivers following abstraction for cooling purposes during electrical power generation (Webb 1996) and other industrial processes. The quantity and spatial distribution of thermal effluents have changed significantly in recent years and need to be accounted for when interpreting temperature records. Thermal discharges will have a greater effect on water temperature when river discharge is low (Solomon 2005) and can increase river temperature by

several degrees, often affecting oxidation rates and the solubility of gases (Alabaster and Lloyd 1980).

6. **Climate change**. Water temperature is known to respond to air temperature, with a strong linear correlation between the two at temperatures greater than 0°C (Crisp and Howson 1982, Stefan and Preud'homme 1993, Mohseni and Stefan 1999, Erickson and Stefan 2000). Air temperatures are predicted to increase over the coming years as a result of global warming, and this is likely to result in a corresponding increase in water temperature. For example, analysis of a 30-year record of water temperature from Scotland suggested that mean daily maximum temperatures in winter and spring have increased with time as a result of changes in climate (Langan *et al.* 2001), and Webb and Nobilis (2007) found a significant increase (0.8°C) in monthly mean river water temperatures in Austrian rivers over the twentieth century, and particularly since 1970. The pattern of the North Atlantic Oscillation (NAO) is also known to influence the climate, and Webb and Nobilis (2007) found that both water and especially air temperatures in Austria showed statistically significant correlations with the NAO index. It should be noted that in comparison with the previous 130 years, the positive phase of the NAO seen during the 1990s was unprecedented and it is suggested that external forcing of the climate (e.g. solar irradiation, stratospheric ozone levels) may be responsible (Osborn 2004). Changes in water temperature as a result of climatic warming have been projected using various modelling techniques. These are described in Section 1.2.3 below.

1.2.3 Water temperature models

Water temperature can be modelled using a variety of techniques. These can be classified into three groups: regression modelling, stochastic modelling and deterministic modelling (Caissie 2006). These range in complexity from simple regression models to elaborate deterministic approaches that take into account all relevant heat fluxes at the water surface and at the sediment/water interface (Caissie *et al.* 2005).

Estimation of stream temperature from air temperature by linear regression is a popular method because only one input variable (air temperature) is required. Water temperature has been successfully predicted with simple linear regression models using weekly or monthly air temperature as the input parameter (Mackey and Berrie 1991, Stefan and Preud'homme 1993, Webb and Nobilis 1997). For example, Crisp and Howson (1982) developed a water temperature model based on a 5-day and 7-day mean water temperature that explained 86–96% of the variability in water temperature. However, Morrill *et al.* (2005) evaluated the relationship between air temperature and stream temperature for a geographically diverse set of streams and found that very few streams showed a linear air–water temperature relationship. A nonlinear model produced a better fit than a simple linear model for most of these streams.

The time lag between a change in air temperature and a corresponding change in water temperature ranges from 4 hours for shallow rivers (less than 1 metre deep) to 7 days for deeper rivers (~ 5 metres deep) (Stefan and Preud'homme 1993). These authors showed that incorporating a time lag into the regression analysis improved the estimation of daily water temperatures from air temperatures. Investigation of the air–water temperature relationship in the Exe Basin, Devon, also found that the power of a simple regression model based on hourly data was improved by the incorporation of a lag (Webb *et al.* 2003). Multiple regression models can be used to incorporate other explanatory variables, such as time lag data, river discharge, depth of water etc, into the model (Caissie 2006).

Both stochastic and deterministic models have been used to model water temperature for daily time steps and have similar modelling performances. Stochastic models often involve the separation of the water temperature time series into the long-term annual component and the short-term component and can provide good predictions of daily water temperature (Caissie *et al.* 1998, 2001). Deterministic models aim to quantify the total energy flux of the river and then fit the total energy flux to observed changes in water temperature. They are therefore often applied to complex problems such as the impact of thermal effluent discharges on the temperature of receiving waters. However, deterministic models are more complicated than stochastic models, requiring input of all relevant meteorological data in addition to air temperature (Caissie 2006).

Different time-scales will result in different air–water temperature relationships, as will differences in stream type, such as groundwater-dominated versus non-groundwater-dominated streams (Caissie 2006). For example, the thermal regime of chalk streams is different from that of other rivers due to the stabilising influence of groundwater discharge. A study of four English chalk streams with a large groundwater component confirmed these differences and concluded that, while air temperature is a good indicator of the thermal regime of a river, groundwater-dominated streams such as chalk streams should be considered separately from other stream types (Mackey and Berrie 1991). This study also suggested that chalk streams are less likely to be affected by climatic changes than other types of river and is in agreement with previous predictions of stream water temperature on a chalk stream, the Lambourn, and the Water of Leith (Smith 1981).

Several authors have looked at the potential for using air temperature to predict stream temperatures under a global warming scenario. Mohseni and Stefan (1999) examined the validity of using linear extrapolation to project stream temperatures under a warmer climate. At moderate air temperatures of between 0 and 20°C, the air–water temperature relationship was found to be linear. However, at low air temperatures this relationship is flat and at high air temperatures it has a moderate slope with a tendency towards levelling off. The overall relationship between stream temperature and air temperature therefore resembles an S-shaped function. The study concluded that linear regression models will not accurately predict stream temperatures at high air temperatures and are therefore not suitable for projecting the effects of warming due to climate change.

A four-parameter nonlinear function of weekly air temperatures was used by Mohseni *et al.* (1999) to project changes in mean weekly stream temperatures in response to global warming. Weekly air temperature data from 166 weather stations were incremented by the output of the Canadian Center of Climate Modelling (CCC) general circulation model (GCM) and applied to nonlinear stream temperature models developed for 803 gauging stations. Mean annual stream temperatures in the USA were predicted to rise by 2–5°C at 764 of these gauging stations, with no significant changes being seen at the remaining 39. Similarly, temperatures in Minnesota are projected by the CCC GCM to rise by 4.3°C during the summer season, translating to an average rise of 4.1°C in stream temperature (Pilgrim *et al.* 1998).

Good air temperature records are more readily available than good water temperature records, and have therefore frequently been used to predict river water temperatures. However, there are complications with this method as discussed, particularly associated with the projection of water temperature increases under a climate change scenario. It is difficult for any model to accurately simulate events outside the range of the calibration set, such as the extreme temperatures expected under a climate change scenario. Therefore, while the air–water temperature relationship may be useful for infilling gaps in a water temperature record, actual measured water temperature records are preferable for monitoring and estimating climate change and are required to evaluate the impact of climate change effectively.

1.2.4 Lakes and climate change

Deep lakes are considered to be good indicators of climate change (Dokulil *et al.* 2006) based on long-term changes in ice cover, surface temperature and mixing regimes (Salmaso *et al.* 2003, Johnson and Stefan 2006). For example, Magnuson *et al.* (2000) found consistent evidence of later freezing (5.8 days per 100 years later) and earlier thaw (6.5 days per 100 years earlier) of ice on lakes and rivers in the Northern Hemisphere from 1846 to 1995. The appearance of ice on Lake Windermere is used by Defra as a climate change indicator, and in recent years high values of the NAO index have resulted in mild winters and few days with ice cover on the lake. However, it is not yet known whether or not this is an aberration or the beginning of a new trend.

Livingstone (2003) identified strong climate-related mean water temperature increases in monthly temperature profiles from Lake Zurich, Switzerland, over a 52-year period. A 20% increase in thermal stability and a 2–3-week extension in the stratification period of this lake have resulted from the high rates of warming seen between the 1950s and 1990s. Similarly, Carvalho and Kirika (2003) observed an increase in annual mean temperature in Loch Leven of approximately 1°C over a 34-year period, with greater increases occurring during winter and spring periods.

Changes in climate variables such as precipitation, wind speed, solar radiation and air temperature as a result of global climate change will have a direct influence on lake water quality, potentially resulting in changes to lake water quality (Hassan *et al.* 1998b). This effect may vary in magnitude depending on the physical character of the lake in question; for example, modelling has shown that in eutrophic lakes with long water residence times, high phosphorus concentrations and therefore high phytoplankton production may become a problem under a climate warming scenario (Malmaeus *et al.* 2006). Statistical analysis of the relationship between meteorological conditions and lake water quality over a 17-year period showed that water quality indicators such as increased chemical oxygen demand and decreased transparency corresponded to an increase in air temperature (Fukushima *et al.* 2000). Changes in air/lake water temperature and temperature stratification dynamics can therefore have a significant impact on biological and chemical processes within lakes.

The effects of global warming on lake and reservoir ecosystems have been simulated using a combined water temperature–ecological model (Hosomi *et al.* 1996). This model was applied to Lake Yunoko, Japan, and changes in the water temperature and quality were simulated in response to a 2–4°C rise in air temperature. The results indicate that in response to this air temperature increase, nutrient concentrations in the bottom water will increase, phytoplankton will increase in concentration at the beginning of autumn, and phytoplankton species composition will change. Lake water temperature has also been successfully simulated by several others (Hondzo and Stefan 1993, Rasmussen *et al.* 1995, Antonopoulos and Gianniou 2003, Fang *et al.* 2004).

Fluctuations in the NAO have a strong influence on lakes in North America and Europe (George *et al.* 2004, Dokulil *et al.* 2006, Webb and Nobilis 2007). Temperatures in the hypolimnion (the bottom waters of a thermally stratified lake) of 12 deep European lakes were observed to rise in all lakes by approximately 0.1–0.2°C per decade and were predicted most consistently by the mean NAO index for January to May (Dokulil *et al.* 2006). This temperature rise affects mixing conditions, thermal stability and oxygen concentrations within the lake. In agreement with this, George *et al.* (2004) found that air temperature and lake surface and bottom temperatures of four English Lake District lakes showed a strong positive correlation with the NAO index and also influenced winter nitrate concentrations and phytoplankton growth. This effect was particularly pronounced in smaller or shallower lakes. Again, it is difficult to distinguish whether or not the recent sequence of warm years is the beginning of a new trend or simply part of a natural cycle, but the influence on water temperatures can be significant.

2 Methods

2.1 Data collection

The first and most critical stage of the project involved the identification and acquisition of relevant freshwater temperature datasets. Potential sources were identified to be data already collected and held by the Environment Agency, or data available from external organisations such as water companies and universities. Datasets from both rivers and lakes were requested. To facilitate the process, a Data Request Form was devised and sent to all contacts with the initial data request, as reproduced in Appendix A. This asked for detailed information on the datasets held, enabling an informed decision to be made regarding suitability for inclusion in the analysis.

2.1.1 Environment Agency datasets

The Environment Agency project team acted as the main source of internal contacts for temperature data already held within the Environment Agency. Regional contacts were approached in the first instance, and the request passed on to others as appropriate. The largest single source of data was the Environment Agency's Water Information Management System (WIMS) database, which holds thousands of records for each of the eight Environment Agency regions. All freshwater temperature records from this database were passed to Entec in the form of an Access database containing tables of regional data, which was queried in order to summarise sites by length of record, sampling frequency and waterbody type (river or lake).

In addition, individual temperature records held within the Environment Agency outside WIMS (regional monitoring, the Water Information Management System Kisters (WISKI) database etc) were also listed and sourced where appropriate. Many of these had not been quality assured and therefore required a significant amount of checking before they could be used. These datasets ranged in size from single records to quite large databases containing records for many sites, such as the Tideway Information Management System (TIMS) received from the Thames Region. Regional summaries listing all water temperature data sources identified during this project can be seen in Appendix B.

2.1.2 External datasets

External sources of water temperature data were identified using Entec and Environment Agency knowledge and were contacted by Entec with a request to complete the Data Request Form. Organisations contacted included the Centre for Ecology and Hydrology (CEH), the Countryside Council for Wales (CCW), the Freshwater Biological Association (FBA), the Natural Environment Research Council (NERC) Environmental Change Network (ECN), the major water companies (Anglian Water, Thames Water, Southern Water etc), and several universities. Cost was an important consideration when considering data held by external organisations, as many will not release data without a charge. Every effort was therefore made to record the quality of datasets that were not freely available, so that their value could be accurately assessed. All known available datasets and associated costs have been recorded as part of the project output and are listed in the regional summary tables in Appendix B.

It should be noted that there are a number of 'Lake Dynamics Monitoring Stations' (LDMSs) located in the Wales and North West Regions. CEH had funding to build buoys and develop the technology to monitor water chemistry and temperature in lakes. However, the funding to deploy, run and co-ordinate the results from them, has not yet been made available. Currently a number of different universities are collecting data from the buoys, but the co-ordination of the results has yet to occur.

2.1.3 Air temperature data

The cost of sourcing Met Office air temperature data to cover all regions was investigated. Air temperature data could potentially be used to hindcast river water temperatures to infill gaps in a temperature record, or to extend a record further back in time than the first recorded measurement. Air temperatures have also been used to predict future water temperatures in cases where air temperature data are more readily available than water temperature data.

2.2 Data processing

2.2.1 Assessing dataset quality

All WIMS river and lake records were extracted from the Access database to produce a full list of sites for each Environment Agency region including site name, grid reference, first and last sampling date, and the number of samples taken during this period. The first and last sampling dates were converted to a sampling duration (in days), which was then used to sort the records by length. This information was used to calculate an average sampling frequency by dividing the sampling duration (in days) by the total count of samples taken for that record. This calculated frequency was an average value and might also include sampling frequencies significantly higher or lower than the average, as well as gaps in the time series. However, it represented a fast and reasonably accurate method with which to reduce the number of records under consideration. Generally, any site with a sampling frequency of greater than 15 days (a fortnight) was deleted, although for regions in which the number of sites with high frequency sampling was limited (e.g. Wales) some sampling frequencies that would otherwise have been rejected were retained.

For individual records not in the WIMS database, a preliminary decision on their value was made on the basis of information given on sampling frequency and record length and completeness as stated by the respondent on the Data Request Form. All suitable records that were freely available were obtained in full, and taken to the next stage of assessment with the retained WIMS records (Section 2.2.2).

2.2.2 Assessing individual records

All records remaining after this processing were extracted in full from the WIMS database or obtained from the data owner and subjected to further analysis. Some quality assurance procedures were carried out at this stage, with outlying temperature values being removed from the time series and sites with any known artificial influences (e.g. discharges, water transfers) being excluded. However, it was not within the remit of this project to undertake detailed quality assurance. In addition, it should be noted that the rivers and sites included in the analysis will be subject to many artificial influences that could affect water temperature (e.g. discharges, water transfer schemes, regulation releases). Regional knowledge is required to identify sites that are subject to such influences.

A scoring system was applied to each record to generate a final number for comparison with other records. Each temperature measurement was given a score based on the time that had elapsed since the previous measurement, as follows:

1. a gap of 8 days or less between samples scored 10;

2. a gap of 9 to 17 days scored 8;
3. a gap of 18 to 39 days scored 6;
4. a gap of 40 to 59 days scored 2;
5. a gap of greater than 60 days scored 0.

The total score for the record was then summed to give a final score that reflected the length and completeness of the record as well as the sampling frequency. Table 2.1 shows an example of this scoring system from a site in the Anglian Region.

The final output of this process for each of the eight regions was a list of river sites and a list of lake sites, giving a total of 16 tables. These tables contained the sites short-listed in Section 2.2.1 and for each site included the river WFD typology, details of first and last sampling dates, missing data, the score as generated above, and a weighted score generated by dividing this score by the number of months of temperature data available for the site. This information was used to select sites to be included in the analysis as described below (Section 2.3).

Table 2.1 Water temperature record scoring system

Sample name	Sample date	Sample time	Temperature	Days to next sample	Score
R.Can Beaches Mill	21-Jan-04	0945	7.80	26	6
R.Can Beaches Mill	16-Feb-04	1135	7.16	30	6
R.Can Beaches Mill	17-Mar-04	1210	12.60	34	6
R.Can Beaches Mill	20-Apr-04	1135	9.47	42	2
R.Can Beaches Mill	01-Jun-04	1035	15.18	6	10
R.Can Beaches Mill	07-Jun-04	1100	17.84	30	6
R.Can Beaches Mill	07-Jul-04	1130	16.24	30	6
R.Can Beaches Mill	06-Aug-04	1155	20.15	45	2
R.Can Beaches Mill	20-Sep-04	1210	14.54	28	6
R.Can Beaches Mill	18-Oct-04	1120	10.55	22	6
R.Can Beaches Mill	09-Nov-04	1135	10.67	30	6
R.Can Beaches Mill	09-Dec-04	1105	7.40	49	2
R.Can Beaches Mill	27-Jan-05	1450	4.60	42	2
R.Can Beaches Mill	10-Mar-05	1200	6.20	26	6
R.Can Beaches Mill	05-Apr-05	0955	9.20	41	2

Sample name	Sample date	Sample time	Temperature	Days to next sample	Score
R.Can Beaches Mill	16-May-05	1205	12.75	24	6
R.Can Beaches Mill	09-Jun-05	1140	14.54	28	6
R.Can Beaches Mill	07-Jul-05	1105	5.58	33	6
R.Can Beaches Mill	09-Aug-05	1140	15.22	28	6
R.Can Beaches Mill	06-Sep-05	1134	18.27	17	8
R.Can Beaches Mill	23-Sep-05	1147	14.33	25	6
R.Can Beaches Mill	18-Oct-05	1158	12.61	24	6
R.Can Beaches Mill	11-Nov-05	1156	11.41	18	6
R.Can Beaches Mill	29-Nov-05	1254	4.35		Total 124

2.2.3 Location maps and typologies

All sites that made it through the initial selection process described in Section 2.2.1 were imported onto a GIS map, with separate maps being produced for each region. A WFD river typology was assigned to each of the mapped sites for use in the selection of river types for analysis (Section 2.3.2). Table 2.2 provides a full description of the WFD river typology (Defra 2005). This table was derived from the Water Framework Directive (WFD) ArcView GIS shapefile provided by the Environment Agency. It should be noted that there are no upland rivers (i.e. those > 800 m high) in this dataset.

Table 2.2 WFD river typology where temperature data available (from Environment Agency river typology)

Catchment altitude	Catchment geology	Catchment size	Type
Low	Si	S	1
Low	Ca	S	2
Low	Or	S	3
Low	Si	M	4
Low	Ca	M	5
Low	Or	M	6
Low	Si	L	7
Low	Ca	L	8
Mid	Si	S	10
Mid	Ca	S	11
Mid	Or	S	12
Mid	Si	M	13
Mid	Ca	M	14
Mid	Or	M	15
Mid	Si	L	16
Mid	Ca	L	17
Low	Sa	S	28
Low	Si	XS	37
Mid	Si	XS	38
Low	Ca	XS	40
Low	Or	XS	43

Altitude: Low < 200 m, Mid 200–800 m, High > 800 m (not represented in this dataset); **Geology**: Si siliceous, Ca calcareous, Or organic, Sa salt; **Size**: XS < 10 km^2, S 10–100 km^2, M 100–1000 km^2, L 1000–10,000 km^2

2.3 Site selection

2.3.1 Selection of main rivers

Within each region, one main river was chosen as the focus of the analysis. Within Anglian Region, the Ouse was included in addition to the Stour, so that the pattern of temperature change within a river subject to flow modification could be explored. The rivers to be used were chosen with reference to the list of sites and scores previously created, with the aim of selecting the river within each region with the highest possible number of long-term temperature records. If daily data from a main river had been collected, wherever possible this was the river selected for the main river analysis. Following selection, the original database was revisited in order to gather all the additional temperature records for each river. Only sites at which temperature monitoring is still ongoing were included in the analysis.

The main rivers selected for each region are shown in Table 2.3. Figures 2.1 to 2.8 show the locations of all the sites analysed in each region.

Table 2.3 Main rivers selected by region

Region	River	Types included*
Anglian	Stour and Ouse	2, 5, 8
Midlands	Severn	7, 8, 10, 13
North East	Lower Tyne and Tyne	2, 11, 14
North West	Ribble	11, 14, 17
Southern	Test	5, 8
South West	Tamar	1, 4
Thames	Thames	5, 8
Wales	Dee	13, 17

* Refer to Table 2.2 for a description of typologies

2.3.2 Selection of river types

As far as possible, two examples of each river type present in each region were included in the analysis. Again, these were selected using the list of sites and scores, so that for each river type the longest and most frequently monitored sites were used. Therefore, it was not always possible to include all types in the analysis due to lack of suitable temperature datasets. Table 2.4 shows the river types selected and analysed within each region, and Figures 2.1 to 2.8 show the site locations.

Table 2.4 River types analysed within regions

Region	Types analysed*	Rivers included
Anglian	1, 2, 3, 5, 6, 8, 40	Stour, Ouse, Hundred Foot, Thurne, Whittlesey Dyke, Bevills Leam, Blackwater, Chelmer, Forty Foot, Nene, Ramsey, Spickets
Midlands	1, 2, 4, 5, 7, 8,10, 11, 13, 14, 17, 40	Strine, Rea Brook, Erewash, Camlad, Trent, Idle, Soar, Afon Clywedog, Severn, Wye, Morda, Derwent, Churnet, Dove, Marton Drain, Dimore Brook
North East	1, 2, 4, 5, 8, 10, 11, 12, 13, 14, 17	Coquet, Oak Beck, Doe Lea, Dove, Blyth, Wansbeck, Hull, Dearne, Ouse, Aire, Holme, Little Don, Don, Dibb, Lewisburn, Wharfe, Calder, Tees
North West	1, 2, 4, 5, 8, 10, 11, 12, 13, 14, 15, 16, 17, 28	Roe, Ive, Irk, Yarrow, Wyre, Darwen, Irwell, Alt, Mersey, Weaver, Esk, Ogden, Chew Brook, Etherow, Leven, Calder, Ribble, Lune, Petteril, Rookery Brook
Southern	1, 2, 4, 5, 8, 37, 40	Wallers Haven, Arun, Rother, Ouse,

Region	Types analysed*	Rivers included
		Uck, Lymington, Cuckmere, Blackwater, Test, Botley Stream, Broad Rife, Chichester Canal
South West	1, 2, 4, 5, 7, 8, 10, 11, 13	Carnon, Wolf, Brit, Tamar, Lyd, Axe, Exe, Alphin Brook, Avon, Erme, Walkham, Culm, Tavy, Plym
Thames	1, 2, 4, 5, 8, 11, 40	Boveney Ditch, Thames, Blackwater, Hogsmill, Cherwell, Wey, Lee, Colne, Eye, Churn, Beam
Wales	1, 2, 4, 5, 10, 11, 13, 14, 16, 17	Llan, Gwenfro, Clywedog, Rhymney, Cleddau, Loughor, Ely, Afan, Seiont, Afon Llwyd, Tawe, Ogmore, Alyn, Neath, Tywi, Gwili, Dee, Wye

* Refer to Table 2.2 for a description of typologies

For the analysis of river types between regions, only types found in more than one of the eight regions could be included in the analysis. These types are shown in Table 2.5, and the site locations can be seen in Figures 2.1 to 2.8.

Table 2.5 River types analysed between regions

River type	Regions analysed*
1	A, M, NE, NW, S, SW, T, W
2	A, M, NE, NW, S, SW, T, W
4	M, NE, NW, S, SW, T, W
5	A, M, NE, NW, S, SW, T, W
8	A, M, NE, NW, S, SW, T
10	M, NE, NW, SW, W
11	M, NE, NW, SW, T, W
13	M, NE, NW, SW, W
14	M, NE, NW, W
17	M, NE, NW, W
40	A, M, S, T

* Regions are labelled as follows: A = Anglian; M = Midlands; NE = North East; NW = North West; S = Southern; SW = South West; T = Thames; W = Wales

2.3.3 Selection of daily data

Daily data were received for four regions: Midlands, North East, Thames and Wales. The rivers that were included in the daily analysis are shown in Table 2.6, and are mapped in Figures 2.1 to 2.8.

Table 2.6 Daily temperature records analysed

Region	Sites analysed	Types included
Midlands	Afon Clywedog, Severn, Teme, Vyrnwy	7, 8, 10, 13
North East	Humber, Ouse, Tyne	2, 5, 14, 17
Thames	Kennet, Lee, Loddon, Pymmes Brook, Thames, Wey	2, 4, 5, 8
Wales	Dee, Taff, Tywi, Wye	10, 13, 16, 17

The water temperature data for Thames, Wales and North East Regions was supplied as sub-daily data, whereas the Midlands Region data were supplied as daily mean values. An Excel macro was used to convert sub-daily data to a mean daily time series and to infill any missing days.

2.3.4 Selection of lake sites

Due to time constraints and lack of readily available lake temperature records, the statistical analysis was limited to river water temperature data only, as described in Section 2.4 below. A list of lake temperature records identified as part of the data collection exercise can be found in Appendix B.

2.4 Data analysis

Statistical analysis of the water temperature data was carried out using SPSS software. Although the Kolmogorov-Smirnov test for normality showed that the temperature data were not normally distributed, Analysis of Variance (ANOVA) was used based on the principle that ANOVA is robust to departures from normality, particularly when sample sizes are large (Stevens 1996, Gravetter and Wallnau 2000). Similarly, although Levene's test for homogeneity of variances showed variances to be unequal, it is considered that ANOVA is robust to the violation of this assumption when group sizes are approximately equal (e.g. largest/smallest = 1.5) (Stevens 1996). Group sizes were checked for all tests, and most were approximately equal. However, any single group within a test that was smaller than the others was considered to be unsuitable for analysis and excluded from the dataset. Similarly, where any single group was considerably larger than the others, temperature records were excluded on a site by site basis to reduce the dataset size and eliminate bias.

To further verify the results, the Kruskal-Wallis test was run on the same data. This is a non-parametric test that does not assume a normal distribution or equal variances. The results of all tests in terms of significance were the same, leading to the conclusion that in this case ANOVA was robust.

Taking the above into account, post hoc analysis using Tukey's Honestly Significant Difference test (HSD) was also carried out in order to identify any differences in water temperature between groups. Although this test carries the same assumptions as ANOVA, for the reasons stated above it was considered suitable to use for the purposes of this analysis.

2.4.1 Analysis of monthly data

All sites monitored less frequently than daily were included in this analysis (e.g. weekly, fortnightly and monthly). All temperature records to be analysed were converted to a time series of monthly mean values, and months during which no temperature had been recorded were infilled with a specified value (-9999) to produce a standardised monthly time series for statistical analysis using SPSS. It should be noted that records were not audited to take account of the time of day at which temperature measurements were taken. As river water temperature varies temporally on a daily cycle, the point in the cycle at which a measurement is taken may affect weekly and monthly temperature means calculated from the data.

The locations of the monthly temperature records analysed in each region are shown in Figures 2.1 to 2.8, and a full list of all the sites included in the analysis is given in Appendix C.

Six different analyses were carried out on the monthly data:

1. *Regional analysis.* This analysis aims to uncover regional differences in water temperature; for example, is river water temperature in Anglian Region different from river water temperature in Wales? Monthly temperature data from the main river in each of the eight regions were included in the analysis: Anglian, Midlands, North East, North West, Southern, South West, Thames and Wales.

2. *Type analysis within regions.* This analysis aims to uncover type-related differences in water temperature within each region; for example, is the temperature regime of a Thames Region Type 2 river different from a Thames Region Type 5 river? As far as possible, monthly temperature records from two of each river type within each region were included in this analysis.

3. *Type analysis between regions.* This analysis aims to uncover region-related differences in water temperature within types; for example, is the temperature regime of a Type 2 river in Thames Region different from the temperature regime of a Type 2 river in Wales? As far as possible, two monthly temperature records from each region were included in each analysis.

4. *Moving average analysis.* This analysis was designed to look at any trends in temperature over time for a number of sites on the same river. To achieve this, the main river sites selected for each of the regions were utilised. The monthly temperature data were plotted for all sites and moving average (12-month) trendlines were displayed for a number of selected sites on each river: one in the upper reach, one in the middle reach and one in the lower reach.

5. *Annual mean trend analysis.* Assessment of the mean annual trend in water temperature of the best site in each region. The best site was selected with regard to length and completeness of record and frequency of monitoring, as previously assessed by the scoring system in Section 2.2. The rate of annual mean river water temperature change (°C per decade) was also calculated for each selected site and compared with the rate of air temperature warming shown by the Hadley Centre Central England Temperature (HadCET) dataset (Parker *et al.* 1992).

6. *Seasonal analysis.* The monthly data were divided into seasonal data. Winter was represented by January–February–March temperatures, spring was represented by April-May-June, summer was represented by July–August–September and autumn by October–November–December. The three months of temperature data were then averaged to give a single figure for the season. The seasonal data were graphed and a 5-year moving average trendline plotted. In addition, the raw seasonal data were plotted for each of the main rivers in each region for an upper reach site and a lower reach site.

