NRA-SOUTH WEST 510

NATIONAL RIVERS AUTHORITY SOUTH WESTERN REGION

RIVER OTTER ENVIRONMENTAL STUDY - 1993/94

CONSULTANTS REPORT : RIVER OTTER : ENVIRONMENTAL DATA REVIEW

W S Atkins February 1994

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South West Region

FOREWORD TO THE W.S.ATKINS RIVER OTTER ENVIRONMENTAL DATA REVIEW REPORT

Background

This report has been drafted by W S Atkins as consultants to the NRA. It has been undertaken as part of a wider review of the environmental status of the Otter catchment in East Devon. The consultant's report has been circulated to members of the River Otter Catchment Action Group for information as previously agreed.

The consultant's brief was:

- to examine the adequacy of available data for environmental studies,

and where that data is available:

- to identify significant changes which have occurred over the 1973 - 1992 period.

The opinions expressed in the report are the consultant's views. They have not been modified by the NRA and do not represent the opinions of the NRA.

The next phase of the NRA review

Recommendations will be carefully reviewed. Particular attention will be paid to the necessary further studies which are required to confirm that identified changes have occurred.

Related studies

Groundwater modelling is being carried out in parallel with the environmental data review to identify impacts of abstraction from the Otter Valley Triassic aquifer on river flow.

Catchment Management

The long term aim is to develop an appropriate Catchment Management Plan for the River Otter.

A Groundwater Management Strategy covering the resources of the Otter Valley Triassic aquifer is already in place. The opportunity will be taken to review this as part of the work associated with the Plan if the results of the environmental and modelling studies identify the need for this to be done.

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1. INTRODUCTION

1.1 THE TERMS OF REFERENCE

This document constitutes the River Otter Environmental Data Review as defined in the terms of reference issued by the NRA on the 17 February 1993 (TB/JLM). The terms of reference require the assessment of environmental data and information held by the NRA. The data are to be used to identify any changes and impacts that have occurred over at least the last 20 years in the River Otter Catchment. The terms of reference are not concerned with the causes of any change.

The River Otter has given cause for concern for many years with regard to low flows, increased sedimentation, poor water quality and over-fishing. Over a period of 20 years, abstractions from boreholes in the catchment and from the river itself have significantly increased and it may be necessary to licence further trial abstractions. The impact of these abstractions and the possible impact of future increases in abstraction for drinking water is not obvious.

The objectives of this study are therefore threefold:

° To identify significant environmental changes and impacts over at least the last 20 years using information held by the NRA.

° To consult with representatives of identified concerned organisations and to obtain and include any further evidence or information which may be relevant.

° To recommend environmental studies to confirm where necessary that identified changes have occurred.

To fulfil the terms of reference and objectives of the study, the following were addressed:

- Fisheries/fishing
- Water Quality
- Biology
- Abstraction
- Groundwater level
- River flows, velocity and stage
- Sedimentation
- Eutrophication
- Changes in drainage patterns

To establish where changes in river flow are natural, the River Axe has been used for comparison.

1.2 CATCHMENT DESCRIPTION

The River Otter is a rural lowland river which rises in the Blackdown Hills south of Taunton. It flows southwest through Honiton to Ottery St Mary and finally joins the sea at Budleigh Salterton. A number of tributaries enter the River Otter including: River Wick (north of Honiton), River Wolf (south of Honiton) and River Tale (at Ottery St Mary).

The geological structure of the upper river valley is clay with flints overlaying greensand while the river below Honiton cuts through Triassic marl and'sandstone. The flood plain is alluvium.

The river valley is mainly farmland with grazing pasture predominating. A few arable fields are found in the lower valley. The only major road in the area is the A30 near Honiton which is the largest town in the catchment. Other major population centres in the lower catchment include Ottery St Mary, Tipton St John and Otterton. Access to the river is obtained from a public footpath along the west bank. Access to the east bank is restricted between Honiton and Ottery St Mary, so the river is secluded along this stretch and has some undisturbed reaches. The river is managed for angling and there are many old weirs, mill leats and mills.

The River Otter Catchment includes a number of designated areas including: Area of Great Landscape Value, Coastal Preservation Area, Rural Development Area Blackdown Hills Area of Outstanding Natural Beauty (AONB), East Devon AONB and Nature Conservation Zone.

For the purposes of this study the River Otter has been divided into the following reaches:

A - River Otter to just downstream of Otterhead Lakes
B - River Otter from just downstream of Otterhead Lakes to Honiton
C - Honiton to Fenny Bridges
D - Fenny Bridges to Ottery St Mary
G - Salston Stream to confluence with River Otter
H - Blackbrook to confluence with River Otter
I - Colaton Raleigh stream to confluence with River Otter
J - Kersbrook stream to confluence with River Otter

Throughout the study reaches, the River Otter is characteristic of a lowland river with broad meanders, eroding earth banks and developing shingle banks.

The river channel is characterised by slacks, riffles and pools with submerged and emergent vegetation which is diverse and supports many aquatic insects. Bankside vegetation consists of alder and willow which is coppiced in places.

2. METHODOLOGY

2.1 INTRODUCTION

The data used in this review have been, for the most part, provided by the NRA. These data have been provided in both hard copy and on magnetic disk in a variety of formats. Additional information was made available by the River Otter Association, partly as a result of a questionnaire (Appendix A) circulated to interested parties including:

Mr G Jones, East Devon District Council;
M A Rafelt, River Otter Fly Fish;
Mr J R L Orange, Colyford Syndicate;
Mr S Noar, The Deer Park Hotel;
Mr R J T Market, Beech Walk;
Brigadier H.A.H. Sheppard, Beaumont Mews;
Mr A Knights, River Otter Association.

A listing of the data sources and their format is presented in Appendices B, C and D.

2.2 HYDROLOGY DATA

The data for a number of locations (Figures 2.2.1 and 2.2.2) were provided by the NRA in a variety of formats on magnetic disk and hard copy. Account was taken of local geology, where appropriate (Figure 2.2.3). The data were imported into Lotus 1-2-3 and a number of plots were produced that addressed the following:

a) Rainfall
b) River Flows
c) River Levels and Velocities
d) Ground Water Levels
e) Abstractions and Discharges

In addition to providing an understanding of the changes in the above parameters over a twenty year period, every attempt was made to address the issues raised by the River Otter Association[1] (Appendix K).

2.3 WATER QUALITY DATA

The data for a number of locations (Figures 2.3.1 and 2.3.2 and Appendix C) were provided from the NRA in a variety of formats for the twenty year period of study. These data sets are listed in Appendix B. These data were imported into Lotus 1-2-3 and plotted using Lotus 1-2-3 and Statgraphics in the following manner:

a) Plot of untransformed data against time showing quality of data set;
b) Plots of log transformed annual means with 95% confidence limits against time showing between year changes.
c) Plots of National Water Council (NWC) River Water Classifications were provided by the NRA and have been included as histograms over time.

[1] River Otter Association, Independent Water Resources Study on the River Otter. Brigadier Sheppard.

In addition, regressions of the water quality parameters against time were undertaken.

2.4 AQUATIC INVERTEBRATE DATA

From the historical biology surveys, BMWP scores, ASPT scores and numbers of families were calculated for the twenty year period of the study. These were combined with scores already calculated by NRA for more recent surveys. The resulting data set was plotted using Lotus 1-2-3 software. Examination of the data revealed errors due to changes in sampling effort. A detailed discussion of the value of these data is included in the relevant section.

2.5 AQUATIC PLANT DATA

Non-numerical information including a River Corridor Survey and land use surveys has been discussed in an attempt to identify changes over the twenty year period of study.

2.6 FISHERIES DATA

A number of fisheries surveys have been summarised in the form of tables and plots showing changes in fish populations in a number of years during the twenty year period of the study.

2.7 OTHER DATA

A number of reports and studies (Appendix B) concerned with conservation and land use (see Figure 2.7.1) have been made available including the Phase I Habitat Survey of 1983 and the Aerial Photographic Survey of 1992. These studies have been examined and are discussed in outline in the relevant sections.

2.8 CHRONOLOGICAL CHANGE AND IMPACT

Many of the above data have been drawn together in the form of a table showing change and impact over the twenty year period of the study. A number of years for individual reaches have been highlighted as `poor' years.

3. RESULTS

3.1 HYDROLOGY

This section of the report reviews the hydrology-related data made available for the study. It also outlines the availability of data for further hydrological studies.

A detailed summary of the available data is presented in Section 3.1.1 and Appendix D. The basic methodology, including a brief description of the graphs and tables produced, is outlined in Section 3.1.2. The main presentation and discussion of data then follows and addresses rainfall, river flows, river levels and velocities, ground water levels, and abstractions and discharges in Sections 3.1.3 to 3.1.7, respectively. The principal conclusions are drawn together in Section 4.1.1, with recommendations made in Section 4.1.2.

3.1.1 Available Data

Hydrology-related data available to this study include data on rainfall, river flows, rating curves, spot flow gaugings, ground water levels from within and around the Otter catchment, and licensed abstractions. They are detailed in Appendix D. Additionally, some data were available for actual abstractions for certain licences. The National Rivers Authority have used these figures to estimate actual abstractions over the twenty years covered by this study. These data are not listed in Appendix D.

Not all of the available data have been analysed in the course of this study due to time constraints. However, the key components are presented in this report. Data actually used in the study are detailed in the relevant sections, below. A summary of these data are outlined here. The locations of selected raingauges, river flow gauges, and ground water monitoring sites are identified in Figure 2.2.2.

Rainfall data for five raingauges in the Otter catchment were selected to assess the variability of rainfall across the catchment through time. Spatial variability of rainfall within the Otter catchment has not been considered. Rainfall data from the following raingauges in the Otter catchment have been used: Honiton, Feniton Court, Ottery St Mary (KS), Dotton, and Kersbrook. These stations were selected on the basis that their records were continuous throughout the study period (1973-92), and that they were situated strategically so as to describe the distribution of rainfall across the whole of the catchment. The Ottery St Mary gauge was later dropped from the study when its record was shown to be nonhomogeneous.

Rainfall data from four gauges within the Axe catchment were also assessed. These included the records at Holyford, Axminster, Forde Abbey, and Warmbrook. These gauges were selected for this study by the NRA as being representative of the spread of rainfall across the Axe catchment.

Flows in the Otter catchment are gauged by three main river flow gauging stations. Two of these are on the River Otter at Fenny Bridges and Dotton. The third is on the main tributary of the Otter, the River Tale at Fairmile. The River Axe flows through the adjacent catchment to the east of the Otter and is gauged at Whitford Bridge. Flows at Dotton and Whitford have been recorded since 1963 and 1964, respectively. The gauging station at Fenny Bridges started recording flows somewhat later, in 1974, while those at Fairmile commenced in 1978. Gauged flows were also provided for several other locations within the catchment, namely: Back Brook at Goosemoor; Colaton Stream at Pophams Farm; tributary at Riggles Farm; West Hill Stream at Salston; and Colaton Stream at Stowford. Time did not permit the analysis of data from these stations.

Borehole hydrographs are reproduced in Appendix E for 44 boreholes out of a total of 77 for which data were provided. The locations of these boreholes are indicated on the map in Figure 2.2.1.

Abstraction licence data were used from the NRA licensing database to assess all current and historical abstraction licences in the Otter catchment. These data are presented in summary form for each of the six main river reaches on the Otter, described in Section 1.2 of this report, and in Appendix F. The NRA have also estimated historical actual abstractions for all licences assessed. Both the description of the estimation procedure used, and a summary of the results on a reach-by-reach basis are also presented in Appendix F.

It should be noted that the information provided, and used, in this report is based on that currently available to the NRA. The NRA and its officers accept no liability whatsoever for any loss or damage arising from the interpretation or use of the information.

3.1.2 Methodology

General

The Terms of Reference indicated that the 20 year period from 1973 to 1992 should form the basic time frame of the study within which to look for changes in the available data. Observations have therefore been restricted to this time frame. However, it should be noted that many aspects of climate, river flows, ground water, geomorphology and other variables have a natural and inherent variability. Assessing changes in any of these aspects due to long term trends, or unnatural causes, therefore requires a sound understanding of the natural variability of the system, which is difficult to achieve by observation within a relatively short period. For this reason it is more feasible to attempt to identify the existence of abrupt changes. Subtle changes can be more confidently detected through the use of calibrated catchment models.

The Terms of Reference also required the various characteristics of the River Otter catchment to be compared with corresponding ones from the River Axe. Therefore, these comparisons have been included in the study. However, there are licensed abstractions in the Axe catchment which may affect some of the characteristics being compared. The extent to which these are affected by artificial influences in the River Axe, or have changed through time, have not been explicitly studied in our report. However, certain aspects, such as river flows, have been plotted as time series, thus enabling a visual inspection to be made. The availability of abstraction data on the River Axe has not been investigated as part of this study. The effects of artificial influences on flow characteristics of the Axe catchment should be more thoroughly investigated before comparisons between the two catchments can be relied upon.

Comparison with other catchments has not been carried out at this stage as this was outside the Terms of Reference. The usefulness of such comparisons with the Otter may be limited due to the special hydrogeology of the Otter catchment (Figure 2.2.3): the upper part of the catchment to Fenny Bridges gauging station is underlain by predominantly Mercia mudstones of the upper Triassic, with upper greensand outcropping on the high ground to the east and north of the river; the lower part of the catchment, including the river to Dotton gauging station, flows mainly over the outcrop of the Triassic sherwood sandstone aquifer. Comparisons with other hydrogeologically similar rivers may be worth investigating, although the number of rivers exhibiting this hydrogeological mix in the area is limited.

a) **Rainfall**

Data from raingauges in both the River Otter and River Axe catchments were used to set the climatological background to the study, and in particular, to ascertain any notable wet or dry periods in the last twenty years.

The distribution of annual rainfall (1941-70 average) over the Otter catchment is presented in Figure 3.1.1. The annual rainfall profile at Dotton raingauge was also plotted (Figure 3.1.2).

A number of double mass plots were produced in which cumulative rainfall and/or runoff at two sites are plotted against each other. Double mass plots have been used to indicate the homogeneity of both rainfall and surface runoff data. With these plots the cumulative totals through time for, as an example, rainfall at two sites are plotted against each other. It can be inferred if a straight line is produced, that the rainfall measured at one site is consistent through time with the rainfall measured at the other site. The sites are then said to be homogeneous with each other.

If, however, the line bends towards one of the axes, and this deviation is found to be statistically significant, then it may be concluded that the quantity being recorded has reduced at one site, or increased at the other, due to some external influence. It should be noted that double mass plots only show relative changes, and not actual changes in the measured variable. Furthermore, it is not possible to state which part of the record is erroneous without a physical explanation. For example, the earlier part of a flow record may be overestimating flows, or the latter part may be indicating a reduction in flows: both of these scenarios will produce a similar shaped double mass plot against a consistent record.

Double mass plots were produced for each of the following four raingauges against combined rainfall of the three remaining gauges: Honiton, Feniton, Dotton, and Kersbrook (Figures 3.1.3 to 3.1.6). Similar plots were produced for the Axe raingauges: Holyford, Axminster, Forde Abbey, and Warmbrook (Figures 3.1.7 to 3.1.10), and for combined Otter against combined Axe raingauges (Figure 3.1.11). This latter plot was produced to identify any unusual features in the rainfall regime in either the Axe or Otter catchments. It is important to establish that both catchments have experienced the same relative rainfall over the period of analysis before moving on to compare other aspects of the two catchments.

b) **River Flows**

Flows in the River Otter were compared to flows in the River Axe in the adjacent catchment. The NRA requested this comparison in order to provide a benchmark against which to compare flows in the River Otter. The basic catchment characteristics and flow statistics for Dotton, Fenny Bridges (both on the River Otter), and Whitford (on the River Axe) are presented in Table 3.1.1 (Section 3.1.4). The limitations of this comparison are discussed in Section 3.1.2 (General).

Annual mean flows for Dotton, Fenny Bridges, and Whitford were plotted in Figures 3.1.12 to 3.1.14, respectively. Table 3.1.2 (Section 3.1.4) ranks the last twenty years in terms of wettest (at Dotton raingauge) and greatest runoff (at Dotton, Fenny

Bridges, and Whitford). Figure 3.1.15 shows variations from the long term mean flows for each year at Dotton, Fairmile, Fenny Bridges, and Whitford.

Double mass plots of the combined rainfall for the four selected Otter catchment raingauges against annual runoff at Dotton, Fenny Bridges, Fairmile, and Whitford were produced (Figures 3.1.16 to 3.1.19, respectively).

