ENVIRONMENT AGENCY
North East Region

SECOND INTERIM REPORT ON THE ENVIRONMENTAL IMPACTS OF THE DROUGHT ON YORKSHIRE'S RIVERS 1995-1996

December 1997

Frontispiece

The Drought in Yorkshire

River Wharfe in Langstrothdale, summer 1996

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EXECUTIVE SUMMARY

This second interim report summarises the results available from the environmental actions carried out by the Environment Agency and Yorkshire Water Services (YWS) to monitor and reduce the impact on rivers of the severe drought experienced in Yorkshire during 1995 and 1996. It is confined to those rivers affected by Drought Orders/Permits and Time Limited Licences (TLLs) granted to YWS, namely the Aire, Calder, Don, Hull, Ouse, Ure and Wharfe.

The report largely draws from surveys and other work in the period on hydrology, water quality, river habitats, macrophytes, macro-invertebrates and fish populations. The studies are at various stages of evaluation and comprehensive monitoring of the effects of the drought and the TLLs, taking place over three years, finishes in 1998. A Final Report *with full interpretation of results* will be completed after this process.

Yorkshire's rivers experienced extremely low flows during the latter half of 1995 and in 1996 as a result of below average rainfall and many were below their critical (or prescribed) flows for considerable periods. Flows patterns differed between the flashy Pennine rivers (that are dependent on summer rainfall to maintain flows) and the groundwater-influenced Rivers Derwent and Hull in the east. Although the drought was considered to be over by the end of 1996 in the west of Yorskhire due to sufficient autumnal rain, groundwater reserves in the eastern Chalk area continued to decline, reducing flows in the Rivers Hull and Derwent.This situation persisted into 1997. However, reservoir stocks were generally much better in 1996 than 1995.

The predictable physico-chemical effects of these low flows have been localised water quality changes, reduction in water velocities and wetted widths, obstruction of feeder streams, exposure and drying of gravel spawning areas and increased siltation. Although interpretation is complicated by widespread and often intense manmade influences, including pesticide impact, habitat modification and riparian use (such as cattle grazing), it is clear that the natural drought has had an impact on aquatic ecology in Yorkshire, without influences from discrete waste effluents, reductions in compensation releases, or increased abstraction. Some of these effects have been detrimental, but what may be perceived as beneficial impacts have been observed in the good quality rivers, with increases in macroinvertebrate diversity and breeding success of many coarse fish species. This runs counter to the common perception that droughts or artificially imposed low flows lead to ecological harm.

Overall, most of Yorkshire's rivers have not suffered any *acute* water quality effects during the drought, although measures were taken to protect fisheries when necessary. Artificial aeration of rivers during periods of critical low dissolved oxygen levels was required on the Calder catchment and elsewhere but may be relatively ineffective. Unsurprisingly, deteriorations in water quality were observed in some stretches in all of the river catchments, but particularly in the Calder, Don and the Ouse downstream of York. Elevated levels of ammonia and/or biochemical oxygen demand were often accompanied by lower concentrations of dissolved oxygen (usually for short periods) even in some of the good quality rivers such as the Ure and Wharfe. These effects were probably due to lack of dilution of treated sewage (and other) effluents during extreme low flows, although improvements in other stretches may have been caused by the lower frequency of storm sewer overflow events and enhanced performance at some YWS sewage treatment works (STWs). Increases in pH and nutrients (phosphates and nitrates) were also recorded coincidently with the drought period. Lack of runoff from acidic upland areas may have led to these higher pH levels.

Most of the reported water quality deteriorations for 1995 were not sustained in 1996, as some are now thought to have been caused by pollution events. In contrast, most of the improvements reported for 1995 were maintained in 1996 and a few reaches exhibiting ' no change' in 1995 improved in 1996. In the lower, poorer quality reaches of the Pennine rivers of the Ridings Area compensation flows make up a very small percentage of total flows and these reaches were not perceived to be at risk from drought. Preliminary analysis of the General Quality Assessment data for these river stretches suggests that quality did not deteriorate further during the drought. In the Don downstream of Blackburn Meadows STW, water quality improvements were recorded during the low-flow period and reflect the efforts of YWS to maintain and improve the efficiency of their operations. Many of their STWs, such as those on the Wharfe, have been performing better than the more stringent temporary consents placed on them by the Agency.

As in 1995 extensive algal films (diatoms) and growths of filamentous green algae (blanketweed) were reported from several rivers. These almost certainly benefited from the combination of higher light levels, slightly elevated nutrient levels and low water velocities, and they persisted into the autumn before breaking up due to rising river levels and spates. High numbers of blue-green algae occurred in the Wharfe during August-September 1996 but it did not originate in the river itself although low flows certainly aided their retention in the river and hence their detection. Higher plant growth in river margins was also prominent in lowland rivers such as the Ouse and proved to be a nuisance for anglers. It is not possible to say whether the drought has harmed flow-loving macrophytes such as water-crowfoot, partly as there is a deficiency in suitable long-term data.

Some changes in the macroinvertebrate faunas of the Wharfe and other clean spatey rivers were predictable responses to natural drought and low flows and reflect their inherently high variability. The most common response has been the higher numbers of many groups, including pollution sensitive cased and caseless caddis flies, and species favoured by slow flowing or ponded situations such as snails and water hoglice. This has also involved their migration, or colonisation, into reaches upstream of their 'normal' or regular range.

There is *no* evidence of a catastrophic decline of *any* aquatic species as a result of the drought although some flow-loving groups such as stoneflies have been much less abundant during the period. Further analysis of the macroinvertebrate data from the lowland River Hull and the compensation streams in the Ridings Area could yet show significant changes, as they may be less adapted to long periods of low flows and display less 'protective' variability. It can be confidently predicted that, providing drought does not continue year after year, recovery of normal patterns is assured and the potential local extinction of some species will be averted.

Reductions in compensation releases from reservoirs in the Calder and Aire (Worth) catchments also raised concern about impacts on downstream trout populations and fisheries surveys were carried out on behalf of YWS. The first *Interim Report* concluded that siltation of spawning gravels was potentially damaging but, although high suspended solids were observed, this would not appear to have had any significant effect on spawning success. The high numbers of 0+ fish found throughout the two catchments signify good recruitment. This could indicate an increased downstream migration of larger trout to the main rivers, as has been found on other rivers affected by the drought.

Elswhere, the quality of the compensation water itself has been questioned, notably the releases from Grimwith Reservoir down the River Dibb into the Wharfe. There is no evidence to suggest that there is any ecological impact from this particular release and the short stretch of the Wharfe down to Lobwood may actually benefit from the extra water. Nevertheless, the drought has highlighted anomalies in *some* of the compensation regimes operated by YWS in the Ridings Area, as they originated from obsolete industrial demands and are now inappropriate for protecting the environment.They are soon to be reviewed by YWS and the Agency.

Other possible drought impacts on the region's fisheries included some movement of flow-loving fish into remaining stretches of faster water (and some downstream displacement), counterbalanced by increased growth rates and fry survival of both trout and coarse fish. The latter, particularly in the Ure, Ouse and Wharfe, should support future angling with strong year-classes from 1995. Coarse fish typical of slow, lowland rivers such as roach and perch appear to have been favoured during the drought relative to those typical of fast flowing rivers such as dace and barbel. In spite of this, it was clear that angling was influenced by the hot, sunny weather, the condition of the rivers and possibly by changes in fish distribution during 1995 and 1996. Angling catches were variable, although lack of success was widely reported.

Two fish rescues, because of low flow conditions rather than poor water quality, have been carried out successfully on the Calder and other mitigation work has been dealt with. This included clearance of cobble and gravel bars at the mouth of feeder streams on the Wharfe that are important for salmonid spawning, and changes to the operations of the Lobwood intakes after trout and crayfish had been entrained on the screens.

Assessing whether increased abstraction, or reductions in compensation releases, have had ecological consequences is the essence of the current monitoring work being carried out by the Agency. Yet, in many cases, assigning terms such as ecological 'damage' is difficult without a thorough understanding of spatial and temporal variability, combined with better definition of ecosystem sensitivities and rates of change or recovery. As winter spates are probably significant controllers of ecological communities in the Pennine rivers, especially for macrophytes, algae and macroinvertebrates (with summer and autumn spates limiting coarse fish fry survival), a focus solely on low flows no longer seems appropriate. The return of wetter conditions in 1997 might therefore have drawn a line under the environmental drought responses.

Recommendations are made principally in the context of preparation of the final drought report, in which operational/management decisons will be made related to Drought Permits and TLLs, as well as the adequacy and future of monitoring programmes. Interim recommendations include the involvement of local Agency staff's expertise to produce detailed catchment reports and a greater effort to draw on ecological information held by other local environmental and naturalists groups. It is important that the Agency endeavours to carry out specialist tasks outlined in fisheries and biology reports to improve focus, methods and data interpretation.

1.0 CATCHMENT SUMMARIES

1.1 River Aire Catchment

During 1995 the Aire catchment had only 70% of the 1961-1990 Long Term Average (LTA) rainfall. The hot, dry summer meant that reservoir stocks were severely depleted when Drought Orders were put in place. The first half of 1996 remained dry, but storms in late summer and the more prolonged autumnal rain meant that 1996 had 88% of the LTA rainfall.

The Aire catchment has relatively few reservoirs compared with the Calder and Don systems. Most of these reservoirs were subject to Drought Orders in 1995 and 1996 that continued until February 1997, but the reduction of compensation flows in the River Worth sub catchment caused most concern because the Worth is an important fishery and spawning area and perceived to be at greater risk.

Overall, compensation flows were reduced by two thirds, but they were cut totally from Leeshaw Reservoir in November 1995 when it reached 3% of capacity and was virtually discharging mud. In mitigation, releases from Leeming Reservoir (itself at 10%) were increased so that, although there was a localised deleterious effect, there was no change on the Worth. Most of the reservoir stocks were much better in 1996 than 1995; rising steadily from 30% full at the beginning of the year and then fluctuating around 50% during the spring and summer. With the onset of wetter weather in the autumn, stocks increased to 86% by November.

Most of the enhanced water quality monitoring programme carried out by the Agency was concentrated on the Worth catchment and showed no reduction in quality in the headwaters. Leeshaw Beck, Leeming Beck and Morkin Beck all maintained chemical General Quality Assessment (GQA) grade B. However, quality in Bridgehouse Beck downstream of Oxenhope STW dropped from GQA grade B to grade C in 1995 and 1996. As Oxenhope STW effluent remained within its consent limits, this downgrade was thought to be a result of reduced dilution because of smaller compensation flows.

Water quality in the lower reaches of the River Aire, which was considered to be at risk of deterioration from lower dilution of effluents, is being maintained or improved. However, in the upper tributaries and upper reaches of the main river there has been a noticeable reduction in chemical quality. Many stretches have fallen from chemical GQA grades A or B to grade C. The lower grades are in most cases attributable to lower dissolved oxygen levels in the water. The reasons for this have not been established, but as these tributaries are not impounded and have not been subjected to compensation reductions, other factors such nutrient inputs or diffuse pollution magnified by the natural drought may be involved.

The Agency has carried out special macro-invertebrate surveys in the Aire catchment downstream of eight reduced reservoir compensation flows, ie at Lower Laithe, Leeshaw, Leeming, Eldwick, Weecher, Reva, Keighley Moor and Ponden reservoirs. Sampling started in Autumn 1995 and is continuing in the spring and autumn seasons. Routine sampling was extended to include certain sites in the upper reaches of the main river, and in the Worth catchment to investigate the effects of the low flows and reduced compensation releases. YWS undertook some of the invertebrate monitoring in 1995 and 1996. A full analysis, encompassing both Agency and YWS data, will be produced at the end of the three years monitoring. Preliminary analysis of Agency data shows very few significant biological quality changes during the 1995/96 period. At Providence Lane (River Worth) poorer quality was recorded during Autumn 1995 with a recovery seen in Spring 1996. All other sites sampled appeared to maintain quality from season to season.

YWS have undertaken River Habitat Surveys to monitor habitat changes along the river corridor. Results from these have been sent to the Institute of Freshwater Ecology for inclusion on the Agency's RHS database.

Fisheries surveys were carried out by consultants acting for YWS. The headwaters of the River Worth and Bridgehouse Beck support valuable brown trout populations. The fishery habitats provide excellent conditions for recruitment, and previous surveys indicate that the fish populations are highly productive. Downstream migration of larger trout provides a significant benefit to the lower River Worth and the main River Aire at Keighley. The latest fishery survey indicated that the biomass of trout at Haworth was significantly lower during 1996, but numbers of 0+ fish remained almost unchanged. This could indicate an increased downstream migration of larger trout to the main river, a pattern that has been found on many of the Region's other rivers affected by the drought.

1.2 River Calder Catchment

The Calder rises west of Todmorden on the Pennine Moors and flows 87 km to join the Aire at Castleford. There are no river abstractions for public supply on the Calder catchment, but many moorland streams at the head of the Calder Valley are uncontaminated and consequently have been heavily exploited for public water supply. There are thirty-nine reservoirs licensed for this purpose, and the area's needs are supplemented by imports from Winscar Reservoir, at the head of the Don catchment, and from the rivers of North Yorkshire.

The Pennine Reservoirs Drought Order was the first order to be applied for by YWS. The Order covered many reservoirs and involved proposals for reductions in the compensation releases for a range of tributaries of varying ecological importance. The likely impacts of the reductions were prioritised and initial cuts involved only those identified as likely to have a 'low-level' effect on the watercourse. However, as the effects of the drought worsened, reduced compensation releases from those reservoirs listed as likely to have a medium and high effect were of necessity included.

During 1995, the Calder catchment had only 79% of the long term average rainfall, with most before the end of March. The hot, dry summer meant that reservoir stocks became severely depleted and several successive Drought Orders were sought in September, October, and November 1995; these continued with extensions until February 1997. The first half of 1996 continued dry, but storms in late summer and the more prolonged rain in autumn meant that 1996 had 82% of the LTA. Reservoir stocks were much better in 1996 than 1995: they rose steadily from 30% capacity at the beginning of the year, fluctuated around 50% during the spring and summer, and with the onset of wetter weather in the autumn, increased to 86% by November. Although the 'supply drought' for the Calder catchment was not as severe in 1996 as in 1995, the 'environmental drought' persisted in 1996.

In spite of the drought, improvements in water quality were recorded in 1995 and most of these were maintained in 1996. In addition, one or two reaches exhibiting ' no change' in 1995 improved in 1996, eg. the reach Cragg Brook to Luddenden Brook. As many of the improvements reported in 1995 were ascribed to less frequent operation of storm overflows, it is not surprising that these carried on through the dry weather in 1996. In one case, an upgrading reported in 1995 was further improved in 1996 due to continuing better effluent quality at the STW on Mag Brook.

In contrast most of the reported water quality deteriorations for 1995 were not sustained in 1996. Some of the 1995 deteriorations are now thought to be due to pollution events, as they are the result of a low number (often one) of uncharacteristic samples in the data set. Other deteriorations reported for 1995 may not be statistically significant.

As concerns about water quality has been the main issue in the Calder catchment, most of the routine invertebrate monitoring in recent years took place in the lower, poorer quality, reaches. Final and full analysis will encompass both Agency and YWS data, but preliminary interpretation, looking at biological GQA grades and cluster analysis of the data sets, suggests that there have been some marked reductions in quality in the tributaries Hebden Water, River Holme and Cragg Brook.

The 1996 fisheries survey of the Calder and its tributaries showed some changes from 1995. Moderate to large reductions in total trout numerical densities and trout biomass densities were found at most sites, although few of the sites showed increases and two remained unchanged. This is probably accounted for by primarily large reductions in the occurrences of older, larger trout. Almost all sites showed large or very large increases in the occurrence of 0+ trout, which could suggest that the drought benefitted spawning, but is probably due to the lack of predation by larger fish that had been displaced downstream. Mean lengths of 0+ trout were significantly smaller in 1996 than 1995, and may reflect increased competition for food due to their higher population densities.

1.3 River Don Catchment

The River Don's headwater catchments are moderate to steep undeveloped moorlands which feed reservoirs used for public water supply to Barnsley and Sheffield. The reservoirs are arranged in six groups located on the Don and its five main tributaries in the upper catchment. Each reservoir group makes compensation releases to the river downstream.

Due to pressures on the water supply and exceptionally low levels in the reservoirs, YWS applied for Drought Orders in December 1995 for the Sheffield and Barnsley reservoirs, which reduced compensation releases to a third of their licensed statutory amounts. In March 1996, with the drought conditions continuing and with stocks in Winscar Reservoir, which feeds the upper Don, down to less than 20%, a further Order was applied for on this group. The Winscar drought order expired in November 1996 and that for the Sheffield source reservoirs did so in January 1997.

The supply drought hit the Don catchment much later than some of the other river catchments, and water from Winscar Reservoir had actually been used to augment supplies to the Calder conurbations. With the continuation of the drought, Drought Orders were issued for the Don catchment, and conditions were imposed that covered the requirements for monitoring, mitigation and restoration of the river. The particular concerns for the Don related to the longer term impact of the reduced flows on the ecology of a river that was just starting to show signs of recovery from more than a century of industrial pollution. Monitoring (and planning for any required mitigation measures) started in January 1996.

In 1995, rainfall in the Don catchment amounted to 80% of the LTA, and 82% in 1996. Although there was rain in February and March of 1996, the lack of rainfall in April meant the Don started to fall behind the other Pennine catchments.

The YWS Southern Division reservoirs were less than 30% full at the beginning of 1996, but quickly rose to over 60% during February and March. A steady fall then took stocks down to 33%, with the low point occurring in mid-October, before they rose following heavy rainfall. The reservoir levels rose from 36% full to 91% full in four weeks - the fastest rise on record. They were completely full by the end of the year.

Like the other Pennine rivers, the upper Don and its tributaries respond rapidly to rainfall, but the response downstream is both later and lower. Flows were still only just above the dry weather flow (DWF) by the end of 1995. The DWF in 1996 was reached around a month earlier than 1995 for the Don at Doncaster, and six weeks earlier for the Rother and the Dearne. The flows remained at or below the DWF from mid-June into November and continued to rise slowly until just before Christmas, when there were very high flows following heavy rain. The flows then fell steadily until the end of the year, when they were below half their average.

Although the drought was less severe in 1996 than it had been in 1995, water quality results show a greater impact on parts of the Don catchment in 1996. This was because none of the compensation flows, which provide a very significant proportion of the base summer flows in the Don upstream of Blackburn Meadows STW, were reduced in 1995. The impact of drought on water quality was not as severe as had been feared, although deteriorations did take place in several stretches of the Don. Metal analysis was done for the Don catchment as it was believed that reduced dilution would elevate their levels. In fact, it did not have a significant effect.

On the main river Don, deteriorations in water quality were found downstream of the confluence with the Scout Dyke, downstream of Stocksbridge STW and downstream of Jamont. Deteriorations were also found in the stretch between the confluence with the River Loxley and the confluence with the River Sheaf. The cause of these deteriorations was almost certainly reduced dilution for discharges, resulting from the very substantial reductions in compensation flows. Downstream of Jamont, the deterioration was also, in part, caused by poor effluent quality: a result of the company having to recycle the effluent because the cut backs in compensation flow from More Hall Reservoir reduced the availability of process water.

Downstream of Blackburn Meadows STW water quality was generally better, due to reduced ammonia levels in the effluent, in spite of the drought. This was all the more remarkable bearing in mind the substantially reduced dilution for this effluent.

In the Don tributaries no significant grade changes took place, although there were in some instances higher peaks in BOD and ammonia, probably resulting from reduced dilutions for discharges from Combined Sewer Overflows (CSOs) and industrial effluents. It is worth noting that water quality in the River Sheaf, which does not receive discharges of compensation water, showed little variation between 1995 and 1996.

A situation similar to that of the Calder catchment exists on the Don catchment, in that water quality problems have been the main issue in relation to river ecology: consequently, most of the routine invertebrate monitoring in recent years has taken place in the lower, poorer quality reaches. The headwaters have sparse data records, so reliable comparisons with non-drought data in the upper reaches will only be possible when the watercourses have made some recovery after the drought. A full analysis, encompassing both Agency and YWS data, will be produced when all of the three years of monitoring have been completed.

Initial biology GQA grade interpretations from the Agency data suggest that there was a balance between biological quality improvements, deteriorations and 'no change' at the monitored sites during 1995/96. In the cleaner reaches there was a deterioration in the autumn of 1995, followed by a slight recovery in the following spring, whereas this situation was reversed in the poorer water quality reaches. Cluster analysis of historical data bears out this finding. Determination of causes will need correlation of these results with chemical quality and water quantity data.

A crayfish survey was undertaken by YWS as part of the monitoring work, but no crayfish were found.

During 1996 (and 1997) fisheries surveys were carried out on behalf of YWS by the Institute of Freshwater Ecology. The surveys initially included six sites on streams affected by drought orders and two on unaffected sites to act as controls. Subsequently, one of the control sites on the River Don at Dunford Bridge became affected as a result of the inclusion of the Winscar reservoirs group in drought orders.

Although the results of the 1997 surveys indicated overall decreases in trout densities at all sites apart from those on the Ewden Beck and River Rivelin, attributing this to drought orders was not possible due to the effects of siltation caused by restoration work on a dam connected to the R. Sheaf immediately above the remaining control site. To address this problem further control sites are planned for the 1997 autumn survey that will assist in the final interpretation of results.

In addition to changes in population density, failures of recruitment were observed on the R. Rivelin and on the Little Don, although no significant changes were noted on the two other heavily impacted sites on Ewden Beck and R. Loxley.

1.4 River Hull

The headwaters of the River Hull form the most northerly chalk stream system in Britain, and as such have been designated a Site of Special Scientific Interest (SSSI). The chalk is an important aquifer with abstraction for public water supply and agriculture, and there is a public supply surface water abstraction point from the River Hull itself at Hempholme. This aquifer provides all of the public water supply in the northern part of the Wolds and around half the public water supply in the Hull area.

The Hull catchment typically has around 625mm of rain each year. Rainfall was fairly low in 1995, with 90% of the LTA, but 1996 was considerably drier, with only 74%.

The River Hull is a spring fed system, and flows in the river are related to the winter recharge of the chalk aquifer. Prior to the Drought Order, flows were often well below average during 1995, despite periods of rain during the winter. The low rainfall figures and the very low base flows in 1996 resulted in a drop in flows occurring much earlier than in 1995. The flows fell to between two-thirds and one-third of the 1995 volumes in the smaller rivers, and around two-thirds in the River Hull. The river flows followed the same pattern as 1995, but from a lower starting point, and remained lower until well into the autumn of 1996.

YWS are able to abstract an average 68.2 tcmd during the year, with a minimum flow of 45 tcmd maintained over Hempholme Weir. Due to the low natural flows in 1996, when YWS were experiencing difficulties maintaining flows at the 45 tcmd level and still abstracting sufficient supplies for the treatment works, they applied to the Agency for a Drought Permit. The application requested that minimum flows over Hempholme Weir be reduced from 45 tcmd to 22.5 tcmd, when necessary, in order to maintain public supply to the Hull area. The Permit was granted in July 1996 and expired at the end of January 1997. The application was not to increase abstraction rates.

One of the major concerns about the reduction in flows over Hempholme Weir was the lack of dilution for the effluent from Beverley STW, and the possibility of an increase in the extent of very poor water quality below the works. This is in the tidal reaches of the River Hull system and it was feared that at certain tides, fish might become trapped between this band of very poor water quality and the incoming saline water. As part of the drought order conditions, YWS undertook to tighten the operation of Beverley STW, monitor the effluent from the works and also to install some in-river monitors downstream of the works. The Agency undertook a sonar survey of the River Hull which confirmed the absence of fish between the entry point of the STW effluent and the saline limits. It is believed that in 1996 low flows placed fish at increased risk of mortality due to a combination of conditions which caused them to move to areas of poor water quality. In addition, fish production was probably reduced by poor water quality which limited their natural feeding ranges.

Water quality data collected by the Agency showed an improvement from chemical GQA grade E in 1995 to grade D in 1996 in the stretch downstream of Beverley STW, due to a decrease in ammonia levels. This is thought to be due to the more efficient operation of the works and stricter trade effluent control upon discharges received by the works. No separate effects of low flows on water quality due to reduced dilution of effluents were recorded.