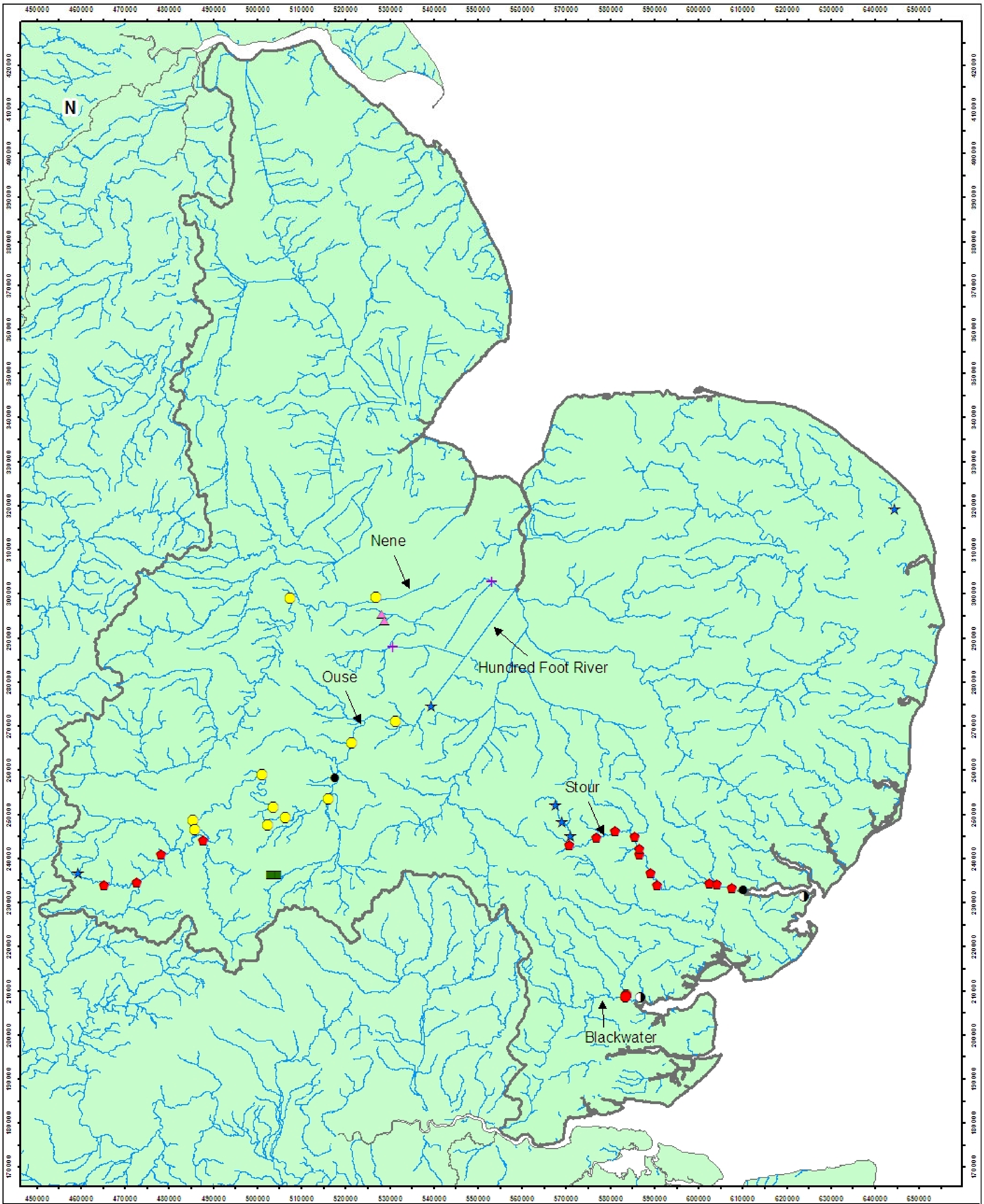
2.4.2 Analysis of daily data

All daily and sub-daily temperature records to be analysed were converted to a time series of daily mean values, and missing days were infilled with a specified value to enable recognition of null values during the statistical analysis. This produced a standardised daily time series for entry into the SPSS statistical software.

The daily temperature data were analysed for differences between regions. Daily data were only obtained for four regions: Midlands, North East, Thames and Wales. Therefore, there were not enough data available to allow for a meaningful comparison of types within or between regions. Figures 2.1 to 2.8 show the location of the daily temperature records analysed in each region, and a full list of all the sites included in the analysis for each region is given in Appendix C.

2.4.3 Infilling water temperature time series

The water temperature datasets in some regions such as Thames, North West and North East begin in the early 1970s, whereas the Midlands and Anglian monthly data do not start until the mid 1980s. Regression analysis was therefore trialled to ascertain whether or not temperature data from one region could be used to produce a historical time series for another region. Such techniques can have wide-ranging applications: for example, infilling and reconstruction techniques have previously been used to extend river flow records using rainfall data (Jones *et al.* 2006).



Key:

RIVER TYPE

● Unclassified
■ 1
★ 2
▲ 3
● 5
+ 6
○ 8
◑ 40

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Climate Change Impacts and Water Temperature

Figure 2.1
Location of temperature monitoring sites analysed in Anglian Region

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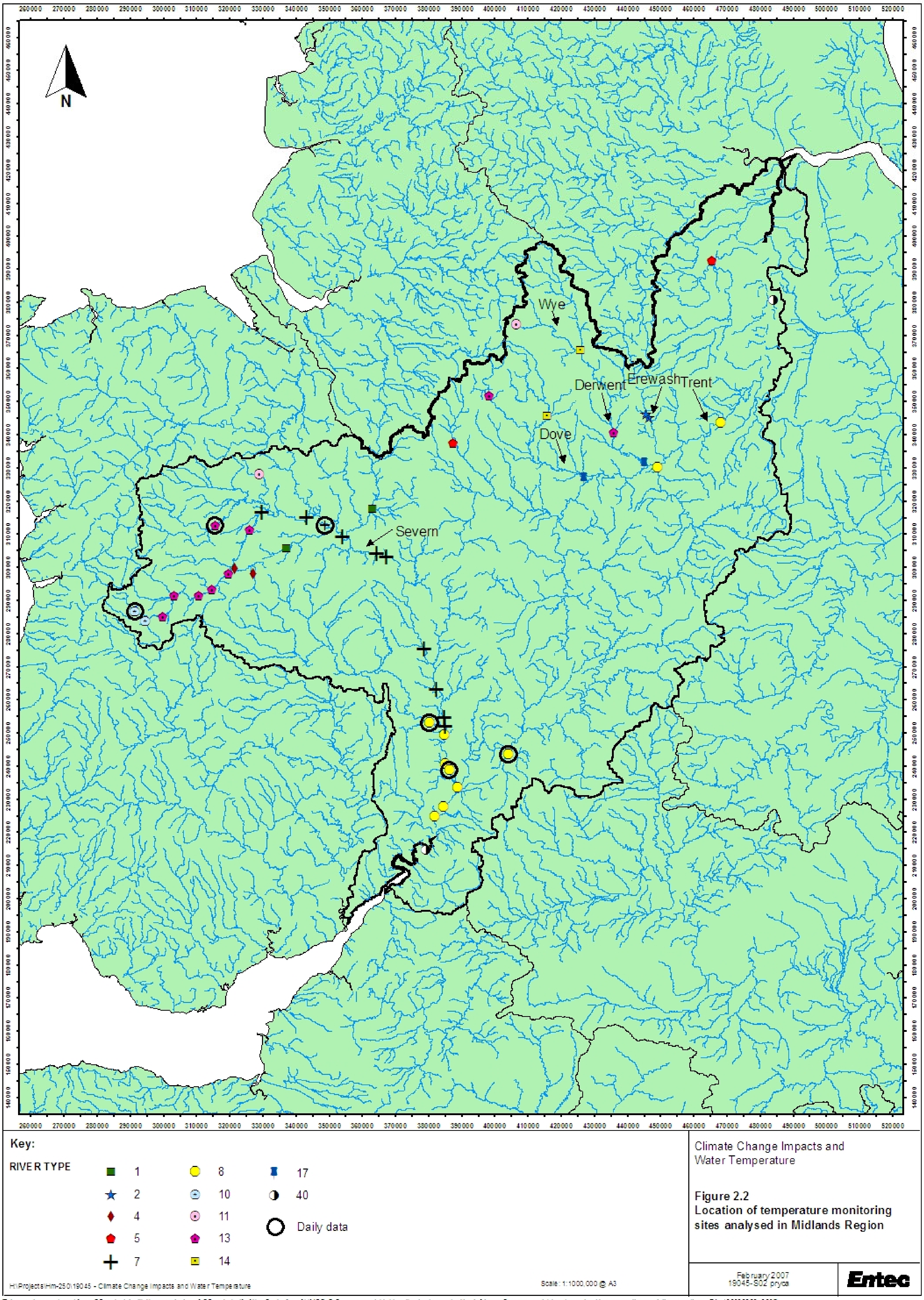
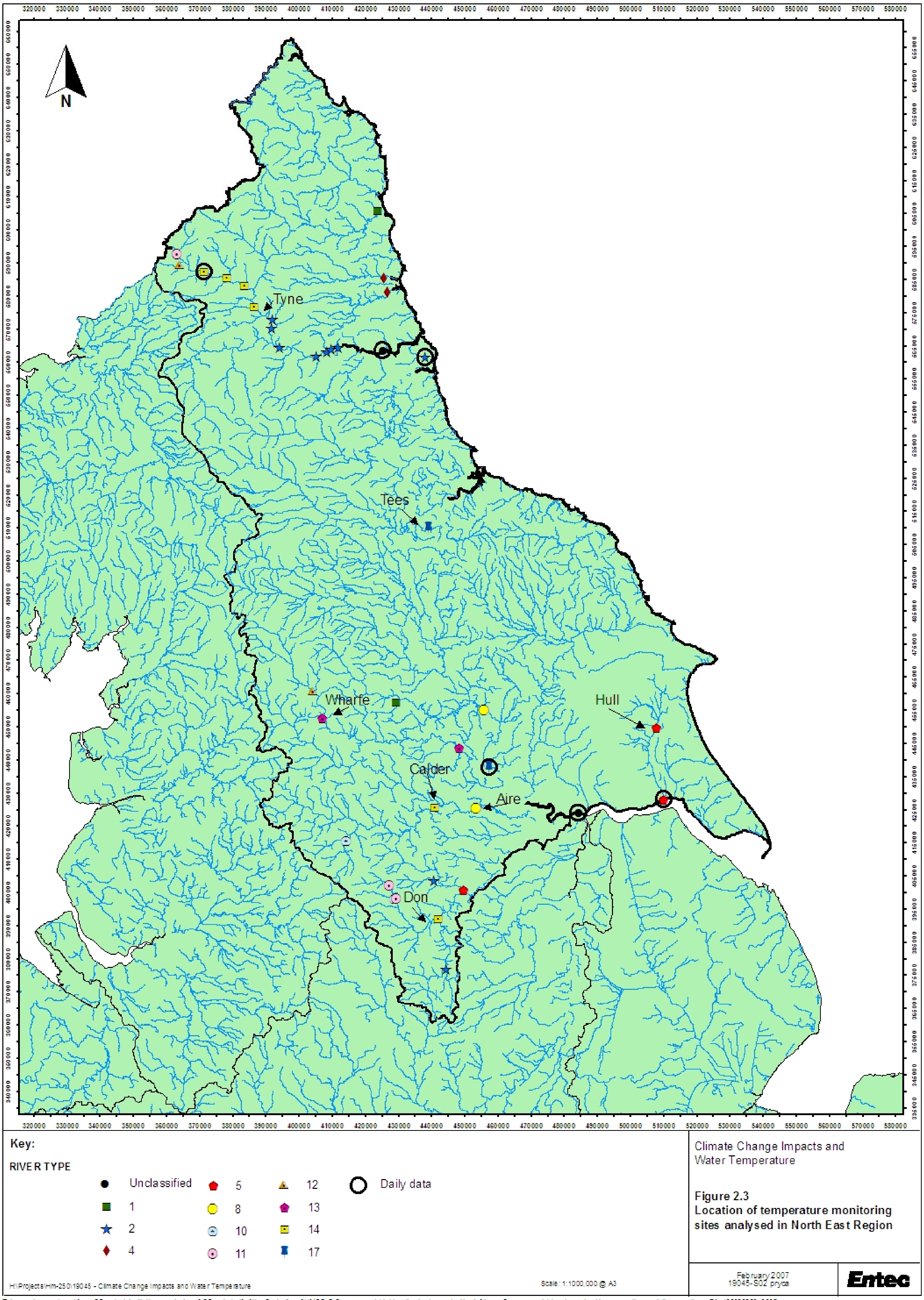


Figure 2.2
Location of temperature monitoring sites analysed in Midlands Region


N
Tyne
Tees
Wharfe
Hull
Calder
Aire
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Key:
RIVER TYPE
Unclassified
1
2
4
5
8
10
11
12
13
14
17
Daily data
Climate Change Impacts and Water Temperature
Figure 2.3
Location of temperature monitoring sites analysed in North East Region
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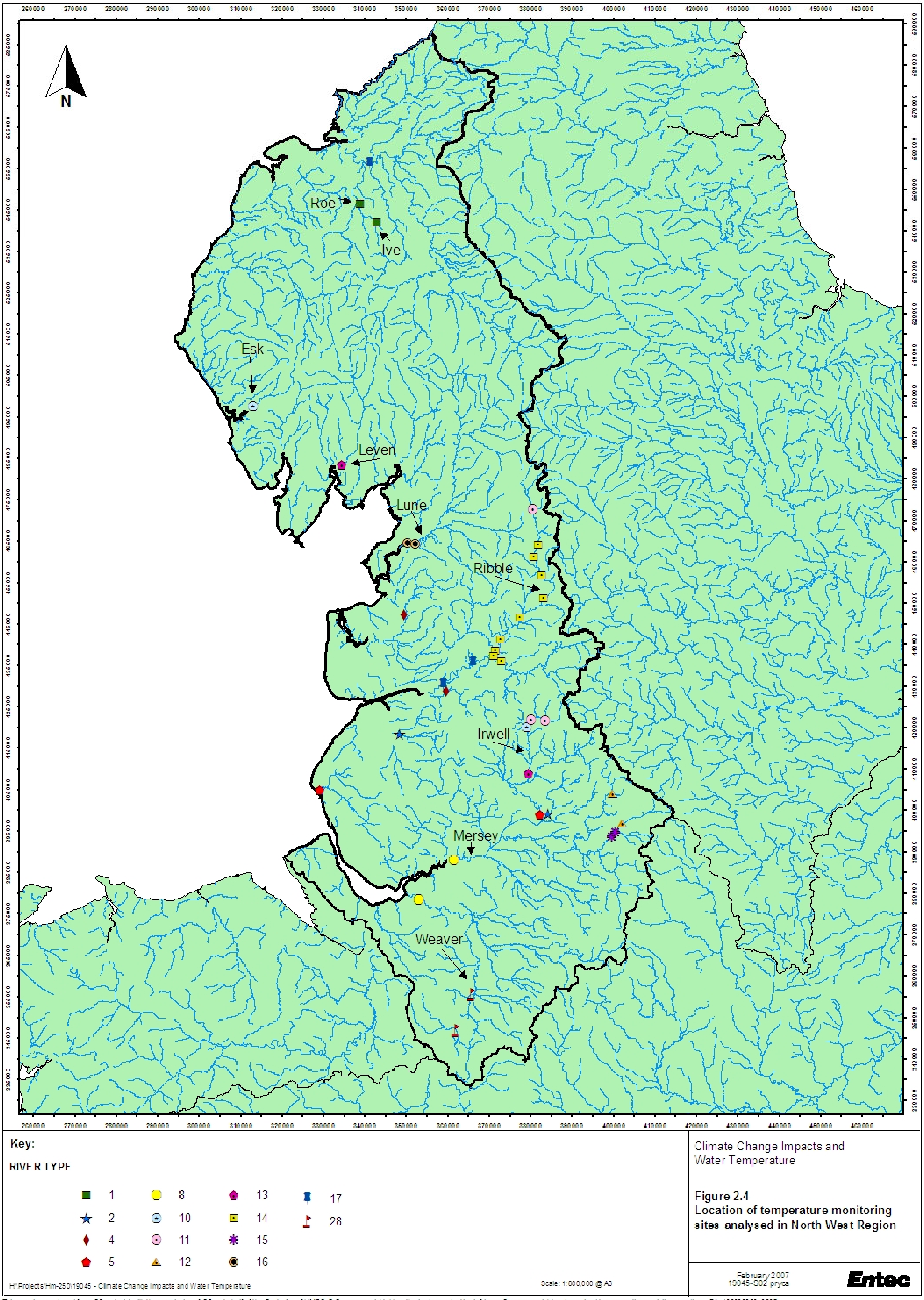
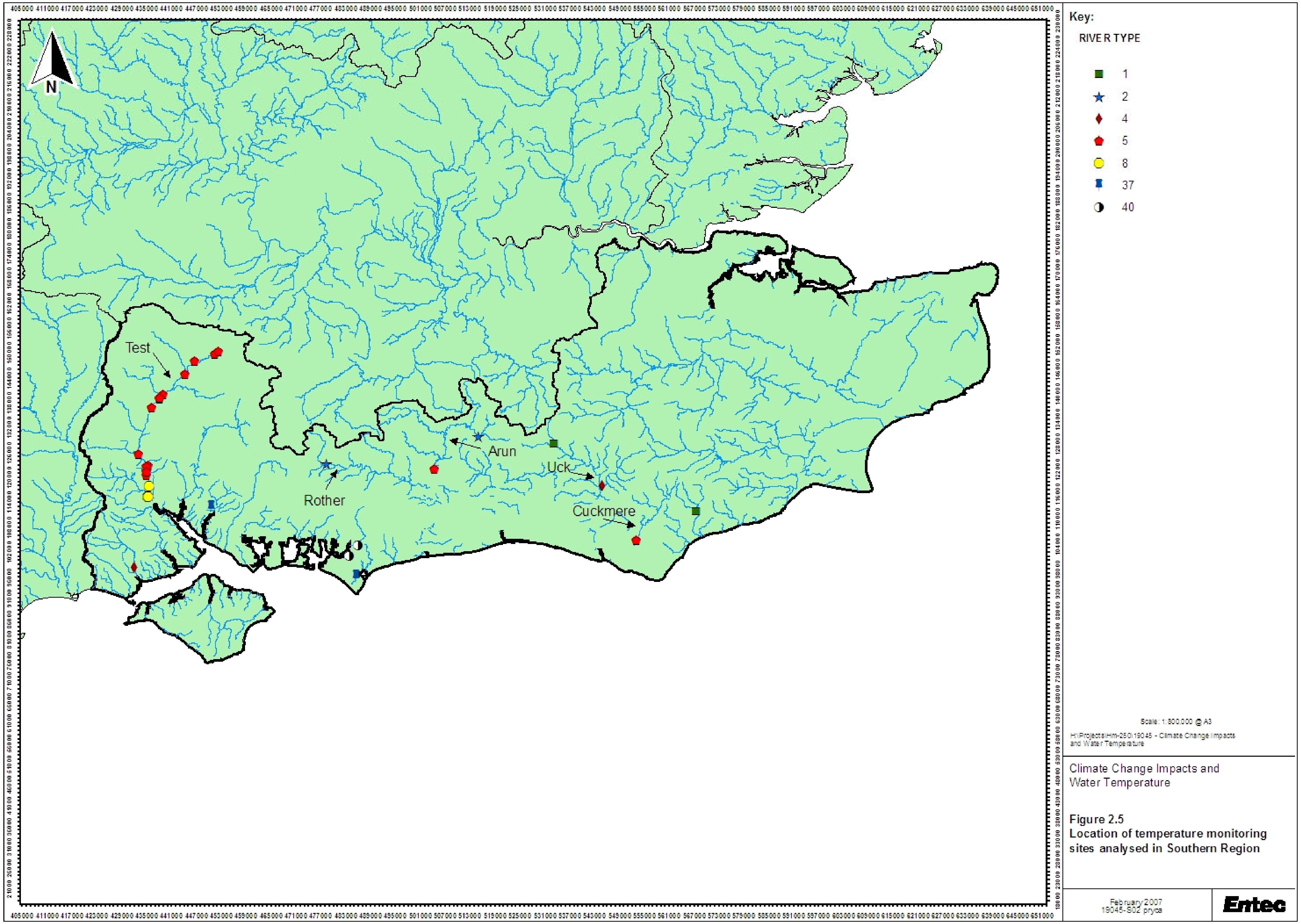


Figure 2.4
Location of temperature monitoring sites analysed in North West Region



Climate Change Impacts and Water Temperature

Figure 2.5
Location of temperature monitoring sites analysed in Southern Region

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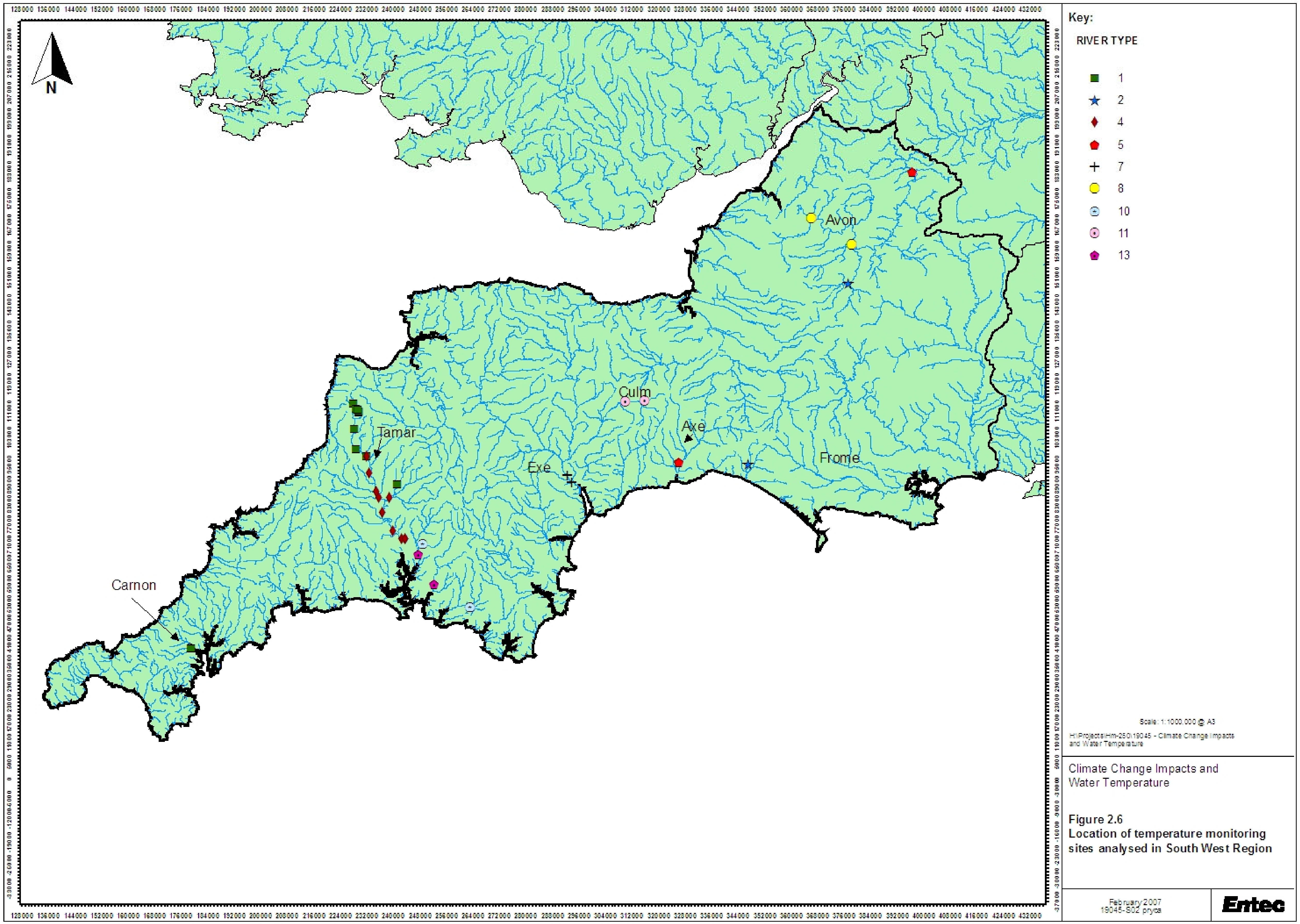


Figure 2.6
Location of temperature monitoring sites analysed in South West Region

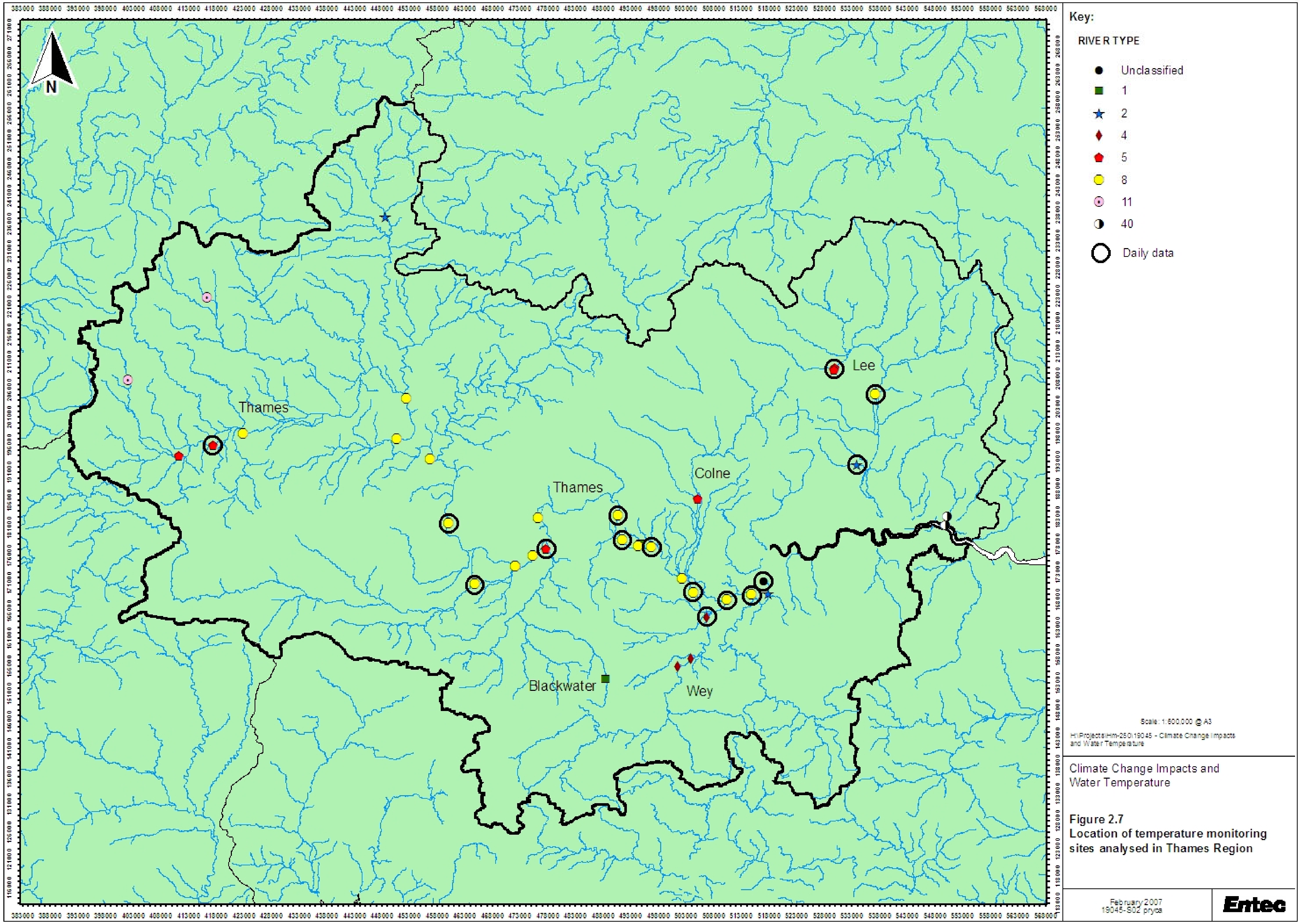
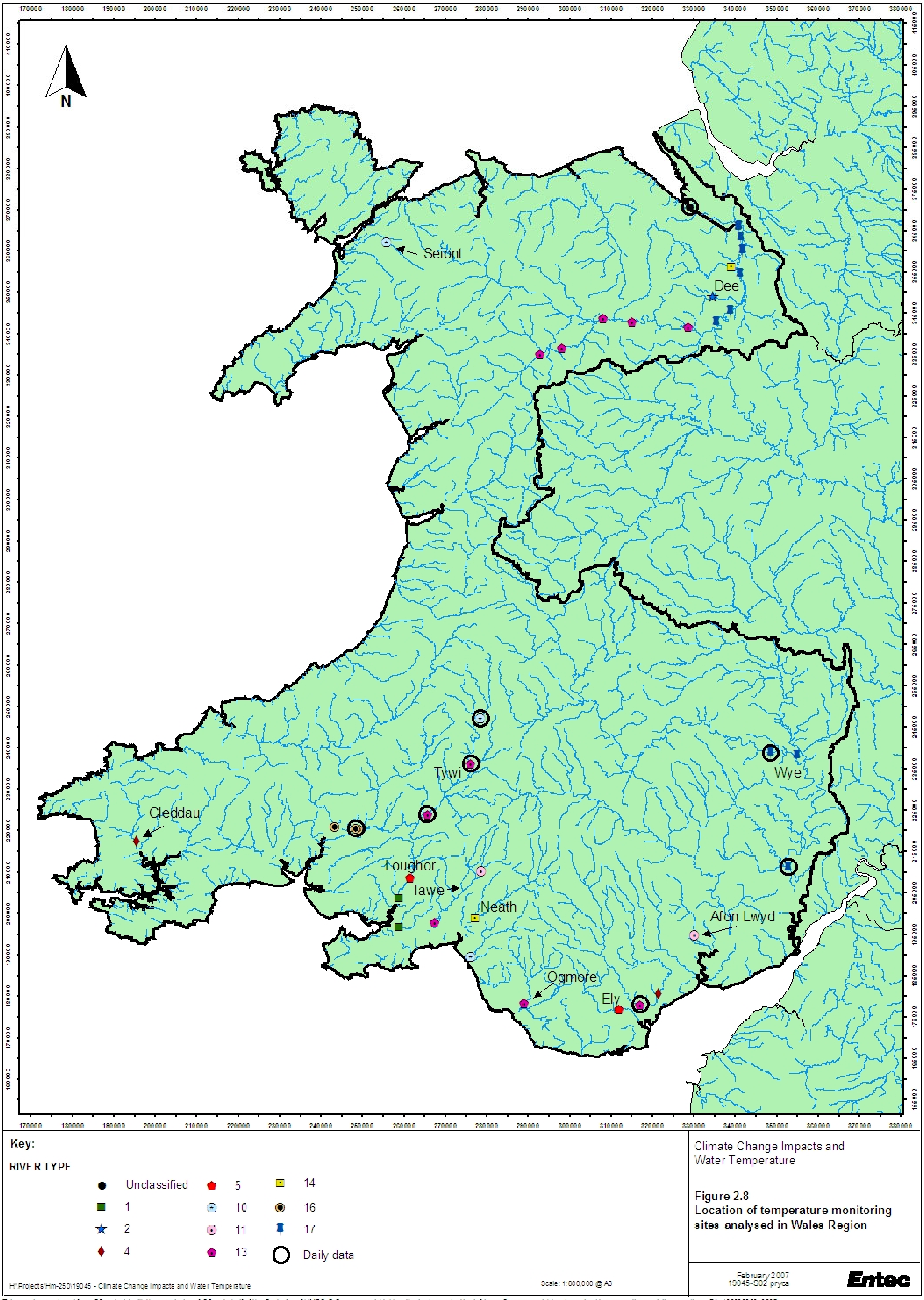


Figure 2.7
Location of temperature monitoring sites analysed in Thames Region



Climate Change Impacts and Water Temperature

Figure 2.8
Location of temperature monitoring sites analysed in Wales Region

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3 Results and observations

3.1 Analysis of monthly data

3.1.1 Regional analysis

Statistical analysis using both ANOVA and the nonparametric Kruskal-Wallis test revealed there to be significant differences in river water temperature between the eight regions ($p < 0.01$). A significance level of $p < 0.05$ was used throughout the analysis. Tukey's post hoc test (used to determine where significant differences lie) revealed statistically significant differences in water temperature between most combinations of regions except for Anglian and Thames, Midlands and Southern, Midlands and South West, Midlands and Wales, and Southern and South West. Substituting the Ouse for the Stour as the main river in Anglian Region does not change this result.