Cumulative annual runoff was plotted as double mass for Dotton against Fenny Bridges, and Dotton against Whitford (Figures 3.1.20 and 3.1.22, respectively). Whitford flows were also plotted against the combined rainfall for four selected raingauges in the Axe catchment (Figure 3.1.21). A statistical test was carried out on the Dotton versus Whitford double mass curve to determine the significance of the plot. Fenny Bridges runoff was plotted against Whitford runoff as double mass (Figure 3.1.23).

Three annual hydrographs were plotted for each of the gauging stations at Dotton, Fenny Bridges (both on the Otter), and Whitford (on the Axe) at full and expanded scales to compare the behaviour of the catchments (Figures 3.1.24 to 3.1.29 inclusive).

Percentage variation of summer (defined as June, July, and August) flows in each year from the study period mean flow was plotted for Dotton, Fairmile, Fenny Bridges, and Whitford (Figure 3.1.30). August mean flows and percentage variation of August flows around the long term August mean were plotted in Figures 3.1.31 and 3.1.32, respectively. Figures 3.1.33 to 3.1.35 show summer modal flows at Dotton, Fenny Bridges, and Whitford.

c) **River Levels and Velocities**

River levels and velocities are directly related to two main features of a river: the flow of water in the river; and the hydraulic characteristics of the channel conveying the flow at any particular location. Any changes in the frequency of river flows will result in changes to the frequency with which various depths and velocities are experienced at any particular point along the river. These changes will be identified in the river flow analysis part of the study.

Hydraulic conditions in the river also control water depth and velocity. For any given flow the velocity will be controlled principally by the channel roughness, river bed gradient, and cross sectional area. Changes in these factors will therefore impact on water depths and velocities. It is unlikely that bed gradient will have changed significantly over the study period, although local sediment deposition and erosion may have modified channel characteristics. Channel roughness and cross sectional area could both be affected by, for example, bank erosion, sediment deposition, or seasonal weed growth.

Changes in depths and velocities due to channel geometry are difficult to assess. Water depths and velocities can change considerably within a few metres as the cross section of the river changes. It is these changes in the channel shape which result in the pool and riffle sequences so vital for the ecological health of a river. Furthermore, changes in channel geometry at one location due to erosion are likely to be complemented elsewhere along the river by increased deposition. It is therefore unlikely that general comments concerning velocities and depths can be made.

Instead, site-specific studies must be undertaken to identify changes in local channel geometry. If significant changes in channel geometry are identified at several sites, then it is likely that the river geomorphology has been affected, and therefore large parts of the catchment may have experienced an increase in rates of erosion and deposition.

There are several ways of identifying changes in velocities and depths due to changes in channel geometry. The most direct of these is the inspection of data collected in spot gauging measurements at a site through time for various flows. Other sources, such as old maps, old photographs (including aerial photographs), reports, books, river corridor and other surveys, may provide additional information (eg the river corridor survey included in the MRM Consultants Report, 1989, Volume 5). Unfortunately, time did not permit the investigation or inspection of these data during the course of this report, but this should be done before any catchment modelling is undertaken. An indication of the extent of spot flow gauging data available on the Otter for further study is provided in Appendix D.

River depths and velocities at the main gauging stations were, however, considered. These were derived from available rating equations at Dotton, Fenny Bridges, and Whitford gauging stations. The relevant rating equations, and the dates over which they apply, are referenced in Appendix D.

Summer modal river levels derived from flows were plotted for Dotton (Figure 3.1.36) Fenny Bridges (Figure 3.1.37), and Whitford (Figure 3.1.38).

d) **Ground Water Levels**

Water level data are available for some 77 boreholes, as listed in Appendix D. Of these, the NRA have provided borehole hydrographs for 44 boreholes (see Appendix E), most of which are located in the Otter Valley and record water levels in the Triassic sherwood sandstone. Five of these are reproduced in the main body of this report (Heathlands, Alfington No 1, Berry House, Wiggaton No 4, and The Haywain, Figures 3.1.39 to 3.1.43, respectively). Their locations are indicated on Figure 2.2.2. A map summarising the geology of the catchment is shown in Figure 2.2.3.

The principal boreholes whose water levels are known to be affected by ground water pumping have been identified by the NRA. Those boreholes, where the influence of ground water abstractions on water levels is uncertain, are indicated in Appendix E. Boreholes whose water levels are thought not to be influenced by abstractions are also presented in this appendix.

Two plots comparing annual maximum observed ground water levels with annual potential recharge, derived from the NRA aquifer recharge model, are presented in Figures 3.1.44 and 3.1.45, for Berry House and Wiggaton No 4, respectively.

e) **Abstractions and Discharges**

Water which is abstracted directly from rivers and unconfined aquifers, and is not returned to the system, usually constitutes the single most important artificial influence on the water balance of a catchment. For this reason it is important to have a knowledge of the location of abstractions within the catchment, the use to which abstracted water has been put, and the volume which has been abstracted through time.

Information on discharges to the river (and aquifer, if soakaways are present within the catchment) is required to assess what proportion of the abstracted water is returned to the river, and where. This is particularly important under dry weather flow conditions because it is often the case that effluent discharges from sewage treatment works lend significant support to low river flows. This is especially so if the discharged water has been stored, for example, in a reservoir, or abstracted from the aquifer some distance away from the river.

Unfortunately, flow data on discharges to the Otter are not kept by the NRA and have therefore not been analysed in this study. Some information on dry weather flow consents to discharge for sewage treatment works was available, but a preliminary analysis revealed that the information was incomplete. This is an important area, therefore, where further investigative work must be carried out in order to gain an understanding of how much water has been discharged into the Otter through time.

The NRA have provided all data on actual and licensed abstractions in the Otter catchment. The methodology used in selecting the relevant licences, and in deriving estimates of actual abstractions is presented in Appendix F. The calculations listed are based on data held on the NRA licensing archive. Licences have been allocated to one of the river reaches defined in Section 1.2. The total licensed and actual quantities for both consumptive and non-consumptive uses presented and discussed in this report derive from the data in Appendix F.

A map indicating the locations of the main abstractions is presented in Figure 3.1.46. The temporal profile of total licensed and estimated actual abstraction volumes in each year is shown in Figure 3.1.47. Abstractions were summarised as public water supply (SWU), other consumptive (Non-SWU), and non-consumptive. Cumulative licensed and actual abstractions for the whole catchment on a reach-by-reach basis are presented in Table 3.1.3 for three years: 1973, 1982, and 1992. They are summarised for 1992 in Figure 3.1.48. The spatial profiles of licensed abstractions for the first two categories (SWU and Non-SWU) for the three years are shown in Figures 3.1.49 and 3.1.50, respectively. The 1992 profiles for both SWU and Non-SWU are shown together on Figure 3.1.51, along with the average annual runoff volume at selected sites in the Otter catchment.

3.1.3 Rainfall

The distribution of average annual rainfall (1941-70) across the Otter catchment is shown in Figure 3.1.1. Rainfall varies with altitude from 780mm at the mouth of the River Otter (Budleigh Salterton) to over 1130mm on the higher ground of the Blackdown Hills. The figure is taken from 'The River Otter Catchment Description Final Draft Report, 1993' produced by the NRA.

The variation in annual rainfall between 1973 and 1992 for the Dotton raingauge is shown in Figure 3.1.2. This gauge is located in the lower half of the Otter catchment (see Figure 2.2.2). For much of the period 1973-1992 the annual rainfall levels are below the long-term (1941-1970) average for the site (874mm). Indeed, annual rainfall has exceeded the long term average in only four of the last twenty years and never since 1982. However, no long-term trend is evident. Rainfall in the latter half of the 1970s and early 1980s was higher than that experienced in the middle to late 1980s and early 1990s, but the driest period experienced was during the mid 1970s.

Cumulative rainfall for each of four raingauges (Honiton, Feniton Court, Dotton, and Kersbrook) was plotted against the cumulative sum of the remaining three for each raingauge to test its homogeneity. The results are shown in Figure 3.1.3 to 3.1.6, respectively. It can be seen that each of the raingauges exhibits a homogeneous record compared to the other three.

A similar exercise was carried out for four raingauges in the Axe catchment (Holyford, Axminster, Forde Abbey, and Warmbrook). The results (Figures 3.1.7 to 3.1.10) suggest that all raingauges, apart from perhaps Holyford, have homogeneous records. The Holyford plot (Figure 3.1.7) indicates a slightly erratic record with several minor discontinuities.

The combined rainfall from each of the Otter catchment raingauges was plotted against those of the Axe catchment (Figure 3.1.11). The line is not perfect, but discontinuities are, again, minor.

Further analysis of rainfall was outside the Terms of Reference for the study, but should be undertaken. In particular, catchment averaged monthly rainfall should be derived as far back as rainfall records reasonably allow for both the Otter and the Axe catchments. These should be used to investigate historical cumulative rainfall deficit events. An analysis of the frequency of these should be performed. Similarly, frequency analysis of rainfall totals for several different durations ranging from one month to 60 months should be performed. These analyses should be carried out for both fixed and floating starting dates, particularly for the shorter (less than 36 months) durations. The results from such an exercise would show whether climatic conditions over the Otter catchment have been unusual in recent years.

3.1.4 River Flows

Summary statistics for the two Otter flow gauges (Dotton and Fenny Bridges) and the Axe gauge (Whitford) are presented in Table 3.1.1. Catchment losses are defined as the annual average difference between the estimated catchment rainfall (mm) and measured catchment runoff (mm) above a river flow gauging station. Q95 is defined as the flow which is exceeded 95% of the time, or, on average, on all but 18 days in a year. BFI is the base flow index which is derived by applying a smoothing algorithm to the time series of daily flows. It expresses the proportion of river flow that is derived from storage within the catchment. It is a relatively stable statistic in that it changes little from year to year. The stability of other flow related statistics, such as mean flow, mean annual minimum flow, and Q95 flow is affected by the length of gauged flow record from which they are derived: these statistics can vary considerably from one year to the next.

Table 3.1.1

Summary of gauging station statistics

Station name	Fenny Bridges	Dotton	Whitford Bridge
Gauged river	Otter	Otter	Axe
Catchment area (km^2)[1]	104.2	202.5	288.5
Catchment rainfall (mm)[1]	1037	982	999
Catchment runoff (mm)[1]	623	487	539
Catchment losses (mm)	414	495	460
Period of record (PoR)	1975-93	1963-93	1964-93
Mean flow (study period) (m^3s^{-1})[2]	2.00[3]	2.95	4.77
Q95 (m^3s^{-1})[1]	0.50	0.95	1.19
Q95 (as % of mean flow)	25	32	25
Base Flow Index[1]	0.49	0.53	0.50

Note: 1 Data taken from Hydrometric Register and Statistics 1986-90, Hydrological Data UK Series, Institute of Hydrology and British Geological Survey, 1993.

2 Study period is 1973-92. Mean flows calculated from data supplied by NRA.

3 Study period for Fenny Bridges commences in 1975.

The River Otter at Fenny Bridges has a catchment area of around 100km^2. At Dotton, it is around 200km^2. The catchment area of the Axe at Whitford is almost half as big again, at around 290km^2. This difference in scale is reflected in the mean flows of the Otter at Dotton (2.95m^3s^{-1}) and the Axe (4.77m^3s^{-1}): the Axe mean flow is 60% higher than the Otter mean flow. However, the Axe ninety five percentile flow (Q95) is only 25% greater than the Otter Q95 at Dotton.

These statistics, and others in the table, suggest that the Axe at Whitford is a catchment more prone to flash floods than the Otter at Dotton. The flow regime of the Otter at Fenny Bridges, on the other hand, appears to be more similar to that of the Axe, albeit on a smaller scale. The Q95 flow at Fenny Bridges and at Whitford Bridge is 25% of the mean flow, compared to the 32% at Dotton. This implication is also reflected in the base flow indices for the three stations. The similarity in Q95 and BFI at Fenny Bridges and Whitford reflects the similarity in the hydrogeology of the two catchments. Both rivers above these gauging stations rise in the upper greensand and flow predominantly over impervious Triassic mudstones. It is worth noting that the national average value of Q95 is around 18% of mean flow, and impervious catchments usually experience much smaller low flows, with Q95 values between 5% and 12% of mean flow. It is therefore apparent that flows in both the Otter at Fenny Bridges and the Axe at Whitford receive some support at times of low flow from storage, probably the Upper Greensand. Additionally a small amount of upper Cretaceous chalk outcrops in the Axe catchment further supporting dry weather flows.

The Otter between Fenny Bridges and Dotton flows entirely over the Sherwood Sandstone aquifer (and valley alluvium) and its flow regime is significantly modified by the aquifer. This is reflected in both the higher Q95 (as a percentage of mean flow) and in the Base Flow Index. The BFI of 0.53 at Dotton, compared to 0.49 at Fenny Bridges, indicates that the flow regime is slightly more subdued than that experienced at Fenny Bridges. This is in keeping with the slower response times to rainfall that occur over aquifer outcrops. The increase in Q95 from 25% to 32% of mean flow between Fenny Bridges and Dotton suggests that flows in the Otter receive significant support from the aquifer during periods of low flow.

The catchment losses are taken to indicate the quantity of rainfall which is lost to the river by a variety of means. The principal loss is due to the evapotranspiration of water by plants. The potential loss of water due to these processes in 1991 for the Otter catchment was between 500 and 540mm. The actual loss during the growing season, is limited by the availability of soil water, and supplemented by rainfall.

There are two other main causes to which losses are attributed, although these are usually minor compared to evapotranspiration losses. The first relates to the depth of rainfall which infiltrates to replenish ground water stocks and which does not discharge to the river above the location at which it is gauged. These are not usually losses to the catchment as a whole since most ground water flow usually ends up discharging into the river towards the downstream outcrop of the aquifer. However, if this discharge has not occurred upstream of the gauging station then it will be included in the calculated losses. Ground water that does not discharge to the river but is discharged to the sea is considered as a genuine loss to the catchment.

The second cause relates to the depth-equivalent of water abstracted from the catchment and not returned to the river upstream of the gauging location. These are usually referred to as consumptive abstractions and can include a variety of uses. Most abstractions only consume a relatively small proportion of the water abstracted, with the majority being returned to the river in the form of effluent discharges. However, some abstractions do constitute a 100% loss from the catchment, such as abstractions for spray irrigation, evaporative cooling, and exports to neighbouring catchments.

Table 3.1.1 suggests that more water is lost from the Otter catchment at Dotton than from the Axe catchment, and that this loss occurs primarily between Fenny Bridges and Dotton. The cause of this increase in catchment loss could be due in part to infiltration to ground water and/or licensed abstractions. It is not possible, at this stage, to identify the direct cause but these losses should be considered in stage two with the help of a catchment ground water-surface water interaction model.

Rigorous check gauging is, and has been, carried out at these stations on a continuous basis. As soon as any significant departure in the stage discharge relationship is detected the rating is reviewed. To date 286 check gaugings have been carried out at the Dotton gauging station since records began on 20/9/62; 181 check gaugings have been performed at Fenny Bridges since 2/8/74; and 378 gaugings have been carried out at Whitford since 1/10/64. Both Dotton and Fenny Bridges have low level bed controls while a compound crump weir is in operation at Whitford. Bed control was installed at Dotton in 1971 which gave a much improved stage/discharge relationship. Prior to this time the river acted as a rated velocity-area section. Potential changes in water level produced by weed growth, especially in summer months, are taken into account by removal of growth on site and applying an appropriate linear drift correction to these data. This action has been necessary at all sites, but in particular at Whitford.

Mean annual flows for the Otter at Dotton, Otter at Fenny Bridges, and Axe at Whitford are displayed in Figure 3.1.12 to 3.1.14, respectively. It can be seen that annual flows at all these stations have been below the study period mean since 1984 (1983 on the Axe) with the exception of 1986.

These annual mean flows have been ranked and the corresponding years are presented in Table 3.1.2, below, along with ranked rainfall years for the Dotton raingauge. Rank one indicates the wettest year or the year with the greatest runoff, with rank 20 being the driest or having the least runoff. The years falling in the latter half of each record in the study period (1983-92) are emboldened to help show the relative positioning of the last ten years.

Table 3.1.2

Ranked rainfall and runoff years (1=wettest/greatest)

Rank	Dotton Rainfall	Dotton Flows	Fenny Bridge Flows	Whitford Flows
1	1974	1974	1981	1974
2	1979	1981	1977	1979
3	1981	1977	1979	1986
4	1982	1978	1978	1977
5	1989	1982	1982	1982
6	1977	1979	1986	1981
7	1986	1986	1983	1978
8	1978	1980	1980	1980
9	1980	1983	1988	1984
10	1988	1988	1984	1987
11	1984	1984	1976	1989
12	1987	1990	1990	1988
13	1983	1989	1989	1985
14	1976	1987	1991	1991
15	1990	1976	1987	1983
16	1992	1985	1985	1990
17	1985	1991	1992	1976
18	1991	1992	1975	1992
19	1973	1975		1975
20	1975	1973		1973

A one-to-one correlation between wet years and high runoff years is not necessarily to be expected as rainfall at different times of the year may or may not be hydrologically effective. For example, 1989 was the fifth wettest year in the last twenty at the Dotton raingauge, but the annual runoff was only the eleventh highest on the Axe and thirteenth highest on the Otter. Similarly, neither should a direct correlation between catchments be necessarily expected as different hydrological characteristics dominate runoff generation. For example 1976 was the fourteenth wettest year at Dotton and produced the fifteenth greatest annual runoff at Dotton. However, at Fenny Bridges 1976 had the eleventh highest runoff.