Upstream of the abstraction point, where low flows were due to the drought alone, there was no quality change between 1995 and 1996, although the chemical GQA grade D (*fair*) was worse than in previous years (grade C, *fairly good*). It was concluded that the low natural flows experienced in the last two years did not afford the dilution necessary for the effluents from trout farms or sewage works to maintain the chemical water quality.

Monitoring of changes in the faunal community was also considered to be important, and six sites were chosen. Preliminary analysis of these data shows a decline in quality at Beverley from biology GQA grade d (*fair*) to f (*bad*), and in the cleaner reaches there would seem to be a seasonal change in quality. More data analysis will be required before any definitive account of the drought's effects can be compiled.

1.5 River Ouse

The non-tidal River Ouse is formed by the combination of the rivers Swale, Ure and Nidd. The river, draining as it does the bulk of the Yorkshire Pennines, is particularly flashy by lowland standards, and subject to vast variations in flow. Abstractions for Leeds at Moor Monkton and York at Acomb Landing make the river a key provider of water for public supply.

Low flows in the Ouse started in early May 1995 and persisted largely uninterrupted until November. Due to pressures on the public water supply and the forecast of below average winter and spring rainfall, YWS were granted a Drought Order in November 1995 to abstract more water at all flows. This was followed in January 1996 by a one-month Emergency Drought Order allowing a further increase. Also, a Time Limited Licence was granted for three years from March 1996, permitting further abstractions when flows in the Ouse are greater than the naturalised 650 tcmd flow at Skelton. For example, 294 tcmd are licensed when the flows are above the prescribed 970 tcmd level. While the lowest flows in the river are affected by the Drought Orders, they are not by the revised licence. This Licence allows an increase in the proportion of the flow taken near the 650 tcmd level from 10% to 20%.

In view of this situation, extra monitoring and mitigation actions were required, covering flow, water quality, biology and fisheries interests. This work was supplemented, as a condition of the TLL, with ecological work carried out by the Agency and YWS throughout 1996. A major concern of the Agency was the possible sensitivity to drought impact of the Ouse downstream of Naburn STW (which serves the city of York).

Water quality in the non-tidal Ouse is generally good upstream of York, but deteriorates downstream of the city and the Naburn STW. In 1995 and 1996, the good quality upstream at Nether Poppleton was maintained but the face-value chemical GQA grade fell from B (*good*) to C (*fairly good*) at Scarborough Rail Bridge, and from C to D (*fair*) at Acaster Malbis. Some high levels of ammonia in the Ouse downstream of Naburn during the very low summer flows of 1995 exceeded the EC Fisheries Directive. The very low dissolved oxygen levels leading to a grade *d* at Nether Poppleton in 1996 were attributable to sampling error.

Abundant higher plant and filamentous algal growth were evident during the period, especially in the margins. This was an inconvenience to anglers.

Biological surveys carried out by the Agency and YWS also showed distinct differences between the invertebrate faunas upstream and downstream of York. Good biological quality was maintained upstream of York during 1995 and 1996, but in the autumn of 1995 a fall in quality was observed at Acaster Malbis, associated with extreme summer low flows and a lack of dilution from the large Naburn STW effluent discharge. Some improvement was seen in 1996 during the somewhat better flow conditions, from biological GQA grade *e* (*poor*) to *c* (*fairly good*).

The drought impact on the Ouse appears to be slight in the stretch upstream of York, with only minor shifts in faunal composition, mainly involving an enrichment of faunas through higher densities of some types. A few flow-loving invertebrates have been disadvantaged, and there is evidence that some still-water groups are becoming more prevalent as flows have become consistently lower. Some of these were present in the early 1970s, but their occurrence then, and since, has usually been very sporadic.

Fishery surveys in 1996, including sonar work, showed no clear indications that the drought caused any deleterious effects to coarse fish populations. Roach dominated catches in the Ouse, and most coarse fish were supported by a strong 1995 year-class. This was particularly evident for bream upstream of Linton Lock. Growth rates of most fish were also greater than those observed in 1993. Some changes in species composition were evident, with indications that dace and gudgeon recruitment had been reduced at Beningborough since the drought of 1989 and the number of perch had increased.

Although considered to be primarily a coarse fishery, salmon use the Ouse as a corridor to their spawning grounds on the Ure and are required to negotiate the poor water quality conditions of the tidal river. Entrainment of small numbers of juvenile salmon may occur at abstraction points at York Water Works at Acomb Landing and Drax Power Station. Examination of these is needed in order to evaluate any losses.

1.6 River Ure Catchment

The Ure rises on the Pennines and is joined by a series of tributaries, such as the Cover, Bain, Burn and Skell, before it joins the Swale near Boroughbridge. The flow of the Ure is predominantly unregulated, and tollows a natural pattern of seasonal variations largely determined by recent weather conditions. Rainfall in the catchment during 1995/96 amounted to 80% of the LTA and river flows were below the prescribed level of 163 tcmd at Kilgram Bridge for long periods, especially during the summer of 1995.

There is relatively little abstraction, with the only potable river abstraction at Kilgram Bridge formerly serving just Thornton Steward Reservoir. A Drought Order granted to YWS increased the abstraction from the Ure by 30 tcmd (to 52.3tcmd) when the net flows were greater than a new prescribed flow of 163 tcmd. The TLL granted on 16 May 1996 (for a three year period) is a continuation of this regime. Data on abstractions during 1995/96 showed an under utilisation of this licence, averaging only eight tcmd and 11 tcmd for the two years respectively.

The Ure is a high quality river with only localised impacts on water quality, biology and fisheries below a few, relatively minor, effluent discharges. The main effluent discharges are in the lower reaches, from Ripon to Boroughbridge STWs and West Cumbrian Farmers Foods Ltd at Boroughbridge. Any changes or deteriorations in water quality as a result of low flows are more likely to occur in this stretch than in the upper reaches. The six water quality monitoring sites assigned to the Ure attained chemical GQA grade B (*good*) during 1995-96, the exceptions being Wensley (grade A, *very good*) and Boroughbridge (grade C, *fairly good*) during 1995. Lower dissolved oxygen levels in the Ure at Hewick Bridge and Boroughbridge may reflect less dilution for organic wastes and increased levels of microbial activity.

Concerns about the changes to the abstraction licence initiated a detailed ecological monitoring programme, even though predicted impacts, other than for salmonid spawning, were slight or nonexistent. The abundant macrophyte growth along the margins of the lower Ure during the summer has been of concern to anglers, primarily as a result of reduced access to fishing pegs. A macrophyte survey carried out by consultants during 1996 confirmed the prevalence of algae, but also the distinct longitudinal zonation and widespread human influences which interfere with the interpretation of drought impact.

Biological quality was largely unchanged (eg at Bainbridge) or suggested a slight decline in 1996 (Wensley and West Tanfield). The reason for this apparent slight deterioration at the latter sites can be explained by the relatively high abundances of pollution-tolerant and silt-tolerant macroinvertebrates compared to pollution-sensitive types and those more characteristic of coarser substrates.

The similarity of the spring 1996 fauna with that from the previous autumn parallels the situation on the Wharfe, and this may be related to lower winter flows and a lack of significant faunal washout and redistribution. Two invertebrate families that have experienced a significant fall in average abundance in both the upper and middle Ure are the Perlidae (stoneflies) and Polycentropidae (caseless caddis); however, the reasons for this are not clear, although both are flow-loving groups usually characteristic of the upper part of the fast flowing Dales rivers.

Overall, the changes in invertebrate faunas in the River Ure since autumn 1995 appear similar to those shown in the Wharfe: the upper part of the catchment appears to have reduced productivity, whereas it has increased in the middle and lower sections. The diversity of invertebrates sampled appears not to have altered greatly, but there have been distinct changes in the relative abundances. Pollution-sensitive and flow loving animals have been present in lower numbers, and there have been increases in those families associated with lower flows, and increased enrichment.

Fisheries surveys were carried out by the Agency on the main river and two salmonid spawning becks. Most coarse fish species in the lower Ure were supported by a strong 1995 year-class: notably, bream of this year-class were very evident at Aldwark Bridge. Compared with previous years, the growth rates of most fish were greater than those observed in 1993. Low flows were not thought to be directly correlated to successful recruitment of coarse fish in the Ure, although the associated high water temperatures during drought conditions may have had a strong positive effect. Coarse fish appeared less susceptible to the effects of higher temperatures than salmonids, and notable increases in fry growth rates were observed.

At this stage in the study, there are no indications that the drought has caused any deleterious effects to coarse fish populations in the Ure or marked changes in species composition, rather there is evidence of good recruitment by several species. The fact that dace did not benefit as much as other coarse fish under these conditions (as expected) suggests some species are affected more than others.

The numbers of juvenile salmon observed in the Ure in 1996 are encouraging, as the numbers observed in the tributary streams appear to have fallen during the drought of 1995/96. Similarly, a relatively large decline in the number of juvenile salmon found in Ure tributary streams was reported in 1992 and attributed to poor water quality conditions in the tidal Ouse and low flows in the nursery streams as a result of the 1989-90 drought.

1.7 River Wharfe Catchment

Unprecedented low flows and drought in the Wharfe catchment during 1995 and 1996, together with the granting of a TLL to YWS for the operation of their abstraction at Lobwood and Arthington, required monitoring work to be carried out by both YWS and the Agency.

Until September 1995, the abstractions were fully supported by releases from Grimwith, but afterwards the pattern was largely of a water deficit in the Wharfe compared to the natural flow regime. However, there appear to have been no significant water quality problems arising from the drought, although there were localised increases in ammonia levels and a more general increase in pH values and nutrients. The effluent quality at the sewage treatment works have been maintained at higher operating standards than allowed for by their actual consents.

In 1996, river habitat and macrophyte surveys were carried out at eighteen sites on the Wharfe between Starbotton and Tadcaster Weir in response to the TLL applications from YWS. The eighteen sites showed a range of physical features and habitats. With only one set of RHS data available, this means that only a description of the river can be given, and no comment can be made on the impact of increased abstractions and altered compensation releases. Large amounts of filamentous algae and slow-flow plant species were reported, and blue-green algae were found in the Wharfe at Tadcaster on the 16 August 1996. Their source was not the Wharfe, but Harewood Lake and Stank Beck downstream.

Thirteen biology GQA sites on the main river Wharfe were supplemented by two on the higher Wharfe to provide data relevant to the natural drought. The only long term data trend is that of more recent higher faunal richness in the upper Wharfe, probably as a result of the increased frequency of low-flow events in the latter half of the 1995-96 period. Concerns about the impact of the compensation releases from the River Dibb on the ecology of the Wharfe are not borne out by examination of data from Burnsall, upstream, and Bolton Bridge, downstream.

A mortality of large numbers of signal crayfish near Grassington during mid August 1996 was accompanied by poor autumn macro-invertebrate faunas recorded in both the Skirfare and higher Wharfe. It is believed that three sheep-dip pollution incidents occurred during the late summer and early autumn of 1996. The Agency has successfully followed up these putative incidents.

Overall, the drought impact on the Wharfe's macro-invertebrates has been one of promoting biodiversity and abundance throughout most of its length. Coupled with this has been the suppression of seasonal change (notably between autumn and spring), because of the relative lack of flushing spates, and some evidence of decline in a few flow-loving types such as leuctrid stoneflies. All of these changes are reversible with the onset of more normal flow patterns.

In the Wharfe, the fish populations and individual fish appeared to be in good condition, and few changes had occurred since earlier, pre-drought surveys. Indications were that, during the summer, larger fish were concentrated in faster, well oxygenated water with relatively few such fish in slow runs and deep pools. Smaller fish were more widely dispersed. A sonar survey at Smaws Ings indicated that fish stocks were similar to other good coarse fisheries in the region.

Recruitment of brown trout upstream of the Dibb confluence was relatively poor in 1995, but otherwise there was satisfactory recruitment in both 1995 and 1996. Grayling catches were larger than in 1993 and significant recruitment had occurred during 1995 and 1996. Pike have continued to spread upstream in the Wharfe, but stocks were relatively low. Some fish favoured by low flows, especially perch, were more prominent in 1996. Recruitment of most coarse fish was particularly good in 1995, promoted by high summer water temperatures, but relatively poor in 1996, following the same pattern as in the 1989 to 1991 droughts.

In the Wharfe's tributaries, a more complex situation than in the main river was apparent. Whilst good trout recruitment was seen in Skyreholme, Kex and Bow Becks, poor trout fry production in Barden Beck was probably the result of low flows exacerbated by lack of a compensation release from Lower Barden Reservoir. Recent deterioration of trout stocks in Hundwith Beck was probably due to enrichment and physical habitat damage as well as low flows. Very low flows in the Washburn between Thruscross and Lindley Wood Reservoirs were associated with severely reduced trout stocks but increased numbers of perch.

Some brown trout, notably old individuals, captured from spawning becks in autumn were relatively thin, but it is uncertain whether this is a drought effect. Body condition and gonad development of brown trout from the main river were not adversely impacted by the drought. Macroparasite incidence and infestation levels did not appear to be elevated in 1996.

No fish mortalities directly attributable to the drought were recorded for the Wharfe or its tributaries, although reduced dilution may have increased the severity of pollution mediated mortalities. Only one such mortality occurred in 1996, compared to five in 1995. However, increased abstraction rates at Lobwood were associated with impingement of fish. Liaison was carried out with YWS, who have acted to prevent such problems at both Lobwood and Arthington intakes. Clearance of boulders was also successfully carried out at the confluences of several becks with the Wharfe in order to improve access for spawning trout.

During the summer months, pleasure angling was concentrated on restricted lengths of the river and during the early morning and evening. Match angling was adversely affected by the patchy fish distribution and difficult river conditions, including low clear water and prolific macrophyte growth, although catch parameters remained satisfactory.

The main short term drought effects have been alterations in fish distribution and behaviour, with consequent effects on angling activity and success. The major medium term effects have been adverse impacts on trout stocks in tributaries downstream of reservoirs without the provision of compensation releases, increased growth of small and medium size fish and the production of successful 1995 year classes of most coarse fish.

A long term effect, which is not yet apparent, is likely to be a change in the main river fish community, with species favoured by slower summer flows, (such as roach, bream and perch), increasing relative to fast river species, such as grayling, dace and barbel. However, high winter flows may restrict the expansion of the populations of the former species. Long term changes are likely to be more marked if the drought continues through 1997 and beyond.

Apart from impingement of fish at Lobwood, no direct effects of abstraction could be distinguished from 'natural' drought effects, although any unsupported abstractions are likely to exacerbate such drought influences.

2.0 PURPOSE

The main purpose of this second interim report is to summarise the results and analyses currently available from the environmental actions carried out or instigated by the Agency to monitor and reduce any impact on rivers of the severe drought experienced in Yorkshire during 1995 and 1996. It provides an update on the previous *Interim Report on the Environmental Impacts of the Drought on Yorkshire's Rivers - April 1995 to April 1996.* The report is confined to those rivers affected by Drought Orders and Time Limited Licences granted to YWS - the Aire, Calder, Don, Hull, Ouse, Ure and Wharfe - during the period April 1995 to December 1996.

Other rivers in Yorkshire were influenced by the drought and these environmental responses will be, or have been, picked up in routine monitoring reports such as the chemical GQA, fisheries rolling program and routine biology surveys. Extensive ecological work related to the proposed Tees-Wiske transfer scheme has also covered several rivers not featured in this Drought Report (ie. the Tees, Wiske and Swale).

The main information used in this report is drawn from surveys carried out in relation to water quality, river habitats, aquatic macrophytes and invertebrates and fish populations. In addition, site inspections, Environmental Statements supporting Drought Order and TLL applications, and work carried out as Drought Order conditions provide essential and valuable data and information.

The main aim of these programmes is to answer the following questions:

- What were the effects of the drought on the habitat and quality of Yorkshire's rivers, and any subsequent impacts on the ecology, from algae to mammals?

- What is the effect of the Drought Order/Time Limited Licence on the flow regimes, and does this have a significant impact on the ecology?

Comprehensive measures have been implemented to monitor the effects of the drought, Drought Orders and TLLs, and will take several years to complete. A large amount of fisheries and other ecological work carried out in the spring, summer and autumn by both the Agency and YWS in 1996, 1997 and 1998 on the TLLs will be fully reported in 1999 at the end of the three-year licence period.

The report generally follows the format used in the first *Interim Report*, with catchment summaries forming the basis for the text. Although some descriptive sections are included, further details and supporting data can be found in technical reports, where indicated. Different levels of detail in the sections have been largely governed by the availability of long term data for comparison with those from the drought period.

3.0 BACKGROUND AND ISSUES

3.1 Environmental impacts of low flows

The background to the 1995 drought and the Agency's responses were outlined in the first *Interim Report,* although some details are repeated here, as are the Agency/YWS actions in assessing the impact of Drought Orders. Low flows and drought are increasingly contentious issues with water suppliers, the regulators and environmentalists. Although it is not the role of this report to examine the political and economic factors behind the current welter of claim and counterclaim, there are certain facts and issues which are not in dispute.

Water supply in Yorkshire is currently heavily reliant on surface waters, with groundwater only important in the eastern chalk area. This means that the Pennine rivers, which are dependent on summer rainfall to maintain flows, are fully exploited during low flow periods with superimposed Drought Orders. Compensation releases are also frequently an integral feature of abstraction regimes, ostensibly designed to protect the riverine habitat from extreme low flows. Increasing use of Drought Orders/Permits and Time Limited Licences to vary the conditions presents very great challenges to those attempting to evaluate their possible impacts over the short, medium and long term.

Environmental impacts as a consequence of low flows and drought are diverse and often habitat-specific, making generic evaluation criteria very difficult to establish. Nevertheless, in its national strategies the Agency is developing key policies and objectives which are essential in achieving environmentally sustainable use of water resources - this requires an understanding of the environmental impact of abstractions and proposed variations, drought and low flows before strategy options can be considered. The Agency also has legal obligations under the Habitats Directive and a commitment to Biodiversity Action Plans.

Some generalised environmental concerns with regard to drought (and abstraction) are related to:

- Changes to, and loss of habitats under low flow conditions. This has many potential consequences for aquatic organisms. However, this must be set against the natural pattern or cycle.

- Lack of dilution for effluent discharges and other diffuse sources of polluting substances.

- Increases in water temperatures during hot periods, leading to potential thermal stress and mortality in fish and invertebrates.

- Loss of flow variability in ecosystems which, in the Pennine rivers of Yorkshire, are largely adapted to, and characteristic of, physical disturbance (ie spates) and short low-flow periods. In ecological terms, this means a transition from *disturbance* to *stability* influencing biological community development.

- Loss of amenity, as anglers are affected by disturbances to fish distribution patterns and exceptional growths of marginal vegetation, hindering their pastime.

Abstractions from rivers can also have direct impacts, such as entrainment and impingement of fish and invertebrates (such as crayfish) onto intake screens, and they can increase the periods of time when rivers are at or near their critical flows. The actual consequences of the latter influence have yet to be determined, since they are fundamental to the monitoring and review of the several Time Limited Licences currently held by YWS, although it might be believed that they would exacerbate the effects of natural low flows.

Changes to compensation regimes may also have severe consequences for downstream river systems if they are poorly designed and excessive. Compensation releases in themselves can act as spates if not stepped-up or cut back gradually, and their reduction mimics natural drought, especially in those streams almost or entirely dependant on reservoir water - as is the case in the Calder/Don catchments - with both habitat and water quality consequences. In contrast, compensation releases may also smooth out fluctuations in natural flows, that may be critical for maintaining instream biodiversity. Chemical quality of the water in releases may differ substantially from the receiving river and could potentially create problems: an example is the relatively less alkaline and more humic water from the Dibb meeting the more base-rich and clear Wharfe upstream of Bolton Abbey.

Although the emphasis by the Agency in this report is, understandably, on the posible *harmful* effects of drought, there may be *benefits* for some elements of Yorkshire's aquatic ecosystems. Among these are the reduction in intermittent polluting discharges from combined sewer outfalls, higher water temperatures which promote biological activity and growth, the creation of new habitats from ponding, weed growth and siltation, and less downstream loss of juvenile stages of fish and invertebrates.

3.2 Rainfall and river flows during the period

Drought is "*usually considered to be a period in which the rainfall consistently falls short of the climatically expected amount, such that the natural vegetation does not flourish and agricultural crops fail*" (Shaw, 1994), and "*The chief characteristic is a decrease of water availability in a particular period and over a particular* area" (Beran & Rodier, cited by Mawdsley *et al* 1994). However, the assessment of drought *severity* is dependent one's viewpoint and there are three valid perspectives, namely scientific, water supply and socio-economic (Mawdsley *op.cit*).

Rainfall, or lack of it, impacts on river flow regimes and this influence can be compounded by the effects of water abstraction and effluent discharges. Since truly natural flow regimes on the Pennine rivers no longer exist, analysis of catchment rainfall gives a good indication of the severity of drought, especially if natural and artificial influences on the environment are to be separated.

The drought of 1995 and early 1996 was described in the *Interim Report*, but 1996 continued to be relatively dry until the significant rain in the autumn in the western half of the region; drought persisted until at least the end of the year in the east **(Figure 3.2a)**, where groundwater supplies have been at record low levels. In many of the rivers, flows were, on average, actually lower in 1996 because of the lack of rainfall in winter 1996/spring 1997: a contrast to the early part of 1995, which was extremely wet. The drought of 1995/96 was severe, with some of the largest rainfall deficits of recent times being observed. Particularly noticeable was the lack of rainfall in the upland Pennine catchments. The result was some very low river flows, with long term minima occurring in several months.

Further details on rainfall and river flows are dealt with under the relevant catchment section.

3.3 Current status of the Drought Orders and Drought Permits in Yorkshire

The situation with regard to the Drought Orders issued since 1995 is shown in **Table 3.2a**, updating that given in the first *Interim Report*.

3.4 Predicting the impact of a low flows and Drought Orders

In assessing the likely environmental impacts, the guiding principles were:

- The rivers are of high ecological quality and should be protected as far as possible;
- A precautionary approach was to be adopted where appropriate, as many of the impacts take time to be evident;
- Cumulative effects of more than one Drought Order need to be considered;
- Potential environmental impacts need to be monitored to give better data for future occasions;
- Mitigation should be sought where appropriate;
- A comprehensive environmental statement was expected given the high ecological value of the rivers.

The predictions were evaluated to produce an action plan that it is anticipated will eventually provide sufficiently detailed information to assess any damage (or possible benefits) and its causes, as well as what could be done to minimise adverse impacts.

3.5 Making Drought Order responses - action to protect the environment

Many of the Agency's responses contained specific conditions which required agreement before the application could be supported. Agreement with YWS on these conditions was obtained in all cases, generally after negotiations. These conditions were referred to in the inspector's reports following public hearings, but were not specifically part of the resulting official Drought Order: the DoE took the opinion that they could not be included. The agreement was effectively made by an exchange of letters between the Agency and YWS. Some issues required more time to resolve and were left "as to be agreed with the Environment Agency".

The Agency has provided a comprehensive list of potential requirements for action under a Drought Order, summarised below:

Monitoring to collect data to understand the impact of the Drought Orders, and how these related to the original prediction. Monitoring is also used to target mitigation measures where immediate action is required, such as where fish are in distress and need to be rescued. The type of work covers physical habitat, aquatic flora and fauna including fish, birds and mammals and also the water quality and flows in the river. These measurements were required over a period of up to three years, as appropriate, to ensure that adequate data were available.

Mitigation measures include the provision of aeration facilities on standby, cutting weeds where this improved oxygen levels, carrying out fish rescues and the use of fish screens to prevent fish getting pulled into the intakes at abstraction points from rivers. In addition, control of water levels was altered to increase soil moisture content where appropriate and 'freshets' were released from reservoirs to improve quality. YWS were also required to provide measures that would alleviate any acute problems of water quality by maintaining sewage works and combined sewer overflows to the highest possible standard.

Restoration and improvement measures include work to restore the river where necessary by fish restocking, removal of obstructions to access to fish spawning areas and providing fisheries habitat and fish pass improvements.

Some of the conditions will be followed over several years, three in the case of the TLL assessment. The Agency and YWS have been sharing data to help define the best monitoring to carry out. With any balance between the needs of the public and the environment, an element of subjectivity is inevitable. Whether the Agency has achieved the correct balance only time will tell. To judge whether any changes can be classed as unacceptable damage will also take time and, consequently, continued monitoring is vital.

