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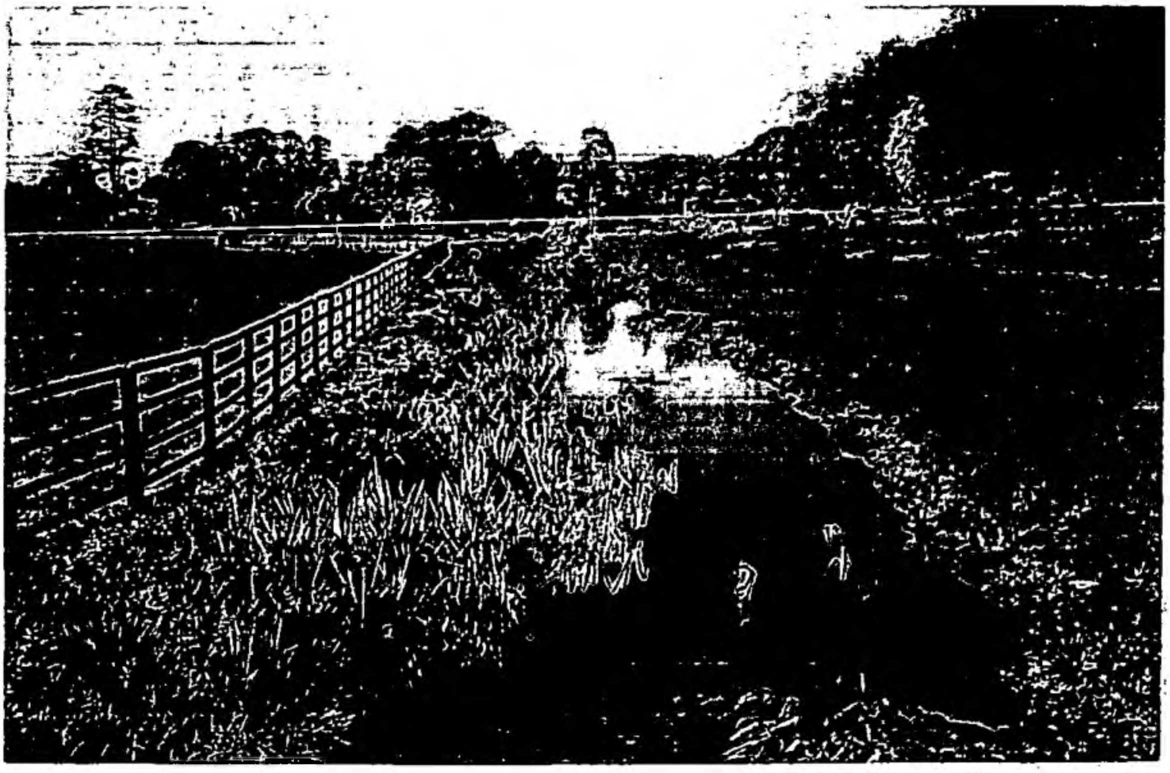
Thames Region

KENNET AND COLN RIVER LEVELS STUDY

Final Report

VOLUME TWO - RIVER COLN



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WS Atkins

August 1992

KENNET AND COLN RIVER LEVELS STUDY

FINAL REPORT

VOLUME TWO - RIVER COLN

CLIENT: National Rivers Authority - Thames Region

CONSULTANT: WS Atkins Consultants Ltd.

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EXECUTIVE SUMMARY

This document is Volume Two of the two volume Final Report on the Kennet and Coln River Levels Study and considers the Coln catchment. The Study was commissioned largely as a result of public concern that the character of the river had changed over the last 30 years. The fundamental concern was with reduced river levels and the general view was that reductions were caused, in great part, by groundwater abstraction for public supply outside the Coln catchment.

The Study was divided into two stages and an Interim Report on the Stage One Study was issued in December 1991. This Report updates the findings of the Stage One Study and presents the findings for both Stage One and Stage Two.

Stage One of the Study considered how the four main measures of the character of the catchment viz:

- Groundwater levels
- Surface flow, water level and the upper limit of flow
- Water quality
- Flora and fauna

have changed with time. Three separate approaches were undertaken for each factor as below:

- Public perception, from interviews with local concerned individuals and groups.

- Historical perspective, from research into historical maps and records.

- Factual analysis, from the available data.

The main findings of the Stage One Study were :

- The public perception is that groundwater levels have reduced significantly both over the last 6-7 years and between the 1950s and the present day. The loss of submerged weed and increased siltiness are also reported over the same 6-7 year period.

- The public concern is focused upon the central reach of the catchment, from Fossebridge downstream to Bibury. Riparian owners voice similar concerns along the reach downstream of Bibury.

- Parts of the Great Oolite aquifer can dewater fully in response to severe droughts. This can result in a central section of the river drying in the late summer as is reported from 1890 and 1976.

- The impact on groundwater levels and surface flows of the current drought appears less severe than in 1976.

- Analysis of the flow and meteorological record indicates that surface flows have remained fairly constant over the last 30 years. A small increase in flows is apparent from the mid 1970's.

- A change in the character of weed growth, from submerged weed (*Ranunculus, Starwort* etc) to emergent and encroaching weed, and blanket weed, has been noted throughout this catchment over the last few years.

- Water quality does not appear to be an issue of concern. The reports of increased siltiness are not supported by the data but there was some visual evidence of bank trampling leading to increased sediment loadings. Silt build up on the river bed is a major problem, but is believed to be caused by reduced flushing flows rather than increased silt loadings.

- Natural brown trout recruitment has reduced significantly in the last few years. This is considered to be due largely to increased bed siltation and the loss of submerged weed.

Stage Two of the study considered the possible causes of the changes identified in Stage One. The main findings were:

- Severe one year droughts and, in particular, failures of winter rainfall (e.g. 1976) are considered to have a greater detrimental impact on river flow than more extended periods of less severe drought, as experienced in the 1988-91 period.

- The 1988-91 drought period has reduced natural mean flows by approximately 30 per cent.

- Actual groundwater abstraction has increased steadily over the last 25 to 30 years. The impact on natural flows is relatively minor however, representing approximately 5 per cent of mean flow and 10 per cent of low summer flow. This analysis does not include for the small and beneficial but ungauged effects on surface flows of the augmentation outflow from an artesian borehole at Bibury.

- In summary, groundwater abstraction is at most only a minor factor in the reduced river levels recorded in the river over the last few years. The natural reductions caused by the recent drought are considered to be an order of magnitude greater than the effects of abstraction.

- One of the effects of reduced flow rate has been to reduce submerged weed growth in preference for encroaching and blanket weed. Loss of submerged weed can reduce river levels by up to a further 50 per cent and have a severe impact on both the appearance and ecological value of the river.

- Increased bed siltation and reduction in natural spawning of brown trout are further widespread consequences of reduced flow rate along the river.

- River and land management do not appear, over the last 30 years or so, to have had a significant impact upon the river, although some reaches were overdredged in the 1950's.

At the end of the Report various remedial measures and further works are suggested.

KENNET AND COLN RIVER LEVELS STUDY
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GENERAL

1. INTRODUCTION

In October 1991 the National Rivers Authority - Thames Region appointed WS Atkins Consultants Ltd to undertake a study of the Upper Kennet and Coln Rivers. The study was divided into 2 stages and in December 1991 we produced an interim report (K1064/070/O/001) presenting the findings of the Stage One study with respect to both rivers. In February 1992 we produced a Draft Final Report in two volumes for the Kennet (Volume One - K1064/070/O/003) and Coln (Volume Two - K1064/070/O/004).

This volume of the Final Report (Volume 2) presents the findings from both Stage One and Stage Two of the study for the River Coln, revised and updated following a review of the Draft Report. Volume One presents the findings from Stages One and Two for the River Kennet.

Both the Kennet and Coln rivers have been the subject of considerable public concern as to their condition and, in particular, the river levels over the past few years. In both cases the fundamental cause of change in river condition was considered by the public to be groundwater abstraction which was largely exported from the catchment. The initial data analysis by NRA-Thames did not substantiate this viewpoint but the public debate continued. It was decided therefore to commission this two stage study examining, in Stage One, the changes which each catchment has undergone over the historical record and, in Stage Two, the contributory causes of the changes identified.

The Report on Stage One is divided into sections, assessing the following parameters for evidence of change in catchment characteristics:

- Groundwater Levels
- Surface Water Flow, including river levels and upper limits of flow
- Water Quality
- Flora and Fauna

Each of these factors are considered with respect to:

* Historical Perspective - references to catchment characteristics from historical documents.

* Public Perception - contributions received both in writing and during meetings with local inhabitants and interest groups.

* Factual Data - analyses of data held by the NRA or collected from third parties during the study.

The changes are identified and summarised at the end of each section and initial conclusions, specific to the factor, are made.

The Report on Stage Two is divided into sections considering each of the potential causes of catchment change, as below:

- Meteorology
- Abstraction
- Discharge
- River Management
- Land Management

The history of the catchment with respect to each of these features is considered and the changes with respect to each of them are analysed. The findings are summarised in a separate section, wherein the relative contribution of each factor to the changes in river environment identified in Stage One are considered.

An A3 plan of the catchment is included in most sections showing the location of each of the specific sites noted. A letter coding is used in the text, following the site name (e.g. Bibury gauging station (A)), and the encircled letter is used to identify the location on the plan.

ACKNOWLEDGEMENT

This study, by its nature, has been very reliant on information and views from both members of the public and data from NRA staff. We are very grateful to all contributors and would like to thank all those who have helped in the production of this Report.

2. BACKGROUND TO THE STUDY

2.1 The Study Area

The River Coln is a tributary of the Upper Thames and flows south east through the Cotswolds of Gloucestershire to join the Thames at Lechlade. The catchment is elongate, approximately 30 km long and 5 km across, and is one of five similar catchments draining south east from the Cotswold hills to the Thames. The catchment covers an area of 150 square kilometres and is predominantly rural in nature, consisting largely of arable land, with pasture in the valley bottom and some forest cover.

The Coln valley has a shape which is distinctive to the Cotswold Hills catchments. The valley sides are steep and deeply incised with a topographic range in the order of 70m. The flood plain is flat and relatively wide, at between 100 and 300m across. The river forms an integral part of the landscape and is an attractive feature of the villages located along its banks.

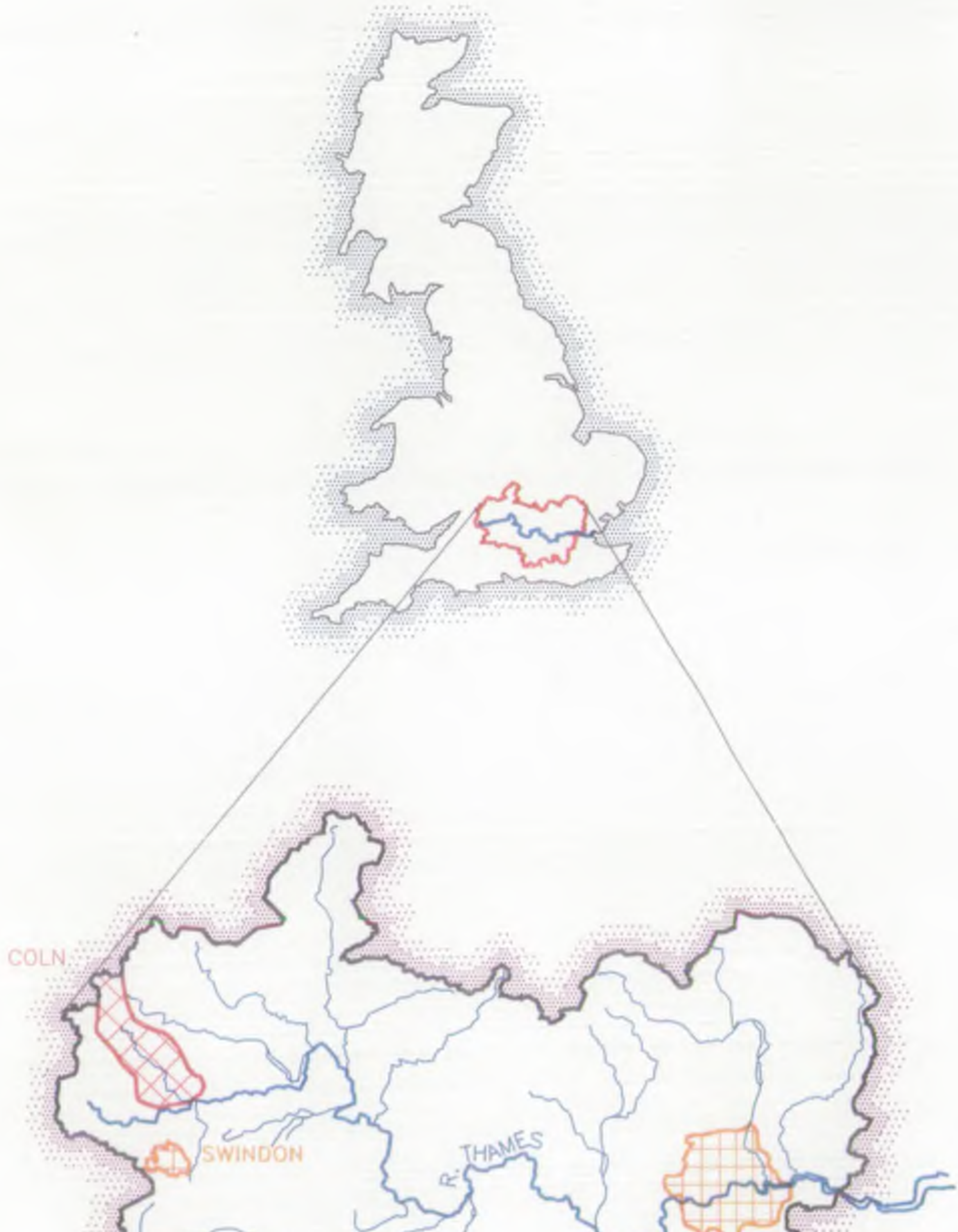
The location of the catchment is shown on Figure 2.1 and a plan of the Coln and surrounding Cotswold catchments is given in Figure 2.2.

2.2 History of Public Concern

This sub-section provides a brief overview of the history of public concern as to the river character. Detailed descriptions of public concerns and perceptions can be found in the relevant sections.

Public concerns are, in general, related to the present day reduction in river levels and the consequent detrimental effect on the appearance of the river. The impact of the current drought period is acknowledged but there is a general belief that the main cause is public groundwater supply to towns outside the catchment.

The current condition of the river is compared unfavourably with the condition in the early 1980's. It has also been stated by a number of locals that the river levels have deteriorated significantly since the 1950's. The level of public concern does not appear as high as in the Upper Kennet but there have been a number of articles in the local press, culminating in a full page article, in October 1989, in the Observer Magazine. Public concerns have concentrated on the central reach of the river from Fossebridge downstream to Bibury although problems are also reported from the reaches downstream of Bibury. As well as reduced river levels, the public have reported increased siltation, reduced submerged weed growth and an increase in algal blooms.



LOCATION PLAN

FIGURE 2.1

NORTHERN COTSWOLD STREAMS

FIGURE 2.2

3. CATCHMENT GEOLOGY AND HYDROGEOLOGY

The geology of the Coln catchment, as illustrated in Figure 3.1, consists of Jurassic oolitic limestones with interbedded clays. The geological sequence is common to the whole of the Cotswolds Region and the oolitic limestone provides the buff yellow building stone which is so characteristic of the area. Surface river flow is supplied largely by baseflow from the underlying aquifers and the baseflow index (BFI) for the Coln at Bibury is 0.94. The two main aquifers are the Inferior and Great Oolite, which are divided by the low permeability Fullers Earth. The strata dip gently to the south east and the aquifers as shown on the cross-section are present at depth downstream of the outcrop.

The plan and sectional geometry of the catchment has a significant influence on its hydrogeological characteristics as below:-

- The catchment is narrow and the impact of some of the major groundwater abstractions is considered to extend outside the surface catchment boundaries. This is considered further in Section 10.

- There is a pronounced topographic variation across the catchment from the valley to the interfluves. A typical annual groundwater level variation is in the order of 20 metres and the unconfined aquifer in the interfluves may, during drought periods, drain completely to the valley. This was recorded for the Great Oolite in 1976 and 1984 and is discussed further in Section 4.

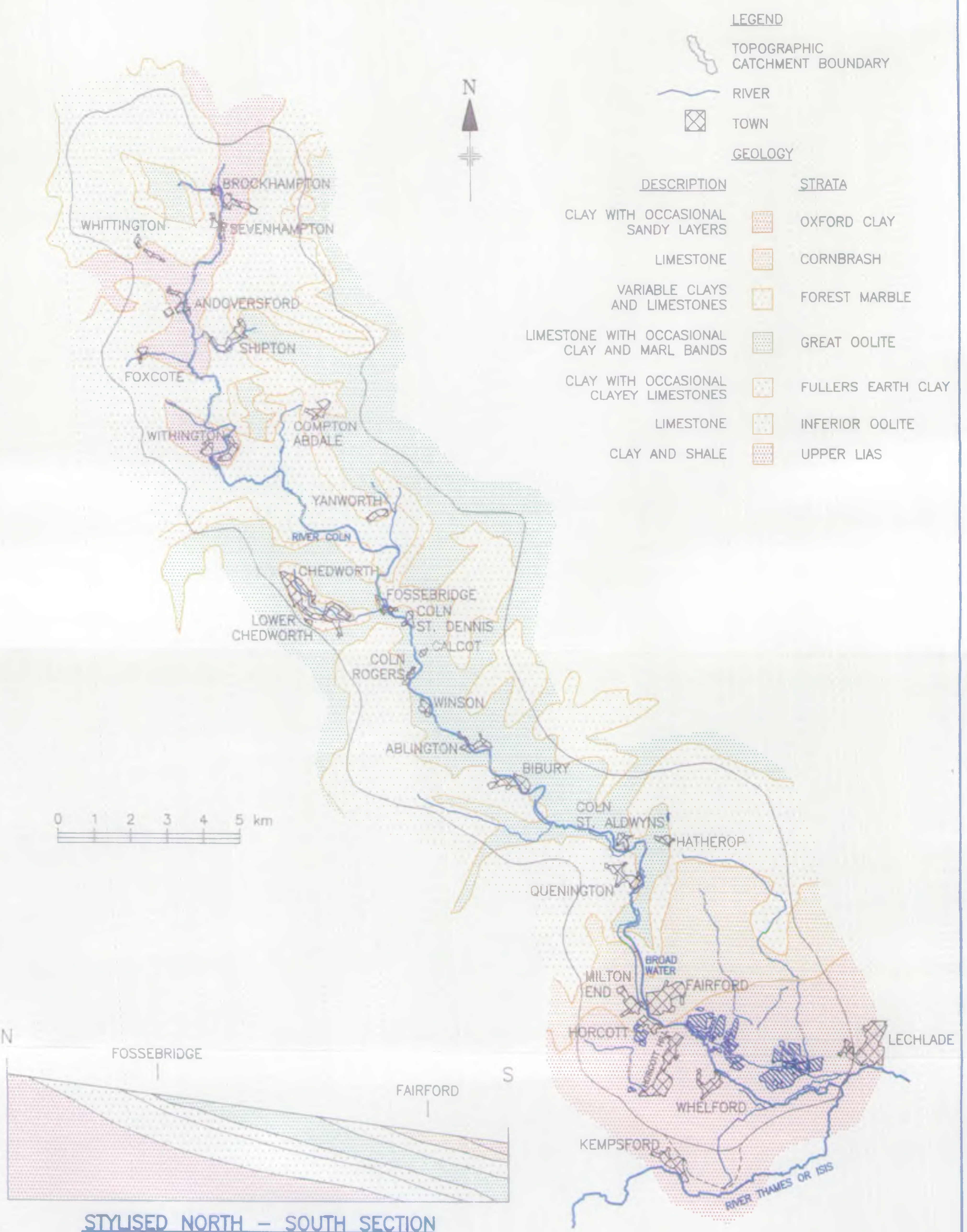
The Inferior Oolite aquifer outcrops in the northern part of the catchment and is present in the base of the river as far south as Chedworth. This aquifer provides a relatively minor but stable baseflow component to the upper part of the River Coln. The Inferior Oolite is present at depth over the southern part of the catchment. This confined aquifer is a major source of public groundwater supply for the Cotswolds and Bibury PS, which largely abstracts from the Inferior Oolite and is the largest supply source in the catchment. Abstraction from major Inferior Oolite sources in nearby catchments is also considered to be, in part, at the expense of baseflow to the Coln. This feature is considered further in Section 10.

The Great Oolite is separated from the Inferior Oolite by the low permeability Fullers Earth Clay. Groundwater level data show a large head difference between the aquifers over much of the catchment (see Section 4). This indicates that the Fullers Earth acts as an effective barrier to inter aquifer flow over most of the catchment. However, as described below in relation to the Bibury Spring, inter aquifer flows are thought to occur at specific locations, along fault zones of preferential flow.

The Great Oolite outcrops in the river base from Fossebridge downstream to below Quenington, a total distance of over 10 kilometres. The Great Oolite provides the major part of the baseflow to the river. However, one of the effects of the Great Oolite drying out completely is that the upper reaches of the river become influent, i.e. lose surface water to the aquifer. The river occasionally dries along the Great Oolite outcrop reach downstream of Fossebridge in response to severe drought conditions. This feature is considered further in Section 5.

Base flows from the Great Oolite tend to be concentrated at specific springs with major sources at Winson, Ablington and Bibury. The spring sources are considered to be related to preferential flow paths along faults. Studies into the spring water from Bibury Spring (Morgan Jones and Eggboro, 1981) have provided conflicting evidence as to its origin. The current understanding (NRA, pers. comm) is that groundwater both flows downwards to the Inferior Oolite and returns to the Great Oolite within the Bibury Fault zone, resulting in a spring outflow with characteristics of both aquifers. Certainly, the relationship between the Great and Inferior Oolite aquifers are known to be rather complex in this area. A detailed investigation into the hydraulics controlling the relationship is outside the scope of this study.

20/05/92 – 14:12---SG File-\COLN\FIG3-1



RIVER COLN CATCHMENT
CATCHMENT HYDROLOGY & HYDROGEOLOGY

FIGURE 3.1

STAGE ONE - CHANGES IN CATCHMENT CHARACTERISTICS

4. GROUNDWATER LEVELS

4.1 General

The main aquifers of the Coln Catchment are the Great Oolite and Inferior Oolite. These are separated by the low permeability Fuller's Earth which is considered to act as a barrier to inter-aquifer flow over much of the catchment. The general geology and hydrogeology are considered in Section 3 and the catchment geology is illustrated in Figure 3.1.

4.2 Historical Perspective

Reports of wells having dried for short periods in the late summer of recent years have been noted but there is no evidence that this is not a natural phenomenon related to the drought. We investigated a number of wells in the village of Ablington which are in the order of 300 to 400 years old. These wells were installed in the Great Oolite along a line up the side of the valley. If these wells were shown to dry regularly, this would indicate that groundwater levels are lower now than in the historical past. Unfortunately, at present each of the wells is capped with a concrete cover, one of the recommendations of the study is to drill through these covers and use the wells as additional groundwater monitoring points.

4.3 Public Perception

Public perceptions are not, in general, attuned to the issue of groundwater level as it does not in most cases affect the public directly. We have not received any specific complaints to date with regard to dry wells for example, although we did receive one report regarding a farm where the well has been deepened progressively.

4.4 Factual Data

Figure 4.2 records the actual groundwater level from 1986-1991, along with minimum, mean and maximum levels over the total period of record for the Dean Farm Well (A) in the Great Oolite and Figure 4.3 shows a similar plot for Southrop Well (B) in the Inferior Oolite.

The following points can be made from these plots:

- the range in groundwater levels recorded at Dean Farm (Great Oolite) is large at approximately 10 metres. The range at Southrop (Inferior Oolite) is smaller at 1 to 2 metres.

- maximum recorded groundwater levels are recorded at both wells in early to mid 1990, followed by minimum recorded levels in late 1990

- the variation in groundwater levels appears generally consistent between the two boreholes with the levels in the Inferior Oolite a subdued reflection of those in the Great Oolite.

Figure 4.4 shows minimum groundwater levels in 1984 for both aquifers. The piezometric surface for the Inferior Oolite just upstream of Fossebridge is 122mOD. The water table elevation in the Great Oolite at this point is around 130mOD. If there were any hydraulic contact between the two aquifers around this area therefore, there would be a downward component of flow from the Great Oolite aquifer to the Inferior Oolite below.

The piezometric surface in the Inferior Oolite just downstream of Bibury is 107mOD and the level in the Great Oolite is 99mOD. If the aquifers were in hydraulic continuity at this point flow between the aquifers would be reversed, with a component of flow from the Inferior Oolite to the Great Oolite above.

The shape of the Great Oolite groundwater contours in the reaches of the Coln above Bibury indicates that the river is effluent along this stretch, i.e. groundwater is seeping into the river and supporting baseflow. In the stretch below Bibury, at Quenington, the shape of the Great Oolite groundwater contour crossing the river has reversed, indicating that the river is influent at this point, i.e. losing to groundwater. This feature is identified again in Section 5 of this report while assessing river flow accretion profiles in the Coln. It is interesting to note that the Great Oolite could, potentially, be receiving water both from the Inferior Oolite and the river along this reach.

Figure 4.5 shows the same minimum groundwater contours for the Great Oolite from 1984, and also shows the actual values recorded at each borehole and the areas where the aquifer is considered to have drained dry. Figure 4.6 shows minimum groundwater level data for the Great Oolite from 1989. These data include the area immediately to the west of the Coln surface water catchment.

Comparing minimum groundwater levels for 1984 and 1989 the Great Oolite can be divided into three areas as shown on Figure 4.6 and described below:

- In the south west (area 1) groundwater levels were 2 to 6m lower in 1989 compared to 1984.

- In the central area (area 2) levels appear to have been higher in 1989 than 1984. The 'dry aquifer' recorded on the plan for 1984 was not a feature noted in 1989 although levels were only significantly higher at one borehole.

- Over the rest of the aquifer (area 3) the minimum groundwater levels were essentially the same in 1984 and 1989.

The interpretation of these data, related to groundwater abstractions, is shown in Section 10 of this document.

Minimum annual groundwater levels for a number of Great Oolite boreholes viz Dean Farm (A), Hintons Farm (D) and Pigeon House (E) are plotted as Figures 4.7 to 4.9. The data indicate that minimum levels are fairly consistent over the data period at these locations.

4.5 Summary and Conclusions

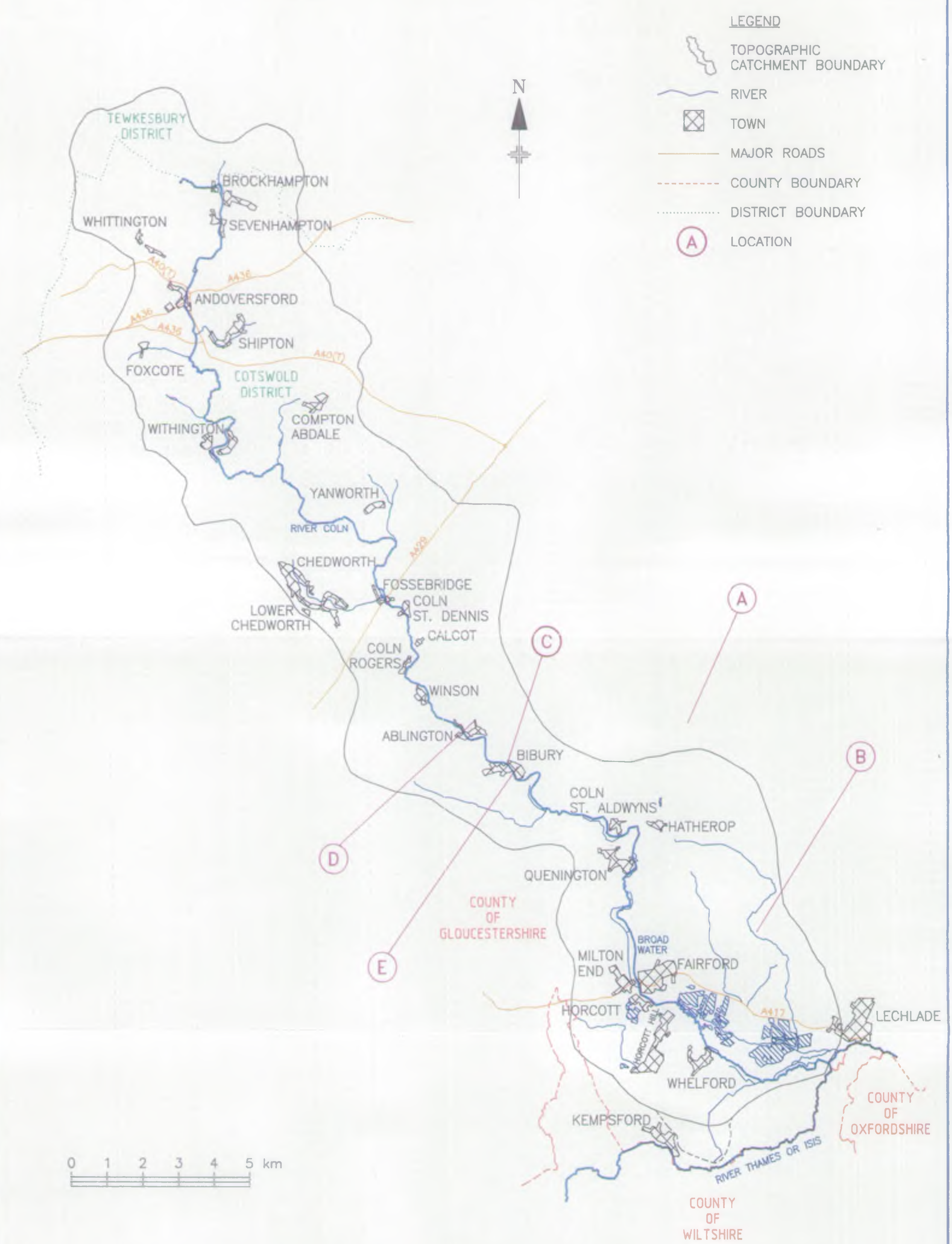
The Great Oolite aquifer appears to drain almost completely by the end of each low flow year. This is considered to be due to the rapid lateral flow of groundwater to the river, reflected in rapid variations and a wide range in groundwater levels.

The aquifer retains relatively little stored groundwater therefore and there does not appear to be a significant cumulative impact from a second year of reduced recharge -as compared to the Kennet chalk for example. This feature is considered further in Section 9.

Groundwater flow in the Great Oolite above Fossebridge would have a downward component to the Inferior Oolite if a flow path were to exist between the two aquifers. Downstream of Fossebridge, groundwater levels indicate the potential for upward flow and there is some evidence that Bibury Spring, for example, is fed in part by flow from the Inferior Oolite.

In general the minimum groundwater levels in the catchment do not show any clear trend over the last 15 years or so. However, there is evidence that groundwater levels in the Great Oolite in the south west of the catchment have reduced since 1984.