Nevertheless, general indications can be inferred. One year in the last ten at Dotton raingauge ranked in the wettest five, and one year in the last ten at Whitford had an annual runoff in the top five. None of the last ten years at Dotton or Fenny Bridges gauging stations appear in the top five. However, the wet year at Dotton raingauge and the high runoff year at Whitford referred to above were not the same (1989 and 1986, respectively).

Three of the last ten years at the Dotton raingauge were among the ten wettest (1986,1988, and 1989). Three of the last ten years also produced annual runoff figures in the top ten for all three gauging stations: 1983, 1986, and 1988 at Dotton and Fenny Bridges; and 1984, 1986, and 1987 at Whitford. It is interesting to note that the years producing the greatest runoff in the last ten were not the same years on the Axe as on the Otter, nor were they the wettest.

At the other end of the scale, three of the last ten years are among the driest five recorded in the last twenty at the Dotton raingauge. These three years (1985, 1991, and 1992) also produced the lowest runoff in the last ten years at Dotton. Seven of the last decade were in the driest ten.

Mean flows at Dotton, Fairmile, Fenny Bridges and Whitford are illustrated as a percentage of the study period mean flow in Figure 3.1.15. Maximum positive and negative deviations from the study period mean vary from about 25-35% for all these stations. The major trend which appears true for all these locations is that there are more negative variations from the mean as the 1980s progress, although there were several large negative deviations in the early 1970s. The Otter experienced an opposite deviation from the Axe in three years in the 1970s (1974, 1975, 1976). This phenomenon occurred only once in the 1980s (1983). The plot does not indicate any trend in the variability of mean flows on the Otter when compared with the Axe. The scale of variation is generally similar on both rivers and has rarely exceeded 20% in the last ten years on either river - a more frequent occurrence in the previous ten years.

The notable feature of Table 3.1.2 and Figures 3.1.2 and 3.1.12 through 3.1.15 is that rainfall and runoff on both the Otter and Axe catchments was noticeably lower in the last decade than in the previous decade. It is not possible to say whether this is a long term effect due to climatic change, or merely a statistical oddity. A much longer period of analysis is required (50 or more years) to set these figures in perspective. This could be achieved by extending flow records back by the use of rainfall records and a calibrated rainfall-runoff model.

The double mass plot in Figure 3.1.16 shows cumulative annual runoff at Dotton against cumulative rainfall from the four Otter catchment raingauges. The plot suggests that a definite change in the nature of the gauged flows occurred around 1983/84.

A similar plot for the Otter at Fenny Bridges is shown in Figure 3.1.17. Again, a break in homogeneity can be identified around 1983/84 suggesting a relative change in the gauged flows at this time.

It is worth noting that both Figures 3.1.16 and 3.1.17 indicate distinct changes occurring around 1983 which have produced a permanent, but constant, change in relative runoff volumes. Double mass plots of rainfall against runoff are not generally recommended as the relationship between rainfall and runoff is not a linear one. These plots, on their own, therefore, do not constitute a valid test of the Otter flow record. However, they do suggest that a change in the Otter flow record has occurred which requires further testing.

Fairmile runoff is plotted against cumulative rainfall in Figure 3.1.18. Although the record is shorter, and the line far from straight, no consistent change in gauged flows is suggested.

Runoff on the River Axe (Figure 3.1.19) does not indicate the changes suggested in Figures 3.1.16 and 3.1.17. The line is not perfect but the plot does imply that Axe runoff is homogeneous with Otter rainfall.

A double mass plot of cumulative monthly runoff at Dotton against cumulative monthly runoff at Fenny Bridges is shown in Figure 3.1.20. The reasonably straight line produced suggests that records for the two sites are homogeneous with each other. This may indicate that the changes implied in Figures 3.1.16 and 3.1.17 are due to changes in the behaviour of the catchment, or that both records are equally affected by some external influence.

Cumulative runoff in the River Axe at Whitford was plotted against the combined cumulative rainfall of the Axe raingauges to verify its consistency (Figure 3.1.21) The plot confirms the homogeneity of the Axe flow record.

A double mass plot of Dotton flows against Whitford flows is shown in Figure 3.1.22. This suggests that between 1979 and 1992 there were several changes in either or both of the Dotton and Whitford records. It can be seen that the plotted line curves off slightly towards the Whitford axis from about 1979 onwards. A further, and more pronounced break occurs in 1985, in the same direction. A statistical 'F' test was carried out on the double mass plot to see if the breaks indicated in 1979 and 1985 were significant. The break in 1979 was not found to be significant, but the break in 1985 was found to be significant at the 2.5% level. This result can be interpreted as meaning that there is a 2.5% chance that the break is due to natural variability in the records being compared. Another way of looking at it is to say there is a 2.5% chance of being wrong when concluding there is a definite break in the record. This level of significance can be taken as being reasonably conclusive that there is a genuine break in the record. A more certain result would have been significant at the 1% level.

A plot of Fenny Bridges flows against Whitford flows (Figure 3.1.23) was similarly tested for a break in 1985. While the break is apparent from the plot, it is not significant at the 5% level.

A test was also performed on Otter raingauges versus Dotton flows double mass plot (Figure 3.1.16) for a break in 1983. The result was significant at the 5% level, although just short of being significant at the 2.5% level.

The results of these tests using independent data sets against River Otter flows at Dotton strongly suggests that a significant change has occurred in the mean flow since the early to mid 1980s. The change is indicative of an overestimation of Dotton runoff in the early (pre 1985) part of the record, or decreased surface runoff at Dotton (River Otter) in relation to Whitford (River Axe) and rainfall over the Otter catchment in the later (post 1985) part of the record. This implied change requires confirmation through comparisons with other flow records. Further analysis of the Otter flow record should then be focused to see whether the change can be attributed to the earlier or later part of the record, and to a particular range of flows (eg floods, low flows, or a general reduction in all flows). This analysis should be performed both at Dotton and at Fenny Bridges. Once the results from these analyses are available, the need for catchment modelling can be more clearly defined in order to investigate the causes of the change.

Abstractions are licensed from both the Rivers Otter and Axe. In order to achieve a fair comparison between them, and also to allow model calibration, both river flow records should be naturalised as far as possible. This will assist in determining which effects are due to catchment processes and which are due to artificial influences, such as abstractions and discharges. Basic annual abstraction data for the River Otter are available in Appendix F for the 21 years from 1972 to 1992. Monthly abstraction data from the main production boreholes are available in the MRM Consultants report (Volume 2, Resource Modelling) from the early 1970s up to 1988.

As part of this exercise residual flow diagrams should be produced for each of two different weeks in recent years. The diagrams show how much water in the river is derived from natural inflows, and how much is derived from the nett effect of abstractions and discharges, in any one reach in that particular week. Both diagrams should be based on a week in which base flows are predominant throughout the catchment. There should not have been any significant rainfall for at least four or five weeks before the selected periods of analysis. One of the diagrams should cover a period when abstractions were operating under normal licence conditions. The other diagram should be set in a period when the majority of licences tied to prescribed flows or water levels were restricted by these conditions. Reaches identified on the residual flow diagrams should be taken from the Micro Low Flows system. Natural inflows to each reach can then be estimated from the 'natural' Q95 flows provided in Micro Low Flows. If insufficient abstraction and discharge data are available to accomplish this exercise then consideration should be given to collecting such information in the summer of 1994.

Three annual hydrographs for the Otter at Dotton are presented in Figure 3.1.24. The hydrographs displayed are those of 1976, (very low summer flows), 1982 a wet year, see Table 3.1.2 and Figure 3.1.2), and 1992 (a dry year with low summer flows). It can be seen that winter flows in January to March of 1992 were similar to those of 1976, but well below those of 1982. The winters of 1975-76 and 1991-92 were notably dry.

The low flow section of the hydrograph can be more clearly seen in Figure 3.1.25 where the vertical scale has been expanded to show flows below $5m^3s^{-1}$. Flows in April and early May of 1992 were significantly higher than the corresponding period of 1976, being supported by rainfall events. However flows in late May 1992 dropped sharply and approached those of 1976. Rainfall in early June 1992 produced a small flood event but served to raise the baseflow significantly above the 1976 level throughout the rest of the summer. Base flows in the spring and summer of 1982 were approximately $0.5m^3s^{-1}$ higher than those of 1976, which dropped from around $1m^3s^{-1}$ at the beginning of May to $0.5m^3s^{-1}$ at the end of August. Flows in 1992 remained low and parallel to, although slightly higher than (around $0.1m^3s^{-1}$ higher), those in 1976 through June, July, and into early August. Rainfall in mid August 1992 resulted in several runoff events, although base flows remained relatively depressed until the beginning of November.

Annual hydrographs for the same years at Fenny Bridges are shown in Figure 3.1.26. The low flows are presented in Figure 3.1.27. From these plots it is apparent that both winter and summer base flows in 1976 were considerably lower than in 1982 or 1992. Spring base flows in 1992 were generally similar to those in 1982 through to mid May, when the steeper recession in base flow recognised in Figure 3.1.25 at Dotton can be seen. Thereafter summer flows in 1992 lay more or less midway between those experienced in 1976 and 1982, at around $0.1m^3s^{-1}$ higher than 1976 flows. The base flow in 1976 dropped from around $0.6m^3s^{-1}$ at the beginning of May to $0.25m^3s^{-1}$ at the end of August. Summer base flows in 1982 were in the order of $0.3m^3s^{-1}$ higher than those of 1976. 1992 summer flows were therefore relatively higher at Fenny Bridges than at Dotton when compared to the summer flows experienced in 1976 and 1982.

The corresponding hydrographs for the Axe at Whitford are presented in Figures 3.1.28 and 3.1.29. It can be seen from the vertical axis of Figure 3.1.28 that the range of flows experienced at Whitford (up to $80m^3s^{-1}$) is double that experienced at Dotton (up to $40m^3s^{-1}$, Figure 3.1.24) in the three years presented. The base flow recessions are also steeper on the Axe with 1976 flows falling from around $1.2m^3s^{-1}$ at the beginning of May to $0.5m^3s^{-1}$ at the end of August. It is interesting to note that the steep recession in May 1992 identified in both the Dotton and Fenny Bridges hydrographs is also present on the Axe hydrograph. 1982 base flows remained around $1m^3s^{-1}$ higher than 1976 base flows, while 1992 base flows varied between $0.2m^3s^{-1}$ and $0.4m^3s^{-1}$ higher than 1976.

In general terms, the Otter and the Axe hydrographs are similar in many respects. Both catchments respond to the same rainfall events and appear to be highly correlated. It is also apparent that although the Axe catchment is some 45% larger than the Otter catchment at Dotton, flows in the River Axe at the end of the summer of 1976 were virtually the same as those in the Otter.

An analysis of annual rainfall and mean flows is important but, due to the dominance of, for example, high flows, more subtle changes in summer low flows can be masked. Seasonal analysis of rainfall, flows, runoff volumes, runoff deficits and many other variables, are therefore useful in uncovering these masked changes in summer low flows. Such a comprehensive review of rainfall and flow data was outside the scope of this report but should be undertaken. An analysis of summer (June, July, and August) mean flows is, however, presented here.

A plot of the variation of the three monthly mean flow from the study period mean flow for the summer months, (as defined above), in each year is shown in Figure 3.1.30. There is no obvious trend in these data: the percentage deviation from the summer mean flow in the Axe (Whitford) is generally of a similar proportion in most years in the 1980s to that observed at Dotton on the Otter. It can be seen that summer flows in three of the last four years were around 30% below the mean. However, flows in the Axe were relatively lower than those in the Otter in these years.

The summer mean flow at Fenny Bridges in 11 of the 17 years record shows an opposite deviation to the other three records. In six years this is positive deviation when the others show a negative one, and vice versa in the other five years. We have not looked into the cause of this behaviour, although it may prove interesting to do so.

August mean flows have been plotted for the Whitford, Dotton, and Fenny Bridges records on Figure 3.1.31 for the period 1970 to 1993. The pattern of August flows is the same for all three records. 1976 experienced the lowest August flow during the period, while the highest occurred in 1986. In general, though, August flows in the 1980s at all three sites seem relatively depressed compared to the 1970s.

The variation of August flows about the average August flow over the period is presented in Figure 3.1.32. The plot confirms the general pattern that August flows have been below the mean at all three gauging stations for the majority of the last decade. However, in 1988 and in 1992, August flows in the Otter were above average, while those in the Axe were below average.

Summer modal flows at Dotton are shown in Figure 3.1.33. These have been defined as the flows that are most commonly experienced during the months of June, July and August each year. It is during this period when most rivers tend to experience their lowest flows. It can be seen that summer modal flows since 1982 have been consistently below those experienced between 1977 and 1981, apart from in 1988. However, prior to 1977 modal flows of a similar magnitude to those of post 1982 were experienced.

The consistency of low summer flows indicated in Figure 3.1.33 draws attention to the possibility of the effect of changes in the longer term due to climatic change. As previously noted, however, the twenty year study period is too short to identify any long term trends or changes.

Summer modal flows at Fenny Bridges (Figure 3.1.34) in five of the last ten years were similar to those of the late 1970s. This is slightly different to the pattern indicated at Dotton, above. The pattern of summer modal flows on the Axe, Figure 3.1.35, differs slightly from to both the Fenny Bridges and Dotton plots. The main difference here, however, lies in the modal flows of the middle to late 1970s, which, on the Axe, were considerably lower than those on the Otter. This gives the impression that modal flows on the Axe in the 1980s were not much different to those of the 1970s.

The general pattern emerging from all of these plots and tables is that both mean and low flows in the River Otter were lower in the 1980s and 1990s than in the 1970s. However, the comparison with rainfall records in the Otter catchment and flows in the River Axe suggests that this phenomenon was not unique to the River Otter and may be related, in large part, to climatological effects.

Further extensive seasonal analyses should be undertaken in order to understand the nature of seasonal variability of runoff in the Otter catchment. These studies should be complemented by similar analyses of rainfall and recharge. In particular, the frequency of low flows of different durations should be investigated over at least the full period of record. If flow records are to be extended back using rainfall, evaporation, and a rainfall-runoff model, then the frequency analysis should include these data.

Flow data were available for several other minor stream support gauging-stations, as referred to in Appendix D. Time did not permit an analysis of these data but they should be considered before moving on to a more detailed study involving the use of catchment models.

3.1.5 River Levels and Velocities

Summer modal water levels at Dotton calculated from the surface modal flows, incorporating rating changes, are shown in Figure 3.1.36. The pattern is almost identical to that displayed in Figure 3.1.33 for summer modal flows, since flows are derived from the measurement of water level. It is worth noting that the maximum variation in these modal water levels over the study period is 9cm. The difference between modal water levels in the late 1970s (the highest in the study period) and 1992 is 6cm.

Changes in summer modal water levels at Fenny Bridges over the same period are illustrated in Figure 3.1.37, and are minor in comparison. Whilst the maximum variation experienced is 8cm, the difference in modal water levels between the late 1970s and 1992 is only 3cm.

The magnitude of the maximum variation in summer modal water levels in the Axe over the study period (Figure 3.1.38) is much greater, at 16cm. The average variation can be seen to lie within a range of around 6cm.

Further analysis of river water levels should be undertaken using the available spot flow gauging data, as outlined in section 3.1.2 c).

It should be noted from these figures that the scale of variation in water levels in the river is very much smaller than that experienced in neighbouring boreholes. There are a number of reasons for this; the most important of which relate to the differences between ground water and river hydraulics. Changes in ground water level do not correlate to a one to one change in river water level. Several other factors also control water levels in rivers indirectly. For example, geomorphological changes and weed growth can both affect the hydraulic conditions in the river, and thus water levels.

3.1.6 Ground Water Levels

The principal aquifer in the Otter catchment is the unconfined Triassic Sherwood Sandstone formation. This group is locally sub-divided into the Otter sandstone series, and the underlying Budleigh Salterton Pebble Beds. The geology of the catchment is summarised in Figure 2.2.3 and its hydrogeology is described in more detail in Appendix E. A location plan of the ground water monitoring network in the Otter and neighbouring catchments is shown in Figure 2.2.1.