The Agency was aware that the later measures taken by YWS had the potential to cause environmental damage in the rivers, but that the seriousness of the public water supply situation then and now has made the acceptance of any limited, or short-term, damage necessary. The solution is to ensure that mechanisms are found and developed to deal with any of the problems with public water supply so that this situation cannot recur.

3.6 Environment Agency actions

The following actions were undertaken during 1995 to manage and measure the effects of the drought. Many of these actions were pursued as the drought conditions persisted during 1996.

- Close liaison between Fisheries, Recreation, Conservation & Navigation and Water Resources & Quality Departments was kept to monitor river water quality, especially at high vulnerability locations, notably downstream of waste water treatment works. Towards the end of the summer, the frequency of monitoring surveys was increased as water quality data suggested conditions likely to result in fish mortalities.

- Towards the end of the summer of 1995, weekly liaison meetings were held with YWS to review and modify as necessary the river water quality monitoring. The provision of aeration equipment was made at high risk locations to try to maintain minimum threshold oxygen levels.

- Using the water quality survey data as a trigger point, an 'Emergency Fish Rescue Action Plan' was developed. This was in preparation for possible isolation of fish in tributaries when compensation flows from reservoirs were reduced. The plan identified equipment and staffing needs and, due to the extensive lengths of possible high risk areas, called upon fisheries teams from neighbouring Agency areas/regions to be placed on standby for mobilisation at short notice.

- As reservoirs became seriously reduced in volume, the impacts of high suspended solids in their outflows became a concern. These levels were monitored both by chemical analysis and visual assessment. Measures to reduce this material by installation of straw bale dams to filter and settle the solids were trialed at a few locations. It remained a serious problem and fish recruitment was forecast to be adversely affected in 1996 (although no evidence of this was subsequently found).

- Access arrangements to high risk locations requiring emergency fish rescues were investigated, and relevant angling interests were notified of possible emergency transfers. Locations for short and long term storage of rescued fish stocks were identified to allow restocking to take place on restoration of 'normal conditions'. The aim of fish rescues in small streams is to retain genetic identity of local stocks by leaving the smaller fish and allowing the transferred larger individuals to migrate back upstream when higher flows return.

- In preparation for predicted fish rescues and transfers to other waters, samples of fish were obtained and health tested according to fisheries legislative requirements. The investigation looked for indications of poor health, general condition and signs of reproductive failure were also examined.

- On receipt of Drought Orders, angling interests were notified and potential impacts on fisheries were identified to allow these groups to formulate comments for submission at Drought Order public hearings.

- Photographic records were obtained at key locations downstream of reservoirs affected by compensation flow reductions. Features such as reduced flows, reduced channel widths, siltation effects, etc. were recorded.

- Regular inspections were made on river and reservoir conditions.

3.7 Yorkshire Water Services' actions

It was vital that the water company undertook the agreed conditions set under the Drought Orders and TLLs as well as continuing to run its own routine operations efficiently. Up to the time covered by this report:

- YWS have to date maintained high operational standards at their sewage works and combined sewer overflows.

- YWS have carried out the improvements to the fish screens on their abstractions.

- YWS have carried out, or are carrying out, the agreed monitoring, but full evaluation of the results continues, in conjunction with those from the Agency's work.

- YWS have commissioned fisheries surveys of the numerous streams in south and west Yorkshire which are influenced by changes to compensation releases.

- The Agency and YWS have provided and used emergency aeration equipment, when required, with the aim of preventing fish mortalities on the Calder in particular.

4.0 METHODS AND ANALYSIS

4.1 General

The Agency has recently finalised a document which can be used to determine the extent and nature of monitoring work related to drought and low flows: *Guidelines for monitoring methodologies for water resources projects.* Wherever possible, these have been followed.

In this report, every effort has been made to reduce technical words and jargon to a minimum, although their use is sometimes unavoidable, if not preferable, for clarity and brevity. A glossary of terms is appended.

Further details of methodologies may be found in the various technical reports which form the basis of this overview.

4.2 Hydrology and water resources

Analysis has largely concentrated on the 1995/1996 drought period as compared with the long term averages (LTAs). The methods of analysis used include flow duration statistics, minimum flow for periods of days, percentage of long term average flow and rainfall, cumulative rainfall deficit and impact of various abstraction regimes.

Rainfall is measured on a daily basis by volunteer observers, in accordance with standard practice for the UK. Whilst occasional measurement errors are unavoidable, most are picked up during data processing and Quality Assessment. Data are checked by the Meteorological Office for consistency. Some bias may occur in converting point measurements to averages for particular areas, but a consistent approach should limit this. It should be noted that *LTA* rainfall totals are based on the average rainfall over a thirty year period. Currently, the standard period quoted by the Meteorological Office is 1961-1990.

Rainfall deficit has been analysed by broadly following the method outlined by Bryant *et al* (1992). Cumulative deficits have been calculated where the start of an accumulation period is triggered by three consecutive months of below average rainfall and the end of an accumulation period (drought) is triggered by a three month period where rainfall exceeds the three monthly mean.

In this report, reference is made to *observed* and *adjusted* flows. Observed flows are those measured at the Agency's gauging stations, and are affected by artificial influences such as abstractions and discharges. *Adjusted* flows are the observed flows, corrected for the most significant artificial influences (such as public water supply abstraction), so that the natural flow regime of the river can be described. This should not be confused with a fully *naturalised* flow, which would account for all upstream abstractions and discharges The use of adjusted flows allows the natural and artificial effects of the drought to be assessed.

The creation of adjusted flows is dependent on the supply of abstraction data from YWS - these are available from Section 201 returns. Monthly figures are available for several years, and more recent years have a mixture of some weekly and some daily figures. Where weekly figures are given, these have been uniformly divided over the seven days to give an estimated daily figure.

Where the impacts on the river flow pattern of the TLL variations have been compared with the previous licence conditions, the annual licensed quantity has been ignored and maximum use within prescribed flow limits has been assumed. This is intended to show the *potential* impact of the licence on any particular day; it is not intended to give a true reflection of the *total* impact over an annual period.

4.3 Water Quality

All those sites believed to be at risk from low-flows, through lack of dilution, in the Aire, Calder and Don catchments were sampled at weekly (x 52) or fortnightly (x 26) intervals. Unless stated otherwise, other river water quality sites have been sampled at the normal frequency during 1995 and 1996 (ie fifteen times a year) as part of the GQA programme. Data from these and other sites are available on the Public Register, accessed at local Agency offices. More frequent and targeted monitoring has occurred where potential for water quality deteriorations has been identified.

Water quality data are collated from the results of national sampling programmes implemented by the Agency as one of its statutory requirements. Raw data extracted were interpreted by the Con-GQA programme, which is normally used for producing a GQA of water courses in a national rolling programme. In order to compare the combined effects of the three major sanitary determinands (*dissolved oxygen, ammoniacal nitrogen* and *Biochemical Oxygen Demand*[5] *+ATU*), the data were subjected to the Con-GQA programme to determine a GQA style grade; ie '**face-value**' grade. This was done on a year by year basis for each sample point where sufficient data were available (usually nine results for all three determinands). It should be borne in mind that this does not reflect the **formally reported** GQA grades for the years in question, as this strictly requires three years' data as a means of eliminating or reducing yearly variability. This methodology is useful for deriving a standardised method of comparison because it uses *percentiles*. The 90%-ile refers to the value which is not exceeded by 90% of the data set and the 10%-ile refers to the value exceeded by 90% of the data set. These may imply something about the variability in the data. GQA values derived from this process range from grade A (the highest quality water, *very good*) and grade F, the lowest (*bad*).

Time series plots of the primary GQA determinands were generated for the period 1991 to 1996 as this period is long enough to take into account the last recognised drought in 1991, through what are perceived to be 'normal' years, 1992-94, and into the latest drought period, 1995-96. This presentation of water quality data aims to summarise considerable amounts of technical information in:

- Line graphs describing the full data set.

- Percentile values/means for the three GQA determinands.
- A table of Face Value GQA grades for each year.

Statistical trend analysis using the Cusum technique was also applied to the long-term data in order to pick up significant changes in mean determinand levels, independent of the calendar year or other designated (eg drought) periods. Cusum (cumulative sum) analysis is a technique for identifying periods within a time series when a determinand shows different underlying mean quality.

4.4 River Habitat Surveys

This method allows an assessment of river geomorphology and *potential* habitat features, not specific habitats related to particular species or ecological communities.

River habitat surveys followed the most recent guidelines developed nationally by the Agency (*1996 RHS Field Guidance Manual*). The river corridor survey methodology used conformed with that set out in the NRA/Environment Agency *Guidelines for river corridor survey* - 1996 version. On the Ure and Wharfe, the RHS was also complemented by a River Macrophyte Survey undertaken by staff of **Scott Wilson Resource Consultants**, on behalf of YWS.

Surveys were made on 500m sections of the rivers concerned, these reaches being selected in advance so as to provide a representative overview of the river, although ease of access was also an important factor in site selection.

4.5 Aquatic macro-invertebrates

These organisms have long been used to assess water quality, and methods and interpretation have evolved over time. Environment Agency sampling comprised one three-minute standard kick sample plus a one-minute search to ensure compatibility with methodology approved for RIVPACS (River Invertebrate Prediction and Classification System). YWS sampling at some sites replicated this procedure to provide three kick samples, or used a Surber sampler to obtain five replicate quantitative samples, as recommended by the Agency. In deeper rivers, an airlift or naturalist's dredge was used to obtain benthic samples, supplemented by sweep-netting in marginal vegetation.

Identification of the fauna was to a level agreed between the Agency and YWS. This was primarily species-level, although some groups such as oligochaete worms, chironomid midge larvae and pea mussels remain to be dealt with. Numbers of invertebrate specimens were recorded as actual counts, but for some of the subsequent multivariate analyses RIVPACS abundance categories were derived. Log-abundance classes were used for two primary reasons: the first was pragmatic, in that some historical data were only represented by this form of enumeration, and the second was more theoretically based: the scale represents a data-transformation suitable for dealing with a variety of non/semi-quantitative sampling methods of invertebrates that occur across a wide range of (often highly aggregated) population densities.

The invertebrate data from the monitoring programme during the period 1990-96 were assessed in biological water quality terms using the Yorkshire Interpretative Index (YID) as well as using the newly developed Operational GQA (GQAO)[1] biological quality grades. These use the same grade definitions as the GQA scheme so, for example, GQAO grade *c (fairly good)* describes the same quality as GQA grade *c (fairly good)*. However, they are derived in a slightly different way, most often through single, or different sampling seasons - which means that the allocation of a grade to a site will often be a little less reliable than for the formal GQA classification based on a combined spring + autumn sample.

As an example (hypothetical), the effect of this could be that a site which has probabilities of belonging to the GQA grades of 10% *a (very good)*, 70% *b (good)*, 20% *c (fairly good)*, may have GQAO probabilities of 14% *a (very good)*, 60% *b (good)*, 26% *c (fairly good)* due to the greater variability of the data.

The GQAO grades in this report were derived from single seasons' (or combination of seasons) samples using RIVPACS environmental variables suite 1, and exclude analytical variability, whereas a formal GQA grade is derived from combined data from spring and autumn samples using RIVPACS environmental variables suite 1 and includes analytical bias. Some of the results were also analysed using a test version of RIVPACS III+, which includes a new module to allow comparison of samples to produce an assessment of confidence in quality changes and also to provide an initial figure of probability of quality class. Data from samples taken prior to 1995/1996 were included in this analysis where available.

Whilst there are no standard methodologies for such biological quality analyses as yet, it is thought to be most likely that the approach adopted above will become more widely used if it performs successfully in trials.

Data for the catchments were also analysed using multivariate techniques to look for trends and patterns. These included cluster analysis (Bray-Curtis coefficient and group-average clustering) followed by ordination (MDS - Multi-Dimensional Scaling) to detect site/sample groupings or site/sample discrimination. Supporting statistical techniques were used to examine levels of significance in differences between data sets and the inherent taxonomic reasons behind these. Determination of faunal discriminators of the resultant groupings of sites was achieved by using the 'SIMPER' program within the PRIMER statistics package.

More specifically, as the Pennine rivers show a strong longitudinal zonation in ecological features such as fish populations and invertebrate assemblages, the multivariate analysis of faunal data was used to help delineate river zones, and therefore reduce spatial influence on the subsequent analyses and interpretation of drought impact and temporal changes. In these zones it was considered that the biological sampling sites formed

[1] This is still under development and terminology may alter in the near future.

largely natural groups, and could be treated as genuine replicates. Several approaches to this analysis were tested and the most consistent approach adopted was first to average all available data for a site and to run the analyses for a whole catchment or main river to determine if there were any distinct zonation on which to build further analyses. Secondly, or alternatively, the data for each site prior to 1995 were combined to provide average spring and average autumn sample data against which data collected in each season in 1995 and 1996 could be compared. Comparisons were made using groups of sites identified in the first set of analyses. These techniques highlight areas for further work when all data are available, in 1999. No attempt has been made at this stage to attribute cause and effect.

4.6 Fisheries

Fisheries surveys were carried out by Agency fisheries science teams on the Hull, Ouse, Ure and Wharfe, and YWS commissioned external consultants to study the systems influenced by compensation releases on the Aire, Calder and Don.

The sites for the Aire, Calder and Don catchments were selected jointly by the Agency and YWS. In monitoring the effects of reduced flow caused by reductions in compensation flows, consideration was given to the various techniques available for surveying the fishery on the middle reaches of these catchments. Fisheries surveys are normally carried out using electro fishing or netting methods, but it was recognised that these techniques would only provide qualitative information due to the depth and width of the sections concerned. Use of hydroacoustics was also considered, but again discounted on the basis that it was unlikely to produce reliable information. Surveys were therefore concentrated in the headwater streams which were directly affected by reduced compensation flows, the surveys were conducted by external consultants working for YWS and they used standard triple catch methodology.

In most instances where main rivers were surveyed, the Agency's triennial rolling programme and annual fry survey formed the basis of site selection in order to compare long-term monitoring data sets to detect any changes.

In shallow, wadeable water single or double anode electro fishing was conducted but, in larger, deeper rivers, a multi-method sampling protocol was adopted in order to limit species, size and age selectivity. The various techniques used included seine and gill netting and multi anode, "Wessex Array", boom boat electric fishing. At sites where different methods were used, the 'traditional' single anode electric fishing was also conducted in order to ascertain the level of efficiency of previous surveys conducted solely by this method. Gill nets were retrieved after all other methods had been conducted. Fish samples obtained by each method were retained separately prior to processing. Fry were sampled using a 20m x 1.8m micromesh seine net set in the margins.

In the lower Ure, Ouse, Wharfe and Hull assessment of fish stocks was conducted using Simrad side scan sonar, usually at night (when fish are generally more active) in order to maximise fish detection.

Further details of sampling methods and site details are given in the individual Fisheries Science reports.

The fork length of fish captured was recorded and scales were taken from a sub-sample for age determination. Minor species such as minnow, eels and coarse fish fry captured/observed by electric fishing were assigned a subjective score of abundance and fry captured by the micromesh seine were fixed in 10% neutral buffered formalin and returned to the laboratory where they were identified, counted and their fork length recorded.

Samples of eels were retained in order to analyse white muscle contamination by red maggot dye, thought to have food chain health implications, and to determine the level of infection of pathogenic parasites, which may limit populations.

Supplementing the surveying work, a catch return system based upon the results from coarse fishing matches has been running since 1971 and is utilised to demonstrate changes in species composition and catch indices. Angling clubs participating in the Agency catch return system send in details of each fishing match either by a postage paid reply postcard to the Agency office or via their angling club, where they are collected by Agency staff. The cards are processed annually to reveal trends in catch indices and species composition. In 1997, the Fisheries Classification system was introduced to the match return system which allows a venue to be assigned a letter from A to D based upon weight of fish caught per hour. Class A is awarded when catches exceed 149g (5.26oz) per angling hour and class D when catches fall below 71g (2.51oz) per hour.

Other information was gained from studies of body condition, stomach content analysis, parasite burden and level of disease/infection.

All reports received from anglers during 1996 have been collated to detail a useful source of information. Reports received have either been verbal or written details have been sent in. Similarly, Agency Fisheries staff monthly reports have been collated for 1996 to provide a further source of information about the river state and its fisheries throughout the year.

5.0 RIVER AIRE CATCHMENT

5.1 Background and issues

The River Aire catchment has relatively few reservoirs compared with the Calder and Don systems, and the reductions in compensation flows in the upper Aire catchment in 1995 and 1996 were not thought to as potentially detrimental. They affected relatively clean watercourses in mainly rural areas with few deleterious discharges to them. The reduction in compensation flows to the Worth catchment did however, give cause for concern. The River Worth is a tributary of the Aire, flowing from its headwaters above Haworth and joining the Aire at Stockbridge near Keighley. The Worth is regulated by compensation flows discharged from Ponden and Lower Laithe Reservoirs. It is joined by Bridgehouse Beck at Mytholmes downstream of Haworth. Flows on this tributary are also regulated by compensation water from Leeming and Leeshaw reservoirs. Upstream of its confluence with North Beck, the Worth is a productive trout stream and provides a valuable nursery stream for the Aire. North Beck had numerous Combined Storm Overflows (CSOs) discharging to it, but these are now subject to a new sewerage scheme. Bridgehouse Beck receives the effluent from Oxenhope STW.

Reservoirs in the Worth catchment supply water to the populations along the Worth Valley and the Elslack reservoir group supplies Skipton and the adjoining rural areas. Overall, compensation flows were reduced by two thirds. They were cut completely from Leeshaw Reservoir, which supplies Keighley (Worth catchment), in November 1995 when the level reached 3% of capacity and it was virtually discharging mud. To mitigate for this, releases from Leeming Reservoir (itself down to 10%) were increased so that although there was a localised deleterious effect, there was no change in the Worth. The majority of reservoir stocks were much better in 1996 than 1995. They rose steadily from 30% full at the beginning of the year, fluctuated around 50% during the spring and summer, and with the onset of wetter weather in the autumn increased to 86% full by November.

Most of the reservoirs on the Aire were subject to Drought Orders, but the reduction of compensation flows in the Worth sub-catchment caused most concern as the Worth is an important fishery and spawning ground and so was perceived to be at greater risk. As many of the upland tributaries of the Aire are not impounded, they can be used as control sites to monitor the progression of the natural drought.

Drought Orders were introduced in the summer of 1995 and, with extensions, remained in force until February 1997.

5.2 Purpose

The Agency already had a comprehensive monitoring programme in place covering flow, quality, biology and fisheries interests. This work was enhanced as a condition of the Drought Orders with extra ecological work to be carried out by both YWS and the Agency in 1995 and throughout 1996. At the start of the drought, an action plan was devised to manage and measure its effects, and included an emergency fish rescue plan. Various monitoring programmes were set up to investigate the drought's impacts, supplementing the existing programme. The extent of the drought monitoring work done in the Aire catchment can be seen in **Figure 5.2a**.

5.3 Hydrology and water resources

The Aire catchment typically has around 965mm of rain each year, but in 1996 it had 845mm, or 88% of the LTA. The first half of the year was very dry, with 33% of the year's total rainfall. Prolonged thunder storms at the end of June and a wet August contributed rain; the snow of November and the storms just before Christmas left the Aire the wettest catchment in the Ridings area when compared to the LTA. In 1995, the catchment was considerably drier and had only 678mm, equal to 70% of the LTA.

River flows in the upper Aire are measured at Kildwick and Armley, and in the lower Aire at Fleet Weir and Beal. Several of the main tributaries are also monitored. The upper Aire responds rapidly to rainfall, but the response of the lower river is both later and lower. Flows were still only just above the dry weather flow (DWF -see Glossary) at the beginning of 1996. Despite periods of higher flow in January, February and March 1996, only the highest values for February were above the LTA. The other winter months remained entirely below average, even when swollen by rainfall.

The low rainfall figures and the very low base flows resulted in a drop to DWF occurring slightly earlier in 1996 than 1995 for the lower Aire. The upper Aire remained at these very low levels from May until the end of August. Although not obvious, the underlying base flow started to rise away from the DWF after the heavy rain at the end of August. In 1995, this rise did not happen until November. The flows continued to rise until just before the end of 1996, when they were very high following rain. They then fell steadily until the end of the year, to below half their average volume.

The reservoirs at the beginning of 1996 were less than 30% full, but quickly rose to over 50% during February and March, and then climbed very slowly up to 57% by early July. The normal summer draw-down reduced stocks, apart from a rise due to the late August rain, until the onset of wetter weather late in September. Thereafter followed a sustained increase in stocks, from 45% in the middle of September to 86% by the end of November. River flows, reservoir stocks and rainfall figures for 1996, and comparisons with the LTA for 1995 and 1996 can be seen in **Figure 5.3a**.

During the drought period, five reservoirs feeding the River Worth catchment were affected by Drought Orders:

Leeshaw Reservoir - discharging to Leeshaw Beck
Leeming Reservoir - discharging to Leeming Beck
Keighley Moor Reservoir - discharging to Morkin Beck (not reduced)
Lower Laithes Reservoir - discharging to River Worth at Springhead Weir
Ponden Reservoir - discharging to River Worth at Springhead Weir

At these reservoirs, compensation flows were reduced periodically between June 1995 and November 1996. Flows from the reservoirs had all returned to normal by April 1997.The Agency undertook an enhanced programme of spot gauging measurements of compensation flows to check compliance with drought orders. The programme checking flows from the reservoirs was increased from twice a year to once a month to check compliance with drought orders during 1995 and 1996 **(Table 5.3a)**.

5.4 Water quality

Most of the cuts in compensation releases were to reservoirs on the River Worth and the enhanced sampling programme was devised in order to determine whether the reduced compensation flows were having an effect on water quality. Only one other reservoir in the catchment (Elslack Reservoir) was subject to compensation flow reductions during drought. The flow from this reservoir is released into a small tributary of Broughton Beck. It was not considered that there would be a significant impact on the flow in this receiving watercourse to warrant extra sampling.

The Worth is a major source of water to the Aire catchment, so reduced flows from the Worth reservoirs plus reduced flows from Elslack reservoirs could have had an impact in the lower reaches of the Aire as a consequence of reduced dilution water. Analysis of chemical GQA data for the Aire catchment from 1994 to 1996 shows that water quality in the lower reaches of the Aire is being maintained or improved. However, in the upper tributaries and upper reaches of the main river there has been a noticeable reduction in chemical quality and many stretches have fallen from chemical GQA Grade A (*very good*) or B (*good*) to grade C (*fairly good*). While the lower grades are in most cases attributable to lower dissolved oxygen levels in the water, the reasons for this have not yet been established. As these tributaries are not impounded and have not been subjected to compensation reductions, the natural effects of the drought may be a strong contributory factor.

The routine river water quality sampling programme was increased from monthly to fortnightly sampling at each GQA site on the Worth catchment, with extra sites added in vulnerable locations, mainly to assist in operational decisions. The major changes in water quality are summarised in **Table 5.4a**, supplemented by **Figures 5.4a-d**.

Results from the enhanced Worth catchment programme indicate that Leeshaw Beck, Leeming Beck and Morkin Beck all maintained chemical GQA grade B status. Leeming and Leeshaw Beck join to form Bridgehouse Beck. Analysis of river quality data for the downstream stretches of this beck reveals that quality dropped from chemical GQA grade B (the objective for the stretch) in 1994 to grade C in 1995 and 1996 **(Figure 5.4a)**.

Oxenhope STW discharges to this stretch of the watercourse, although the quality of effluent discharging from the works did not deteriorate during the drought period and the Consent was not breached. It is possible, however, that reduced dilution of the effluent (as a result of upstream reductions in compensation flows) is responsible for the downgrading of the lower reaches of Bridgehouse Beck.

5.5 Ecology

The source of the Aire around Malham is an SSSI, notified because of its limestone flora and geological features, and falls within the Yorkshire Dales National Park. The Aire and its tributaries between Skipton and Bingley have undergone significant modifications for Flood Defence purposes and now have limited conservation value. YWS have undertaken River Habitat Surveys to monitor habitat changes along the river corridor. The biological quality of the upper Aire is generally good, but quality declines below the major STWs.