FIG4-1



RIVER COLN CATCHMENT

GROUNDWATER LEVELS : LOCATION PLAN

FIGURE 4.1

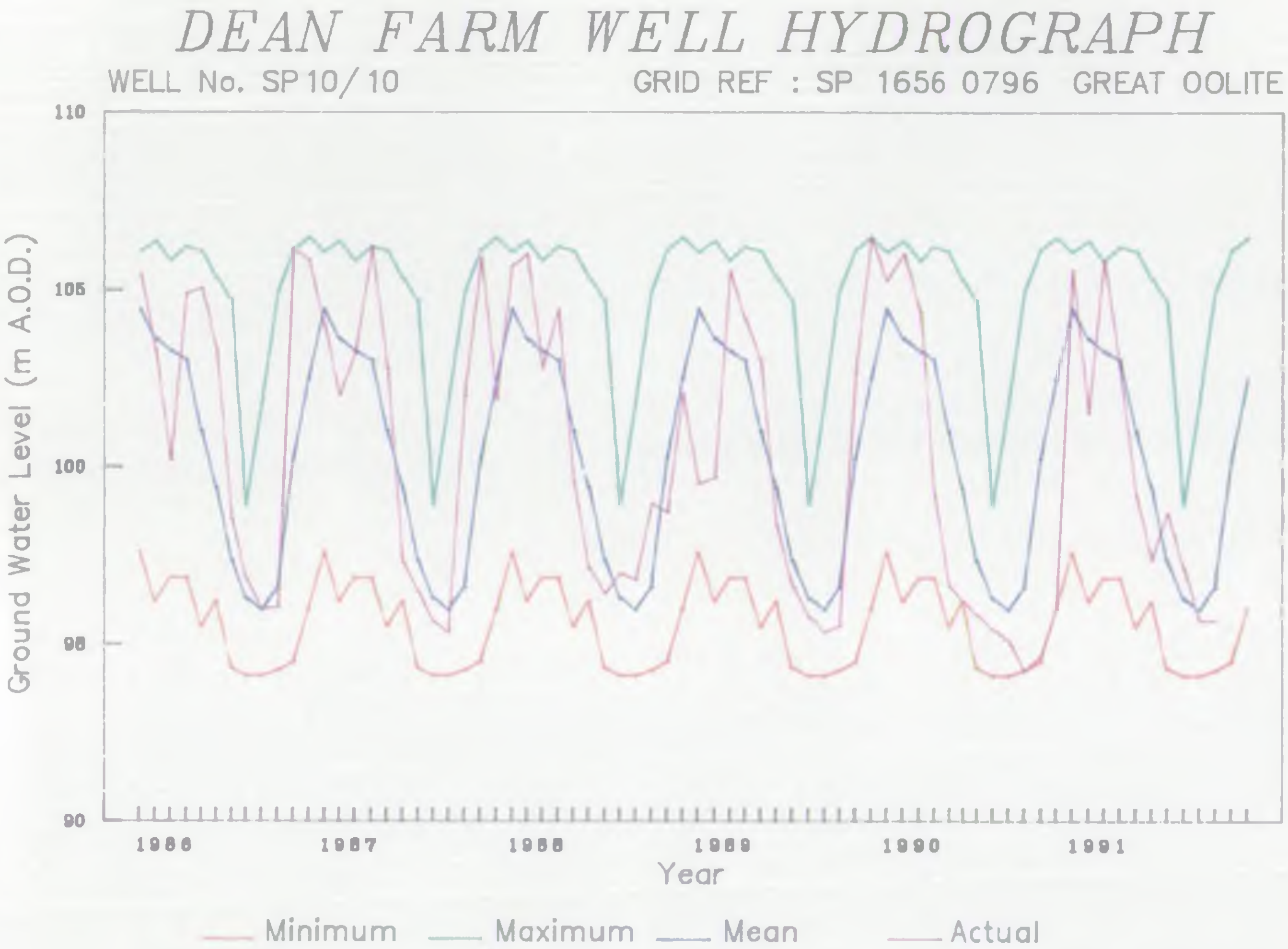

DEAN FARM WELL HYDROGRAPH
WELL No. SP 10/10
GRID REF : SP 1656 0796 GREAT OOLITE
Ground Water Level (m A.O.D.)
110
105
100
95
90
1986
1987
1988
1989
1990
1991
Year
Minimum
Maximum
Mean
Actual

Figure 4.2

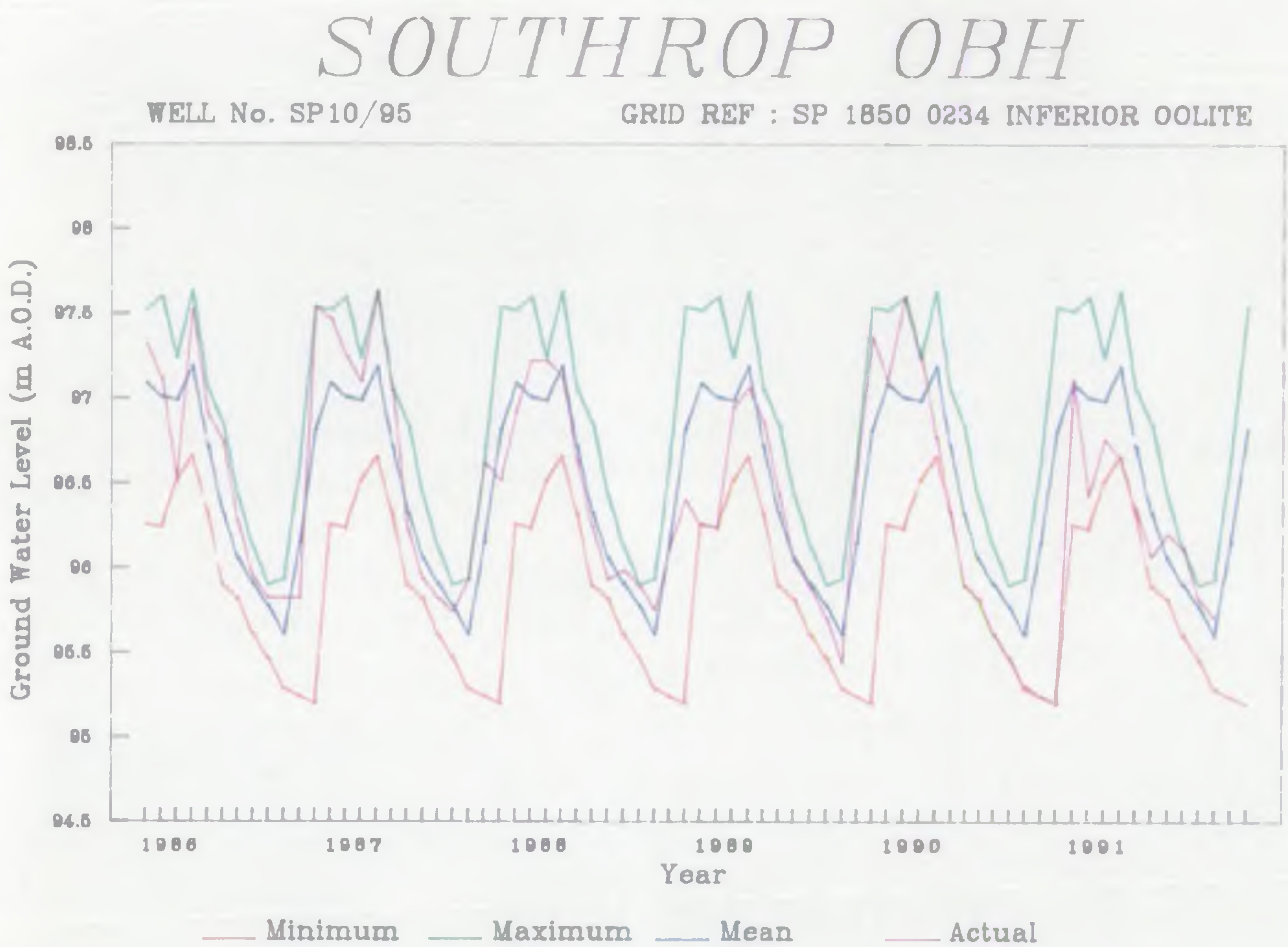

SOUTHROP OBH
WELL No. SP10/95
GRID REF : SP 1850 0234 INFERIOR OOLITE
Ground Water Level (m A.O.D.)
98.5
98
97.5
97
96.5
96
95.5
95
94.5
1986
1987
1988
1989
1990
1991
Year
Minimum
Maximum
Mean
Actual

Figure 4.3

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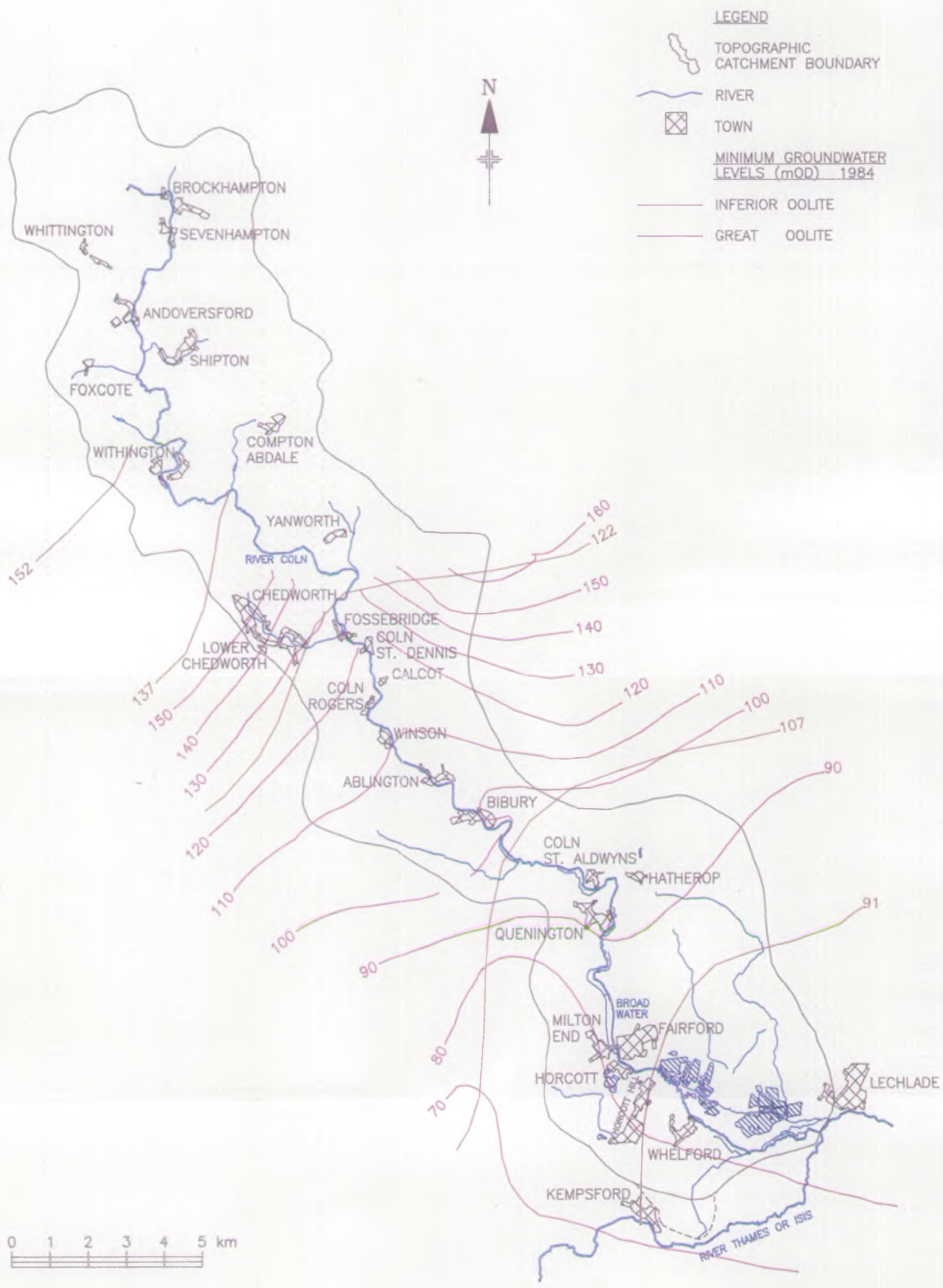

RIVER COLN CATCHMENT
MINIMUM RECORDED LEVELS - 1984

FIGURE 4.4

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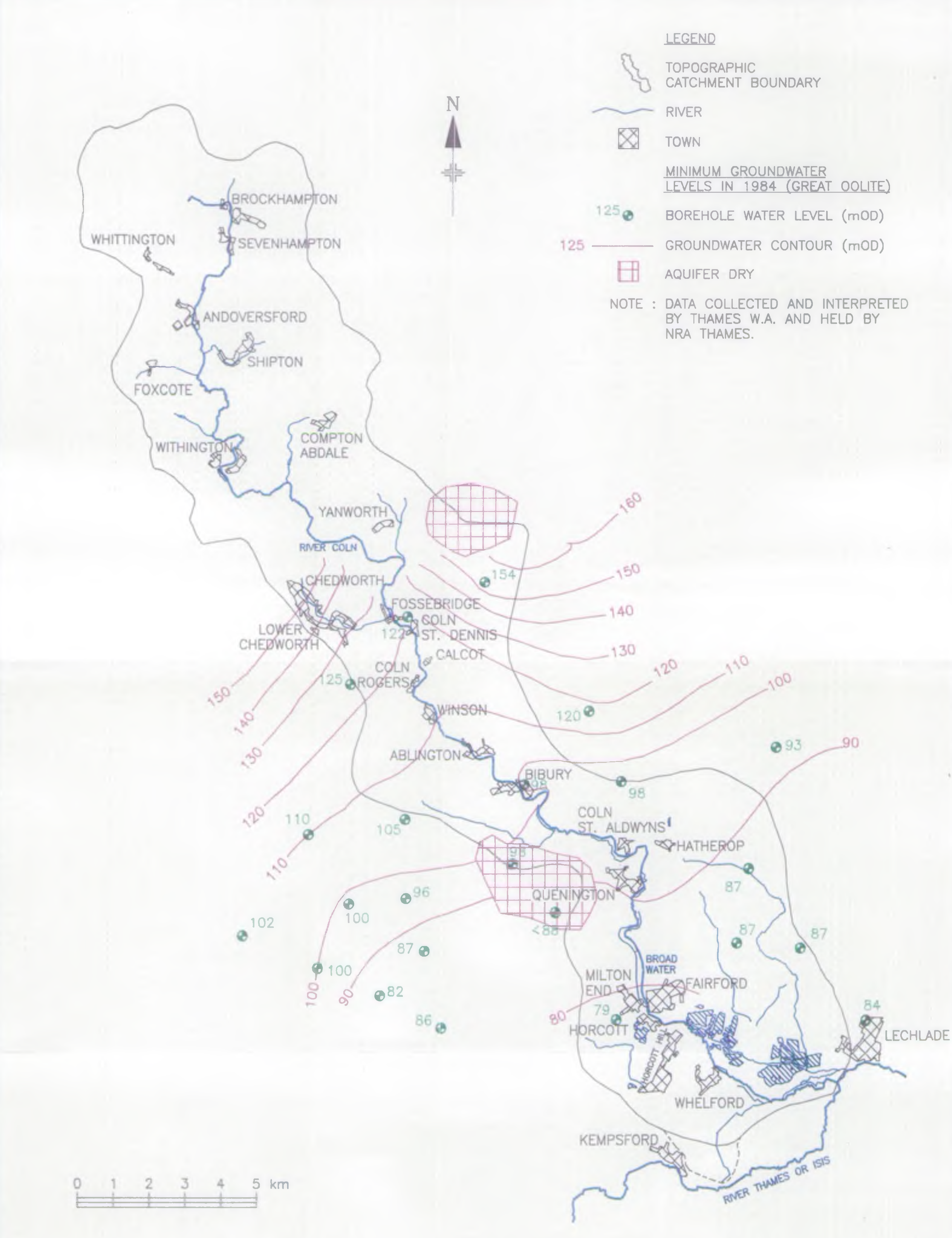
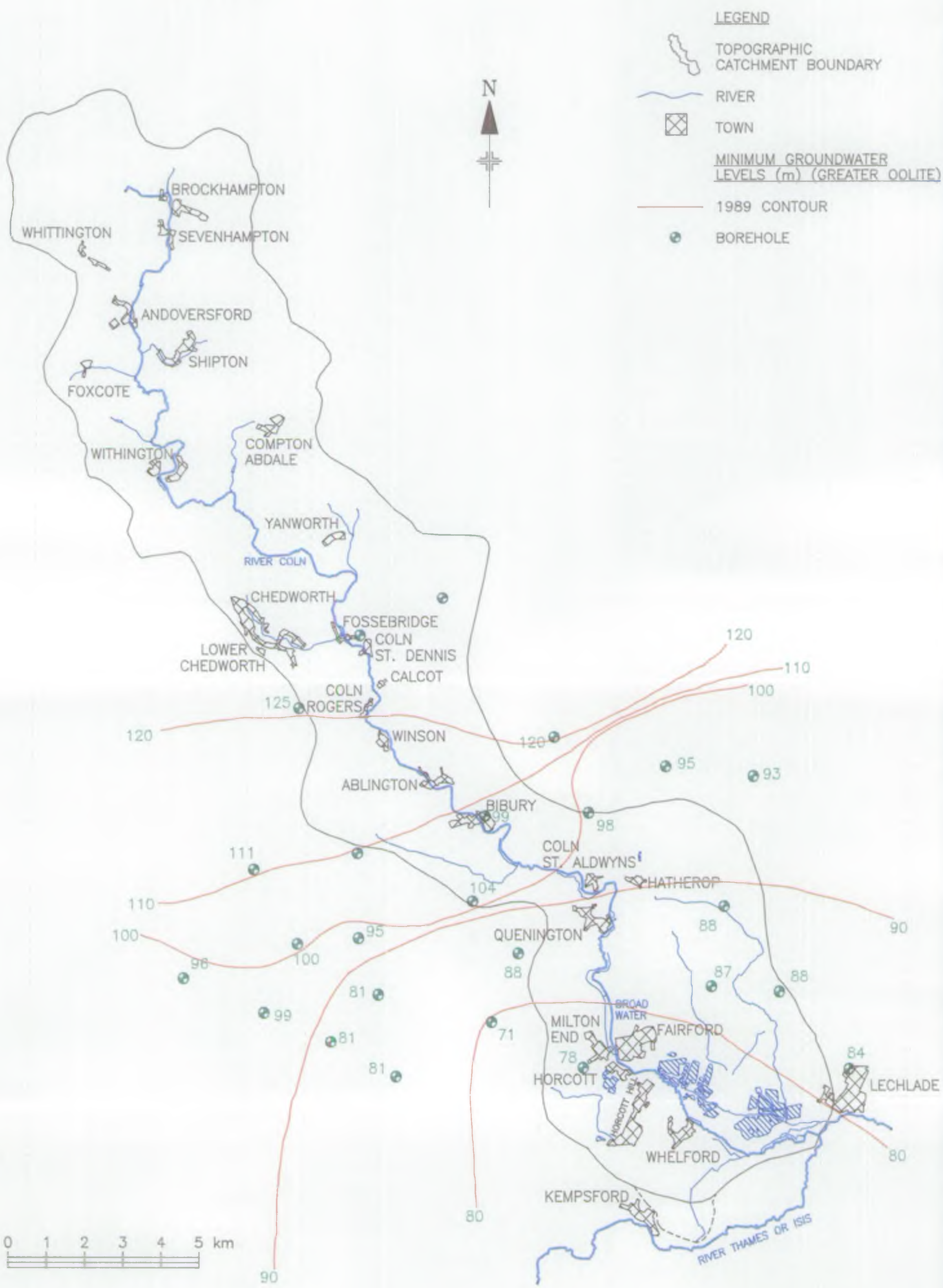


RIVER COLN CATCHMENT
BOREHOLE LEVELS & INTERPRETED CONTOURS
FROM 1984 SURVEY

FIGURE 4.5

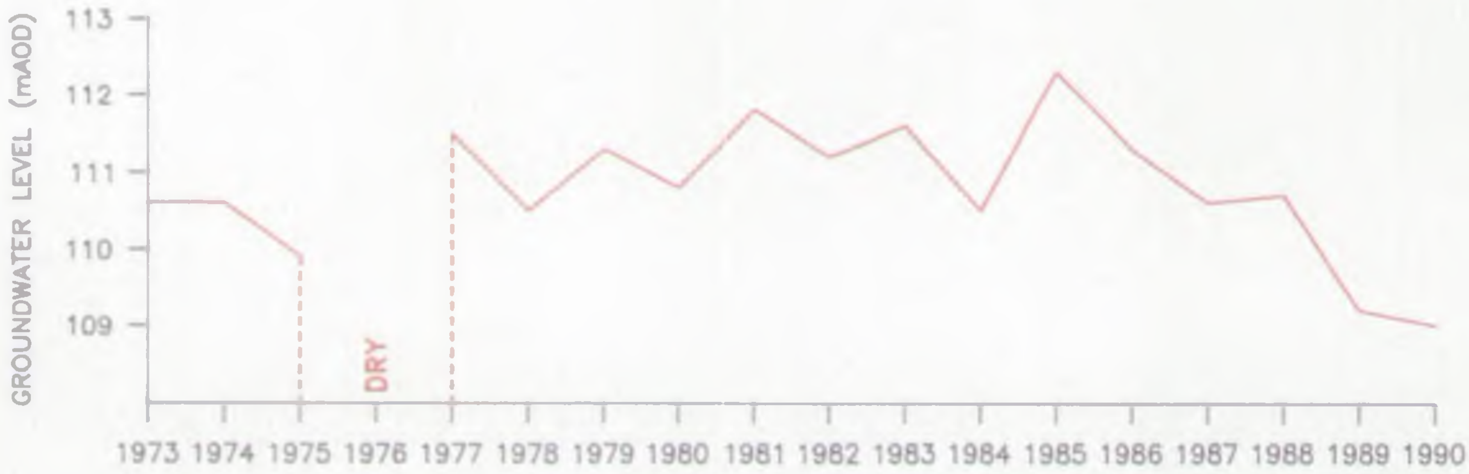


RIVER COLN CATCHMENT
MINIMUM RECORDED LEVELS - 1989

FIGURE 4.6

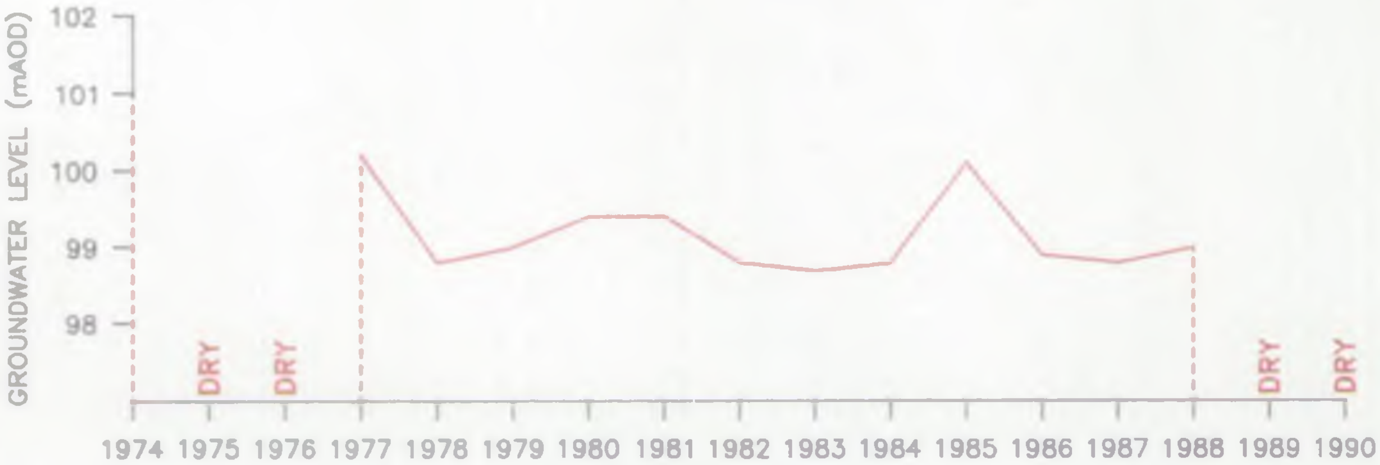
LEACH CATCHMENT - WELL REF. SP10/10 DEAN FARM
GREAT OOLITE (BOREHOLE A - FIG. 4.1)
LOWEST ANNUAL GROUNDWATER LEVELS

FIGURE 4.7



COLN - WELL REF. SP10/40 HINTONS FARM
GREAT OOLITE (BOREHOLE D - FIG. 4.1)
LOWEST ANNUAL GROUNDWATER LEVELS

FIGURE 4.8



COLN - WELL REF. SP10/75 PIGEON HOUSE
GREAT OOLITE (BOREHOLE E - FIG. 4.1)
LOWEST ANNUAL GROUNDWATER LEVELS

FIGURE 4.9

5. SURFACE FLOWS

5.1 General

The River Coln can be subdivided into three main reaches on the basis of general surface flow characteristics, related to the underlying geology, as follows:

° **Upstream Section** from the source near Brockhampton to Fossebridge. The outcrop along this section is of Inferior Oolite and underlying Upper Lias Clay. The upper limit of flow is relatively stable, even during drought conditions. Flows increase only slightly along the reach. There are historical references to the river losing flow to the Inferior Oolite aquifer along the section downstream of Withington.

° **Central Section** from Fossebridge to Bibury. Under natural conditions much of the accretion to the entire river occurs along this reach, from a series of major and minor springs. The reach coincides with the outcrop of Great Oolite and much of the spring discharge is considered to be from this formation. There may also be upward spring flow from the Inferior Oolite at Bibury Spring.

  The shape, and consequent hydraulics, of the Coln Valley are such that a significant part of the Great Oolite aquifer drains completely to the river system each year. As a consequence, the high accretion zone of the river moves downstream as spring flows reduce during the summer. The nature and degree of any long term changes to this accretion profile are of fundamental importance to the study of this river.

° **The Downstream Section** extends from Bibury to the confluence with the Thames at Lechlade. The river flows across Great Oolite outcrop and the overlying Forest Marble Clays. Accretion along this section is low. The Cornbrash, which outcrops above the clays at Fairford, also contributes to river baseflow.

River flows will be considered with regard to these three river reaches, concentrating on the central section about which much of the public concern has been expressed.

5.2 *Historical Perspective*

An indication of the nature of surface flows in the distant past can be made from an assessment of the age and location of mills along the river. The uppermost sites of mills are at Withington (A) and Shipton Solers (B). Both sites probably date from the 16th-17th century and both are now converted to Public Houses. There is no mill pond present at either site.

The River Coln has been heavily developed for water power and mill locations are discussed further in Section 12. Along extensive reaches there is both the natural stream channel and the artificial leat running side by side. This clearly reduces the flow in the natural channel and may have a significant effect along some reaches.

The earliest relevant reference to the Coln catchment is from John Bravender in 1864. He refers to stream losses along the Inferior Oolite section of both the Coln and nearby Churn rivers during the drought year of 1859. He estimates flow losses over a 10km reach downstream of a major spring flow on the Churn as approximately 12 Ml/d and considers that flow losses along the Coln are much greater than the loss from the Churn.

Bravender recommended that the bed of the Coln along the Inferior Oolite was puddled with clay to reduce losses and provide a water source for livestock during dry periods. Apparently an annual tithe was levied within the Churn catchment to puddle the river bed using oxen. We have found no evidence that the base of the Coln has been puddled although it is reported (NRA, pers. comm) that puddling of a man-made leat in the Coln St. Aldwyns area to the south of Bibury has taken place.

In 'A Cotswold Village' (JA Gibbs, 1898) the author describes the River Coln as one of the most delightful of angling rivers. He states that the river, '... flows continuously and swells out to fishable proportions just above Lord Eldon's Stowell properties at Cassey Compton' (C). The river is also said to 'widen considerably on leaving Winson' and the author notes the 'copious springs of transparent water ..' downstream of Bibury.

It was reported to us (private comm) that a central reach of the Coln was dry in the 1890's. This evidence is believed to have been presented during the Public Enquiry for Bibury PS in the 1950s although the reference has not been located.

A report to the Thames Conservancy in 1922 with regard to conditions in the previous year's drought notes that "The River Coln maintained flow throughout its course although its volume became considerably below summer normal .." The Coln was also reported to be flowing from its true source throughout the drought of 1934.

A Report on the Wells and Springs of Gloucestershire (Richardson 1930) refers to a spring at Syreford (D) which yielded up to 20 Ml/d. It is not clear where this spring is located. The same document suggests that yields from Bibury Spring (E) and Winson Spring (F) are about equal at, or above, 5 Ml/d.

No further documents have been obtained on the state of river flows in the Coln prior to the recent body of evidence from the 1960s, 1970s and 1980s, summarised in Section 5.3 and 5.4.

5.3 *Public Perceptions*

The focus of concern from the general public has been largely upon the central reach of the river from Fossebridge down to Bibury. The substance of complaint is the reduction in river levels along this reach, leading to the loss of its value both as a fishery and for general amenity. There have been fewer but similar concerns expressed for the downstream reach, particularly by the local fishing interests.

The existing correspondence and newspaper reports date from September 1988 and complainants claim that, in this year, river levels dropped substantially in comparison to previous years. The reports also state that river levels had been falling over the previous four years, indicating an initial year for flow reduction of 1984.

We discussed the condition of the river with Mr Arthur Chisman of Bibury Fish Farm (G), who has over 30 years experience of working on the river. He stated that the reduction in water levels at and above Bibury started about 6-7 years ago and worsened in the last 2-3 years. The fish farm itself does not always have sufficient supply (from Bibury Spring and a borehole) to operate to capacity and an aerator is used in the tanks to increase oxygen content. However, the fish farm has expanded steadily since its inception in 1902. Mr Chisman also stated that the nature of the flow regime appears to be somewhat different than in the past, with water levels falling away much more rapidly following the Spring high flows than previously. He also noted however that similar low flows had been seen in the river in the 1930's.

Messrs Michael and David Henriques have lived in Winson, for over 40 years. Michael Henriques considers that river levels have dropped considerably over recent years and quoted as an example the fact that where he previously could not cross the river in wellingtons he can now do so in shoes. David Henriques identified a general decline in the river since his Undergraduate days in the 1950s when he would fish the river up to Coln Rogers. He no longer manages his own river reach at Winson for fishing, largely due to a reduction in river levels.

The impact of the 1989-90 drought on spring flows and river levels is generally not considered to be as severe as the drought of 1976. For example, it has been stated that several springs in the area of Winson which dried in 1976 continued to flow through the recent drought.

In particular the Winson Spring (F) feeding the Coln dried in September 1976 and there was no flow in the entire river reach from Winson upstream at least to Coln Rogers, although ponded water remained in the channel. It is understood that flow has continued along this reach throughout the recent drought.