The highest mean water temperatures for the whole temperature dataset were recorded in the Thames and Anglian Regions (11.98 and 11.87°C, respectively) and the lowest in the North East Region (9.51°C).

3.1.2 Type analysis within regions

ANOVA revealed significant differences in mean water temperature for the whole dataset between river types within all regions apart from Anglian Region ($p < 0.01$). The results of the Kruskal-Wallis test confirm these differences. Table 3.1 shows these results in addition to the results of Tukey's post hoc test.

Table 3.1 ANOVA and Kruskal-Wallis test statistics – within regions

Region	ANOVA	Kruskal-Wallis	Tukey's post hoc
Anglian	0.589	0.807	No significant differences between types*
Midlands	0.000	0.000	Significant differences between most types
North East	0.000	0.000	Significant differences between most types
North West	0.000	0.000	Significant differences between many types: type 8 is different from all others
Southern	0.000	0.000	Significant differences: type 1 and 5; 37 and 1, 2, 4; 40 and 1, 2, 4, 8
South West	0.000	0.000	Significant differences: type 1 and all others; 11 and 1, 2, 4, 5, 7, 8; 10 and 7, 8; 13 and 7, 8
Thames	0.000	0.000	Significant differences: type 4 and 5, 8, 40; 11 and 1, 2, 4, 5, 8, 40
Wales	0.000	0.004	Significant differences: type 1 and 11, 13; 5 and 11, 13; 11 and 17

*Refer to Table 2.2 for a description of typologies

3.1.3 Type analysis between regions

ANOVA revealed significant differences in water temperature of the same river type between different regions ($p < 0.05$). Again, the results of the Kruskal-Wallis test confirm these differences. Table 3.2 shows these results in addition to the results of Tukey's post hoc test.

The river types 12 and 16 were only present in two regions, therefore the t-test was used to analyse these types instead of ANOVA. The results showed a significant difference in Type 12 water temperature data between North East and North West Regions ($p < 0.01$), but no difference in Type 16 data between North West and Thames Regions.

Table 3.2 ANOVA and Kruskal-Wallis test statistics – between regions

River type	ANOVA	Kruskal-Wallis	Tukey's post hoc
1	0.000	0.000	Significant differences between most regions*, especially SW and all others
2	0.000	0.000	Significant differences: A and NE, NW, S, SW, T; W and NE, NW, S, SW, T
4	0.000	0.000	Significant differences: NE and NW, S, SW, T, W; NW and SW, W
5	0.000	0.000	Significant differences: W and M, NE, NW, S, SW, T
8	0.000	0.000	Significant differences: NW and A, NE, S, SW; S and W
10	0.000	0.000	Significant differences: M and NE, SW, T; NW and NE, SW, T
11	0.000	0.000	Significant differences: NE and SW, T, W; NW and SW, T, W;
13	0.048	0.005	No significant differences between regions
14	0.000	0.000	Significant differences: NE and NW, T
17	0.002	0.004	Significant differences: NW and T
40	0.004	0.008	Significant differences: A and W

***** Regions are abbreviated as follows: A = Anglian; M = Midlands; NE = North East; NW = North West; S = Southern; SW = South West; T = Thames; W = Wales

3.1.4 Moving average trends for each region

The monthly temperature data have been plotted for all the sites on the selected main river for each region. It should be noted that on some rivers such as the Thames it was not possible to plot all the sites due to the large number of available records; therefore, only sites with the longest and most complete records have been plotted. The annual temperature cycle is clearly evident in all the plots. The 12-month moving average of temperature has also been included (i.e. the mean of the previous 12 months' temperature data) to smooth out short-term fluctuations and highlight longer term trends. The data have been plotted in 'stream order' with the most upstream site first and the most downstream site last. For each river the years with the highest and lowest temperatures are noted and referred to as the warmest/hottest and coldest.

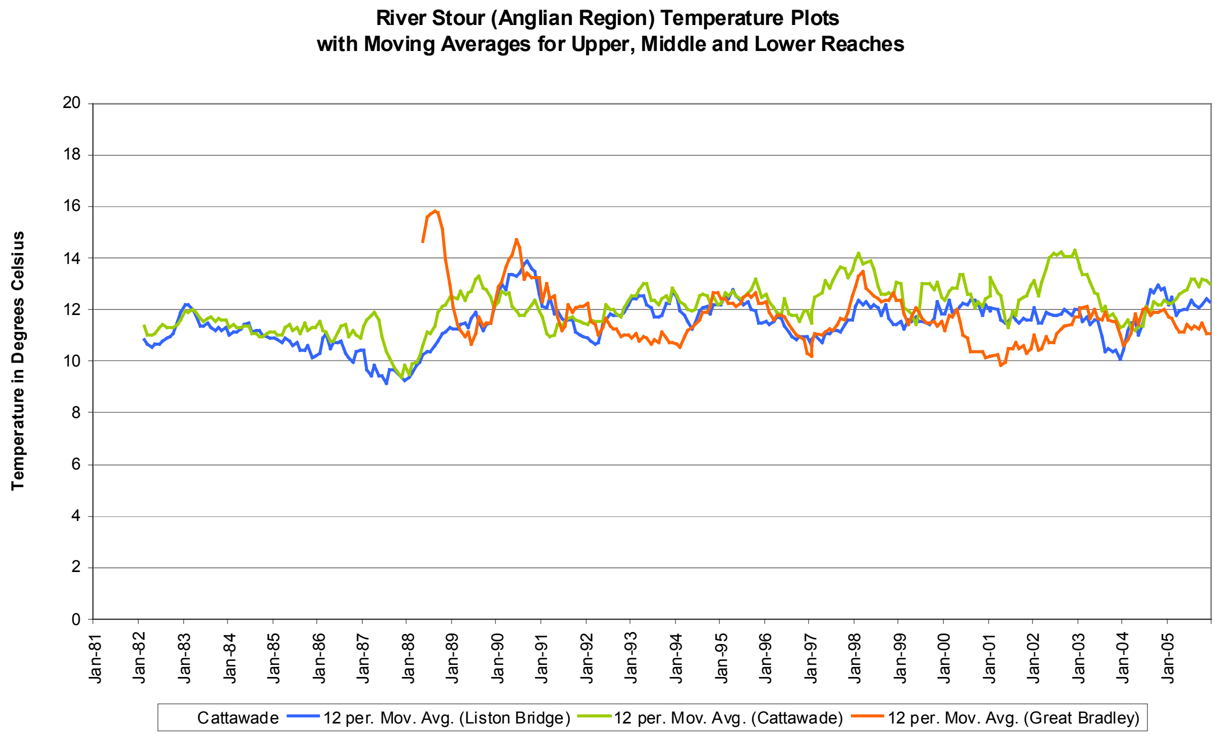


Figure 3.1 Anglian Region – River Stour moving average plots – upper, middle and lower reaches

Figure 3.1 illustrates the monthly temperature data for all sites on the Stour. The coldest years were 1986 and 1991 and the hottest years were 1994, 1995 and 2005. Records were available from 1981 to 2005, although the early period of the temperature record at the Great Bradley site has a significant amount of missing data. For the upper reach site (Great Bradley) temperatures appear to have remained steady from 1989 onwards. For both the middle reach site (Liston Weir) and lower reach site (Cattawade) there has been a gradual rise in temperature of 1–2°C between the early 1980s and 2005.

Figure 3.2 shows the monthly temperature data and moving average plots for the Ouse in Anglian Region. For this river the upper and middle reach sites (Brackley and Olney Weir) show a slight increase in temperature of approximately 1°C between the early 1980s and 2005, whereas at the lower reach site (Offord) there does not appear to be any overall change in temperature. At Brackley in particular, there is a distinct rise in temperature of approximately 5°C between 1990 and 2001.

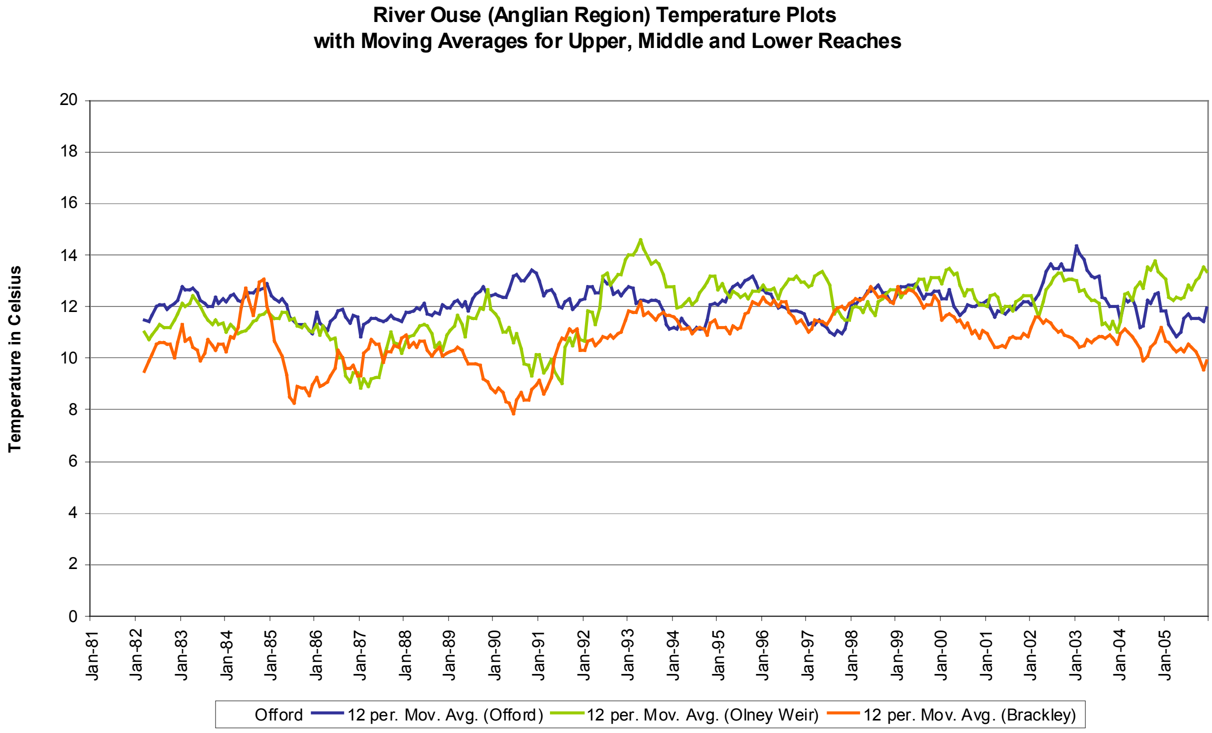


Figure 3.2 Anglian Region – River Ouse moving average plots – upper, middle and lower reaches

The River Severn moving average plots are shown in Figure 3.3. The upper reach site (Llandrinio) shows a slight overall decrease in temperature between 1987 and 2005. In the middle reach the site at Dolwen shows no change in temperature for the historical period, while Bewdley shows an upward temperature trend of approximately 1°C. The lower reach site at Mythe also shows an upward trend. The coldest years were 1997 and 2002 and the warmest years were 1995, 2003 and 2005.

Temperature data for the River Tyne in North East Region are shown in Figure 3.4. The upper reach site at Kielder shows no change in temperature for the period of the record (1973 to 2005), whereas both the middle and lower reach sites show a slight increase in temperature (approximately 1°C). The moving average trendlines show that the lower reach site (Wylam Bridge) is generally the warmest site and the upper reach site is generally the coolest. In the early part of the record during the years 1975, 1977, 1978, 1980 and 1982, temperatures were close to zero during the winter at a number of sites. In later years, temperatures are close to zero at just one site in 1999. The hottest years of the record are 1975, 1995 and 2005.

Figure 3.5 illustrates the monthly temperature data for the River Ribble in North West Region. Records were available from 1971 to 2005. In the early years (1975 to 1990) temperatures in the upper and middle reach sites are very similar, whereas from 1990 to 2002 and in 2005 the upper reach site (Settle Weir) is cooler than the middle reach site (Sawley Bridge). The lower reach site (Samlesbury) shows a slight increase (approximately 1°C) in temperature over the historical record

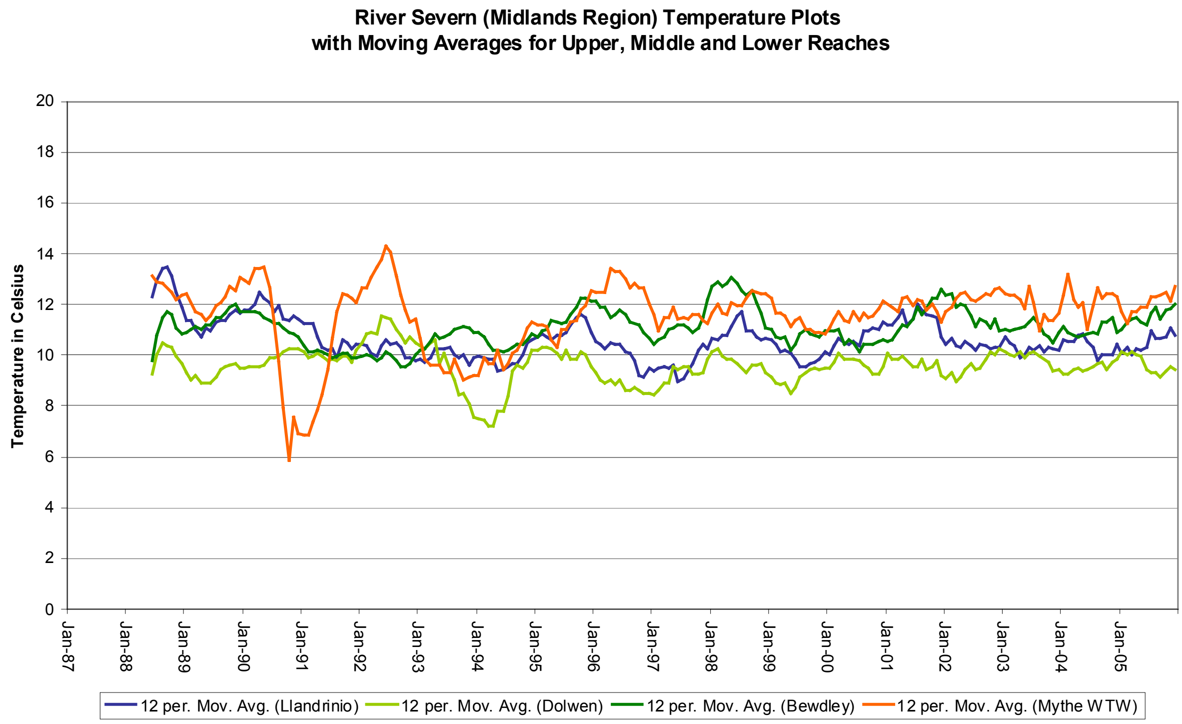


Figure 3.3 Midlands Region – River Severn moving average plots – upper, middle and lower reaches

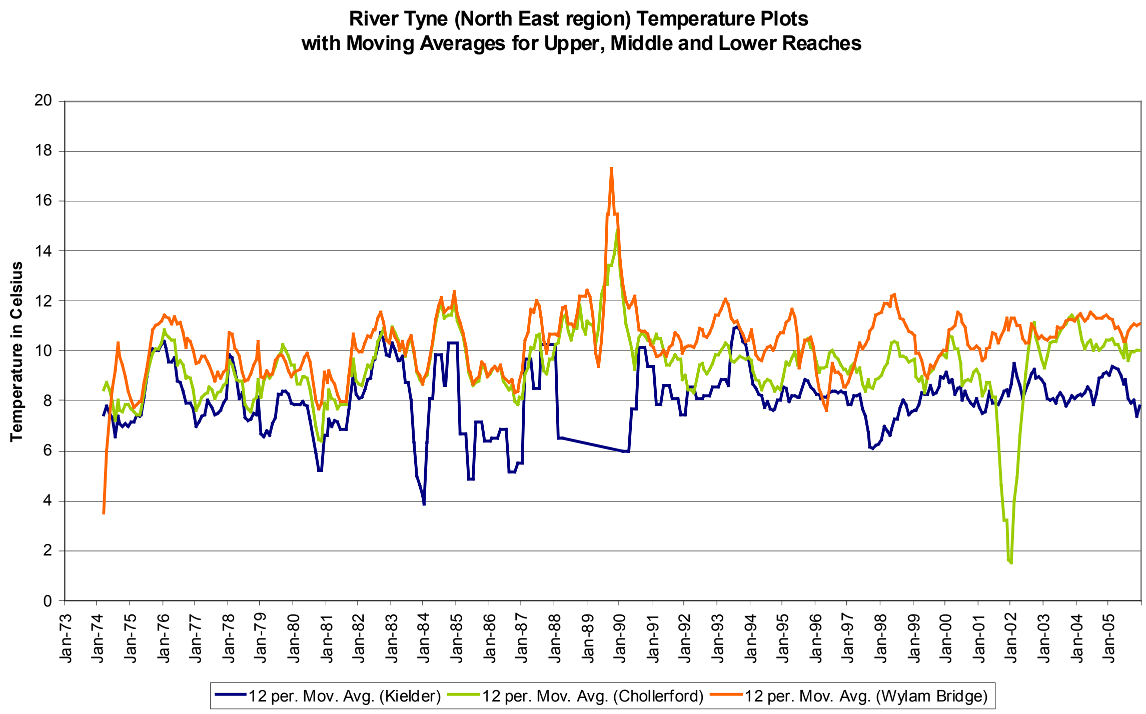


Figure 3.4 North East Region – River Tyne moving average plots – upper, middle and lower reaches

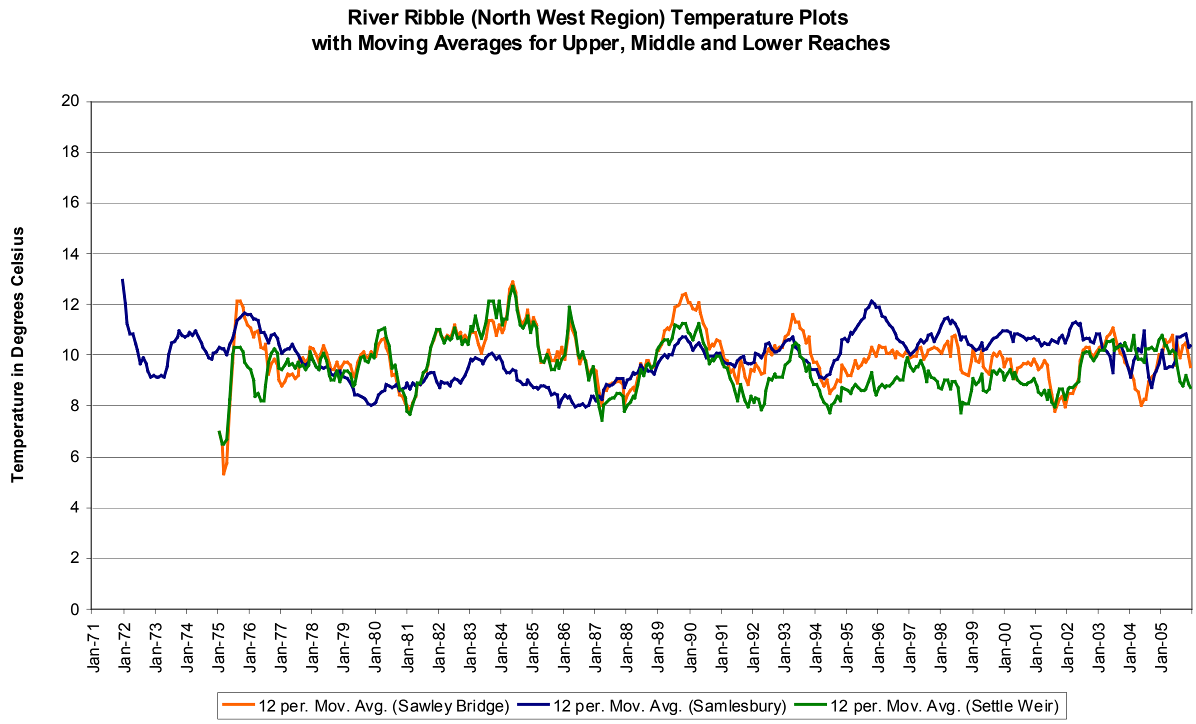


Figure 3.5 North West Region – River Ribble moving average plots – upper, middle and lower reaches

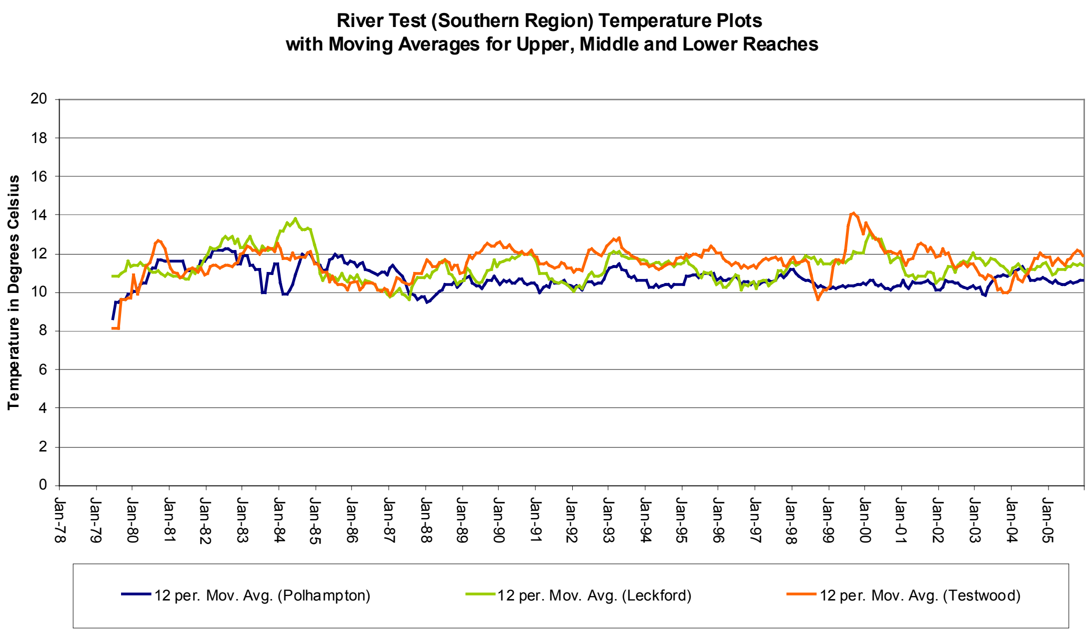


Figure 3.6 Southern Region – River Test moving average plots – upper, middle and lower reaches

Figure 3.6 shows the temperature data for the River Test in Southern Region. The temperature record runs from 1978 to 2005. The upper reach site (Polhampton) shows an overall slight decrease in temperature for this historical period, the middle reach site (Leckford) indicates that the temperature does not change over the period of the record, and the lower reach site (Testwood) shows a very small increase in temperature. The lower reach site is generally the warmest site and the upper reach site is the coolest. The coldest years are 1982 and 1986 and the warmest years are 1981, 1987, 1995 and 2005.

The Tamar temperature data are shown in Figure 3.7. All the representative reach sites show an overall increase in temperature of 1–2°C from 1974 to 2005. The coldest years are 1986, 1992 and 2000 and the hottest years are 1994, 1995, 1996, 1997 and 2003. The middle and lower reach sites (Boyton Bridge and Gunnislake Bridge, respectively) generally have a very similar temperature pattern except for 1984, 1988 and 1989 where missing data have resulted in relatively higher or lower temperatures for the 12-month moving average calculations.

For the River Thames (Thames Region), all the representative reach sites show an overall increase in temperature of 1–2°C between 1972 and 2005 (see Figure 3.8). Temperatures are lowest in the uppermost reach (Aston Keynes) and highest in the lowermost reach (Teddington). The coldest years are 1985, 1986 and 1997 and the hottest years are 1983, 1989, 1995 and 2003. For the early part of the record (1973 to 1988) the temperature profile is similar at Day's Weir, Teddington, Caversham and Egham. After 1988 the temperature profile at Egham becomes much more variable and Caversham becomes relatively cooler than the other sites. Temperatures at Buscot are lower than the other middle reach sites between 1981 and 1991 and between 1999 and 2001.

Finally, the moving average plots for the River Dee (Wales Region) are illustrated in Figure 3.9. A linear trendline shows that all three reaches increase in temperature by 1–2°C between 1974 and 2005. The coldest years are 1984, 1985 and 1996, and the warmest years are 2001, 2002, 2003 and 2005. The representative site for the upper reach (Llandderfel Bridge) is consistently cooler than the lower reach site (Iron Bridge) except in 2001, where missing data in the Iron Bridge time series causes an apparent drop in the moving average trendline. The temperature series for the middle reach (Overton Bridge) is variable, being warmer than the lower reach site in 1977, 1978, 1987 to 1991, 1997 and 2001, and cooler than the lower reach in the remaining years. Newbridge is warmer than the upper reach site except in 1991 and 1992, when missing data in the time series may again be altering the trendline.

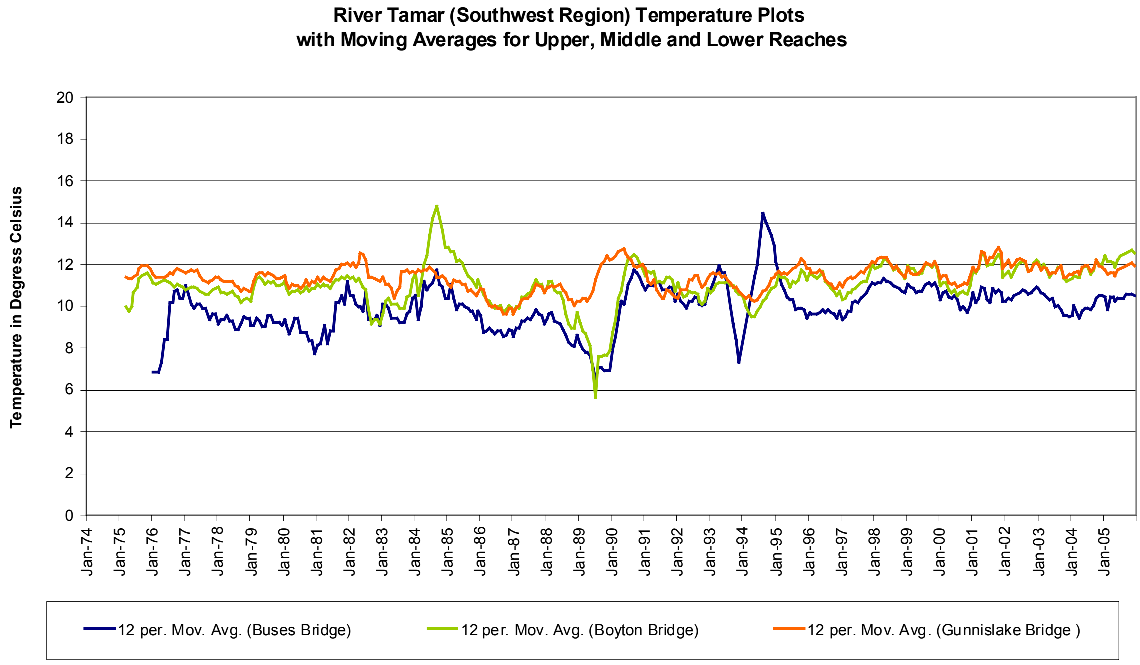


Figure 3.7 South West Region – River Tamar moving average plots – upper, middle and lower reaches

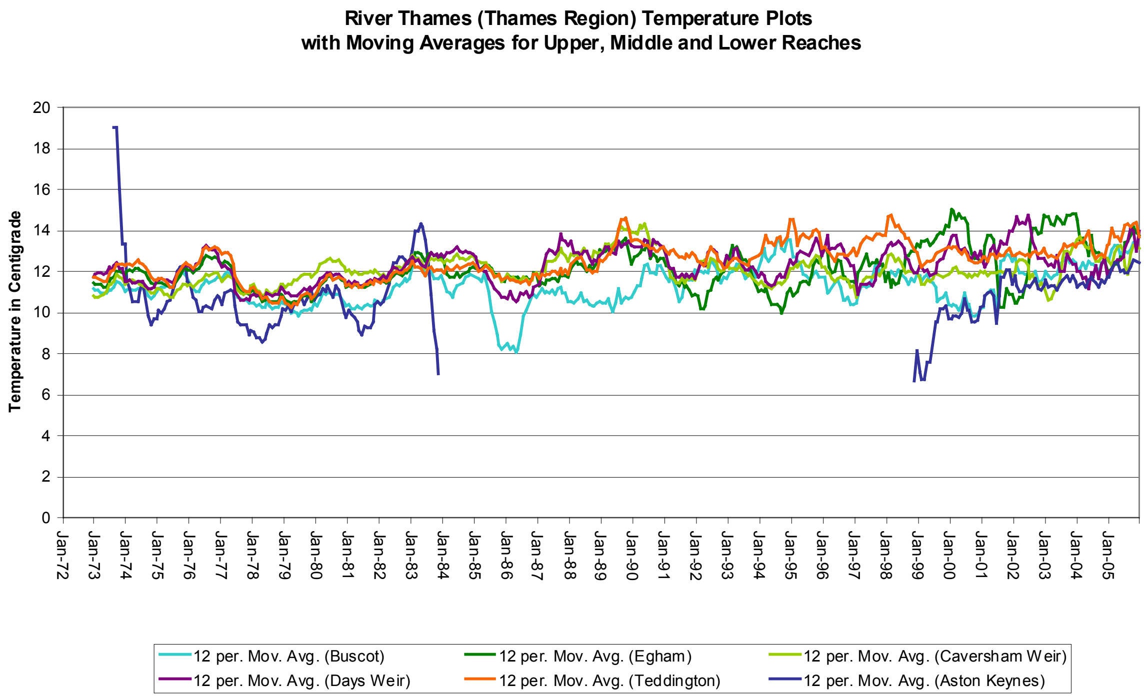


Figure 3.8 Thames Region – River Thames moving average plots – upper, middle and lower reaches