The Worth is a major tributary of the Aire, and is generally of excellent biological quality in its upper reaches. Adjacent to Knowles Park, downstream of the confluence with Bridgehouse Beck, quality is somewhat reduced. By the centre of Keighley, slight recovery is achieved. Bridgehouse Beck upstream of Oxenhope STW is of good biological quality, but the faunal diversity deteriorates downstream of the input from the sewage works and again upstream of the confluence with the River Worth.

5.5.1 Aquatic macro-invertebrates

The Agency has carried out special macro-invertebrate surveys in the Aire catchment downstream of eight reservoirs with reduced compensation flows, ie. at Lower Laithe, Leeshaw, Leeming, Eldwick, Weecher, Reva, Keighley Moor and Ponden reservoirs. Sampling started in autumn 1995 and is continuing in the spring and autumn seasons. Routine sampling was extended to include certain sites in the upper reaches of the main river and in the River Worth catchment to investigate the effects of the low flows and reduced compensation releases.

YWS have also been carrying out surveys, as agreed with the Agency. Semi-quantitative and quantitative samples have been taken of the invertebrate communities. Some sites sampled by YWS have also been sampled by the Agency to audit results. The 1997 survey will be carried out by Agency staff and a full report that will encompass both Agency and YWS data will be produced at the end of the three years of monitoring. A preliminary analysis of Agency data for 1995 and 1996 and comparisons with back data, has been made.

Eighteen sites on the Aire were sampled by the Agency and seven sites by YWS (**Table 5.5a**). The Agency's sampling in this catchment was concentrated mainly on the upper Aire and tributaries, and designed to assess the biological quality of the streams affected by natural drought. These studies will act as controls against which to assess the impacts of Drought Order-induced changes. YWS's sampling was to assess the effects of changes in flow conditions on the faunal communities in the Worth system and, since little data exists for the system prior to the implementation of the Drought Order, sampling is to continue for a period of at least two years after cessation of the drought to ensure recovery of the fauna and to have data available for comparative analysis.

Results are given in **Table 5.5b**. The biological GQAO is represented both by a colour and a letter, *a* being very good water quality and *e* being poor quality. Improvements (within confidence limits) from one season to the next are represented by a blue colouration in the season's column, and deteriorations (with the same confidence limits) are represented by a red colouration in the season's column.

Most sites sampled appeared to maintain quality from season to season and initial comparisons with chemical water quality results show a parallel response. Only at **Providence Lane (River Worth)** and the **Aire at Annerley Bridge** were any significant GQAO grade changes noted during the 1995/96 period. At the former, poorer quality was recorded during autumn 1995, with a recovery to grade *a* seen in spring 1996, but the same grade *(b, good)* was seen in the autumns of 1991 and 1992. The quality at Annerley Bridge has regularly alternated between grades *e* and *f*, and does not appear to be related to the drought.

Clustering and MDS ordination of these data is continuing as more data are acquired.

5.5.2 Fisheries

The headwaters of the River Worth and Bridgehouse Beck support valuable brown trout populations. The fishery habitat provides excellent conditions for recruitment, and previous surveys indicate that the fish populations are highly productive. Downstream migration of larger trout provides a significant benefit to the lower Worth and the main River Aire at Keighley.

The latest fishery survey on the Worth indicated that the biomass of trout at Haworth was significantly lower during 1996, but numbers of 0+ fish remained almost unchanged. This could indicate a downstream migration of larger trout to the main river, a pattern that has been found on many of the Region's other rivers affected by the Drought.

- *The Stanbury site showed greater numbers of 0+ fish in 1995 than in 1996. Equal numbers of 0+ trout were found at Haworth during 1995 and 1996. Fish in the middle size range 10-20cm, and >20cm were more abundant in 1995 at both sites* (extracted from Fisheries Surveys 1996 report).

As identified in previous fisheries surveys, siltation of spawning gravels may require remedial action upon the restoration of normal flows. Mitigation fish restocking has not been required to date in the Aire catchment. If losses to fish populations are identified in surveys, this option will be carried out on restoration of normal flows.

6.0 RIVER CALDER CATCHMENT

6.1 Background and issues

The Calder rises west of Todmorden on the Pennine Moors and flows 87 km to join the Aire at Castleford. Many moorland streams at the head of the Calder Valley are uncontaminated, and have been heavily exploited for public water supply. There are thirty-nine reservoirs licensed for this purpose, and the area's needs are supplemented by imports from the Winscar Reservoir at the head of the Don catchment and from the rivers of North Yorkshire. When rain fails to occur in large quantities, any that does fall upstream of the Pennine reservoirs is retained to raise reservoir stock levels. This results in the rivers being provided only with the minimum compensation flows required by statute, or even a reduced figure allowed under a Drought Order.

The reservoirs in the Pennine headwaters of the Calder catchment are linked by a complex pipe network, with the effect that reservoirs from one system can be used to supply populations in adjacent systems. For example, the water supply for Bradford can be supplied from a number of reservoirs. This allowed the Agency in 1995, before the severity of the drought was known, to form a priority list of reservoirs where a cut in compensation flows would have a greater or lesser effect on the tributaries that they supply. This list was drawn up by a multi-functional team comprising an ecologist, a fisheries officer, an environmental protection officer, and a water resources officer.

Each reservoir and its associated tributary was considered in relation to the following points:

- The amount of other water that could be expected to come from ground water and other tributaries.
- The requirements of downstream abstractors.
- The required dilution for downstream discharges.
- The conservation value, including fishery status, of the receiving watercourse.

The priority list produced is appended as **Table 6.1a**

The intention was that compensation flows should first be reduced from those identified as low impact and if need be from those with a medium impact. The initial phase of compensation cuts had involved only those reservoirs identified as 'low' priority. However, as the effects of the drought worsened and water supplies became critical, the reservoirs listed as medium and high priority were included. By 1996, all of the compensation flows in the Calder catchment had been cut to a third. The Calder group supplies Kirklees and Calderdale, and total flows for the group had been reduced from 97.6 tcmd to 32.6 tcmd. Drought Orders that were introduced in the late summer and autumn of 1995 continued, with extensions through to February 1997.

The Calder valley has a history of industrial exploitation and neglect, and the legacy of this can be seen throughout the river's length from Todmorden down to its confluence with the Aire at Castleford. Water quality in the main river remains a restricting factor in the development and maintenance of its fish populations. Above Todmorden, the effects of long abandoned mine workings still have an impact, while further downstream discharges from several sewage treatment works continue to limit the development of sustainable fisheries.

One of the main water quality issues was considered to be a lack of dilution for the many discharges to the river, most notably the STWs in this heavily populated catchment. In the summer of 1995, YWS had installed continuous dissolved oxygen (DO) monitors at critical locations and a comprehensive plan was devised whereby actions were triggered as DO levels dropped (see **Figure 6.1a**). The situation at Brookfoot, which is downstream of a major STW, had given concern in the summer of 1995; aeration and daily bank walking had been introduced. In the summer of 1996, with the continuing dry sunny weather, the DO levels at Brookfoot dropped below two mg/litre (particularly at night), despite aeration. Weed was cut to try to alleviate the situation.

6.2 Purpose

There are no river abstractions for public supply on the Calder catchment, but most of the headwaters are impounded and flows are maintained by compensation releases. Since the Pennine Reservoir Drought Orders cut the compensation flows, a variety of monitoring activities was undertaken to evaluate the potential impact and provide early warning that mitigation measures should be implemented. **Figure 6.2a** shows the extent of the monitoring programme.

6.3 Hydrology and Water Resources

The Calder catchment typically has around 1315mm of rain each year. In 1996, the catchment had 1085mm, which was 82% of the LTA. In the first half of the year rainfall had amounted to just 37% of the year's total, before the storms of the late summer and the more prolonged rain of the autumn. November had 133% of its LTA, including a week with 73mm (much of it snow), which was over double the LTA. The raingauge at Gorple Reservoir recorded 19mm of rain in an hour on 25 November, although the wettest week of the year was just before Christmas, with 83mm. Drier conditions prevailed in 1995, with only 1019mm, amounting to 79% of the LTA.

The flows in the Calder are measured at Caldene Bridge in Mytholmroyd, at Elland, and at Methley, just upstream of the confluence with the Aire. Several of the main tributaries are also gauged. The upper Calder responds rapidly to rainfall, but the response of the lower Calder is both later and less pronounced. Flows in the Calder were still only just above the dry weather flow at the beginning of 1996. Despite periods of higher flow in January, February and March, only the highest values for February were above the LTA; the other winter months remained entirely below average, even after rain. The low rainfall figures and the very low base flows resulted in a drop to the DWF. This happened in June 1996 for the upper Calder (around two months earlier than 1995), and in August for the lower river (around the same time as 1995). The flows remained close to or below the DWF from mid-June until the rain at the end of August. Although the underlying base flow started to rise away from the DWF, this did not occur until October. It did not happen at all in 1995. The flows continued to rise until just before Christmas, when there were very high flows following the rain. They then fell steadily until the end of the year, by which time they were well below half their LTA.

The reservoirs at the beginning of 1996 were less than 30% full, but quickly rose to over 50% during February and March, and then climbed very slowly up to 57% by early July. The normal summer draw-down reduced stocks, apart from a rise due to the late August rain, until the onset of wetter weather late in September. There followed a sustained increase in stocks, from 45% in the middle of September to 86% full by the end of November.

Reservoir stocks, rainfall figures for 1996 and the comparisons with the LTA for 1995 and 1996 can be seen in **Figures 6.3 a.**

6.4 Water quality

The Agency's water quality department's role in the drought was twofold: firstly, to protect the Calder's environment from the worst effects of the drought, introducing mitigation measures where appropriate, and secondly, to monitor the effects of the drought, both for short term operational requirements and for the longer term assessments.

Water quality monitoring was undertaken by the Agency and YWS. Part of the Drought Order conditions required YWS to monitor the effluent from STWs in drought- affected reaches. Results from the following STWs were reported to the Agency:

- Calder: Eastwood, Redacre, Milner Royd, Halifax* and Brighouse STWs
- Ryburn: Ripponden Wood STW*
- Holme: Neiley STW*

The effluents were tested for BOD, NH_3, COD (Chemical Oxygen Demand) and suspended solids. Results were supplied weekly except for the critical STWs marked*, which were sampled three times a week.

Instream spot sampling by YWS, to monitor for DO and NH_3 was originally requested at several locations on the Calder and its tributaries. This was later superseded by continuous DO monitoring at critical locations on the Calder. The locations were chosen in light of the results of the spot sampling programme. Continuous monitoring was deemed necessary when it was realised that random spot sampling would not be effective in monitoring diurnal sags in DO levels, and that the reporting of critical levels would come too late to be of use. The original drought orders had specified that aeration was to take place when oxygen levels fell below 60%. In the coarse fish reaches, this was inappropriate as levels were normally in this range, and the installation of continuous monitoring allowed DO levels to fall below this point before aeration was triggered.

Continuous DO monitors were installed at the following locations:

- **River Holme at Honley (downstream Mag Brook)**, that replaced daily sampling for DO and Ammonia between 6am and 7am at three locations: downstream Neiley STW, downstream Mag Brook and downstream Holme/Colne confluence.

- **River Ryburn downstream Ripponden Wood STW,** that replaced daily sampling at the same location.

- **River Calder at Brookfoot**, that replaced twice weekly sampling at North Dean and Brighouse.

The random spot checks on compensation flow releases were increased from twice a year to monthly and at certain times weekly. This was to check that YWS were adhering to the reduced compensation flows allowed under the drought orders. Site locations, which were mostly just below the reservoir outfalls, are listed in **Table 6.4a**.

In the critical locations, weekly and in some cases daily results were faxed to the Agency to aid in the day to day decisions that had to be made in order to sustain the oxygen levels in the river. As well as monitoring the results supplied by YWS, the Agency increased its own GQA sampling frequency at critical locations. On the Calder these were done weekly instead of monthly. The analysis of the basic set of determinands for rivers (ammonia, BOD, conductivity, nitrite, pH, solids and TON (Total Organic Nitrogen). During 1996, this monitoring programme was focused on specific reaches identified as likely to be affected during a continued drought. The major changes in water quality are summarised in **Table 6.4b**.

Water quality modelling of the Calder was carried out to assess the deterioration in water quality that could arise from reductions in compensation flows. This was done by modifying the existing TOMCAT model of the Calder to represent effluent loads and river flows for summer 1995. Checks were carried out to ensure that the model gave realistic predictions of river quality prior to testing the effect of reduced compensation flows.

Initial fears that the lack of dilution from STWs on all the rivers affected by reduced compensation flows would cause increased ammonia levels proved to be unfounded. Ammonia monitoring by YWS was consequently dropped in favour of continuous DO monitoring where appropriate. The Agency continued to monitor ammonia levels throughout the period.

To assess the effects of the drought on chemical water quality, an assessment using GQA methodology was carried out on river samples taken during 1995. This was then compared to a baseline GQA for 1992-94. A similar procedure was adopted for the 1996 data, but where back data were available, GQA quality assessments were made for the individual years from 1991-1994, to give a fuller picture, **Figures 6.4a to 6.4i.**

In the Calder catchment, the majority of the reported water quality deteriorations for 1995 were not sustained in 1996 (**Table 6.4b**). Some, but not all, of the 1995 'deteriorations' are now thought to be due to pollution events as they are the result of a low number (often one) of uncharacteristic samples in the data set (eg Black Brook, **Figures 6.4a-b** and Cusum analyse **6.4j-k**). It could also be argued that low river flows limit the dilution available to absorb one-off pollution incidents, which therefore tend to be more significant in their effect. The possible exception is the R. Ryburn downstream of Ripponden Wood STW where lower available dilution is likely to have contributed to the marginal grade change in 1995. Other deteriorations reported for 1995, when looked at in more detail, were marginal. These changed again in 1996, almost certainly because both years' classifications were based on a limited number of data points (eg. Calder between the confluence with the Colne and Mirfield, **Figure 6.4c**.

One previously reported deterioration that was not carried through into 1996 was due to capital improvement at Huddersfield STW where the storm tank effluent was diverted out of the receiving watercourse (R. Colne at Deighton) into the main R. Calder, **(Figure 6.4d)**.

The vast majority of the improvements in water quality reported for 1995 were maintained in 1996. In addition, one or two reaches exhibiting 'no change' in 1995 improved in 1996, for example, the reach Cragg Brook to Luddenden Brook which is sampled at Brearley Weir (**Figure 6.4e** and Cusum analysis **6.4l**). Many of the improvements reported in 1995 were ascribed to less frequent operation of CSOs. In 1996 all the improvements in river quality were in reaches receiving inputs from CSO and can therefore also be attributed to their less frequent operation in drought conditions. Two of the improved reaches were also downstream of STWs where recent capital expenditure has resulted in significant diversions of effluent out of the catchment (Meltham and Huddersfield- Deighton). An upgrading reported in 1995 was further enhanced in 1996 due to continuing effluent quality improvements at Meltham STW (Mag Brook, **Figure 6.4f**).

Particular stretches were thought to be vulnerable to low dissolved oxygen (DO) levels. Between 1994 and 1995, the Cragg Brook to Luddenden Brook stretch of the Calder showed a deterioration from chemical GQA grade B to C (**Figure 6.4e**). Although quality deteriorated, the DO was, however, maintained at adequate levels: the 10%-ile value was 66% saturation. In 1995, both the Agency and YWS installed DO meters during the early part of the drought, until it became established that, even in low flow conditions, low DO was not threatening the fishery.

The Black Brook to River Colne stretch of the Calder was also considered vulnerable and, as it is a long reach, it was subdivided by a non-GQA sampling point. While the lower section showed no discernable change **(Figure 6.4g)**, the additional sampling point at Brighouse indicated reduced DO levels, pointing to a possible dissolved oxygen sag within the reach. This was confirmed by boat surveys in 1995 that pinpointed the sag in the Cromwell Bottom - Brookfoot area. Aeration was put in at the former Elland Power

Station site in November 1995. Surveys suggested that the type of aeration used was limited in its effectiveness. A recording DO meter was installed at Brookfoot and control levels were agreed with YWS at which aeration and *daily bank walking* would commence, based on the information from the meter. *If any dead or distressed fish were observed this would have triggered the emergency fish rescue procedure.* Dissolved oxygen levels remained low throughout the summer of 1996, despite near continuous aeration at Brookfoot, especially at night when they dropped below 2mg/litre. The nocturnal nature of the sags suggested that excessive weed growth was involved. At the end of July, low DO was also being recorded at midday and weed was cut on 30 July in an attempt to alleviate the situation.

The exceptionally low DO levels recorded in the mid-reaches of the River Calder at Brookfoot, Brighouse, are believed to be due to a combination of: low river flow; a high proportion of treated sewage effluent; the fact that the stretch of river affected is in effect split into a series of 'pounds' separated by weirs; high temperatures and excessive weed growth. Further investigations in this area are planned.

Other vulnerable locations included the trout fishery headwaters that take STW effluents such as the River Ryburn (Ripponden Wood STW) and the River Holme (Neiley STW). In 1995 attempts were made to aerate the effluent from Ripponden Wood prior to discharge to the river. Continuous DO monitoring downstream showed that this action was of limited benefit, and in fact the DO did not fall to levels that put the trout fishery at risk **(Figures 6.4h-i and 6.4m)**. These measures were not repeated in 1996, but the downstream monitoring was left in place.

As the Calder reservoirs became seriously reduced in volume, the impacts of high suspended solids became a concern. These levels were monitored both by chemical analysis and visual assessment. Measures to reduce these suspended solids by installation of straw bale dams to filter and settle the solids were experimented with at a few locations. It remained a serious problem, and fish recruitment was forecast to be adversely affected in 1996 through interstitial filling of the spawning gravels. No acute toxic effects were caused and no fish mortalities occurred as a direct consequence of suspended solids.

6.5 Ecology

The Calder catchment supports several conservation sites that are important at international, national and county levels. Some of the wildlife depends upon small acid flushes, marshy areas etc., which are sensitive to low flow conditions. In general, streams in the upper reaches of the Calder catchment are of good biological quality, supporting stonefly dominated faunas, although the minewaters in the upper reaches of the river appear to restrict the abundance of some taxa.

Some of the upper tributaries are vulnerable to acidification because of their poorly buffered nature (these have been identified as Alcomden Water, Luddenden Brook, Booth Dean Clough, Merrydale Clough, Walsden Water, Holywell Brook, River Ribble, and

New Mill Dyke). The main river channel is heavily engineered in this urbanised valley throughout most of its length, especially through Todmorden. This reduces the river's capacity for self purification downstream of polluting inputs. The urban runoff from Todmorden causes a reduction in biological quality and a further reduction occurs downstream of the effluent from Eastwood STW. Downstream of Hebden Bridge some recovery is achieved, aided by the diluting influences of Hebden Water. At Sowerby Bridge there are problems with intermittent pollution that have been difficult to trace.

Biological quality decreases further in Sowerby Bridge, and from Copley downstream the quality remains generally poor. Downstream of Huddersfield STW final effluent, the fauna supported by the river is seriously restricted and little recovery is achieved. In general, the more urbanised areas have problems with mild sewage pollution and the heavily industrialised rivers Colne and Holme have considerable problems with chemical pollution.

River habitat surveys (RHS) were undertaken by YWS to monitor habitat changes along the river corridor and to identify the best (most typical) site for invertebrate sampling in the headwaters where new sites needed to be located.

6.5.1 Aquatic macro-invertebrates

As water quality problems have been the main issue in the Calder catchment, most of the routine invertebrate monitoring in recent years took place in the lower, poorer quality reaches. The pristine headwaters have a small data set: consequently, reliable comparisons with non-drought data in the upper reaches will only be possible at the end of the drought when the watercourses have made some recovery. This final full analysis will encompass both Agency and YWS data. Agency data for 1995 and 1996 have been looked at and reported on for this report

Before the 1995 drought, many sites were already routinely monitored by the Agency for their biological quality. During 1995 an increased sampling programme for the GQA survey was carried out. Sites were sampled twice during the year, once in spring (March to May) and again in the autumn (September to November). The routine sampling programme for 1996 was extended to include sites that may have been sensitive to the prolonged drought conditions: this involved a detailed survey of sites on both impounded and non-impounded watercourses in the upper Calder catchment. Sites were chosen preferentially where there were previous data available, although for many sites these did not exist and RHS surveys were used to aid new site selection. It was agreed that this detailed survey should continue until three years after drought conditions had ceased in order to establish the effects of the drought and monitor the recovery process. All sampling and sorting have been carried out using standard techniques and a quality audit system is in place. All samples taken in 1995 and 1996 have been sorted to species level.

YWS have also been carrying out surveys, at sites agreed with the Agency. In 1995, staff from YWS did this work, but in 1996 they employed outside consultants. Some of the YWS sites have also been sampled by the Agency to check results.

Thirty-two sites on the Calder were sampled by the Agency and thirty-five sites by YWS (**Table 6.5a**). The Agency's sampling in this catchment was designed to assess the biological quality of the tributaries affected by changes in compensation flows. The work would provide a comparison with the representative catchments on which YWS detailed survey work was derived. YWS's sampling was to assess the effects of changes in flow conditions on the faunal communities in the Calder and a few representative tributaries, and since few data exist for the system prior to the implementation of the Drought Orders, sampling is to continue for a period of at least two years after cessation of the drought to ensure recovery of the fauna and to have data available for comparative analysis. The complete report, looking at both YWS sites and Agency sites, will be produced in the future; however, from the Agency's sampling programme and past data, some trends can be seen and some tentative conclusions drawn.

Results from the RIVPACS analysis are given in **Table 6.5b**. Although most sites showed little or no change during 1995-96, three sites showed distinct patterns, possibly related to the drought, although a full analysis is not possible until the end of the monitoring programme. **Hebden Water at Hebden Bridge** showed deteriorations in biological quality in both autumn 1995 and 1996 from GQAO grade *b (good)* to *d (fair)* and from grade *b (good)* to *e (poor)* respectively, with recovery noted in spring 1996.

River Holme at Bottoms Mill showed a reduction in biological quality in spring 1996, from grade *b (good)* to *e (poor)*, but recovered only to grade *c (fairly good)* in autumn 1996. Prior to 1996 it had been grade *d (fair)*. **Black Brook at Greetland** showed an improvement in biological quality in spring 1995 from previous poor status. This then deteriorated in autumn 1995 from grade *c (fairly good)* to *d (fair)*, and there was only slight improvement in autumn 1996, although this change is probably not a significant one.

Cragg Brook upstream of the Calder showed deterioration in biological quality in the autumns of both 1995 and 1996, from grade *b (good)* to *c (fairly good)*, and from grade *b (good)* to *d (fair)* for respective years.

In an effort to reduce spatial and zonal influences on the analysis of drought impact, multivariate analyses were carried out. Clustering and ordination of the combined data for the main River Calder indicated three distinct zones and an outlier (**Figure 6.5a**).

a. Upper Calder - Lydgate and upstream of Tannery
b. Intermediate - Woodhouse to downstream of Brearly Weir
c. Lower - Copley to Mirfield
d. outlier - Sowerby Bridge

Clustering and ordination of the combined data for the tributaries provides a set of groupings based mainly on biological quality rather than catchment, confirming the impact of biological quality (**Figure 6.5b**). Further analysis is ongoing to determine specific trends in relation to the data from individual seasons.

6.5.2 Fisheries

Almost from its source, the Calder suffers from the effects of industrial activity. Abandoned mines upstream of Todmorden quickly combine with the river's natural acidity to limit the maintenance and development of the brown trout populations. As the river flows down towards Hebden Bridge, conditions begin to improve as tributaries such as Colden and Hebden Water add their flow. Many of the tributary sub-catchments have also been subjected to industrial development and, although water quality in many has now recovered, there remains a legacy of impoundments that limit the free movement of fish within the system.

Hebden Water is one of the most important of these tributary streams. It is a highly productive brown trout nursery area, contributing significantly to the maintenance of populations of this species in the main river.

Between Hebden Bridge and Sowerby Bridge, the Calder receives discharges from several sewage treatment work facilities which, in the past, have been implicated in major fish kills. From Sowerby Bridge to Mirfield, the Calder is principally a coarse fishery. Traditionally, natural reproduction has been supplemented by restocking work carried out by, and on behalf of, angling interests. The natural sustainability of these populations remains chronically affected by variable water quality.

Below the outfall from Huddersfield STW at Mirfield, the chemical quality of the Calder deteriorates rapidly, falling to water quality Class E (poor). Below this point, fish populations are, at best, sporadic, and in some areas almost totally absent.