The above is confirmed by flow data collected by Thames Water Authority which indicate that the river was ponded from Coln Rogers, and possibly Ablington, upstream to Stowell (H). Above this point the river flowed and the upstream limit of flow was near Brockhampton, close to the normal upstream limit. These records also indicate that there was a moderate flow in the central reach during the 1989-90 period. Arthur Chisman noted that, in 1976, two of the three Bibury Springs also dried.

In September 1988 an article appeared in the Observer newspaper claiming that the River Coln was 'drying up'. The newspaper quoted a fall in Summer water levels of around two feet and also noted that levels were considered to have been falling over the previous two to three years.

The general tenor of comments, both as sent to the NRA and received by ourselves, is that later summer water levels have not improved but neither have they become significantly worse over the last two years. Further deterioration in this period is noted more in the floral character of the river (See Section 7).

5.4 *Factual Data*

Hydrographs

River flows in the Coln have been gauged continuously by a flow gauging station at Bibury (I) since 1963. The Bibury Spring flows are gauged separately by two crump weirs and the total flow is measured at the main crump weir on the river downstream. The crump weirs on the springs were only installed in the mid 1970s. Prior to this, the spring flows were measured with a much cruder device and NRA are not confident as to the accuracy of the earlier data.

The topographic catchment area is 107 km^2 at Bibury, with a mean flow of 114 Ml/d, equivalent to 390 mm of runoff per year. The catchment average annual rainfall (1941-70) is 819 mm.

Three year hydrographs of daily mean flows for selected periods as measured at Bibury are presented in Figure 5.2. The driest year in the record is included (1964) as are the years with the highest and lowest runoff volumes (1966 and 1976 respectively). The wettest year in the gauged period (1967) is not included however.

The flows throughout 1976 up to November can be seen as exceptional. However, both the range of flows indicated by the hydrographs presented for the 1980s and the shape of those hydrographs appear unremarkable relative to the hydrographs of the 1960s and the 1970s. Flow recessions have a variety of gradients with none appearing to dominate any period, although possibly those in the 1960s are slightly less steep than the others. Autumn flows in both 1989 and 1990 are very low, with 1989 shadowing 1975 very closely.

Annual Catchment Runoff

The time series of annual catchment runoff (in mm) for the Coln at Bibury, Leach at Lechlade, and Kennet at Knighton are shown in Figure 5.3. The River Leach is included as there are no major groundwater abstractions either within or close to the catchment and flows may be considered as largely natural. The natural year to year variability of annual runoff can be seen clearly. The recent sequence of runoff depths in the Coln shows a decline from above the mean since 1986, with 1989 and 1990 below the mean. The three consecutive years with declining runoff (1987-1989) on the Coln are considered unremarkable and do not compare with, for example, the seven year continuous decline experienced on the river between 1966 and 1973.

20 Day Minimum Flows

The 20 day annual minimum series of flows on the Coln and the Leach are shown in Figure 5.4. It can be seen that the lowest flows in each year have been more or less in decline on the Coln since 1986, but this is from a high starting point. The 20 day minimum flow in 1985 was the second highest since the record began in 1964, and only in 1989 and 1990 does the 20 day minimum drop below the long term mean.

The pattern of decline in low flows in the few years preceding 1990 is very similar to that which occurred preceding 1973, whose minimum flow was only marginally higher than that of 1990. Minimum flows in the Leach show a more severe decline in recent years with flows in 1989 and 1990 being lower even than those experienced in 1976.

Double Mass Analyses

A method of testing the homogeneity of a time series record is to plot consecutive values as a running cumulative total against a similar cumulative record of known homogeneity. This is known as a double mass plot. Figure 5.5 shows such a plot for both the total rainfall and the percolation for the Cotswolds West unit (including the Coln catchment) and the Berkshire Downs (including the Kennet). If records are homogenous the resulting plot will form, more or less, a straight line. The linearity of the plot can be observed by looking down the line along the plane of the page. Figure 5.5 shows strong homogeneity for both the rainfall and percolation data series when observed in this way.

The plot does not prove that the rainfall series are 'correct' but does show that they are consistent with each other through time. This indicates that (i) the pattern of rainfall and percolation (but not the actual amounts) experienced in both regions have been similar and (ii) there are no internal discrepancies within the data record for either catchment over this period.

The River Lambourn catchment is part of the Berkshire Downs unit and flows into the Kennet downstream of our study area (Volume One - River Kennet). The catchment is of interest because it is considered to be largely unaffected by abstraction, with only three very small public supply boreholes, and the surface flow regime is considered to be largely natural.

Figure 5.6 shows a double mass plot of the Berkshire Downs rainfall with surface flow as recorded at the main gauging station for the Lambourn at Shaw. The plot also compares cumulative percolation with flow. The plot shows a good straight line relation between the parameters and indicates that their relationship has remained constant. As the rainfall and percolation data are considered, from Figure 5.5, to be internally consistent, the Lambourn flow regime is indicated as being essentially unaffected by any change in outside influence over the period of record.

The plots on Figures 5.5 and 5.6 indicate that the data record for (i) rainfall and (ii) effective rainfall for Cotswolds West and (iii) flow on the Lambourn at Shaw are internally consistent.

Figures 5.7 to 5.9 present double mass analyses of each of these data sets compared with cumulative flow for the Coln at Bibury. The main features of the three plots are considered below:

- Each plot shows relatively consistent data from 1963 to 1975-76.

- There is a break in each line in 1975-76. This is pronounced in the rainfall (Figure 5.7) and effective rainfall (Figure 5.8) plots and indicates that flow increased in 1975-76, and decreased in the subsequent 3 to 4 years, relative to the pre-1976 line. The Lambourn plot (Figure 5.9) indicates a slight reduction in the Bibury flow in comparison with Shaw in 1975-76.

- The slope of the line is increased following 1975-76 in each case. For the rainfall plot (Figure 5.7) this translates to an increase in flow of 8 Ml/d in surface flow at Bibury. For effective rainfall (Figure 5.8) an increase of 7 Ml/d is indicated. For Shaw (Figure 5.9) the increase at Bibury is approximately 4 Ml/d.

The interpretation of double mass plots is somewhat subjective and these results should be considered as indicative and not accurate. Nevertheless, there is evidence from two separate data sources (meteorology and Lambourn flows) of a slight change in the surface flow regime in 1975-76 and an increase in flows along the Coln in subsequent years. These data are considered further in Section 10.

Flow Accretion Profiles

Flow accretion profiles have been plotted from available spot gauging data along the length of the River Coln. These are presented in Figure 5.10 as a log-normal plot. The measured data are not continuous and estimates of flow were made at a number of sites (by NRA Thames) to provide a sensibly continuous profile down the river. There are few data for recent years.

Three main features can be identified from Figure 5.10 as below:

- A relatively large increase in flow occurs between Brockhampton and Andoversford in the extreme upper reaches of the catchment. The inflow is variable and dwindled to almost nothing in 1976. There is no information concerning this part of the catchment in recent years. In 1973, when the river was dry at Brockhampton, a flow of 0.025 m^3/s (2.2 Ml/d) was recorded upstream at Andoversford.

- A large inflow to the river occurs between Ablington and Bibury Gauging Station. In October 1976 the flow at Ablington, some 26km downstream of the usual source of the river, was 0.4 Ml/d. Two kilometres downstream, at Bibury, the flow was 16.4 Ml/d, indicating an inflow of 16 Ml/d. In October 1990 the flow at Ablington was 5 Ml/d. At Bibury the flow was 34 Ml/d, indicating an inflow of 29 Ml/d.

  Similarly, in November 1973, when the flow at Ablington was 6.7 Ml/d, the inflow at Bibury was indicated as 24 Ml/d. In October 1980 the inflow was of the order of 63 Ml/d when the flow at Ablington was 21.6 Ml/d. It can be seen from the 1990 and 1973 examples cited above that the inflow that occurs in this reach is not always proportional to the flow in the river at Ablington.

- The river is influent in the reach between Bibury and Quenington, i.e. surface flow is lost to groundwater. In October 1980 this loss was at a rate of 9 Ml/d over the 8 km reach. In August 1984 the loss rate was equivalent to 8 Ml/d, and in September 1990 it was equivalent to 5 Ml/d. In each case flow rates increase again downstream of Quenington.

5.5 *Summary and Conclusions*

Flow accretion is relatively low in the Upper Reach but flows are consistent and the upper limit of flow is very stable during drought periods.

Flow accretion can be high in the Central Reach with particularly high flows from springs at Winson and Bibury. The inflow at Bibury does not appear to be directly related to flows upstream. The Central Reach can also lose surface flows to the aquifer during low flow periods. The river ceased to flow at least from Stowell to Coln Rogers in 1976 and a section of the river is understood to have been dry in the 1890s. Flow continued throughout this reach in 1989.

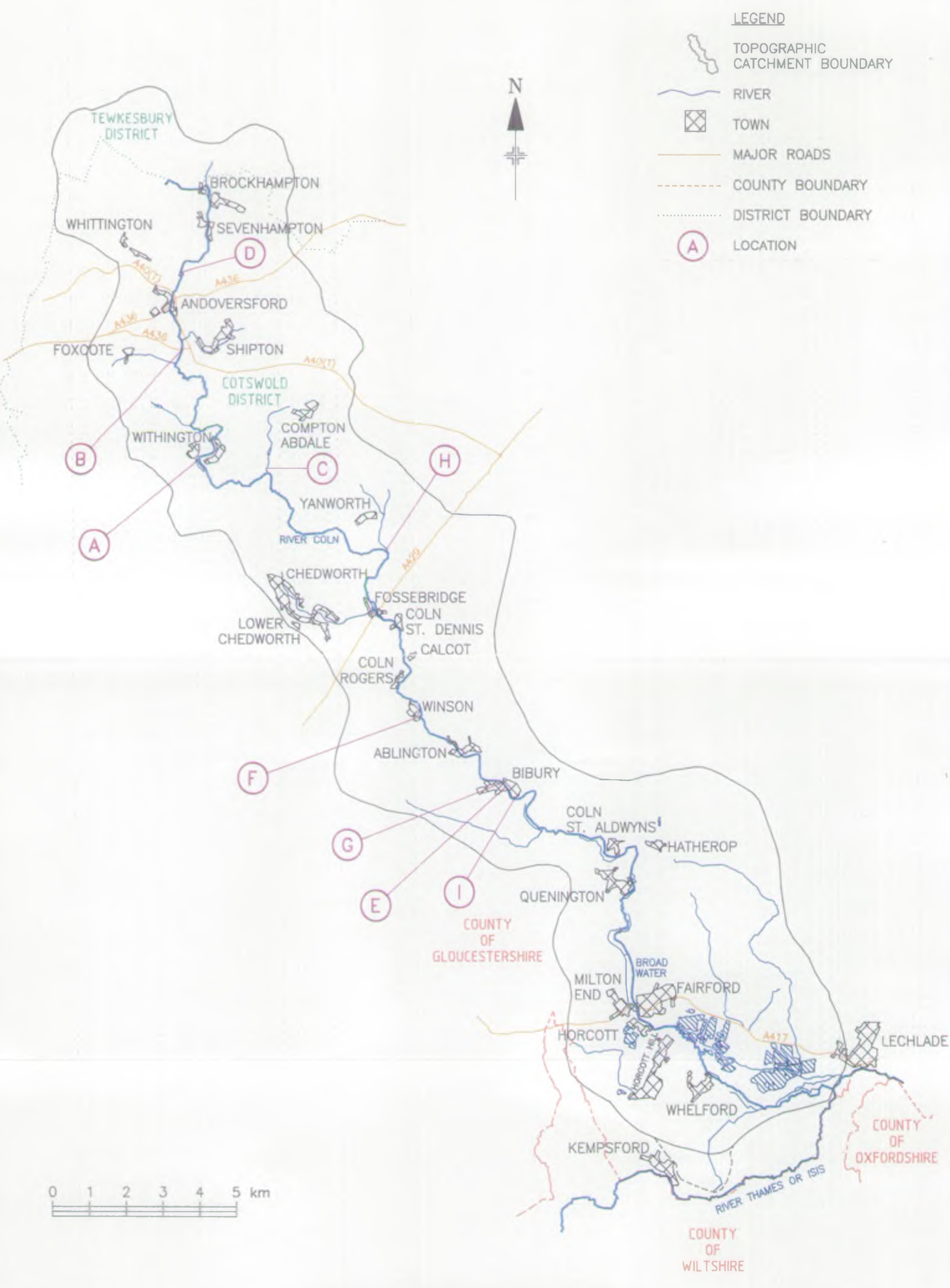
This reach coincides with the upper margins of outcrop from the Great Oolite and dewatering of this aquifer occurs during low flow periods. This results in losses from the river to the aquifer and a progressive extension of the dry river bed from Stowell downstream.

The flow accretion data support the theory that flows from Bibury Spring are sourced, at least in part, from the Inferior Oolite as the flow downstream of Bibury does not appear to be related directly to the variation in flows upstream.

A section of the Lower Reach, from Bibury to Quenington, loses flow to the aquifer. These losses appear to be fairly consistent at around 5 to 10 Ml/d. Rushton et al (in press) consider these flow losses to be due to 'short-circuiting', with surface flows lost to groundwater only to rejoin the river downstream of Quenington.

The public perception is that river levels have reduced considerably, along the Central Reach in particular, since the mid 1980s. Comparison has also been made with considerably higher levels in the 1950s. Surface flow analysis indicates a general reduction in both mean and low flows from a higher level in 1985. The flow reductions however are (i) directly comparable to flow reductions in the adjoining Leach catchment and (ii) statistically unremarkable over the 28 year flow record.

The double mass analyses indicate that there has been a change in the surface flow regime of the river to Bibury Gauge around 1975-76. An increase in surface flow relative to rainfall is followed by a nett increase in flows at Bibury in the order of 3-8 Ml/d. An increase is registered in comparison with both meteorological data and surface flows for another catchment.



RIVER COLN CATCHMENT

SURFACE FLOWS : LOCATION PLAN

FIGURE 5.1

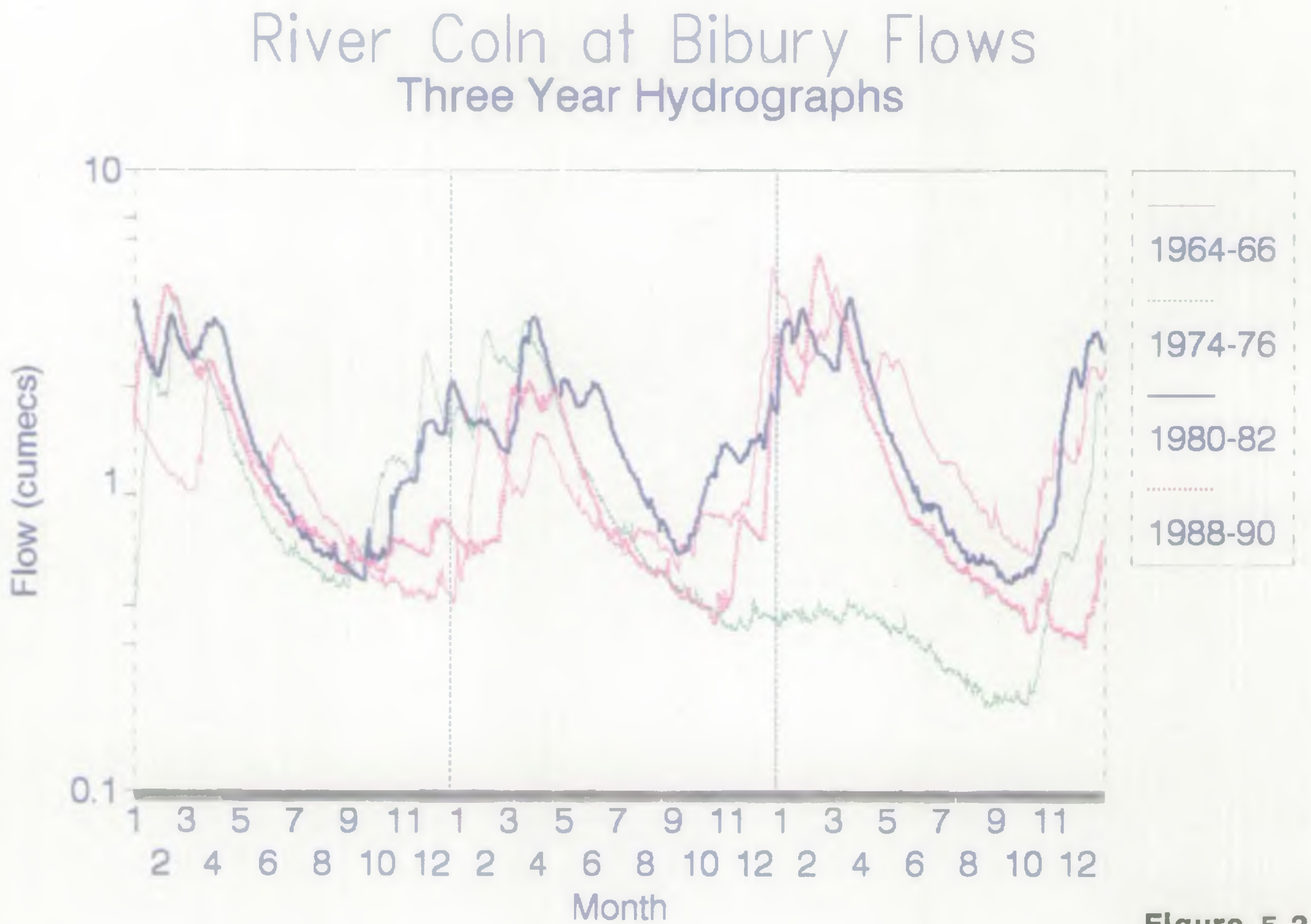
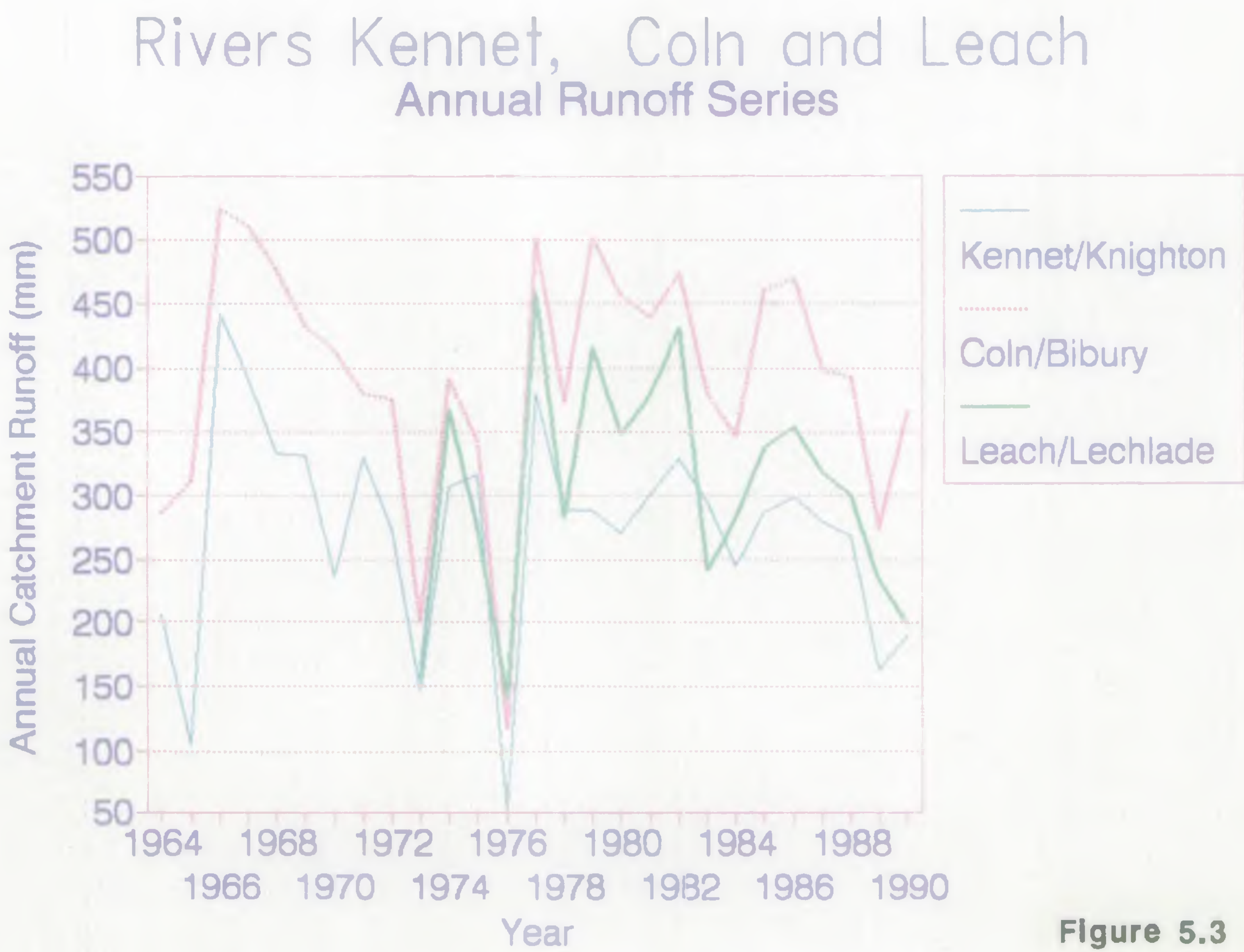

River Coln at Bibury Flows
Three Year Hydrographs
10
1
0.1
Flow (cumecs)
1 3 5 7 9 11 1 3 5 7 9 11 1 3 5 7 9 11
2 4 6 8 10 12 2 4 6 8 10 12 2 4 6 8 10 12
Month
1964-66
1974-76
1980-82
1988-90

Figure 5.2



Rivers Kennet, Coln and Leach
Annual Runoff Series
Annual Catchment Runoff (mm)
550
500
450
400
350
300
250
200
150
100
50
1964
1968
1972
1976
1980
1984
1988
1966
1970
1974
1978
1982
1986
1990
Year
Kennet/Knighton
Coln/Bibury
Leach/Lechlade

Figure 5.3

20 DAY ANNUAL MINIMUM FLOW SERIES

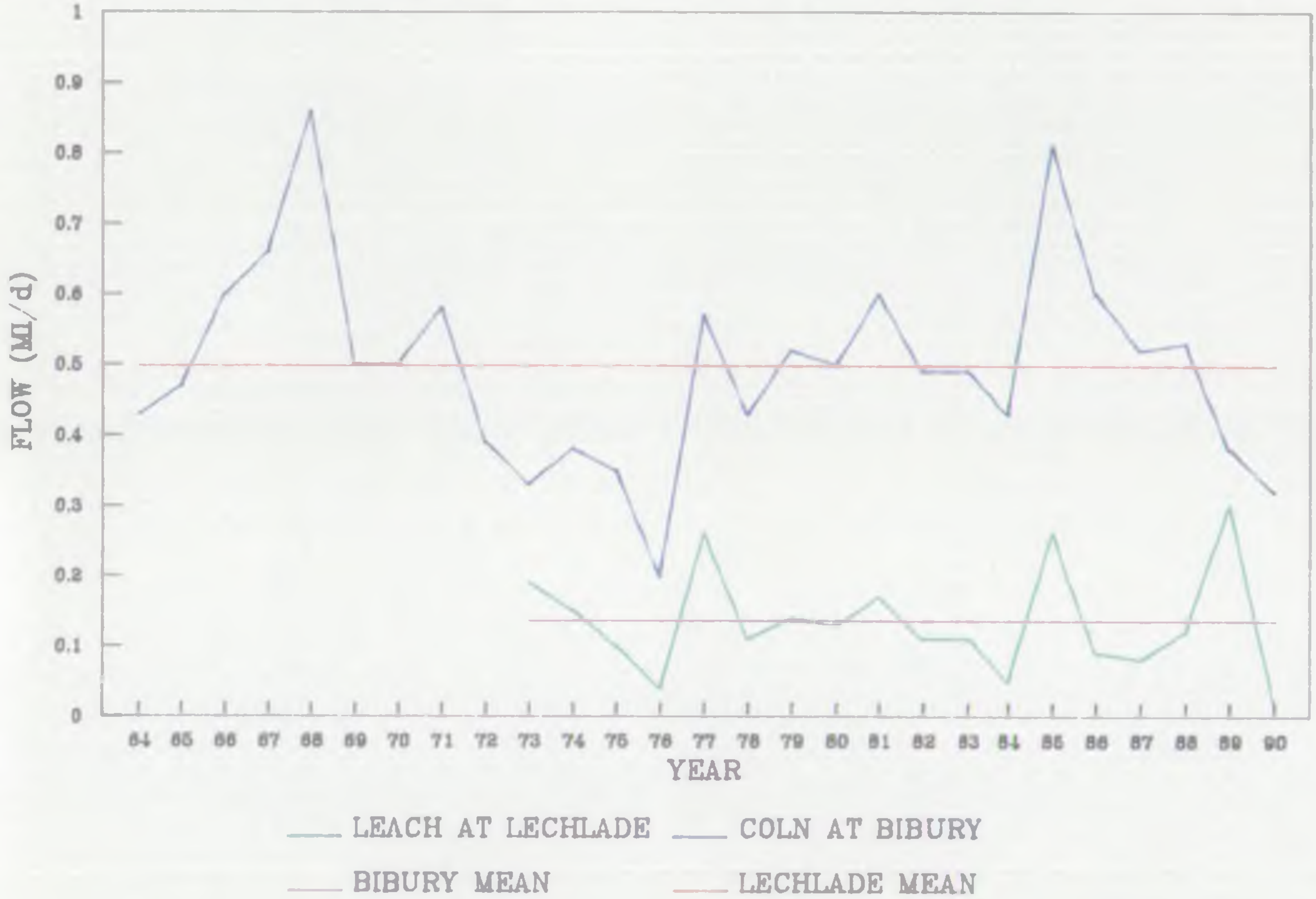


Figure 5.4

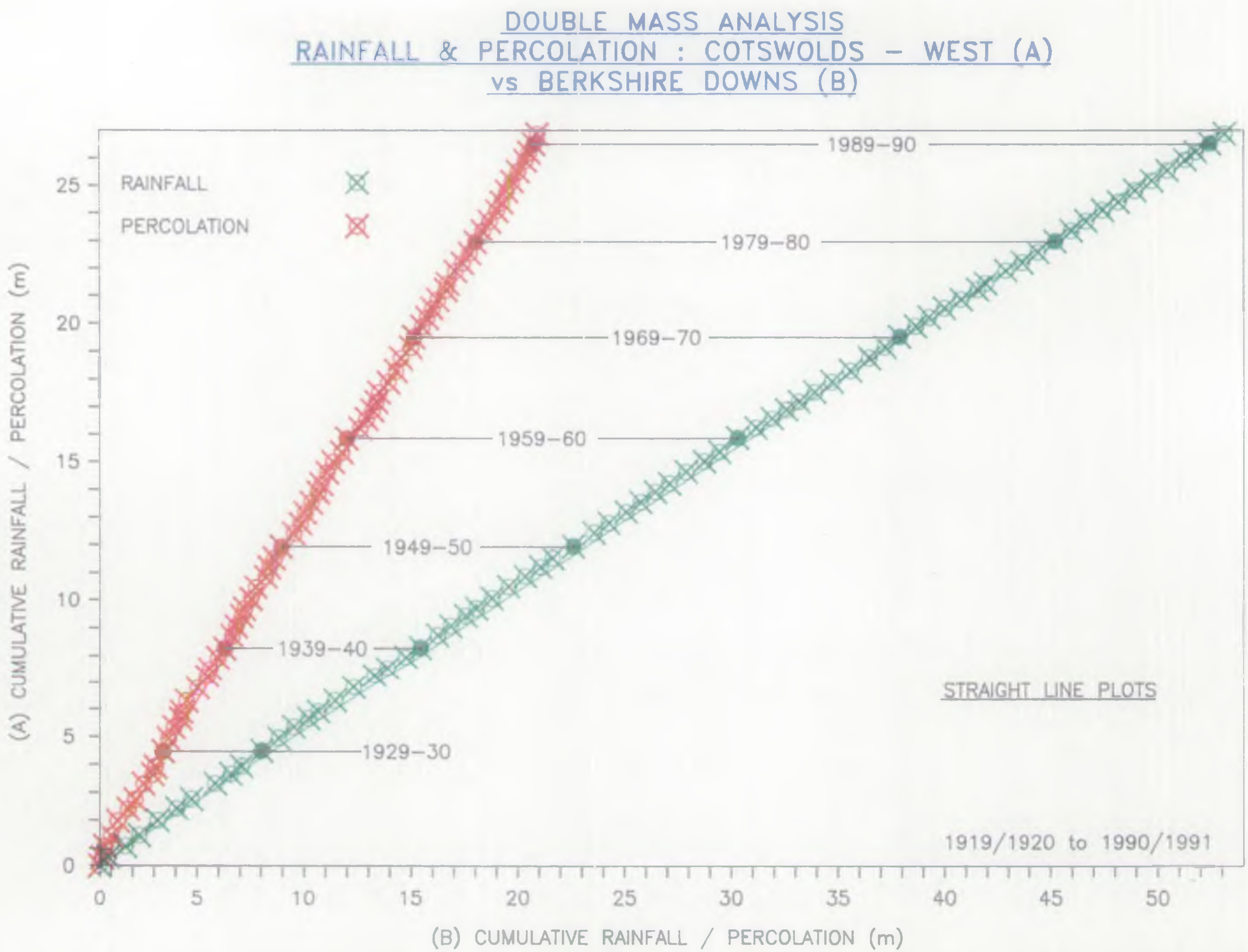

DOUBLE MASS ANALYSIS
RAINFALL & PERCOLATION : COTSWOLDS - WEST (A)
vs BERKSHIRE DOWNS (B)
RAINFALL
PERCOLATION
1989-90
1979-80
1969-70
1959-60
1949-50
1939-40
1929-30
STRAIGHT LINE PLOTS
1919/1920 to 1990/1991
(A) CUMULATIVE RAINFALL / PERCOLATION (m)
(B) CUMULATIVE RAINFALL / PERCOLATION (m)
0
5
10
15
20
25
30
35
40
45
50