The interaction between ground water and river flows in the Otter catchment is a complex one. The aquifer is thought to be locally confined below the river bed in most places but in hydraulic continuity with the river in others (MRM Report, Vol 2). Additionally, ground water abstractions disturb the local water table giving rise to local differences in the interaction between the river and ground water. For these reasons a simplistic approach to assessing both the long term changes in ground water levels, and the interaction between the river and ground water, can be seriously misleading (Appendix L).

A substantial amount of work in this area has already been done by MRM Consultants (1989), who developed a ground water model of the sherwood sandstone aquifer in the Otter Valley. The model was used to assess the likely impact of certain abstraction policies on ground water levels in the aquifer, and resultant changes in the flow regime of the Otter between Fenny Bridges and Dotton. Calibration of the model was difficult to achieve, and modelled ground water levels were sometimes as much as 15m adrift from estimated ground water level after calibration. These discrepancies probably arise from the adopted assumption that the aquifer permeability is constant across the whole catchment (ie that the aquifer is homogeneous and isotropic). In practice, permeability can be highly variable, substantially affecting local transmissivities and rates of water table recession and drawdown.

For the purposes of this study, borehole hydrographs for 44 sites are presented in Appendix E to allow a visual inspection of ground water levels through time at various locations. These sites have been grouped into two sets by the NRA. The first set includes boreholes that are not thought to be affected by ground water abstractions and to be used as 'control' sites for further studies. The second set includes those boreholes which may be ('possible impact' sites), and those which are known to be ('known impact' sites), affected by ground water pumping. It should be noted that the list of 'control' sites is not definitive and requires reviewing.

Ground water hydrographs for five boreholes in Appendix E are reproduced here. Their locations are shown on Figure 2.2.2. The Heathlands record is the longest in the Otter catchment (Figure 3.1.39), extending from 1950. The site is located close to the western edge of the Otter Sandstone aquifer outcrop, midway between Dotton and the confluence with the River Tale. It is dip-read fortnightly and is unaffected by aquifer pumping. The Alfington No 1 borehole hydrograph is shown in Figure 3.1.40. This site is part of the Greatwell group of boreholes and is located 2km south of Fenny Bridges on the eastern edge of the aquifer outcrop. It is dipped monthly and is significantly affected by ground water pumping. The Berry House well (Figure 3.1.41) is located about 0.5km south of Fenny Bridges, close to the eastern edge of the aquifer outcrop. It is dipped fortnightly and is considered by the NRA to be unaffected by pumping. Wiggaton No 4 borehole (Figure 3.1.42) lies adjacent to the River Otter on the west side, about half way between Fenny Bridges and Dotton, and is dipped monthly. It, too, is considered to be unaffected by ground water pumping. The Haywain (Figure 3.1.43) lies in the Culm catchment to the north of the Otter, about 6km south west of Wellington. The Culm is a major tributary of the neighbouring River Exe. Water levels are continuously monitored by a chart recorder, and are considered to be unaffected by pumping. All five sites monitor water levels in the Otter Sandstone. Wiggaton No 4 also taps the Budleigh Salterton pebble beds.

The Heathlands hydrograph (Figure 3.1.39) shows that ground water levels in this part of the aquifer experience an annual variation of between 1m and 1.5m. Three years are missing from the record (1981-83), but it is apparent that the 1990s have experienced the lowest ground water levels since records began. Maximum ground water levels have only reached 93.0mAOD once since 1984, in 1990. The mean ground water level in this period was around 92.0mAOD. The only other time when maximum ground water levels failed to reach 93.0mAOD for any number of years was between 1953 and 1958. During this period the average ground water level was around 92.3mAOD. It can therefore be concluded that both average and minimum annual ground water levels between 1984 and 1992 at Heathlands are the lowest since 1953.

The hydrograph for Alfington No 1 borehole (Figure 3.1.40) is dramatically different from the Heathlands hydrograph. In this case there is very little evidence of any annual recharge reaching the borehole, and ground water levels have been in a more or less continual decline since 1973. Over the past twenty years the water level has dropped some 3.5m from 49.0mAOD to 45.5mAOD. A few brief interludes can be identified in 1977, 1982, and 1990 when the water level rose more than in other years. The general hydrograph recession then continued from these increased levels.

The Berry House hydrograph (Figure 3.1.41) extends from 1966. This displays an average annual variation in water levels of around 0.5m, with average water level of around 57.4mAOD between 1966 and 1982. Since 1983, the nature of the hydrograph appears to have changed; with water level fluctuations due to annual recharge more difficult to discern. Data are missing for 1990 and 1991. However, there does appear to be a general decline in water levels since 1983. A small increase in water level can be detected in 1987 and 1988. Nevertheless, the lowest water level on record at this site was recorded in 1992.

Water levels at Wiggaton No 4 (Figure 3.1.42) show only a small annual fluctuation of around 0.2m, indicating high storativity, and probably, therefore, a fair degree of hydraulic connectivity with the river itself. There is little else unusual about the hydrograph. Water levels do appear to have been slightly lower between 1984 and 1992 than in the period 1977 to 1983, however they are not noticeably different from those observed in the record prior to 1977.

Water levels recorded at The Haywain (Figure 3.1.43) exhibit a 1-2m annual fluctuation depending on recharge. The minimum water level in the last 20 years was recorded in 1976, when they dropped below the 1975 level. The minimum water level at Heathlands in 1976 was about the same as that recorded in 1975 (Figure 3.1.39). If the two plots are overlain, they can be seen to be remarkably similar, both in the scale of annual fluctuation, and in the pattern of recharge through time. Recharge experienced at The Haywain over the winter of 1991/92 can be seen to be greater than that experienced at Heathlands, so that minimum water levels at the Haywain in 1992 were not as severe as those experienced at Heathlands.

The NRA have an aquifer recharge model. This has been used to derive estimates of winter and summer potential recharge for Berry House and Wiggaton No 4 sites . These are plotted on a graph together with maximum observed ground water levels for the period 1968 to 1991 in Figures 3.1.44 and 3.1.45, respectively. For the purposes of these plots, winter is defined as November to April inclusive and summer is defined as May to October inclusive. Rainfall data for the recharge model have been taken from the Dotton raingauge. Potential evapotranspiration data have been taken from Exeter Airport (1968-1981) and Bicton (1982-1992) climate stations. The correlation between recharge and maximum ground water levels at the two sites appears to be generally better in the period before 1983 than that after 1983. The correlation at Berry House appears to be better than that of Wiggaton for the earlier part of the record.

The general impression provided by the hydrographs at Heathlands, Berry House, Wiggaton No 4, and The Haywain is that ground water levels since the early to mid 1980s are generally slightly lower than those prior to this period. It would also appear that these variations are not completely explained by the aquifer recharge estimates derived from the recharge model.

A methodology for investigating the pattern of ground water levels throughout the aquifer, and the effect of ground water abstractions on these water levels, is proposed by the NRA in Appendix E.

It should be noted that sites identified as 'control' sites require reviewing. This should include an assessment of whether the present monitoring network provides adequate coverage for model calibration. Results from past model runs should be used to help identify areas where further data are required. The results of the aquifer recharge model should be reviewed and analysed. They should then be used as a first stage assessment of whether 'control' sites appear to be affected by ground water pumping. The possibility of regional aquifer drawdown through the long term effects of pumping should not be overlooked.

The calibration of the Otter Valley ground water model should be reviewed. In particular, the assumption of regional homogeneity and isotropy in the aquifer should be tested. Variations in regional porosity/storativity, suggested by differences in the annual fluctuation of water levels at different sites (eg 0.2m at Wiggaton No 4, and more than 3m at Higher Pitt Cottage, see Appendix E), indicate that the aquifer is far from homogeneous or isotropic. Transmissivities were also assumed constant during the transient runs. This assumption is clearly in error, for example, at the Alfington No 1 borehole featured in Figure 3.1.40, where the saturated depth of the aquifer has not reached steady state after 20 years. The sensitivity of this assumption should therefore be tested. The model was based on a 250m x 250m square grid. This grid size is probably too coarse to adequately describe the interaction between a number of pumping boreholes in close proximity to each other and/or the river. Consideration should therefore be given to refining the grid size to, for example, a 50m, or even 20m, spacing along the river corridor to include the Greatwell, Harpford, Dotton, Colaton Raleigh, and Otterton groups of boreholes.

3.1.7 Abstractions and Discharges

The locations of licensed abstractions from within the Otter catchment are shown on Figure 3.1.46. The relative size of the licensed annual volume (expressed in cubic metres per day) is indicated by the size of the symbol, and the source of the water (surface or ground) is indicated by the symbol shape. It is immediately apparent that the vast majority of water licensed for abstraction is taken from the catchment below Fenny Bridges. It is also apparent that the bulk of this water is taken from ground water sources. The principal borehole licence groups are boxed and named on the diagram. It should be noted that abstractions from Squabmoor Reservoir do not constitute abstractions from the Otter catchment.

A comparison of total volume of water licensed for abstraction, and estimated actual abstractions, from the entire Otter catchment for the years 1972-1992 is presented in Figure 3.1.47. The licensed volumes include both consumptive and non-consumptive uses and are derived from Appendix F. Estimated actual abstractions have been taken from Table 3.6.1 (see later), which is, itself, derived from data in Appendix F. The large drop in the licensed volume between 1973 and 1974 was due to a reduction in the volume of a large non-consumptive licence in Reach E (Fenny Bridges to Dotton).

Non-consumptive uses include fish farming, hydro-power generation, non-evaporative cooling and amenity flows to ponds. Abstractions covering these uses in the Otter catchment and their local effects on the river are considered in detail in Appendix G.

The total quantity of water estimated to actually have been abstracted from sources within the Otter catchment was around 8,140Ml in 1972, rising to 10,130Ml in 1992, representing an increase of 25%. By way of comparison, the average volume of water to run off from the Otter catchment in a year is around 106,000Ml. The total volume of water abstracted from sources within the catchment is therefore slightly less than 10% of the annual runoff volume. It should be noted that discharges back into the river are not included in these figures so the actual loss of water from the river is significantly less than the figures suggest. It should also be noted that many of the licences are tied to prescribed flows which prohibit, or reduce, the volume of water which may be abstracted when the flows in the river, or water levels in boreholes, at specific locations fall to a predefined figure.

Three years were selected for more detailed inspection of the temporal and spatial pattern of abstractions down the catchment. The years selected were 1973, 1982, and 1992, representing the beginning, middle, and end of the study period. The results are presented in Table 3.1.3. The table has been split into two parts. The first part (i) deals with licences not returning abstracted water directly to the river or aquifer (consumptive). These have been split into public water supply (SWU - Statutory Water Undertaking), and Non-SWU abstractions. The total annual licensed and estimated actual volumes (in Ml) are presented for each reach and as a cumulative total for the catchment to the bottom of each reach. In the second part of the table (ii), consumptive and non-consumptive licences are compared. The totals for each reach under the 'consumptive' heading are taken from the first part of the table. Note that there are no nett actual abstractions against the non-consumptive licences as they return their abstracted water directly to the river or aquifer within their reach. Data in the table are derived from Appendix F.

The table is summarised for 1992 on the map in Figure 3.1.48. The histograms show both the licensed (AU) and estimated actual (ACT) volumes for public water supply (SWU), other consumptive (Non-SWU), and non consumptive (Non-C) licences for each reach. The reaches are labelled and their limits are indicated by dotted lines crossing the river.

Additionally, the relative proportions of the total licensed volume for ground water sources (GW) and surface water sources (SW) are indicated by the pie charts. This information is taken from the data presented in Appendix F.

From Table 3.1.3 it can be seen that the total volume of water licensed for consumptive use rose by 23% between 1973 and 1992 from 13,826Ml to 16,361Ml. Of the total volume licensed for consumptive use in 1992, 94% was for intended public water supply.

The increasing importance of ground water as the major source water down the catchment is apparent in Figure 3.1.48. It is also apparent that more water is licensed for abstraction from the bottom reach of the catchment (F, 9467Ml) than from all the other reaches (A-E, 6894Ml) added together. Nevertheless, substantial volumes of water are licensed (5435Ml) for abstraction from reaches D and E. In 1992 approximately 83% (4515Ml) of this total was abstracted in these two reaches. The corresponding figures for reaches A, B, C, and F are 72%, 50%, 49%, and 51% respectively.

For the catchment as a whole, down to Dotton, 78% (5370Ml) of the total volume licensed for consumptive abstraction is estimated to have been taken in 1992. This compares with only 53% (4926Ml) of the total licensed for consumptive use (9310Ml) being taken in 1982, and 54% (4272Ml) of the licensed total (7902Ml) in 1973. In all cases the bulk of this water is taken from the aquifer in the reaches between Fenny Bridges and Dotton. It can be seen from these figures that, while the total volume licensed for abstraction above Dotton has decreased by around 25% (and correspondingly increased in the reach below Dotton) in the ten years from 1982 to 1992, the actual uptake of those licences remaining has increased such that around 10% more water was abstracted upstream of Dotton in 1992 than in 1982. The hoped for environmental benefits of these licence variations (see Appendix F) have therefore not been realised.

The total licensed figures include abstractions from both surface and ground water sources. In 1982 the proportion of the total licensed for abstraction from ground water was around 91% for the catchment as a whole. This figure has remained relatively constant over the last ten years (see Table 3.6.1).

Local variations do, however, occur. The proportion of the licensed total for abstraction from ground water in the upper part of the catchment above Fenny Bridges is less than 10% due to the absence of any major aquifer. The figure for the lower part of the catchment below Dotton was around 84% in 1992 (see Appendix F).

The profile of cumulative licensed abstraction volumes for public water supply (SWU) for the three years (1973, 1982, and 1992) is shown in Figure 3.1.49. The reaches are as defined elsewhere in this report. Similarly, the cumulative profile of licensed volumes for other (Non-SWU) abstractions for the three years is shown in Figure 3.1.50. Note that the vertical scales on the two figures are different. Cumulative volumes licensed for public water supply (SWU) and other (Non-SWU) licences in 1992 are shown on the same plot in Figure 3.1.51. Also shown for comparison are the average annual runoff volumes (ARV) for the Otter at Fenny Bridges, Dotton, and the tidal limit. The annual runoff volumes are estimated from the Micro Low Flows system.

The annual profile of estimated actual abstractions within each reach, derived from data in Appendix F, is presented in Table 3.6.1. The table is split into two parts. The first part (i) shows the year to year variation of public water supply (SWU) and other consumptive (Non-SWU) abstractions within each reach. The public water supply abstractions are identified as licence groups within each reach. The total estimated abstraction for the whole catchment for each year is also listed.

The second part of the table (ii) presents both the total estimated abstraction within each reach, and the cumulative volume abstracted from the catchment above the bottom end of the reach for each year. The overall percentage of the volume taken from ground water is shown, as is the total catchment runoff for each year. The estimated volume actually abstracted is shown as a percentage of the catchment runoff in each year.

The average volume abstracted between 1972 and 1992 is estimated as 9320Ml. The annual volume abstracted was below this figure in every year from 1972 to 1982, and above this figure in every year from 1983 to 1992. Similarly the average volume of water abstracted between 1972 and 1992 is estimated as 9.2% of the runoff in each year. The annual volume abstracted has been above this percentage in every year since 1984. It should be remembered, however, that conclusions based on abstraction data alone are unsound since they do not include discharges which return a large proportion of the water abstracted to the catchment.

An initial investigation of discharge consents suggested that a large proportion of the water abstracted from the river was not returned. However, these data appeared to be unreliable. It is unlikely that sewage treatment works discharges are actually documented, although the water service companies should be approached to confirm this. An alternative, but less reliable, method could involve historically assessing the operation of the water distribution system (supply) and the water reticulation system (sewage collecting). This would provide an independent check on the abstraction/discharge water balance.

The relationship between the quantities of water abstracted and discharged should be investigated to give a reliable picture of the historical variation of net abstractions. A certain amount of water is exported from the catchment and imported to the catchment. The principal destinations of this water abstracted within the Otter are Exmouth, Sidmouth and Seaton for South West Water Services, and the Otterhead abstraction for Wessex Water. These exports are utilised for public water supply.

3.2 WATER QUALITY

3.2.1 Available Data

The NRA has supplied water quality data collected at eleven sites along the River Otter between April 1974 and March 1993 (Appendices B and C). The key determinands (dissolved oxygen (DO), temperature, pH, biochemical oxygen demand (BOD), total ammonia (NH_3) suspended solids, nitrate and orthophosphate) are plotted against time in Figures 3.2.1 to 3.2.8. Data for copper, zinc and unionised ammonia (for use in determining NWC classification) are summarised in Table 3.2.1.