Some fisheries monitoring was devised in 1995 using the priority list of watercourses which were vulnerable to reduced flows (**Table 6.1a**). Fish population surveys were repeated in November-December 1996, slightly later than the 1995 surveys. The full report by Fisheries Surveys Ltd is available. In summary, these surveys identified a number of significant changes in fish population structure. Verbatim extracts from the report are included in italics where appropriate.

The impacts of these changes when examined in connection with Drought Order-affected reduced flows and associated factors, eg. elevated suspended solids, are not yet clear. Variations in fish populations occur naturally, and several years' data usually have to be examined before conclusions can be drawn. The third survey, to be carried out in 1997, will identify with more confidence the impacts of the 1995/96 drought.

At this stage, some of the predicted adverse impacts, eg loss of/absence of the 1995/96 year class of brown trout, have not been borne out by the survey reports. At several sites, elevated numbers of 0+ age group brown trout were reported. However, from other fisheries surveys carried out elsewhere in Yorkshire, it has been established that 1996 produced a strong year class for brown trout compared with 1995. This feature therefore was not unique to the Calder catchment.

Also, there was an overall reduction in older year classes of brown trout. This latter observation is significant and it is possible that the increased numbers of 0+ fish are a result of reduced interspecific competition and predation as opposed to improved spawning success.

Downstream migration of larger brown trout from tributaries into the main river Calder was identified by the increased incidence of brown trout in angler catches during 1995, which is also supported by the surveys.

The Calder tributaries were also surveyed in 1996 and results can be summarised as follows:

- Moderate to large reductions in total trout densities. A small number of sites showed increases and two remained unchanged.

- Moderate to large reductions in trout biomass density. Two sites showed increases, and two remained about the same.

- The above observations are accounted for primarily by reductions in the occurrences of older, larger trout (>10cm).

- Almost all sites showed large or very large increases in the occurrence of 0+ trout. There are some exceptions where the differences were much smaller.

- Mean lengths of 0+ trout were significantly smaller in 1996 than 1995. This may reflect increased competition for food due to higher densities.

In the **Hebden Water catchment** the following observations were considered significant:

- *Hebden stream gauge, Crimsworth Dean confluence and Rose Mill Hill sites showed greater numbers of 0+ fish in 1996 than in 1995. However, all three sets of samples showed lower numbers of fish in the 10-20cm and >20cm length ranges in 1996. The mean size of first year fish was marginally greater in 1995. Overall densities were similar in the two years at Crimsworth Dean Beck and Rose Mill Hill, but slightly higher at Hebden Stream Gauge in 1995.*

- *The control sites at New Bridge and Crimsworth Dean Beck both showed a marked loss of 1+ and larger fish in 1996. Crimsworth Dean showed a 71% loss and New Bridge declined by 26%.*

Changes in numbers of larger trout between 1995 and 1996 were less drastic than at many other sites in the regulated sub-catchments. This constitutes the only indication that reservoir regulation activities may have produced impacts over and above those caused by the drought itself.

In **Hebble Brook:** *numbers of 0+ fish were relatively low in both years at Ogden and*

Mixenden. At Wheatley, 0+ numbers were greatest in 1996. Fish in the middle and larger size ranges were more abundant in 1995 than in 1996 at all sites. The mean size of the first year fish was marginally greater in 1995 at both sites.

At all sites surveyed on the Hebble Brook, there was an overall reduction in both density and biomass for older year classes in 1996. The 1995 surveys identified high levels of turbidity at the upper sites, and settled sediments at the lower sites, representing a potentially serious hazard to spawning success in Hebble Brook. In contrast, the 1996 surveys identified that successful spawning had taken place, but this could be attributed to better survival rates caused by less predation from older fish.

Extensive lengths of Hebble Brook are culverted through Halifax: therefore, recruitment from downstream is unlikely.

Midgelden and Gorpley Beck

- *There were no fish found at Midgelden Brook or in its tributary, Gorpley Beck, which was a replica of the survey results of 1995.* It is probable that there are naturally no fish in these tributaries.

6.5.3 Agency Fisheries actions

As the drought continued into 1996, the 'Emergency Fish Rescue Action Plan' was again brought into action. Critical areas of the Calder and its tributaries were identified, continuous monitoring of dissolved oxygen levels was undertaken and an emergency response procedure was implemented similar to that of 1995. When oxygen levels dropped below 4mg/l, daily oxygen monitoring was carried out. When levels dropped below 3.5mg/l, emergency aeration of the river was undertaken and early morning inspection of the river from the bank at critical locations was organised to look for indications of distressed fish. Fish rescue teams were placed on standby to begin emergency fish rescues upon confirmation of reports of distressed fish. No such major sightings were reported and thus there was no requirement for fish rescues during 1996.

Sublethal levels of dissolved oxygen were recorded in 1996, despite aeration. Although the aeration was thought to have had only a limited effect, and was relatively expensive, it is likely that the marginal increase did prevent fish mortalities. At one critical site on the Calder, extensive beds of submerged aquatic weed were cut and removed to reduce diurnal effects of plant respiration which was contributing to the very low nocturnal oxygen levels.

Inspections were carried out on all tributaries affected by reduced flows to record evidence of siltation and loss of available spawning gravels.

It was initially assumed that the reduced flows in the tributaries would inhibit spawning, and in 1995 funds were allocated for replacement of stocks in those tributaries affected by reduced compensation flows. Restocking was reserved for those areas identified by the fish population survey as having suffered damage. Maintenance of the genetic integrity of these fish populations is highly valued and so restocking would only have been considered if significant damage had been identified. No restocking was in fact required, as the survey reports for 1995 and 1996 indicated spawning had been very successful. The high levels of brown trout recruitment had been attributed to reduced levels of predation through the downstream displacement of adult fish, through loss of habitats. It was thought that introductions of the same age class would have further increased competition in the following year, providing no benefit, and may have caused damage to the ecosystem.

7.0 RIVER DON CATCHMENT

7.1 Background and issues

The River Don drains the Pennines to the west of Sheffield and flows through Sheffield, Rotherham and Doncaster to join the tidal River Ouse at Goole. The Don catchment can conveniently be divided into the upper Don, comprising the upland headwaters and the stretch of main river through Sheffield to the River Rother confluence, and the lower Don, from the Rother confluence down to the Ouse. The headwater catchments are moderate to steep undeveloped moorlands, which feed reservoirs used for public water supply to Barnsley and Sheffield. The reservoirs are arranged in six groups located on the Don and its five main tributaries in the upper catchment. Each reservoir group makes compensation releases to the river downstream.

The supply drought affected the Don catchment much later than some of the other river catchments: indeed, water from Winscar Reservoir had been used to augment supplies to the Calder conurbations. With the continuation of the drought, Drought Orders were issued for the Don catchment in January 1996 for the Sheffield source reservoirs. The orders reduced the levels of release of compensation water to a third of their licensed statutory amounts. In March 1996, with the drought conditions continuing and with stocks in Winscar Reservoir (which feeds the upper Don) down to less than 20%, a further order was applied for on this group; it was granted in May 1996. The Winscar Reservoir Compensation Order expired in November 1996, and the Sheffield reservoir Drought Order was renewed in June 1996 but expired in January 1997.

7.2 Purpose

The YWS Environmental Statement accompanying the Drought Order application concluded that the proposed reductions in compensations would have no acute impact on the quality and ecology of the Don and its tributaries. This was a reasonable assumption, provided the major effluent treatment works were operated to their maximum potential and that the Order related to the winter period when the impacts could be expected to be less. Conditions were imposed on the Drought Orders that covered the requirements for monitoring, mitigation and restoration of the river. The particular concerns for the Don related to the longer term impact of the reduced flows on the ecology of a river that was just starting to show signs of recovery from more than a century of industrial pollution. Mitigation measures were taken, and monitoring started in January 1996, (see **Figure 7.2a** for extent).

7.3 Hydrology and water resources

The Don catchment typically has around 784mm of rain each year but in 1996 the catchment had 643mm, or 82% of the LTA. The first half of the year had 41% of the year's total rainfall, although it was the end of September before consistent rainfall replaced the occasional thunderstorm. November had 160% of its LTA, although much of this fell as snow. The raingauge at Winscar recorded 130mm for one week, although this figure would not be exceptional in a non-drought year. In 1995, the catchment had only 633mm, amounting to 80% of the LTA.

The flows in the Don are measured at Hadfields (Meadowhall) and Doncaster. Several of the main tributaries are also gauged. Like the other Pennine rivers, the upper Don and its tributaries respond rapidly to rainfall. However, the response downstream is both later and less. Flows were still only just above the dry weather flow by the end of 1995, so despite periods of higher flow during the winter, only the highest values for February were above the LTA; the other winter months remained entirely below average, even when swollen by rainfall.

The low rainfall figures and the very low base flows resulted in a steady fall to DWF occurring again in 1996. The DWF was reached around a month earlier than 1995 for the Don at Doncaster, and six weeks earlier for the Rother and the Dearne. The flows remained at or below the DWF from mid-June into November. The flows rose slowly until just before Christmas, when there were very high flows following the rain. The Don's flow on 20 December was the third highest ever recorded. The flows then fell steadily until the end of the year, when they were back below half their average.

The YWS Southern Division reservoirs at the beginning of 1996 were less than 30% full, but quickly rose to over 60% during February and March. Stocks remained almost steady until the end of June. A steady fall then took stocks down to 33%, with the low point occurring in mid-October, before they rose with the rainfall. The reservoir levels rose from 36% full to 91% in four weeks (the fastest rise on record), and were completely full by the end of the year. Reservoir stocks, rainfall figures for 1996 and the comparisons with the LTA for 1995 and 1996 can be seen in **Figure 7.3a**.

The Agency undertook an enhanced programme of spot gauging of compensation flows, with random monthly checks downstream of the releases (normally biannual), to check compliance with drought orders. A list of these sites is appended as **Table 7.3a**.

7.4 Water quality

7.4.1 Changes and state of water quality

Although in terms of rainfall, the drought was less severe in 1996 than it had been in 1995, in terms of water quality there was a greater impact on parts of the Don catchment in 1996. This was because none of the compensation flows, which provide a very significant proportion of the base summer flows in the Don upstream of Blackburn Meadows STW, were reduced in 1995. However, in January 1996, following the granting of Drought Orders, most of the compensation flows (with the exception of Winscar) were reduced to one third of their normal values. This was followed in May 1996 by a similar reduction at Winscar.

In 1995 the lowest mean daily flow (which occurred on 6 August at Hadfields) was 109.4 tcmd, whereas in 1996 the lowest mean daily flow was only 65.49 tcmd, reducing the dilution ratio for Blackburn Meadows STW Final Effluent from just less than 1:1 to 1 part river to two parts sewage effluent. In comparison, the River Sheaf (which does not receive any compensation flows, but was affected by low summer flows) had a lowest mean daily flow in 1995 (on 21 August) of 4.92 tcmd, whereas in 1996 the lowest mean daily flow (on 19 September) was 5.53 tcmd.

A site by site evaluation of all the GQA results and conclusions regarding likely causes is shown in **Table 7.4a** and **Figures 7.4a-h**. Cusum analysis has been performed on some of them and are available.

The main findings were that on the **Don,** a deterioration in water quality equivalent to GQA grade B in 1995 to grade C in 1996, took place downstream of the confluence with the Scout Dyke (**Figure 7.4a**), downstream of Stocksbridge STW, and downstream of Jamont. The change was due to a slight rise in average BOD (from 1.90 mg/l to 2.42 mg/l).There was also a deterioration in the 1994-96 GQA grade from B to C compared to the 1993-95 period downstream of Stocksbridge STW (**Figure 7.4b**), downstream of Jamont, and in the stretch between the confluence with the River Loxley and the confluence with the River Sheaf (**Figure 7.4h**).

The cause of these deteriorations was almost certainly reduced dilution for discharges (including those from CSOs in the Hillborough area) resulting from the very substantial reductions in compensation flows. Downstream of Jamont, the deterioration was also partly caused by poor effluent quality from Jamont itself. This poor quality effluent was as a result of the company having to recycle the effluent, because the cutbacks in compensation flow from More Hall Reservoir reduced the availability of process water.

Downstream of Blackburn Meadows STW water quality was generally better (**Figures 7.4c** & g and particularly **Figure 7.4.i**), due to reduced ammonia levels in Blackburn Meadows effluent. This was in spite of the drought, and was all the more remarkable bearing in mind the substantially reduced dilution for this effluent. Improvements have been seen since 1991 due to the commissioning of the first phase of the diffused air plant.

On the Don tributaries, no significant grade changes took place, although there were in some instances peaks in BOD and ammonia, probably resulting from reduced dilutions for discharges from CSOs and industrial effluents. It is also worth noting that water quality in the River Sheaf, which does not receive discharges of compensation water, showed little variation between 1995 and 1996.

The impact of drought on water quality was not as severe as had been feared, although significant deteriorations did take place in several stretches of the Don. Emphasis was placed on metal analyses in the Don catchment as it was perceived that reduced dilution of minewaters would have had an effect on their concentrations. However, no significant effect was found.

7.4.2 Other Water Quality actions

A letter was sent out to all traders who are consented to discharge to river, informing them of the situation regarding potential lack of dilution water in the rivers receiving their effluents, and asking them to be more vigilant.

As part of the mitigation measures requested in the drought orders, YWS was asked to review the operation of a number of their STWs to improve efficiency where possible. A team of people from the Agency and YWS visited all of the STWs to recommend measures that could be taken. The performance of the various STWs is listed below:

- Blackburn Meadows: Ammonia levels were significantly lower than in previous years, although suspended solids levels were higher. This is thought to be a spin-off from the refurbishment of the primary tanks, completed early 1996, which reduced the organic load to the aeration units, **(Figures 7.4c & 7.4j)**.

- Crow Edge: These works were extensively refurbished in 1996, following which there has been a significant improvement in effluent quality. However, there was a temporary deterioration in effluent quality while the refurbishment work was being carried out.

- Ingbirchworth: Some samples indicating poor effluent quality were obtained early in 1996, after which time YWS introduced intermittent chemical dosing, and constructed a tertiary reed bed, which resulted in considerable improvements in effluent quality.

- Cheesebottom: Effluent quality in 1996 was, disappointingly, generally not as good as in 1995. The most likely cause for the slight deterioration was mechanical breakdown of the filter drives. These are scheduled for replacement in 1997.

- Stocksbridge: Some of the disused sludge drying beds were converted for use as tertiary treatment tanks, and this appears to have resulted in a slight reduction in suspended solids levels in the effluent. The works generally have continued to perform well within current consent limits, **(Figures 7.4b & 7.4k)**.

- Wharncliffe Side: Effluent quality in 1995 and 1996 was generally better than in preceding years, and the works has continued to perform well within current consent limits.

- Aldwarke: YWS was granted a temporary relaxation in flows requiring full treatment to enable partial nitrification to be maintained, pending completion of the Urban Waste Water Treatment Directive. This resulted in considerably lower ammonia levels in the final effluent, with a beneficial effect on the Don downstream.

There was concern over other major impacts on the Don system, and the actions and implications are discussed below.

The drought had a major impact on the discharge from the Jamont (Oughtibridge Mill) effluent treatment plant. Jamont is licensed to abstract up to 8.8 tcmd from Ewden Beck, just downstream of the More Hall compensation release. This amounts to virtually all of the available compensation water. YWS had originally planned to reduce the volume of compensation water to 3.03 tcmd (one third of the original amount, as with most of the other compensation releases), but following representations from Jamont and the Agency, they agreed to cut back to only 4.55 tcmd. Jamont had indicated that with this available water, although they would have to recycle 40% of their process water from final effluent, they should be able to maintain production and meet discharge consent limits. However, following on from the imposition of the effluent recycle regime the final effluent quality was not as good as in the preceding years. Solids content was higher, as was BOD in overall concentration terms (**Figures 7.4l & 7.4m**), although overall load was similar. In order to combat the problem of a large growth of filamentous bacteria, it eventually became necessary to stop the recycling and to kill off and then reseed the resident bio-population within the effluent plant. The recycling was replaced by a temporary importation of Don river water from the turbine cooling water discharge, and finally an easing of the flow restriction from More Hall Reservoir into Ewden Beck to 7.2 tcmd. Since then, the plant has performed well.

It was anticipated that minewaters, in particular the discharges from the abandoned Bullhouse and Sheephousewood collieries, would have a greater impact than normal due to the reduced dilution in the receiving watercourses. However, examination of the data at the downstream sampling points did not show any significant increases in the total iron concentrations. There are two possible reasons for this: firstly, the low rainfall may have resulted in the volumes of minewater discharged being significantly reduced and secondly, the lower river flows may have resulted in more of the iron being precipitated out immediately downstream of the discharge points, and upstream of the routine sampling points.

7.5 Ecology

The Don's source and upland catchment falls within the South Pennine Moors Special Protected Area and the Dark Peak SSSI, an upland of international conservation importance. As the Don flows off the moors, it passes through attractive wooded valleys, notably Wharncliffe Wood and Wharncliffe Craggs SSSI. The tributaries of the main river are equally attractive, particularly the Rivelin and Loxley valleys. The natural beauty of the watercourses in the upper Don catchment and their proximity to large centres of population ensures that they are well used by walkers, cyclists, birdwatchers and anglers. The Trans-Pennine Trail follows the Don valley for part of its route. In addition, the Five Weirs Walk initiative, by creating a footpath in the centre of Sheffield, has made the river more accessible to a greater number of people.

The white-clawed crayfish, *Austropotamobius pallipes,* has been recorded at several sites in the Don catchment. This species is protected under the Wildlife and Countryside Act 1981 and various other legislation. As populations are in decline globally, and there are some very important populations in the UK it was felt that more information on their distribution in the Don catchment and how they are affected by the low flows would be very important. YWS agreed to investigate by trapping and conducting a hand search at sites on the Loxley, Rivelin and upper Don. Despite previous records of crayfish in the upper Don, none were found in this survey.

7.5.1 Aquatic macro-invertebrates

The biological quality of the Don and its tributaries has been monitored routinely for many years. The routine sampling sites were selected to assess the general quality of the river and to assess the impact of particular discharges. The main discharges are the Cheesebottom, Stocksbridge and Blackburn Meadows STWs and the Jamont works, formerly called British Tissues. In addition, there are the Bullhouse, Loxley Bottom and Sheephouse Wood minewaters, which cause a reduction in the biological quality.

A joint Agency/YWS biological sampling programme on the upper Don catchment began in the spring of 1996. This included an extension of the Agency's routine monitoring programme, and river habitat surveys. Biological sites monitored for the drought were selected to assess the impact of low flows in general and to monitor the effects of specific discharges. Control sites on unaffected watercourses were included. Extra samples were taken to examine changes to the impact of the Bullhouse and Loxley Bottom and Sheephouse Wood minewaters; this was a repeat of special survey work carried out before the drought. In most cases, use of existing sampling sites allowed a comprehensive monitoring programme with the added advantage of having historical data for comparative purposes.

Fourteen sites on the River Don were sampled by the Agency and eighteen sites by YWS (**Table 7.5a**) although the Agency's sampling was confined mostly to the main river. It was designed to assess the biological quality of the system, since there was concern that reduction in flows, due to both drought and reduced compensation flows, would reduce effluent dilution, which could adversely affect water quality. The sampling by YWS included some sites on the main river but concentrated on those tributaries which would receive reduced compensation flows. Some control sites were also included. The purpose of this work was to assess the effects of changes in flow conditions on the faunal communities and, since few data exist for the system prior to the implementation of the Drought Orders (particularly in the upper pristine reaches directly affected by reduced compensation releases), sampling is to continue for a period of at least two years after cessation of the drought to ensure recovery of the fauna and to have data available for comparative analysis.

Environment Agency data for 1996 have been reviewed and, where previous data exist, comparisons with earlier years have been made. Biological quality gradings can be seen in **Table 7.5b**. At the uppermost site, Dunford Bridge, past data show a general good biological quality with GQAO grade *a (very good)* or *b (good)* being recorded. In autumn 1995, however, there was a deterioration from grade *a (very good)* to grade *c (fairly good)*, followed in spring 1996 by recovery back to grade *a*.

At sites further downstream, where quality was poorer, fluctuating between grade *d (fair)* and *e (poor)*, there was a pattern of poor quality recorded in spring, with slight improvements recorded in autumn. There will need to be comparison of these results with chemical quality and water quantity data to try to determine causes.

In order to understand the variability and patterns in the faunals from the upper Don catchment, preliminary cluster analysis and ordination for the combined site data was done. These indicated two zones and an outlier (**Figure 7.5a**). More detailed analysis will be undertaken at the end of the monitoring programme.

a. The upper river from Dunford Bridge to Soughley Bridge together with sites on the tributaries Sheaf and Loxley.

b. Mid and lower sites from upstream Morehall Bridge to Blackburn Meadows.

c. Outlier site for River Little Don.

Initial work on zone *a* indicated that the tributaries were sufficiently distinct from the sites on the main river to allow them to be considered separately, and that Dunford Bridge was also sufficiently distinct to omit from the grouping.

The ordination of the remaining four upper Don sites using average season and 1995/96 data showed both geographical and temporal trends (**Figure 7.5b**). The clustering identifies Starling Bridge as a unique site, with all but one sample clustering together to the exclusion of other sites, whilst the other three sites cluster variably.

The ordination of the middle and lower Don sites shows temporal and biological quality trends (**Figure 7.5c**) indicating that the faunal communities of all sites were sufficiently similar to remove any geographical split. This is a result of the restricted diversity caused by the poor biological quality of the sites. Clustering also reflects seasonal groupings and reflects the findings of the quality analysis that spring samples tend to have poorer quality than autumn samples.

Grouping of the two tributaries (Sheaf at Abbeydale and Loxley at A61 - **Figure 7.5d**) indicated that they were sufficiently distinct to preclude any linking of data, apart from the combined pre-1995 spring samples, which clustered at the highest level for the data set. Due to poor quality, the spring 1995 sample for the Loxley was shown as an outlier from the remainder of the data.

This preliminary study should help the assessment of drought effects as against habitat, zonal and water quality influences.

7.5.2 Fisheries

The River Don, once a prolific salmon river, has suffered from over a century and a half of industrial degradation. Extensive lengths of the river were rendered largely devoid of aquatic life due to the effects of both urban and industrial pollution. Major improvements in water quality achieved within the last decade have led to the restoration of fish populations throughout its length. The first salmon to return to the river, found in Doncaster in January 1996, is testimony to these improvements. The headwater streams, including the rivers Loxley, Rivelin and Sheaf, all support significant trout populations, and trout are also now present in the centre of Sheffield. The middle and lower reaches support valuable coarse fish stocks, and angling in these reaches is popular again.

The fish population data supplied by YWS to support the Environmental Statement for the River Don Drought Orders were based on out-of-date surveys. Advice was given by the Agency to instigate a more relevant investigation into the status of the fish populations and details of sites likely to be affected were identified and surveys arranged. Repeat surveys to measure post-drought effects have been organised, and these will be undertaken throughout the next three years.

The Institute of Freshwater Ecology was commissioned by YWS to undertake the fish population surveys at eight sites in the headwaters directly affected by Drought Orders within the Don catchment. These were carried out in April and October 1996, and also in March 1997. Comparisons between surveys have been restricted to the spring surveys only, to avoid natural influences in fish populations. The timing of fish population surveys for the Don catchment was different to that of the Aire and Calder, due to the later applications for drought orders/permits by YWS for this catchment. Unlike the River Calder catchment, no drought orders were imposed upon the Don catchment during 1995 and hence comparisons with survey data for that year were not possible.

Close liaison was kept with the Salmon and Trout Association, which controls much of the angling in the upper reaches of the river. Details of angler catch data for previous years were reviewed and examined concerning Drought Order proposals. The collection of data for 1996 was requested to investigate changes in species composition, changes in population densities and size frequencies.

In order to standardise the survey summaries, comments have been restricted to the brown trout populations only. There were twelve other species caught during the surveys, but many of these will have originated from adjacent still waters (eg. perch, roach, pike and ruffe). Only grayling and minor species (eg. bullheads, minnows, and stone loach etc.), can be regarded as indigenous to all of the sites surveyed.