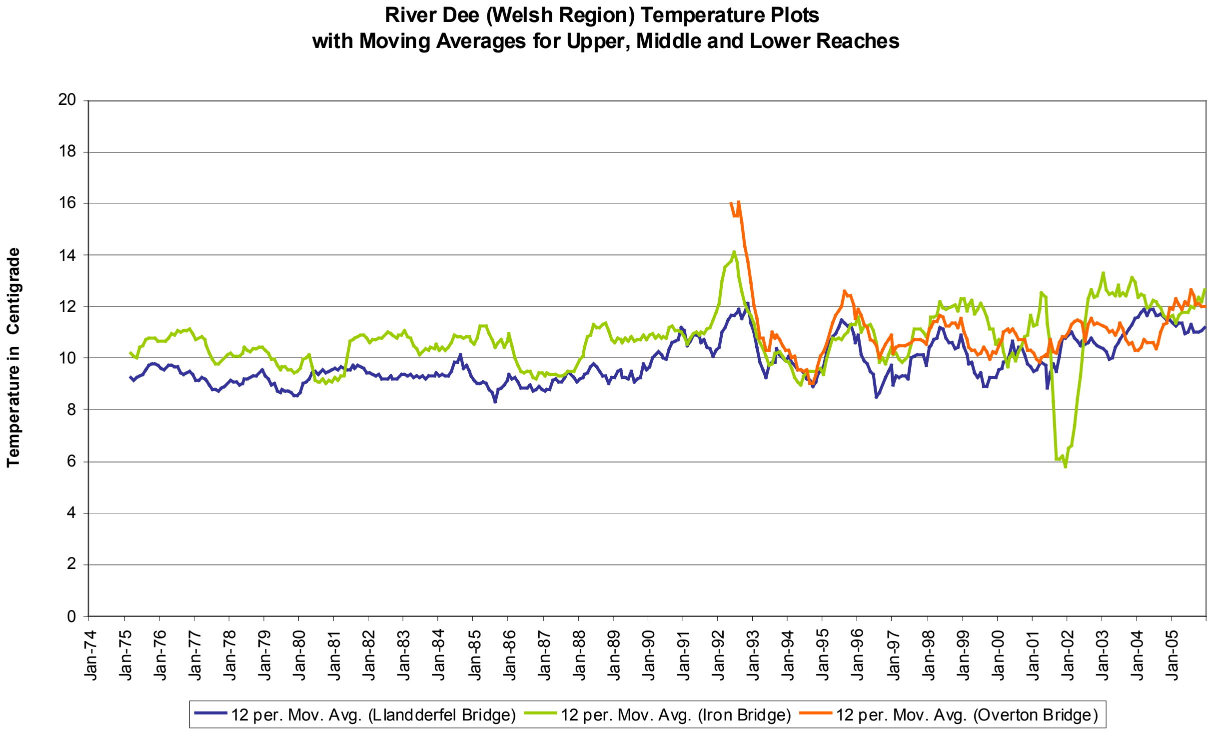


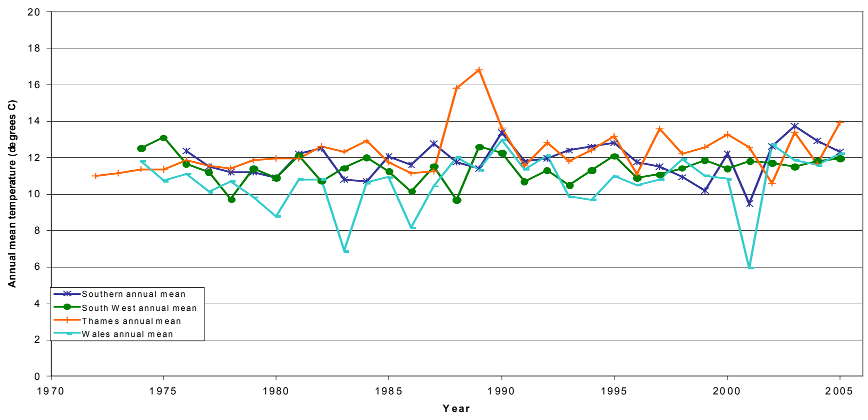
Figure 3.9 Wales Region – River Dee moving average plots – upper, middle and lower reaches

3.1.5 Annual mean and decadal trend analysis

Figure 3.10 shows the annual mean temperature trend for the best water temperature record in each Environment Agency region, with standard error plots for each site in Figure 3.11. Details of each of the benchmark temperature monitoring sites are provided in Table 3.3. A summary of the rate of annual mean river water temperature change (°C per decade) is given for each site in Table 3.4, with these results also being represented graphically in Figures 3.12 to 3.14.

Table 3.3 Benchmark site information

Site name	Region	NGR	WFD type	Record start date	Record end date	Average sampling frequency (days)
R Stour Wixoe WQMS intake pier	Anglian	TL7083643102	5	30/03/1981	15/12/2005	6.25
Severn at Saxons Lode	Midlands	SO8633039050	8	01/06/1975	31/10/2006	1.02
River Hull at Hempholme Lock	North East	TA0798449885	5	01/04/1974	24/11/2005	5.17
River Calder at Whalley	North West	SD7292736058	14	30/04/1971	15/12/2005	7.12
River Cuckmere Sherman Bridge	Southern	TQ5320005050	5	07/01/1976	30/11/2005	11.20
River Tamar at Gunnislake Bridge	South West	SX4349372436	4	03/04/1974	15/12/2005	8.88
Thames at Caversham Weir	Thames	SU7213574053	8	05/01/1972	09/12/2005	4.17
River Dee at Iron Bridge	Wales	SJ4180060100	17	09/04/1974	29/11/2005	12.56



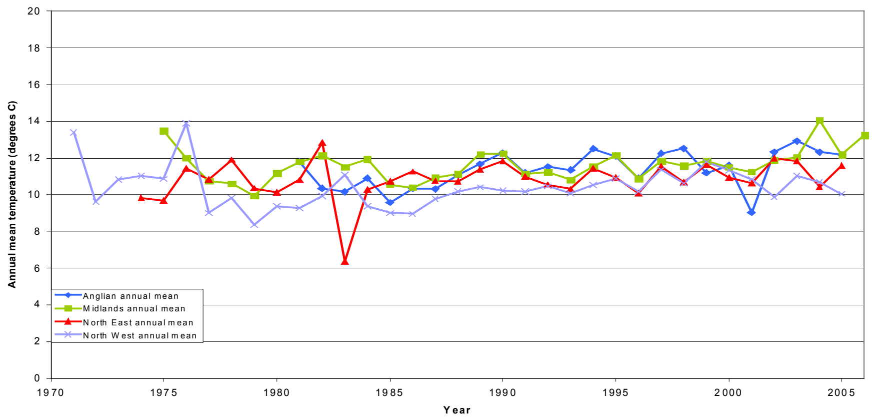
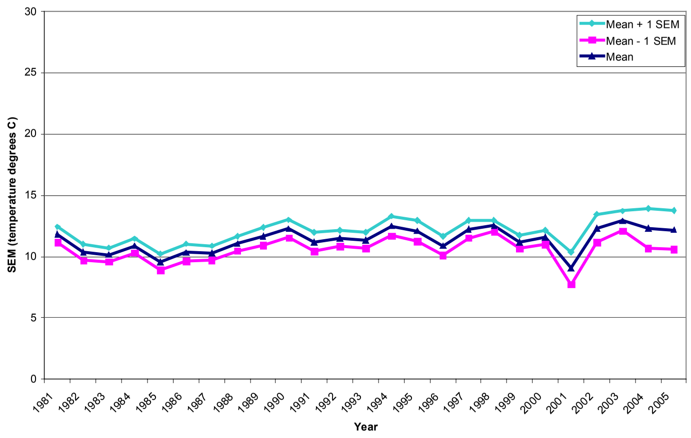
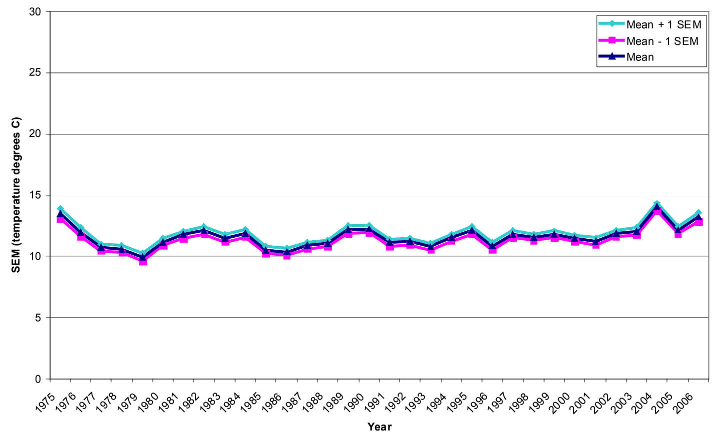


Figure 3.10 Annual mean water temperature trends for benchmark sites

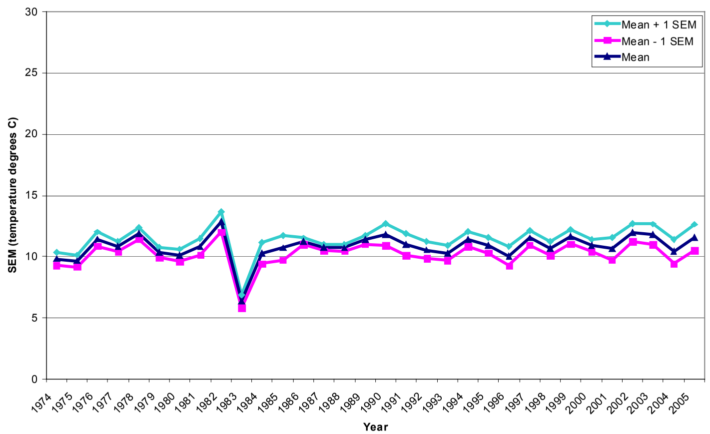
Stour at Wixoe (Anglian Region) Standard Error Plot



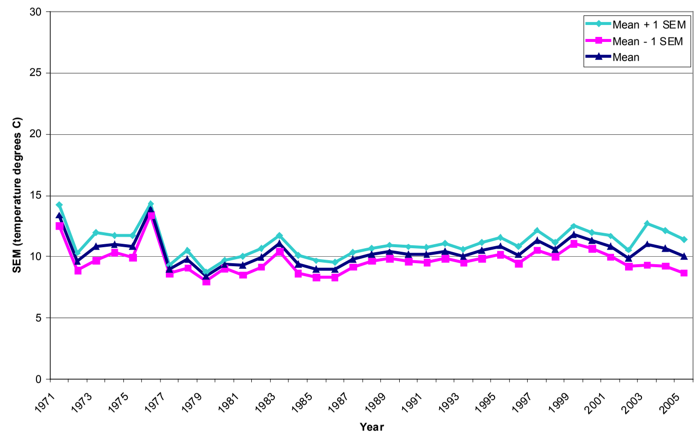
Severn at Saxons Lode (Midlands Region) Standard Error Plot



Hull at Hempholme Lock (North East Region) Standard Error Plot



Calder at Whalley (North West Region) Standard Error Plot



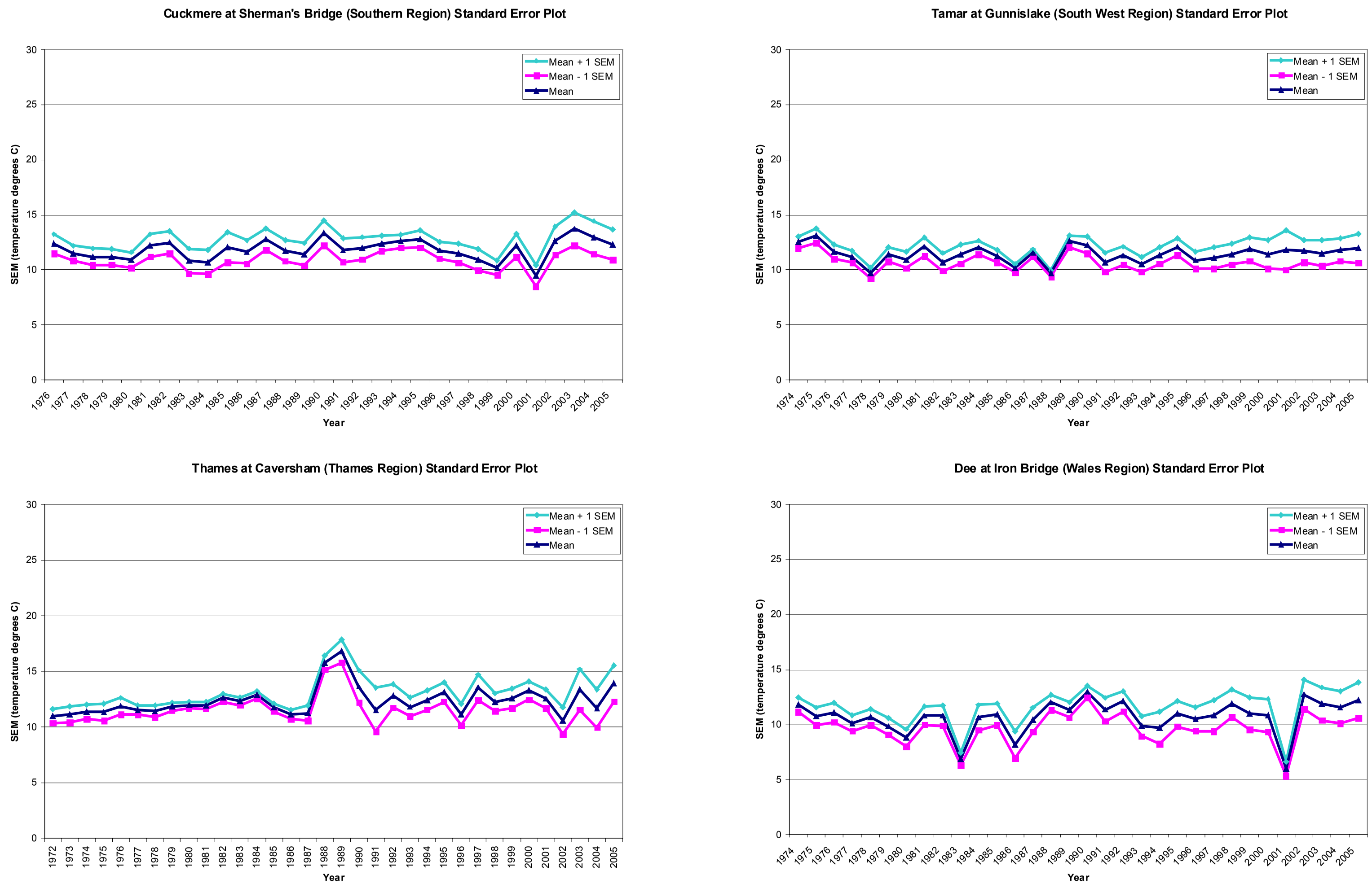


Figure 3.11 Standard error plots for benchmark site annual temperature trends

Table 3.4 Rate of decadal temperature change

Site name	Temperature change 1970–1980 (°C)	Temperature change 1980–1990 (°C)	Temperature change 1990–2000 (°C)
River Stour Wixoe WQMS intake pier	No data	1.10	-0.06
Severn at Saxons Lode	0.02	0.15	0.78
River Hull at Hempholme Lock	-0.14	0.46	0.23
River Calder at Whalley	-1.02	0.89	0.01
River Cuckmere Sherman Bridge	0.11	0.26	0.28
River Tamar at Gunnislake Bridge	-0.36	0.10	0.36
Thames at Caversham Weir	1.41	-0.36	0.07
River Dee at Iron Bridge	-0.64	1.04	-0.25
Air temperatures (HadCET)	-0.02	0.58	0.34

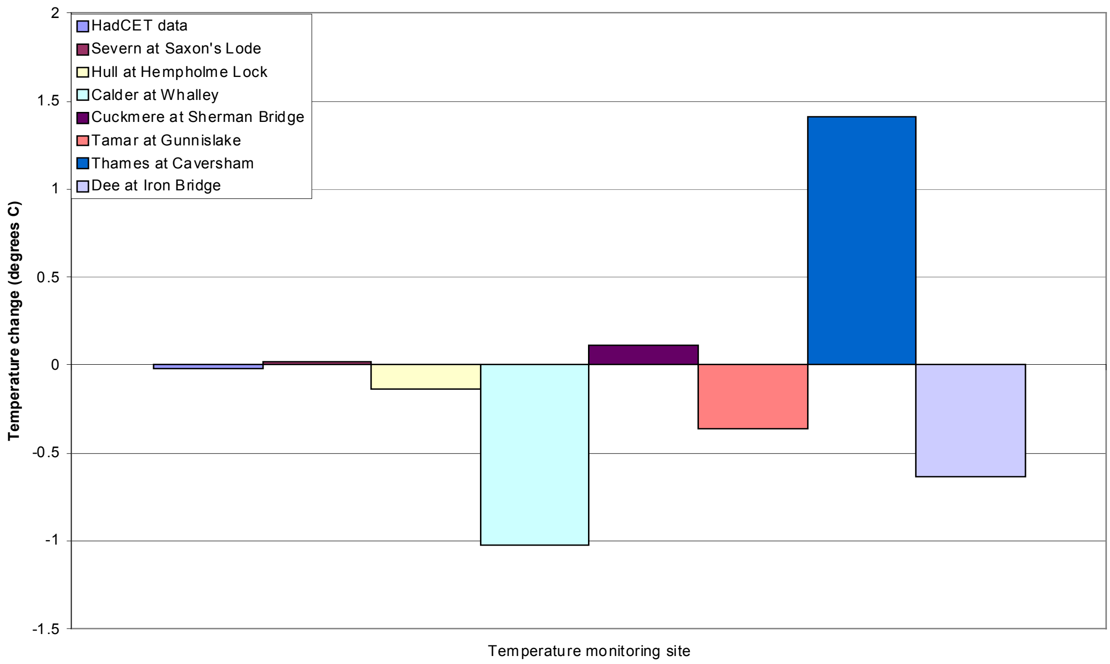


Figure 3.12 Decadal temperature change at benchmark sites, 1970-1980

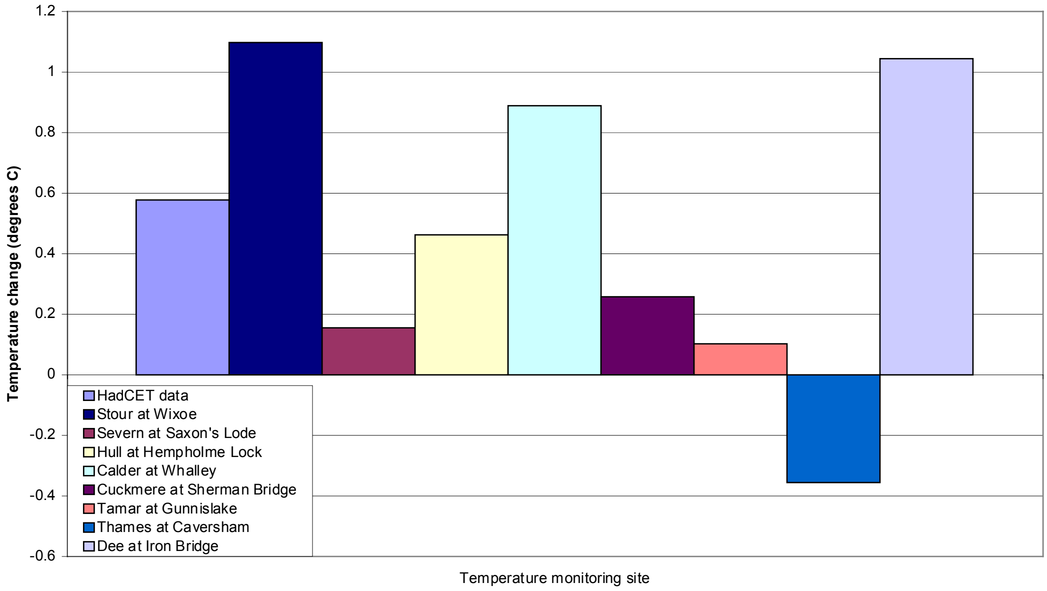


Figure 3.13 Decadal temperature change at benchmark sites, 1980–1990

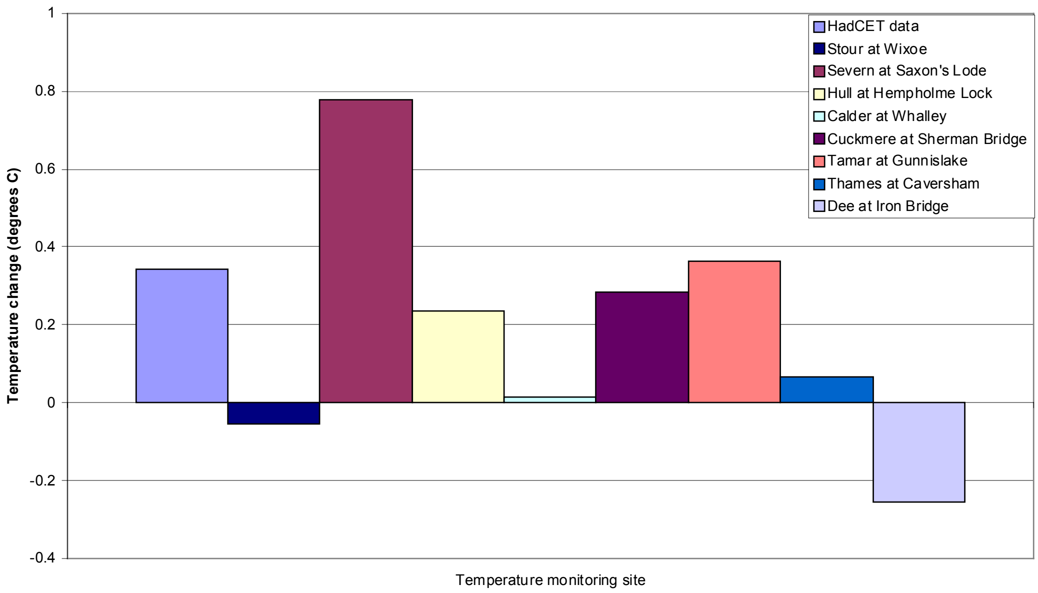


Figure 3.14 Decadal temperature change at benchmark sites, 1990–2000

3.1.6 Seasonal analysis

The seasonal analysis uses January to March as winter, April to June as spring, July to September as summer and October to December as winter (as requested by the Environment Agency). Figures 3.15 to 3.18 show the 5-year moving averages for upper and lower reach sites on the main rivers selected for each region. The Aston Keynes site on the Thames has missing data for 1984 to 1998, the River Stour at Great Bradley has missing data from 1984 to 1988, the Horton site on the River Ribble has missing data from 1984 to 1992 and the Tyne has missing data from 1988 to 1989. This missing data causes anomalous peaks and troughs in the moving average data.

Figure 3.15 indicates that all the upper reach sites show a similar trend in winter except for the Stour site, which is likely to be affected by transfers from the Ouse catchment, and the Tyne site, which may be affected by Kielder reservoir. Both the Stour and Tyne sites show a slight downward temperature trend whereas all the other sites show an upward trend.

Figure 3.16 indicates that all the lower reach sites show an upward temperature trend in winter. The Stour site (Cattawade) experienced particularly high temperatures during the early years (1980 to 1988) and the Tyne site (Wylam Bridge) experienced high temperatures between 1985 and 1991.

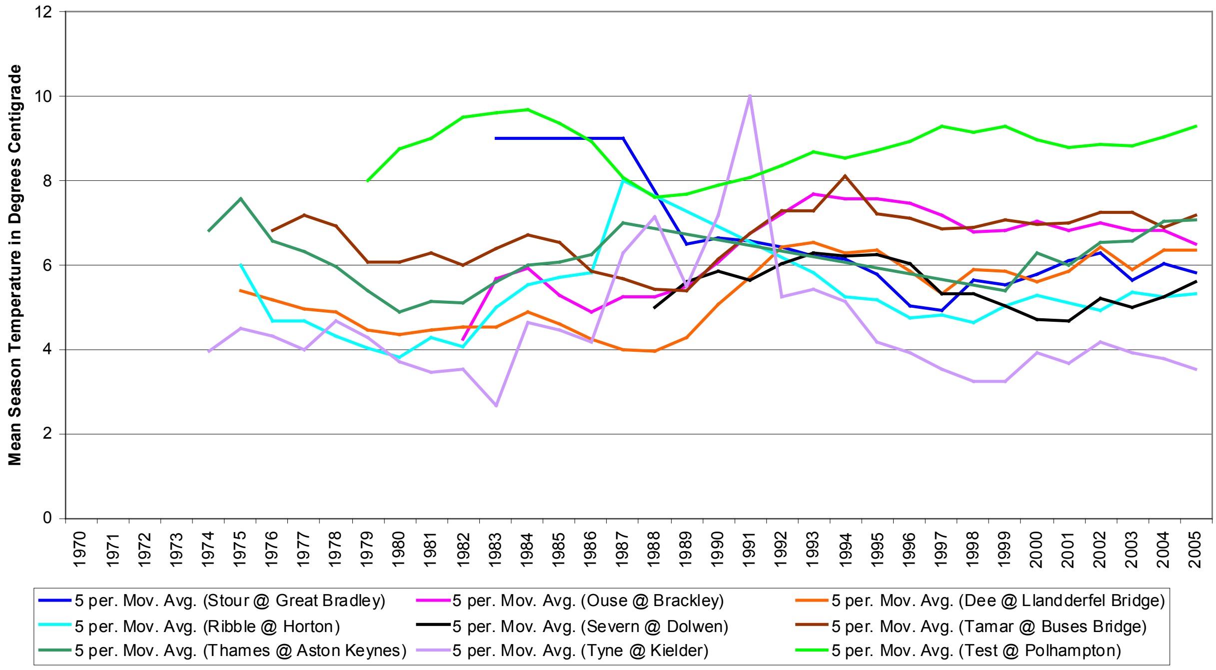


Figure 3.15 Upper reach sites winter 5-year moving average trends

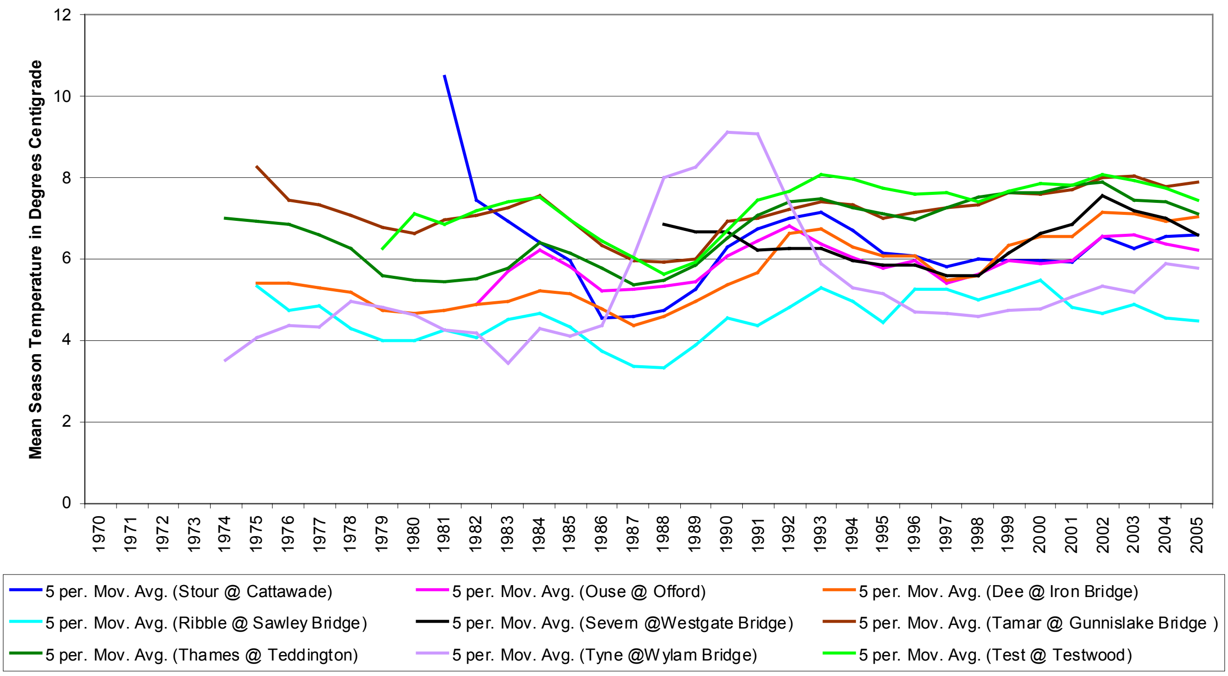


Figure 3.16 Lower reach sites winter 5-year moving average trends

The upper reach spring temperatures shown in Figure 3.17 again illustrate a general upward trend in water temperatures, although the Rivers Ribble and Stour show a slight downward trend.

The lower reach spring temperatures in Figure 3.18 also show a general upward trend over time except for the Ribble, Tamar and Ouse. The River Ribble in particular shows a dip in temperatures between 2000 and 2003.

Overall, the water temperature of rivers in northern England such as the Tyne (North East Region) are cooler than rivers in southeast England such as the Thames (Thames Region) and the Ouse (Anglian Region).