It can be seen, from the plots of raw data (Figs 3.2.1 - 3.2.8), that four of the sites (Rawridge, Monkton, Cottarson Farm and Fenny Bridges) are recent additions to the NRA's sampling programme and, as such, do not provide sufficiently long records for use on this project. The remaining seven sites (Table 3.2.2 below) each provide a twenty year data record, and as a result the interpretation of changes in water quality are primarily based on these seven sites.

Table 3.2.2

Sample Sites within Identified Reaches

Reach	Sample site	NGR OF SAMPLE SITE
Reach B	Hoemoor Farm Clapperlane Bridge	ST2210 1035 ST1633 0120
Reach C	Weston	ST1430 0009
Reach D	Ottery St Mary	SY0935 9606
Reach E	Tipton St John Dotton Mill	SY0901 9180 SY0873 8853
Reach F	Otterton	SY0791 8529

3.2.2 Data Analysis

a) Water Quality Classification

The NRA provided calculated National Water Council River Water Quality Classifications. These data were plotted for the period 1977 to 1992 at each of the seven long term monitoring sites listed in Table 3.2.2 (Figure 3.2.9).

b) Trend Analysis

In order to identify any significant trends, regression analyses of determinand concentrations over time were carried out. This technique was applied to each of the eight key determinands at each of the seven long term monitoring sites. The regressions were considered significant if the F-ratio exceeded the 5% probability level (Table 3.2.3).

A more detailed examination was undertaken for those determinands showing a significant upward or downward trend by determining the % change over the twenty year period of concern.

In addition plots of annual means and 95% confidence intervals against time were produced (Figures 3.2.10 - 3.2.47). Annual means for BOD and ammonia were also plotted at all long term monitoring sites, irrespective of whether significant long term trends had been identified because of their importance in water quality. These plots were used to identify short term significant changes within the twenty year period as opposed to the overall trends shown in Tables 3.2.3 and 3.2.4.

3.2.3 Discussion of Results

a) Reach A - River Otter to just downstream of Otterhead Lakes

No long term water quality data are available for this stretch of water. It may be reasonable, however, to use the Hoemoor Farm sampling site (about 3 km downstream of Royston) as a guide to water quality within Reach A. This site is discussed under 'Reach B' below.

b) Reach B - River Otter from just downstream of Otterhead Lakes to Honiton (13km)

This stretch of the river contains two long term monitoring sites; Hoemoor Farm (3 km below Royston) and Clapperlane Bridge (Honiton). Sampling frequency prior to 1983 is low at both sites with less than ten samples per annum being available. Since 1983 however, data collection has been good except for copper and zinc determinations, which are largely absent.

In recent years two further water quality monitoring sites have been added within the reach (Rawridge, 1990 and Monkton, 1986) but neither has a sufficiently long data record for use in this study.

i) Hoemoor Farm

<u>NWC Classification, including DO, BOD and Ammonia</u>

Typically the river at Hoemoor Farm has been of class 1A or 1B quality (Figure 3.2.9). However during the early 1980s (1980, 1981, 1982 and 1984) elevated BOD concentration caused a lowering of water quality to class 2. Over the twenty year period BOD appears to have risen to a maximum in 1980-1982. The remaining years have consistent BOD levels.

Regression analysis has confirmed no significant overall upward or downward trend in BOD at this site. DO concentrations (Figure 3.2.10) have to some extent mirrored the movement in BOD, falling to a lowest mean level in 1980. Regression analysis of DO concentration over the whole period indicated a significant rise of some 6% overall (Table 3.2.4). Regression analysis of ammonia concentration indicated a significant overall fall of some 80% over the twenty year period (Table 3.2.4). Analysis of annual means for these parameters over time revealed no marked steps within the twenty year period. (Figures 3.2.10, 3.2.11 and 3.2.12).

Nutrients

Regression analysis of nitrate and orthophosphate concentrations (Table 3.2.3) indicated a significant rise in nitrate concentration of 36% (Table 3.2.4), but an overall fall in orthophosphate concentration of 38% (Table 3.2.4). Whilst no particular short term changes were found within the nitrate data set (Figure 3.2.13), there are some indications of a general fall in orthophosphate concentration after 1982 (Figure 3.2.14).

Temperature, pH and Suspended Solids

Regression analysis of temperature shows no significant trend. A slight rise in pH level and a significant fall of about 38% in suspended solids concentration were identified (Table 3.2.4). No specific patterns within the twenty year period were evident although 1980 and 1982 stood out as being years when pH values were particularly low and suspended solids high (Figure 3.2.15 and 3.2.16).

ii) **Clapperlane Bridge**

NWC Classification, including DO, BOD and Ammonia

Water quality at this site (Figure 3.2.9) has generally been poorer than at Hoemoor Farm, falling into class 3 during 1980 - 1982 and class 2 between 1983 and 1988. The 1A classification prior to 1980 is based on a limited data set. The site does however show recovery after 1988 with class 1A achieved again in 1992.

Regression analysis of BOD and DO concentrations showed no significant change over the twenty year period (Table 3.2.3) and indeed no short term changes of significance were highlighted from an examination of annual means (Figures 3.2.17 and 3.2.18). The lower mean BOD values obtained between 1979 and 1981 may be a reflection of the limited data set available for these years. Note that although mean BOD concentration was low, occasional high values affected the NWC River Classification. However, a significant fall (55%) in ammonia concentration was indicated by regression analysis (Table 3.2.4). An examination of annual means (Figure 3.2.19) indicated a somewhat varied picture with highest values occurring during the 1980s. The data prior to the peak of 1982 are few and the trend is therefore not reliable.

Nutrients

Regression analysis of nitrate and orthophosphate concentrations (Tables 3.2.3 and 3.2.4) indicate overall a significant increase of 26% and decrease of 28% respectively. There were however no marked short term changes within the twenty year period (Figure 3.2.20 and 3.2.21).

Temperature, pH and Suspended Solids

No long term trends were identified for temperature or suspended solids (Table 3.2.3). There was, however, an indication of a slight overall rise in pH (Table 3.2.3 and 3.2.4 and Figure 3.2.18). Lower than usual values for pH were observed in 1980 and 1982 (Figure 3.2.22).

c) **Reach C - Honiton to Fenny Bridges (5 km)**

This stretch of river contains one long term monitoring point at Weston (2 km below Honiton) plus two recently added monitoring points at Cottarson Farm (1985) and Fenny Bridges (1990). Weston has a good data record and is situated downstream of Honiton sewage treatment works outfall. Analysis has therefore been confined to this one site.

NWC Classification, Including DO, BOD and Ammonia

The river at Weston has been class 2 since 1983 (Figure 3.2.9). From 1980 to 1982 the river was class 3 due to high BOD and suspended solid concentrations. Prior to 1980 the classification is variable.

No long term trends were identified with respect to BOD and ammonia at this site (Table 3.2.3). DO, however, showed a significant deterioration by some 10% over the twelve year period (Table 3.2.4). The decline is more pronounced prior to 1983 with some recovery occurring between 1983 and 1986. Lower concentrations were again found between 1987 and 1992 (Figure 3.2.23). BOD was found to rise in the late 1970s; the level then remained relatively constant during the 1980s and fell again after 1989 (Figure 3.2.24). Ammonia concentrations were found to be highly variable prior to 1984 but relatively constant thereafter (Figure 3.2.25). 1981 stood out as an odd year with low BOD, low ammonia and high DO. This follows the pattern for that year seen in Reach B.

Nutrients

Regression analysis of nitrate and orthophosphate concentrations (Tables 3.2.3 & 3.2.4) indicated overall increases of 66% and 56% respectively. The increase for nitrate was twice that seen in Reach B and that for orthophosphate is a reversal of the trend seen in Reach B. This probably reflects the presence of effluent from Honiton sewage treatment works. Nitrate concentrations were found to rise fairly rapidly prior to 1985 and, after remaining constant for the next three years, to rise again between 1989 and 1991 before falling a little in 1992 (Figure 3.2.26). Orthophosphate concentrations were variable throughout the whole period but generally rose to a peak in 1989 before falling again over the next three years (1990 -1992) (Figure 3.2.27). A high mean concentration of orthophosphate was also apparent atypically in 1979. No nitrate data were available for that year.

Temperature, pH and Suspended Solids

No significant trends were identified for temperature, pH or suspended solids at Weston (Tables 3.2.3 and 3.2.4).

d) Reach D - Fenny Bridges to Ottery St Mary (4 km)

This stretch of river contains one long term water quality monitoring site situated at Ottery St Mary about 1 km upstream of the lower end of the reach. The site has a good data record except for low sample numbers prior to 1983 and the absence of information concerning copper and zinc concentration. There are no other monitoring sites within this reach.

NWC Classification. Including DO, BOD and Ammonia

The river varies between class 2 and 3 between 1980 and 1992 with class 3 classifications in 1980 - 1982 and 1986 - 1988. The low classifications in 1980 - 1982 are due to high BOD and suspended solid concentrations, whilst the low scores in 1986 - 1988 are due only to high suspended solid concentrations.

No specific long term trends were identified for BOD or ammonia at this site (Tables 3.2.3 and 3.2.4) and no significant peaks or troughs throughout the period were observed (Figure 3.2.28 and 3.2.29).

Regression analysis of DO concentration revealed a downward trend amounting to about 11% over the twenty year period (Tables 3.2.3 and 3.2.4) Throughout the period oxygen levels have fluctuated somewhat with the lowest annual means occurring in 1980 and 1991 and the highest in 1976 (Figure 3.2.30). Following 1980 oxygen levels rose to a peak in 1985 (inferior to 1976) before falling steadily over the next six years. Some recovery was recorded in 1992.

Nutrients

Regression analysis of nitrate and orthophosphate concentrations revealed upward trends amounting to increases of 56% and 34% respectively over the twenty year period (Tables 3.2.3 and 3.2.4). Nitrate concentrations rose sharply between 1981 and 1983, thereafter remaining constant until 1988 after which a further rise occurred. Some recovery towards levels occurring in the mid 1980s was observed in 1991/92 (Figure 3.2.31). Orthophosphate concentrations were extremely variable but with a general rise occurring toward a peak annual mean concentration in 1989 followed by an apparent sharp fall over the next 3 years (Figure 3.2.32).

Temperature, pH and Suspended Solids

No significant upward or downward long term trends were observed for these determinands (Table 3.2.3 and 3.2.4).

e) Reach E - River Otter from Ottery St Mary to Dotton

This stretch of river contains two long term water quality monitoring sites at Tipton St John and Dotton Mill. The second of these two sites, situated at the bottom end of the reach, contains an excellent data record in terms of sample numbers per annum throughout the twenty year period. Tipton St John, situated about half way along the reach,1980 has a data record comparable to the other sites observed on this project.

i) **Tipton St John**

NWC Classification, Including DO, BOD and Ammonia

The river is classified as 3 in 1980 - 1982 and 1986 - 1988. During 1980 - 1982, the low classification is due to high BOD and high suspended solid concentrations. In 1986 - 1988 the low classification is due to high suspended solid concentrations only. From 1989 to 1992 the river attained class 1B. Between the two periods of class 3 (1980, 1982 and 1986 - 1988), the river reached 1B in 1984.

Regression analysis of DO, BOD and ammonia concentrations revealed a decreasing trend in oxygen levels of about 10% over the twenty year period but no corresponding rise in BOD or ammonia (Tables 3.2.3 and 3.2.4). Closer examination of these determinands revealed no particular short term changes in BOD or ammonia (Figures 3.2.33 and 3.2.34) at this site and only slight variation in mean oxygen concentration (Figure 3.2.35). Peak values in mean oxygen were observed in 1976 and 1985 whilst lowest values occurred in 1982 and 1988.

Nutrients

Regression analysis of nitrate and orthophosphate concentrations revealed upward trends amounting to increases of 58% and 57% respectively over the twenty year period (Table 3.2.3 and 3.2.4). Closer examination of nitrate data (Figure 3.2.36) revealed a gradual rise in concentration with no significant steps. The annual mean value for 1992 was lower than might have been expected. Orthophosphate concentrations were variable throughout the period (Figure 3.2.37). Notable maxima occurred in 1983 and 1989 with an apparent decline following the latter.

Temperature, pH and Suspended Solids

Regression analysis revealed no significant long term upward or downward trends in temperature, pH or suspended solids at this site (Tables 3.2.3 and 3.2.4).

ii) **Dotton Mill**

NWC Classification, Including DO, BOD and Ammonia

The NWC classification at Dotton Mill is locally similar to that shown at Tipton St John. From 1979 to 1983 the class was 2, with 1B in 1984 and 1985, followed by a period of class 3 in 1986 to 1988. The causes of this pattern were high copper concentrations in 1979 - 1981, high BOD 1982 and 1983 and high suspended solids in 1986 - 1988.

Regression analysis of DO concentrations indicated a downward trend amounting to about 7% over the twenty year period (Table 3.2.3 and 3.2.4) No significant long term trends were identified for BOD and ammonia.

Closer examination of annual mean DO concentrations (Figure 3.2.38) revealed a pattern of well defined peaks and troughs. Highest values were observed in 1976 and 1985 whilst the lowest values occurred in 1982 and 1988. Similar examinations of BOD and ammonia data (Figures 3.2.39 and 3.2.40 respectively) however revealed highly variable data with no distinct patterns. Highest values in both cases were observed in 1986.

Nutrients

Regression analysis of nitrate and orthophosphate concentrations (Table 3.2.3 and 3.2.4) identified upward trends amounting to 65% and 39% over the twenty year period. No significant short term changes were observed (Figures 3.2.41 and 3.2.42).

Temperatures, pH and Suspended Solids

Apart from an apparent decrease in temperature levels of about 13% over the twenty year period no significant long term trends were observed for these determinands (Table 3.2.3 and 3.2.4).

f) Reach F - River Otter from Dotton to the tidal limit

This stretch of water contains one long term water quality monitoring station situated at Otterton about 1.5 km above the tidal limit. The data set for this site is again limited in the early years.

NWC Classification, Including DO, BOD and Ammonia

Otterton is characterised by class 3 in 1980 - 1982 and 1986 - 1988. The causes for these low classifications are high concentrations of BOD and suspended solids in 1980 - 1982 and high concentrations of suspended solids in 1986 - 1988. The remaining years are typically class 1B (Figure 3.2.9).

Regression analysis of DO concentrations revealed a downward trend amounting to about 14% over the twenty year period (Table 3.2.3 and 3.2.4). No significant long term trends were identified for BOD and ammonia.

An examination of annual mean concentrations revealed no significant short term changes for any of the determinands. Highest BOD and ammonia concentrations were recorded in 1980 with a second peak in 1986 (Figures 3.2.43 to 3.2.45).

Nutrients

Regression analysis of nitrate and orthophosphate concentrations revealed upward trends amounting to 57% and 33% respectively over the twenty year period (Table 3.2.3 and 3.2.4). In both cases the observed trend was a gradual rise with no significant steps (Figure 3.2.46 and 3.2.47).

Temperature, pH and Suspended Solids

No significant upward or downward trends were identified for these parameters (Table 3.2.3 and 3.2.4).

3.3 AQUATIC INVERTEBRATE DATA

3.3.1 Overview

This review of aquatic invertebrate data for the River Otter has involved collation and interpretation of data held by the NRA for a period extending from 1968 to 1992. Interpretation to produce a reliable historical review of changes in aquatic ecology of the River Otter at various locations has been severely limited by the varying quality of surveys undertaken over these 24 years. However, an attempt is made to provide an indication of general trends and any significant changes in the aquatic ecology within this time period.

3.3.2 Available Data

Data on the aquatic ecology of the River Otter were provided for the years 1968, 1973, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1985, 1986, 1990, 1991 and 1992. These consist mainly of data sheets of aquatic invertebrate sampling programmes. Unfortunately, methods of sampling have changed over the years and there are major differences in the methodology used in recording invertebrate populations and therefore the results for these data are unreliable and are both noncomparable and incompatible. These methods range from a simple abundance scale for the main families used for field sorting to actual figures for individual species for samples sorted in the laboratory. The available data are listed in Appendix B.

Extensive river surveys were carried out in certain years (eg, 1983, 1984, 1985, 1986). These involved a large number of sampling points on the main River Otter and its many tributaries, but many of these sampling locations have not been resurveyed in later years. The most frequently surveyed sites over the last 24 years have been used for the detailed analysis of changes in aquatic invertebrate populations over time. These sites are:

River Otter, Hoemoor Farm (NGR 221 104)
River Otter, Monkton (NGR 185 031)
River Otter, Clapperlane Bridge (NGR 163 012)
River Otter, Weston (NGR 142 000)
River Otter, Fenny Bridges (NGR 114 987)
River Otter, Ottery St Mary (NGR 093 960)
River Otter, Tipton St John (NGR 098 919)
River Otter, Dotton Mill (NGR 087 885)
River Otter, Otterton (NGR 079 852)

Field observations of aquatic flora, including macrophytes and algae, are recorded on some of the field data sheets but the amount of information is insufficient to allow comment on any changes in flora over the last 24 years.