Summarised findings of the fish population surveys are as follows:

- The total density of brown trout altered significantly between April 1996 and March 1997 at all sites apart from Ewden Beck and the Rivelin:

Slight increases in overall density were observed at the Bullhouse Minewater site and at Oxspring.

Overall decreases in trout densities were noted on the Sheaf, the Don downstream of Winscar Reservoir, the Little Don and the Loxley.

- Failures of recruitment of brown trout were observed in 1996 at two sites affected by drought orders. These were the Little Don and Rivelin. Recruitment was not observed to change significantly at the other two heavily impacted sites, Ewden Beck and the Loxley.

- Reduction in 0+ brown trout in the unregulated control site on the Sheaf are thought to have been related to redevelopment works undertaken at Abbeydale Industrial Hamlet. The value of the results from this site is thus negated.

- Below Winscar Reservoir, elevated temperature of the compensation water discharged is thought to account for the increased growth rates of 0+ brown trout. Increased growth rates could have also been caused by the observed decrease in trout density and biomass.

Comparisons between the spring surveys of 1996 and 1997 in the **Sheaf** displayed a decrease in total trout density. The Abbeydale Industrial hamlet mill dam restoration is thought to have had an adverse effect on fish populations due to increased suspended solids and siltation of gravel areas. This makes it difficult to use as a control site. Because of this and the loss of the other control site at Dunford Bridge following the granting of the Winscar Drought Order, other control sites are planned for future work.

No records for the introduction of artificially reared brown trout could be found for either the Sheaf or the mill dam at Abbeydale Industrial Hamlet. The following, however, is an extract from the fish population survey report and may indicate an un-consented fish introduction.

- *Of the 12 brown trout over 20cm captured three fish were identified as stocked fish by the presence of large numbers of replacement scales. The other trout examined all exhibited growth rates that are typical of naturally produced fish.*

Comparisons of the fish population survey results from the **Don upstream Bullhouse Minewater** showed increased trout biomass and total density. Numbers of 0+ trout remained unchanged. No records of stocking of artificially reared trout could be found, nor was there any information obtained from local angling interests to support the comments below. It is possible that extensive scale loss has resulted from low flows and the inability for fish to ascend or descend normally passable obstructions during natural migrations.

- *The increase in the estimated number of trout at this site observed in October 1996 has carried forward to the spring 1997 survey. This is probably due to the* *large numbers of stocked fish present and seven such fish were identified by appearance and large numbers of replacement scales.*

It is suggested by the fishery survey contractors that growth rates for the 1996 year class in the **Don downstream Winscar Reservoir** increased as a result of the discharge of warmer water from the reservoir. The habitat in this section of river is shallow and more suited to small fish; larger individuals would have to drop downstream to the deeper sections. Comparisons between the two spring surveys revealed that there was a significant reduction in total trout density at this site, with a reduced overall biomass. This factor could result in increased growth rates due to reduced intraspecific competition.

- *The 1996 year class has grown significantly faster than the 1995 year class in its first year. An increase of this size would normally be the result of a decrease in density or an increase in the temperature of the water.*

Reference to large numbers of stocked fish is again identified for the **Don at Oxspring** but this cannot be corroborated with documented evidence in the form of consents etc.

- *The greater number of trout captured at this site in October has carried through to this spring but as suggested at the time this is the result of a larger number of stocked fish being present in the river this spring.*

The occurrence of a small number of rainbow trout in **Ewden Beck** is most likely to have been a result of artificial stocking. The absence of a 1996 year class supports this theory. Stocking of rainbow trout into this type of watercourse would not have received Agency approval and, consequently, the introduction will have been un-consented, or they will have escaped from an adjacent stillwater.

- *Apart from one very large brown trout the population structure for brown trout in this stream remained unusual with few fish greater than 22cm found. The reason for this is unclear as the habitat at this site contained plenty of cover and deep water and was suitable to support larger trout.*

- *The population structure of both brown and rainbow trout suggests that there may have been some event that resulted in large or complete mortality of fish and these were replaced with a large stocking of rainbow and brown trout fry in 1995.*

Brown trout fry were introduced to Ewden Beck during May 1995 and it is unlikely (but possible) that rainbows were accidentally supplied at that time by the fish farm. Summarised comparisons between the two spring surveys showed similar overall densities for trout but a slightly raised biomass. Numbers of 0+ trout had declined in 1996. The influence of hatchery reared fry should be considered here.

The overall biomass had reduced in the **Little Don downstream of Underbank**

Reservoir and the population density of brown trout was significantly reduced. There was a complete absence of 0+ fry during the 1996 survey.

- *The population of brown trout captured at this site was heavily influenced by the presence of the weir pool in the top section. There were no brown trout from the 1996 year class captured in this survey indicating very poor recruitment from that year.*

Different contractors were commissioned by YWS on the Calder and the Don. Survey methodology varied slightly and it was recognised that this could lead to differences in interpretation. For future surveys, consistent methodology has been agreed.

The summarised findings regarding fish populations and changes between the years show significant differences between the Calder and Don:

- High survival and increased production of 0+ brown trout identified within the Calder catchment was not found on the Don catchment.

- Total failure of recruitment was found at two sites on the Don.

- There were greater reductions in overall biomass and density for larger trout within the Don catchment than the Calder.

- Influences of angler activity and stocking practices identified by survey contractors are under investigation by the Agency.

8.0 RIVER HULL

8.1 Background and issues

The headwaters of the River Hull form the most northerly chalk stream system in Britain. The chalk gives rise to a characteristic scenery of gently undulating land and there is little surface drainage on the highly permeable chalk of the Wolds. Where the Chalk formation disappears under the Holderness clays along a line from Bridlington to Driffield to Hull, there are many springs that eventually combine to form the River Hull. The River Hull and the Beverley and Barmston Drain have a complex two level drainage system taking the spring flows from the Chalk and local land drainage from the heavy low lying glacial land of Holderness. The Chalk is an important aquifer, with abstraction both for public water supply and agriculture, and there is a surface water abstraction point from the Hull at Hempholme.

The major centres of population are Hull, Driffield, Beverley and Market Weighton, with seasonal tourist centres at Bridlington, Hornsea, Withernsea and Skipsea. Although the pressures of industry and large urban populations are lower in this area than in other catchments in the Ridings Area. There is, however, a large concentration of industry in and around the city of Hull. Beverley STW discharges just above the tidal limit of the River Hull, and it has been known for some time that there is a zone of very poor water quality around the STW down to the saline limits. Dependant on the tide, this zone of poor quality water moves up and down the River Hull. Fish avoid this zone during the summer months, and it was feared that reductions in flow of clean water over the weir at Hempholme would extend the poor quality zone. In addition, fish could be trapped between the saline water from the estuary and the de-oxygenated zone, as low freshwater flows permitted greater saline intrusion. This could result in fish mortalities.

Groundwater levels generally show a smooth hydrograph through the year. Recharge takes place during the winter when rainfall exceeds the evaporation, and the quantity of recharge is dependent on the total winter precipitation, particularly heavy snowfall. The low volume of effective storage in the Chalk aquifer and the high flow along the fissure system means that groundwater flows rapidly to springs and is discharged into the surface water system of the river. The flow pattern of the Hull is unlike that of other rivers in Yorkshire, and is also characterised by a smooth hydrograph and a high proportion of spring flow derived from the aquifer. This aquifer provides all of the public water supply in the northern part of the Wolds and around half the public water supply in the Hull area.

The Chalk is an aquifer that is susceptible to drought conditions. Below average recharge in the winter is followed by below average flows from springs and, in turn, below average flows in the Hull during the following summer. After a sequence of low recharge levels, borehole yields may be reduced considerably because of de-watering of fissure systems. The reliable yield of boreholes during drought may be considerably lower than the normal yields.

Water for public supply is abstracted from boreholes and also from a major licensed abstraction point from the non tidal Hull at Tophill Low, upstream of Hempholme Weir. Normally YWS is licensed to abstract an average 68.2 tcmd during the year: however, a minimum flow of 45 tcmd must be maintained over Hempholme Weir.

Due to low natural flows in 1996, YWS applied to the Agency for a Drought Permit when it was becoming difficult to maintain flows at the 45 tcmd level and continue abstraction. The application requested that minimum flows over Hempholme Weir be reduced from 45 tcmd to 22.5 tcmd when necessary in order to maintain public supply to the Hull area. The Permit was granted in July 1996 and expired at the end of January 1997. The application was not to increase abstraction rates.

8.2 Purpose

As part of the Drought Permit conditions, YWS was required to tighten the operation of the STW at Beverley, and to monitor the effluent daily. The potential risk to the fishery below Beverley STW was acknowledged, and a sonar survey was undertaken on behalf of YWS by Dales Area fisheries science teams. The full report is available and a summary of this forms the basis of the section 8.5.2. below.

Monitoring of changes in the macro-invertebrate faunal community was also considered to be important, and six sites were chosen to allow comparisons between sites above both the tidal limit and the abstraction point and the bottom end of the river, close to where it discharges into the Humber Estuary. Priority was given to those that had been previously sampled. All of the sites were sampled in summer 1996, prior to the drought permit coming into effect. **Figure 8.2a** summarises the extent of the monitoring on the Hull.

8.3 Hydrology and water resources

The Hull catchment has a different character from the Aire, Calder and Don catchments, being subject to rainfall from easterly onshore winds. The catchment characteristically has many dry days with most of the rainfall occurring during a small number of relatively intense events, and typically has about 625mm of rain each year. In 1996, the catchment had 483mm, which was only 77% of the LTA. The first six months of the year had just 36% of the year's total rainfall. Around April, there was only 3.8mm in a fifty day period. In 1995 the catchment had 557mm of rain, amounting to over 90% of the LTA. The drought in 1995 was the result of the uneven distribution of the rainfall through the year. Three months were very dry, and three very wet, the others being close to the LTA.

The flows in the Hull itself are measured at Hempholme Lock. The main tributaries and other nearby rivers are also monitored. The flat nature of the catchment, and the Chalk aquifer, result in a much lower response to rainfall than that of the Pennine catchments. Flows were still well below the LTA at the end of 1995, and had not risen much from the lowest level reached during that year. Despite periods of rain during the winter, the highest values remained entirely below average. The low rainfall figures and the very low base flows resulted in a drop in flows occurring much earlier in 1996 than in 1995. The flows fell to between two-thirds and one-third of the 1995 flows in the smaller rivers, and around two-thirds in the Hull. The fall in the flow of all the rivers followed the same pattern as 1995, but from a lower starting point. Mires Beck was already beneath the dry weather flow (DWF) by the end of June, with the others reaching DWF during July or August. West Beck was the least badly affected, but Mires Beck and the Foulness remained at or below the 1995 level well into the autumn. Flows and rainfall figures for 1996 and the comparisons with the LTA for 1995 and 1996 can be seen in **Figure 8.3a**.

There are no impoundment reservoirs in the Hull catchment. YWS take water from the Hull immediately upstream of the weir at Hempholme Lock. A Drought Permit allowing a lower flow over the weir was in place from 30 July 1996 until 30 January 1997.

8.4 Water Quality

The water quality problems of the River Hull fall into three distinct areas of concern: the headwaters, upstream of Hempholme Weir, and the lower sections downstream of the abstraction point.

The upstream system starts to the south west of Driffield, being fed by groundwater from the chalk aquifer. This high quality water receives direct discharges from four trout farms and an indirect discharge from another trout farm. STW effluent and agricultural runoff are received via the main tributaries of Driffield Canal, Old Howe, Kelk Beck and Scurf Dyke.

The downstream system passes Beverley and goes through Hull to the Humber Estuary. The flow is influenced by tides and by the YWS public supply abstraction point above Hempholme Weir. Quality is influenced by discharges from STWs at Beverley and Bransholme and by industrial discharges in Hull from Croda Universal, Holliday Pigments and Cargill plc. The greatest deleterious effect was considered to be the discharge from Beverley STW and lowered flows over Hempholme Weir meant a lack of dilution water to the system.

The organic load from Beverley STW results in a zone of poor water quality, ie low dissolved oxygen and high ammonia levels. This zone moves upstream and downstream of the discharge point with the tide and is unlikely to sustain fish populations. This situation has been the case for a number of years and is to be addressed by major capital improvements to the works.

Low natural flows in the upstream system of the Hull, although having potential water quality implications, were not seen as a reason to increase the number or frequency of sampling of river water quality or discharge points. The implications of reducing flows over Hempholme Weir combined with an existing zone of poor water quality at Beverley were seen to be of greater importance. The Agency was concerned that the zone of poor water quality would deteriorate further and that its linear extent would increase both upstream and downstream of the discharge point (due to tidal effects). Lower flows would also affect the extent of saline intrusion in the tidal reach. The combination of these factors increased the risk of fish mortalities in the downstream system of the Hull, and consequently most of the water quality sampling was done in the lower reaches.

Previous work carried out by the NRA resulted in a model being produced to predict river quality under certain conditions. However, the accuracy of this model could not be assured. For this reason, as part of the granting of the Drought Permit, YWS was required to undertake the following actions:

- Carry out fish population surveys to determine densities and movements in relation to zones of saline and poor water quality.
- Set up two continuous monitoring points for dissolved oxygen, ammonia, pH, conductivity and temperature at Hull Bridge and at Weel. Site choice was based upon model predictions of the extent of the poor quality water zone under drought conditions. These locations complement an existing Agency site at Grovehill.
- Transfer of sludge liquors from Beverley STW to reduce ammonia levels from the final effluent discharge.
- Flocculation of incoming sewage to Beverley STW to reduce the biochemical oxygen demand from the final effluent discharge.
- Chemical analyses of final effluent discharges from Beverley and Bransholme STWs to be submitted to the Agency to supplement existing Agency monitoring programmes.
- River flows over Hempholme Weir to be recorded and submitted on a daily basis to the Agency to supplement weekly Agency site inspections of weir flows at Hempholme.

The monitoring was intended to provide information for future reference and not as a trigger for emergency response, eg. aeration. In this instance, aeration was not regarded as an option for increasing dissolved oxygen levels as deployment was not practical due to the movement of poor quality zone, and it was also unlikely to increase oxygen levels (in an area possibly devoid of fish, due to their movement away from that zone).

Extra water quality monitoring sites were not instituted by the Agency, as the drought permit conditions outlined above ensured YWS undertook all the monitoring necessary to understand the conditions likely to occur during the drought period.

Information gathered from YWS monitors confirmed the predictions that water quality in the zone of poor quality deteriorated, and its movement and linear extent increased, along with saline intrusion increased to a greater extent than model predictions. Although no fish mortalities were recorded, probably due to the movement of fish populations away from such zones, the situation could have worsened if water temperatures had increased to 1995 levels.

Agency data were analysed and the main findings are summarised below (and **Figures 8.4a-c**).

The chemical GQA grade of the Hull at Grovehill improved from E (*poor*) in 1995 to grade D (*fair*) in 1996, ammonia levels having decreased. The transfer of sludge liquors from Beverley STW later in the year is likely to have helped the situation, but stricter trade effluent control upon discharges received by the works probably had the most significant effect on ammonia levels in the final effluent discharge. Improvements to Beverley STW will have been the main influencing factor rather than reduced dilution in the low flows.

The water quality of the Hull at Hempholme Lock remained the same as 1995 at GQA grade D. Prior to 1995, the grade had been C, when lower dissolved oxygen levels were responsible for the deterioration. The low natural flows experienced in the last two years have not afforded the dilution for effluents from trout farms or sewage works. The reduction of dissolved oxygen from the trout farms will have contributed to this deterioration in water quality. A major capital scheme at Driffield STW, to be completed summer 1997, will improve water quality in the Driffield Canal.

8.5 Ecology

The upper reaches of the Hull are known as West Beck. This is the most northerly chalk stream in Britain, as well as being an SSSI. Because it is fed by springs, it is extremely susceptible to changes in the water table, and therefore prone to natural droughts. West Beck was affected by severe droughts in 1990 and 1995, but flows have been below normal in other years. It is probable that 1988 was the last year during which there were normal flows in this chalk stream.

The upper reaches of the Hull have a diverse fauna and flora, typical of a fast flowing chalk stream. It is characterised by diverse populations of both mayfly nymphs and caddisfly larvae, and large beds of *Ranunculus fluitans* (water crowfoot). Further downstream, the fauna changes to that characteristic of a slow flowing, deep river. The *Ranunculus* beds are replaced by macrophytes more suited to the deeper, slower conditions. The numbers of mayflies and caddis flies decline, but there are increased abundances of snails, beetles and bugs.

8.5.1 Aquatic macro-invertebrates

Six sites were selected in 1996 to examine the impact of the Drought Order on the Hull, and the proposed increase in abstraction at Hempholme: Rotsea, Hempholme Lock, Wilfholme, Hull Bridge, Tickton, Weel Bridge at Beverley and Sutton Road Bridge (**Table 8.5a**). It was feared that increased abstraction from the Hull at Hempholme could lead to changes in the river's ecology by causing it to become more saline. Such a change in the lower reaches may be insignificant, but could be more severe in the reach just downstream of Hempholme where salinity levels are usually modest. .

The Hull at Rotsea was selected as a reference site as it is upstream of YWS's intake at Hempholme, but close to the emergency intake. Rotsea is downstream of the SSSI and is non-tidal. This site forms part of the Agency's routine sampling programme, and would allow comparison with several years of past data. Another reference site was located at Hempholme Lock, just upstream of the YWS intake. The third site was at Wilfholme, just downstream of the abstraction point. This site had been sampled in the past, but had not been included in more recent sampling programmes. The next site was at Hull Bridge, Tickton. It is upstream of the confluence of Beverley Beck, but may be affected by the sewage pollution being moved upstream with the incoming tide. This site had been sampled in the past, but had never formed part of the routine monitoring programme. The fifth site was at Weel Bridge, Beverley, and has been routinely sampled. The most downstream site was located at Sutton Road Bridge in Hull. It is sampled once a year in autumn, as part of the Humber Management Group's tidal rivers survey.

Agency data from the summer and autumn of 1996 have been analysed. Of the six sites, three had been sampled for the 1995 GQA survey and thus good quality data were available. Data back to 1990 were also available for all sites apart from at Hull Bridge. Results from the RIVPACS analysis are given in **Table 8.5a**.

The site at **Rotsea** has achieved GQA/GQAO grade *a (very good)* on most occasions with grade *b (good)* being recorded in some seasons. However, since autumn 1990 the changes between grade *a* and *b* was not sufficiently significant to indicate a definitive grade change until the drop to grade to *b* in autumn 1996. Data for **Wilfholme** are sparse prior to 1995, but this site has fluctuating quality between grade *e (poor)* in 1992 and grade *b* in spring 1994 and autumn 1996. **Beverley** has also had a fluctuating quality regime. Prior to 1995, the main fluctuation was between grade *e* and grade *d (fair)*, with a deterioration to grade *f (bad)* on one occasion. However, from spring 1996 onward grade *f (bad)* has been recorded.

Cluster analysis and MDS Ordination of the data have provided some interesting initial patterns of the data (**Figure 8.5a**). The ordination shows a geographical trend in the data determined by distinct faunal associations in a downstream gradient. Superimposed on this is the clustering of samples of most similar faunas. In the upper reaches of the Hull (**Rotsea** and **Hempholme**), samples from the same sites group together throughout time, whereas in the lower section there is an inconsistency in the clustering. Samples from **Beverley** collected in 1996 and autumn 1995 are more similar to samples from the tidal site at **Sutton Road Bridge**, than samples collected in spring 1995 and earlier. These show more similarity with upstream sites of **Hull Bridge** and **Wilfholme**.

The inference is that the lowered freshwater flows have an influence on biological quality at Beverley through less dilution of the effluent from Beverley STW, allowing a higher penetration upstream of this polluted water and a possible increase in the limit of saline intrusion.

8.5.2 Fisheries

Hydro acoustic fish population surveys were carried out at a series of sites in the tidal Hull in July 1996 during periods of moderate freshwater flows and spring tides. This was followed by a corresponding series of surveys during a period of lower freshwater flows in autumn 1996, after the granting of the Drought Permit to YWS. These surveys were undertaken in order to establish whether substantial numbers of fish were present in the tidal Hull downstream of Beverley during the summer months and how these fish reacted to tide and changing water quality, and whether they were at risk from poor water quality conditions. This information could assist YWS and the Agency in targeting ameliorative measures to minimise adverse effects of Drought Permit flows upon fish populations.

The surveys indicated substantial numbers of fish living upstream and downstream of the depleted oxygen zone which exists in the tidal Hull. Conditions in this zone of poor water quality deteriorate further during low flow periods, possibly due to reduced dilution for effluents. Fish species present include roach, perch and gudgeon. They move with the tide, apparently in response to gradients of dissolved oxygen and salinity. It appears that there is a zone downstream of Beverley STW outfall which is frequented by few fish at any stage of the tide, which may be associated primarily with high ammonia levels. A full report on this survey was prepared by the Agency on behalf of YWS and is available.

Under conditions of low freshwater flow and high tides, gradients of salinity and oxygen are steeper and fish responses appear more marked. At higher salinities, the response to increasing salinity can override the response to decreasing oxygen availability. Hence, fish in the lower tidal river may be forced by saline intrusion into zones of very low oxygen concentrations where mortalities could occur. This mechanism is the probable cause of fish mortalities which were observed in the lower tidal Hull during 1990-1992.

In 1996, natural low flows and abstraction under the conditions of the Drought Permit placed fish at increased *risk* of mortality due to a combination of conditions which caused them to move to areas of poor water quality. In addition, fish production was probably reduced by poor water quality which limited their natural feeding ranges.

9.0 RIVER OUSE

9.1 Background and issues

Although a lowland river, the Ouse can be affected by severe spates, as it receives the flows from the three 'flashy' upland rivers the Swale, Ure and Nidd. Abstractions at Moor Monkton (for Leeds and the new link to Elvington) and Acomb Landing (for York) make the river a key provider of water for public supply. Low flows in the Ouse started in early May 1995 and persisted largely uninterrupted until that November. Prior to this, YWS were granted a variation in their licence to increase the abstraction when the flows at Skelton were higher than 1000 tcmd, but due to the pressures on public water supply and the forecast of below average winter and spring rainfall, YWS were further granted a Drought Order in November 1995 to abstract more water at all flows. This was followed by a one-month Drought Order allowing another increase. In March 1996, YWS were granted a three-year TLL permitting further abstractions when flows in the Ouse are greater than the prescribed 650 tcmd naturalised flow at Skelton.

YWS's Environmental Statement accompanying the initial Ouse Drought Order application concluded that the proposed increase in abstraction would have little impact on the quality and ecology of the Ouse. In the stretch from Linton Lock to Naburn Weir there are few shallow areas apart from a few marginal sandbanks near Acomb Landing and in York. Consequently, low-flows impact on the riverine habitat mainly through lower water levels and reductions in water velocities. These can lead to modifications of marginal zones with increased sediment stability and slack water, and to increased deposition of fine sediments, in the absence of substantial scouring episodes during spates. These physical changes may be accompanied by shifts in water quality, especially when large organic inputs such as the River Foss and effluent from Naburn STW are in combination with a distinct ponding effect from Naburn Weir in the lower section of the non-tidal river.

9.2 Purpose

The aim of this report is to outline the impact of the 1995/96 drought on river flows and rainfall in the River Ouse catchment, with particular emphasis on the effect of public water supply abstractions at Moor Monkton. Previous studies indicated that the Agency's main area of concern should be the potential impact on the river downstream of Naburn STW. In view of this situation, enhanced monitoring and mitigation actions were required, particularly at Naburn STW. (See **Figure 9.2a** for extent of monitoring)

9.3 Hydrology and water resources

Since the Ouse is the culmination of several large Pennine rivers, a large catchment contributes to the flow regime. Rainfall data are available from a number of stations throughout the Swale, Ure and Nidd catchments but for this analysis the gauges selected are Moorland Cottage (near Garsdale Head), Burtersett, Arkengarthdale, Birstwith Hall and Little Crakehall.

Analysis of these data shows that the 1995/96 period had been extremely dry. The records for all of the rain gauges used in the analysis show a large cumulative deficit from the LTA **(Table 9.3a)**. The rainfall for these two complete years was only 83% of the LTA and for the eighteen-month period from 1 April 1995 to 30 September 1996, only 65%. The cumulative rainfall deficits over the period of recordand the individual monthly rainfall balances are shown in **Figures 9.3a-e**.