FIGURE 5.5

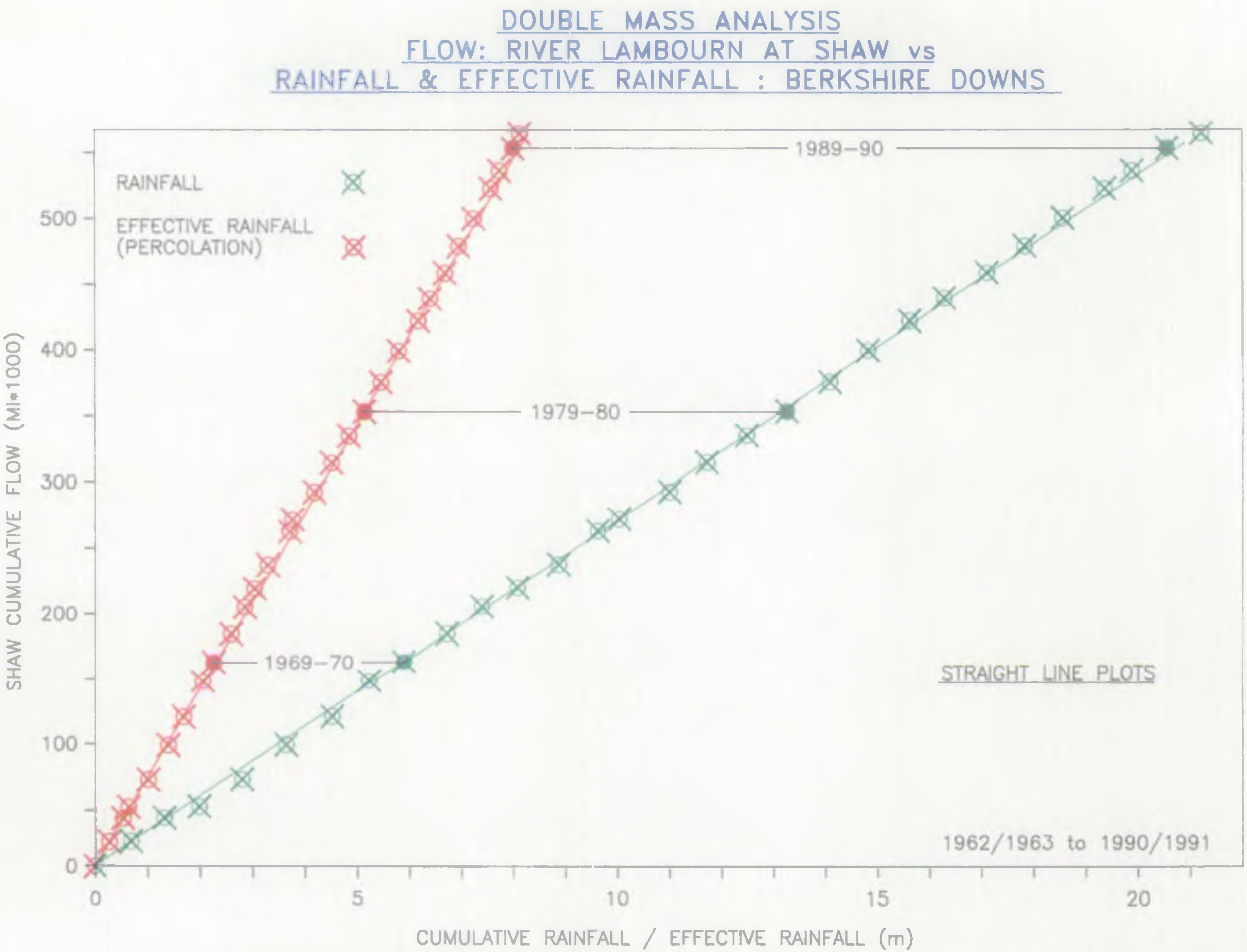
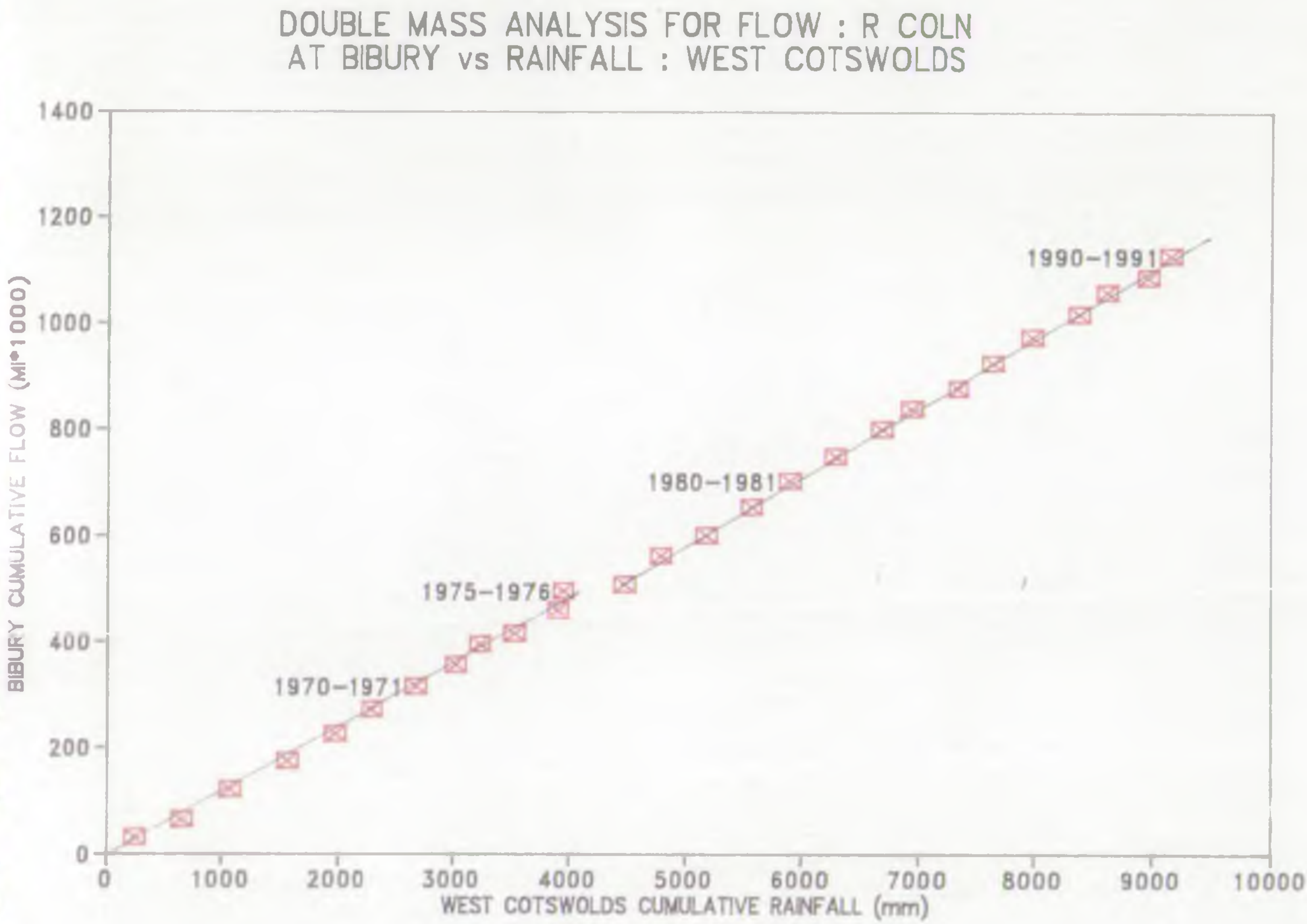

DOUBLE MASS ANALYSIS
FLOW: RIVER LAMBOURN AT SHAW vs
RAINFALL & EFFECTIVE RAINFALL : BERKSHIRE DOWNS
RAINFALL
EFFECTIVE RAINFALL (PERCOLATION)
1989-90
1979-80
1969-70
STRAIGHT LINE PLOTS
1962/1963 to 1990/1991
SHAW CUMULATIVE FLOW (Ml*1000)
CUMULATIVE RAINFALL / EFFECTIVE RAINFALL (m)
0
100
200
300
400
500
5
10
15
20

FIGURE 5.6



DOUBLE MASS ANALYSIS FOR FLOW : R COLN
AT BIBURY vs RAINFALL : WEST COTSWOLDS
BIBURY CUMULATIVE FLOW (Ml*1000)
WEST COTSWOLDS CUMULATIVE RAINFALL (mm)
1970–1971
1975–1976
1980–1981
1990–1991
0
200
400
600
800
1000
1200
1400
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

Figure 5.7

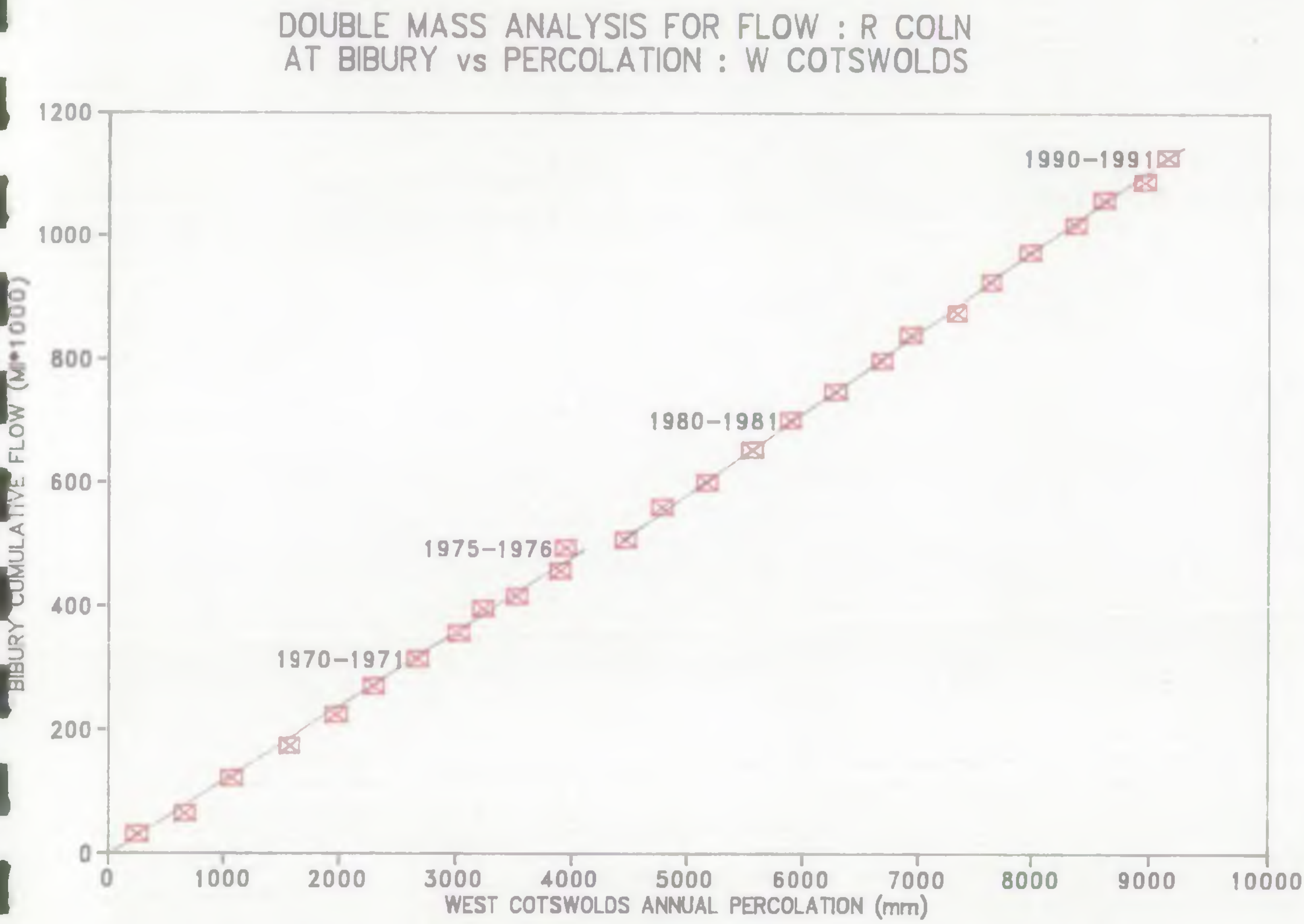

DOUBLE MASS ANALYSIS FOR FLOW : R COLN
AT BIBURY vs PERCOLATION : W COTSWOLDS
BIBURY CUMULATIVE FLOW (Ml*1000)
WEST COTSWOLDS ANNUAL PERCOLATION (mm)
1970-1971
1975-1976
1980-1981
1990-1991
0
200
400
600
800
1000
1200
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

Figure 5.8

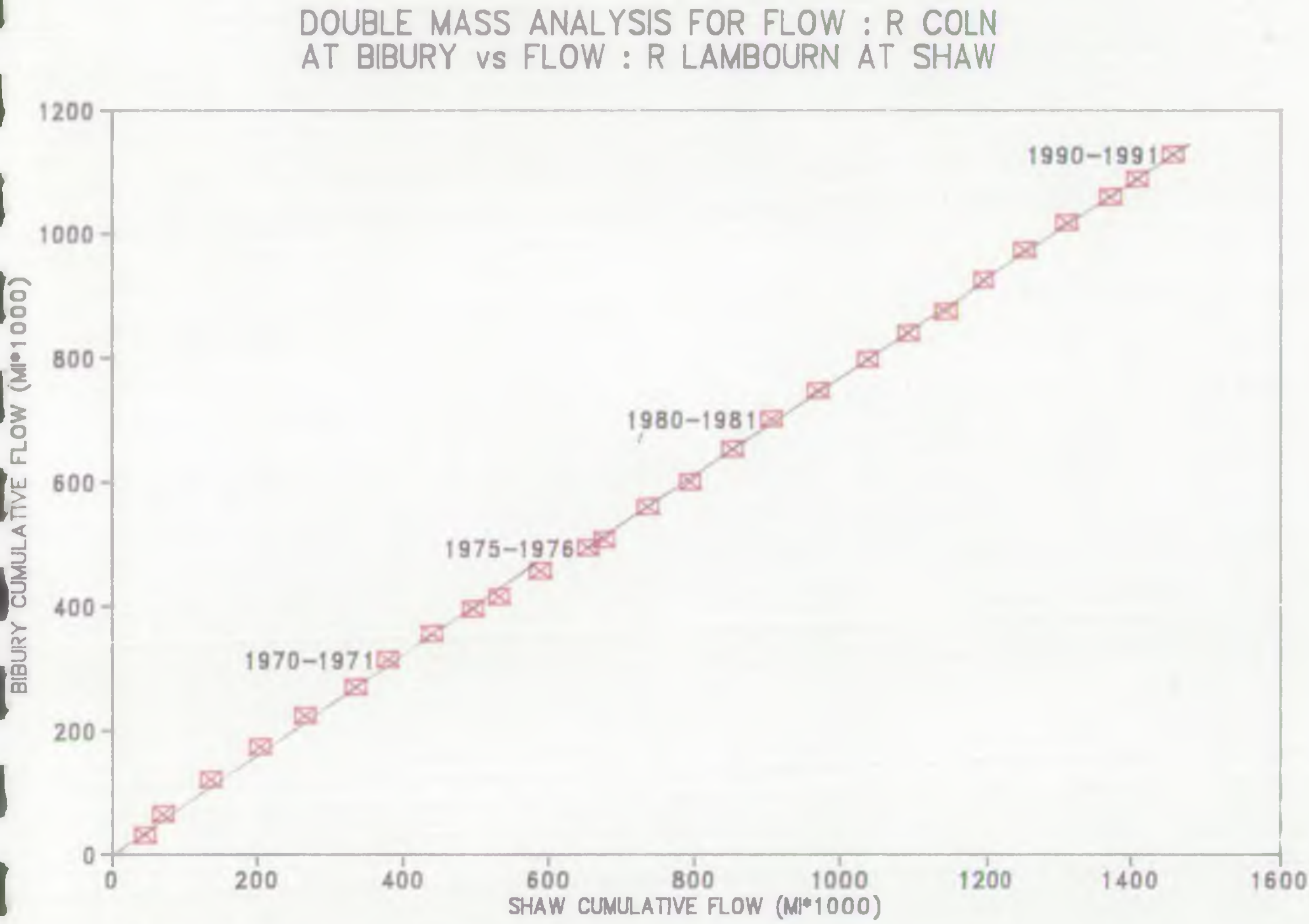
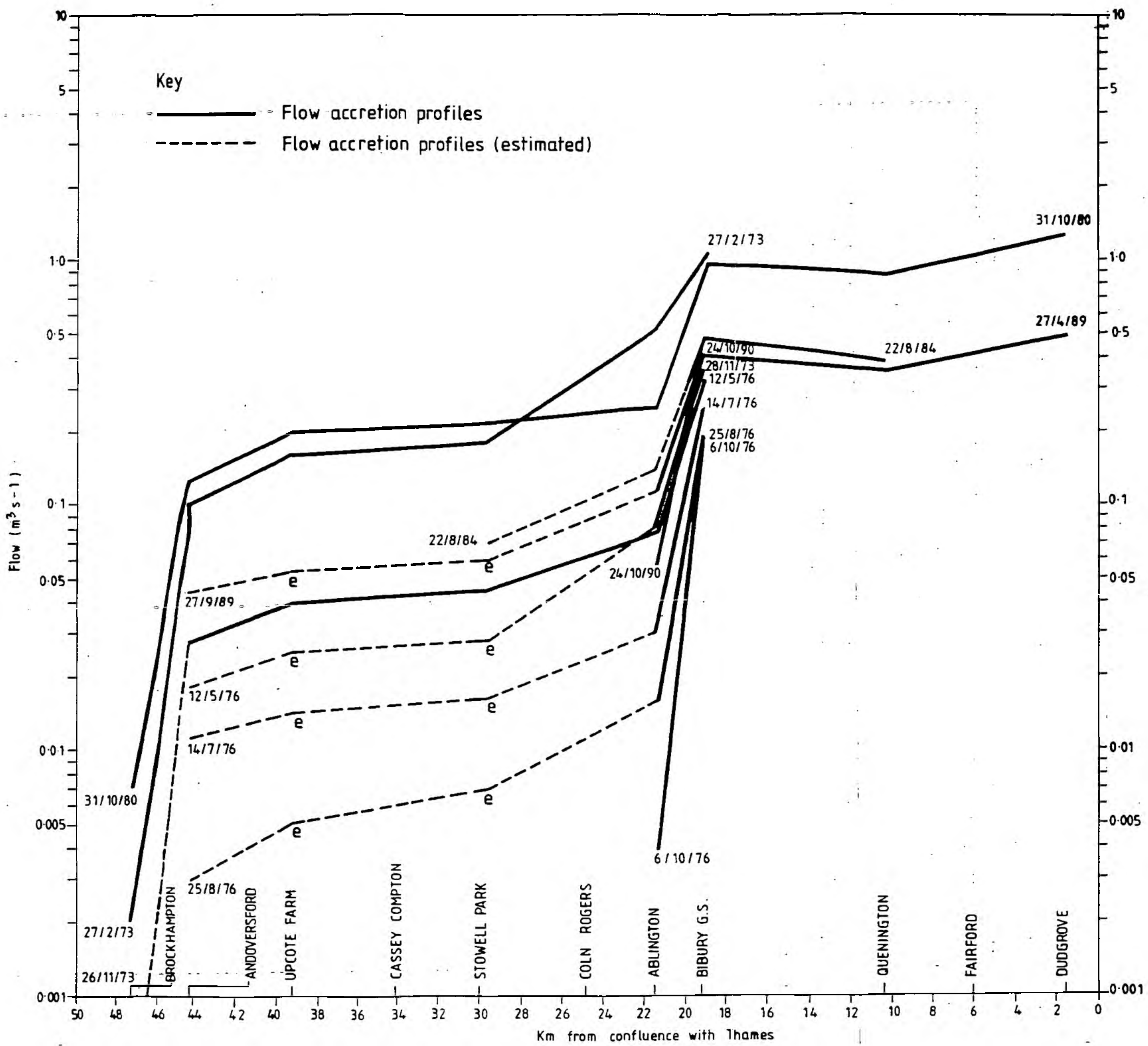

DOUBLE MASS ANALYSIS FOR FLOW : R COLN
AT BIBURY vs FLOW : R LAMBOURN AT SHAW
BIBURY CUMULATIVE FLOW (Ml*1000)
SHAW CUMULATIVE FLOW (Ml*1000)
0
200
400
600
800
1000
1200
1400
1600
1970-1971
1975-1976
1980-1981
1990-1991

Figure 5.9



RIVER COLN FLOW ACCRETION **Figure 5.10**

6. WATER QUALITY

6.1 Introduction

This section considers the information and data on river water quality. The effect of discharges from sewage works and from farms and other pollutant inputs is addressed in Section 11.

The River Coln drains the Oolitic limestone aquifers of the Cotswolds. River flows are predominantly derived as baseflow from the aquifers. Groundwater derived from the Oolitic limestone tends to be clear, of even temperature and high chemical quality.

6.2 Historical Perspective

The only historical reference to water quality is found in Gibbs (1898). He compares water clarity above Bibury with that of the spring outflows and notes that '... at Bibury, and at intervals of about half a mile all the way down, the river is fed by copious springs of transparent water; the lower down you go, and the more springs that fall in the river, the more glassy does it become'. Its clarity is described later in the book as, '... like looking into a gin bottle', or 'as clear as gin'. The water in the upper reaches on the other hand '... when in good trim, is of a whey colour, though after June it becomes low and clear'.

Gibbs also described on one occasion, above the Roman Villa (A) when the river was '... as thick as pea soup. Sheep washing had been going on a mile or so above me ...'. In fact, the sheep washing provided a large amount of food for the fish and the cloudy water disguised his artificial fly. Consequently, Gibbs had a successful day's fishing.

6.3 Public Perception

The main concern with regard to water quality is a widely held belief that water clarity has deteriorated in recent times. A deterioration in clarity has been reported throughout much of the middle and lower sections of the river. A number of interviewees have noted that the stream used to be characteristically 'gin clear' and the sediment load has increased in recent years. A complaint was received by the NRA in 1990 referring to the 'milky-green hue' in the river.

During one of our visits to the catchment in October 1991 we noted, in a traverse upstream from Bibury, that there were varying degrees of cloudiness in the water flow. A likely contributory cause of this was noted on the eastern bank of the river near Cassey Compton (B). The bank was stripped of grass cover over a 10m width and 200m length due to trampling by livestock. The consequent soil loss was introducing sediment into the river.

Further contributions to the milky and cloudy state of the river may be (i) the precipitation of calcium carbonate in the river due to the pressure decrease and temperature increase following outflow from the aquifer and (ii) the suspension of algal matter, which has generally increased within the catchment (see Section 7).

6.4 Factual Data

Water Quality Objectives and the NWC Classification

The Water Quality Objective (WQO) for the River Coln is 1A apart from a reach of 10.5km from Bibury Trout Farm to Fairford Mill which has a WQO of 1B.

According to the Report of the 1990 Water Quality Survey (NRA, 1991) the entire length of the River Coln achieved 1A. The classification is determined mainly on concentrations of dissolved oxygen, biochemical oxygen demand (BOD) and ammonia obtained from routine NRA monitoring work. Class 1A is the highest class and is described under the scheme as water of high quality suitable for potable supply abstractions, game or other high class fisheries and high amenity value. In 1991 reduced levels of dissolved oxygen resulted in the river achieving class 1B. The reasons for this are discussed in the appropriate section below.

Parameter Concentrations

Figures 6.2 to 6.6 show the changes in average annual concentrations of BOD, ammoniacal nitrogen, nitrates (TON), phosphates and dissolved oxygen respectively for the three major water sampling sites at Lechlade (C), Bibury (D) and Fossebridge (E) since 1975.

BOD concentrations in the river show considerable variations through time (Figure 6.2), although there appears to be little discernible trend either temporally or between the three sites. Lechlade at the bottom of the catchment and Fossebridge in the upper part, probably display the greatest variations, although it is noticeable that all three sites have become more homogenous with respect to BOD concentration since 1987 and that BOD levels increased steeply at all three sites in 1991.

Ammoniacal nitrogen levels are low in the River Coln (Figure 6.3). The only anomaly, at Lechlade in 1979, is the result of a single very high reading which is either an error in the data or a routine sample picking up some form of intermittent pollution event. There appears to be a marginal increase in ammoniacal nitrogen over time at each site.

The average BOD and, particularly, NH_4 readings found in the Coln, are very low when compared with other surface waters and, irrespective of the limited changes found with respect to NH_4 and BOD, the water quality remains of very high quality.

Nitrate concentration, as measured by total oxidised nitrogen (Figure 6.4), displays a modest but steady increase in concentration through time at all three sampling locations. This trend has been mirrored in many other chalk and limestone rivers throughout the UK, and has been attributed largely to increased diffuse source inputs, largely from fertiliser application to or ploughing of arable land.

Mean annual phosphate concentrations (Figure 6.5) display relatively large variations for all three sites on the river but do not indicate any long term trends. Interestingly, Bibury and Lechlade have tended to mirror one another since 1986, while all three sites display a sharp increase in 1990. It should be remembered, however, that these fluctuations occur against a background of relatively low river phosphate concentration when compared to other chalk or limestone rivers. The concentrations found are unlikely to give rise to specific water quality issues in a fast flowing river such as the Coln.

Dissolved oxygen data, plotted on Figure 6.6, show a slow but steady increase in saturation over the period from 1976 to 1989. The data for 1990 and 1991 indicate a significant reduction in saturation. The boundary between 1A and 1B classification is a DO saturation of 90 per cent and this graph indicates that, in 1991 the river was classified as 1B, on the basis of reduced DO, at each of the three main water quality monitoring stations. The reduction in DO is considered to be largely due to reduced flow rates over the last two years and a consequent decreases in turbulence and increase in residence time for the river water.

Total Loadings

Variations in the annual average catchment throughput (i.e. total load) for each parameter are also important in understanding the variations in, and the major sources of, these parameters.

Figure 6.7 compares the average daily throughput (as calculated by multiplying the annual average concentration with the average daily flow) with the average daily flow for each year. Bibury flow and water quality data were used as they represent the longest record of both in the catchment.

Figure 6.7 indicates that the average annual loads of BOD, phosphate and ammoniacal nitrogen have remained relatively constant through time, and therefore the annual throughputs are largely independent of flows. The data indicate that these parameters are derived largely from point sources at very low concentrations.

Annual nitrate loadings display considerable variation through time, but do not appear to follow any clear trend. It is interesting to note the very close relationship nitrate throughput has with average daily flows. This indicates that nitrate loadings to the river are derived primarily from diffuse groundwater baseflow.

Temperature

The annual mean, minimum and maximum temperature values recorded at Lechlade since 1974 are shown on Table 6.1 and plotted as Figure 6.7. The mean annual temperature ranges from 7.5 to 12.2°C while the minimum and maximum values recorded over the period were 0.5 and 24°C respectively. These temperatures, although more variable than measured for the Kennet, are still within the limits for a trout habitat.

Table 6.1 - Annual Mean, Minimum & Maximum Temperature at Lechlade

Year	Min °C	Max °C	Mean °C
1974	6.5	17	11.25
1975	4	19.5	9.79
1976	1	18	7.5
1977	5	15	8.6
1978	4	16	9.7
1979	2	16	9.6
1980	2	17	9.7
1981	4	18	10.2
1982	0.5	24	11.6
1983	3	18	9.6
1984	5	21	12.0
1985	4	15.5	9.9
1986	6.5	17	10.9
1987	4.0	16	9.7
1988	6	16	9.9
1989	6.6	19	11.5
1990	4	18	11.35
1991	5	17	12.2

Suspended Solids

The data on suspended solids are limited to 12 years (between 1975 and 1991) recorded at Lechlade. These data are shown on Table 6.2 and plotted on Figure 6.8. It has been reported that water clarity has decreased in recent years. These data indicate that, at least at the base of the catchment, suspended solid concentrations have remained constant or reduced slightly over the last 15 years and suspended solids are unlikely to be the cause of any increase in river cloudiness.

A good set of suspended solids data are not available elsewhere in the catchment.

Table 6.2 - Suspended Solids Data for Lechlade

	Concentrations (mg/l)		
	Min	Max	Mean
1975	0.1	20.2	5.9
1976	4.8	27.5	11.5
1977	1.2	56.5	12.23
1978	1	55.3	13.3
1979	2.9	12.8	23.4
1980	1	26.6	10.5
1981	2.5	66	14.4
1982	0.8	38.0	11.5
1983	2.0	28	9.76
1984	3.0	44.5	13.87
1985	2.5	26.5	13.68
1986	3.0	29.0	10.9
1987	4.4	66	19.92
1988	3.2	40	15.19
1989	1.5	27	8.6
1990	1	30	9.37
1991	2.0	14.5	7.48
Mean			13.06

Although suspended solid concentrations do not appear to have increased over the data period, the reports of increased build up of silt on the river bed are supported by our own observations. This is considered to be due to less than average winter flow rates, resulting in a reduced scour of the river bed.

The causes of the milky hue in the Cotswolds Streams have been investigated recently for an adjacent catchment (NRA, pers.comm). The precipitation of calcium carbonate from groundwater baseflow, due to changes in temperature and pressure, and the suspension of fine clay particles have been offered as explanations. In addition, algal blooms have been recorded on these rivers in recent years. Dark brown algal matter rising in suspension has been reported on the River Coln and this is considered further in Section 7.

6.5 *Summary and Conclusions*

- Water quality is generally of a very high standard. Most of the river has a WQO of 1A and the entire river length was of 1A standard under the 1990 NWC Classification. Reductions in dissolved oxygen in 1991 have resulted in the river being of 1B standard in that year.

- There are few discernible trends with respect to annual average BOD, NH_4 or PO_4 concentration, and all three determinands exhibit relatively low concentration throughout the period of record. The concentrations of each of these parameters, irrespective of any trends identified, are unlikely to give rise to significant water quality issues.

- Dissolved oxygen concentrations show a steady increase through time up to 1989 followed by a significant reduction in the last 2 years. This has resulted in the river falling to class 1B in 1991 under the NWC Classification. The reduction in dissolved oxygen is considered to be largely a result of reduced flow rates leading to less turbulence and increased residence time over the last 2 years.

- The average annual catchment throughputs for BOD, NH_4 and PO_4 have remained largely similar through time and are largely unaffected by annual flow variation. The primary sources of BOD, NH_4 and PO_4 within the catchment are likely to be non flow related sources such as natural biological activity within the river or specific point source discharges.

- NO_3 concentrations have shown a modest but consistent annual average increase at all sampling sites through time. The average annual catchment throughput for NO_3 is seen to fluctuate considerably over time. The throughput is very clearly correlated with annual flow. The primary source of NO_3 within the catchment is likely to be diffuse groundwater baseflow related to increased nitrate levels in recharge waters.

- Historically, spring flows near Bibury are noted as 'gin clear' whereas the flows upstream are naturally 'whey coloured', becoming clearer as flows reduce. This pattern is also noted in the present day. The whey colouration is considered to be due, in part, to calcium carbonate coming out of solution in response to increased temperature and decreased pressure when compared to groundwater.