Sampling methods, frequency of sampling, accuracy of invertebrate sorting and recording, and recording methods have changed over the last 24 years. Much of the available data are only strictly comparable with data collected during the same survey. From 1990 onwards the survey techniques, degree of sorting and methods of recording have been standardised. Prior to this, separate river surveys appear to have been conducted, many with new briefs on methodology for each project.

The biological audit samples appear to be more reliable in terms of consistency of sampling method and sorting. These were collected in 1968, 1973, 1979, 1980, 1981 and 1982. Unfortunately the number of sampling points studied dropped from 13 in 1968 to only 3 in

1979, 1981 and 1982. There are numerical data available solely for aquatic invertebrates from 1968 to 1992. Limited numerical data are therefore only available for about half of the study period.

Sampling has been carried out during different seasons throughout the study period, so further reducing the reliability of any comparison of invertebrate populations.

The skill of the biologist in sorting the samples is another variable which may have affected results, particularly if this is down to species level.

The above limitations in the quality of data available from 1968 to 1992 mean that any direct comparison of invertebrate populations recorded over these 24 years should be treated with extreme caution. An attempt has been made to determine any trends or significant changes in invertebrate populations over this time period, but the interpretation of the information is only as reliable as the data itself.

3.3.3 Data Analysis

Due to the limitations of the available data only the more consistent records from the biological audits of 1968, 1973, 1979, 1980, 1981 and 1992 and recent surveys of 1990-92 have been used to study changes in groups and/or species of aquatic invertebrate. However all available data from 1968 to 1992 has been used to calculate the Biological Monitoring Working Party (BMWP) Score, the number of families represented, and the Average Score Per Taxon (ASPT) for the nine sites studied (Table 3.3.1). Graphs showing changes in ASPT over time have been drawn up for each location (Figure 3.3.1). Where groups were not identified to family, eg cased caddis, flat worms, damselflies and dragonflies, the ASPT were not calculated.

3.3.4 Interpretation of Data

(a) Biological Monitoring Working Party Scores

The general trend throughout the length of the river of an increase in BMWP score could simply be a reflection of the improvement in sampling effort. Therefore the BMWP scores are not further discussed.

(b) Average Score Per Taxon

The ASPT score tends to be less variable than the BMWP score, and in this particular study is useful as it may balance out the variability in sampling technique and degree of sorting. However, it should be noted that ASPT is not independent of sampling effort with a tendency for score to rise with sampling effort as the rarer high scoring species are increasingly recorded. Hence, although samples taken on the same day may give a laboratory BMWP score twice as high as in the field record, the ASPT tends to be of a similar level as ASPT values are less dependent on the numbers of taxa. A high ASPT value generally is characteristic of clean upland rivers with larger numbers of high scoring taxa, whereas a lower ASPT would be calculated for a polluted watercourse supporting mainly low scoring taxa. The ASPT values for sites upstream of Honiton tend to be around 6.0, whereas sites downstream are around 5.5 and tend to have greater fluctuations.

i) **Reach A - River Otter to just downstream of Otterhead Lakes.**

No invertebrate data are available for this reach.

ii) **Reach B - River Otter from just downstream of Otterhead Lakes to Honiton (13km)**

Hoemoor Farm

The ASPT values are 6.0 or more for most years at Hoemoor Farm reaching an average of 6.6 for the 1990s. This indicates a good quality watercourse supporting a high number of pollution-intolerant species. The ASPT does not show marked fluctuations over the 24 year period apart from a deterioration in 1977 to ASPT 5.6 and 5.9 in 1980.

Monkton

This site shows fluctuations between 5.6 to 6.4 from 1968 to 1992, again indicating a good quality watercourse, but with slightly fewer of the pollution-intolerant species.

Clapperlane Bridge

ASPT scores for Clapperlane Bridge range from 5.7 to 6.2; the highest ASPT value was recorded in 1968.

iii) **Reach C - Honiton to Fenny Bridges (5km)**

Weston

Whereas the three upstream sites show a tendency for ASPT scores to be even, at Weston the ASPT figures range from 4.4 to 6.2. The ASPT peaks at 6.2 in 1982 and falls to around 4.4 in 1983.

Fenny Bridges

The decline in ASPT at Fenny Bridges in 1983 appears more dramatic with a decrease from 5.8 in 1980 to 4.3 in 1983. The 1990 average of 5.5 indicates a slight improvement at this point over the last 24 years, but reflects the decline in water quality below Honiton.

iv) **Reach D - Fenny Bridges to Ottery St Mary (4km)**

Ottery St Mary

The ASPT fluctuates between 4.7 and 6.0. There is a deterioration from ASPT 6.0 in 1980 to 4.7 in 1983 as indicated for this period at other sites. The average ASPT for the 1990 scores is again 5.5.

v) **Reach E - River Otter from Ottery St Mary to Dotton**

Tipton St John

The ASPT scores in 1960 and 1970 are often over 6.0. There is a more marked decrease in ASPT from 6.6 in 1980 to 5.2 in 1983. The 1980 score is higher than that at the nearby upstream sites of Weston, Fenny Bridges and Ottery St Mary. The higher ASPT at Tipton St John at this time indicates that there had been considerable breakdown of the organic pollution from the Honiton area by this point, hence enabling more pollution-intolerant species to recolonise. However the 1990 average ASPT of 5.4 indicates that the Otter is now suffering from pollution from upstream sources at this point.

Dotton Mill

The ASPT scores range from 6.1 to 4.4. The average 1990s ASPT is 5.6, similar to other sites below Honiton. In 1979 the ASPT fell from 5.9 in 1977 to 5.1 in 1979; this was followed by recovery to 6.1 in 1980.

vi) **Reach F - River Otter from Dotton to the tidal limit**

Otterton

At Otterton ASPT values fluctuated between 5.1 and 6.1. The 1968 figure of 5.6 is same as for 1990 and the graph indicates little change over time at this point. The ASPT score of 1983 is high at 6.1.

3.4 AQUATIC PLANT DATA

3.4.1 Aquatic Plants

There are insufficient historical data to enable study of changes in the macrophyte and algal populations of the River Otter over the last 20 years. There are no numerical data or detailed surveys of vegetation abundance and only patchy records of dominant species have been recorded during invertebrate sampling.

The descriptive 1990 River Otter Corridor Survey (NRA-SW 1990), which provides good background information on habitat characteristics along the river includes no detailed survey work on vegetation. At the time of the survey it was noted that algal growth was particularly heavy, tending to obscure submerged vegetation, so further limiting the use of this survey for monitoring change in macrophytes. The maps provided show broad areas of importance along the watercourse, including occurrence of certain vegetation types or species: reed or sedge, water crowfoot, Canadian pondweed, fool's watercress, and watercress, but these are not in sufficient detail for study of changes in the vegetation assemblages over time.

In 1991 and 1992 'Aquatic Macrophyte and Vertebrate Surveys' were undertaken. Only four sites were studied in both years: Rawridge, Clapperlane Bridge, Fenny Bridges and Dotton Mill. The surveys were undertaken by different samplers in 1991 and 1992. Surveys were undertaken in the spring, summer and autumn of 1991, but only in the summer of 1992. In addition it is possible that there was under-recording in 1991 compared to 1992. The field sheets record the presence of species in the river channel but give no abundance information.

Plant scores used in "Methods for the Use of Aquatic Macrophytes for Assessing Water Quality 1985-86" by Dr J P C Harding (The Surveying and Assessment of Macrophytes in Watercourses: Method B) are used and provide a total score, the number of scoring plant species, and average score per species. There are a number of limitations associated with this approach. In particular the method does not relate to the South West flora and does not take into account sensitivity to pollutants as a function of a species' geographical range. No equivalent information is available for any other years so limiting the use of this work until similar future surveys are undertaken. The lack of abundance data also restricts the value of such survey work for the monitoring of changes over time.

The 1991 and 1992 summer plant survey scores for the four sites studied are given below (Table 3.4.1).

Table 3.4.1

1991 and 1992 Summer Survey Scores

Site	Year	Summer Score	Number Scoring Plants	Average Score per Species
45 m u/s Rawridge	1991 1992	23 35	5 9	4.6 3.89
70 m u/s Clapperlane Bridge	1991 1992	13 38	3 9	4.33 4.22
150 m u/s Fenny Bridges	1991 1992	34 34	8 11	4.25 3.09
50 m u/s Dotton Mill	1991 1992	45 45	10 11	4.5 4.09

All sites show a slight decrease in the average score per species from 1991 to 1992 which could reflect a slight deterioration in water quality. The number of scoring plants recorded increased from 1991 to 1992, and the summer scores were significantly greater with the exception of Dotton Mill and Fenny Bridges where the scores for 1991 and 1992 are the same. This indicates that in 1992 there were a greater number of lower scoring plants. This may reflect higher pollution levels or lower flow conditions resulting in shallower pools. This would allow a greater diversity of plants to grow within the river channel than under higher flow conditions.

However, the field data on presence/absence of species for these two years do not provide either clear indications of changes in the aquatic environment or confirm the above observations. At Rawridge lower scoring duckweed (*Lemna sp*) was not recorded in 1992, neither were *Polygonum amphibium*, *Veronica beccabunga* and *Glyceria sp*, all of which tend to grow in still/slow moving water or along muddy margins. These were all recorded in 1991.

At Clapperlane Bridge the lower scoring species *Apium nodiflorum*, *Iris pseudacorus* and *Phalaris arundinacea* are present in 1991 but not 1992. At this point *Glyceria* sp was present in 1992 but not in 1991. The less pollution-tolerant *Nasturtium officinale* (high scoring) was also absent in 1991, but present in 1992.

At Fenny Bridges *Nasturtium officinale* was present in 1991 but absent in 1992, as were the lower scoring *Elodea canadensis, Elodea nutallii* and *Sparganium*. The low scoring *Alisma plantago-aquatica* and *Potamogeton crispus* which colonize mud/clay substrate, and the high scoring *Carex* sp were present in 1992 only.

At Dotton Mill *Callitriche stagnalis* and *Agrostis stolonifera* were present in 1992 but absent in 1991; *Lythrum salicaria, Myosotis scorpioides, Juncus bulbosus, Lemna* sp were present in 1991 but absent in 1992.

3.5 FISHERIES

3.5.1 Overview

There are limited data available that describe the fisheries of the River Otter.

3.5.2 Data Sources

Five sources of data were examined:

(a) South West Water Authority (SWWA). Fisheries Survey, River Otter 1978.
(b) National Rivers Authority. River Otter Fish Surveys 1983-1992.
(c) National Rivers Authority. Comparative Rod Catches 1968-1991.
(d) Alabaster JS 1987. Water Resources Development in East Devon. Otter Valley Catchment Study - Review of Environmental Data (Stage 1).
(e) River Otter Association. Report on the Decline of the River Otter. 1992.

These data provide an indication of the history and present status of the fisheries. However, it should be noted that reliance should not be placed on rod catches as an indicator of the present status of the fisheries, unless it is supported by effort data.

3.5.3 River Otter

(a) Salmon

The SWWA survey undertaken in September and November 1978 reports salmon present downstream of Otterton Weir, which is considered a barrier to salmon. Spawning, as indicated by the presence of only one year class (1 + juveniles), was considered not to be self-sustaining given the absence of mature fish.

The rod catches as reported by the NRA include data for 1990 with 0 and 2 salmon recorded in 1990 and 1992 respectively (Figure 3.5.1) and with juveniles recorded in 1992. Data for previous years were not recorded as the River Otter is not considered to be a salmon river. However, these recent data suggest that the River Otter below Otterton Weir may now be a self-sustaining salmon river.

Alabaster (1987) notes that migratory fish are rare in the River Otter with only 8 returns for the Otter and Sid combined between 1951 and 1982.

(b) Sea Trout

The SWWA survey in September and November 1978 makes little mention of sea trout populations.

The NRA comparative rod catches for sea trout (Figure 3.5.1) show marked fluctuations but no apparent long term trends and relate to waters below Otterton weir. The average catch is in the region of 50 sea trout per year. Noticeably low catches occurred in 1976, 1985 and 1986, coinciding with dry summers and high catches in 1981 coincided with a wet summer.

Alabaster notes that the Otterton weir and possibly weirs at Tipton and Ottery act as barriers to sea trout movement.

(c) Brown Trout

The NRA have undertaken electrofishing and report catches for trout fry (0+) and parr (1+). These data are presented in Appendix H.

The trout fry and parr catches are highly variable in the four years of the electrofishing survey. For fry this is a reflection of the critical nature of the date of sampling. The electrofishing data in general are not comprehensive with sampling undertaken irregularly and in different locations. The four years of the survey: 1983, 1984, 1986 and 1992 include one year; 1984, when samples were collected at different locations to the remaining years. In addition, the sampling date is considered to have been more precise in 1992 compared to previous years with regard to fry catches.

i) Reaches A - F, River Otter

The fry catches in the upper River Otter and in the years where comparable sites were sampled (1983, 1986 and 1992) are highly variable. Catches were particularly low in 1986, whilst catches in 1992 and 1983 are broadly similar.

The SWWS (1978) survey reported an odd trout population structure. This was indicated by low densities of fry (0+) in the main river and relatively higher densities of parr (1+) at the same locations. The cause of this imbalance was variously ascribed to a poor spawning in 1977-1978, inadequate sampling of 0+ fish, or the effects of stocking fry 1+ fish. This suggests that stocking has been practised for a number of years in the Otter and not restricted to 1979. Growth was considered to be generally good for both stocked and wild fish.

The River Otter Association (1992) have reported rod catches of wild trout in a half mile section between Honiton STW and the Express Dairy at Honiton (Figure 3.5). These catches are not supported by effort data. These data indicate a decline from the early 1970s to a trough in 1983, a minor peak in 1987 with a continued decline to 1991. The long term decline in rod catches may be compounded by stocking of the river around Honiton which began in 1979 (Otter Association pers com.). However, the apparent improvement from 1983 to 1987 and subsequent decline is not explained by stocking activity.

ii) Reach G - Salston Stream to Confluence with River Otter

In Salston Stream electrofishing was carried out solely in 1992 with good numbers of fry recorded. Several parr were also caught.

iii) **Reach H - Blackbrook to Confluence with River Otter**

At Hillside on Black Brook the fry catches were similar and in good numbers in 1983 and 1992; the two years when electrofishing was undertaken. No parr were captured at Hillside in 1983 with average catches reported in 1992.

iv) **Reach I - Colaton Raleigh stream to Confluence with River Otter**

In Colaton Raleigh stream, only Pophams Farm was fished for two years and the data indicates a similar density of fish in 1983 and 1992. The parr catches were low in both years at this site.

v) **Reach J - Kersbrook Stream to Confluence with River Otter.**

There appear to be no electrofishing data available for this tributary.

(d) **Other Species**

The SWWA survey of September and November 1978 discusses other species including eels, dace, roach, loach and bullheads. These data, and those presented by Alabaster, do not lend themselves to trend analysis.

3.5.4 River Otter compared to the River Axe

Salmon catches in the River Axe (Figure 3.5.1) show a long term decline. This decline is not apparent in the River Otter, as there are insufficient data, but it should be noted that the river is not considered to be a salmon river.

Sea trout catches in the River Otter and the River Axe are very similar (Figure 3.5.1). This suggests that the factors affecting sea trout populations in the River Otter are not localised and therefore not caused by man on a local basis.

3.6 SEDIMENTATION

3.6.1 Overview and Available Data

The NRA has provided information on the level of suspended solids as discussed in the section relating to water quality. These data consist of spot samples taken on an irregular basis.

3.6.2 The River Otter

It is not possible to meaningfully assess the loads of suspended solids in the River Otter using the available data. It would be possible to make an unsubstantiated estimate of the inputs from the various discharges; however, these could not be related to the inputs from the catchment.

An examination of the suspended solids data over the period of study shows great variability in suspended sediment concentration in the river water. In general there are no trends with the exception of Hoemoor Farm which shows a long term decline in suspended solid concentration.

3.7 EUTROPHICATION

3.7.1 Overview

The extent of eutrophication in running waters can be gauged against a set of criteria drawn up by the NRA[1]. The criteria are based on various factors such as phosphorous content, plant growth and dissolved oxygen content. Nitrate is not considered to be a criteria against which the severity of eutrophication should be assessed. However, eutrophication is not entirely dependent on water chemistry in lowland rivers where nutrients are rarely limiting; rather the hydrology of the river must be taken into account.