River flow data are available for the Ure at Kilgram Bridge, the Swale at Crakehall, the Nidd at Skip Bridge and the Ouse at Skelton. The extremely low rainfall over this period had a significant impact on river flows during 1995/96. The mean flow in the Swale, Ure, Nidd and Ouse during 1995/96 was just less than 80% of the LTA. The period from 1 April 1995 to 30 September 1996 averaged less than 50% of the expected flow for these months. All four of the stations studied recorded long term (since 1970) minima for at least two months during 1995. It is interesting to note, however, that so far in 1997, January and April have been lower than previous minima at three of the four gauging stations. The flows in the Ouse at Skelton GS are shown graphically in **Figure 9.3f**. A breakdown of flows as compared with the LTAs is shown in **Table 9.3b**.

During the last eight months of 1995 and for most of 1996, the Ouse experienced very low averaged monthly flows (2888 tcmd in 1996), unmatched since 1975 (2576 tcmd). Although the average for 1995 as a whole was higher (3692 tcmd) because of the wet spring, the lowest monthly flow occurred in August 1995 (377 tcmd). The annual mean monthly flow was actually marginally lower in 1992 (3648 tcmd) than 1995, and much lower in 1989 (3010 tcmd).

The Ouse is a major source of potable water and YWS are now heavily reliant on the TLL to maintain their capability to meet water demand. The abstraction from the Ouse is approximately 5 km upstream of Skelton gauging station. The TLL for the Moor Monkton abstraction allows a take of 294 tcmd with a residual flow at Skelton of 970 tcmd. (The value of 970 tcmd is known as the *precribed flow* (sometimes seen as a *critical flow*), and has been derived to protect the river environment downstream, using a Surface Water Abstraction Policy (SWALP) methodology). Below this flow, abstraction is limited to 144 tcmd with a residual flow of 650 tcmd. The old licence allowed abstraction of 99 tcmd with a residual flow of 1000 tcmd. Both licences allow abstraction of 68 tcmd at all times. Daily abstraction figures are available from late 1996 for Moor Monkton and are summarised in **Figure 9.3g**.

Analysis of the abstractions for 1995/96 shows significant usage of this licence. The average abstractions were 69 tcmd in 1995 and 113 tcmd in 1996; that for 1996 was 25% greater than could have been made under the old licence conditions. The actual abstraction between 1 April 1995 and 30 September 1996 caused a reduction of 4.5% to the average flow over that period. Under the old licence conditions, the reduction could only have been 4.3% and under the new licence conditions this reduction could have been 10%. However, the *potential* abstraction under the new licence for 1995/96 would have been 2½ times that available with the old licence.

The lower of the prescribed flows equates approximately to the 95% exceedance flow. Close to the prescribed flow limit (650 tcmd), the new licence would allow abstraction of approximately 20% of the river flow. The maximum under the old licence would have been 10%. The actual quantity forms a smaller proportion of the total river flow than the Ure abstraction at Kilgram Bridge.

In addition to the large YWS abstraction, York Waterworks Company also abstract from the Ouse further downstream at Acomb Landing to serve York, and are licensed to take 96 tcmd under any flow conditions, although in practice this is rarely greater than 60 tcmd, as happened in the summer of 1995.

9.4 Water Quality

The Ouse upstream of York has higher water quality than the lower non-tidal reaches that receive effluents from combined sewer overflows in York, the Foss and Naburn STW. Modelling by YWS of the impact of the increased abstraction had suggested that changes in dissolved oxygen would be negligible, less than the resolution of the model, and within any variation that occurs across the channel. Dissolved oxygen levels are believed to decline gradually in the York to Naburn stretch naturally, as the river becomes increasingly ponded behind Naburn Weir. This situation was exacerbated in 1995 as it was an exceptionally dry year and flows in the Ouse were significantly lower than normal; there was less dilution for the discharges to the river, the most significant of which is Naburn STW.

Actual monitoring of water quality in 1995 and 1996 was covered by the Agency's GQA and existing effluent sampling programme. There are three GQA sample points on the non-tidal Ouse below Moor Monkton: at Nether Poppleton, Scarborough Railway Bridge and Naburn Weir. In addition, there are three sites on the tidal stretch upstream of the Aire confluence. Sampling in all cases was at the normal frequency (fifteen per year).

Levels of the main GQA determinands BOD, dissolved oxygen and ammonia, together with the face value GQA grades, are shown in **Figures 9.4a-c**. From these data there is evidence that downstream of York water quality declined during 1995 and 1996, with the face value GQA grades lowest in 1996, ie. grade C (*fairly good*) at Scarborough Rail Bridge and D (*fair*) at Naburn Weir. It is surprising that the quality at Nether Poppleton also fell to grade D in 1996, but a sampling error was identified as the cause of some very low levels of dissolved oxygen - these led to the drop in face-value GQA grade.

As a whole, the time series data show few trends with respect to wet/dry years, and the tidal sites, at Selby and Long Drax show no correlation between face-value GQA grade and perceived non-drought/drought years. Nevertheless, Cusum analysis does reveal significant changes in some of the water quality determinands that can be linked to the drought period (ie mid 1995 onwards), among them higher pH, lower dissolved oxygen and higher ammonia levels (**Table 9.4a, Figures 9.4 d-g**). Less dilution of decaying organic material and warmer temperatures can account for the last two changes, and it is possible that higher pH values arise from the relative lack of flows from the upland, more acidic, catchments. A similar pattern has been observed in the Ure and Wharfe data.

9.5 Ecology

9.5.1 Macrophytes

A detailed survey of the macrophytes of the Ouse carried out for YWS during July 1993 concluded that the communities were similar throughout the stretch from Nether Poppleton to Acaster Malbis. These were dominated by fennel-leaved pondweed, unbranched bur-reed and flowering rush, although yellow waterlily, common clubrush and filamentous green algae were also common. Recent observations by the Agency upstream of Moor Monkton suggest that the macrophyte communities are somewhat richer in species, and less dominated by species such as *Potamogeton pectinatus* (fennel-leaved pondweed).

Nevertheless, in 1995 and 1996, fennel-leaved pondweed was again present throughout much of the stretch, usually in linear beds close to each river margin, as might be expected in a river of this type and under similar conditions. This abundant macrophyte growth along lower Ure and Ouse during the summer has been of concern to anglers primarily as a result of reduced access to fishing pegs but one angler has expressed concern over the amount of filamentous algae "smothering other weeds" and what effect it may be having on the river.

Fisheries Inspectors from the Agency also observed abundant macrophyte growth, with large mats of filamentous algae noted along the margins of the Overton-Poppleton stretch.

9.5.2 Aquatic macro-invertebrates

Because of its highly variable flow regime, the macro-invertebrate communities of the non-tidal Ouse show neither fully developed 'upland' nor 'lowland' characteristics (*cf* the Derwent downstream of Stamford Bridge). However, many species typical of lower river zones are present that are not dependent on high current velocities and water flows. The river was tidal upstream to York before Naburn Weir was constructed. The fauna is characterised by a diverse range of caddis flies and molluscs, including large river snails (*Viviparus*) and swan mussels (Unionidae). Recently, the Agency has confirmed the presence of the scarce, and perhaps threatened, depressed river mussel *Pseudanodonta complanata* in the Ouse. This species is represented in the Biodiversity Action Plan, and the Agency has a lead role in developing conservation strategies for this mollusc. There are also historical records of the native white-clawed crayfish *Austropotamobius pallipes* from the Ouse, but recent surveys carried out by YWS have not recorded any of this protected species.

Biological monitoring of the non-tidal Ouse has, historically, focused on two sampling sites, upstream and downstream of York: Nether Poppleton and Acaster Malbis. Macro-invertebrate data stretch back to 1980 and 1971 respectively for these two sites, although methods changed from bankside sweep-sampling to airlifting (plus a sweep) in 1980. In 1995, the NRA sampled these two sites together with a new (GQA) location in York just upstream of the Scarborough Rail Bridge. This monitoring formed part of the 1995 National Quinquennial River Quality Survey, and the sites were sampled in spring (March-May) and autumn (September-November) in accordance with this programme, and identification of invertebrates done to mixed taxonomic level (ie species whenever practicable).

With the introduction of the TLL, the three GQA sites were sampled in 1996 during three seasons (spring, summer and autumn) and additional sites were sampled upstream of Moor Monkton in summer and autumn, also by the airlift/sweep method. These two sites (Beningborough Hall, SE513586, and downstream of Niddsmouth, SE521581) also helped environmental assessment of the proposed Tees-Wiske river transfer. The locations of the sites are shown in **Figure 9.2a**.

Following concern about the apparently poor faunal situation in the lower non-tidal Ouse in the autumn of 1995, and supporting their application for the TLL, YWS repeated the diver survey carried out in 1993, involving quantitative benthic samples from six sites on the Ouse from Nether Poppleton to Acaster Malbis. The results from this survey were reported in the *River Ouse TLL 1996 Environmental Review*, by Scott Wilson Resource Consultants.

A primary concern of the Agency, and others, has been the possibility that low flows in the Ouse can adversely impact on water quality, with its knock-on effect on ecological or biological quality. The biological GQA and GQAO grades for the Ouse sites during the years 1990-96 are shown in **Table 9.5a**, along with the independently derived Yorkshire Interpretative Index (YII). The observed/expected values for the *ASPT* and *number of BMWP taxa* are also shown, these being the basis for the GQA grades.

During 1990-96, Nether Poppleton consistently received a YII classification of B1B (ie *good*); the GQA grade varied between *a* (*very good*) and *b* (*good*). The fauna in 1995 overall failed to achieve grade *a* for both the number of taxa and the ASPT, as it also did in 1991. In biological quality terms, the drought appears to have had a slight impact at this site, but similar faunal conditions have been observed before.

At the site in York (Scarborough Rail Bridge), the GQA classifications were the same in both years (grade *b, good*), although the derived environmental quality indices (EQIs) were somewhat lower in 1996; the YII suggested a slight fall in quality within grade B2, consistent with these results. Habitat quality is not as good at this site but it is also downstream of organic discharges from Rawcliffe STW and British Sugar. No historical data are available to put the 1995 and 1996 results into context, but the pre-drought sample in spring 1995 had a higher *ASPT* value (5.41) than any of the subsequent post-drought samples (4.71-4.95), although the autumn 1995 sample contained more taxa.

In contrast to these two sites, the fauna at Acaster Malbis has regularly attained a YII biological grade within B2 (*fair*), but this fell to B3 (*poor*) in 1995. The GQA system indicates that this site exhibits a wide range in biological quality, between *b* (*good*) in 1992 to *e* (*poor*) in 1995, and it is apparently deficient in the observed number of taxa and in ASPT. This lower quality, compared to the site at Nether Poppleton, has been variously attributed to natural processes resulting from the ponding effect of Naburn Weir, the combined impacts of York's storm overflows, the Foss, and the large discharge of treated sewage effluent from Naburn STW.

A very poor macro-invertebrate fauna was observed in a good airlift/sweep sample from Acaster Malbis in the autumn of 1995 (see the first *Interim Report*), indicating a decline in biological quality. This was linked to the lack of dilution created by extremely low and stable flows in the summer and early autumn, coupled with high levels of ammonia in the Naburn STW effluent on certain occasions. A more diverse fauna was recorded in YWS diver samples two months later, possibly as some relatively high flows were seen in the intervening period, bringing organisms from upstream. In the spring of 1996 the fauna indicated a return to the quality observed in previous years, although it remains dominated by organic-pollution tolerant groups and pollution sensitive and flow-loving species occur in low single figures or as singletons.

Historical data from the two main Ouse monitoring sites, with some from the other three, allow the events of 1995-96 can be put in context. Over the period 1981-96 all three univariate biological indices show that the Nether Poppleton site has achieved higher values than that at Acaster Malbis, with very few exceptions (**Figure 9.5b**). There are also indications that there has been greater disparity between the sites after 1988, with evidence of a trend towards increasing richness (*BMWP score* and *numbers of taxa*) at Nether Poppleton, with four of the seven autumn samples taken since 1988 exceeding those from the previous seven. The converse may be apparent at Acaster Malbis, with five out of the eight autumn samples since 1988 having lower *BMWP scores* than in the previous seven years. No trend is evident in the 'quality' of the Nether Poppleton fauna as measured by the *ASPT* value during 1981-96, although the quality in the latter half of the period appears to be slightly lower at Acaster Malbis.

An interpretation of these findings is that the increased frequency of low flow events in the latter half of the 1981-96 period has led to an increase in biological richness in the good quality section of the Ouse, concomitant with similar responses in the Wharfe and Ure. With the influence of both organic discharges and ponding (and associated siltation), the lower part of the non-tidal Ouse appears to have experienced a negative impact from the droughts.

As spatial factors can influence discrimination and grouping of invertebrate data, this aspect was explored first using the Ouse historical data (following an identical approach taken with studies of the Ure and Wharfe). In the first *Interim Report* it was shown that the Acaster Malbis fauna could be readily separated in multivariate terms from those at Nether Poppleton and York, even on the basis of family-level identification and highly transformed abundance counts. Some additional, species, differences are hidden within these patterns; for example, the replacement of relatively pollution-intolerant oligochaete worm communities (mainly *Stylodrilus heringianus* and *Psammoryctides barbatus*) at

Nether Poppleton, with pollution-tolerant tubificids (eg. *Limnodrilus hoffmeisteri*, *L. profundicola* and *Potamothrix moldaviensis*) at Acaster Malbis.

Seasonality is another factor to be considered when interpreting changes in faunal composition, even in a large lowland river such as the Ouse. It is fairly well developed in the upper Ouse fauna as, even though the data are dominated by autumn samples, there is reasonable discrimination among the three seasons (**Figure 9.5c**). Set in this context, autumn faunas from Nether Poppleton and York in 1995 and 1996 were on the edge of variation seen in previous years, although not clearly distinct. In spring 1996, the Nether Poppleton fauna remained similar to that from the previous autumn (a pattern also seen in Ure and Wharfe invertebrate data). The 1996 summer faunas at Nether Poppleton and York did not change substantially, but they were distinct from those upstream at Beningborough Hall and near Niddsmouth, which were more similar to earlier summer faunas. The last two sites were characterised by higher abundance values of the majority of macro-invertebrate groups.

When the faunal data from the upper Ouse are examined to determine the taxonomic background to the multivariate pattern, it is revealed that seventeen common or frequently recorded groups were less abundant than the long term average, twelve more abundant and one or two more or less the same (**Figure 9.5d**). No clear pattern or consistent response is indicated, although it may be significant that flow-loving heptageniid mayflies and hydropsychid caddis flies were not recorded in these two years, either by airlift/sweep sampling or YWS diver surveys. The possible drought impact is more obvious when rare and infrequent types are examined (**Figure 9.5d** - lower graph); even allowing for chance occurrences and absences, bithynid and planorbid molluscs (not recorded in YWS diver surveys), and coenagriid damselflies were recorded in greater numbers in 1995 and 1996 compared to the previous long-term average.

The likely drought impact on the lower non-tidal Ouse has already been discussed in general biological water quality terms, and it was suggested that the invertebrate fauna of the routine sampling site at Acaster Malbis is clearly distinguishable from those upstream. Further analysis of these data seems to indicate (**Figure 9.5e**) that a shift in the fauna occurred between the autumn of 1989 and the following spring, and since then it has never been of the same type. In general, most macro-invertebrates were recorded in lower numbers in the more recent period (**Table 9.5b**), including a few which have not since been recorded in the NRA/Agency's combined airlift/sweep samples: phryganeid, hydropsychid, molannid and psychomyid caddis flies, sysirid sponge flies, simuliid flies and taeniopterygid stoneflies. Most of these are pollution-sensitive taxa and/or those that 'prefer' flowing water. *It should not be inferred that these groups are now completely absent from this section of the Ouse, as very low numbers of psychomyids and a single phryganeid were recorded in four diver surveys carried out by YWS in 1993 and 1995.* Some other scarce taxa have been newly recorded by the NRA/Agency since 1989, including bithynid snails, corixids and coenagriid damselflies, which generally prefer slow-flowing or still waters.

The environmental background to this apparent change is that the spring to early autumn period in 1989 constituted a low-flow event and the annual averaged-monthly flows in the Ouse in 1989 were the lowest since 1975 (3010 tcmd versus 2745 tcmd), and lower in fact than 1995 (3692 tcmd). It is possible that the fauna in the Ouse was in fact perturbed by this and shifted into a new 'equilibrium' position, as may have occurred in other rivers in Yorkshire.

Overall, it appears that there are similarities in the Agency and YWS surveys, especially in the generality of the changes in the Ouse fauna, both spatially and temporally. A possible drought response appears to be indicated in the upper part of the river through faunal enrichment, but in the lower river, where ponding and organic discharges are involved, the pattern is not so clear and indicates both enrichment and impoverishment variously across the invertebrate fauna.

From the evidence and analyses available so far:

- The drought impact on the macro-invertebrates of the Ouse appears to be slight in the stretch upstream of York, with only minor shifts in composition, mainly involving an enrichment of faunas through higher densities of some groups.

- A few flow-loving invertebrate groups may have been disadvantaged, such as heptageniid mayflies, stoneflies and hydropsychid caddis flies (although these are usually rare of infrequent), and there is evidence that some still/slow flow groups (eg pea and orb mussels, planorbid and bithynid snails, coenagriid damselflies) are becoming more prevalent as flows have become consistently lower. Some of these taxa were present in the early 1970s but their occurrence then, and since, has been otherwise very sporadic.

- Good biological quality was maintained upstream of York during 1995 and 1996, but in autumn of 1995 a fall in quality was observed at Acaster Malbis, probably associated with extreme summer low flows and a lack of dilution from the large Naburn STW effluent discharge. Some improvement was seen in 1996 during the slightly better flow conditions.

There is a clear need to address more fully the issue of abstraction from the Ouse at Moor Monkton, and in 1996 the Agency responded by including monitoring sites upstream at Niddsmouth and Beningborough Hall. As preliminary analyses suggest that there may be some faunal differences between these sites and that at Nether Poppleton, the influence of habitat quality and diversity needs to be further assessed before investigating any potential effects from water abstraction regimes. In 1997, YWS carried out macrophyte surveys at two sites, up (SE523577) and downstream (SE536569) of Moor Monkton which will further assist the evaluation of the TLL. The Agency also took complementary macro-invertebrate samples from the downstream site.

In addition, there is a need to clarify the apparent ecological changes in the lower Ouse with new biological monitoring sites upstream and downstream of Naburn STW (near the A64 bridge and Naburn marina respectively), and these were sampled three times in

1997 by the Agency.

9.5.3 Fisheries

The Agency requires information on fish populations with regards to drought conditions and any possible effect that abstractions from the Ouse may have when considering licence renewal.

(i) Sites and methods

A fish population survey was conducted between 18 and 26 July 1996, covering six sites. Coarse fish fry were sampled at Acaster Malbis and Beningbrough during the annual fry survey on 18 and 19 September 1996 respectively. These dates are relatively consistent with the timing of earlier surveys, thus allowing a direct comparison with previous results. A multi-method sampling protocol was adopted for the main survey to limit species, size and age selectivity (see Fisheries Science Report [FSR]22/97).

Match returns were analysed from two sections on the Ouse, and will include a small section of the Ure which is part of the historical data set. The sections are: Dunsforth to Linton-On-Ouse and Linton-on-Ouse to Naburn Weir.

(ii) Main findings

Comparisons of percentage species compositions caught by single anode electrofishing at five Ouse sites from 1990 to 1996 are shown in **Figure 9.6f.** These highlight that roach dominated catches throughout the Ouse and perch were the second most abundant species at **Beningbrough** and **Nether Poppleton**, but in the lower river at **Acaster Malbis** and below **Naburn Weir** bleak were the second most numerous species. At **Linton-on-Ouse**, above the weir, roach were prolific, with gudgeon and perch the next most numerous species and bream also well represented. As compared with previous surveys, dace were more apparent below the two weirs, Linton and Naburn, with relatively large numbers from **Naburn.** Chub were caught in fewer numbers than in the previous surveys, apart from a relatively large number from **Acaster Malbis**. Pike were recorded in similar numbers to the previous surveys, with the exception of more fish recorded at **Naburn** in 1996. Silver bream, which were recorded in relatively high numbers below **Naburn Weir** in 1993 were not as evident in 1996.

Eels were recorded from all Ouse sites except Acaster Malbis. The increased depth at Acaster, relative to the other sites, may limit their susceptibility to capture by electric fishing. All sites showed the prevalence of the swimbladder nematode *Anguillicola crassus*.

Most coarse fish species were supported by a strong 1995 year-class (with the exception of a 1994 year-class of dace indicating that this species did not benefit from the 1995 drought), and notably bream of this year-class were evident above Linton Weir. Ruffe were not captured in sufficient numbers to indicate that recruitment had been particularly successful. Pike were mostly represented by fish from 1994 and 1992 and, as with perch, the older fish were from 1989-1992 year-classes.

Compared with previous years, **the growth rates of most fish were greater than those observed in 1993**. For example, the 1+ 1995 cohorts of roach exhibited faster growth rates than 1+ fish in 1990, as shown by the Coarse Fish Fry Surveys (FSR 17/91 and 49/96). The reports demonstrate that their relatively faster rates of growth were instigated by very good growth in their first year, with fry in 1995 attaining greater mean lengths than those in 1990. However, 4+ and 5+ roach were generally slower growing, suggesting perhaps that previous strong cohorts from 1989 and 1990 may have exhibited intraspecific competition. Perch also showed differences in growth rates when comparing results from the 1990 and 1996 surveys, with older fish (>3+) having similar rates, whilst younger fish in 1996 were generally slower growing than comparative age-groups in 1990.

In 1996, seven species were recorded from the fry survey samples at Beningborough, with notable absences of bleak, dace and perch, that were recorded in 1995. At Acaster Malbis, the number of species captured was also much reduced in 1996 compared with the two preceding years. In the drought years of 1989 to 1991, a similar observation of reduced species diversity of fry was made at this site. It would be of value to understand the factors, such as water quality, competition or fry dispersal, producing such a phenomenon. The presence of flow-loving species such as dace and barbel in this ponded section is probably accounted for by downstream dispersal from spawning locations upstream of York.

Changes in species composition are highlighted, with indications that dace and gudgeon recruitment may have been reduced at Beningbrough since the drought of 1989 and the numbers of perch have been increased. The relatively low numbers of fish captured at Acaster Malbis compared to Beningbrough make direct long-term trend comparisons difficult.

The growth rates of fry were elevated during the hot summers, notably 1984, 1989 and 1995 when, as expected, river flows were low. Coarse fish production, measured as mean fry growth by September, shows a strong positive correlation with water temperature and some correlation to low summer flows (**Figures 9.g & h**).

(iii) Angling catch returns

Catch returns are summarised in FSR 11/97. A change in the rating system in 1994, which allowed for the recording of more species from the catch return records, accounts for the apparent large declines in the ratings of the most abundant species such as roach and perch.

Numbers of match returns for the **Dunsforth to Linton** stretch in 1996 were higher than 1993 but still low compared to other years. A similar percentage of anglers weighing in was recorded compared to previous years. Catch indices have continued to fall since

1994; however, they remain higher than figures recorded in the 1970s and 80s. Perch and roach continue to dominate (**Figure 9.5i**), with increases in ratings for dace and chub. Eel ratings have fallen, while pike and bream were not recorded. Fisheries classification increased in 1992 from *D* (<71 g/2.51 oz per hour) to *C* (71-109 g/2.51-3.85 oz per hour), although the class has returned to *D* in 1996 with the decline in catch indices.

Catch returns for **Newton to Acaster** have remained high in recent years. However, in 1996 they dropped to half the 1995 figure and a quarter that of 1991. Percentage of anglers weighing in and other indices all remain high. A good range of species was still recorded, with roach and perch remaining the dominant species and increases in the ratings of ruffe, bream and roach (see **Figure 9.5i**). Ratings for pike and dace have fallen. The classification for this section on the Ouse improved from a C to a B during the 1990s, indicating this stretch as a good quality fishery. Warm summers increased recruitment of fish, thereby improving fishing quality in the early to mid 1990's.

(iv) Angler reports

Concern was expressed by York and District AA over the lack of large bream recorded in angling catches during the start of the 1996 fishing season, when in previous years they have been numerous. Further complaints followed regarding the poor quality of fishing above York during the summer, which is supported by the analysis of catch returns.