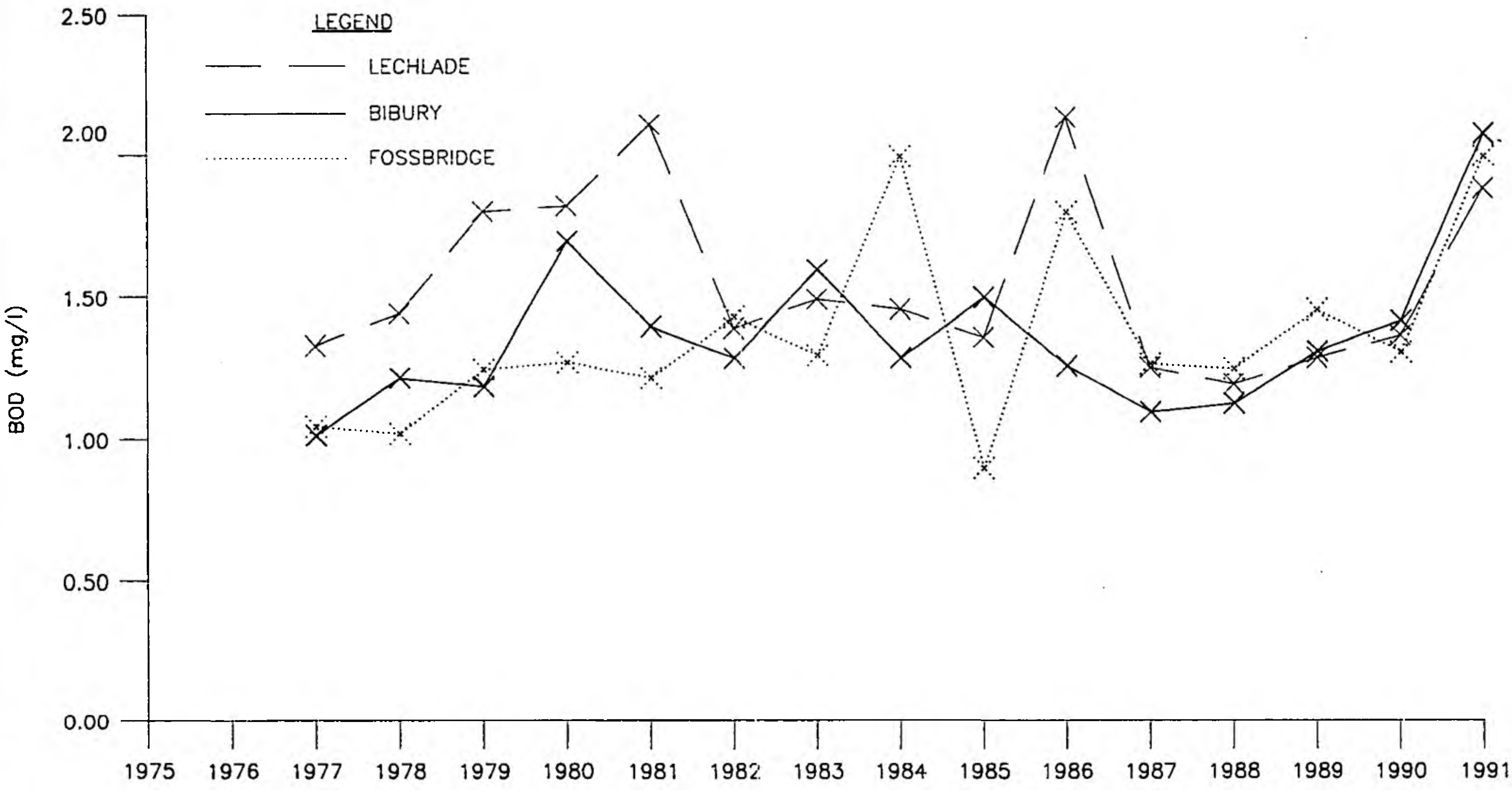
- There are significant silt inputs to the river at present. These are related, in part at least, to bank erosion from livestock trampling. However, there is no discernible increase in suspended solid concentrations over the 15 year data period. Silt concentrations appear to be related to flow rate and are probably controlled in part by the degree of (i) surface runoff and (ii) sediment scouring. Reduced sediment scour in the last few years due to lower winter flows, has resulted in a build up of sediment on the river bed.

01/06/92 - 15:55---SG File-\COLN\FIG6-1

RIVER COLN CATCHMENT

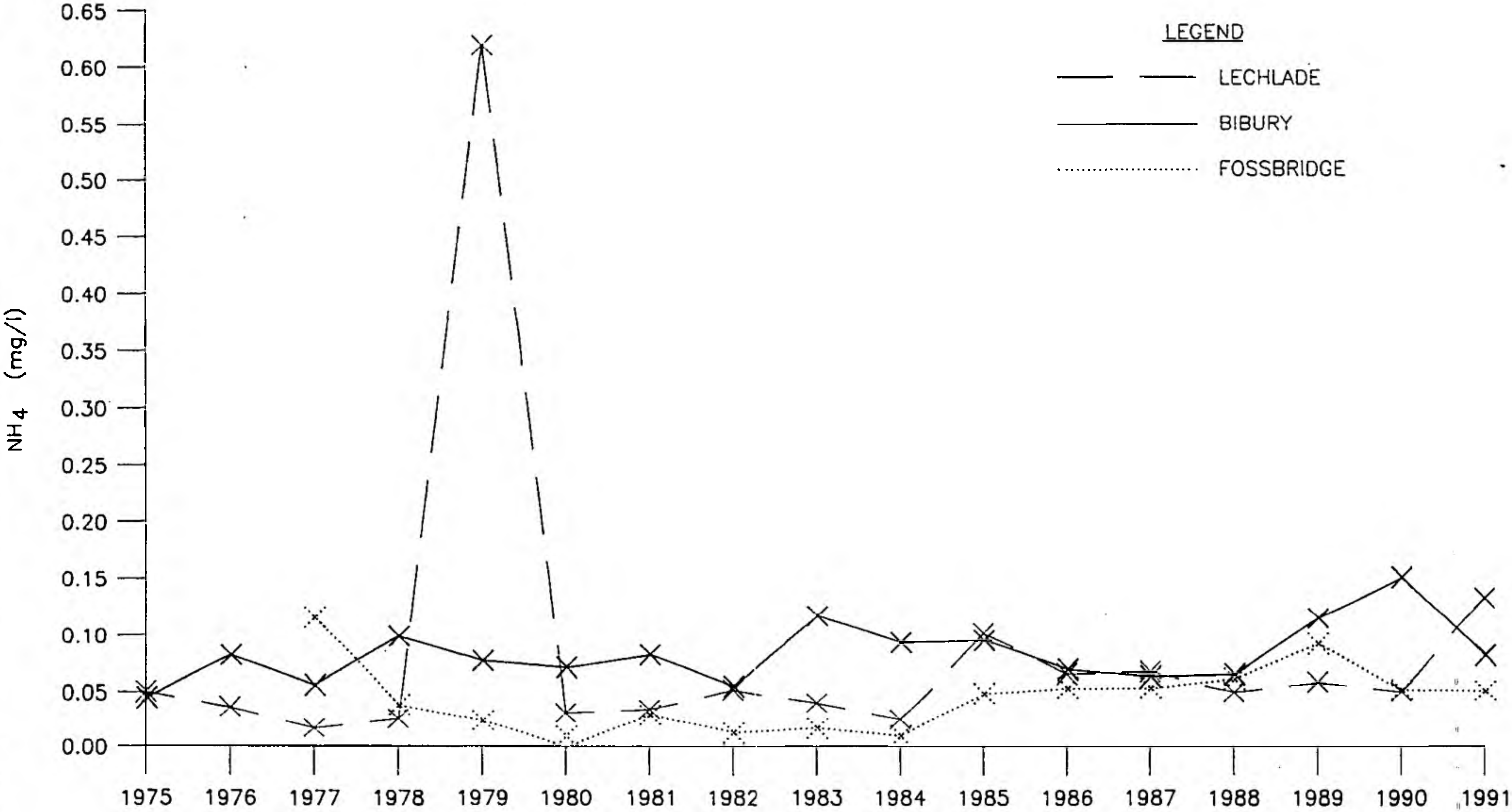
WATER QUALITY : LOCATION PLAN

FIGURE 6.1



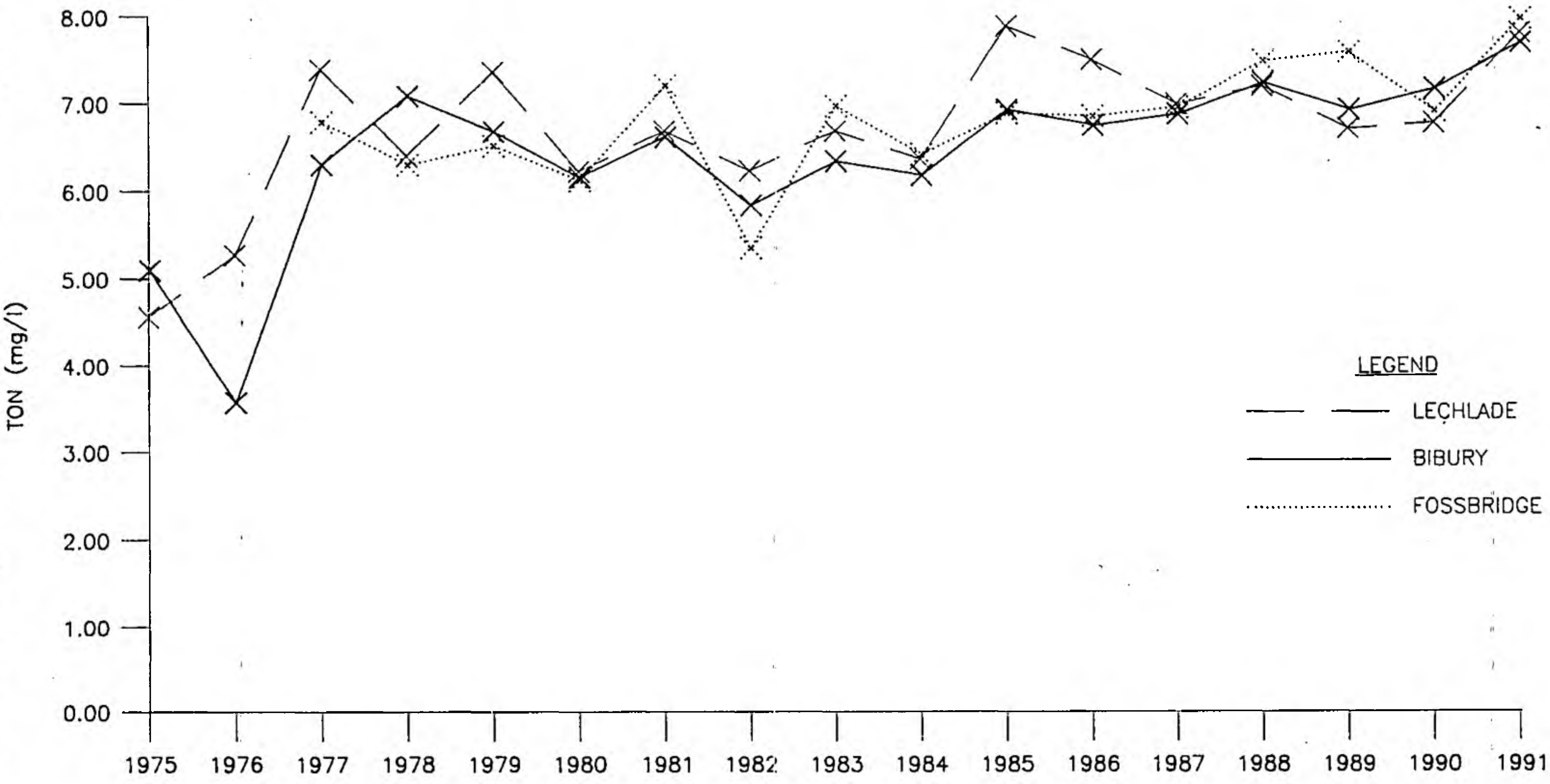
WATER QUALITY CHANGES THROUGH TIME FOR LECHLADE. BIBURY & FOSSBRIDGE – RIVER COLN (BOD LEVELS)

FIGURE 6.2



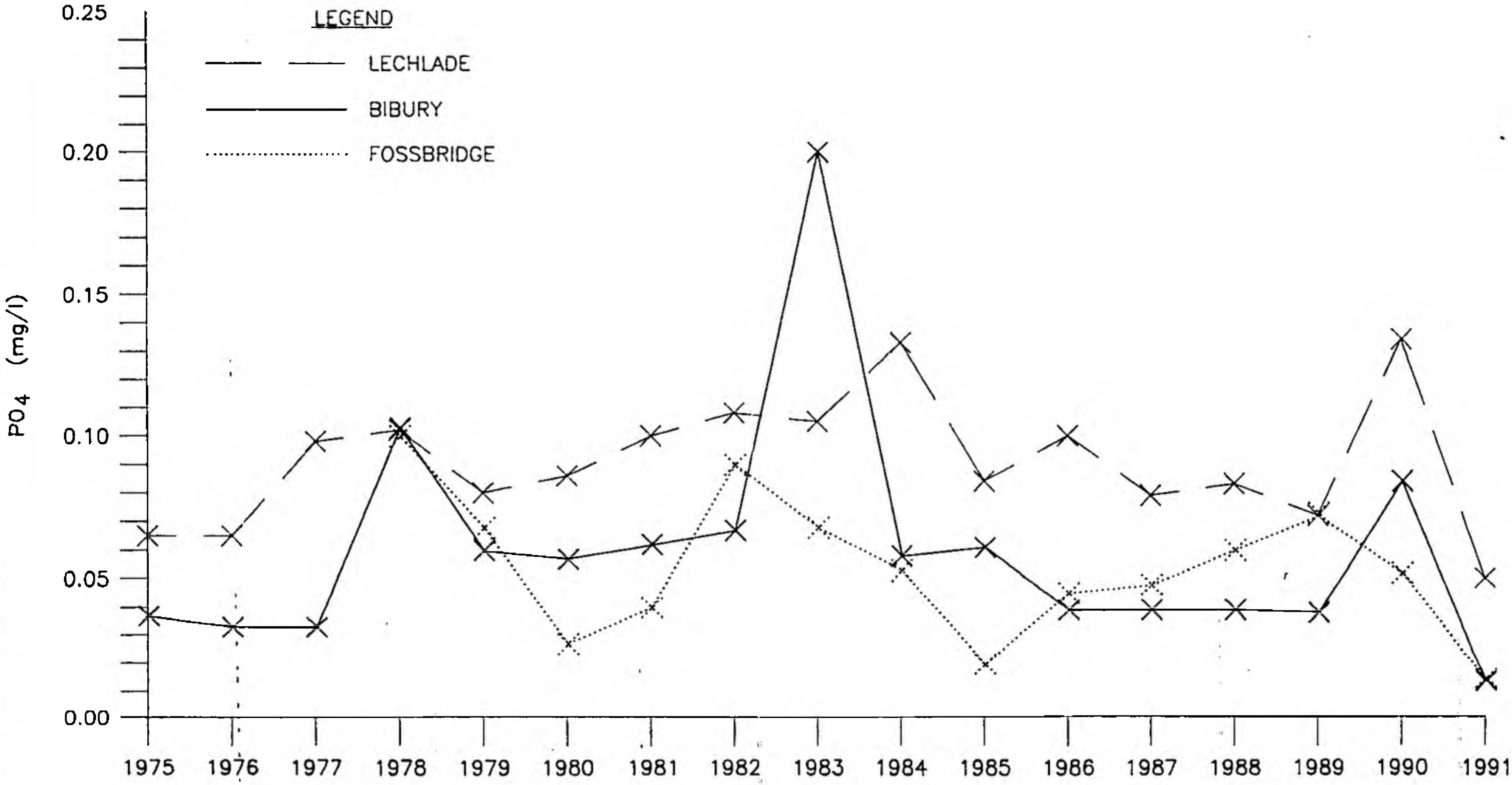
WATER QUALITY CHANGES THROUGH TIME FOR LECHLADE, BIBURY & FOSSBRIDGE – RIVER COLN (NH_4 LEVELS)

FIGURE 6.3



WATER QUALITY CHANGES THROUGH TIME FOR LECHLADE, BIBURY & FOSSBRIDGE – RIVER COLN (TON LEVELS)

FIGURE 6.4



WATER QUALITY CHANGES THROUGH TIME FOR LECHLADE, BIBURY & FOSSBRIDGE – RIVER COLN (PO_4 LEVELS)

FIGURE 6.5

Water Quality Changes Through Time For
Lechlade, Bibury and Fossebridge
River Coln (DO levels)

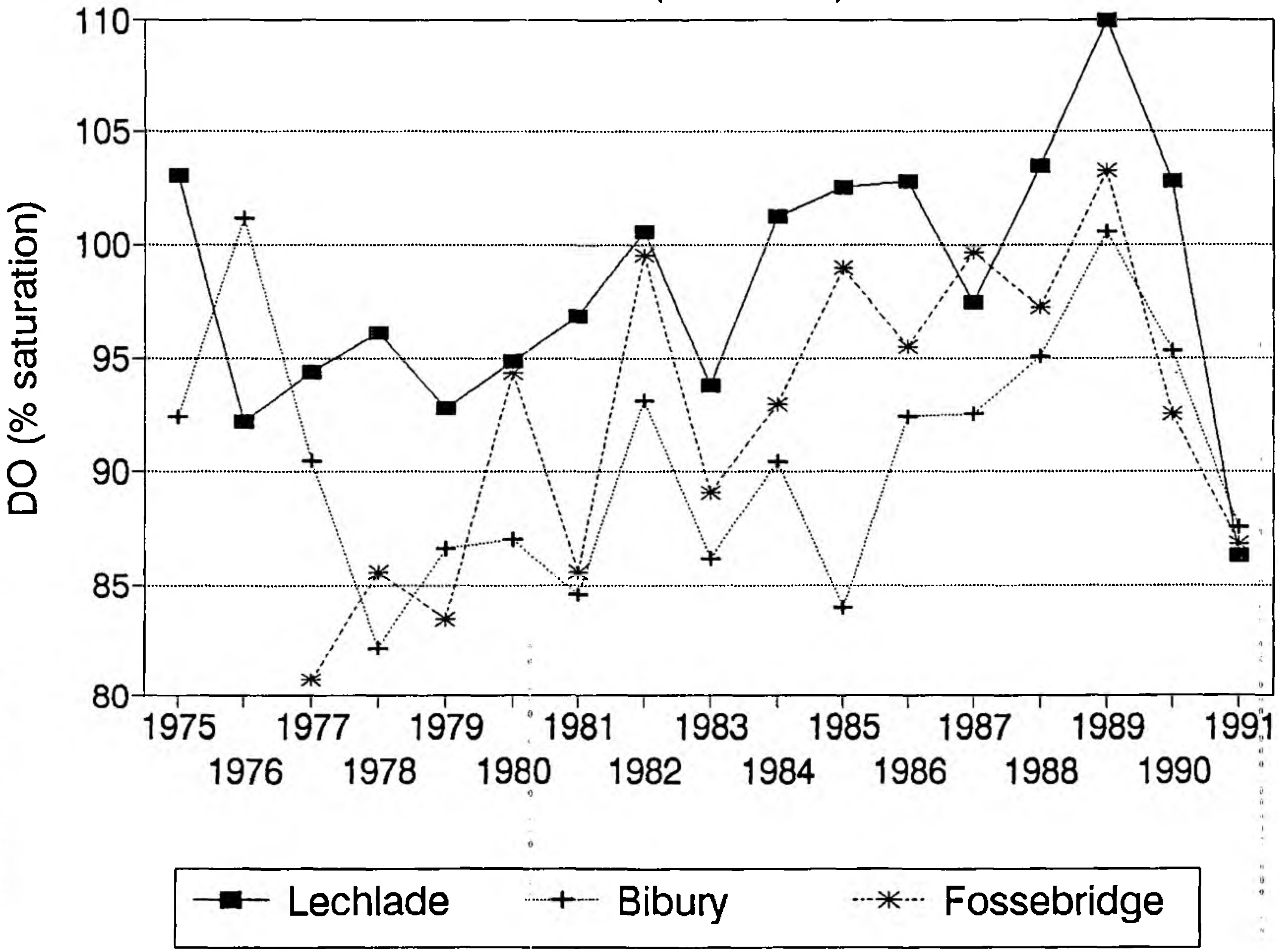
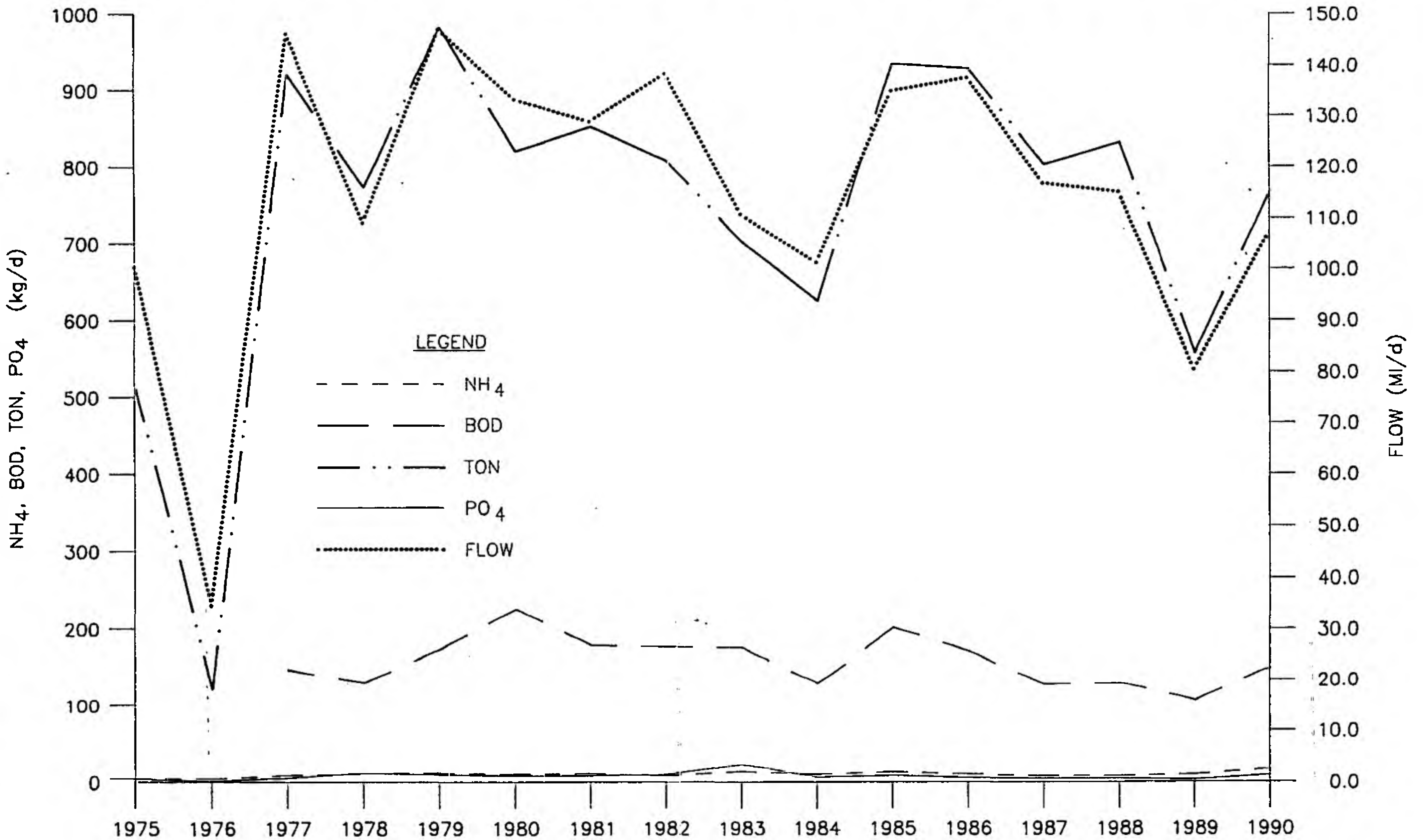
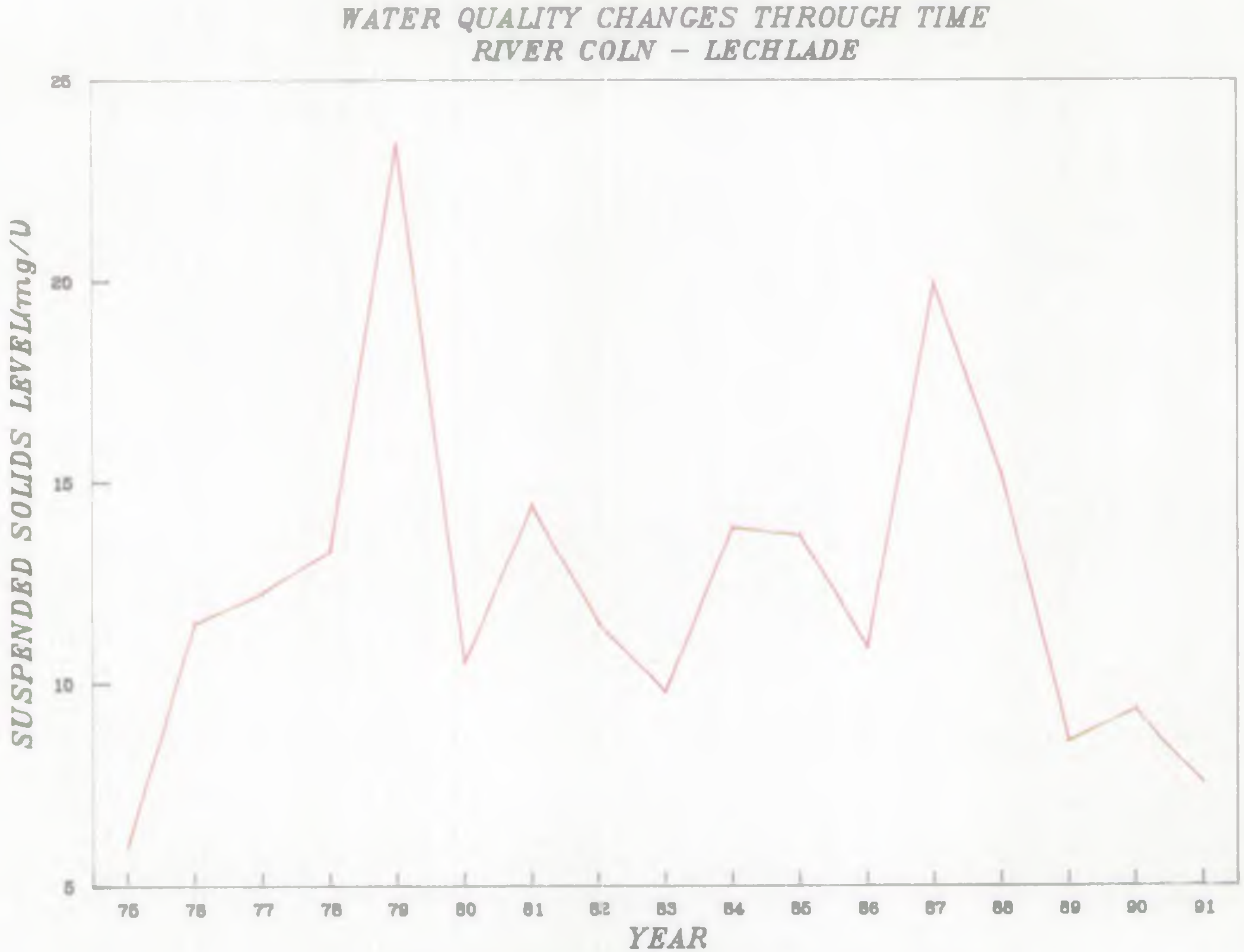


FIGURE 6.6



AVERAGE THROUGH PUT IN kg/d FOR SELECTED WATER QUALITY PARAMETERS AT BIBURY ON THE RIVER COLN

FIGURE 6.7



SUSPENDED SOLIDS AT LECHLADE

Figure 6.8

7.0 FLORA AND FAUNA

7.1 Introduction

The Coln is a good example of a highly productive, lowland, limestone river catchment. It supports a rich assemblage of plants and animals and the high pH limestone groundwater enhances the diversity of the crustaceans and molluscs in particular. The surface flow is largely sourced from groundwater baseflow and this results in a time-lag between high-rainfall events and discharge to the river. The emerging spring-water is typically clear and shows little temperature variation over the year. Thus streams arising from such sources are usually clear and show relatively low fluctuations of temperature and flow.

Seasonal differences in river level may be manifested by natural berms in the channel where bankside ledges flooded in winter are exposed in summer to support marshland vegetation. This is seen for example, along the Coln upstream of Fossebridge. In general the comparative constancy of environmental conditions within the river favours the development and maintenance of diverse and rich communities.

In this document we have referred to instream vegetation by their common names as below.

Submerged Weed - this group roots in the stream base and exists mainly beneath the water surface although some produce flowers which are borne above the surface. Examples include *Potamogeton* (Pondweeds), *Ranunculus* (Water Crowfoots) and *Callitriche* (Water Starworts).

Emergent Weed - these plants have both leaves and stems growing up out of the water or along the water margins. Examples include *Veronica* (Brooklime).

Blanket Weed - this is a filamentous algae which forms an unsightly, scum-like floating mass. Also known as Flannel Weed, or Cott.

Throughout this document the term "weed" has been used which, although not botanically correct, is the common generic term for all instream vegetation.

7.2 *Historical Perspective*

Descriptive evidence on the quality of the valley flora and fauna from Gibbs, (1898) states for example that the river '... affords some 15 miles of excellent fishing' with '... a tremendous rise of fly early in June'. Above Williamstrip (A) the fish are reported as up to 2½ lbs in weight and '.. it is very rarely that a three pounder is caught in the Coln above Bibury'. He considers that the river widens to fishable proportions upstream of Stowell (B). He describes the stocking of 500 Loch Leven yearling trout in the central reaches, indicating that fish stocking is far from a recent feature of the river.

He notes that pike and other coarse fish are not found above the lower reaches. Among the other fauna referred to are otters, corncrake, kingfishers, dabchicks and wild duck.

The management of rich, 'water-meadow' systems such as those downstream of Coln Rogers (C), are believed to have operated from the 1600s to the turn of the Century, and were dependent upon an annual inundation of surface flows.

7.3 *Public Perception*

Historically, the River Coln has been described as a 'typical' Cotswold stream with the ecology reflecting, for example, the presence of spring-fed ponds (at Winson and Fossebridge) and with the river course flowing through damp grazing pasture and woodland.

The past three to four years have witnessed a significant increase in the public awareness and concern for the environmental quality in the River Coln. There have been a number of articles in the local press and for example, in October 1988 the Wilts and Gloucestershire Standard voiced the concerns of the villagers of Coln St Dennis that over abstraction was causing the river to 'dry-up'. The Observer Magazine in October 1989, went further and described the River Coln as 'a sluggish snake of water choked with weed'.

The broad nature of perceived changes are summarised below:

- Reduced fish communities
- Loss of ranunculus (crow foot)
- Increase in filamentous algae (blanket weed)
- Increased siltation

Overall, it is generally perceived that a decline in the environmental quality of the River Coln began during the 1980s.

The decline in conditions has most obviously attracted the attention of those concerned with the river's fishing potential. Indeed, the Coln has long been noted for both natural and stocked fish, including wild trout and grayling. During the 1950s it seems that the river may have been fished as far upstream as Coln St Rogers and, in general was described as 'appearing deeper' with plentiful weed growth.

The river at Winson is no longer managed for fishing due, it is claimed, to reduced flow.