3.7.2 Data Quality

The data discussed in this section are the same data as discussed in Section 3.2 above.

3.7.3 Eutrophication in the River Otter

The criteria discussed below are not absolute and a judgement on the seriousness and implications of eutrophication will be based on local conditions and knowledge.

(a) Nitrate and Phosphorous

Phosphorous is considered to be a contributing cause of eutrophication if the annual average orthophosphate concentration is over 100 μg/l with peak values well in excess of this concentration. This value is exceeded in all years as an annual mean at all stations below and including Cottarson Farm (Fig 3.2.6). The range of annual mean values at Cottarson Farm is between 0.34 mg/l in 1992 and 0.57 mg/l in 1986. The stations above Cottarson Farm (Clapperlane Bridge, Monkton, Rawridge and Hoemoor Farm) are characterised by concentrations of approximately 0.1 mg/l or less. For Clapperlane Bridge the annual mean concentration is below 0.1 mg/l in 1977, 1990, 1992 and 1993 with concentrations of 0.09, 0.09, 0.09 and 0.08 mg/l respectively. At Monkton only the 1986 mean was greater than 0.1 mg/l. At Rawridge the concentration was always less than 0.1 mg/l and ranged between 0.06 mg/l and 0.09 mg/l. At Hoemoor Farm the standard of 0.1 mg/l was exceeded in 1974 (0.11 mg/l) 1978 (0.13 mg/l), 1980 (0.11 mg/l) and 1981 (0.11 mg/l). The remaining years ranged between 0.05 mg/l in 1987 and 0.1 mg/l in 1976.

The trends in orthophosphate concentration have been discussed elsewhere (Section 3.2). At stations below and including Weston the general trend is for an increase in orthophosphate concentration at all sites between 1973 and the present day. At stations above Weston the trend, if present, is a decline in orthophosphate concentration.

In terms of orthophosphate the River Otter can be considered to be suffering from eutrophication below Cottarson Farm. The long term trend suggests that this situation is currently worsening.

At Clapperlane Bridge and above, the river can be considered to be at risk of eutrophication. However, the long term trend suggests that this situation may be

[1] NRA. River Exe Water Resources Scheme. Assessment of potential impact of new and increased abstractions on water quality in the River Exe Catchment and Estuary. June 1992. 2nd Edition.

improving with orthophosphate concentration declining.

Nitrate is not considered to be a criteria against which the severity of eutrophication should be assessed, see above.

The dissolved oxygen saturation over a twenty four hour period is used to assess plant activity. Supersaturation (150%) and reduced night-time saturation is an indication of eutrophication. The variation in dissolved oxygen indicates variations of this order (Figure 3.2.4). The long term trends in oxygen concentration noted in Section 3.2 at stations below Ottery St Mary may not be directly related to eutrophication and associated plant growth.

Other criteria, such as algal biomass, water retention time and effects on fauna, macroflora and microflora, are used to assess eutrophication. These factors either have not been assessed due to lack of data (algal biomass, water retention time, microflora) or do not indicate changes due to eutrophication (fauna and macroflora).

3.8 DRAINAGE PATTERNS

3.8.1 Overview

Designated Sites of Special Scientific Interest (SSSIs) are included in Appendix J. Large parts of the Otter Catchment are designated as an Area of Outstanding Natural Beauty (AONB) and Areas of Great Landscape Value (AGLV) (Figure 2.7.1). In both types of area development is carefully controlled. The land is predominantly used for agricultural purposes: most of this is accounted for by dairy farming but some intensive pig and poultry units are found in the north of the catchment. Percentage urbanisation is less than 5% of land area; this is mainly attributable to Budleigh Salterton, Ottery St Mary and Honiton[1].

3.8.2 Data Sources

The following reports were used to assess changes in drainage patterns:

a) MRM. The Otter Valley Catchment Study. Volume 1 - Executive Report. Draft Final Report (August 1989).

b) Lawrence Gould Consultants Ltd. River Otter Catchment Study. Agricultural Component - Stage One (October 1987).

c) Phase I Habitat Survey, NRA 1983.

d) Aerial Photographic Survey, NRA 1992.

3.8.3 River Otter

Lawrence Gould assessed agricultural practice in the catchment between 1940 and 1985. A number of trends were identified. Changes in permanent pasture included a decline from 68% of total land use in 1940 to 58% in 1985. Cereals and fallow were 14% of the total in 1940 becoming 18% in 1985. The percentage area as leys increased from 3% in 1940 to 16% in 1985 (Appendix I).

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[1] MRM. The Otter Valley Catchment Study. Volume 1 - Executive Report. Draft Final Report (August 1989).

The grazing livestock units increased by 75%; these comprise mainly dairy stock but also contain a small proportion of sheep. The numbers of pig and poultry units have declined since 1940 but the size of the remaining units has increased. The number of poultry units reached a peak in the 1970s. Pig production, however, has shown a continuous increase since the 1940s. Lawrence Gould notes that a number of large pig and poultry units are in the region. Lawrence Gould further notes that the exact locations of these intensive units is unknown but notes that "the main pollution problem in the River Otter catchment is in the same locality".

Lawrence Gould makes a number of predictions:-

a) The number of part-time farmers will continue to grow.

b) Livestock farmers will diversify away from agriculture.

c) Poor quality agricultural land may be planted with forestry.

d) Cereals will decline, livestock farming will become more extensive and potato cropping will increase.

e) It is considered by Lawrence Gould that there will be a decline in overall application of inorganic nitrogen fertiliser.

In summary the changes in land usage will consist of a move away from arable to livestock farming.

Additional information held by the NRA that could be used to identify changes that have taken place in the catchment include the Phase I Habitat Survey (1983) and the Aerial Photographic Survey (1992). To be able to assess changes that have taken place in the catchment would require a comparison of the two surveys. To be able to utilise the aerial photographic survey would require a considerable amount of effort outside the remit of the present study.

3.9 SUMMARY OF CHANGE

3.9.1 Overview

An attempt has been made to summarise chronological change in the form of a single table (Table 3.10.1). This table summarises input from sections on water quality, aquatic biology and hydrology. The data have been presented in such a way as to highlight years in which decline in water quality has taken place since the previous year and therefore do not indicate continuing poor quality in successive years. This has been achieved by highlighting parameters that have worsened by 10% or more from the previous year (nitrate, orthophosphate) or a change in NWC class for each of DO, BOD, ammonia and suspended solids. A subjective assessment of a year being a 'Poor' year was made if three of the above parameters had worsened from the previous year. ASPT data have been included to act as substantiating evidence for any observed change. In addition, abstraction data on a reach by reach basis have been included. These data have been summarised from all of the licences in the River Otter. It should be noted that these data do not take into account any recharge to the catchment and will therefore be an over-estimate of the impact of abstraction.

3.9.2 Annual Analysis

a) 1980

1980 is considered to be a poor year at all of the locations with an extensive data series, excepting Tipton St John and Dotton Mill. This poor year extends down the whole river. This year is not reflected by high abstraction, compared to previous years in any of the reaches. Annual mean flows in 1980 have shown a slight decline from the previous three years but is not exceptionally low (Figure 3.1.12). Summer model flow are high in 1980 (Figure 3.1.33).

In terms of water quality the indications of the poor year are typically due to DO, BOD, ammonia and suspended solids. The biological scores shown by the ASPT are lower at the upper stations (Weston and Ottery St Mary) compared to the late 80s and the 90s. ASPTs further down the river do not show low values in 1980.

b) 1982

1982 is considered a poor year at Clapperlane Bridge and Dotton. Abstraction does not show a pronounced change in 1982 in any of the reaches. Annual flows in 1982 at Dotton are above the study period mean (Figure 3.1.12), summer model flows are relatively high (Figure 3.1.33).

The water quality is considered poor primarily due to DO, BOD and ammonia and to a lesser extent nitrate and suspended solids. There are no ASPT data available for 1982.

c) 1985

1985 was a poor year at Ottery St Mary. Abstraction does not show a pronounced change in 1985 on any of the Reaches. Annual flow at Fenny Bridges in 1985 was low, but by no means the lowest (Figure 3.1.13). Summer model flow was not unusually low (Figure 3.1.37).

The poor year was indicated by orthophosphate, BOD and ammonia valves. Abstraction shows a general increase in this reach from 1984.

d) 1986

1986 is considered a poor year at Otterton due to increases in BOD, total ammonia and suspended solids compared to the previous year. Abstraction does not show any change in this reach compared to the previous year.

3.9.3 Trend Analysis

a) Nitrate

Nitrate levels have shown a significant increase at all locations (Table 3.2.3). This trend is expected to continue in the short term. In the longer term the expected decline in nitrate fertilizer application may eventually lead to a fall in nitrate concentrations. Concern is expressed over the continuing nutrient enrichment of the river.

b) **Orthophosphate**

Orthophosphate levels have decreased at the upper stations (Hoemoor Farm and Clapperlane Bridge). (Table 3.2.3). Levels have increased significantly at all the remaining stations with Weston being the most upstream of these. Honiton STW discharges upstream of Weston. Concern is expressed over the continuing nutrient enrichment of the River Otter.

c) **Dissolved Oxygen**

Dissolved oxygen concentrations either increased (Hoemoor Farm) or showed no trend (Clapperlane Bridge) at the upper stations on the River Otter. At all of the remaining stations dissolved oxygen has shown a significant decline. This decline is first shown at Weston, which is located below Honiton STW.

d) **Biochemical Oxygen Demand.**

No significant trend was found for this parameter. However, BOD is an important factor in determining the NWC River Classification and has been responsible for low scores throughout the river particularly in the early 1980s.

e) **Total Ammonia**

Total ammonia concentrations decreased at the upper two stations with no confirmed trend at the remaining stations. Possible trends include an increase at all stations except Otterton where the possible trend is a decline. Ammonia is used to calculate the NWC River Classification; however the instances of low scores in the early and mid 1980s are not due to this parameter.

f) **Suspended Solids**

A long term decrease in this parameter was confirmed at Hoemoor Farm in the early and mid 1980s. Moving down the River Otter the various stations show increases or declines in this parameter but these are not significant. This parameter is used in the calculation of the NWC River Classification which has shown short term trends. High suspended solids values were in part responsible for the low scores in both the early and late 1980s throughout the whole river.

g) **Temperature**

A confirmed decline in temperature was observed at Dotton Mill. A possible decline in temperature was observed at all of the other stations.

h) **pH**

An increase in pH was observed at the upper stations (Hoemoor Farm and Clapperlane Bridge). At all of the remaining stations a possible trend showing an increase in pH was observed.

i) **ASPT**

The ASPT data are discontinuous and it is therefore not possible to undertake a meaningful trend analysis for the 20 years of the study period. However it is possible to make a number of observations on differences between reaches in any particular year.

Reach B is characterised by ASPT scores indicating good water quality through the whole study period. In Reach C, below Honiton sewage treatment works, the ASPT scores are variable, with occasional low scores when compared to Reach B. This variability is more pronounced in the lower part of Reach C with a particularly low score in 1983. There is an indication of improvement in 1990. Reach D shows a similar pattern, with a low score in 1983 and an improvement in 1990. In Reach E at Tipton St John the ASPTs were generally indicative of good water quality in the 1960s and 1970s, but a low score was obtained in 1983 and no improvement in 1990 was observed. Finally, at Otterton the ASPT is generally not indicative of either good or poor water quality, with the exception of the 1983 ASPT score which is indicative of good water quality.

j) **Abstraction**

The annual abstraction data have been summarised on a reach by reach basis and as previously noted are an over-estimate of the effect of abstraction since no allowance is made for recharge to the River Otter. Abstraction in the whole catchment peaked in 1977, declined until 1980 and then gradually increased to the 1992 value. In several reaches the following trends can be seen.

Reach A - Abstraction was variable being at a minimum in 1977 and a maximum in 1976. Abstraction volume was 1475 megalitres in 1976 and 4 megalitres in 1977. This minimum has been followed by an irregular increase to 1989 of 857 megalitres followed by a slight decline to 1992.

Reach B - A gradual increase in abstraction from approximately 260 megalitres in 1974 to 305 megalitres in 1991.

Reach C - Abstraction has remained constant at approximately 70 megalitres.

Reach D - Abstraction has gradually increased from 1372 megalitres in 1972 to 3285 megalitres in 1991.

Reach E - Abstraction has been variable throughout this study period being 2744 megalitres in 1972 to 1624 megalitres in 1992.

Reach F - Abstraction has increased in an irregular fashion from 3535 megalitres in 1974 to 4764 megalitres in 1992.

k) **Flow**

Both mean and low flows in the River Otter were lower in the 1980's and 90's than in the 1970's. It should be noted that this phenomenon was not unique to the River Otter.

l) Rainfall

Rainfall was significantly less in 1983-92 compared to 1973-82.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 HYDROLOGY

4.1.1 Conclusions

There are significant amounts of hydrological data available for the Otter, including rainfall, river flows, spot gaugings, and ground water levels, as indicated in Appendix D. It has only been possible to consider a limited volume of this within the time constraints of the study.

a) Rainfall

i) Rainfall at the Dotton raingauge was significantly less in the decade 1983-92 than in the decade 1973-82. Rainfall in both periods was less than the 1941-70 long term mean.

ii) Rainfall at the selected Otter catchment raingauges is homogeneous with rainfall from Axe catchment raingauges.

b) River Flows

i) Both mean and low flows in the River Otter were lower in the 1980s and 1990s than in the 1970s. However, the comparison with rainfall records in the Otter catchment and flows in the River Axe suggests that this phenomenon was not unique to the River Otter and is likely to be related primarily to climatological effects.

ii) The variation in both annual and summer mean flows has been less in the last ten years than in the previous ten for both the Otter and Axe catchments.

iii) River flows in the Otter at Dotton and Fenny Bridges are not homogeneous with rainfall or Axe flows. The Dotton records reveals a significant (at the 2.5% level) change in gauged flows occurred around 1984/5.

c) River levels and Velocities

i) These appear to have been lower in the last 10 years in line with river flows.

ii) Water levels for a given flow have varied by more than 30% from year to year in the past.

d) Ground water levels

i) Ground water levels since the early to mid 1980s are generally slightly lower than those prior to this period. This is shown by the hydrographs at Heathlands, Berry House, and Wiggaton No 4.

ii) Both average and minimum annual ground water levels between 1984 and 1992 at Heathlands are the lowest since 1953.

iii) The scale and pattern of recharge and recession at Heathlands is very similar to that at the Haywain in the Culm catchment.

iv) Maximum ground water levels at Wiggaton No 4 and Berry House do not appear to be explained by the aquifer recharge estimates alone, as derived from the recharge model.

v) Calibration of the Otter Valley ground water model was difficult to achieve.

e) Abstractions and Discharges

i) The total annual volume of water licensed for consumptive abstraction for the whole catchment rose by 23% between 1973 and 1992, from 13,286Ml to 16,361Ml.

ii) 94% of the licensed volume for consumptive abstraction in 1992 was for intended public water supply.

iii) Actual abstractions in the Otter catchment are estimated to have increased by 25% between 1972 and 1992, from 8,140Ml to 10,130Ml.

iv) 90% of the volume abstracted is taken from ground water.

v) The annual volume of water abstracted is equivalent to around 10% of the average volume of water that discharges from the Otter to the sea in a year.

vi) The bulk of the water abstracted is taken from reaches D, E, and F, downstream of Fenny Bridges.

vii) The uptake of licences above Dotton has increased from 54% in 1973 (and 53% in 1982) to 78% in 1992.

viii) Actual discharge data for the Otter catchment were not available. Discharge consent data were unreliable.