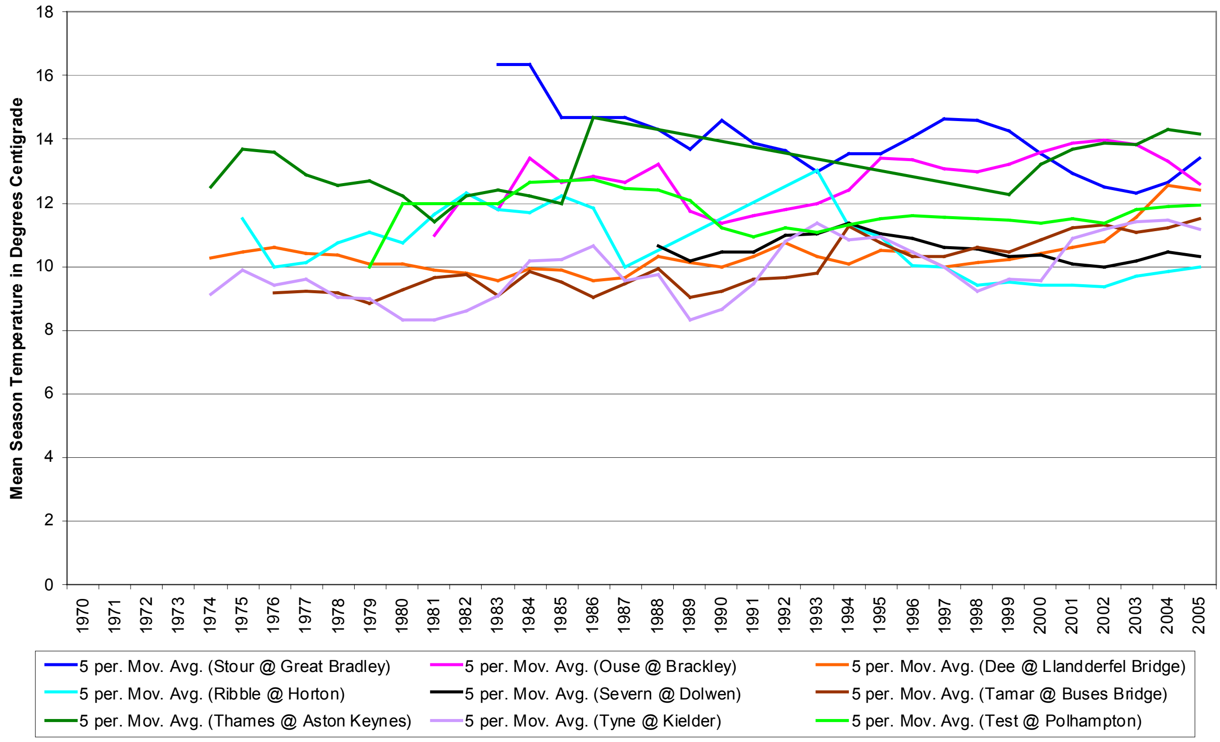


Figure 3.17 Upper reach sites spring 5-year moving average trends

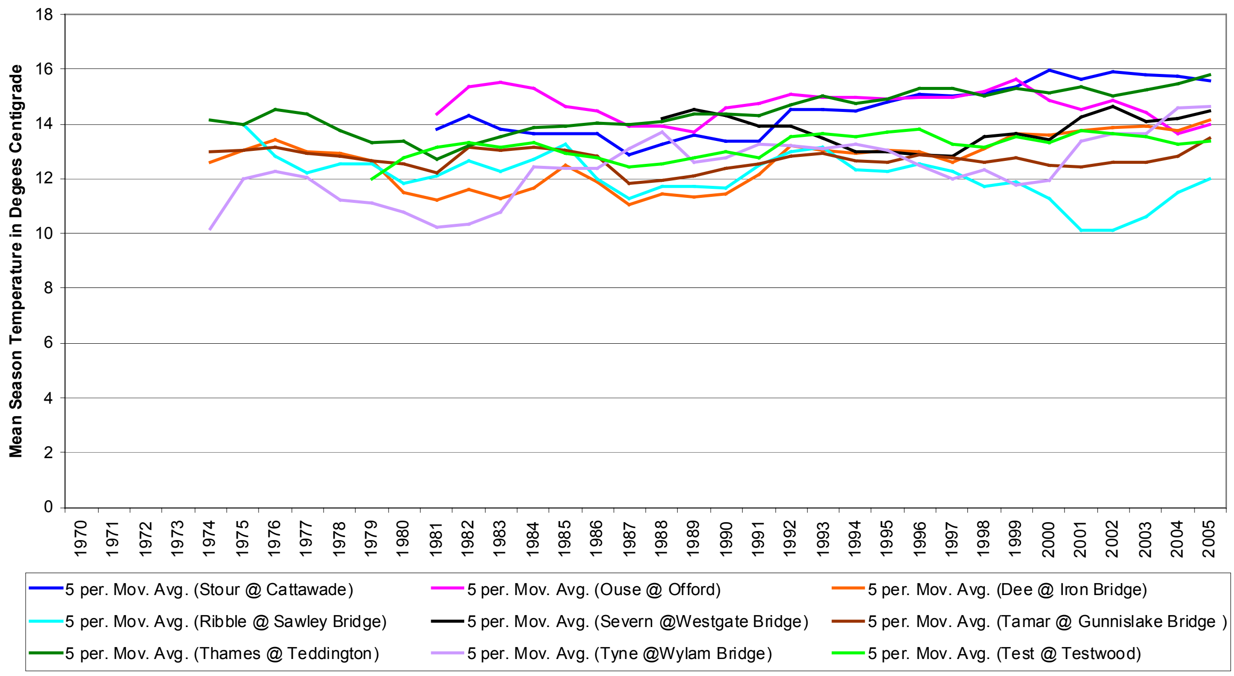
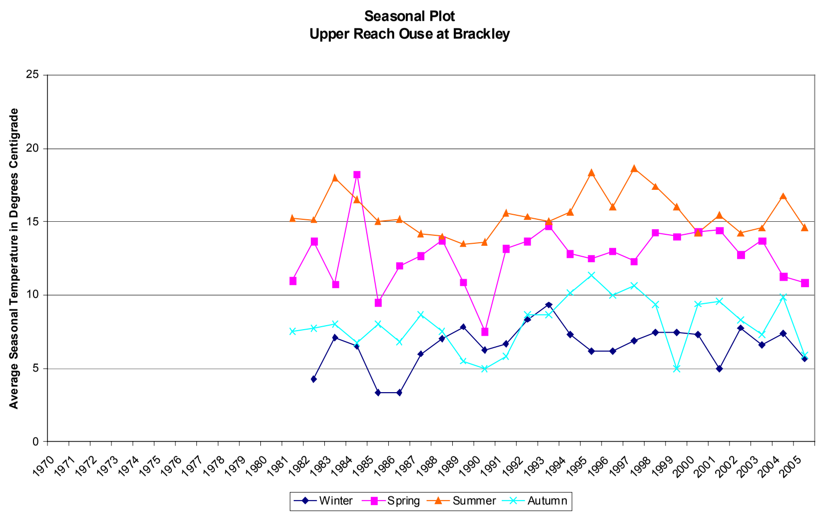
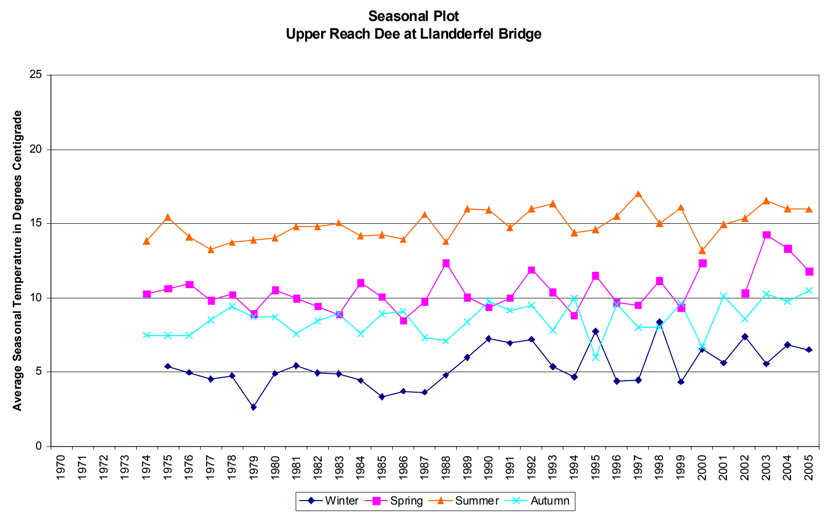
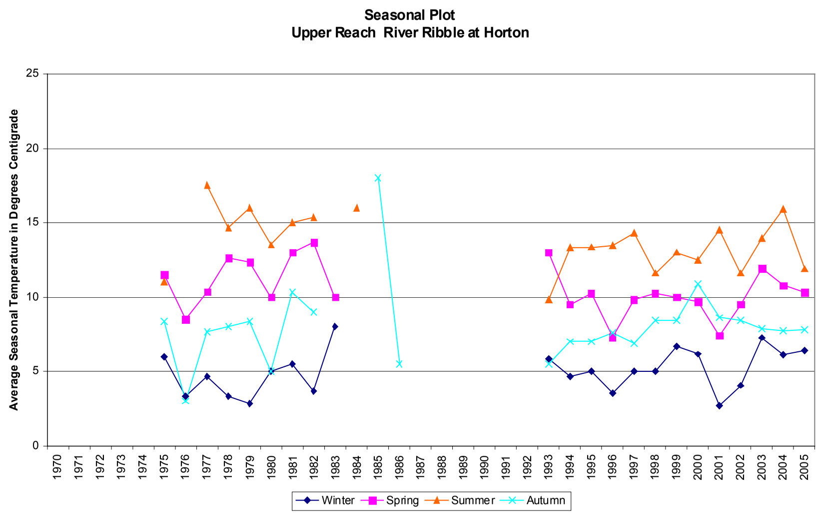


Figure 3.18 Lower reach sites spring 5-year moving average trends


Seasonal Plot
Upper Reach Ouse at Brackley
Average Seasonal Temperature in Degrees Centigrade
Winter
Spring
Summer
Autumn


Seasonal Plot
Upper Reach Dee at Llandderfel Bridge
Average Seasonal Temperature in Degrees Centigrade
Winter
Spring
Summer
Autumn


Seasonal Plot
Upper Reach River Ribble at Horton
Average Seasonal Temperature in Degrees Centigrade
Winter
Spring
Summer
Autumn

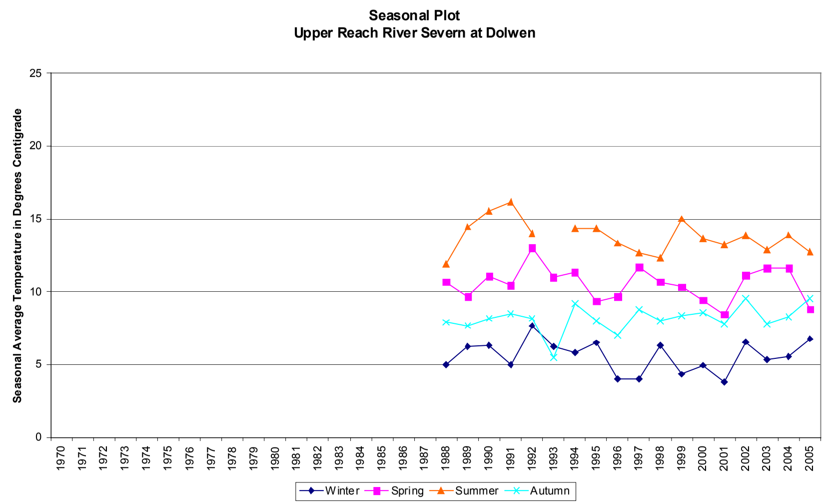
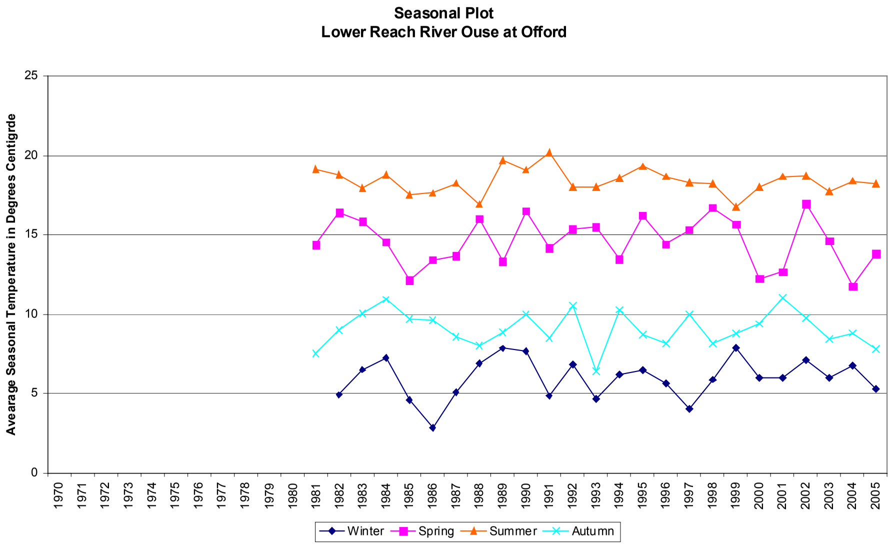
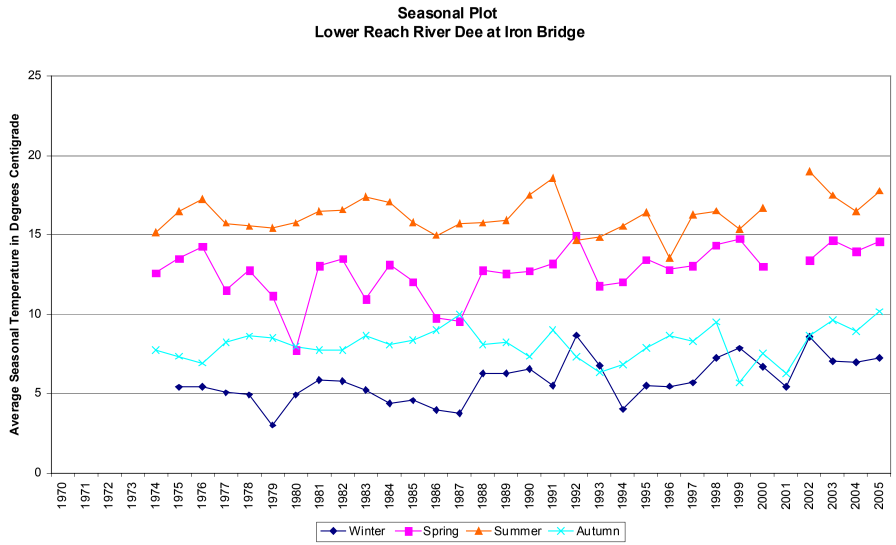
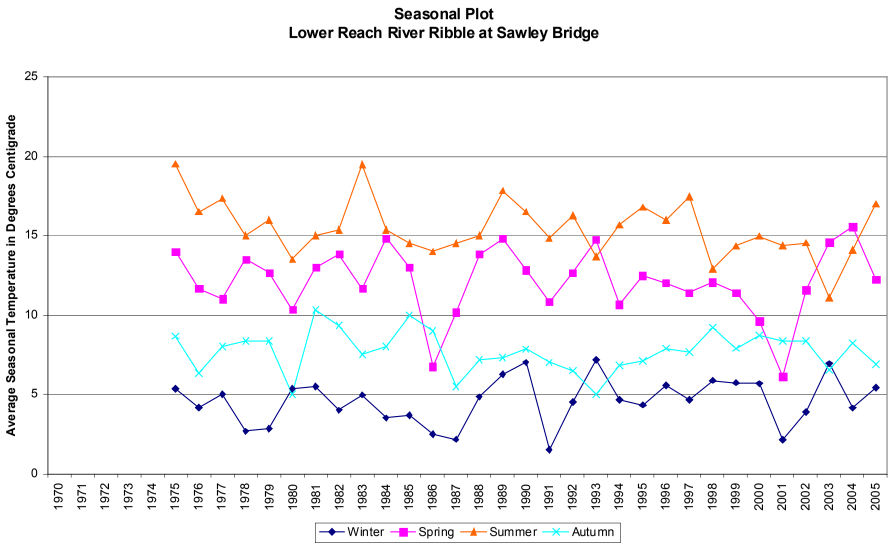
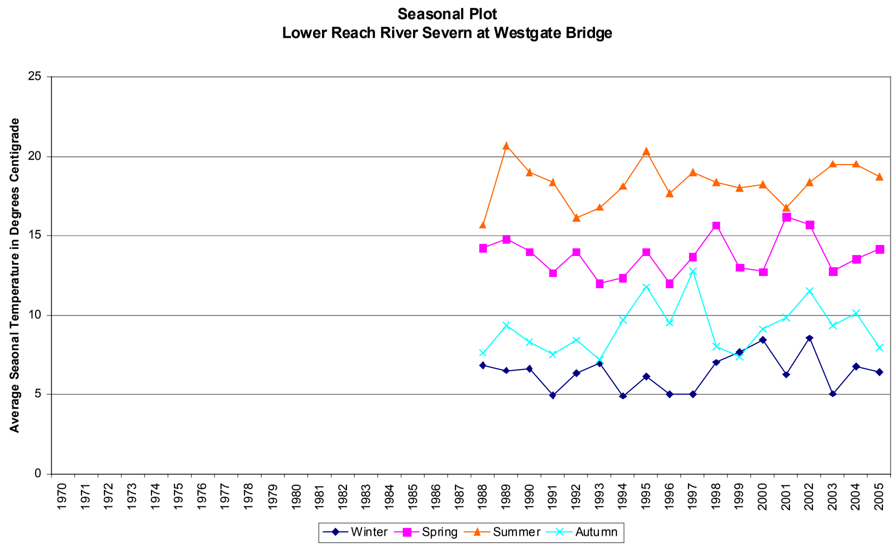

Seasonal Plot
Upper Reach River Severn at Dolwen
Seasonal Average Temperature in Degrees Centigrade
Winter
Spring
Summer
Autumn

Figure 3.19 Upper reach seasonal comparisons for individual sites


Seasonal Plot
Lower Reach River Ouse at Offord
Average Seasonal Temperature in Degrees Centigrde
Winter
Spring
Summer
Autumn


Seasonal Plot
Lower Reach River Dee at Iron Bridge
Average Seasonal Temperature in Degrees Centigrade
Winter
Spring
Summer
Autumn


Seasonal Plot
Lower Reach River Ribble at Sawley Bridge
Average Seasonal Temperature in Degrees Centigrade
Winter
Spring
Summer
Autumn


Seasonal Plot
Lower Reach River Severn at Westgate Bridge
Winter
Spring
Summer
Autumn

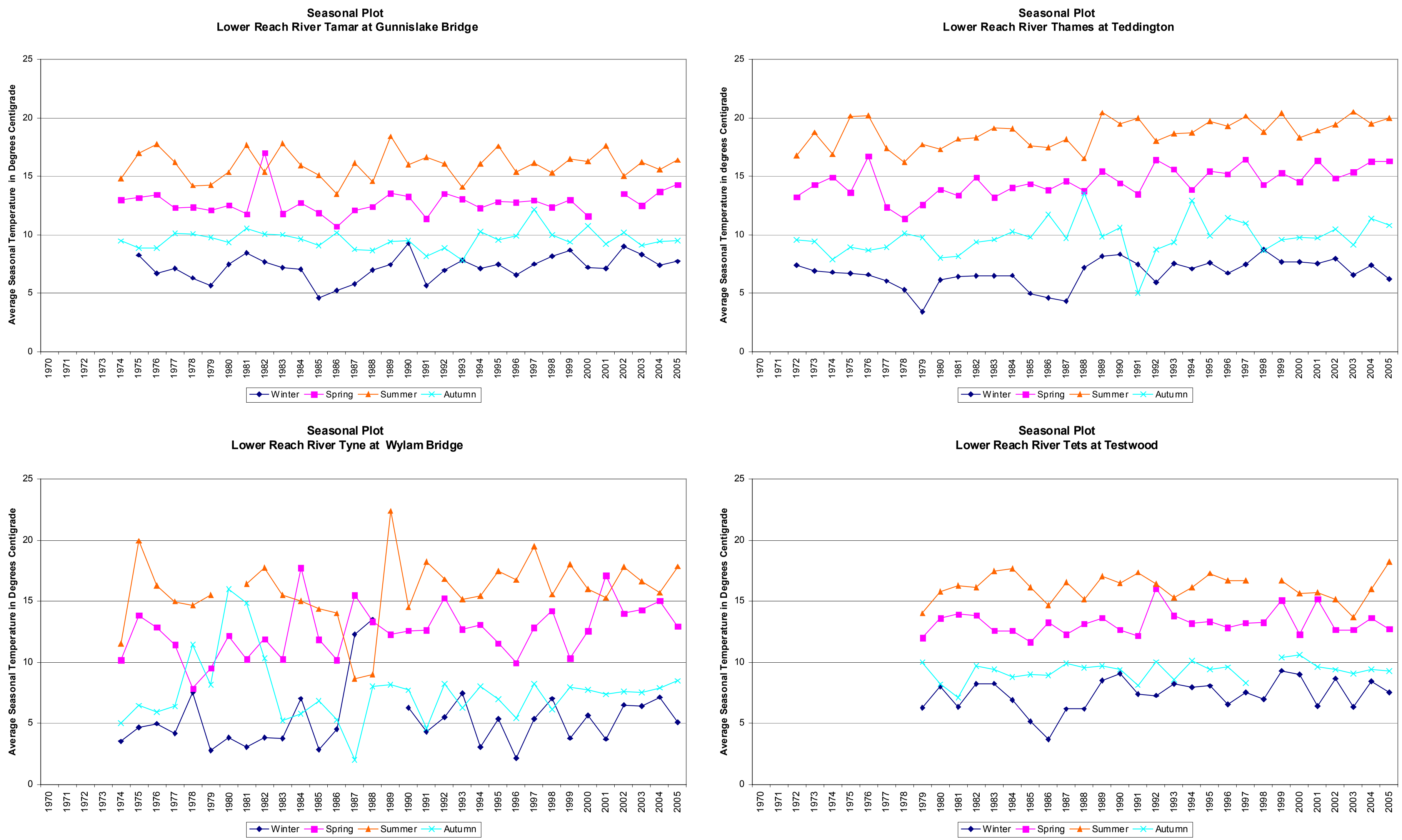


Figure 3.20 Lower reach seasonal comparisons for individual sites

Figure 3.19 shows the seasonal temperature curves for individual upper reach sites. As expected, temperatures are lowest in winter and highest in summer. For the Ouse at Brackley there is some overlap between the winter and spring temperatures in 1989, 1990 and 1999. For the Tyne at Kielder there is overlap between autumn and spring temperatures between 1976 and 1987 and unusually warm winter temperatures in 1984 and 1987. This could be due to erroneous data or the effects of Kielder reservoir. The River Test at Polhampton shows an overlap in winter and spring temperatures in 1982 and 1990. The Rivers Tyne and Ribble have lower winter temperatures than rivers in the more southern regions.

The seasonal plots for the lower reach sites are shown on Figure 3.20. Again, rivers in the North East and North West Regions have the lowest winter temperatures. Winter and spring temperatures for the River Tyne at Wylam Bridge overlap in 1986 to 1988 and 1998 and spring and summer temperatures overlap in 1987, 1988 and 2001.

3.2 Analysis of daily data

3.2.1 Regional analysis

Daily data were obtained for four regions: Midlands, North East, Thames and Wales. ANOVA revealed significant differences in water temperature between all four regions and combinations of regions ($p < 0.01$). The highest mean water temperature was recorded in Thames Region (12.24°C) and the lowest in Wales (10.08°C).

3.3 Infilling water temperature time series

Table 3.5 shows the results from regression analysis between sites of the same typology from different regions. The regression was carried out to ascertain the feasibility of infilling and/or hindcasting temperature time series data using a donor site of the same type from another region. The table illustrates that the R-squared values (the amount of explained variance) from the regression analysis are high, ranging from 0.83 to 0.88. It should be noted that infilling can only be successfully accomplished by using near-neighbour donor sites. It is not appropriate to use a donor site in Southern Region to infill temperature data for a river in North West Region for example.

Figures 3.21 and 3.22 show the regression analysis of WFD Type 13 rivers at sites in the North East and North West Regions regressed against the Churnet and Derwent in the Midlands Region. Figures 3.23 and 3.24 show the regression for WFD Type 8 rivers at sites on the River Thames regressed against sites on the River Severn in Midlands Region.

Table 3.5 Regression analysis results

Donor site	Infill site	Regression equation	R-squared
Thames Type 8	***Midlands Type 8***		
Thames at Buscot	Severn at Haw Bridge	y = 0.9969x + 0.1850	0.83
Thames at Abingdon	Severn at Haw Bridge	y = 0.9176x + 0.5918	0.88
Thames at Buscot	Severn at Tewkesbury	y = 1.0528x – 0.8136	0.85
Thames at Abingdon	Severn at Tewkesbury	y = 0.9481x – 0.0943	0.88
North East Type 13	***Midlands Type 13***		
Wharf at Tadcaster	Churnet at Cheddleton	Y = 0.8121x + 1.6165	0.85
Wharf at Tadcaster	Derwent at Little Eaton	Y = 0.7843x + 2.0885	0.85
North West Type 13	***Midlands Type 13***		
Irwell at Wark Weir	Churnet at Cheddleton	Y = 0.8544x + 1.4461	0.86
Irwell at Wark Weir	Derwent at Little Eaton	Y = 0.8377x + 1.7909	0.84

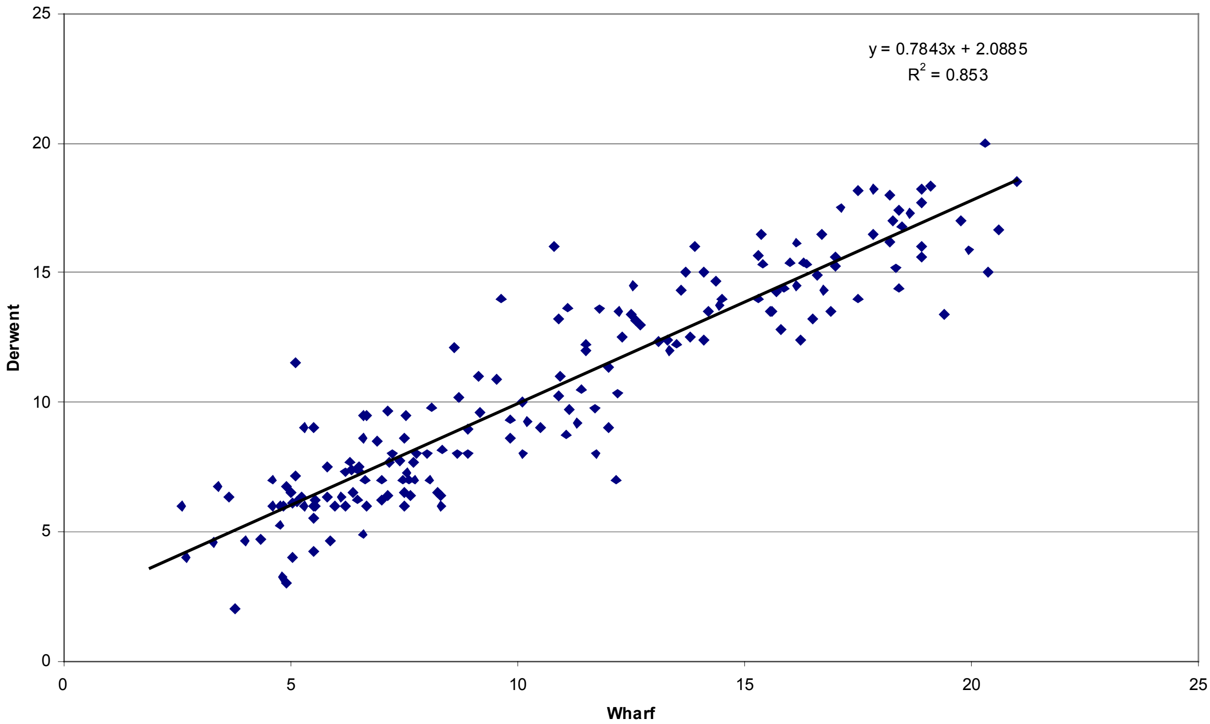


Figure 3.21 Regression analysis of River Wharf at Tadcaster (Type 13 North East Region) versus River Derwent at Little Eaton (Type 13 Midlands Region)

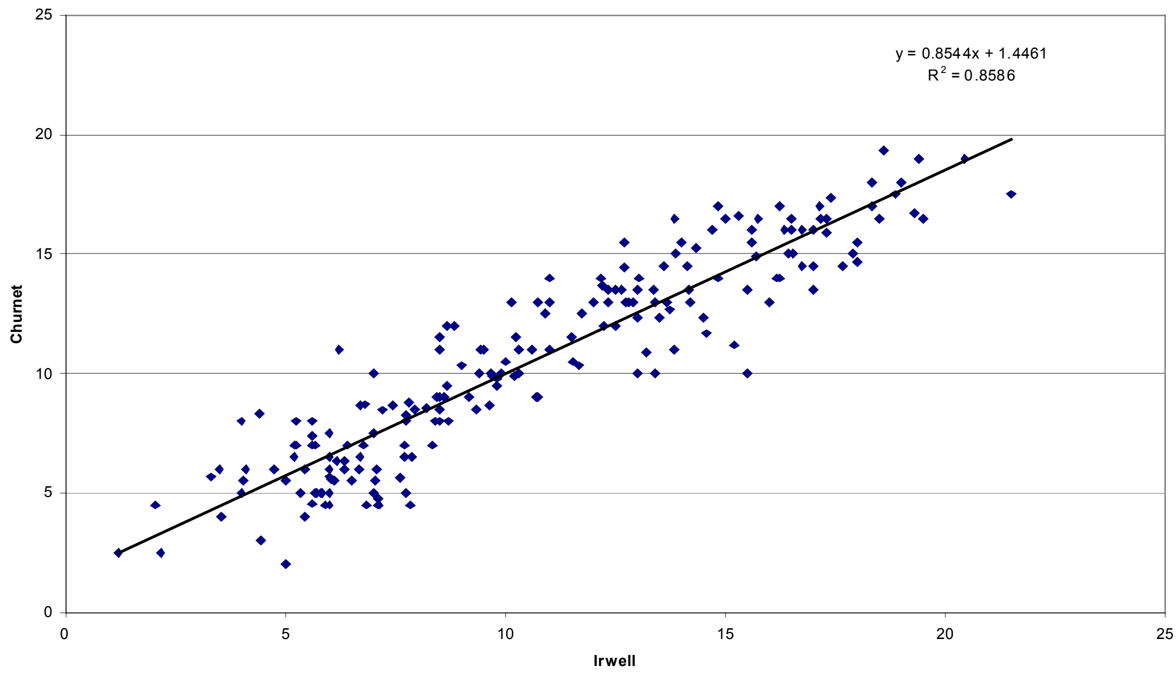


Figure 3.22 Regression analysis of River Irwell at Wark Weir (Type 13 North West Region) versus River Churnet at Cheddleton Station (Type 13 Midlands Region)