Weed growth in this central section and, in particular, between Ablington and Bibury, has been much reduced since 1988 and is believed to have started deteriorating in 1985.

The actual composition of the weed appears to have changed on the Coln. It used to be dominated by *Ranunculus* but now seems to be dominated by broadleaf emergents such as Brooklime and the submerged or floating emergent *Potamogeton* (pond weeds) which in some reaches cover the entire channel.

Of particular interest, the spring fed leat at Bibury immediately above the fish farm has retained a healthy weed growth whilst the weed in the natural river bed has reduced significantly in recent years. It is reported (NRA pers. comm) that the channel through Bibury was choked with the submerged weed Starwort as recently as 1988. The loss of weed is reported to have increased the fish losses due to herons.

A brown algal growth is reported as covering much of the bed along some central reaches and '.. tends to detach itself from the bottom in the early evening, rise to the surface and be carried downstream like a brown slurry'. This is considered (NRA pers. comm) to be a mat of diatomaceous algae which is often termed as a 'rising sludge'. The sludge rises due to the presence of gases held beneath the mats, methane from bacteria and oxygen from the algae.

At Williamstrip (A) it was reported that 15-20 years ago the weed growth was such that it was cut twice per year and required upwards of 6 men for 2-3 weeks. Last year it was only cut once by 2 men over a 2 week period. In fact weed cutting is done now only in response to observed problems rather than on a regular basis as was done previously. It has also been noted that coarse fish such as perch, roach, pike and eels were no longer found in this reach whereas they had been present in the past.

It is also reported that silt build up is increasing and a former mill leat in the downstream river section is believed to have over a metre of silt in its base, built up over 25 years (pers. comm). Trout will not breed on a silty substrate.

An absence of stone loach and minnows has been reported (pers. comm) which may reflect a poorly oxygenated state as well as the noted reduction in the presence of snails, shrimps and mayfly.

There is a general belief that many of the ecological changes are, in part, related to a reduction in water quality. The presence of a 'milky green' hue to the water has recently been observed. The inability of low flows to 'flush out' accumulated silt will favour the development of filamentous algae (the blanket weed observed in some stretches of the Coln). A possible cause of the milky green hue is a combination of algae and the calcium carbonate precipitate noted in Section 6.

An increase in the frequency or seriousness of individual pollutant events would also affect the local ecology. Certain incidents have been reported such as, for example, the diesel spillage at Stowell Park (B), in 1985 and problems with effluent input at Fossebridge Hotel in the late 1980s although the discharges were very small in this case. The last major pollution incident on the Coln was in 1979 below Fairford, which decimated the fish stocks on the 2 to 3 kilometre stretch to the downstream catchment limit.

The increase in size of Bibury fish farm is considered by some locals to increase the pollutant load carried by the river downstream although there is no evidence of a decrease in water quality (see Section 6 and 11). The frequent escape of rainbow trout from the farm is considered to be a significant problem by downstream fishermen.

7.4 Factual Data

This sub-section analyses the factual data on both the range and density of invertebrate life, fish stocking records and weed development. Further general information on the floral and faunal species generally associated with chalk and limestone streams is given in Appendix B.

Aquatic Weeds

The Cotswold streams, with their stable, nutrient rich flow regimes, provide ideal conditions for the growth of aquatic plants. Under natural, non-drought conditions these streams are dominated by dense growths of the submerged perennial *Ranunculus* (water crowfoot), particularly in the swifter flowing areas; other submerged and emergent aquatic plants common in these streams, all exploiting slightly differing niches of flow velocity, light availability and substrate composition include *Apium nodiflorum* (fools water cress), *Callitriche* (starwort), *Rorippa* (watercress), *Veronica* (brooklime) *Potamogeton* (pondweed) and *Schoenoplectus* (club rush).

Typical seasonal growth patterns of Ranunculus show that growth begins in the Autumn or early Winter, although it is late Winter to early Spring before significant increases in biomass are generally observed. Growth during the Spring is typically rapid and maximum biomass is reached by Summer. With the advent of flowering between May and July, much of the plant's growth effort is diverted to reproduction. One of the effects of weed cutting during this period may be to prevent seeding and promote vegetative growth. Shortly after flowering the plants wither and die. Increased flows in the Autumn and Winter will tend to rip out and remove this decaying vegetation.

Traditionally, intensive management has been required in order to control weed growths in the Coln catchment. Dense growths are capable of severely impeding flows and may increase the risk of localised flooding. Similarly, dense growths of weed may make angling, particularly fly fishing, impossible.

As reported in Section 7.3 above, there has been a progressive decrease in the growth of river weed and Ranunculus in particular reported, and replacement with blanket weed. The issue of progressive weed loss is not unique to the Coln catchment. On the contrary, many of the river catchments in south eastern England, and particularly those that are fed largely by groundwater baseflow, have been affected by loss of Ranunculus. Among the catchments affected are both the Wiltshire and Hampshire Avons, the Test and Itchen, Wylye, Windrush, Kennet and Cherwell.

We discussed the whole issue of weed loss with the Aquatic Weed Research Unit at Reading University and the following points were made :

° The growth of Ranunculus is dependent largely on its photosynthetic ability. This ability is determined largely by flow velocity across the weed, controlling the dissolved oxygen available to the weed and the related issue of epiphytic (algal) growth on the weed. It has been found that reduced flow velocities will reduce photosynthetic capability by 95 per cent.

° Water quality can control weed growth. Ranunculus receives sufficient nutrient for growth from very low nutrient waters. Algae require a nutrient loading of 15-20 ug/l, but this is still well below the concentrations in virtually all rivers and streams. Above this lower limit, the balance between weed and diatom growth appears to be related principally to flow velocity and oxygen concentration. There will clearly also be an upper tolerance limit for weed growth but it is not considered that water quality in the Coln approaches this limit.

° Root clogging, for example by silt, organic material and algae, restricts weed growth. Weed will also die in warm shallow water.

° Emergent and encroaching weeds will tend to grow in preference to Ranunculus if (i) the water levels are reduced, (ii) flow velocity is reduced, (iii) silt substrate is increased and (iv) the frequency of flood flows is reduced.

° Swans in particular, but also other wildfowl, are considered, particularly by river keepers, to have a significant detrimental effect on weed growth. Swans rip weeds from the substrate when feeding and this may be detrimental to the river, particularly where weed is already sparse. It is also relevant that, due to lower river levels, it has become easier for the swans to reach and take young fresh shoots, whereas in normal conditions they would only reach the mature plant. Under normal flow conditions the detrimental effects of swans are considered a lot less severe.

° It is not considered that the herbicides, pesticides and fungicides applied to arable crops will have any detrimental impact on aquatic weed.

° Weed requires sunlight for growth. Shading can reduce weed growth but is not considered reliable as a control method.

- *Ranunculus* will re-colonise rapidly as long as (i) the instream conditions are suitable and (ii) either roots are present or there is a healthy flowering growth upstream.

In summary, it appears that the primary factor controlling weed growth is flow velocity. If flow velocity is lost (i) conditions are more favourable for both emergent weeds and blanket weed, (ii) dissolved oxygen levels reduce and (iii) silt will build up, tending to smother the root systems. Loss of submerged weed leads directly to reduced river levels as noted below and, under these conditions, the young weed shoots are more vulnerable to wildfowl.

As shown in Section 6, the mean dissolved oxygen levels in the Coln have fallen significantly from a high in 1989. This is considered to be a result largely of reduced flow rates.

A study was undertaken 10 years ago considering weed growth in the River Lambourn catchment (Ham et al 1981), a tributary of the Kennet which flows into the Kennet about 20 km east of Knighton. The study showed a close positive correlation between the growth of *Ranunculus* between March and June of any year and the mean daily flow over this period.

The actual flows in the March to June period of 1988 to 1991 were, for each year, between 88 and 95 per cent of the mean for this period. These data indicate that the main factor may be the cumulative impact of a number of years of reduced flow.

The loss of weed may be a significant contributory cause to the reduced river levels within the river that have been reported by the general public. It has been reported that major weed cuts may reduce levels within the river by over a half with no change in flow rate (NRA, pers. comm). Those reports are supported by use of Mannings equation, as used in flood studies. Values of roughness co-efficient for streams like the Coln are considered to reduce by a factor of about three without a healthy weed growth, leading to a halving of river level compared to a weed rich river. This change in river character is not identified by flow metering.

Invertebrate Taxa

The presence or absence of a particular invertebrate can be used to assess the ability of a water course to provide adequate habitat. A formal method of assessment is to produce a BMWP (Biological Monitoring Working Party) score for the river. This method allocates a value of between 1 and 10 to each taxon found, with scores allotted to animals according to their tolerance/sensitivity to organic pollution/oxygen levels. In general the higher the score, the better the in-stream environment.. Another measure is the ASPT (Average Score per Taxa) which, as the name suggests, indicates the mean sensitivity of the taxa present in terms of its BMWP score.

In general, BMWP scores indicate the river water quality. However, (i) BMWP scores may show an increase if the sample covers a mosaic of habitats including still-water zones and (ii) high scores need not always imply flowing water conditions throughout. The ASPT (Average Score Per Taxa) is probably a more sensitive measure of the in-stream environment.

Records are available from Fossebridge (D), Bibury (E) and Lechlade (F) for time periods of between 9 and 12 years. The data are illustrated on Figure 7.2. The curves on the graphs have been smoothed by calculating 3 year moving averages.

Fossebridge is the upstream sampling point. At this point an overall improvement in BMWP and ASPT scores is indicated from around 1987 to 1991 although this may be due, at least in part, to the effect of samples taken at different periods of the year and recording a natural variation in-stream diversity. No overall trends are detectable at the downstream sampling locations at Bibury and Lechlade. Inspection of the taxa lists for Fossebridge reveals an increase in the abundance of taxa preferring flowing water whereas no convincing trend is seen in the still water taxa .

Fisheries

The River Coln is an EC designated salmonoid fishery between Withington and the River Thames, a total length of almost 40 kilometres. The National Rivers Authority, Thames Region have set a fish biomass target of 15 grammes/m^2 with regard to designated salmonoid fisheries.

The Fisheries Survey 1990 for the River Coln (NRA, 1992) included some site monitoring specifically in relation to low flow problems. The document logs a number of consented and NRA fish introductions for 1990 as 3175 brown trout, 600 rainbow trout and 250 grayling. All bar 100 brown trout were in the size range 10-15 inches and most fish were introduced in the area round Lechlade. Culling operations were carried out at two downstream locations, removing 150kg of grayling and 50 kg of pike and grayling in October 1990.

Electric fishing was used by NRA to sample fish populations at Coln St Dennis (G) downstream of Bibury (H) and upstream of Whelford (I). The following findings were noted:

Coln St Dennis

- Substrate of 80 per cent mud and silt and 15 per cent gravel.

- Some submerged and emergent weed with main species as *Ranunculus, Callitriche, Spargarium, Myosotis* and *Carex sp.*

- A good biomass was reported, totalling 15.7 gm/m^2 and comprising brown trout (10.7), grayling (4.7) and rainbow trout (0.3).

- Bull head and minnow were present along with 20 small brown trout.

- The age structure of the fish indicated that there was some natural recruitment (i.e. breeding of wild fish) of brown trout with no effective recruitment of grayling.

Downstream of Bibury

- Substrate of 80 per cent mud and silt and 20 per cent gravel.

- Some submerged weed with main species as *Potamageton, pectinatus and Sparganium*.

- A good biomass was reported, totalling 19.0 g/m^2 and consisting of grayling (13.8), brown trout (4.3) and rainbow trout (0.9). Bull head were also present.

- A poor population of brown trout dominated by large fish (> 12") and no natural recruitment evident.

Upstream of Whelford

- Substrate of 90 per cent gravel and 10 per cent silt and mud.

- Some submerged weed with *Ranunculus* and *Potamageton* dominant.

- A good biomass was reported, totalling 23.8 gm/m^2 and consisting of brown trout (17.2) and grayling (6.6). Minnow, bullhead, lamprey and stone loach were also present.

- The age structure indicates limited natural recruitment of brown trout and some successful recruitment of grayling.

The conclusions of the report note that, whereas the river achieves the target biomass of 15gm/m^2 at each location, there is concern as to the continued lack of effective natural recruitment of brown trout on the river. The good result is considered to be due, in large part, to the river stocking and management of the river. The loss of natural breeding is considered to be due to reduced flow rates and, in consequence increased mud and silt deposition in the river base.

The results of previous fisheries surveys of the Coln (1987, 1988 and 1989, NRA, Thames Region) also indicate specific reaches where the fish stocks are low and the lower age classes under represented, indicating low recruitment to the population. These reaches often show poor habitat quality. In some reaches this was attributable to previous management, eg by dredging of the channel for drainage purposes. The survey of 1988 recorded both a general decline in the population and younger age classes in some of the good reaches recorded in the 1987 survey. Low flows were postulated at the time as one of the principal causes in the absence of any recorded deterioration in water quality or invertebrate populations. Other changes noted were a result of fisheries management by riparian owners, eg, stocking or culling. Siltation of some of the spawning grounds and the growth of blanket weed in the lower than average flow conditions in the summer of 1988 was also thought to be significant in the observed decline of trout in some reaches.

Historical data are available on fish catches from three sites on the River Coln dating back to 1955 and continued until 1978. These data are plotted, on Figure 7.3, in terms of mean catch per day, and compared with mean summer flow data from the nearby River Windrush (dating back to 1955) and Coln for more recent years.

Each plot shows a slight decline in returns over the 1970 to 73 seasons although the Bibury and Williamstrip data show a subsequent recovery to previous catch records. The last two years of the sampling period (1977 and 1978) show the highest mean catches for the Bibury and Williamstrip Estates.

Data from the reach downstream of Fairford appears to show a decline in the numbers of fish caught. Mean catches between 1955 and 1965 are 2.23 per day ($\pm$ 0.55). In the decade 1968-78 catches are 1.61 fish per day ($\pm$0.40).

7.5 *Summary and Conclusions*

The River Coln is a typical Cotswold stream. The diversity and abundance of the ecological communities found reflect the richness and comparative constancy of environmental conditions afforded by the limestone groundwater baseflow.

The public perception of a decline in the character of the River Coln can be broadly summarised as:

- Reduced fish communities
- Loss of submerged weed and a corresponding increase in blanket weed
- Increased siltation
- Deterioration of water quality

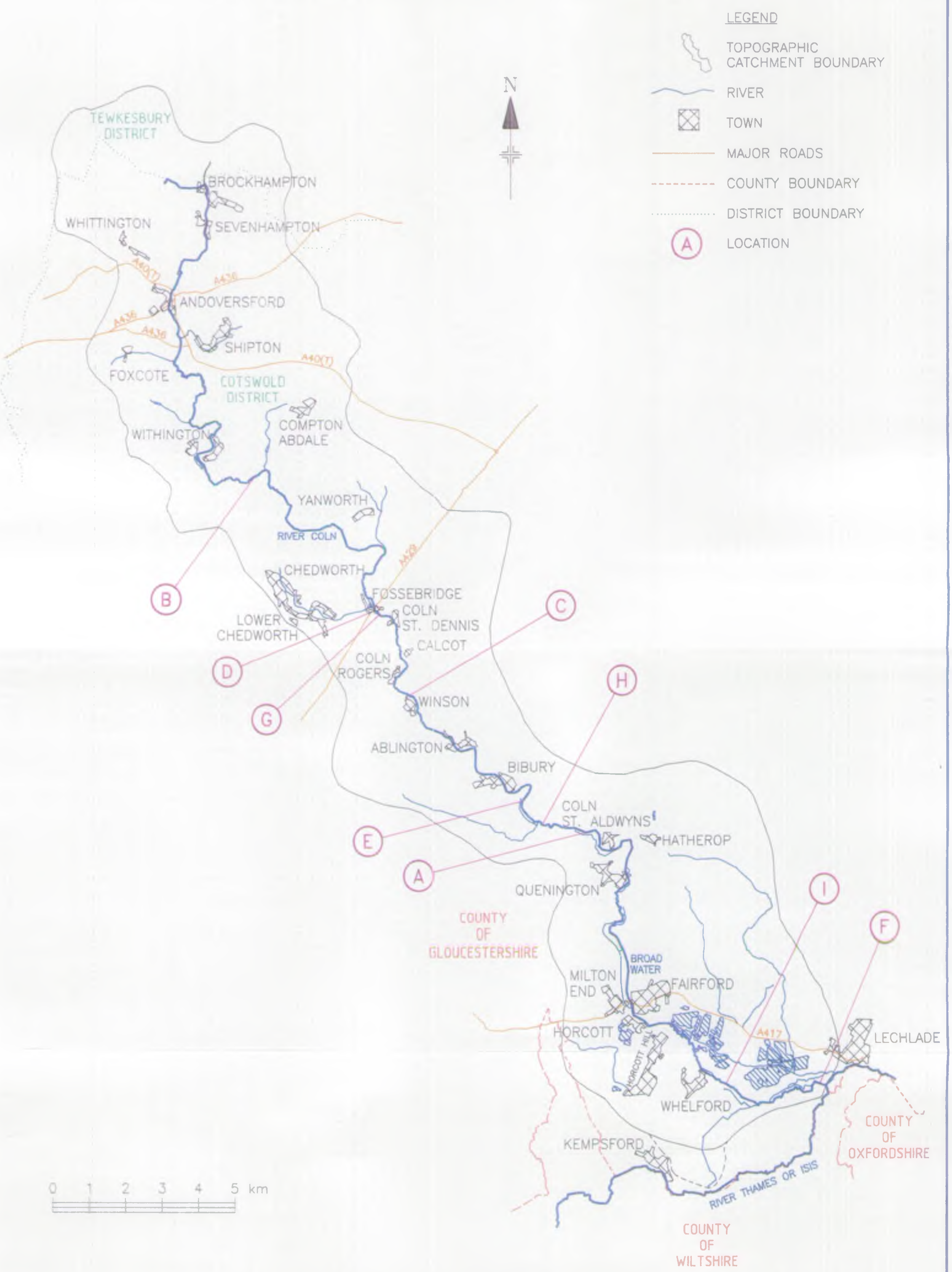
There has been a significant loss of submerged weed in the last few years, most notably through Bibury village, and a general build up of silt on the river bed.

The loss of weed appears to be a general feature of the chalk and limestone streams of south eastern England and is considered to be related principally to reduced flow velocity. A secondary effect of reduced velocity is increased sedimentation, which is also detrimental to submerged weed growth.

There appears to be no overall decline in invertebrate taxa either in terms of BMWP (British Monitoring Working Party) or ASPT (Average Score Per Taxa) scores at the three major monitoring points. Indeed the upper most site at Fossebridge indicates a general increase in both scores since 1987.

Fish stocking rates have remained largely constant since the 1970s. There is some evidence for a decline in catch rates from the lower river since 1955. Fisheries surveys since 1987 indicate poor natural recruitment along the river although the fish biomass is maintained above 15 gm/m^2 due largely to fish stocking and river management. The main cause of reduced natural recruitment is considered to be increased siltation and consequent loss of gravel breeding sites.

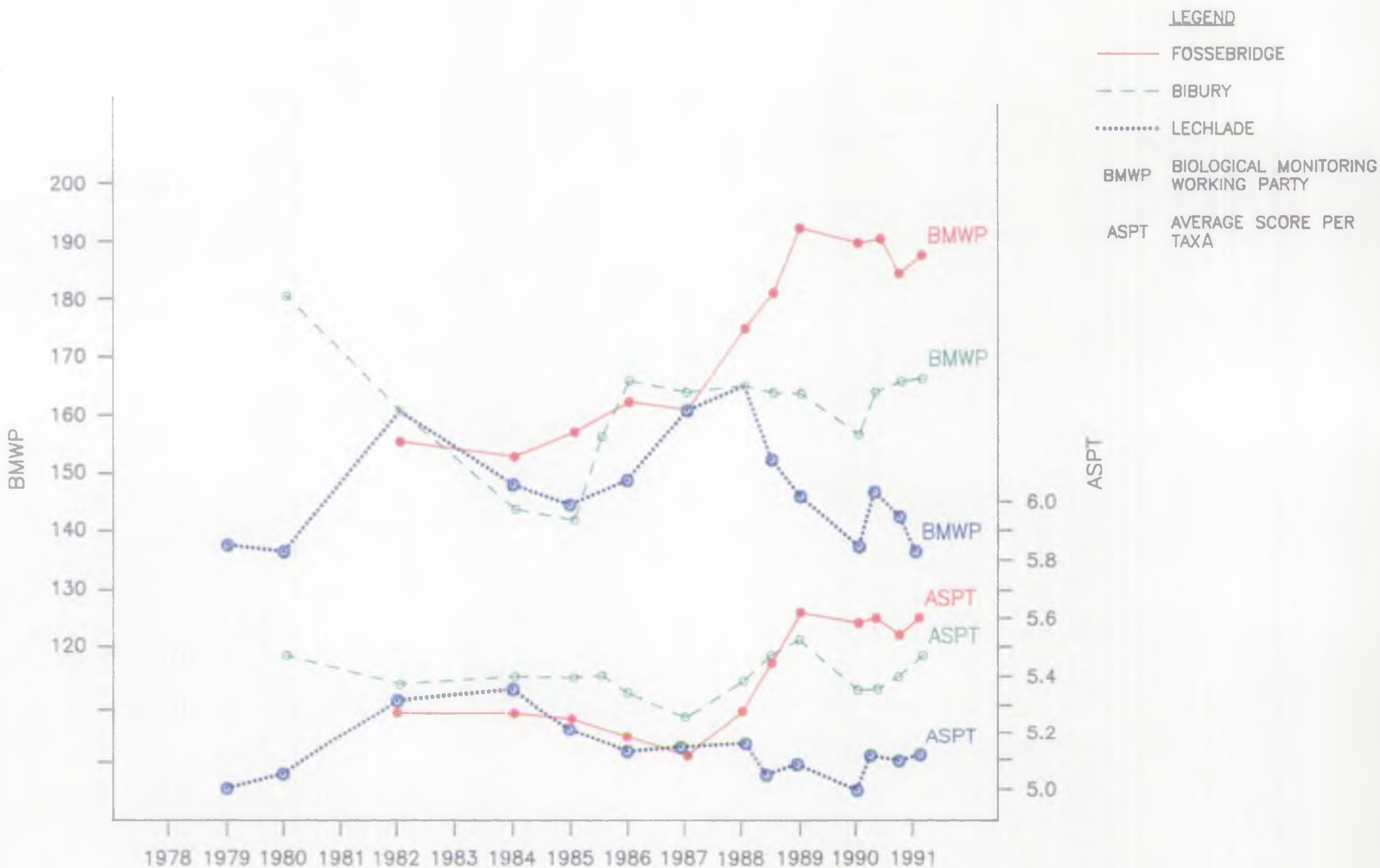
02/06/92 - 14:59---SG File-\COLN\FIG7-1



RIVER COLN CATCHMENT

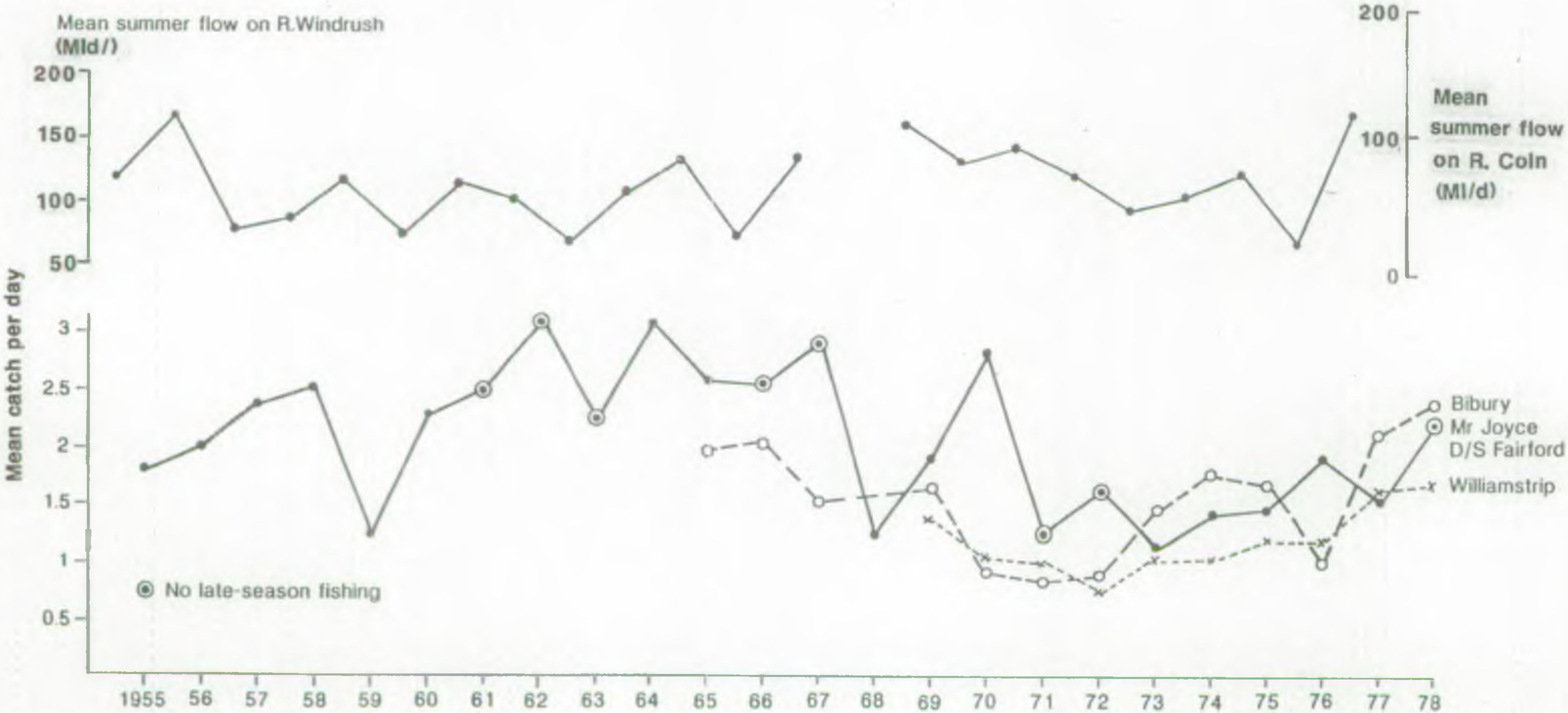
FLORA AND FAUNA : LOCATION PLAN

FIGURE 7.1



INVERTEBRATE DIVERSITY SCORES

FIGURE 7.2



River Coln-Fishing Returns in Mean Catch per Day

Figure 7.3

STAGE TWO -
POTENTIAL FACTORS IN CAUSING CHANGE

STAGE TWO - POTENTIAL FACTORS IN CAUSING CHANGE

8. INTRODUCTION

Sections 9 to 13 of the Stage Two study consider in turn, each of the main factors impacting upon the character of the catchment and examine the likely impact of each factor in relation to the changes identified in Stage One. Section 14 considers the cumulative effect of these factors and summarises our current understanding of the cause and effect relationships operating within the catchment. Section 15 considers, in outline only, (i) the potential remedial measures and (ii) the further works recommended to either investigate or carry out these measures.

9. METEOROLOGY

9.1 General

Meteorology is the most important factor governing variations in river flow within a natural river system. Clearly rainfall is the primary input to the system, although it is the effective rainfall which is a more direct measure of the available water resources.

Effective rainfall is defined as the rainfall minus the losses from evapotranspiration. Effective rainfall results in either surface runoff or recharge ('percolation') to the groundwater aquifer. In the Coln catchment the large majority results in recharge. The effective rainfall to the Coln catchment is therefore considered to represent the 'percolation' and estimates of percolation for the Cotswolds West area are derived by NRA Thames from their regional soil moisture balance model.

This section considers the historical record for both rainfall and percolation and the impact of variations in this record upon surface flows in the Coln catchment.

9.2 Meteorology and the Coln Catchment

The main meteorological features of a typical year for the Coln Catchment are considered below:

- The main period of recharge generally starts in September-October when the Summer soil moisture deficit has diminished or been eliminated. Surface flows and groundwater levels are at a minimum at this time. As recharge continues groundwater levels rise and the surface flows respond.

- Groundwater levels and surface flows generally reach a peak around January-February, after which increased evapotranspiration reduces recharge. Typically there is then very little recharge of the aquifer from May until the following Autumn and there is, accordingly, a natural recession in both groundwater level and surface flow. However, extended periods of rainfall in the summer can produce small but significant recharge episodes.

Groundwater levels and spring flow respond relatively rapidly to recharge indicating a rapid flow through the unsaturated zone and response in the river.

If there is an extended period of reduced rainfall over the winter period this will result in a muted groundwater response and reduced spring flows during the following Spring and Summer. One of the features of this catchment is that the Great Oolite aquifer can drain a large proportion of its available storage in response to a single dry Winter period and this was illustrated by (i) the dry river bed upstream of Winson in 1976 (Section 5) and (ii) areas of dry aquifer reported in 1984 (Section 4).

Under these circumstances it appears that single years of extremely low winter rainfall can have the most detrimental impact on surface flows. The aquifer refills rapidly, however, in response to recharge and the impact of a succession of less than average recharge years does not appear to be as severe as it is in the Kennet catchment for example.

9.3 Data Analysis

The rainfall and percolation data used in these analyses are from the NRA-Thames database of areally averaged data over the West Cotswolds area. The meteorological year is calculated from October to September. Figure 9.1 shows the annual rainfall and Figure 9.2 the annual percolation over the period of record (1920/21 to 1990/91). The following points can be made from these plots :

- the lowest annual rainfall and percolation totals were recorded in 1976

- the annual rainfall and percolation during the 1988-91 period do not appear to be severe, having a return period of approximately 1 in 10 years for rainfall (1988-89) and percolation (1990-91).

- The percolation totals for 1988-89, 1989-90 and 1990-91 were 65, 95 and 45 per cent of the long term mean respectively. On this basis, the overall affect of the last three years of drought is assessed as reducing the Water resources to the catchment by approximately 30 per cent.

Three year running means have also been plotted for both rainfall and percolation and are shown on Figures 9.3 and 9.4. These analyses indicate longer term trends in the meteorological data. The following points are made from these data :

- the 1988-91 three year rainfall total is second lowest behind the 1973-76 period

- the 1988-91 three year percolation total is not severe compared to the historical record. However, the data indicate that percolation has, on average, been below the mean since the early 1970s.

In the 1950s, a period in which flows have been compared favourably with the current flows, percolation is generally above the mean.

As noted above, river flow in the Coln is not considered to be particularly susceptible to longer term reductions in rainfall over and above a single year. However, more than one year of reduced flows is considered to have a degree of cumulative impact upon weed growth, resulting in a change from high flow submerged weeds to emergent vegetation and algal growths, characteristic of low flows.