4.1.2 Recommendations

a) Rainfall

i) Further analysis of available rainfall data should be undertaken. In particular, catchment averaged daily (or weekly, if insufficient data are available) rainfall should be derived as far back as rainfall records reasonably allow for both the Otter and the Axe catchments (see recommendation b)v), below).

ii) Catchment averaged rainfall data should be used to investigate historical cumulative rainfall deficit events. An analysis of the frequency of these events should be carried out.

iii) Similarly, frequency analysis of rainfall totals for various different durations ranging from one month to 60 months should be performed. These analyses should be carried out for both fixed and floating starting dates, particularly for durations less than 36 months. The results from such an exercise would show whether climatic conditions over the Otter catchment have been unusual in recent years.

b) **River Flows**

i) The flow records of ground water support gauging stations should be analysed for evidence of any changes to help in identifying impacts within the catchment. If changes are identified, the cause of these should be investigated, and their influence on flows in the main river identified.

ii) Further analyses should be undertaken in order to understand the nature of seasonal variability of runoff in the Otter catchment. These studies should be complemented by similar analyses of rainfall and recharge. In particular, the frequency of low flows of different durations should be investigated over at least the full period of record, and be compared to similar plots from surrounding river flow gauges. If flow records are to be extended back using rainfall, evaporation, and a rainfall-runoff model, then the frequency analysis should include these data.

iii) The historical interaction of river flows and ground water along the river should be initially investigated through the use of river flow accretion curves, spot gaugings, and recorded river flows.

iv) The implied change in mean flows in the Otter at Dotton requires confirmation through comparisons with other flow records. Further analysis of the Otter flow record should then be focused to see whether the change can be attributed to the earlier (pre 1985) or later (post 1985) part of the record, and to a particular range of flows (eg floods, low flows, or a general reduction in all flows). This analysis should be performed both at Dotton and at Fenny Bridges. Once the results from these analyses are available, the need for catchment modelling can be more clearly defined in order to investigate the causes of the change. It is recommended that these analyses should be undertaken before moving on to investigate any possible effects due to artificial influences using catchment modelling techniques.

v) A much longer period of analysis is required to set the annual rainfall and runoff totals in perspective. It is important to consider the inherent variability of climatic and hydrological phenomena in a long term context.

- The extension of rainfall records could be achieved by calibration with other longer term raingauges in the region. Appropriate raingauges should be carefully selected to achieve this.

- Evaporation records could be estimated from temperature records using empirical relationships. Alternatively, a standard monthly evaporation profile based on existing data could be assumed, with a sensitivity analysis carried out on the evaporation profile to investigate the validity of the assumption.

- Flow records could then be extended back using these derived rainfall and evaporation records and a calibrated rainfall-runoff model. Calibration of the rainfall-runoff model should be undertaken either using naturalised flow data (see recommendation b)vii), below), or using part of the flow record during which the volume of water possibly abstracted could not be expected to significantly influence low flows: for example when the average daily abstraction rate during the summer months in any part of the catchment was less than 5% of the Q95 flow in the river at that point in the catchment. The optimisation function for model calibration should be on low flows rather than mean or peak flows.

vi) The cause of the increase in catchment losses between Fenny Bridges and Dotton should be investigated. This should be considered in stage two with the help of a catchment ground water-surface water interaction model.

vii) Abstractions are licensed from both the Rivers Otter and Axe. In order to achieve a fair comparison between them, and also to allow model calibration, both river flow records should be naturalised as far as possible. This will assist in determining which effects are due to catchment processes and which are due to artificial influences, such as abstractions and discharges. Basic annual abstraction data for the River Otter are available in Appendix F for the 21 years from 1972 to 1992. Monthly abstraction data from the main production boreholes are available in the MRM Consultants report (Volume 2, Resource Modelling) from the early 1970s up to 1988.

viii) As part of the above exercise (b)vii)) residual flow diagrams should be produced for two weeks in recent years. The diagrams will show how much water in the river is derived from natural inflows, and how much is derived from the nett effect of abstractions and discharges, in any one reach on that particular week. Both diagrams should be based on a week in which base flows are predominant throughout the catchment. There should not have been any significant rainfall for *at least* four or five weeks before the selected periods of analysis. One of the diagrams should cover a period when abstractions were operating under normal licence conditions. The other diagram should be set in a period when the majority of licences tied to prescribed flows or water levels were restricted by these conditions. Reaches identified on the residual flow diagrams should be taken from the Micro Low Flows system and coordinate with the reaches defined in this study, as far as possible. Natural inflows to each reach can then be estimated from the 'natural' Q95 flows provided in Micro Low Flows. If insufficient abstraction and discharge data are available to accomplish this exercise then consideration should be given to collecting such information in the summer of 1994 (see recommendation d)v), below).

c) **River Levels and Velocities**

i) Original data collected during spot gauging exercises, undertaken both by the NRA (and South West Water Authority) and MRM Consultants, should be analysed to investigate the variability of water levels and velocities, and channel geometry, through time at locations along the river for various flows.

ii) The cause of any significant changes in river levels and velocities, not directly attributable to a change in flows, and any significant changes in channel geometry, should be investigated. This would include looking at changes in field drainage practices, and land drainage patterns, through time, as well as changes in land use, and any available documentary evidence including photographs, reports, books, and river corridor surveys.

iii) The need for any further studies, including field surveying, should be reviewed in the light of the findings of c)i).

d) Ground Water Levels

i) The sites identified as 'control' sites in Appendix E require reviewing. This should include an assessment of whether the present monitoring network provides adequate coverage for model calibration. Results from past model runs should be used to help identify areas where further data are required.

ii) The results from the aquifer recharge model should be reviewed and analysed. They should then be used as a first stage assessment of whether 'control' sites appear to be affected by ground water pumping. The possibility of regional aquifer drawdown through the long term effects of pumping should not be overlooked during this process.

iii) The calibration of the Otter Valley ground water model should be reviewed:

- The assumption of regional homogeneity and isotropy in the aquifer should be tested. Variations in regional porosity/storativity suggested by differences in the annual fluctuation of water levels at different sites (eg 0.2m at Wiggaton No 4, and more than 3m at Higher Pitt Cottage, see Appendix E) suggest that the aquifer is far from homogeneous or isotropic.

- Transmissivities were assumed constant during the transient runs. This assumption is clearly in error, for example, at the Alfington No 1 borehole featured in Figure 3.1.40, where the saturated depth of the aquifer has not reached steady state after 20 years. The sensitivity of this assumption should therefore be tested.

- The model was based on a 250m x 250m square grid. This grid size is probably too coarse to adequately describe the interaction between a number of pumping boreholes in close proximity to each other and/or the river. Consideration should therefore be given to refining the grid size to, for example, a 50m, or even 20m, spacing along the river corridor to include the Greatwell, Harpford, Dotton, Colaton Raleigh, and Otterton groups of boreholes.

e) Abstractions and Discharges

i) The availability of actual abstraction data back to the late 1960s should be investigated in order to allow naturalisation of gauged river flows (see recommendation b)vii), above). Where data are poor, other methods of estimating actual abstractions should be considered, such as estimating demand for water supply from population and town development data.

ii) The availability of information on discharges to the River Otter through time should be investigated. Unfortunately, data on discharges to the Otter are not kept by the NRA. Further investigative work should be carried out in order to gain an understanding of how much water has been discharged into the Otter through time. The most hopeful source of information is likely to be South West Water Services Ltd.

iii) An alternative, but less reliable, method of estimating nett abstractions from the catchment involves assessing the operation of the water distribution system (supply) and the water reticulation system (sewage collecting) through time. This should be considered, especially if d)ii) proves to yield few data, and would provide an independent check on the abstraction/discharge water balance.

iv) The extent to which other abstracted water is genuinely used consumptively should be investigated, although it is recognised that this might be difficult to accomplish.

v) Full monitoring of the major abstractions and river flows in reaches A, D, E, and F should be undertaken in order to ensure that any adverse effects are picked up and reliable data are collected for future modelling purposes. In addition, consideration should be given to quantitatively monitoring all major discharges to the Otter, or requesting the dischargers to do so.

vi) The availability of abstraction data on the River Axe has not been investigated as part of this study. The effects of artificial influences on characteristics of the Axe catchment should be more thoroughly investigated before comparisons between the two catchments can be relied upon (see recommendation b)vii), above).

vii) The use of a calibrated catchment ground water/river flow interaction model should be considered to investigate the effects of ground water abstractions in reaches D, E, and F on river flows (see recommendation d)iii), above).

4.2 WATER QUALITY

4.2.1 Conclusions

a) Water quality assessment is confined to monitoring sites where a twenty year record is available.

b) BOD atu values are absent prior to 1977 when BOD was recorded as BOD non-atu.

c) Numbers of samples per annum are low prior to 1983 except at Dotton Mill (Reach E).

d) No historical water quality data were available for Reach A although this reach is now being monitored.

e) Within Reach B, DO levels, pH values and nitrate concentrations were found to have increased whilst ammonia, orthophosphate and suspended solids concentrations were found to have decreased. In all cases these trends were more pronounced at the upper end of the reach. No significant trends were found for temperature or BOD although temperature shows a possible long term decline and BOD exhibits a possible long term increase.

f) Within Reach C, DO levels were found to have decreased, whilst nitrate and orthophosphate concentrations had increased. Possible trends were found for temperature (decline), pH (increase), BOD (increase), ammonia (increase) and suspended solids (increase).

g) Within Reach D, DO levels were found to have decreased whilst nitrate and orthophosphate had increased. Possible trends were found for temperature (decline), pH (increase), BOD (increase), ammonia (decline) and suspended solids (increase).

h) Within Reach E, DO levels were found to have decreased whilst nitrate and orthophosphate had increased. Temperature was found to have decreased at the lower end of the Reach. Possible trends were found for pH (increase), BOD (increase), ammonia (increase) and suspended solids (varied).

i) Within Reach F, DO levels were found to have decreased whilst nitrate and orthophosphate concentrations had increased. No significant trends were found for temperature (decline), pH (increase), BOD (decline), ammonia (decline) and suspended solids (decline).

j) Whilst some deterioration in water quality was apparent between the upper and lower ends of Reach B, particularly during the 1980s, the most marked change in quality was found to occur between Reach B and Reach C.

k) No specific trends for water quality in terms of NWC classification were found. There is an indication however that water quality in Reaches D - F may have been generally poorer in the early and late 1980s due to BOD and suspended solids respectively.

4.2.1 Recommendations

a) Historical Changes

Several trends and changes have been identified in the water quality parameters. A number of these trends and changes are historical. These historical changes include:-

- Low NWC River Classifications in Reaches D - F between 1980 - 1982 and 1986 - 1988 due to high values of BOD and suspended solids, and to suspended solids respectively from Weston to Otterton.

- Particularly low pH levels in 1980 and 1982 at both Hoemoor Farm and Clapperlane Bridge.

- An unusual year at Weston in 1981 characterised by low BOD, low ammonia and high DO. (Occasional high BOD values contributed to the low NWC River Classification for that year).

- Low DO levels in 1980 and 1991 at Ottery St Mary.

- A steep increase in nitrate levels until 1982 at Ottery St Mary.

- Low mean oxygen levels in 1982 and 1988 at Tipton St John.

- Low mean oxygen levels in 1982 and 1988 at Dotton.

- High mean concentration of both BOD and ammonia in 1980 and 1986 at Otterton.

Examination of water quality discharge data from South West Water Services Ltd and other sources may, but are unlikely to identify possible causes of these historical events. Consideration should be given to examining the availability and quality of historical discharge data.

b) Present Day Trends and Changes

With respect to those trends shown to be confirmed (Tables 3.2.3 and 3.2.4), it is recommended that the present water quality monitoring programme be continued. The water quality monitoring programme should be complemented by discharge data provided by South West Water Services Ltd. The data gathered can then be used to monitor changes in these trends as a result of any management strategies employed in the future.

Specific recommendations for water quality data gathering activities to confirm possible trends include the following:-

- The possible impact of Honiton STW on the River Otter should be addressed by the installation of a continuous water quality monitor downstream from the works. The data gathered should be correlated with flow and volume data so that dilution effects can be taken into account.

- The impact of suspended sediment on NWC Classification is suspected, particularly in the early and late 1980s. The present monitoring of suspended solids has not allowed the isolation of the reasons for recent improvements in suspended solid extremes. As part of the sedimentation recommendations below, continuous sediment loggers should be installed at Hoemoor, at the location of the continuous water quality monitor downstream of Honiton STW and in addition at Otterton.

- A short term expanded water quality monitoring programme should be undertaken to examine the input of determinands and particularly nutrients from the many tributaries to the River Otter.

c) Further Data Analysis

Further data analysis should be undertaken on the water quality data presented in this report to isolate the effect of season on water quality.

4.3 AQUATIC INVERTEBRATE DATA

4.3.1 Summary

a) Within Reach B no marked fluctuations in ASPT occurred at Hoemoor Farm except for a deterioration in 1977 and 1980.

b) Within Reach B at Monkton the ASPT fluctuates but generally indicates a good quality water course.

c) Within Reach B at Clapperlane Bridge the ASPT fluctuates but generally indicates a good quality water course.

d) Within Reach C at Fenny Bridges the ASPT was low in 1983. Stations upstream of Fenny Bridges typically have an ASPT of 6.0 and above.

e) Within Reach D at Ottery St Mary the ASPT was low in 1983.

f) Reach E at Tipton St John had a low ASPT in 1983. The 1990 ASPT indicates pollution.

g) In Reach E at Dotton Mill had a slight fall in ASPT for 1983.

h) In Reach F at Otterton the ASPT may be unreliable, with a relatively high score in 1983.

The apparent increase in BMWP score over the last 24 years probably reflects an improvement and greater consistency of sampling technique and effort and has therefore been ignored.

4.3.2 Recommendations

The limitations of the data have been discussed. It is recommended that reliable and useful data for the analysis of changes in invertebrate ecology be gathered. It is recommended therefore to continue improving the quality of the invertebrate monitoring and to undertake surveys on an annual basis. In addition, the use of RIVPACS to access the expected biological quality of the River should be undertaken

4.4 AQUATIC PLANT DATA

4.4.1 Summary

The macrophyte data available for 1991 and 1992 does not appear to provide any consistent patterns from which to deduce changes in the aquatic environment of the River Otter over this short period. Previous macrophyte records are very limited, and not detailed enough to enable monitoring of changes in the aquatic macrophyte populations over time.

4.4.2 Recommendations

Quantitative methods should be employed to assess charges in plant ecology using the methodology described in Section 3.4.1 above. These surveys should be undertaken on an annual basis.

4.5 FISHERIES

4.5.1 Conclusions

Salmon have returned to the River Otter below Otterton Weir. Sea Trout catches below Otterton Weir show no trend. Electrofishing results suggest that parr catches of brown trout are improving when 1992 is compared to 1986. Wild trout rod catches at Honiton suggest an improvement in latter years; however these data are unsupported by effort data.

4.5.2 Recommendations

A continued electrofishing programme on a yearly basis should be undertaken. This programme would provide a means of monitoring improvements in the river system in terms of both physical and chemical characteristics.

4.6 SEDIMENTATION

4.6.1 Conclusions

Insufficient data are available to enable a useful analysis of sedimentation to be undertaken.

4.6.2 Recommendations

Continuous suspended sediment data loggers should be installed at strategic locations on the River Otter to enable the problem of sedimentation to be addressed as discussed in Section 4.2.1 b) above. This has the added benefit of addressing concerns over the possible impact of high suspended solid concentrations on NWC River Classification scores. In addition, a further understanding of sedimentation and erosion should be achieved by a comprehensive river corrider surveys.

4.7 EUTROPHICATION

4.7.1 Conclusions

Orthophosphate levels are high enough at all stations below Cottarson Farm to consider that the River Otter is in a state of eutrophication. DO also indicates that the River Otter can be considered to be in a state of eutrophication.

4.7.2 Recommendations

Eutrophication effects are difficult to quantify in flowing water. The NRA South West has been investigating the relationship between benthic diatom growth and eutrophication. This approach should be encouraged.

4.8 DRAINAGE PATTERNS

4.8.1 Conclusions

The available information suggests that farming activity will change from arable to livestock farming. Associated with this change the incidence of pollution incidents can be expected to rise. The levels of nitrate used as fertiliser are expected to decline thereby reducing the nitrate levels in the River Otter.

4.8.2 Recommendations

A second land use survey would provide additional information on trends in land use. This is of relevance when nutrients are considered. Given the concern expressed over orthophosphate levels in the River Otter, a fuller understanding of the distribution of intensive livestock facilities would be extremely relevant.

In addition the 1992 aerial photographic survey should be fully interpreted and compared to the Phase I Habitat Survey of 1983.

Additional data, held by the Ministry of Agriculture Fisheries and Food, concerning farming practices should be analysed to assess the charges in drainage patterns over the past two decades.

4.9 CHANGES

The hydrological analysis has identified a number of changes as noted in the above sections. In addition, many of the other factors considered in detail have also identified changes. Many of these changes have been brought together in the form of a summary table. This table has identified the following years as being of particular concern in various reaches; 1980, 1982, 1985 and 1986. These years of concern have been identified primarily on the basis of water quality information supported by information on abstraction, river flow and invertebrate biology. Of the identified years, 1980 is poor in many of the reaches, 1982 is poor at two locations and 1985 and 1986 at single locations.

A number of trends have also been identifed, some of which give cause for concern. Nitrate levels show an increase in all reaches, phosphate levels increased in lower reaches, dissolved oxygen has decreased in lower reaches. None of the other determinands show a confirmed trend and include; biological oxygen demand, total ammonia, suspended solids, temperature and pH.

Biological data are considered unreliable for the most part. Trend analysis has therefore proved unreliable. There appear to be no long term trends that can be identified.

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