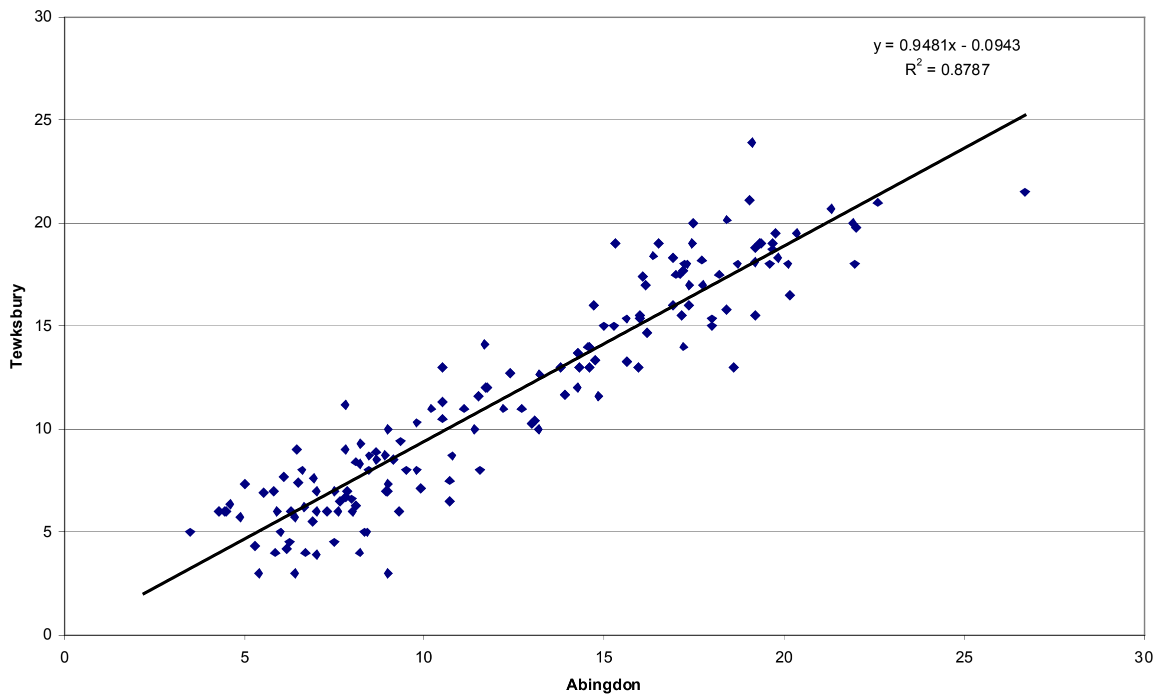


Figure 3.23 Regression analysis of River Thames at Abingdon (Type 8 Thames Region) versus River Severn at Tewkesbury (Type 8 Midlands Region)

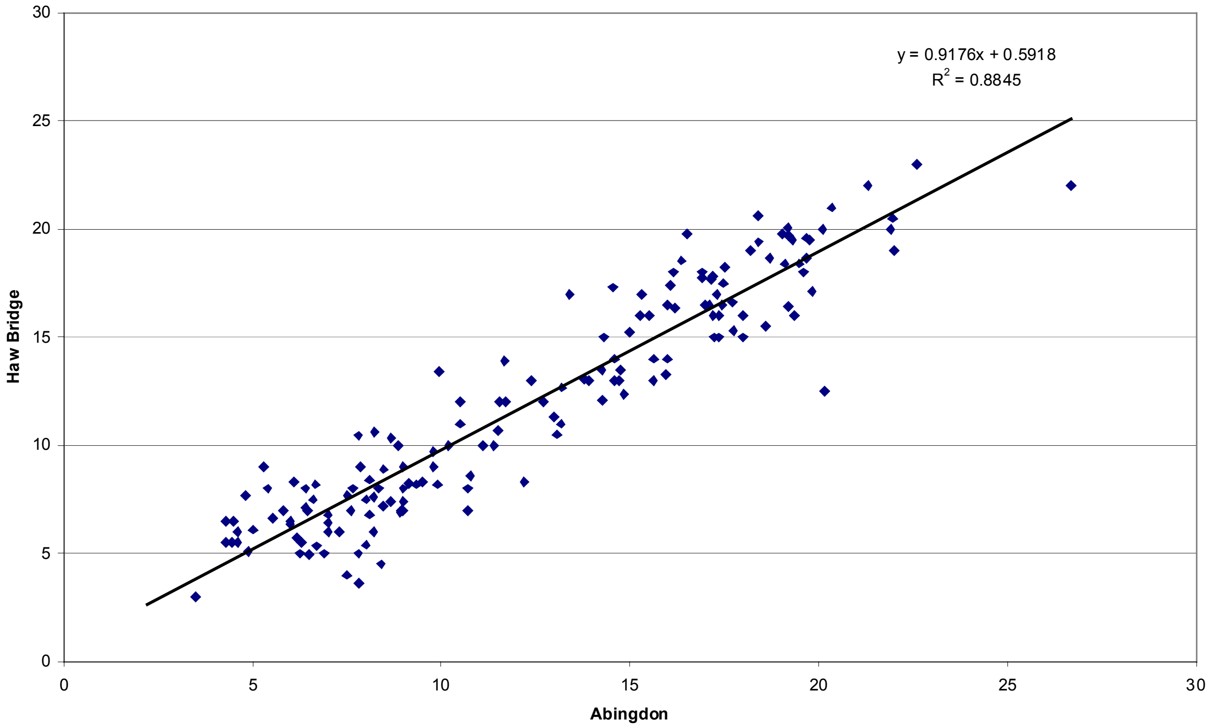


Figure 3.24 Regression analysis of River Thames at Abingdon (Type 8 Thames Region) versus River Severn at Haw Bridge (Type 8 Midlands Region)

3.4 Air temperature data

The Hadley Centre Central England Temperature (HadCET) dataset is already in the public domain, and holds monthly mean temperatures from 1659 and daily temperatures from 1772 (Parker *et al.* 1992). The HadCET area is roughly representative of a triangle enclosed by Bristol, Lancashire and London. Daily and monthly maximum and minimum temperatures have been calculated for the period beginning 1878 and monthly and annual gridded 5 x 5 km temperature datasets for the period 1961–2000 are freely available from the Met Office for research purposes. Information on the available data can be found on the Met Office website.

If additional MORECS data are required, costs for a licence have been quoted by the Met Office to be £5936.00 + VAT for weekly maximum and minimum temperatures covering all of England and Wales (130 squares) for the entire record available (1961–2006). Data for a shorter time period are also available at a reduced cost of £5147.00 + VAT for 1970–2006 and £3967.00 + VAT for 1980–2006. This licence is for a period of 5 years only and is subject to Met Office Terms and Conditions. Data should be delivered within 10 days of a request.

At a cost, the Met Office will also give consultancy advice on obtaining the most relevant data for a particular project if detailed information is provided on the aims and objectives.

4 Analysis and discussion

4.1 Analysis of monthly data

4.1.1 Regional analysis

Significant regional differences in river water temperature have been identified, with the highest values being recorded in the Thames (River Thames) and Anglian Regions (Rivers Stour and Ouse) and the lowest in the North East Region (River Tyne). While ANOVA revealed there to be significant differences in water temperature between most combinations of regions (Section 3.1.1), no significant differences were found between Anglian and Thames Regions, Midlands and Southern Regions, Midlands and South West Regions, Midlands and Wales Regions, and Southern and South West Regions. This result is not unexpected, with the more southerly regions (Anglian and Thames, Southern and South West) being more similar to each other in terms of water temperature than the northern regions (Midlands and Wales, North East and North West) and vice versa. The similarity between Midlands and Southern Regions, and Midlands and South West Regions, however, is surprising and not easily explained.

4.1.2 Type analysis within regions

River typology appears to have a significant effect on river water temperatures within regions, with ANOVA revealing significant differences in water temperature between river types for all regions apart from Anglian Region. This anomaly may be explained by lack of topographic range of the Anglian rivers, to the lack of rainfall and to the significant management of the Anglian rivers used in the analysis.In contrast within Welsh Region for example, the water temperature of Type 1 (low altitude, siliceous geology, small catchment size) rivers is different from that of Type 11 (mid altitude, calcareous, small catchment size) and Type 13 (mid altitude, siliceous, medium catchment size) rivers, but similar to all other types present in the region. As typology is derived from the combination of catchment altitude, geology and size, it is probably a combination of these factors that influences water temperature – no single factor has been identified as the major influence. For example, it is well known that the temperature regime of groundwater-fed chalk streams is relatively stable compared with that of clay or limestone rivers that receive less significant groundwater inputs (Mackey and Berrie 1991). Similarly, a large river will be less sensitive to air temperature fluctuations than a small headwater stream (Caissie *et al.* 1998).

As each region contained a different number and range of river types, meaningful comparisons cannot be made regarding which types differ most often within regions in terms of water temperature. In particular, high altitude sites were not well represented in the datasets collected and cannot be included in the conclusions. It is interesting to note that within Anglian Region there are apparently no differences in river water temperature related to type. All of the river types included in the Anglian analysis were classed as low altitude, whereas all possible geologies and sizes were covered. This might be the cause of the lack of differences in water temperature. However, similar types were included within the Thames Region analysis, which did show differences in water temperature related to type and between types of the same altitude. More detailed statistical analysis of the existing water temperature data stratified by catchment altitude, geology and size is required to further investigate the causes of the temperature differences.

4.1.3 Type analysis between regions

Statistical analysis revealed that the water temperature of all river types included in the analysis differs between regions. For example, the water temperature of a Type 2 river in Anglian Region is not the same as the water temperature of a Type 2 river in North East, North West, Southern, South West and Thames regions. Therefore, the effect of region on river water temperature revealed by the regional analysis appears to be stronger in some cases than the effects of river type (catchment altitude, geology and size).

As not all types were present in all regions, the number of regions compared for each type was not equal and conclusions cannot therefore be made regarding which types differ more often between regions in terms of water temperature. In particular, there was a lack of upland river sites suitable for inclusion in the analysis.

4.1.4 Moving average trends for each region

An upward trend in mean annual river water temperatures over the period of the temperature record was identified in all regions. In particular, all reaches of the River Thames (Thames Region) and River Tamar (South West Region) and most reaches in Anglian Region (Rivers Ouse and Stour) showed an increase in water temperature with time. The highest temperatures were more likely to be seen after 1990 and the coldest temperatures in the earlier part of the record (1970s and 1980s). Within rivers in the more northern regions such as the North East and North West Regions (Rivers Tyne and Ribble, respectively), the warming trend was less apparent and often seen only in the middle and lower reaches of the river. However, all rivers showed some evidence of a warming trend in the lower reaches, and the warmest years were again seen in the later part of the record. This confirms that river water temperatures are rising across the UK and suggests that such increases are likely to occur more often (but not exclusively) in the south and east of the country, and in the middle and lower reaches of the river.

4.1.5 Annual mean and decadal trend analysis

The trend in annual mean water temperatures for the benchmark site in each region (Figure 3.10) spans approximately 35 years (1970 to 2005). A temperature record of at least 100 years is ideally required to identify any warming trends that have occurred during the last century. However, a slight warming trend since approximately 1980 can be seen in nearly all regions, although this follows an apparent dip in annual mean temperatures during the 1970s. Annual mean temperatures from regions in the south and east of the country (e.g. Southern, Thames) tend to be higher than those in the north (e.g. North East). Mean annual temperatures in Wales and the North West are generally lower than other regions. The annual mean in Wales was notably lower in 1983 (along with that of North East Region) and 2001 when Southern Region and Anglian also exhibited significant lower annual means. It should be noted that the selection of only one benchmark site from each region might be misleading if the chosen site is not representative of the region as a whole (e.g. if artificial influences are affecting a site).

Figure 3.11 shows the mean annual temperature trend for each benchmark site individually, with the standard error of the mean (SEM) also plotted. This represents the standard deviation of the different sample means and tends to increase as the variability of the data increases and decrease as sample size increases. There is a general trend in the benchmark sites of the SEM to increase noticeably over the last 5 or 6 years of the record (since approximately 2000), particularly in Anglian, Southern and North West Regions. This might be a result of an increase in maximum water temperatures since this time, as confirmed by the slight warming trend identified in Figure 3.10.

The decadal trends in water temperature are shown in Figures 3.12 to 3.14 and Table 3.4. Between 1970 and 1980, the mean annual water temperature at most of the benchmark sites decreased, except in the Southern and Thames Regions. Between 1980 and 1990, and 1990 and 2000, mean annual water temperatures tended to increase, particularly between 1980 and 1990 (with the exception of the Thames at Caversham, which showed a slight decrease). It should be noted in Figure 3.14 that for two sites, the Dee in Welsh Region and the Stour in Anglian Region, the decadal water temperature is lower. No one region experienced consistently more rapid changes in water temperature than the others. The HadCET air temperature dataset shows a similar decadal pattern, suggesting that changes in river water temperature are comparable to changes in air temperature over a time period of several years.

4.1.6 Seasonal analysis

For the upper reach sites in Winter the River Test is significantly warmer, by 1 to 4 degrees, than the other rivers with the Tamar and Ouse generally being the next warmest. The River Tyne is generally colder, with the anomalies in 1988, 1989 and 1991 being due to missing data. For the lower reaches in winter the Rivers Test, Tamar and Thames have the highest temperatures from the late 1980s onwards. Prior to this the River Thames is significantly lower. The Rivers Ribble and Tyne have the lowest temperatures. The River Tyne has missing data in 1989.

Figures 3.17 and 3.18 show the upper and lower sites in spring. For the upper sites Aston Keynes has missing data from 1983 to 1998 and the Tyne has missing data in 1988 and 1989. The Tamar and Tyne are the coolest from the 1970s till the mid 1990s, after which it is the Tyne and Ribble which are the coolest till 2000, with the Severn and Ribble being the coldest from 2000 onwards. For the lower sites in spring the warmest rivers are the Stour, Thames and Ouse with these three rivers being noticeably warmer from the 1990s onwards with a pronounced upward trend. The coldest rivers are Tyne and Dee up until the 1990s, after which it is the Ribble and Tyne which are the coolest until 2000 when the Tyne becomes relatively warmer than the Test.

For the upper and lower reach comparisons on the Ouse, winter water temperatures are slightly higher for the upper reach site whereas spring and summer temperatures are higher for the lower reach site. Winter and autumn temperatures in the River Dee are very similar for both the upper and lower reach sites, but spring and summer water temperatures are higher at the lower reach sites. When comparing the lower and upper reach sites of the Ribble, the seasonal data are very similar from the 1970s through to the mid 1990s. From 1994 the spring and summer temperatures at the upper reach site are lower than those at the lower reach site.

For the Rivers Severn, Tyne and Tamar, winter and autumn temperatures are similar for the upper and lower reach sites whereas spring and summer temperatures are noticeably warmer at the lower reach sites. On the River Thames during the 1970s and 1980s, water temperatures are lower at the upper reach sites in the summer but similar during winter, spring and autumn. However, from 2000 onwards autumn temperatures are lower for the upper reach site and summer temperatures are 4 to 5 degrees lower at the upper reach site. The gradual rise in water temperature from 1970 to 2005, particularly during spring and summer, is very clear in the River Thames plot. For the River Test, winter temperatures are higher in the upper reach sites. Autumn temperatures for this river are similar at both sites and spring and summer temperatures are appreciably higher at the lower reach site.

For the individual river sites, as expected, the winter temperatures are generally the coolest followed by autumn and spring, with the summer being the warmest. Some inter-changeability occurs between winter and autumn temperatures on the River Ouse at Brackley, the Test at Polhampton and the Tyne at Wylam Bridge. Assessing the higher temperatures, the Rivers Test at Polhampton (upper reach) and Ribble at Sawley Bridge (lower reach) have overlap between the spring and summer temperatures.

Analysing the lower reach sites the Rivers Tamar and Test have the least seasonal temperature range and the Ouse, Ribble and Severn have the greatest. Of the upper reach sites the River Test has the least seasonal range and the Rivers Tyne, Thames and Ribble have the greatest range.

The moving average seasonal plots show a general upward trend in water temperature for both winter and spring. As expected, spring water temperatures are higher than winter water temperatures and rivers in the south, southeast and southwest of England are warmer than those in the northwest, northeast or Wales. Overall there appears to be evidence that the upper reaches (headwaters) are warming in winter and spring, whereas the lower reaches are warming in summer.

4.2 Analysis of daily data

4.2.1 Regional analysis

A strong effect of region on daily water temperatures was revealed by ANOVA, with significant differences between all four regions and combinations of regions included in the analysis (Midlands, North East, Thames and Wales). Therefore, river water temperature in Midlands Region is significantly different from river water temperature in North East Region, Thames Region and Wales; river water temperature in North East Region is significantly different from river water temperature in Midlands, Thames and Wales Regions and so on. Although water temperatures in the adjacent Midlands and Wales Regions might be expected to be similar, the results of the regional analysis are in overall support of the conclusions drawn from the monthly regional analysis; regional differences in river water temperature exist and temperatures in the southern and eastern parts of the country tend to differ from temperatures in the north and west. However, a much larger dataset of daily water temperature data from all eight regions is required before firm conclusions can be made.

4.3 Infilling water temperature time series

The R-squared results from the regression analysis suggest that there is a reasonable correlation in water temperature between sites of the same typology from different regions. However, it should be noted that this is not always the case, as demonstrated by the statistical analysis in Section 3.1.3. A good correlation in water temperature between two sites would allow infilling of missing data and the hindcasting of temperature data to simulate a water temperature time series. It is suggested that this type of regression can only be carried out for sites in adjoining regions and ideally those which are geographically close, although again it should be noted that water temperatures in adjoining regions will not necessarily be similar (see Section 3.1.1). It is also recommended that only sites of the same typology are included in this analysis.

4.4 Costs of external datasets

Many water temperature datasets held by external organisations were not freely available to the Environment Agency. The costs associated with obtaining such datasets varies according to the database size, ease of access and the number and length of records requested. Often, the charge is made for staff time to retrieve the records rather than for use of the data itself. For example, weekly river water temperature data are available from the ECN/CEH. Summary ECN data are freely available on the website, but raw data are only made available to other users via a licensing system and with agreement from ECN sponsors. Only academic users can receive the data free of charge while private requests attract a cost both from the sponsors and for CEH staff time in extracting the data. These costs were estimated to be in the region of £150 to £500 depending on the number and type of sites required, and at least 3 weeks is required to fulfil any data requests. There is also an additional requirement for the agreement of the data owner in the case of most datasets, such as datasets from the Lowland Catchment Research programme (LOCAR) and the Catchment Hydrology And Sustainable Management (CHASM) project.

The CEH was found to be the main source of water temperature data that is not freely available and is known to hold some good long-term water temperature datasets that it would be appropriate to extract. Other organisations that will release water temperature data with a likely cost include the Freshwater Biological Association (FBA) at Windermere, and the University College London Acid Waters Monitoring Network (lake data). Details of external datasets and associated costs can be found in Appendix B.

In addition to the problem of costs, it is likely that data requests to external organisations will take several weeks to be fulfilled.

4.5 Maintenance of the archive

Maintaining a national water temperature archive for the sites and rivers identified and included in the analysis should be a relatively simple task. It would require time to be set aside to contact the data owners for regular updates with the most recent data, ideally every 6 months. The majority of the monthly sites are monitored by the Environment Agency and stored on the WIMS database, requiring a simple update at no cost other than the time required. The daily data were obtained from different sources within the Environment Agency and would require more time per site to contact the data owner and obtain the most recent monitoring data. However, there are a relatively small number of daily sites to be kept updated. Should any data in future be obtained from external organisations, these would also need to be contacted for regular updates. It should be considered that updates from external organisations might be associated with a financial cost.

4.6 Gap analysis

During the course of the project, a number of gaps have been identified in terms of data requirements and additional analyses. These are as follows:

1. *Availability of good quality long-term temperature data* (ideally, records spanning at least 100 years). For example, Webb and Nobilis (2007) analysed water temperature data collected from Austrian rivers over the period 1901 to 2001, allowing confident identification of a recent upward trend in river water temperatures. The longest temperature records included in this study ran from the early 1970s to the end of 2005, although a few sites began in the 1960s (North West and South West Regions, Wales).
2. *Frequency of monitoring*. Ideally, temperature should be monitored daily, but at the very least monthly.
3. *Data quality*. Regardless of the length and monitoring frequency of the dataset, the quality is extremely important. Most of the temperature records analysed in this project had gaps in the time series, with months during which no temperatures were recorded. In general, a complete monthly temperature dataset would be preferable to a daily dataset with missing months or years.
4. *River typology*. In order to better analyse the effects of river type on water temperature, full water temperature records for every type present in every region are required. This was not available for this study.

5. *Lake temperature analysis*. This project has already identified suitable lake water temperature datasets. A similar analysis could therefore be undertaken for lake temperatures, and potentially extended to other waterbody types such as estuaries.
6. *Air temperature analysis*. Local air temperatures could be regressed against river water temperatures to determine the relationship between the two. Air temperatures could then be used to hindcast water temperatures back in time before actual monitoring began, and also to model future water temperatures under climate change scenarios. This approach is advantageous because long-term air temperature data are more easily available than long-term water temperature data. Assessment of river water temperature data against local air temperature data for the same time period would be required for each site in order to assess the need for incorporation of a time lag into any model.
7. *Specific site details*. The analysis carried out on the temperature data does not account for any anthropogenic effects on the river water temperatures. In order to assess these effects specific site details need to be collated, which was not part of the brief for this project.

5 Conclusions

Mean river water temperature taken from a subset of rivers differs significantly between Environment Agency regions, with the largest difference of 2.5°C occurring between the Thames and North East Regions. In particular, the highest mean monthly water temperatures were found in the southeast of the UK (Anglian Region and Thames Region) and the lowest in the North East Region. Analysis of daily water temperatures shows the same trend, with significant temperature differences existing between all four regions included in the analysis.

Within the same region, river water temperatures also differ according to the WFD river typology. This is probably related to factors such as the catchment geology, altitude and size. However, the water temperature of all the river types included in the analysis differs between regions, suggesting that the influence of region (geographic location) on river water temperature is often stronger than the influence of river type (catchment altitude, geology and size).

Moving average plots of water temperature data from the main river in each region have revealed an upward temperature trend over the last 20 to 30 years. This trend is particularly apparent in the Anglian, Thames and South West Regions, but is also seen in the lower reaches of the main river analysed in all regions. In addition, moving average seasonal plots from each main river identified a general upward trend in water temperature in winter and spring. The plots confirm that river water temperatures have increased in recent years, and suggest that the warming trend is likely to be more noticeable in the south and east of the UK and in the lower reaches of a river. It should however be noted that no uplands rivers were analysed as there was no temperature data available for these WFD river types.

Analysis of the mean annual and mean decadal water temperature trend for one benchmark site in each region also provides evidence that water temperatures have increased in recent decades, particularly since 1980. The decadal changes in river water temperature are comparable to the changes in air temperature seen during the same period. However, since most of the records analysed began in the 1970s or later, it was not possible to evaluate water temperature trends before this time.

It is important to note that there is an overall lack of high-quality, complete, long-term water temperature monitoring datasets, which has limited the analysis to some extent. Additional long-term water temperature data can be obtained from external organisations at a financial cost, but improved Environment Agency water temperature monitoring would be preferred. The costs of maintaining and updating a water temperature database in the future should not be prohibitively high and are mostly in the form of the staff time required.

Infilling and hindcasting of temperature data is possible if sites are geographically close and of the same typology. The appropriateness of such a methodology would, however, need to be tested for each donor and recipient site pairing to ensure that the resulting R-squared values from the regression analysis were high.

The river water temperature analysis carried out in this project could be built upon and extended to other types of waterbody such as lakes and estuaries, as detailed in the Recommendations.

6 Recommendations

The following recommendations can be made following the completion of this project:

1. Improve Environment Agency water temperature monitoring in terms of frequency, completeness of the time series and quality control. Consideration should also be given to equal representation of sites with regard to river type (catchment size, geology and altitude). High altitude sites in particular are currently not represented. The assessment of future indicator site monitoring requirements for river temperature data needs to be clearly quantified and qualified as the initial step for the next phase of the climate change impact on river temperature programme, particularly in the light of local influences such as significant abstractions and discharges.
2. Obtain urgently any relevant long-term water temperature datasets from external organisations such as CEH. This could be achieved by the establishment of an agreement with research councils and other organisations to share data for the use of non-profit-making projects and reports. Collate any further existing data which reportedly exists, such as daily data for Anglian Region.
3. Maintain a water temperature archive to include regular updates of the best sites identified by this project (as a website or database). This will produce long-term water temperature records for future analysis, and the costs and time required should be relatively small.
4. Undertake more detailed analysis of river water temperature in terms of seasonal trends in warming, to determine whether warming is occurring at a greater rate in summer or winter.
5. Complete the water temperature analysis for lakes using similar analysis techniques to those used for rivers, although the amount of available lake temperature data is smaller. Follow up proposed co-ordination of results from LDMS.
6. Extend the project to cover estuarine and tidal sites.
7. Further investigate the potential of air temperature analysis. Air temperatures could potentially be used to hindcast river water temperatures to create a longer time series, and for modelling of future water temperatures under a climate change scenario. The majority of the air temperature data required for such modelling is likely to be freely available from the Met Office.
8. Specific details for each site need to be collated in order to identify any anthropogenic effects on water temperatures.
9. Assess the effect of temperature changes on ecology. The effects of increased water temperatures on ecology was not part of the current study, but would logically be part of the next phase of work. This would include links to growing seasons, thermal refugia and lethal thresholds.
10. Consideration of adaptive measures. If climate change is significantly affecting water temperature, what can be done to reduce any detrimental effects? What are the costs and benefits of such actions? The effects of land use on water temperature also need to be assessed.

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List of abbreviations

ANOVA	Analysis of Variance
CCC	Canadian Center of Climate Modelling
CCW	Countryside Council for Wales
CEH	Centre for Ecology and Hydrology
CHASM	Catchment Hydrology And Sustainable Management
ECN	Environmental Change Network
FBA	Freshwater Biological Association
GCM	General Circulation Model
HadCET	Hadley Centre Central England Temperature dataset
LDMS	Lake Dynamics Monitoring Stations
LOCAR	Lowland Catchment Research programme
MORECS	Meteorological Office Rainfall and Evaporation Calculation System
NAO	North Atlantic Oscillation
NERC	Natural Environment Research Council
SEM	Standard Error of Mean
SPSS	Statistical Package for the Social Sciences
TIMS	Tideway Information Management System
Tukey's HSD	Tukey's Honestly Significant Difference test
WFD	Water Framework Directive
WIMS	Water Information Management System
WISKI	Water Information Management System Kisters

Appendix A

Pro forma for data collection

TEMPERATURE RECORD PRO FORMA	
A. General information	
Region name	River/lake name
Site name	Grid reference
Contact details (name, phone, email)	
B. Sample information	
Sampling frequency	Length of record (dates)
Is the record continuous? If not, where do gaps of > 1 month exist?	
Has any Quality Assurance been done?	
Reason for data collection	
Other data recorded at site	
C. Data availability	
Storage medium (electronic/paper) and format. Please provide a sample if possible.	
Storage location (central database, local hard drive etc)	
Is the dataset easily accessible? If not, please indicate why.	
Are the data in the public domain or is there a cost? Please indicate any likely costs	
D. Information to be completed for lakes only	
Sampling depth	

Appendix B

List of river and lake water temperature monitoring sites

Anglian River

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Twerton	Anglian	3479 sites	Included	NA	Varies	1981–2005	Varies	Yes – MIDAS	Multiple	Electronic – Oracle downloaded as Access	Twerton	Good	None
Anglian Water Services Ltd	Anglian	Approx 3 sites	Unknown	Unknown	Weekly	Very long	Yes	Unknown	Water company monitoring	Excel or other MS Office	Anglian Water	Good	Unknown

Anglian Lake

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Twerton	Anglian	263 sites	Included	Unknown	Varies	1981–2005	Varies	Yes – MIDAS	Multiple	Electronic – Oracle downloaded as Access	Twerton	Good	None

Midlands River

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Twerton	Midlands	3334 sites	Included	NA	Varies	1987–2005	Varies	Yes – MIDAS	Multiple	Electronic – Oracle downloaded to us as Access	Twerton	Good	None
EA	Midlands	Severn – Abermule	SO16469579	NA	Daily means	1975–present	No – small gaps due to breakdown	Unknown	Fisheries	Electronic – Excel	National Fisheries Technical Team	Good	None
EA	Midlands	Severn – Bewdley	SO78157622	NA	Daily means	1975–present	No – small gaps due to breakdown	Unknown	Fisheries	Electronic – Excel	National Fisheries Technical Team	Good	None
EA	Midlands	Teme – Bransford	SO80385324	NA	Daily means	1975–present	No – small gaps due to breakdown	Unknown	Fisheries	Electronic – Excel	National Fisheries Technical Team	Good	None
EA	Midlands	Clywedog – Bryntail	SN91368678	NA	Daily means	1989–present	No – small gaps due to breakdown	Unknown	Fisheries	Electronic – Excel	National Fisheries Technical Team	Good	None
EA	Midlands	Avon – Evesham	SP04014376	NA	Daily means	1975–present	No – small gaps due to breakdown	Unknown	Fisheries	Electronic – Excel	National Fisheries Technical Team	Good	None
EA	Midlands	Vyrnwy – Meifod	SJ15631292	NA	Daily means	1975–present	No – small gaps due to breakdown	Unknown	Fisheries	Electronic – Excel	National Fisheries Technical Team	Good	None
EA	Midlands	Severn – Montford	SJ41191445	NA	Daily means	1975–2002	No – small gaps due to breakdown	Unknown	Fisheries	Electronic – Excel	National Fisheries Technical Team	Good	None
EA	Midlands	Severn – Saxon's Lode	SO86333905	NA	Daily means	1975–present	No – small gaps due to breakdown	Unknown	Fisheries	Electronic – Excel	National Fisheries Technical Team	Good	None
EA	Midlands	Severn – Shelton (not in use since 1988)	SJ48881273	NA	Daily means	1975–1988	No – small gaps due to breakdown	Unknown	Fisheries	Electronic – Excel	National Fisheries Technical Team	Good	None
EA	Midlands	Severn – Welsh Bridge	SJ48881273	NA	Daily means	1989–present	No – small gaps due to breakdown	Unknown	Fisheries	Electronic – Excel	National Fisheries Technical Team	Good	None
ECN website	Midlands	Bradgate Brook	452200 3099	NA	Weekly	1988–2003	Yes	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£150 to extract all
ECN website	Midlands	Lathkill	422000 364700	NA	Weekly	1987–2003	Yes	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£150 to extract all
LOCAR	Midlands	Coal Brook – Market Drayton	369300 334100	NA	15 min	15/10/2002–08/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	Midlands	Tern – Ternhill	362800 331500	NA	15 min	19/10/2002–08/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	Midlands	Tern – Eaton on Tern	364900 323200	NA	15 min	09/10/2002–08/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	Midlands	Tern – Norton-in-Hales	370700 338500	NA	15 min	15/10/2002–08/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	Midlands	Potford Brook – Sandyford Bridge	363400 322200	NA	15 min	16/10/2002–08/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	Midlands	Bailey Brook – Ternhill	362800 331500	NA	15 min	19/10/2002–08/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission

Midlands Lake

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Twerton	Midlands	78 sites	Included	Unknown	Varies	1999–2005	Varies	Yes – MIDAS	Multiple	Electronic – Oracle downloaded to us as Access	Twerton	Good	None

North East River

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Twerton	North East	3652 sites	Included	NA	Varies	1965–2005	Varies	Yes – MIDAS	Multiple	Electronic – Oracle downloaded to us as Access	Twerton	Good	None
EA Northumbria	North East	River Tyne – Ugly Dub, Bywell, Haydon Bridge	NA	NA	Daily mean	1993–present	Unknown	Unknown	Monitoring	pdfs	EA Northumbria	Good	None
EA	North East	River Tees – Tees Barrage	NZ 463190	NA	Hourly	1995–present	Some gaps due to logger failure	No	Water temp/fish growth study	Excel	Local and central database	Reasonable	None
EA	North East	River Tees – Yarm	NZ 417132	NA	Hourly	1995–present	Some gaps due to logger failure	No	Water temp/fish growth study	Excel	Local and central database	Reasonable	None
EA	North East	River Tees – Low Worsall	NZ 392103	NA	Hourly	1995–present	Some gaps due to logger failure	No	Water temp/fish growth study	Excel	Local and central database	Reasonable	None
EA	North East	River Tees – Low Moor	NZ 365105	NA	Hourly	1995–present	Some gaps due to logger failure	No	Water temp/fish growth study	Excel	Local and central database	Good	None
EA	North East	River Tees – Croft	NZ 290098	NA	Hourly	1995–present	Some gaps due to logger failure	No	Water temp/fish growth study	Excel	Local and central database	Reasonable	None
EA	North East	River Tees – Barnard Castle	NZ 045167	NA	Hourly	1995–present	Some gaps due to logger failure	No	Water temp/fish growth study	Excel	Local and central database	Good	None
EA	North East	River Tees – Middleton In Teesdale	NY 948251	NA	Hourly	1995–present	Some gaps due to logger failure	No	Water temp/fish growth study	Excel	Local and central database	Good	None
EA	North East	River Humber – Corporation Pier	TA 100 282	NA	30 mins	19/12/1991–present	13/09/1994–23/07/1995 and 17/8/2000–19/9/2000	Yes	Monitoring oxygen sag	Electronic – WISKI	WISKI	Good	None
EA	North East	River Ouse – Cawood Bridge	SE 574 378	NA	30 mins	06/07/1992–present	15/12/1994–12/2/1995 and 25/10/2001–11/01/2002	Yes	Monitoring oxygen sag	Electronic – WISKI	WISKI	Good	None
EA	North East	River Humber – Blacktoft Jetty	SE 843 242	NA	30 mins	10/09/1991–present		Yes	Monitoring oxygen sag	Electronic – WISKI	WISKI	Good	None
EA	North East	River Tyne – Swing Bridge	NZ 25228 63717	NA	30 mins	1995–present	14/11/1997–18/5/1998 and 2/10/1998–1/4/1999	Yes	Monitoring oxygen sag	Electronic – WISKI	WISKI	Good	None
ECN website	North East	Coquet	4236 6050	NA	Weekly	1992–2005	Yes	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£150 to extract all
ECN website	North East	Esk	48685 50816	NA	Weekly	1994–2005	Yes	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£150 to extract all
ECN website	North East	Trout Beck	3758 5335	NA	Continuous hourly	1997–2004	Yes	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£250 + VAT
CEH (UKEDI)	North East	Tees	3 sites	NA	Sampling frequency unknown	1991–1998	Unknown	Unknown	Effect of barrage on coarse fish	Excel	Hard disk CEH Dorset	Raw data not accessible	Unknown
CEH Land Ocean Interaction Study (LOIS)	North East	Hundreds of sites, Humber Basin	NA	NA	15 min to monthly	1980s onwards	No – random intervals	QC'd	LOIS	Central Oracle database	CEH Wallingford	Visit required	Possible charge for staff time

North East Lake

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Twerton	North East	33 sites	Included	Unknown	Varies	1979–2005	Varies	Yes – MIDAS	Multiple	Electronic – Oracle downloaded to us as Access	Twerton	Good	None

North West River

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Twerton	North West	3073 sites	Included	NA	Varies	1960–2005	Varies	Yes – MIDAS	Multiple	Electronic – Oracle downloaded to us as Access	Twerton	Good	None
EA	North West	River Lune – Lyon Bridge	SD 5815 6971	NA	Variable	Feb 80–Dec 99 (may be available after this date)	No	Not known	Not known	Excel	Local hard drive	Good	None
EA	North West	River Lune – Forge Weir	SD 51342 64716	NA	Hourly	1999–present	Some gaps > 1 month (2000 and 2004)	Probe calibrated every 3–6 months	Fish movement	Mostly electronic excel	Local external drive	Yes	None
EA	North West	River Esk – Cropple How	SD 13100 97770	NA	15-minute	15/11/1989–26/11/2004	Some gaps	Not for temp. – poor condition	Water quality	Electronic – WISKI	WISKI	Good	None
EA	North West	River Duddon – Duddon Hall	SD 19560 89570	NA	15-minute	20/11/1994–09/11/2004	Some gaps	Not for temp. – poor condition	Water quality	Electronic – WISKI	WISKI	Good	None
EA	North West	River Mersey – Westy	SJ 6283 8835	NA	15-minute	07/01/1992 onwards	Some gaps	Not for temp. – poor condition	Water quality	Electronic – WISKI	WISKI	Good	None
ECN website	North West	Eden	3604 5282	NA	Weekly	1995–2005	No – 2001 missing	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£150 to extract all
CHASM	North West	Eden – Artlegarth Beck, Gais Gil	371400 501100	NA	15 min	Not in use yet	Yes apart from equipment failure	No	CHASM	Electronic csv	Database	Not available yet	Not available yet
CHASM	North West	Eden – Smithfield farm	375300 513000	NA	15 min	Data not yet available	Yes apart from equipment failure	No	CHASM	Electronic csv	Database	Not available yet	Not available yet
CHASM	North West	Eden – The Flothers	369900 576600	NA	15 min	Data not yet available	Yes apart from equipment failure	No	CHASM	Electronic csv	Database	Not available yet	Not available yet
CHASM	North West	Eden – Blind Beck, G. Musgrave	375400 513100	NA	15 min	Not in use yet	Yes apart from equipment failure	No	CHASM	Electronic csv	Database	Not available yet	Not available yet
CHASM	North West	Eden – Appleby	368200 520300	NA	15 min	Not in use yet	Yes apart from equipment failure	No	CHASM	Electronic csv	Database	Not available yet	Not available yet

North West Lake

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Twerton	North West	190 sites	Included	Unknown	Varies	1978–2005	Varies	Yes – MIDAS	Multiple	Electronic – Oracle downloaded to us as Access	Twerton	Good	None
EA Warrington	North West	Bassenthwaite	NY 21304 29604	2	Hourly	1994–2005 (ongoing)	No – some months missing	No – not calibrated for temp	Monitoring	Electronic – Excel	EA Warrington	Good	None
EA Warrington	North West	Brotherswater	NY 40234 12571	1	Hourly	2002–2005 (ongoing)	No – some months missing	No – not calibrated for temp	Monitoring	Electronic – Excel	EA Warrington	Good	None
EA Warrington	North West	Buttermere	NY 18500 15000	1	Hourly	1997–2003 (ongoing)	No – some months missing	No – not calibrated for temp	Monitoring	Electronic – Excel	EA Warrington	Good	None
EA Warrington	North West	Elterwater	NY 32969 04186	2	Hourly	1994–2005 (ongoing)	No – some months missing	No – not calibrated for temp	Monitoring	Electronic – Excel	EA Warrington	Good	None
EA Warrington	North West	Ennerdale	NY 12331 14451	1	Hourly	1997–2005 (ongoing)	No – some months missing	No – not calibrated for temp	Monitoring	Electronic – Excel	EA Warrington	Good	None
EA Warrington	North West	Grasmere	NY 33619 06671	2	Hourly	1994–2005 (ongoing)	No – some months missing	No – not calibrated for temp	Monitoring	Electronic – Excel	EA Warrington	Good	None
EA Warrington	North West	Loweswater	NY 12687 21616	2	Hourly	1996–2005 (ongoing)	No – some months missing	No – not calibrated for temp	Monitoring	Electronic – Excel	EA Warrington	Good	None
EA Warrington	North West	Ullswater North Basin	NY 44431 20458	2	Hourly	1997–2005 (ongoing)	No – some months missing	No – not calibrated for temp	Monitoring	Electronic – Excel	EA Warrington	Good	None

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Warrington	North West	Ullswater South Basin	NY 38987 17544	2	Hourly	1997–2005 (ongoing)	No – some months missing	No – not calibrated for temp	Monitoring	Electronic – Excel	EA Warrington	Good	None
EA Warrington	North West	Coniston	SD 30807 95940	1	Hourly	2002–2005 (ongoing)	No – some months missing	No – not calibrated for temp	Monitoring	Electronic – Excel	EA Warrington	Good	None
ECN website	North West	Esthwaite	3360 4972	Unknown	Fortnightly	1994–2004	Yes	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£250 + VAT
ECN website	North West	Scoat Tarn	3159 5104	Unknown	Fortnightly	1989–1999	Yes	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£150 to extract all
ECN website	North West	Windermere North and South	3382 5007	Unknown	Fortnightly	1994–2004	Yes	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£500 + VAT
CEH (UKEDI)	North West	Windermere	Unknown	Unknown	Daily	1985 onwards	Unknown	Unknown	Background environmental data	Unknown	Unknown	Raw data not accessible	Unknown
CEH (UKEDI)	North West	Bassenthwaite, Derwent, Blelham Tarn, Esthwaite, Grasmere	Unknown	Unknown	Fortnightly	1990 onwards	Unknown	Unknown	Routine lakes monitoring	Oracle	Hard disk CEH Lancaster	Raw data accessible	Unknown
CEH (UKEDI)	North West	Windermere	Unknown	Unknown	Monthly	1992–1998	Unknown	Unknown	Survey of cladophora in Windermere	Excel	Julie Parker network drive	Raw data not accessible	Unknown
CEH (UKEDI)	North West	Esthwaite	Unknown	Unknown	15-min	1992–1998	Unknown	Unknown	Study of Esthwaite Water	Unknown	Unknown	Raw data not accessible	Unknown
CEH (UKEDI)	North West	Windermere – Wray Castle and Back Bay	Unknown	Unknown	Daily	1930–1933	Unknown	Unknown	Study of Windermere	Unknown	Unknown	Raw data not accessible	Unknown
FBA	North West	Windermere – Wrays Castle and Ferry House	Unknown	Unknown	Daily/working days	1933 onwards (2 sites overlap, continuous record with both)	Yes	Yes – some already published	Monitoring	Excel	FBA Cumbria	Legal agreement not in place but theoretically possible	Likely but cost unknown
CEH	North West	Windermere North and South Basins, Esthwaite Water, Blelham Tarn	Unknown	Profiles	Weekly or fortnightly	1947 onwards	Generally OK	Unknown	Cumbrian Lakes monitoring	Unknown	Unknown	Unknown	Unknown
CEH	North West	Grasmere	Unknown	Profiles	Weekly or fortnightly	1969 onwards	Generally OK	Unknown	Cumbrian Lakes monitoring	Unknown	Unknown	Unknown	Unknown
CEH	North West	Derwent Water, Bassenthwaite Lake	Unknown	Profiles	Weekly or fortnightly	July 1990 onwards	Generally OK	Unknown	Cumbrian Lakes monitoring	Unknown	Unknown	Unknown	Unknown
CEH	North West	Windermere Back Bay (Mitchell Wyke)	Unknown	Surface	Daily	1933 onwards	Gaps especially at weekends/holidays	Unknown	Cumbrian Lakes monitoring	Unknown	Unknown	Unknown	Unknown
CEH	North West	Esthwaite	Unknown	Surface	15-min	November 1992 onwards	Generally OK	Unknown	Cumbrian Lakes monitoring	Unknown	Unknown	Unknown	Unknown
University Colege London (UCL), Environmental Change Research Centre (ECRC), Acid Waters Monitoring	Various, upland	Approx. 10 lakes	Unknown	1	2-hourly	7-yrs	Unknown	Unknown	Acid Waters Monitoring Network	Access	UCL	Reasonable	Yes, but cost unknown

Southern River

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Twerton	Southern	1305 sites	Included	NA	Varies	1974–2005	Varies	Yes – MIDAS	Multiple	Electronic – Oracle downloaded to us as Access	Twerton	Good	None
EA Kent	Southern	100s of sites	NA	NA	Mostly monthly	Varies but some back to 1976	Unknown	Unknown	Monitoring	Electronic	EA Kent water quality teams	Good	None
ECN website	Southern	Eden	5520 1438	NA	Weekly	1998–2005	Yes	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£150 to extract all
ECN website	Southern	Old Lodge	5457 1294	NA	Weekly	1988–2003	Yes	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£150 to extract all
CEH (UKEDI)	Southern	Rivers Test, Itchen and Meon	Unknown	NA	Variable	03/1979–03/1980	Unknown	Unknown	Ecological study of chalk streams	Unknown	Unknown	Raw data not accessible	Unknown

Southern Lake

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Twerton	Southern	22 sites	Included	Unknown	Varies	1982–2005	Varies	Yes – MIDAS	Multiple	Electronic – Oracle downloaded to us as Access	Twerton	Good	None

South West River

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Twerton	South West	5706 sites	Included	NA	Varies	1965–2005	Varies	Yes – MIDAS	Multiple	Electronic – Oracle downloaded to us as Access	Twerton	Good	None
ECN website	South West	Exe	2936 1016	NA	Weekly	1994–2005	Yes	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£150 to extract all
ECN website	South West	Frome	3891 8670	NA	Weekly	1994–2005	Yes	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£150 to extract all
LOCAR	South West	Bere Stream – Snatford Bridge	385575, 092975	NA	15 minutes	13/11/2002–09/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	South West	Bovington Stream – Blindmans Wood	384175, 087800	NA	15 minutes	01/10/2002–09/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	South West	Devils Brook – Dewlish village	377800, 098500	NA	15 minutes	23/11/2002–09/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	South West	Frome – East Stoke	386725, 086850	NA	15 minutes	30/08/2002–09/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	South West	Frome – Loudsmill	370850, 090475	NA	15 minutes	02/10/2002–09/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	South West	Frome – Chilfrome	359050, 099125	NA	15 minutes	03/02/2003–09/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	South West	Piddle – Baggs Mill	391325, 087600	NA	15 minutes	30/10/2003–09/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	South West	Piddle – Briantspuddle	382125, 093450	NA	15 minutes	23/11/2002–09/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	South West	Piddle – Little Puddle	371850, 096450	NA	15 minutes	31/10/2002–09/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	South West	Sydling Water – Sydling St. Nicholas	363225, 099900	NA	15 minutes	23/12/2002–09/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	South West	Hooke – Maiden Newton	359475, 097600	NA	15 minutes	05/03/2003–09/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
CEH (UKEDI)	South West	River Wylye	Unknown	NA	Annually	10/1996 onwards	Unknown	Unknown	Grayling population study	Access/Excel	Hard disk CEH Dorset	Raw data not accessible	Unknown
CEH (UKEDI)	South West	Mill Stream	Unknown	NA	Weekly	1991–1997	Unknown	Unknown	Chemical sampling	Excel	Network Drive CEH Dorset	Raw data accessible	Unknown
CEH (UKEDI)	South West	East Stoke Flume, River Frome	Unknown	NA	Daily max and min	1973–1989	Unknown	Unknown	River Frome environmental data	Unknown	Unknown	Raw data not accessible	Unknown
CEH (UKEDI)	South West	River Frome, East Stoke	Unknown	NA	15 minutes	1995–present	Unknown	Unknown	River Frome salmon counter	Excel	Hard disk CEH Dorset	Raw data accessible	Unknown
CEH (UKEDI)	South West	Gussage Stream	Unknown	NA	Variable, not frequent	1973–1976	Unknown	Unknown	Ecological recovery of Gussage Stream	Unknown	Unknown	Raw data not accessible	Unknown
University of Exeter	South West	17 tributaries	NA	NA	15 minutes to hourly	1976/1977 onwards	No	Not all	Research	Electronic	Exeter	Will not pass onto third parties	N/A
Bournemouth and West Hants Water	South West	Knapp Mill	Unknown	NA	15 minutes	2004–present	Unknown	Checked by Environment Agency	Water company monitoring	Unknown	Unknown	Unknown	Unknown
EA	South West	Hampshire Avon – Amesbury	SU 151413	NA	15 minutes	13/02/2004–present	Unknown	No	Unknown	Electronic	WISKI	Good	None
EA	South West	Hampshire Avon – East Mills	SU 158144	NA	15 minutes	18/05/2004–present	Unknown	No	Unknown	Electronic	WISKI	Good	None
EA	South West	River Stour – Hammoon	Unknown	NA	15 minutes	24/03/2004–present	Unknown	No	Unknown	Electronic	WISKI	Good	None
EA	South West	River Stour – Throop	Unknown	NA	15 minutes	24/05/2000–present	Unknown	No	Unknown	Electronic	WISKI	Good	None
EA	South West	River Tamar shellfish	SX4380061000	NA	Approx monthly	20/04/1999–present	Some gaps (missing months)	Unknown	Unknown	Electronic	WISKI	Good	None
EA	South West	RIver Tamar – Gunnislake Bridge	SX4349372436	NA	Variable (every 3 days to monthly)	08/01/1986–present	Occasional missing months	Unknown	Unknown	Electronic	WISKI	Good	None
EA	South West	River Tavy–Lopwell Dam	SX4750065038	NA	Variable (weekly to monthly)	09/01/1986–present	Occasional missing months	Unknown	Unknown	Electronic	WISKI	Good	None

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA	South West	Hampshire Avon – East Mills	SU15871430	NA	15 minutes	18/05/04–present	Gaps	Yes	Fisheries	Electronic	WISKI	Good	None
EA	South West	River Stour – Throop	SZ11309580	NA	15 minutes	24/05/00–present	Gaps	Yes	Fisheries	Electronic	WISKI	Good	None

South West Lake

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Twerton	South West	222 sites	Included	Unknown	Varies	1981–2005	Varies	Yes – MIDAS	Multiple	Electronic – Oracle downloaded to us as Access	Twerton	Good	None

Thames River

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Twerton	Thames	2086 sites	Included	NA	Varies	1972–2005	Varies	Yes – MIDAS	Multiple	Electronic – Oracle	Twerton	Good	None
EA Thames	Thames	70 sites, Thames and tribs (Tideway Information Management System)	NA	NA	15 mins–1 hour	10 + years back	Some downtimes	No – raw data, health warning!	Monitoring	Excel	Reading	Good	None
EA	Thames	River Thames – Teddington	TQ 1670 7150	NA	Up to 24 hourly readings per day (automatic)	June 86–Dec 2000 (may be available after this date)	Oct–-Dec 1986; Apr–-May 1988; Jan–Dec 1991; Apr 1992; Feb–May 1995; Aug–Dec 2000	Not known	Not known	Excel	Local hard drive	Good	None
ECN website	Thames	Coln	4204 1988	NA	Weekly	1998–2005	No – 2001 missing	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£150 to extract all
ECN website	Thames	Lambourn	4453 1691	NA	Weekly	1998–2005	Yes	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£150 to extract all
LOCAR	Thames	Lambourn – East Shefford	438950, 174550	NA	15 min	03/08/2003	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	Thames	Lambourn – Shaw	447000, 168200	NA	15 min	04/11/2003	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	Thames	Pang – Bucklebury	455300, 171000	NA	15 min	30/10/2002–31/08/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	Thames	Pang – Frilsham (Parsonage)	453750, 173000	NA	15 min	14/10/2002	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	Thames	Pang – Tidmarsh Mill	463600, 174775	NA	15 min	30/10/2002	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
LOCAR	Thames	Pang – below Blue Pool	458675, 171850	NA	15 min	03/08/2003–29/08/2006	Yes	No	LOCAR	Oracle csv	CEH Wallingford	Good	No but requires permission
CEH (UKEDI)	Thames	Lambourn	Unknown	NA	Monthly	03/1994–03/1997	Unknown	Unknown	Ecological study of chalk streams	Unknown	Unknown	Raw data not accessible	Unknown
CEH (UKEDI)	Thames	Coln	Unknown	NA	Monthly	03/1978–03/1979	Unknown	Unknown	Ecological study of chalk streams	Unknown	Unknown	Raw data not accessible	Unknown

Thames Lake

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Twerton	Thames	106 sites	Included	Unknown	Varies	1979–2005	Varies	Yes – MIDAS	Multiple	Electronic – Oracle downloaded to us as Access	Twerton	Good	None

Wales River

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Twerton	Wales	1436 sites	Included	NA	Varies	1962–2005	Varies	Yes – MIDAS	Multiple	Electronic – Oracle downloaded to us as Access	Twerton	Good	None
ECN website	Wales	Wye	3536 2099	NA	Weekly	1994–2005	Yes	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£150 to extract all
CEH (UKEDI)	Wales	Afon Hore, Afon Haffren, Afon Cwm	Unknown	NA	Sampling frequency unknown	Dates unknown	Unknown	Unknown	Afon Cwm fish counter	Excel	Hard disk CEH Dorset	Raw data not accessible	Unknown
CHASM	Wales	Severn – Dulas at Cenarth Mill	29755 27767	NA	15 min	14/03/2003–present	Yes apart from equipment failure	No	CHASM	Electronic csv	Database	Good	Permission required, possible charge
CHASM	Wales	Severn – Dulas – Nant Waun-fach	29660 27790	NA	15 min	14/03/2003–present	Yes apart from equipment failure	No	CHASM	Electronic csv	Database	Good	Permission required, possible charge
CHASM	Wales	Severn – Dulas – Nant y Saeson	29490 27685	NA	15 min	14/03/2005–present	Yes apart from equipment failure	No	CHASM	Electronic csv	Database	Good	Permission required, possible charge
CHASM	Wales	Severn – Lower Hafren	28430 28780	NA	15 min	8/3/05–28/9/05	Yes apart from equipment failure	No	CHASM	Electronic csv	Database	Good	Permission required, possible charge
CHASM	Wales	Severn – Tanllwyth	28400 28770	NA	15 min	8/3/05–28/9/05	Yes apart from equipment failure	No	CHASM	Electronic csv	Database	Good	Permission required, possible charge
CHASM	Wales	Severn – Upper Hafren	28280 28930	NA	15 min	8/3/05–10/8/05	Yes apart from equipment failure	No	CHASM	Electronic csv	Database	Good	Permission required, possible charge
EA	Wales	River Tryweryn downstream Llyn Celyn (Dee)	SH 880 399	NA	Daily max/min (continuous chart) 1979–2000	Jul 1979–Jan 2000	Apr 1990–June 1995 – gaps > 1 month	Checked 2003 onwards	Post-regulation monitoring programme	Excel	Local hard drive	Good	None
EA	Wales	River Tryweryn downstream Llyn Celyn (Dee)	SH 880 399	NA	15-min readings (automatic) 2003–present	Oct 2003–present	Apr 1990–June 1995 – gaps > 1 month	Checked 2003 onwards	Post-regulation monitoring programme	Excel	Local hard drive	Good	None
EA	Wales	River Dee – Bala sluices	SH 936 356	NA	Daily max/min (continuous chart)	1990–2000	1990–2000	Checked 2003 onwards	Post-regulation monitoring programme	Excel	Local hard drive	Good	None
EA	Wales	River Dee – Bala sluices	SH 936 356	NA	15-min readings (automatic)		2003–present	Checked 2003 onwards	Post-regulation monitoring programme	Excel	Local hard drive	Good	None
EA	Wales	River Dee – Manley Hall	SJ 3481 4146	NA	Daily max/min (continuous chart) 1965–1999	2003–present	Feb–May 2005 – gaps > 1 month	Checked 2002 onwards	Post-regulation monitoring programme	Excel	Local hard drive	Good	None
EA	Wales	River Dee – Manley Hall	SJ 3481 4146	NA	15-min readings (automatic) 2002–present	June 2002–present	Feb–May 2005 – gaps > 1 month	Checked 2002 onwards	Post-regulation monitoring programme	Excel	Local hard drive	Good	None
EA	Wales	River Wye – Redbrook	SO 5286 1108	NA	Daily 9am	Jan 96–Dec 2000 (may be data available after this date)	Oct–Nov 2000 – gaps > 1 month	Some checking for spurious readings	Not known	Excel	Local hard drive	Good	None
EA	Wales	River Taff – Blackweir	ST17060 78053	NA	30 min – hourly	1993–present	1996 monthly means only, 1997 missing Aug–Dec	Some cross checking	Cardiff Bay fisheries monitoring project	Electronic – Excel	Local G drive	Good	None
EA	Wales	Wye – Belmont	SO 48500 38799	NA	15-minute	14/01/1997–present	Oct-Dec 1997	Up to 2000	Unknown	Electronic	WISKI	Good	None
EA	Wales	Usk – Trallong	SN 94726 29547	NA	15-minute	June 2004–present	Yes	No	Unknown	Electronic	WISKI	Good but not in public domain	None
EA	Wales	Wye – Llandewi	SO 10458 68284	NA	15-minute	Nov 2001–date	Jan–May 2004	No	Unknown	Electronic	WISKI	Good but not in public domain	None
EA	Wales	Wye – Redbrook	SO 52769 11077	NA	15-minute	Jan 1993–present	June–October 1993, May–September 1995	Up to 2001	Unknown	Electronic	WISKI	Good	None
EA	Wales	Wye – Erwood	SO 07580 44490	NA	15-minute	June 1993–Sept 1995	October 2000–July 2001	Up to 2001	Unknown	Electronic	WISKI	Good but not in public domain	None
EA	Wales	Tywi – Capel Dewi, Felin Mynachdy, Manoravon, Dolauhirion, Ystradffin	Various	NA	15-minute	01/06/1997–present	Yes	No	Unknown	Electronic	WISKI	Good	None
EA	Wales	Dee	SH 88077 39939	NA	15-minute	11/03–date	Unknown	Some	Unknown	Electronic	Unknown	Good	None

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA	Wales	Dee	SH 74087 35721	NA	15-minute	11/03–date	Unknown	Some	Unknown	Electronic	Unknown	Good	None
EA	Wales	Dee	SJ 34822 41459	NA	15-minute	06/02–date	Unknown	Some	Unknown	Electronic	Unknown	Good	None
EA	Wales	Dee	SJ 41764 60023	NA	15-minute	11/03–date	Unknown	Some	Unknown	Electronic	Unknown	Good	None
EA	Wales	Dee	SJ 29046 70696	NA	15-minute	12/95–date	Unknown	Some	Unknown	Electronic	Unknown	Good	None

Wales Lake

Data source	Region	Site name	Grid ref	Sampling depth (m)	Sampling frequency	Length of record	Continuous record?	QA/QC	Purpose	Storage medium	Storage location	Accessibility	Cost
EA Twerton	Wales	60 sites	Included	Unknown	Varies	1978–2005	Varies	Yes – MIDAS	Multiple	Electronic – Oracle downloaded to us as Access	Twerton	Good	None
ECN website	Wales	Llyn Llagi	2648 3484	Unknown	Fortnightly	1990–2005	No – 1991–1994 and 1996–1999 missing	Yes	Monitoring	Central Oracle database	CEH Lancaster	3 weeks	£150 to extract all

Appendix C

List of river sites analysed

Anglian Region

Site	NGR	Typology	Start date	End date	Missing data points
Monthly data					
R.Stour Gt.Bradley Hall Bridge	TL6755052328	2	15/03/1983	05/12/2005	94
R.Stour Gt.Wratting Ford	TL6912548424	2	15/04/1981	05/12/2005	29
R.Stour Kedington GS	TL7092145234	2	15/04/1981	05/12/2005	24
R.Stour Ashen Road Bridge Clare	TL7680044899	5	22/07/1981	07/12/2005	82
R.Stour Ballingdon Br.	TL8671740988	5	30/03/1981	02/12/2005	18
R.Stour Brundon Mill	TL8652442275	5	22/04/1981	02/12/2005	91
R.Stour Bures Br.	TL9061434062	5	15/04/1981	02/12/2005	24
R.Stour Flatford Mill Footbridge	TM0754333348	5	02/09/1981	14/12/2005	83
R.Stour Langham Intake	TM0260834523	5	30/03/1981	30/11/2005	5
R.Stour Liston Weir	TL8566044992	5	15/04/1981	02/12/2005	30
R.Stour Pentlow Br.	TL8109546410	5	15/04/1981	07/12/2005	24
R.Stour Pitmere Railway Bridge	TL8907136915	5	21/07/1981	02/12/2005	78
R.Stour Stratford St Mary Intake	TM0422534270	5	30/03/1981	15/12/2005	14
R.Stour Wixoe Wqms Intake Pier	TL7083643102	5	30/03/1981	15/12/2005	7
R.Stour Cattawade Intake	TM1003033044	0	30/03/1981	14/12/2005	19
R.Ouse A422 Rd.Br.Brackley	SP5942736819	2	23/04/1981	14/11/2005	30
R.Ouse A5 Rd.Br.Old Stratford	SP7813040962	5	21/05/1981	29/11/2005	39
R.Ouse B526	SP877874420	5	14/04/198	29/11/200	45