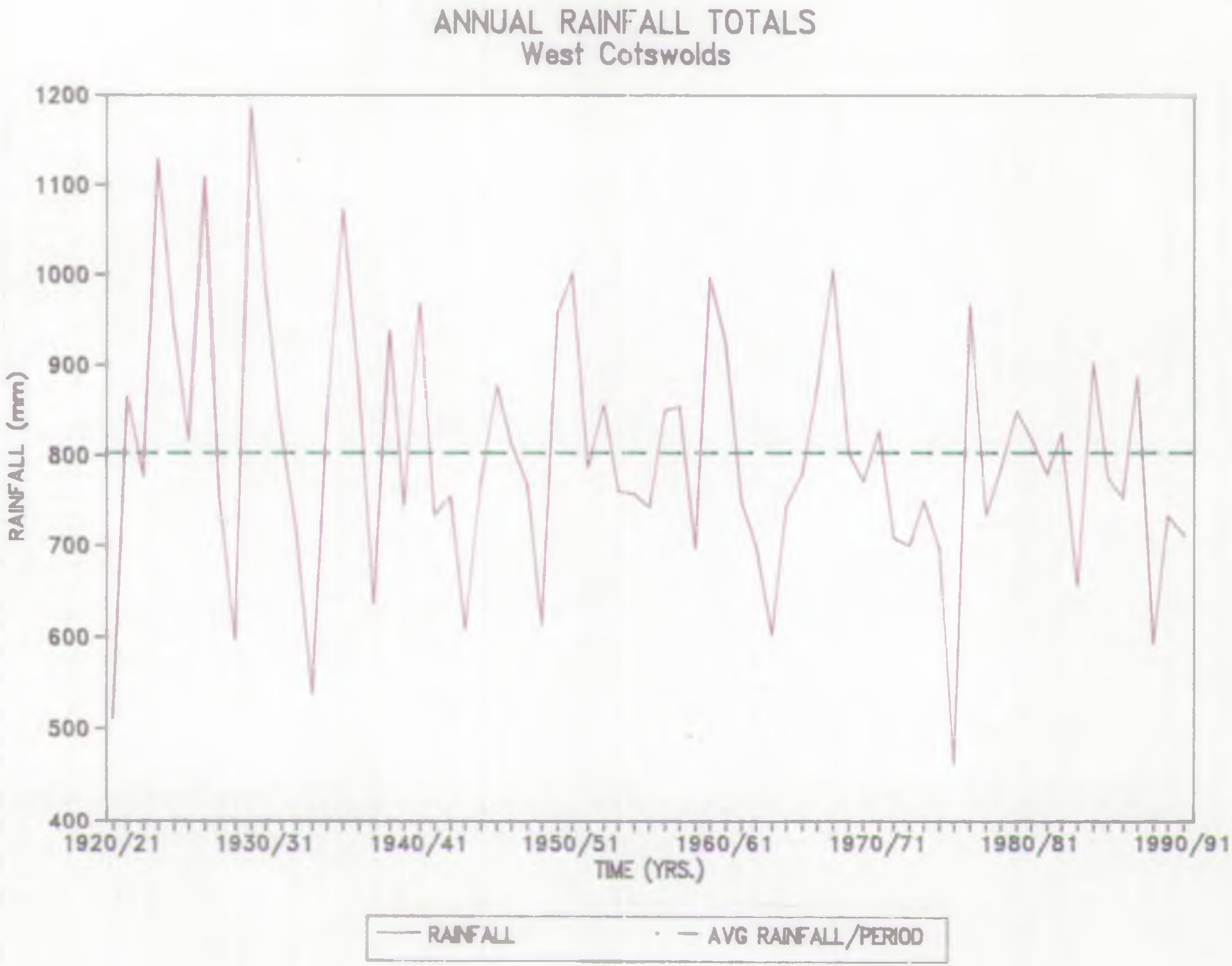
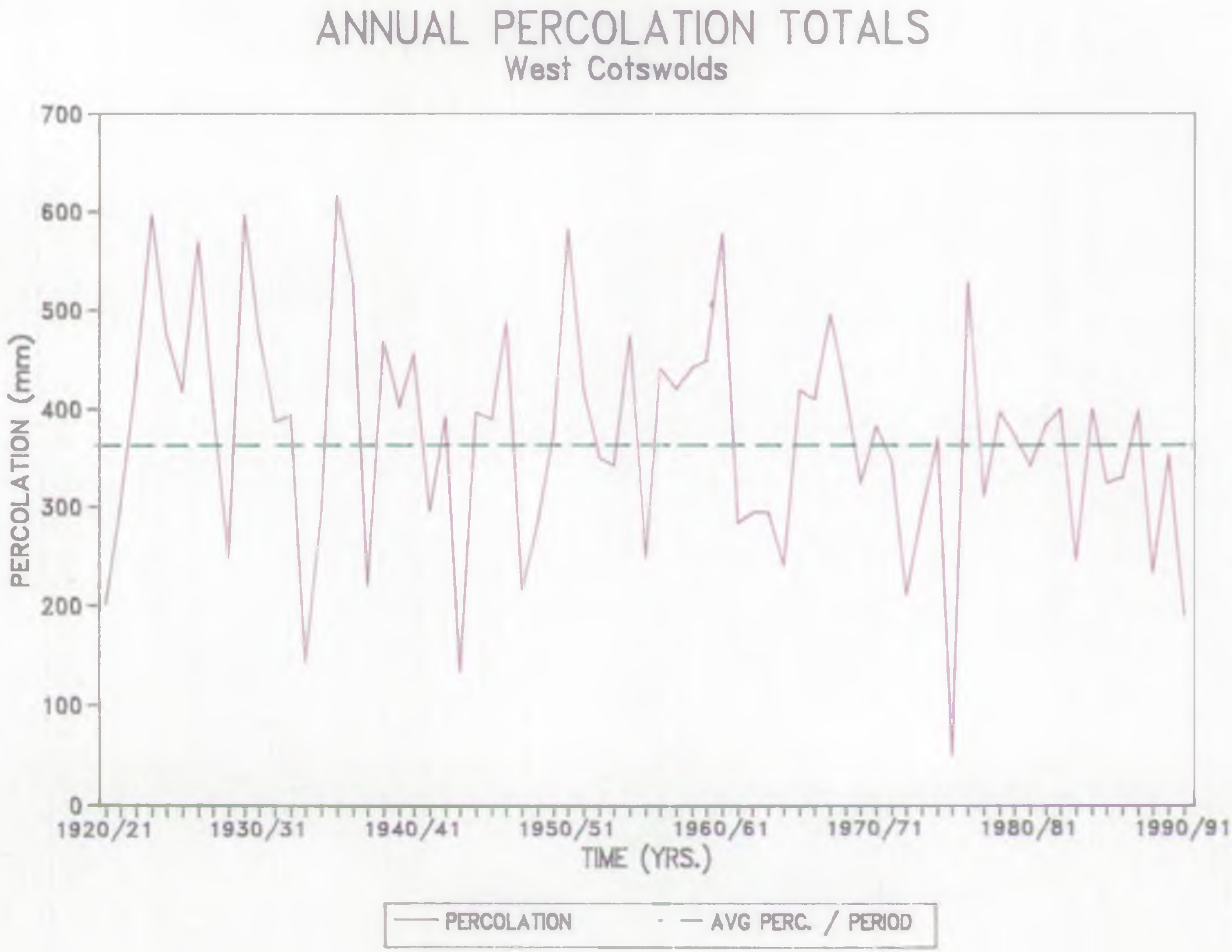
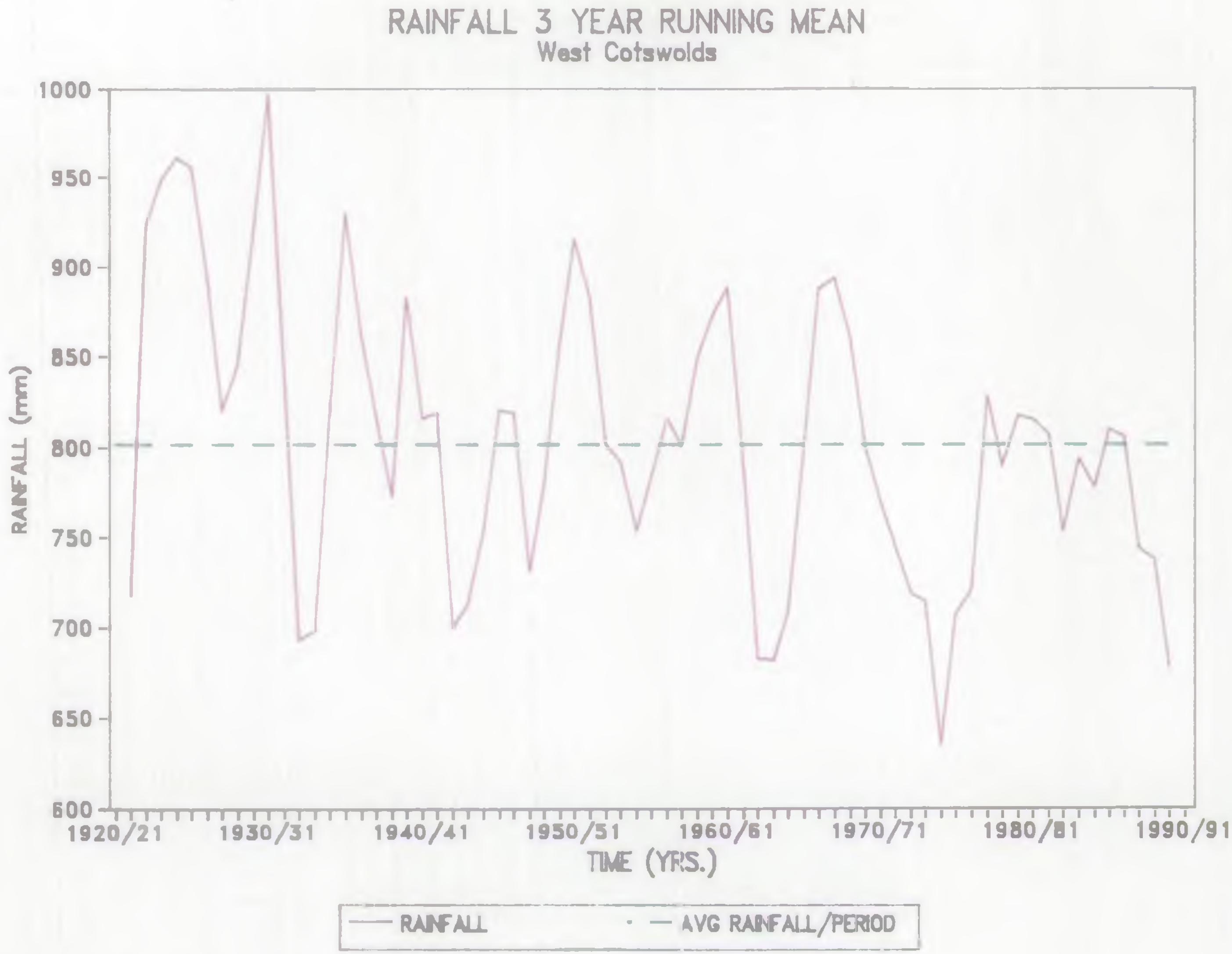

ANNUAL RAINFALL TOTALS
West Cotswolds
1200
1100
1000
900
800
700
600
500
400
RAINFALL (mm)
1920/21
1930/31
1940/41
1950/51
1960/61
1970/71
1980/81
1990/91
TIME (YRS.)
RAINFALL
AVG RAINFALL/PERIOD

Figure 9.1



ANNUAL PERCOLATION TOTALS
West Cotswolds
PERCOLATION (mm)
700
600
500
400
300
200
100
0
1920/21
1930/31
1940/41
1950/51
1960/61
1970/71
1980/81
1990/91
TIME (YRS.)
PERCOLATION
AVG PERC. / PERIOD

Figure 9.2



RAINFALL 3 YEAR RUNNING MEAN
West Cotswolds
RAINFALL (mm)
1000
950
900
850
800
750
700
650
600
1920/21
1930/31
1940/41
1950/51
1960/61
1970/71
1980/81
1990/91
TIME (YRS.)
RAINFALL
AVG RAINFALL/PERIOD

Figure 9.3

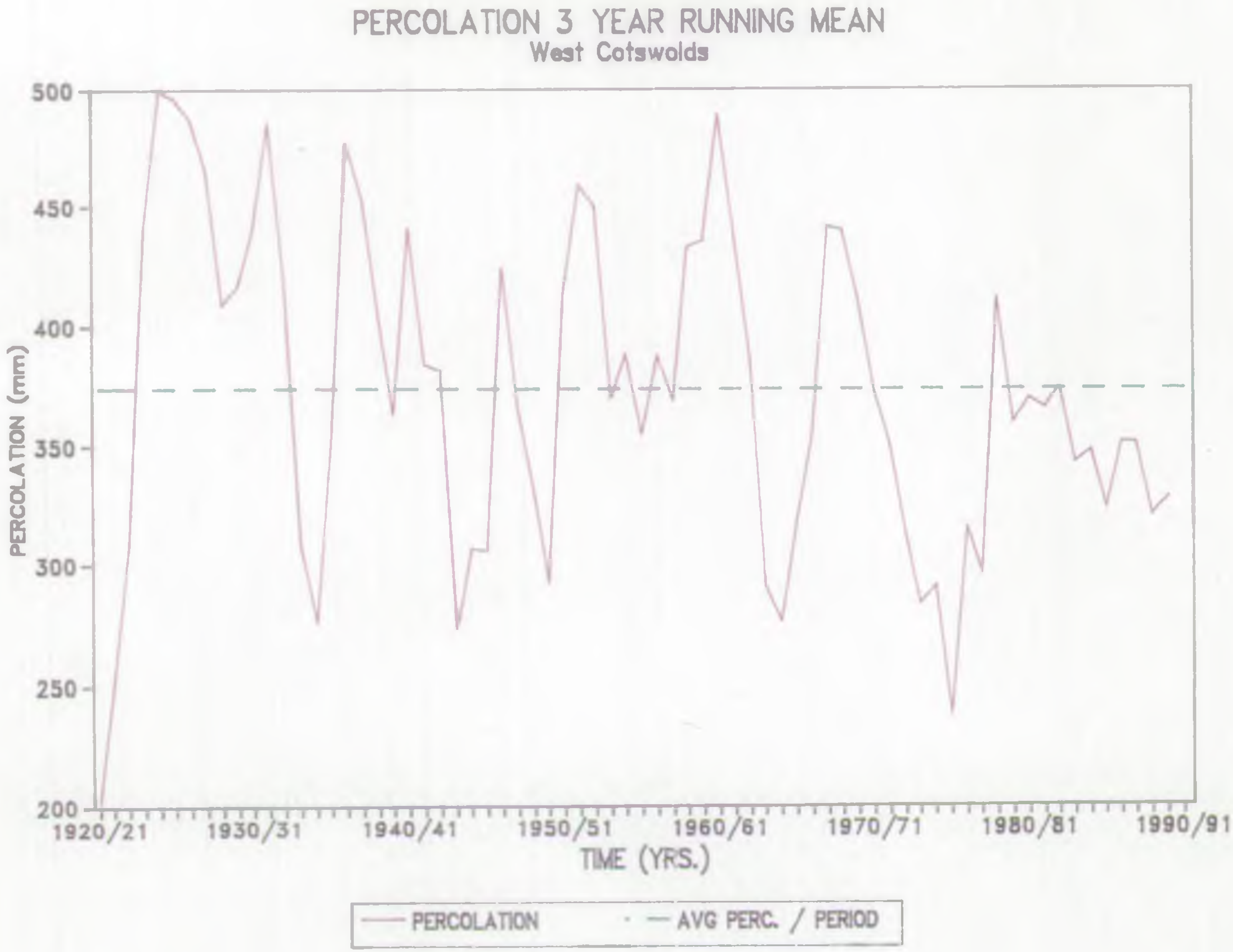

PERCOLATION 3 YEAR RUNNING MEAN
West Cotswolds
PERCOLATION (mm)
500
450
400
350
300
250
200
1920/21
1930/31
1940/41
1950/51
1960/61
1970/71
1980/81
1990/91
TIME (YRS.)
PERCOLATION
AVG PERC. / PERIOD

Figure9.4

10. ABSTRACTION

10.1 General

The first major public supply boreholes within the catchment were installed at Bibury (A) in the 1950s with most of the supply exported from the catchment. Prior to this, the only supplies were within the catchment and consisted of private wells and boreholes and piped supplies from the local springs, for example at Bibury and Winson.

The Bibury Pumping Station was licensed, following the 1963 Water Resources Act, for an annual average maximum yield of 2.3 Ml/d. The licence specifies abstraction from both the Great and Inferior Oolite, but effectively all the Supply is from the Inferior Oolite. In 1967 a second licence was granted and linked to the Licence of Right such that the combined licence total was 6.8 Ml/d. Bibury Fish Farm is fed, in part by spring flows from Bibury, near to the Pumping Station. The abstraction licence was varied, in 1976, to incorporate an additional supply to the fish farm from an artesian borehole near to the Spring and intended to counteract the impact of the Bibury PS on the natural spring flow. The borehole is licensed to supply 5.5 Ml/d and is throttled but not gauged. The effect of this additional supply into the catchment at Bibury is discussed further in Section 10.2 below.

Bibury Pumping Station remains by far the largest groundwater supply within the catchment. There are two further public groundwater supplies, from the Inferior Oolite at Syreford (B) and the Great Oolite at Fairford (C). There is also a surface supply at Lechlade. ?

Meysey Hampton Pumping Station (D) is licensed for 9.1 Ml/d from either the Inferior Oolite and Great Oolite. The source is outside the Coln catchment but a pumping test on the Inferior Oolite borehole indicated that abstraction was in part, at the expense of spring flow at Bibury whereas abstraction from the Great Oolite did not impact upon the Coln (Thames Conservancy 1973).

In consequence the licence has a flow constraint such that, when flow at Bibury is above 68 Ml/d the abstraction at Meysey Hampton is from the Inferior Oolite whereas when flow at Bibury is below 68 Ml/d abstraction is from the Great Oolite borehole.

The impact of Inferior Oolite abstraction at Meysey Hampton on the River Coln at Bibury is considered to be due to a fault/fissure connection between the two (NRA Thames, pers. comm). There are other large supplies at a similar distance from Bibury such as Latton (E) and Baunton (F) pumping stations. Latton abstracts from the Great Oolite and there is no evidence to indicate that abstraction from the Inferior Oolite at Baunton has any effect on the Coln. Consequently these boreholes are not included in the impact analysis in Section 10.2 below.

10.2 Assessment of the Impact of Groundwater Abstraction

This sub section considers the impact of public supply groundwater abstraction upon the surface flow on the Coln as measured at Bibury GS. Public supplies only are considered as the total private licensed abstraction from the catchment is less than 0.3 Ml/d and actual private abstractions, for which data are unavailable, are considered to be significantly lower.

Groundwater abstraction totals are expressed as a percentage of the 'naturalised' surface water flow, and the flow is naturalised by adding the abstracted groundwater to the actual flow. Flows are expressed as mean flow and Q95 flows for each year of record. Q95 flow is the flow which is exceeded for 95 per cent of the flow record for the year and can be considered as the summer low flow for the year.

Groundwater abstractions are considered as follows:

Syreford - a small Inferior Oolite source in the upper catchment. The supply is local and it is estimated that 90 per cent of abstraction is returned to the catchment upstream of Bibury as effluent discharge. The nett impact is only 10 per cent of gross abstraction therefore.

Bibury - largely an Inferior Oolite abstraction. It is assumed that all the public supply abstraction is at the expense of spring flow to the Bibury Springs. This may over-estimate the impact of Bibury PS on the flows to the Bibury Gauge as a proportion of the flow loss may be from baseflow downstream of the gauge. The compensation supply from the artesian borehole to Bibury Fish Farm is not included in this analysis. The flow is licensed for 5.5 Ml/d. It is considered likely to be of nett benefit to surface flows at Bibury Gauge but the nett increase in flow is not known. Not including this will tend to overestimate the impact of abstraction on surface flows.

Meysey Hampton - the Great Oolite supply is not considered to effect flows at Bibury. This is supported by the evidence of groundwater levels from 1984 and 1989 (see Section 4) which show a decreased level up to 5km from Meysey Hampton but no effect on levels around Bibury. The Inferior Oolite supply is considered to effect flows at Bibury. A pumping test carried out on the Mersey Hampton Inferior Oolite borehole in 1973 (TWA, 1974) identified a reduction in spring outflow at Bibury Springs amounting to 20 per cent of the abstraction from the borehole.

The Inferior Oolite borehole only operates above the 68 Ml/d flow constraint, therefore it is assumed that the abstraction from Meysey Hampton does not effect the Q95 flow.

Fairford - this Great Oolite supply is not considered to effect surface flows at Bibury.

Lechlade - this surface water supply does not effect surface flows at Bibury.

The contribution of groundwater storage to the groundwater abstraction during low flows is not considered as most of the abstractions are from confined strata. This assumption is reasonable in the absence of further data but is considered conservative leading to an over-estimate of the impact of abstraction on low flows.

The impact of actual groundwater abstraction on Q95 and mean flow at Bibury GS for each year, expressed as a percentage of naturalised flow, is given in Table 10.1 and illustrated in Figure 10.2.

Table 10.1 and Figure 10.3 show the estimated impact of licensed abstraction, expressed as a percentage of natural flow at Bibury. This analysis assesses the maximum possible impact of abstraction under current licensing conditions.

These assessments are approximate in nature and contain a number of assumptions and simplifications. Nevertheless they are considered to give a fair indication of the effects of groundwater abstraction on surface flow. The main conclusions are:

- Abstraction is assessed as having reduced natural mean flow by between 2 and 7 per cent and Q95 flow by between 3 and 15 per cent over the data period. This compares with the last three years of drought which are assessed (from Section 9) as having reduced catchment resources by approximately 30 per cent.

- Operating the sources to their licensed capacity would have increased the impact on surface flows by about 50 per cent over the last three years. However, the natural effects of drought on mean flows are still 2 to 3 times greater than the maximum potential impact of abstraction.

- Variations in weather patterns appear to have a significantly greater impact on surface flows than groundwater abstraction although abstraction may be significant, particularly during low summer flow periods.

The analysis above indicates a nett decrease in mean flow of approximately 5Ml/d between 1964 and 1990 as a result of abstraction. The double mass analyses, discussed in Section 5, indicate a nett increase, over the same period, of approximately 5Ml/d. This discrepancy has not been fully explained. The beneficial effect on surface flows of the artesian flow at Bibury from 1976 is not included in the analysis above. This flow is licensed at 5.5Ml/d but the nett benefit is likely to be significantly smaller. This may partially, but does not fully, explain the discrepancy.

The main conclusion which can be made from the analyses is that any changes in the flow characteristics of the river during the last 30 years are not major and are well within the range of natural variation as a results of variability in weather patterns. The impact of the current drought appears to be up to an order of magnitude greater than the impact of groundwater abstraction.

KENNET AND COLN RIVER LEVEL STUDY

COLN

FLOW DATA (Ml/d)

GAUGING STATION		1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Bibury	Mean	82.94	90.72	152.93	149.47	139.10	128.14	120.96	110.59	108.86	145.15	114.05	100.22	34.56	146.02	108.86	146.88	133.06	128.74	138.24	110.59	101.09	134.78	137.38	116.64	114.91	80.35	107.14
	Q95	37.15	50.11	52.70	57.02	77.76	44.06	44.93	50.96	33.70	30.24	40.61	30.24	17.28	45.79	37.15	46.66	44.93	55.30	43.20	44.06	38.02	69.98	53.57	46.66	44.93	33.70	26.51

ACTUAL ABSTRACTION EXPRESSED AS A % OF BIBURY FLOW (Ml/d)

BOREHOLES		1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Bibury	Mean	1.60	1.60		1.20	1.30	1.50	1.80	2.60	3.60	2.70	3.10	4.20	13.00	3.30	4.70	3.90	4.40	4.60	4.50	5.50	6.40	4.90	4.80	5.30	5.90	7.80	5.90
	Q95	3.50	2.80		3.20	2.40	4.10	4.20	5.50	10.80	11.70	8.40	12.80	23.50	9.90	12.50	11.40	12.00	10.20	13.10	12.70	15.40	7.80	10.10	10.70	11.60	15.70	17.90

LICENSED ABSTRACTION EXPRESSED AS A % OF BIBURY FLOW (Ml/d)

BOREHOLES		1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Bibury	Mean	10.00	9.20	5.70	5.80	6.20	6.80	7.10	7.70	7.80	6.00	7.50	6.40	20.60	5.90	7.80	5.90	6.50	6.70	6.30	7.70	9.70	7.40	7.30	6.50	6.60	11.80	9.20
	Q95	19.90	15.50	14.90	13.90	10.80	17.30	17.00	18.10	21.50	23.30	18.50	23.30	34.80	18.70	19.80	16.50	17.00	14.30	17.60	17.30	19.50	11.60	14.70	16.50	17.00	21.50	24.40

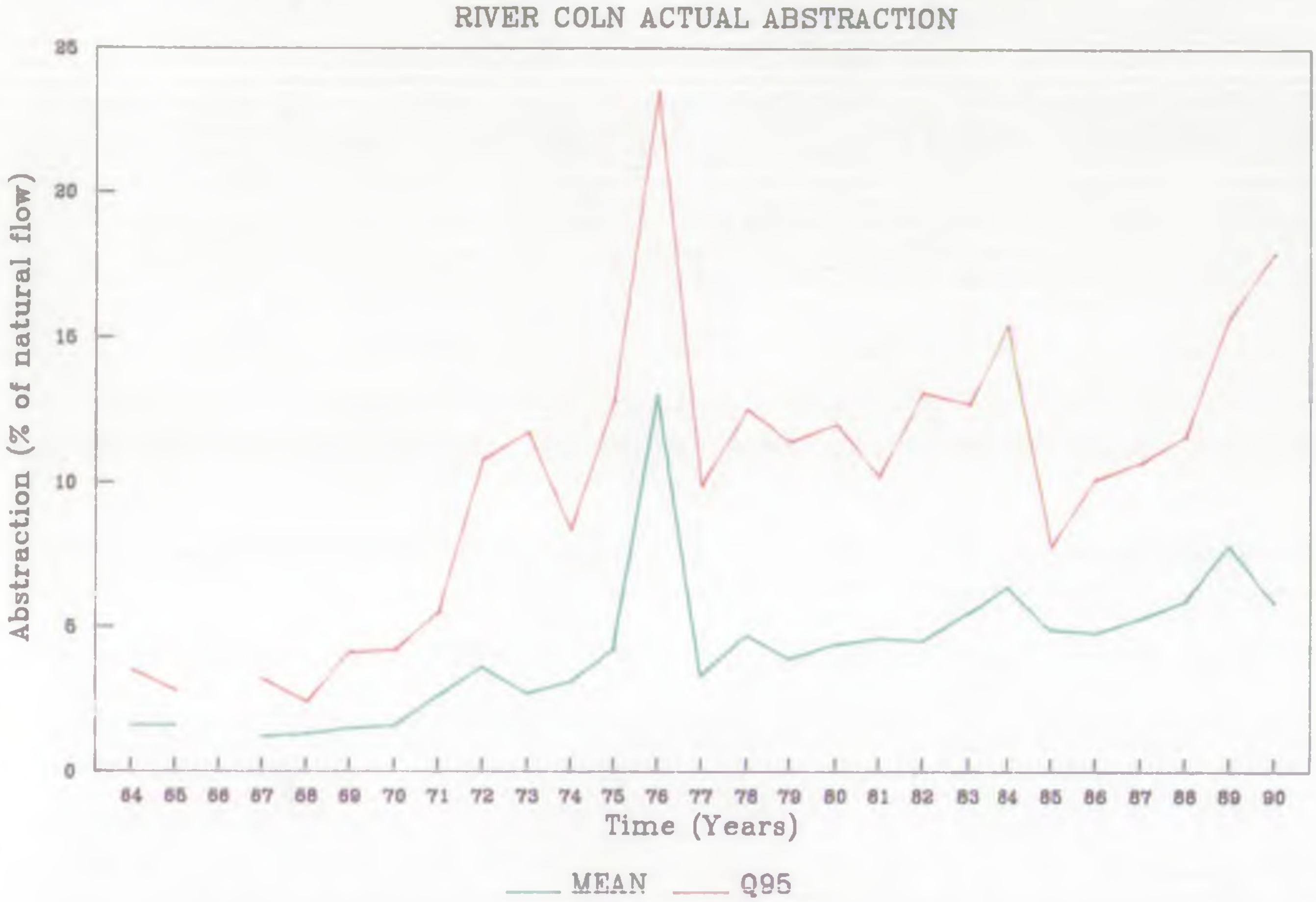
NOTE : Calculations based on percentage impacts for each licence discussed in Section 10.2

Table 10.1

PUBLIC SUPPLY ABSTRACTIONS AROUND THE COLN CATCHMENT

FIGURE 10.1

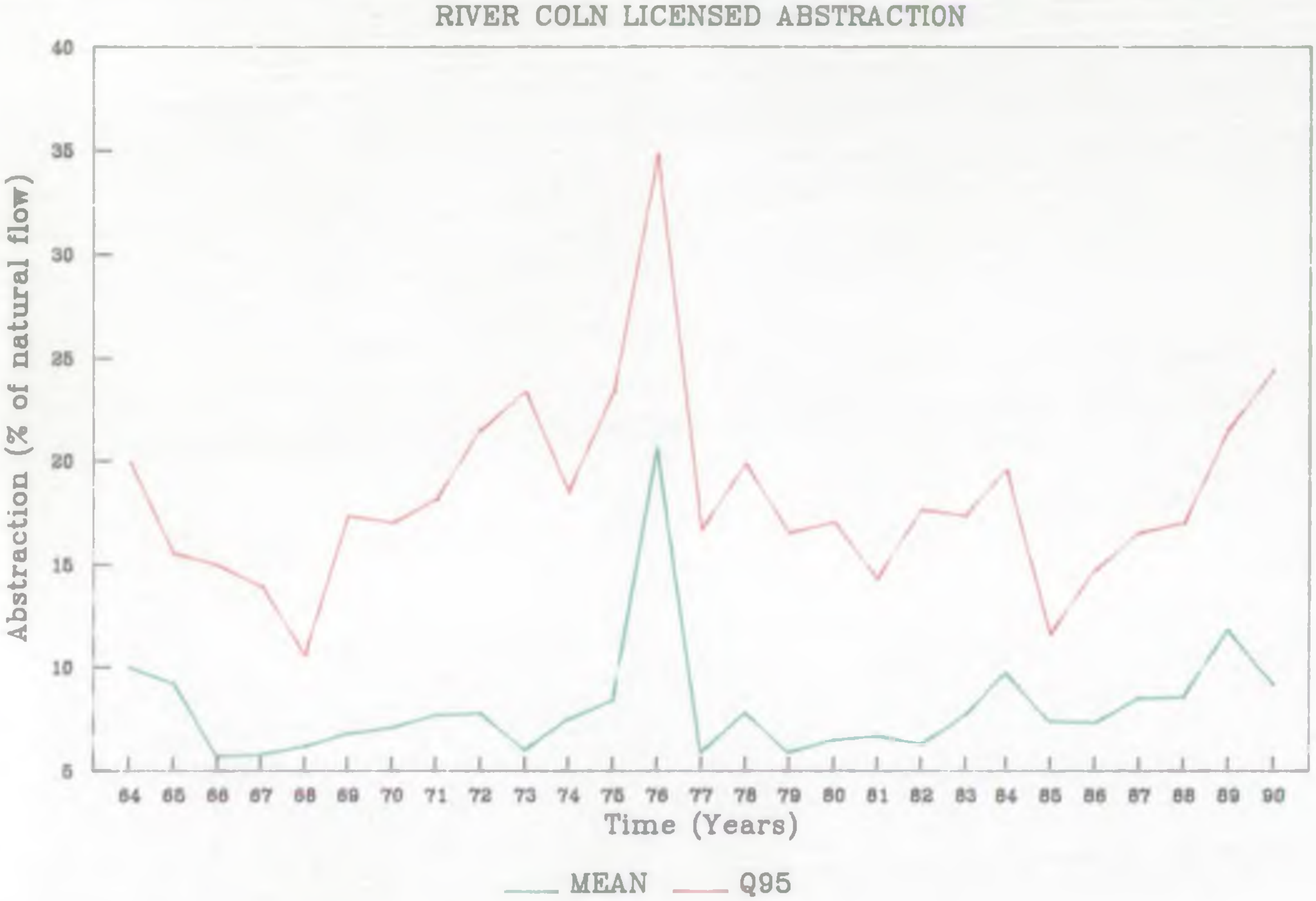
KENNET AND COLN RIVER LEVEL STUDY



TOTAL ACTUAL ABSTRACTION EXPRESSED AS A PERCENTAGE OF NATURAL FLOW AT BIBURY

FIGURE 10.2

KENNET AND COLN RIVER LEVEL STUDY



TOTAL LICENSED ABSTRACTION EXPRESSED AS A PERCENTAGE OF NATURAL FLOW AT BIBURY

Figure 10.3

11. DISCHARGES

Sewage Treatment Works discharges to the catchment are all very minor and have not been considered in resource terms. There have been some problems with the consents on two of the discharges but the volumes concerned are insufficient for there to be significant water quality implications. The BOD, phosphate and ammonia loadings, as measured at the regular water quality monitoring sites discussed in Section 6, are considered to be largely from point sources but are not (i) identifiable to a particular site or (ii) considered to be detrimental to the catchment ecology.

There has been some public concern expressed with regard to the impact of Bibury Fish Farm on the river and, in particular, on the siltation and loss of weed along the reach through Bibury village. However there is no factual evidence for a connection between the fish farm and weed loss and similar conditions are found both upstream and downstream of Bibury.

There have been a small number of point source pollution incidents in the catchment and there was a major pollution incident in the late 1970s which destroyed the fish population downstream of Fairford, but there is not considered to be any significant ongoing pollution problem.

Diffuse pollution from nitrate has increased, in line with the general increase in the south east of England, and is related to both increased ploughing and fertiliser application to arable land. Concentrations are not considered a cause for concern however.

There is no evidence from the data of an increase in suspended solids. However, there is visual evidence that bank trampling by livestock along some reaches is resulting in high sediment loadings to the river. Combined with a decrease in flows in recent years this has contributed to an increased build up of sediment on the bed of the river.

12. RIVER MANAGEMENT

12.1 General

This section considers the impact on the river character of both the current river management practices and the changes in river management which have taken place over the last 100 years. The issue of river management considers both the use to which the river has been put in the past, for example the operation of water meadows and water mills, and the ongoing management by silt removal and dredging, weed management and control, and stock watering.

12.2 Water Mills and Water Meadows

Water mills require a reliable supply of flowing water to operate. If this supply is not available naturally, a method of storing water is used, either by a separate pond, or a depression or pool within the river which can be controlled by stops and hatches.

Figure 12.1 identifies the water mills which are believed to have been in operation towards the end of the nineteenth century. The operation of water mills is considered to have reduced considerably during the early years of this century and there are no longer any operating mills in this catchment. One legacy of their operation is that, along many reaches there are now two surface water channels, both the natural channel along the bottom of the valley and the mill leats which tend to be towards the valley sides. In many cases both these channels are still open but without control from hatches and this results in a reduction of flow to the natural stream.

Water meadows were constructed by digging parallel ditches within a low lying meadow, connected to the river by feeder channels and controlled by sluices. Releases of water were made into the meadows at regular intervals during the Winter, ideally such that a thin sheet of water passed over the entire meadow. This practise ensured that the ground temperature was kept above freezing and also introduced nutrients to the soil. The purpose was to encourage an early growth of grass for sheep during the later Winter and early Spring and so improve the numbers of stock which could over-winter. A hay crop was also taken in the Autumn.

There were a number of meadows constructed along the Coln Catchment and some of these are identified on Figure 12.1. Their period of operation is not known but the system was developed over much of the country during the 17th Century and generally fell into disuse in the late 19th and early 20th Century.

Between one hundred and three hundred years ago, when the mills and meadows were operated, river levels would have been controlled over much of the catchment and the river would have had a rather different appearance to that seen today. There is no evidence that the river has been controlled to any extent over the last 50 years or that the change in appearance due to the loss of river controls has been a factor in the public's concerns. The only significant impact remaining of this period in the river's history is the presence of the mill leats noted above and their effect in reducing flows along the natural river channel.

12.3 Fisheries, Weed Management and Stock Control

Fisheries management on the catchment has been a feature since the late nineteenth century. Management was never as intensive as on other catchments in the South East of England, nevertheless the manpower employed to look after the river was decreased considerably since the Second World War. As a result, weed and sediment removal, and the control of river levels, were no longer undertaken as intensively as in previous years. However, the impact of reduced river management is not considered, from the evidence available, to have had a significant adverse impact on the flow characteristics.

The loss of submerged weed from the catchment is discussed in Section 7 and is considered to be a largely natural phenomenon, related to reduced river flow velocity. As noted in Section 7, the loss of submerged weed is considered to result in a significant reduction in river levels, typically causing a halving of river level with no reduction in flow rate.

The use of the river for stock watering was very important in the last century and there is a possibility that the upper reaches of the catchment were, as is reported from the Churn catchment, regularly puddled with clay to reduce natural bed leakage during the Summer. This practice has clearly not been in operation in recent years and there are significant losses from the river to groundwater following dry Winters particularly in the reaches downstream of Fossebridge.

Present day stock control is, as reported in the previous section, an issue with regard to bank trampling and the input of sediment to the stream.

12.4 Dredging

The over-dredging of a river to reduce flood risk is noted as being an important factor in changing catchment characteristics in the Kennet catchment (see Volume One). In the Coln catchment there are reports of previous over-dredging both at Coln Rogers and also within the Williamstrip Estate downstream of Quenington. However, in general the river section is considered to be of largely natural dimensions and current dredging policy is generally in line with good river management practice.

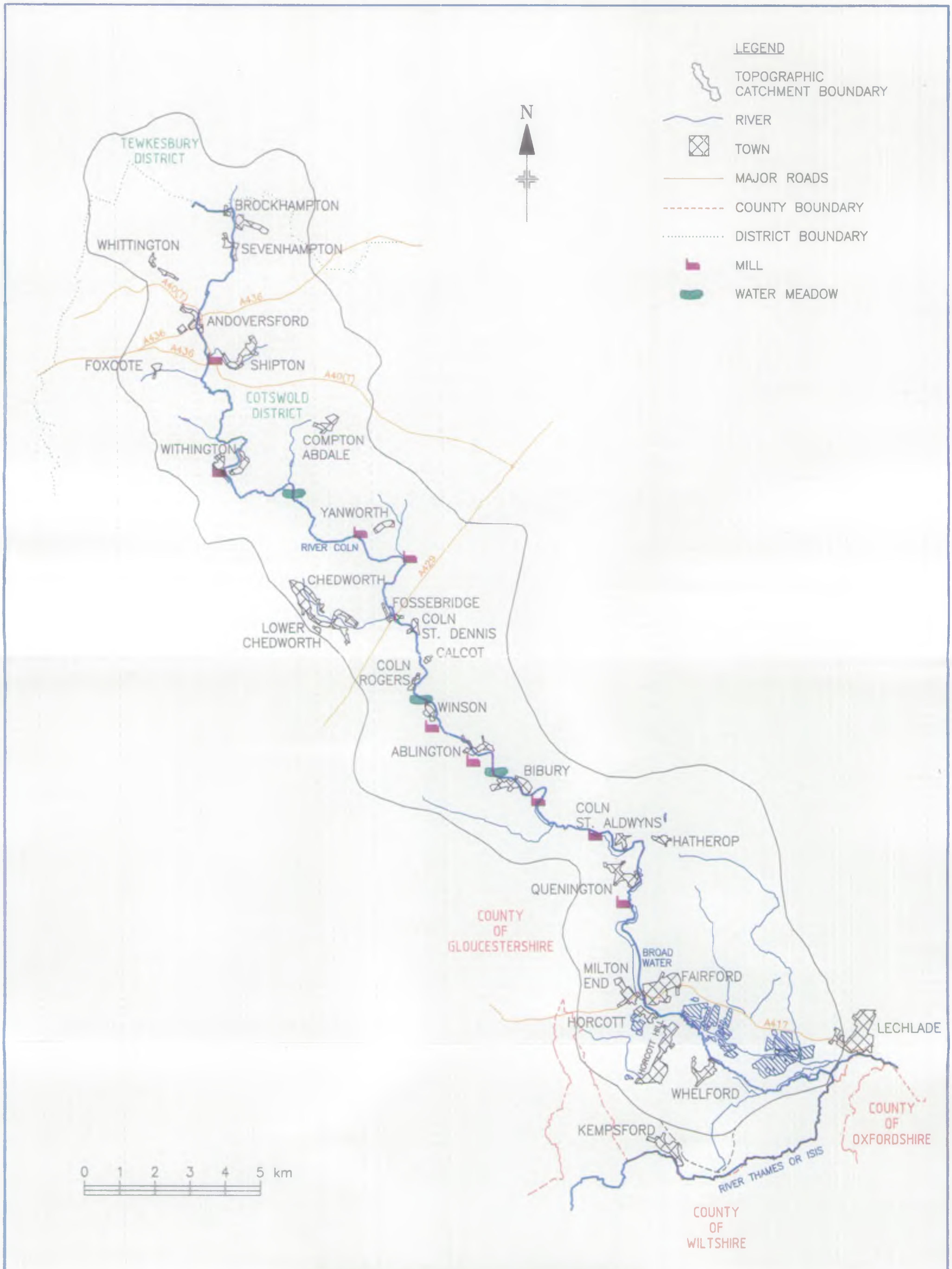
12.5 Habitat Improvement Scheme

The NRA have proposed a habitat improvement scheme for a reach of 1500m length on the Williamstrip Estate. The proposals include

- narrowing of channel width
- the creation of meanders
- construction of a pool and riffle system
- introduction of instream gravel at suitable locations to increase spawning success
- replanting of instream vegetation, particularly Ranunculus
- tree planting to improve bankside cover.

Baseline studies have already been undertaken, highlighting the poor condition of the reach and lack of recruitment of wild brown trout. Further field investigations are proposed following the site work to assess the impact of the scheme proposals.

FIG12-1



RIVER COLN CATCHMENT

RIVER MANAGEMENT : LOCATION PLAN

FIGURE 12.1

13. LAND MANAGEMENT

There have been a number of changes in land use in the catchment, in line with regional changes, between arable cropping and the rearing of livestock. Following the Second World War the uplands and valley slopes were ploughed for cereal crops and this process was accelerated by the Common Agricultural Policy in the 1970s. In recent years, changes in agricultural and environmental policy have encouraged the diversification of land use and the principle of set aside, for the return of land to a more natural state.

The great majority of the river corridor has been retained as unimproved pasture land through all these recent changes. This presents a buffer to the effects of surface runoff from the surrounding arable land and helps to protects the river from any adverse impact.

As reported in Section 6, nitrate concentrations in the river baseflow have increased gradually as a result of the conversion to arable farming but the levels are not considered detrimental.

The catchment has retained a fundamentally rural character and no further impacts of changes in land management have been identified.

14. OVERALL SUMMARY AND CONCLUSIONS

14.1 Public Perceptions of Change

There is a general public perception that the water levels in the river have reduced over the last 6 to 7 years. The concerns of the public have been focused on the central reach of the catchment from Fossebridge to Bibury, although riparian owners record similar issues along the reaches downstream of Bibury. Older inhabitants have noted that river levels in the catchment between Bibury and Winson have reduced in the period since the 1950s. One respondent noted that, in Winson, water levels in 1991 were at ankle depth whereas, in the 1950s, levels were at knee to thigh depth.

A gradual loss in submerged weed growth and replacement with blanket weed is also reported, water clarity is considered to have reduced over the same 6 to 7 year period and there are reports of a reduction in fish recruitment.

14.2 Changes Identified and Possible Causes

Brockhampton to Fossebridge

This upstream river reach has a characteristically low but consistent flow, largely sourced from Inferior Oolite baseflow. The upper limit of flow is not considered to have moved significantly over the last 100 years and the flow characteristics of the reach are considered to be largely natural. Weed losses are reported from this reach which indicates that natural reductions in flow caused by reduced rainfall during the drought have been sufficient to adversely impact the weed growth.

There are a number of mills in this upper reach, none of which are currently operating. The bifurcation of the stream with a proportion flowing down the mill leat, is considered to be the main artificial flow reduction along the reach.

Bank erosion, caused by stock watering, has been identified in the lower parts of this reach. There are no suspended solids data for the reach but the public have identified increased suspended solid loadings as an issue.

Fossebridge to Bibury

This reach is the focus of most public concern and corresponds approximately to the outcrop of Great Oolite along the river valley. The upper reaches of the Great Oolite tend to dewater completely towards the end of the Summer in response to a failure of Winter recharge. In extreme cases this can result in the river bed becoming dry progressively downstream from Fossebridge. This is reported as having occurred in 1890 and in 1976 where flows ceased as far downstream as Winson. Some flow has been retained in the river during the 1988-1991 drought period.

Groundwater abstraction is considered by the general public as the prime reason for reduced river levels. In order to try and identify changes to the flow regime this report has considered

(i) double mass analyses to assess artificial variations in the flow record at Bibury over the 30 year data period (in Section 5)

(ii) the effect of weed loss (Section 7),

(iii) percolation totals to assess the impact of the current drought period on available water resources (Section 9),

(iv) the impact of actual abstraction as a percentage of the naturalised flow at Bibury (Section 10).

Considering these analyses together the following conclusions can be made :

° the double mass analyses indicate that the character of the river has remained largely unchanged. However, there appears to be a small nett increase in flows at Bibury, in the order of 3 to 8Ml/d, dating from the mid to late 1970's. The nett increase may be explained, in part, by the operation of the augmentation flow to Bibury Fish Farm from 1976. This feature would not appear to explain the entire increase, however. There is no evidence from the flow record for any reduction in surface flow as a result of groundwater abstraction.

° the large scale loss of submerged weed has a major impact upon river levels. Reports and our own estimates indicate that water levels may halve in a river like the Coln as a result of losing the instream vegetation.

° percolation has been reduced below the mean by approximately 30 per cent during the 1988-91 drought. This is considered to cause a comparable reduction in surface flows compared to mean natural flow conditions.

- groundwater abstraction has been estimated as reducing mean natural flow conditions by approximately 6 per cent over the 1988-91 drought period. On the basis of these analyses, the impact of drought conditions is 5 times greater than that of abstraction. If groundwater sources were operated at licence capacity, abstraction would have reduced natural flow by approximately 10 per cent.

- the double mass analyses indicate a small increase in flows over the last 30 years whereas a small reduction in flows may have been expected from analysis of the impact of groundwater abstraction. The difference may be explained in part by the augmentation flow from the artesian borehole at Bibury which started in 1976. The main conclusion to be drawn however is that any underlying changes in the surface flow regime have been minor and were of a lower magnitude than the natural variations caused by climatic variability.

In summary, the analyses indicate that natural drought conditions have had a significant direct impact upon flow rates and river levels. A secondary effect of reduced flow rates has been the loss of submerged weed and replacement with encroaching and blanket weed. This change in vegetation results in a further reduction in river levels which may be more severe than that caused directly by the drought. The impact of groundwater abstraction on the river is considered to be relatively minor in comparison to these natural consequences of drought.

The impact of extreme one year droughts such as that of 1975-76 is considered to be more severe than that of sustained 2 to 3 year droughts. This is because the effect of an extreme drought is to largely drain the Great Oolite aquifer and results in the river progressively drying up downstream from the upper limit of Great Oolite outcrop near Fossebridge. Conversely, recovery of the aquifer is rapid in response to rainfall and the storage is replenished relatively quickly.

Water quality is generally very good and although there are reports of increased cloudiness the suspended solids load, at least at the base of the catchment, appears fairly constant. However, one further effect of reduced flow velocities over the last few years has been that sediment has tended to build up in the bed of the river. This contributes to the loss of submerged weed as well as discouraging the breeding of wild trout and adversely effecting the appearance of the river bed.

River management does not appear to have been a significant issue in this catchment and there are very few examples of over-dredging. The river appears to be reasonably natural in its section and a buffer of unimproved pasture is present over much of the reach. The only significant detrimental effect of river management is in the presence of mill leats running parallel to the natural stream. The flow in the stream is thereby reduced below the natural flow.

Bibury to Lechlade

This reach of the river has attracted relatively little concern from the public although riparian owners have expressed similar concerns with regard to river levels and weed loss. In general however, the spring baseflows from the Great Oolite, and possibly the underlying Inferior Oolite, are more reliable and flows have been more sustained than in the reach upstream. There has been some over-dredging recorded along this reach, but, in general, river management does not appear to be a major issue.

15. SUGGESTED REMEDIAL MEASURES AND FURTHER STUDIES

1. River narrowing work has already been carried out on some reaches of the river and where the reach has been widened locally, for example by stock trampling, further narrowing work may be appropriate. In general the river appears to be within its natural channel and narrowing would, for the most part, be inappropriate and may lead to flooding.

2. A habitat improvement scheme has been proposed by the NRA for a 1500m reach near Quenington downstream of Bibury. The fundamental purpose of the scheme is to improve the river habitat to increase natural recruitment of brown trout. The loss of breeding wild trout is a general problem for the river, related to the change in condition of the river bed and in-stream vegetation. The results of this scheme should be studied carefully with a view to adopting any successful measures elsewhere in the catchment.

3. The loss of submerged weed, and its replacement with blanket weed is a serious problem which has been reported from many other catchments in the Thames Region. It is recommended that a detailed study is carried out, on a regional or national basis, to establish the causes and identify possible remedial measures.

4. The impact of groundwater abstraction from adjacent catchments on surface flow in the Coln has been estimated, largely on the basis of previous model results. It may be appropriate to consider this relationship more closely, for the Coln or for other Cotswold rivers, for example by further model runs or by re-examination of pumping test data. This would be of assistance when considering the impact of changes in licence conditions on adjacent or nearby catchments.

5. A public document is recommended which would summarise, in 4 pages, the main findings of the study.

6. It could be useful, in relation to monitoring the impact of groundwater abstraction at Bibury, to use the old wells at Ablington as observation wells.

7. The trampling of river banks and erosion of the surrounding pasture by livestock has caused a significant amount of damage along some reaches. On adjacent reaches the provision of fencing, with properly designed river access to allow livestock watering, has helped to retain the natural river

bank. This provision should be encouraged by the NRA along other reaches as appropriate.

8. The amenity value of the mill leats should be investigated in relation to detrimental impact on flows along the natural river of losses to the mill leats. Rebuilding or relocating flow controls on some leats or stopping up certain section may be appropriate.

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APPENDIX A
TERMS OF REFERENCE

Upper Kennet and Coln River Level Study

Terms of Reference

Introduction

In recent years concern has been expressed about low levels and the generally poor condition of a number of "headwater" rivers of high environmental value in the Thames catchment. Individuals and organisations outside the NRA and internal departments have raised the issue. There is a fear that certain rivers are "dying", although measurements of river flow and groundwater level do not indicate any trends that would not have been expected given the dry weather experienced during this period.

Following extensive publicity, many people have heard of the alleviation of low flow ("ALF") cases, where heavy abstraction is acknowledged to have caused low flows. In the catchments which are to be studied, abstraction occurs but is relatively light. However, there is a perception that abstraction is one of the causes of low levels and poor condition and there is a call for these rivers to be added to those whose flows are to be improved. Consequently, it is essential for the NRA to establish as objectively as possible, what changes, if any, have occurred and what the causes have been, before making commitments on policy and expenditure.

Objectives

The objectives of the study are:-

(i) To investigate the perception that the levels, flow and character of the named rivers have changed within living memory and that the water levels in the aquifers have declined.

(ii) To provide the evidence that such changes have occurred.

(iii) To determine the extent of the changes.

(iv) To assess the possible causes of the changes.

(v) To indicate in outline possible remedial measures.

(vi) To recommend any further studies and monitoring.

The Study Rivers

(i) The Upper Kennet - from the source near Uffcott (SU118786) to the flow gauging station at Knighton (Ramsbury SU294710) including the tributaries of the Og and Aldbourne.

(ii) The Coln - from the source at Brockhampton (SP035234) to the recently commissioned flow gauging station at Fairford (SP151012).

The Problem

Local residents and other people who use the river, such as fishermen, have complained of low river levels and flows and the poor condition of the river. The poor condition of the river is said to include silting up of the channel, poor weed growth of useful species such as rananculus, but growth of blanket weed and undesirable species such as starwort, reduced fish populations and changes of colour to a milky green hue.

Sources of Information

Information available from NRA - Thames Region.

Continuous flow records of various durations are available at several locations for both rivers.

Additionally spot flow measurements are available from a range of locations and the source of the Kennet has been observed approximately monthly since 1972.

Areal values of rainfall, evapotranspiration and percolation (derived from a soil moisture model) are available on a daily, monthly or annual basis.

Groundwater level records of various durations and frequencies are available at many sites.

Groundwater contour maps have been produced.

Records are available of the locations of all licensed abstractions. For the major abstractions records are available of the monthly quantities taken from the late 1960's. In both catchments there are many agricultural licences for which the NRA receive no returns. One abstraction which may influence the Kennet lies in NRA-Wessex Region, data should be sought from them. It should be noted that the actual quantities abstracted by individual licence holders is confidential information. The consultant should not disclose or publish this information to anyone outside the NRA without the permission of the licence holder. The consultant should be aware that the final report will be seen by members of the general public.

A fisheries report for each river has been produced, and fisheries officers have much local knowledge.

River biology data are available from at least 1977.

River water quality data (oxygen levels, BOD, suspended solids, ammonia) are available from approximately 1972.

The Environmental Quality district offices have information on pollution incidents etc. This will be made available. Information on the Upper Kennet is held at Fobney, Reading, that for the Coln at Oxford.

A river corridor survey of the Kennet was carried out in 1987, and a short section of the Coln is due to be surveyed before commencment of this study. The conservation section have also had some correspondence concerning the study rivers. This will be made available.

There has been considerable correspondence between NRA staff and interested members of the public. This will be made available.

Information External to NRA

The consultant should explore all sources of information which they consider relevant. These should include - archive material such as photographs, postcards, newspapers etc; private fishery records, and information held by riparian owners, river bailiffs, local authorities and organised groups such as Action for the River Kennet and Kennet Valley Fisheries Association.

Thames Water Utilities should have information on the development of the sewage system, and effluent discharges.

Scope of The Study

The study will be divided into two stages:-

Stage I
In this stage the consultant will be required to:-

(i) Review and present all relevant information concerning river and groundwater levels and the condition of the two rivers over the past 30 years.

(ii) Assess whether there has been any change in river levels or condition, and report on the amount of change.

(iii) Report on the differences between the surface and groundwater catchments.

Stage II
In this stage the consultant will

(i) Investigate the causes of any changes which should include:-

- hydrological factors eg. rainfall
- river maintenance eg. structures, weed clearance, channel clearance.
- operational structures eg. sluices, diversions.
- agricultural practices eg. field drainage, fertilizers.
- abstractions and effluent returns.
- wildfowl populations.
- any other factors considered relevant by the consultant.

(ii) Provide a quick assessment of possible remedial measures to restore the river levels and quality, and groundwater levels.

(iii) Provide recommendations for further monitoring or future studies.

Administration

Programme
The study is required to be completed to the point of submission of the draft Final Report within 4 months from the date of engagement and the Final Report 1 month later.

Reports
The following reports will be required from the consultant:-

(i) An outline report summarising the findings of the Stage I work, at a date to be agreed before the commencement of the contract. 5 copies.

(ii) A draft Final Report together with any appendices which shall be provided within 4 months from the date of engagement. 20 copies.

(iii) Brief written Progress Reports circulated at least one week prior to any progress meetings.

Progress Meetings will be arranged as required.

Other Matters

Public Relations
An important factor in the Authority's decision to proceed with this study is public concern about the condition of the rivers covered by the study. As a result there has been considerable contact between the Authority's staff and the public through correspondence and meetings with individuals and groups of people.

It is envisaged that the consultant will have discussion with interested parties. The consultant may wish to make site visits which will involve contact with the public. In relation to these activities, which will normally be carried out independently of Thames Region's staff, the consultant is asked to note that the Region is striving to achieve good relations with the public, and to demonstrate its responsibility for the environment.

It must, however, be appreciated that if an undesirable condition is identified there is no automatic decision to deal with it. Such a decision may follow completion of this study, but no undertakings can be given to interested parties at the present time.

Entry onto Private Land
When not accompanied by NRA staff, the consultant will be expected to make his own arrangements for entry onto private land. In both making arrangements and entering onto the land the Consultant should bear in mind the NRA's wish to maintain good public relations and should contact the Authority in the event of difficulties.

CMG
22/7/91
/LJ

APPENDIX B
TECHNICAL APPENDIX

APPENDIX B
FLORAL AND FAUNAL SPECIES TYPICALLY ASSOCIATED WITH UPLAND CHALK AND LIMESTONE STREAMS

Plant species typical of the upstream reaches with faster flows over gravel substrates are the water crowfoots (*Ranunculus* spp), starworts (*Callitriche* spp) and water cress (*Nasturtium officionale*). *Ranunculus calcareus* often dominates the river bed in the faster currents while *Nasturtium* forms beds on siltier substrates in areas of lower flow. These two species may show a cyclical succession where *Nasturtium* starts to colonise *Ranunculus* beds that have raised their level and lowered the flow by accumulating silt over the summer months. Higher winter flows wash away these weak-rooted associations and the cycle repeats itself as the *Ranunculus* beds are re-established the following spring (Dawson, Castellano and Ladle 1978).

With slower flows over finer substrates *Ranunculus* tends to be absent and other submerged species such as mare's tail (*Hippurus vulgaris*), opposite-leaved pondweed (*Groenlandia densa*), river dropwort (*Oenanthe fluviatile*) and Canadian pondweed (*Elodea canadensis*) may colonise. The relative constancy of water level favours the development of a rich marginal fringe of emergent aquatic plants including taller reed species, common reed (*Phragmites australis*) reed sweet-grass (*Glyceria maxima*), branched burr-reed (*Spargarium erectum*), yellow flag (*Iris pseudacoris*) the sedges *Carex acutiformis*, *C. riparia* and C. *paniculata* and lower emergents such as water mint (*Mentha aquatica*), brooklime (*Veronica beccabunga*), water forget-me-not (*Myosotis scorpioides*) lesser water parsnip (*Berula erecta*) and fools water-cress (*Apium nodiflorum*).

There is typically a high diversity of aquatic invertebrates and the larval forms of mayflies (*Ephemeroptera*), caddisflies (*Trichoptera*) true flies (*Diptera*), in particular black flies (*Simuliidae*) and midges (*Chironomidae*) are numerous in addition to the permanent underwater inhabitants, species of molluscs, freshwater shrimps, worms, leeches and flatworms. Many animals of the faster flowing reaches have specialised in-filter feeding or grazing on algal films. They are often streamlined and may have for example, other adaptations such as the holdfasts of Simuliid larvae, or exploit microhabitats of reduced flow between the stems of *Ranunculus* or the gravel interstices.

Species typical of fast-flowing, base-rich waters include mayflies of the families Ephemerellidae and Baetidae the caddis families, Lepidostomatidae, Ryacophilidae, Goeridae, Glossosomatidae, Polycentropidae and Hydropsychidae, the river Limpet *Ancylus fluviatilis*, the Elmidae (riffle beetles) and Simuliidae (blackflies).

These animals are usually dependent on high oxygen levels in the water. The presence of *Ranunculus* beds greatly increases the biomass of invertebrates compared to a bare gravel substrate, not only because it offers physical living spaces but also because of its high photosynthetic rate and the evolution of much oxygen into the water (Giles, Phillips & Barnard 1991, quoting Witcombe).

Pools of slow moving or still water in the river channel, where silt and organic matter accumulate, select for a different community of invertebrates. Many feed on organic detritus or are active predators (e.g. water boatmen, dragonfly larvae). The principal families in such habitats are the Gerridae and Corixidae (water boatmen), Dytiscidae and Hydrophilidae (diving beetles), the Mollusca e.g. pond snails, ramshorn snails (Lymnaeidae and Planorbidae), oligochaete worms and the Asellidae (the water hog louse). Certain mayflies and caddisflies may be present, particularly those of the Ephemeridae and Leptophlebidae respectively. In a natural river system with a sequence of riffle and pool formations both flowing and still water communities will be represented giving a very high, overall diversity.

Invertebrate Taxa

Table 1 : Fast flow indicator groups

	Mean 1982-85 (N=3)	1990-91 (N=6)	Change
Heptageniidae	0.66	0.66	0
Ephemerellidae	0.33	1.16	+0.83
Goeridae	0.33	0.83	+0.50
Brachycentridae	0	1.50	+1.50
Ryacophilidae	0	1.50	+0.50
Polycentropidae	0.33	0.83	+0.50
Ancylidae	0.66	1.33	+0.66
Elmidae	2.33	2.16	-0.17
Hydrosychidae	1.33	1.33	0
Simuliidae	2.0	1.83	-0.17
Baetidae	2.0	1.83	-0.17
N = 11		Total	+3.48

A/N	1982	1984	1985	1986	1987	1988	1989	1990	1991
	0.69	0.61	0.76	1.15	0.69	0.99	0.92	0.94	1.42

Invertebrate Taxa

Table 2 : Slow flow indicator groups

	Mean 1982-85 (N=3)	1990-91 (N=6)	Change
Leptoceridae	0.66	0.66	0
Ephemerellidae	0.33	1.16	+0.83
Corixidae	0.33	0.83	+0.50
Dytiscidae	0	1.50	+1.50
Hydroptilidae	0	1.50	+0.50
Lymnaidae	0.33	0.83	+0.50
Asellidae	0.66	1.33	+0.66
Oligochaeta	2.33	2.16	-0.17
N = 8		Total	-0.17

A/N	1982	1984	1985	1986	1987	1988	1989	1990	1991
	1.44	0.75	0.86	1.11	0.88	1.22	1.11	1.15	1.08