Site	NGR	Typology	Start date	End date	Missing data points
Rd.Br.Newport Pagnell	9		1	5	
R.Ouse Water Stratford Rd.Br.	SP6520534067	5	29/11/1994	14/11/2005	8
R.Ouse Wqms Foxcote Intake	SP7275534636	5	03/01/1986	14/11/2005	32
R.Ouse Clapham Intake	TL0360051600	8	30/11/1988	14/12/2005	34
R.Ouse Kempston Mill	TL0240047700	8	07/05/1981	13/12/2005	31
R.Ouse Newnham Ft.Fb.	TL0637249294	8	12/05/1981	13/12/2005	38
R.Ouse Offord Intake	TL2140066200	8	14/04/1981	17/11/2005	20
R.Ouse Ravenstone Mill	SP8540048600	8	07/05/1981	01/12/2005	88
R.Ouse Roxton Lock	TL1600053500	8	14/04/1981	13/12/2005	23
R.Ouse Sharnbrook Mill	TL0110059000	8	14/04/1981	01/12/2005	30
R.Ouse St Ives Rd.Br.	TL3130071200	8	21/04/1981	12/12/2005	58
R.Ouse Tyringham Bridge	SP8580046500	8	19/07/1984	05/12/2005	68
R.Ouse Eaton Socon Mill	TL1750058500	0	12/05/1981	06/12/2005	83
Running Waters Ruxox Bridge	TL0440036400	1	23/06/1981	08/12/2005	80
Running Waters A5120 Rd.Br.Flitwick	TL0290036400	1	23/06/1981	08/12/2005	133
Hundred Foot River Earith Rd.Br.	TL3940074700	2	21/04/1981	28/11/2005	27
R.Thurne Martham Ferry	TG4450019500	2	20/01/1983	12/12/2005	10
Whittlesey Dyke Turning Tree Bridge	TL2820095600	3	17/11/1981	30/11/2005	80
Bevills Leam Chapel Bridge	TL2890094100	3	25/06/1981	30/11/2005	90
R.Blackwater Langford Intake	TL8364509179	5	30/03/1981	01/12/2005	10
R.Chelmer Langford Intake	TL8341108624	5	30/03/1981	01/12/2005	12
Middle Level MDMullicourt Priory Sluice	TF5310002900	6	21/04/1981	17/11/2005	23

Site	NGR	Typology	Start date	End date	Missing data points
Forty Foot R. Forty Foot Br.Ramsey	TL3080088100	6	14/05/1981	14/12/2005	47
R.Nene Wansford Old Rd.Br.	TL0750099100	8	07/04/1981	24/11/2005	17
R.Nene Dog in a Doublet Sluice	TL2699999257	8	14/04/1981	24/11/2005	32
Ramsey River Parkeston Rd.Br.	TM2382131610	40	02/04/1981	22/11/2005	26
Spickets Bk.inlet to the Mere	TL8680608571	40	04/04/1984	06/12/2005	17
Daily data					
NB: Daily data reportedly do exist for Anglian but were not made available to Entec for this report					

Midlands Region

Site	NGR	Typology	Start date	End date	Gaps
Monthly data					
R.Severn at Atcham	SJ5400009300	7	08/02/1988	08/12/2005	12
R.Severn at Bewdley	SO7875075450	7	04/01/1988	12/12/2005	9
R.Severn at Buildwas	SJ6450004400	7	16/02/1988	08/12/2005	16
R.Severn at Caerhowel Bridge	SO1967098150	13	29/06/1993	29/12/2005	11
R.Severn at Cil Gwran Bridge Aberbechan	SO1450093500	13	10/02/1988	21/12/2005	4
R.Severn at Dolwen	SN9970085200	13	02/03/1988	22/12/2005	13
R.Severn at Llandrinio	SJ2980016900	7	10/02/1988	01/12/2005	9
R.Severn at Llanidloes Felindre Bridge	SN9440083901	10	02/03/1988	22/12/2005	5
R.Severn at Maginnis Bridge	SJ2589011510	13	10/02/1988	09/12/2005	
R.Severn at	SJ432001530	7	18/02/1988	12/12/2005	9

Site	NGR	Typology	Start date	End date	Gaps
Montford Bridge	0				
R.Severn Foot Bridge Back Lane CP NTON	SO1052091640	13	07/07/1988	09/12/2005	4
River Severn at Holt Fleet Meadows, Holt Fleet	SO8245063350	7	04/01/1988	12/12/2005	9
R Severn (Lower) Haw Bridge	SO8455027850	8	04/01/1988	08/12/2005	17
R Severn (Upper) Kempsey (Mid)	SO8465049500	8	09/07/1989	05/12/2005	24
R Severn (Upper) Tewkesbury	SO8887033720	8	12/01/1988	05/12/2005	16
R Severn – Upton on Severn	SO8516040750	8	04/01/1988	05/12/2005	14
R Severn – Caersws	SO0320091700	13	10/02/1988	21/12/2005	10
R Severn – rear of oil depot Bath Rd Worcester	SO8510052320	7	20/06/1990	12/12/2005	26
R Severn – the Ironbridge at Ironbridge	SJ6725003400	7	02/08/1993	08/12/2005	12
R Severn – Worcester Bridge	SO8465054750	7	19/01/1988	12/12/2005	12
R Severn (Lower) Ashleworth	SO8190025060	8	15/01/1988	08/12/2005	22
R.Strine at Crudgington	SJ6300017800	1	25/02/1988	07/12/2005	13
Rea Brook at Horse Bridge	SJ3710005900	1	09/02/1988	15/12/2005	22
River Erewash at Shipley Gate	SK4633745440	2	04/12/1987	08/12/2005	12
River Erewash upstream of Milnhay STW	SK4555146587	2	04/12/1987	08/12/2005	14
River Camlad at Gaer Bridge	SO2140099900	4	10/02/1988	29/12/2005	45
R.Camlad at Chirbury	SO2710098300	4	10/02/1988	29/12/2005	51
Non-tidal River Trent – Tittensor	SJ8750037700	5	22/02/1988	21/12/2005	4

Site	NGR	Typology	Start date	End date	Gaps
River Idle (Maun) – at Bawtry	SK6559092680	5	08/12/1987	16/12/2005	11
Non-tidal River Trent at Gunthorpe	SK6821043757	8	31/12/1987	21/12/2005	1
River Soar at Red Hill Lock	SK4920030200	8	09/02/1988	24/11/2005	9
Afon Clywedog – new gauging weir at Clywedog	SN9130086800	10	02/03/1988	22/12/2005	10
R.Severn at Llanidloes Felindre Bridge	SN9440083901	10	02/03/1988	22/12/2005	5
River Wye at Ashwood Park Buxton	SK0639673544	11	11/03/1988	19/12/2005	17
R.Morda at the A483 Bridge	SJ2880028100	11	17/02/1988	09/12/2005	36
River Derwent – intake to Little Eaton WTW	SK3593640770	13	01/03/1988	28/12/2005	26
River Churnet – Cheddleton Station	SJ9820052100	13	03/03/1988	17/11/2005	7
River Wye at Rowsley	SK2570165684	14	11/03/1988	29/12/2005	21
River Dove Mayfield	SK1580045800	14	03/03/1988	30/11/2005	16
River Dove, Monk's Bridge	SK2680027000	17	02/03/1988	23/11/2005	21
River Derwent at Wilne	SK4520231459	17	25/02/1988	06/12/2005	18
Marton Drain at A156 Bridge at Brampton Grange	SK8416080980	40	15/12/1987	12/12/2005	46
Dimore Brook Elmore	SO7928014810	40	22/01/1988	09/12/2005	53
Daily data					
Severn Saxon's Lode	SO8633039050	8	01/01/1975	31/10/2006	332
Severn Welsh Bridge	SJ4888012730	7	01/01/1989	31/10/2006	3379
Teme at Bransford	SO8038053240	8	01/01/1976	31/10/2006	2001
Clywedog at Bryntail	SN9136086780	10	07/09/2000	31/10/2006	202
Avon at Evesham	SP0401043760	8	01/01/1978	31/10/2006	1344

Site	NGR	Typology	Start date	End date	Gaps
Vyrnwy at Meifod	SJ1563012920	13	01/01/1975	31/10/2006	1349

North East Region

Site	NGR	Typology	Start date	End date	Gaps
Monthly data					
North Tyne at Barrasford Intake	NY9200073200	2	30/08/1990	29/11/2005	47
North Tyne at Bellingham	NY8340083250	14	03/02/1981	08/12/2005	144
North Tyne at Chollerford	NY9180070500	2	03/04/1973	12/12/2005	57
North Tyne at Tarset	NY7820085600	14	03/04/1973	08/12/2005	39
North Tyne at Wark	NY8630077000	14	15/01/1974	08/12/2005	109
North Tyne u/s Kielder	NY6320092800	11	03/04/1973	28/11/2005	123
Tyne at Bywell	NZ0520062000	2	03/04/1973	05/12/2005	56
Tyne at Hexham	NY9410064600	2	03/04/1973	05/12/2005	60
Tyne at Ovingham	NZ0840063400	2	13/03/1989	05/12/2005	34
Tyne at Ovingham Intake	NZ0968064240	2	29/08/1990	24/05/2005	81
Tyne at Wylam Bridge	NZ1190064600	2	13/03/1974	05/12/2005	43
Coquet at Warkworth Dam	NU2370106065	1	05/04/1973	05/12/2005	40
Oak Beck at A61 road bridge	SE2920057600	1	14/05/1974	01/12/2005	60
River Doe Lea at Renishaw	SK4430077000	2	28/05/1974	17/11/2005	36
River Dove at Darfield (Low Valley)	SE4070003800	2	01/04/1974	02/12/2005	76
Blyth at Bedlington Bridge	NZ2660081400	4	05/04/1973	05/12/2005	30
Wansbeck at Sheepwash Dam	NZ2570085700	4	05/04/1973	29/11/2005	41
River Hull	TA079844988	5	01/04/1974	24/11/2005	23

Site	NGR	Typology	Start date	End date	Gaps
at Hempholme Lock	5				
Dearne at Pastures Bridge	SE4980000800	5	01/04/1974	28/11/2005	25
River Ouse at Nether Poppleton (Skelton)	SE5580055100	8	03/04/1974	24/11/2005	30
River Aire at Beal	SE5328625553	8	30/06/1972	08/12/2005	43
River Holme at Queens Mill	SE1419415742	10	04/04/1974	01/12/2005	34
Little Don at Deepcar	SK2890098100	10	29/11/1974	08/11/2005	68
River Don at Deepcar	SK2920098100	11	05/04/1974	08/11/2005	54
River Don at Oxspring Bridge	SE2730002100	11	29/11/1974	18/11/2005	71
River Dibb at Hartlington Bridge	SE0400060900	12	03/04/1974	29/11/2005	52
Lewisburn u/s Kielder	NY6365089650	12	03/04/1973	28/11/2005	126
River Wharfe above Tadcaster Weir	SE4850043700	13	03/04/1974	18/11/2005	18
River Wharfe at Bolton Bridge	SE0720052800	13	03/04/1974	06/12/2005	39
River Calder at Methley Bridge	SE4096825810	14	04/04/1974	30/11/2005	28
River Don at BSC Rotherham Gate 14	SK4210092200	14	05/04/1974	05/12/2005	47
River Ouse at Cawood	SE5740037800	17	03/04/1974	05/12/2005	60
Tees at Low Worsall	NZ3910010200	17	26/04/1973	02/12/2005	64
Daily data					
Tyne at Ugly Dub	NY7130087500	14	28/04/1993	22/11/2006	676

Site	NGR	Typology	Start date	End date	Gaps
Tyne at Bywell	NZ3800061700	2	17/03/1993	22/11/2006	601
Tyne at Swing Bridge	NZ2522863717	0	09/06/1995	10/10/2006	405
Ouse at Cawood Bridge	SE5740037800	17	06/07/1992	02/10/2006	514
Humber at Blacktoft Jetty	SE8430024200	0	10/09/1991	02/10/2006	339
Humber at Corporation Pier	TA1000028200	5	19/12/1991	02/10/2006	650

North West Region

Site	NGR	Typology	Start date	End date	Gaps
Monthly data					
River Ribble at Cleatop Barns	SD80776613 90	14	03/05/1971	13/12/2005	64
River Ribble at Cow Bridge	SD82671569 68	14	18/01/1993	13/12/2005	18
River Ribble at Eddisford Bridge	SD72658414 41	14	05/12/1985	07/12/2005	110
River Ribble at Horton in Ribblesdale	SD80693727 07	11	14/01/1975	15/12/2005	155
River Ribble at Mitton Bridge	SD71560387 24	14	30/04/1971	16/12/2005	10
River Ribble at Mitton Wood PTCRiver Calder	SD71038374 00	14	08/06/1976	02/12/2005	47
River Ribble at Paythorn Bridge	SD83130512 92	14	14/01/1975	13/12/2005	92
River Ribble at Ribchester Bridge	SD66194356 00	17	14/01/1975	16/11/2005	43
River Ribble at Samlesbury PGS	SD58888304 33	17	30/04/1971	15/12/2005	11
River Ribble at Sawley Bridge	SD77491466 24	14	14/01/1975	06/12/2005	37
River Ribble at Settle Weir	SD81787642 21	14	14/01/1975	15/12/2005	42
River Roe at Gaitsgill	NY38794465 90	1	28/09/1976	28/11/2005	98
River Ive at Low Braithwaite Bridge	NY42803421 85	1	28/01/1981	28/11/2005	49
River Irk at Red Bank above Scotland Weir	SJ841999917 1	2	23/04/1974	01/11/2005	16
River Yarrow at Fishery Bridge Croston	SD48426185 66	2	26/04/1972	12/12/2005	37
River Wyre at Gubberford Bridge Scorton	SD49522473 99	4	03/12/1974	05/12/2005	68
River Darwen at Roach Bridge	SD59574288 20	4	02/06/1975	08/12/2005	97
River Irwell at foot bridge at Salford University	SJ822589902 0	5	01/10/1974	29/12/2005	5
River Alt above	SD29211050	5	28/08/1974	16/12/2005	16

Site	NGR	Typology	Start date	End date	Gaps
Altmouth Pumping Station	91				
River Mersey above Howley Weir	SJ6159787999	8	26/09/1974	15/12/2005	1
River Weaver at Frodsham Road Bridge	SJ5301778474	8	18/09/1974	12/12/2005	4
River Esk at Cropple How Gauging Stations	SD1309897770	10	21/06/1980	09/12/2005	56
River Ogden above confluence with River Irwell	SD7918720273	10	06/09/1960	08/12/2005	189
River Irwell at Holme Bridge Townsend Fold	SD8010521953	11	06/01/1960	24/08/2005	133
River Irwell PTC Cowpe Brook	SD8362421686	11	06/01/1960	08/12/2005	140
Chew Brook above confluence with River Tame	SD9957404191	12	07/01/1975	06/12/2005	61
River Etherow below Bottoms Reservoir	SK0205496961	12	12/01/1976	09/12/2005	87
River Irwell above Warth Weir	SD7960409043	13	09/04/1974	08/12/2005	12
River Leven at Low Wood Bridge Haverthwaite	SD3449883600	13	24/02/1960	06/12/2005	138
River Calder at Whalley	SD7292736058	14	30/04/1971	15/12/2005	7
River Ribble at Mitton Bridge	SD7156038724	14	30/04/1971	16/12/2005	10
River Etherow at railway viaduct at Broadbottom	SJ9965493750	15	12/01/1976	09/12/2005	93
River Etherow below confluence with Glossop Brook	SK0042594763	15	12/01/1976	09/12/2005	185
River Lune at Denny Bridge	SD5036464692	16	05/05/1971	14/12/2005	108
River Lune at Crook of Lune Caton	SD5219264600	16	02/04/1980	01/12/2005	146

Site	NGR	Typology	Start date	End date	Gaps
River Ribble at Samlesbury PGS	SD5888830433	17	30/04/1971	15/12/2005	11
River Petteril at Stonyholme	NY4114656439	17	12/01/1976	02/12/2005	52
River Weaver at Sandford Bridge	SJ6197047057	28	10/08/1976	13/12/2005	90
Rookery Brook above confluence with River Weaver	SJ6574855729	28	23/03/1977	13/12/2005	178

Southern Region

Site	NGR	Typology	Start date	End date	Gaps
Monthly data					
River Test at Bridge Street Overton	SU5136049795	5	22/01/1979	10/12/2005	32
River Test at East Aston Common	SU4434344882	5	30/06/1980	10/12/2005	77
River Test at Greatbridge	SU3526622884	5	03/07/1978	14/12/2005	8
River Test at Longbridge	SU3549917847	8	10/07/1978	14/12/2005	32
River Test at Mayfly Inn	SU3817338974	5	22/01/1979	10/12/2005	48
River Test at Middlebridge Romsey	SU3492820675	5	14/07/1988	14/12/2005	14
River Test at Polhampton	SU5237550493	5	22/01/1979	10/12/2005	56
River Test at Testwood	SU3529415330	8	26/01/1979	09/12/2005	25
River Test at Wherwell	SU3894540131	5	19/07/1978	10/12/2005	10
River Test Longstock at Leckford	SU3613436889	5	19/07/1978	10/12/2005	27
River Test upstream Andover STW	SU3819539216	5	15/04/1997	10/12/2005	15
River Test upstream of Meadow Fish Farm	SU3303025781	5	25/01/1979	14/12/2005	39
River Test upstream of Test Valley Trout Farm	SU3503222681	5	24/01/1979	14/12/2005	26
River Test upstream Romsey Trout Farm	SU3485021577	5	25/01/1979	14/12/2005	37
Town Mill, Whitchurch, River Test	SU4668048070	5	11/03/1981	10/12/2005	67
Wallers Haven Boreham Bridge	TQ6761012000	1	06/01/1976	12/12/2005	18
Abstraction point on Ouseby MSW Coy at Ardingly	TQ3320028320	1	05/01/1977	21/12/2005	25

Site	NGR	Typology	Start date	End date	Gaps
River Arun at footbridge downstream of Horsham Bypass (A24)	TQ1505629987	2	10/08/1977	16/12/2005	79
River Rother Durford Bridge	SU7825023300	2	27/01/1976	01/12/2005	20
River Uck at Isfield Mill	TQ4480018030	4	15/01/1976	28/11/2005	31
River Lymington at Boldre Bridge	SZ3199098441	4	03/04/1979	01/12/2005	19
River Arun at Pallingham Manor	TQ0440022200	5	07/01/1976	16/12/2005	19
River Cuckmere Sherman Bridge	TQ5320005050	5	07/01/1976	30/11/2005	10
River Blackwater at Nutsey Bridge	SU3513015240	8	10/07/1978	12/12/2005	12
River Test at Testwood	SU3529415330	8	26/01/1979	09/12/2005	25
Broad Rife Ferry Sluice, Pagham Harbour	SZ8563096280	37	08/01/1976	15/12/2005	32
Botley Stream at Broadoak	SU5062513053	37	08/01/1979	06/12/2005	64
Chichester Canal Bypass Bridge – A27	SU8591003710	40	09/02/1977	14/12/2005	38
Chichester Canal below Birdham Weir	SU8376001070	40	18/05/1976	07/12/2005	50

South West Region

Site	NGR	Typology	Start date	End date	Gaps
Monthly data					
River Tamar at Boyton Bridge below Boyton Stw	SX3282592257	4	02/07/1974	15/12/2005	39
River Tamar at Buses Bridge	SS2808013380	1	05/01/1976	14/12/2005	90
River Tamar at Crowford Bridge	SX2872099425	1	05/01/1976	15/12/2005	82
River Tamar at footbridge below Lower Tamar Lake	SS2956010700	1	21/05/1985	14/12/2005	20
River Tamar at Greystone Bridge	SX3683880363	4	05/01/1976	15/12/2005	66
River Tamar at Gunnislake Bridge	SX4349372436	4	03/04/1974	15/12/2005	14
River Tamar at Gunnislake Gauging Station	SX4265072500	4	12/05/1995	15/12/2005	10
River Tamar at Horsebridge	SX4000174889	4	05/01/1976	15/12/2005	69
River Tamar at Lower Tamar Lake Surface	SS2960010800	1	29/08/1991	14/12/2005	13
River Tamar at Netherbridge	SX3487886703	4	05/01/1976	15/12/2005	78
River Tamar at Polson Bridge Below St Leonard's STW	SX3558484944	4	05/01/1976	15/12/2005	76
River Tamar at Tamarstone Bridge	SS2832805503	1	05/01/1976	15/12/2005	79
River Tamar at Tamerton Bridge below North Tamerton STW	SX3182297405	1	05/01/1976	15/12/2005	78
River Tamar at Upper Tamar Lake Dam surface	SS2880011800	1	29/08/1991	14/12/2005	18
River Tamar below confluence with River Deer	SX3191897257	4	23/01/1990	15/12/2005	17
River Tamar upstream Lower Tamar Lake	SS2930011400	1	24/02/1992	14/12/2005	50
Carnon River at Devoran Bridge below Carnon Downs STW	SW7908739436	1	01/04/1974	29/11/2005	16
River Wolf at Rexon Br. below Broadwoodwidger	SX4133088850	1	20/04/1976	02/12/2005	59

Site	NGR	Typology	Start date	End date	Gaps
STW					
Dolphin Bridge d/s Frome SW	ST7724649589	2	11/03/1969	30/11/2005	119
River Brit at Watford Bridge Pymore	SY4722694952	2	17/01/1977	08/12/2005	42
River Tamar at Gunnislake Bridge	SX4349372436	4	03/04/1974	15/12/2005	17
River Lyd at Lifton Bridge	SX3891184838	4	03/04/1974	02/12/2005	19
Great Somerford Bridge u/s gauging station	ST9651183193	5	06/01/1966	15/12/2005	104
River Axe at Whitford Bridge	SY2622595420	5	22/04/1974	01/12/2005	41
River Exe at Trews Weir Exeter	SX9254691506	7	08/05/1974	17/11/2005	55
Alphin Brook at Countess Wear Bridge	SX9398389386	7	29/04/1974	17/11/2005	152
Avon Limpley Stoke	ST7823661244	8	12/08/1975	17/11/2005	63
Avon Keynsham	ST6616369000	8	28/08/1968	21/11/2005	49
River Erme at Sequer's Bridge	SX6321051880	10	15/07/1974	03/12/2005	107
River Walkham at Grenofen Bridge	SX4900770972	10	03/04/1974	28/11/2005	40
River Culm at Bridgehouse Bridge Clayhidon	ST1599214087	11	12/08/1974	07/12/2005	82
River Culm at Culmstock Above Culmstock STW	ST1011513773	11	02/12/1974	07/12/2005	81
River Tavy at Denham Bridge	SX4769067760	13	25/06/1973	28/11/2005	19
River Plym at Plym Bridge	SX5236658732	13	03/04/1974	01/12/2005	14

Thames Region

Site	NGR	Typology	Start date	End date	Gaps
Monthly data					
Thames Above Nswc Intake, Egham	TQ0225071820	8	05/01/1972	01/12/2005	46
Thames at Abingdon Weir	SU5067697128	8	04/01/1972	21/12/2005	50
Thames at Boveney Weir	SU9440077700	8	12/04/1976	15/12/2005	42
Thames at Caversham Weir	SU7213574053	8	05/01/1972	09/12/2005	13
Thames at Days Lock	SU5676093498	8	04/01/1972	25/11/2005	34
Thames at Donnington Bridge, Oxford	SP5245904368	8	06/06/1989	21/12/2005	26
Thames at Eysey	SU1128794056	5	03/05/1973	19/12/2005	40
Thames at Henley Bridge	SU7631982813	8	11/01/1972	09/12/2005	35
Thames at Sonning Weir	SU7533475895	8	05/01/1972	09/12/2005	69
Thames at water intake, Buscot	SU2290098100	8	05/01/1972	19/12/2005	38
Thames at Teddington Weir	TQ1702071370	0	05/01/1972	02/12/2005	16
Boveney Ditch above Thames	SU9486078120	1	20/01/1972	29/11/2005	66
Blackwater at Lynchford Bridge, Ash Vale	SU8852053770	1	09/02/1972	25/11/2005	33
Hogsmill above Thames	TQ1785069100	2	27/01/1972	02/12/2005	41
Cherwell at Roadbridge, Twyford	SP4869137222	2	12/01/1972	22/11/2005	37
Wey at Cartbridge, Send	TQ0152055920	4	05/02/1975	02/12/2005	33
Wey at Newark Lane, Pyrford	TQ0390057370	4	05/02/1975	02/12/2005	35
Lee at	TL299000990	5	22/05/1974	14/12/2005	33

Site	NGR	Typology	Start date	End date	Gaps
Waterhall	0				
Colne at Gauging Station, Denham	TQ0520086300	5	25/01/1972	06/12/2005	19
Thames at Caversham Weir	SU7213574053	8	05/01/1972	09/12/2005	13
Thames above NSWCIntake, Egham	TQ0225071820	8	05/01/1972	01/12/2005	46
Eye at Lower Slaughter Mill	SP1640022600	11	05/01/1976	28/11/2005	93
Churn at North Cerney	SP0200007800	11	17/03/1977	01/12/2005	143
Beam at Havering Sluice	TQ4991981556	40	05/04/1978	01/12/2005	74
Beam at A13 bridge	TQ5030083100	40	05/04/1978	01/12/2005	74
Daily data					
Pymmes Brook Angel	TQ3398592538	2	01/02/1997	30/06/2006	1218
Thames Bray	SU9147878877	8	01/02/1997	30/06/2006	172
Thames Romney	SU9680077500	8	03/06/1986	23/03/2006	1445
Wey Weybridge	TQ0680064900	4	03/06/1986	05/06/2006	732
Kennet Theale	SU6480070800	8	03/06/1986	30/06/2006	886
Lee Waterhall	TL2980009700	5	03/06/1986	14/02/2006	1322
Thames Sunbury	TQ1040068000	8	12/08/1989	21/04/2006	535
Lee Kings Weir	TL3730005200	8	17/03/1987	30/06/2006	824
Thames Cleave	SU6010081800	8	03/06/1986	01/07/2005	945
Thames Teddington	TQ1700071350	0	16/06/1986	30/06/2006	1637
Thames Hannington	SU1750096000	5	23/06/1986	23/04/2004	852
Thames Penton Hook	TQ0430069300	8	25/07/1989	30/06/2006	678
Thames Molsey	TQ1490068900	8	21/07/1989	31/05/2006	683
Thames Taplow	SU9062883221	8	10/01/1997	31/03/2005	231
Loddon Wargrave	SU7770077300	5	01/01/1997	05/02/2006	636

Wales Region

Site	NGR	Typology	Start date	End date	Gaps
Monthly data					
River Dee at B5437 near Corwen	SJ0820043900	13	01/05/1992	29/11/2005	16
River Dee at Chester Weir	SJ4084065850	17	06/04/1981	25/05/2005	201
River Dee at Farndon Bridge	SJ4117054370	17	01/05/1979	02/12/2005	32
River Dee at Glyndyfrdwy	SJ1510043050	13	01/05/1979	29/11/2005	72
River Dee at Iron Bridge	SJ4180060100	17	09/04/1974	29/11/2005	25
River Dee at Llandderfel Bridge	SH9820036610	13	09/04/1974	01/12/2005	26
River Dee at Newbridge	SJ2873041800	13	04/04/1979	29/11/2005	23
River Dee at Old Bangor Bridge	SJ3880045420	17	28/04/1992	21/11/2005	8
River Dee at Overton Bridge	SJ3542042700	17	21/05/1992	21/11/2005	9
River Dee at Pont Mwnwgl y Llyn	SH9295935134	13	12/09/1979	01/12/2005	76
River Dee at Queenspark Suspension Bridge	SJ4103066010	17	30/04/1992	12/12/2005	13
River Dee,at Chester southerly by-pass	SJ4142163363	17	27/04/1980	22/12/2005	87
River Llan at Gowerton	SS5890096800	1	03/05/1977	09/12/2005	78
Pontardulais Road Bridge	SN5880003800	1	06/05/1975	25/11/2005	82
River Gwenfro u/s of River Clywedog	SJ3472049140	2	17/04/1979	06/12/2005	55
River Clywedog u/s of River Gwenfro	SJ3470049110	2	08/06/1979	06/12/2005	61
R Rhymney at Llanrumney	ST2140980755	4	27/09/1974	13/12/2005	79
W Cleddau Prendergast Gauging Station	SM9540017700	4	02/06/1976	29/11/2005	39
Loughor above Ynys Llwchwr Gauging Station	SN6146108764	5	28/03/1974	06/12/2005	42
R Ely at St Fagans (u/s St Fagans Gauging Station)	ST1194076960	5	27/09/1974	12/12/2005	20
R Afan at Dock Intake Weir	SS7606089740	10	18/04/1977	21/11/2005	77
River Seiont, Pont Pen-y-Llyn, Llanberis	SH5593062330	10	04/06/1979	07/12/2005	103

Site	NGR	Typology	Start date	End date	Gaps
Afon Lwyd, Llanyravon	ST3018494644	11	16/02/1977	17/11/2005	58
River Tawe Ystradgynlais Road Bridge, Ystradgynlais, Powys	SN7860010100	11	19/04/1977	23/11/2005	82
River Tawe at Morriston Road Bridge	SS6740097900	13	15/03/1974	06/12/2005	51
R Ogmore at Merthyrmawr, Dipping Bridge	SS8910078400	13	27/09/1974	05/12/2005	45
River Alyn at Ithels Bridge	SJ3902056230	14	09/04/1974	14/12/2005	46
R Neath d/s Aberdulais Gauging Station	SS7715098910	14	27/09/1974	05/12/2005	77
Towy Nantgaredig, nr Carmarthen,Dyfed	SN4910020400	16	22/03/1974	02/12/2005	86
Gwili at Abergwili Road Bridge, nr Carmarthen, Dyfed	SN4335021040	16	21/04/1977	08/12/2005	85
River Dee at Iron Bridge	SJ4180060100	17	09/04/1974	29/11/2005	29
R Wye at Carrots Pool, Hampton Bishop	SO5497038190	17	02/11/1965	12/12/2005	75
Daily data					
Taff Blackweir	ST1706078053	13	14/12/1993	01/11/2006	1003
Wye Belmont	SO4850038799	17	13/01/1997	09/12/2006	190
Wye Redbrook	SO5276911077	17	01/01/1996	09/12/2006	166
Tywi Capel Dywi	SN4851920582	16	01/09/1997	04/01/2007	476
Tywi Manoravon	SN6574123987	13	01/09/1997	03/01/2007	463
Tywi Dolau Hirion	SN7618936242	13	01/09/1997	03/01/2007	445
Tywi Ystradffin	SN7855947241	10	01/09/1997	04/01/2007	879
Dee Summers Jetty	SJ2904670696	0	08/11/1995	15/01/2007	234

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