Agency Fisheries Inspectors reported that, in December, large catches of bream were taken around Killingbeck, an area not normally associated with good winter catches.

(v) Main issues and impacts

At this stage, there are no indications that the drought has caused any deleterious effects on coarse fish populations or marked changes in species composition. The hot dry summers of 1984, 1989 and 1995 produced conditions for very good fry growth and survival which were subsequently expressed as strong year classes of larger fish.

Almost all coarse fish species have shown good recruitment during the drought of 1995 with the exception of ruffe, which have had limited recruitment success since 1988. Dace recruitment, expressed as the number of juveniles observed in the annual fry survey, has fallen in the period 1989-1996 when compared to the relatively high numbers recorded during 1981 and 1987-1988. Roach have been variable in their recruitment success during 1981-1996 but in recent years, particularly 1989-1996, they have been slightly more successful, which is similar to a trend observed in the Ure (FSR 21/97).

Although considered to be primarily a coarse fishery, salmon use the Ouse as a corridor to their spawning grounds on the Ure and need to negotiate the poor water quality conditions of the tidal river. Detailed discussion and factors affecting their success are described in FSR 21/97. Entrainment of small numbers of juvenile salmon may occur at major abstraction points, namely York Water Works at Acomb Landing and Drax Power Station. Examination of these will be needed to evaluate any losses.

10.0 RIVER URE CATCHMENT

10.1 Background & issues

The Ure rises on the Pennines and is joined by a series of tributaries such as the Cover, Bain, Burn and Skell before it joins the Swale near Boroughbridge. The flow of the Ure is predominantly unregulated, and therefore follows a semi-natural pattern of seasonal variations largely determined by recent rainfall patterns. There is relatively little direct abstraction, with the only potable river abstraction at Kilgram Bridge.

River morphology changes dramatically along the Ure and the variety of habitats along the Ure supports several different invertebrate communities that are also indicative of very good or good water quality. Among the more notable species is the relatively large, long lived white-clawed crayfish (*Austropotamobius pallipes*). The fauna in the Ure, from around Boroughbridge upstream, is adapted to a highly variable flow regime that is very similar to that of the Wharfe. Fish communities also show a longitudinal pattern, with salmonid upper reaches (including salmon), followed by mixed fisheries further downstream, and coarse fisheries in the lowland Vale of York reaches. Several SSSIs are situated along the valley of the Ure, including that at Ripon Parks, significant because of its wide range of habitats, including shingle beaches that are important for a number of breeding birds.

In normal, or 'average' years, the Ure is subject to sudden spates throughout its length which can be brought about by general heavy rain or snow melt throughout the catchment or by localised cloud bursts affecting one or two upland streams. However, during the latter half of 1995 and for most of 1996, the Ure experienced very low flow conditions, with very few winter spates. In addition to this drought, throughout most of 1996 YWS was also operating under a Drought Order, followed by a TLL, at the Kilgram Bridge abstraction point, with a critical flow set at 163 tcmd. During the summer of 1995, the river had fallen below this level for considerable periods but, on average, the river ecosystem experienced lower monthly flows in 1996 than in 1995 (938 tcmd v 1125 tcmd). In long term perspective, since 1972, average monthly flows were lower only during 1975 (901 tcmd). The drought in 1995 produced the driest month in this period: August, with only 26 tcmd (and only 8.3 tcmd on 23 August).

The Agency received a Drought Order application for the Ure from YWS in January 1996 and made representations to the Public Enquiry that was called following objections. These recognised the need and justification for the Order, but outlined additional monitoring, mitigation and restoration requirements to be carried out by YWS to ensure that the environmental concerns were adequately addressed.

10.2 Purpose

Unprecedented low flows and drought in the Ure catchment during 1995 and 1996, together with the granting of a TLL to YWS for the operation of their abstraction at Kilgram Bridge, required detailed investigative and monitoring work to be carried out by both YWS and the Agency. This covered aspects of hydrology, water quality, river habitat and macrophyte surveys, invertebrate and fisheries monitoring and studies on potentially effected birds and mammal, (see **Figure 10.2a**).

10.3 Hydrology and water resources

As with the Wharfe, the Ure is dependent on summer rainfall to maintain flows given the relatively small input from groundwater derived base flows. Consequently, the drought of 1995/96 was severe, with some of the largest rainfall deficits of recent times being observed. Particularly noticeable was the lack of rainfall in the upland Pennine catchments, resulting in some very low river flows, with long term minima occurring in several months.

Data from various sources have been collated and are available. Rainfall data are available from a number of stations throughout the Swale, Ure, Ouse catchment (see section **9.3**). The extremely low rainfall over this period had a significant impact on river flows during 1995/96.

River flow data are available for the Ure at Kilgram Bridge. The station recorded long term minima for at least two months during 1995 and the mean flow in the Ure during 1995/96 was just less than 80% of the LTA. The period from 1 April 1995 to 30 September 1996 averaged less than 50% of the expected flow for these months.

Summer flows in the Ure are usually at a minimum in July, with a mean of 404 tcmd and a median of 150 tcmd. However, set against this pattern is extreme variability (34-6075 tcmd range during 1982-95). During 1995-1996, the Ure was below its critical flow of 163 tcmd for considerable periods (eg for the whole of August 1995), during which the Kilgram abstraction was nonexistent or minimal (see below).The first drop below the critical flow was in the second week of June 1995, and this continued almost uninterrupted until the last week in September (**Figure 10.3a**). A breakdown of flows in the Ure and the other three rivers, as compared with the LTAs, is given in **Table 9.3b**.

The YWS abstraction from the Ure is immediately upstream of the Agency's gauging station at Kilgram Bridge. It provides the ability to fill Thornton Steward Reservoir and/or Leighton Reservoir, or feed directly into Harrogate raw water main. The original licence conditions included a prescribed flow of 161.49 tcmd at the gauging station, above which flows of 22.73 tcmd could be taken. An abstraction of 3.27 tcmd could be taken at all times. The Drought Order granted to YWS increased the abstraction by 30 tcmd to 52.3 tcmd when the net flows were greater than a new critical flow of 163 tcmd. The TLL granted on 16 May 1996 (for a three-year period) is a continuation of this regime. .

Data on the YWS abstractions from the Ure at Kilgram Bridge are available from Section 201 returns, with monthly figures for several years. Analysis of the abstractions made during 1995/96 shows that this licence has been **underutilised (Figure 10.3b)**. The average abstractions were eight tcmd in 1995 and 11 tcmd in 1996. The prescribed flow equates to approximately the 84% exceedance flow, so the lowest flows are unaffected by the abstraction.

The actual abstraction between 1 April 1995 and 30 September 1996 caused a reduction of 1.7% to the average flow over that period. Under the old licence conditions, the reduction was potentially 2.8%, and under the new licence conditions this reduction could have been 6%. Of more relevance, there is most concern when the river is in the low to medium flow range (but above the prescribed flow), where the new licence allows up to a maximum of 25% of the flow to be taken. The old licence only allowed up to 12% of the flow to be taken. In contrast, on the Ouse, the lower of the prescribed flows is close to the 95 percentile flow (Q95 - the flow exceeded 95% of the time) and so abstraction may have a larger impact on the low flow range. The actual quantity forms a smaller proportion of the total river flow than the Ure abstraction.

10.4 Water Quality

The Ure is a high quality river with only localised impacts on water quality, biology and fisheries from a few, relatively minor, effluent discharges. As outlined in the *Interim Report*, in spite of low flows in 1995 the quality remained high and, overall, remained the same as in 1994. The exception was a minor shift downwards in water quality at Boroughbridge, where highly variable levels of dissolved oxygen, BOD and ammonia were observed. The continued monitoring of the Ure as part of the GQA programme and further analysis of the water quality data (including nutrients) ensure that any drought or abstraction impacts are assessed and put into a longer perspective.

Six water quality monitoring sites are assigned to the main River Ure. Most of the sites attained face-value chemical GQA grade B (*good*) during 1995-96, the exceptions being Wensley (grade A, *very good*) and Boroughbridge (grade C, *fairly good*) during 1995. There appears to be no correlation of the individual year GQA grades with perceived drought and non-drought years, although the quality was generally higher in 1994 **(Figures 10.4a-f)**.

Generally, the Cusum analysis of the time series data shows few trends with respect to dry or wet years, with the exception of pH and dissolved oxygen **(Table 10.4a)**. Significantly higher pH values during the later part of 1995 and into 1996 match a similar event in 1989-90 **(Figure 10.4g-h)**, and may be an influence of the limestone geology during low, base flow conditions (and lack of relatively acid runoff from moorland areas). Lower dissolved oxygen levels in the Ure at Hewick Bridge **(Figure 10.4i)** may reflect less dilution for organic wastes and increased levels of microbial activity, although this does not appear to show up in the Cusum and time series analyses for BOD **(Figure 10.4j)**. Ammonia levels were not significantly higher during the drought period, and for most of the sites, levels were lower in the period since 1991/92.

Nutrient levels (nitrate and ortho-phosphate) similarly show no significant trend within the drought period, although nitrate levels were higher after about 1991, and orthophosphate levels were lower during 1990-93 at some sites.

Water quality in the Ure is generally high, and even at naturally occurring low flows (<100 tcmd) high dilution is available for all effluent discharges, allowing the river to remain in chemical GQA grades A and B for its entire length. The main effluent discharges are in the lower reaches, from Ripon to Boroughbridge STWs and West Cumbrian Farmers Foods Ltd at Boroughbridge. Any changes or deteriorations in water quality as a result of low flows are more likely to occur in this stretch than in the upper reaches.

10.5 River Habitat Survey

River Habitat Surveys (RHS) were undertaken as part of the monitoring programme associated with the YWS TLL to increase abstraction from the Ure at Kilgram Bridge. Two of these were above and seven were below the YWS abstraction point at Kilgram Bridge, and were distributed at fairly regular intervals in order to provide an overview of the river.

The nine reaches surveyed displayed a wide range of physical and habitat features and a range of signs of human interference, including derelict weirs and flood defence structures, large scale ponding and canalisation. No impact due to drought or abstractions could be detected at this stage since there are so many influencing factors.

The Ure's upper reaches are at least as variable as the lower ones, from conditions ranging from relatively stable, uniform reaches with smooth linear flows to those which are clearly subject to dramatic erosion and change where gravel banks and shoals are frequent and flows are chaotic, at least in places. Some 500m reaches display the characteristics of both upland and lowland rivers, as at Mickley and Hewick Bridge The lower reaches are more subject to human interference and activities as described above, and are obviously subject to greater flows as rivers such as the Burn, Laver and the Swale join the Ure.

Drought impact on the Ure's riverine habitat may be insignificant in comparison to the human influences. The extraction of sand and gravel direct from the river occurs at North Stainley. Vegetation is removed during the extraction operations and little recolonisation can occur once the river is deepened significantly. Similarly, grazing, and over grazing, is a recurrent problem of riparian management, causing bank erosion, suppression of emergent aquatic plants and riverside tree/shrub growth and some degree of eutrophication. The vegetation had certainly been affected by stock grazing at Middleham, Jervaulx, Clifton Castle, Newby Hall and Dunsforth, at points where stock had access to the river bank. The relative abundance of aquatic vegetation at Aldwark, where the river runs through a golf course, indicates that grazing may be the major factor affecting plant growth.

10.6 Ecology

10.6.1 Macrophytes

Macrophyte surveys were carried out at nine sites on the River Ure between Middleham Bridge and Aldwark. The surveys were undertaken by **Scott Wilson Research Consultancy** between 19 and 21 August 1996. The survey reaches coincided with the nine 500m RHS reaches.

Throughout, filamentous algae were the dominant group, superimposed on a longitudinal change in the other macrophyte species. It was also noted that *Phragmites australis* (common reed) replaced *Phalaris arundinacea* (reed canary-grass) as the dominant emergent aquatic in the Newby Hall reach, and this was accounted for by the artificially maintained water level and high nutrient status. *Phalaris* is more drought-resistant and less palatable to grazing animals than *Phragmites*.

Previous surveys on the Ure include work carried out by Nigel Holmes in 1982 as part of the "*Typing British Rivers According to Their Flora*" project. This was followed up in 1992 by Jane Southey Environmental Consultants, on behalf of English Nature. Whilst a ten-year gap between surveys and slight differences in site locations make direct comparisons difficult, it is possible to detect certain trends. As with the 1996 survey, that of 1992 recorded a high percentage cover of filamentous green algae. The earlier report also states that there were indications of a reduction in species diversity at some sites compared to the 1982 survey, but that this may have been due to differences in survey site locations between the two surveys. Five of the twelve survey sites showed the same vegetation type in both surveys and the rest were broadly similar, even after the three years of drought preceding 1992.

Whilst it is not possible to draw direct comparisons among the 1996 surveys and those from 1982 and 1992, the 1992 results were broadly similar to those of 1982 (with a slight decrease in plant diversity which may only reflect a difference in the sites surveyed). A comparison between the 1992 and 1996 surveys does not indicate any major changes within the past four years.

Observations indicate that spates and dramatically high flows can have a significant effect on aquatic vegetation, as can eutrophication combined with low flows. In 1990, the Ure at Aysgarth (SD998887) was estimated to support a cover within the channel of 50-65% of water crowfoot with some 10% filamentous algae. In April 1991, all the higher plant cover had disappeared and only 10% filamentous algae were still present: this was ascribed to winter floods. Later in the year, large mats of green algae were observed, including *Hydrodictyon* (waternet), that had only been recorded in North Yorkshire once before, in a highly enriched stream during low flows. The algal bloom was ascribed to nutrient enrichment from STWs at Hawes and Bainbridge combined with low flows during that summer. However, by 1992 these green algae had been largely replaced by *Lemanea* (a filamentous red alga indicative of clean water) and the water crowfoot had started to regenerate, recovering to previous levels by 1993.

Low flows may result in a concentration of nutrients close to a discharge point, and subsequent high flows or spates may then flush this down through the system. Whilst this punctuated form of dispersal may be characteristic of spatey rivers such as the Ure, prolonged low flows will exacerbate the effect. This is likely to have a considerable impact on macrophyte communities. The 1996 macrophyte survey has confirmed that filamentous algae have been very abundant at many sites. At Jervaulx, filamentous algae provided 100% marginal cover and at Dunsforth, submerged macrophytes had a 70%-100% covering by filamentous algae.

10.6.2 Aquatic macro-invertebrates

As stated in the first *Interim Report*, the 1995 GQA monitoring programme showed that the 1995 drought had little impact on the invertebrate ecology of the Ure apart from possibly increasing the richness of the faunas in the lower river. Nevertheless, in 1996, three-season macro-invertebrate sampling on the Ure was carried out by the Agency to assess further any additional cumulative biological impacts of the continuing drought and as a component of the joint YWS/Agency TLL environmental monitoring programme.

Biological surveys in 1995 and 1996 included six sites on the main Ure (**Figure 10.2a**). Invertebrate sampling was carried out in spring, summer and autumn, by standard three minute kick sampling, although at Aldwark Bridge in 1995 this deep river site was sampled by naturalist's dredge and marginal sweep-netting (a method approved by the Agency). Subsequent identification was to mixed taxonomic level. In 1997 an airlift sample was taken from this site as part of an Agency biology survey of the lower Ure, which should provide comparative data.

Detailed analysis of the species information, also collected by YWS at additional sites upstream and downstream of the Kilgram Bridge abstraction, will form part of the three-year monitoring programme report, and the present report is confined to family-level analyses.

The drought of 1995 and 1996, together with the introduction of the TLL at the Kilgram Bridge abstraction point, gave rise to concern about possible deteriorations in water quality and its consequences for riverine ecology. Biological water quality between 1990 and 1996 is shown in **Table 10.6a**. The two independent classification systems show a similar trend for the most upstream three sites in the river that were sampled in both 1995 and 1996, with Bainbridge maintaining the same classification during 1995-96, whereas the samples from Wensley and West Tanfield both suggested a slight decline in biological quality in 1996, being graded *good* under the Yorkshire Interpretative Index. This apparent slight deterioration at both sites can be explained by changes in the relative abundances of pollution-tolerant invertebrates compared to pollution-sensitive types.

In contrast, the two biological classifications indicate a conflicting interpretation of the fauna sampled from Boroughbridge, with the YII lowering the 1996 grade to B2+ (*fair*), whereas the GQA is grade *a* (*very good*). At this site, the samples contained comparatively numerous pollution-tolerant groups, coupled with depressed abundance of pollution-sensitive animals. The raw invertebrate data suggest the YII gives truer indication of the biological water quality of the Boroughbridge site, because of the uncharacteristic abundance of pollution-tolerant invertebrates, ostensibly suggesting some organic enrichment. Another interpretation is that these animals are also more characteristic of depositing substrata (ie silts and sands), with the lower flows allowing increased levels of fine material on the river bed.

As a result of preliminary multivariate analyses, the routine sampling sites could be grouped into about four zones: the upper Ure in the stretch from Appersett to Aysgarth; the middle Ure from about Wensley to downstream of Hewick Bridge; and two lower Ure zones represented by sampling sites at Boroughbridge and Aldwark Bridge. Further work on this faunistic background of the Ure is continuing but is not reported here.

Biotic indices of the sites during the period 1985-96 are shown in **Figures 10.6a-c**. Those from Wensley to downstream of Hewick Bridge (straddling the Kilgram abstraction) are reasonably concordant and show no trend during the 1985-96 period, although there are smaller patterns. It is noticeable that the highest biological diversity, as measured by the *BMWP score* and *numbers of taxa*, coincides with periods of low flows, ie in 1989 and 1995, when individual *BMWP scores* of over 200 were recorded.

Examination of the recent and historical data (since 1985) showed that most of the macro-invertebrate samples from the Ure collected since the autumn of 1995 are grouped on the limit of the variation seen in the previous ten years. Data collected in the summer of 1996 from the **upper Ure** also form a distinct group compared with the natural variation of previous summer data (**Figure 10.6d**). The reasons lie primarily in the changes in the relative abundances of the taxa (**Figure 10.6e**). Of the thirty families shown, most (twenty-two) have decreased in average abundance, implying a general reduction in the productivity of the upper Ure.

Invertebrate data collected from the **middle Ure** have also shown changes since autumn 1995 when compared with previous results, although the Wensley fauna showed a different response to that from West Tanfield and Hewick Bridge. These changes were more significant in the spring and autumn samples. Again, much of the data collected in autumn 1995, spring 1996 and autumn 1996 form a distinct group on the edge of the natural variation previously recorded in these seasons (**Figure 10.6f**). Out of the 32 most common families sampled, the majority (23) showed an increase in average abundance, related to more 'beneficial 'river conditions for their reproduction, survival and growth (**Figure 10.6g**). The similarity of the spring 1996 fauna with that from the previous autumn parallels the situation on the Wharfe, and this may be related to lower winter flows and a lack of significant faunal washout and redistribution.

Two invertebrate families that have experienced a significant fall in average abundance in both the upper and middle Ure are the perlid stoneflies and polycentropid caseless caddis; however, the reasons for this are not clear, although both are flow-loving groups usually characteristic of the upper part of the fast flowing Dales rivers.

In the lower Ure, autumn Boroughbridge samples collected from 1995 and 1996 are on the edge of variation compared with previous years, suggesting a drought impact. Comparison of abundance levels suggests that overall numbers of animals in the autumns of 1995 and 1996 varied little compared with previous years, as higher average abundance of certain groups had been offset by lower average abundance of others (**Figure 10.6h**). In effect, the fauna's response to the drought is not as clear cut as in the Ure between Wensley and Hewick Bridge, where this may be a slight enrichment effect. Continued sampling in 1997 should give further information regarding faunal changes at this site, and possible reasons for the difference between the last two autumn samples.

Insufficient seasonal data are available for the site at Aldwark Bridge to assess any impacts the drought may have had on this lower section of the Ure, where the river is more stable, deeper, slower flowing and more sand and silt dominated. Further sampling of this site is to take place in 1997, as well as a survey of the stretch downstream to Linton Lock.

Overall, the changes in invertebrate faunas in the Ure since autumn 1995 appear similar to those shown in the Wharfe: the upper part of the catchment appears to have experienced a reduction in productivity, whereas the middle and lower sections have had an increase. The diversity of invertebrates sampled appears not to have altered greatly, but there have been distinct changes in the relative abundances. Pollution-sensitive and rheophilous animals have been present in lower numbers, and there have been increases in those families associated with lower flows, and increased organic enrichment.

10.6.3 Fisheries

Drought and the granting of a TLL for the abstraction at Kilgram Bridge led to the instigation of a three-year study to examine the fish populations in the Ure and its tributaries.

(i) Sites and methods

The Agency's triennial rolling programme and the annual fry survey formed the basis of site selection on the main River Ure, with additional tributary sites selected on the basis that previous population studies had been done and would offer baseline information in order to detect any trends in population structure. The sites are shown in **Figure 10.2a.**

Tributary and upper Ure sites were sampled by single anode electric fishing, whereas lower Ure sites, being much deeper and wider, were approached with multi-method techniques in order to improve capture efficiency. A full analysis of this issue (selectivity on species, size and age of multi-method techniques at three sites, Aldwark Bridge, Beningbrough and Naburn) is available in FSR 21/97.

The fish population survey was conducted between 19 July and 13 August 1996, covering eleven sites, with the fry sampled at a single site at Boroughbridge during the annual fry survey on 19 September 1996. These dates are relatively consistent with the timing of earlier surveys, thus allowing a direct comparison with previous results.

Catch returns were analysed from three sections on the Ure, and include a small section of the Ouse which is part of the historical data set. The sections are: Spennithorne to Ulshaw Bridge in the upper river, Bishop Monkton to Boroughbridge and Dunsforth to Linton-On-Ouse in the lower river.

(ii) Main observations

Poor catches of brown trout were once again observed at **Worton**, despite the stocking of fry in the spring of 1992. Although the area of suitable habitat for larger trout was reduced as a result of low flows over the weir, the site should support more juvenile fish, and the low catches give cause for concern. Brown trout, grayling and salmon were the most numerous species noted at sites from **Middleham to Mickley,** with coarse fish, notably chub, barbel, gudgeon and ruffe, also relatively abundant at Middleham despite suggestions that ruffe were absence from the river. Greater numbers of fish, particularly grayling, were recorded at **Middleham** than in the previous survey, along with the capture of large chub and barbel. Comparable numbers of large chub and barbel were reported during the 1983 survey when similar low flow conditions prevailed.

The numbers of juvenile salmon observed in the main river are encouraging, as the numbers observed in the tributary streams appear to have fallen during the drought (**Figures 10.i & j**, and see FSR 4/96). In 1992, a relatively large decline in the number of juvenile salmon found in Ure tributary streams was reported and attributed to poor water quality conditions in the tidal Ouse and low flows in the nursery streams as a result of the "drought" 1989-90.

At **Hewick Bridge** the overall number of fish captured was lower than the previous survey, partly as a result of the reduced efficiency of the gill nets, but dace were still relatively abundant. Most notable at this site was the lack of roach compared with the previous survey. Roach, bleak and chub were the most numerous species captured at **Langthorpe**, representing an increase in numbers compared with the previous survey, whilst the numbers of perch and pike were lower. At **Aldborough,** gudgeon, roach and perch were relatively numerous with slightly more pike than at upstream sites. Roach were the most abundant species present at **Aldwark Bridge,** with relatively large numbers of bream also recorded. Perch, bleak and gudgeon were the next most numerous species present, with ruffe being more abundant than at all previous sites except **Middleham.**

Eels were recorded from all Ure sites except Worton and Jervaulx, where habitat may be limiting.

In the main Ure, the 1994 year-class of brown trout was notably stronger than most, with the exception of Mickley, where a stronger 1993 year-class was observed. At Mickley, above average growth rates were also noted, which may suggest that the populations at this site are associated with stocking. The age structure of salmon was numerically dominated by the 1996 year-class (0+), with fish at Clifton Castle expressing slightly faster growth rates than observed at Mickley. The 1996 year-class of grayling was also particularly strong, but both Middleham and Clifton Castle had evidence that the 1995 year-class was fairly well represented. Dace were well represented by the 1995 year-class at Hewick Bridge and Langthorpe. Large, old chub were only captured at three sites on the Ure: Middleham, Jervaulx and Mickley, where the 1983 and 1984 year-classes were most evident.

Most coarse fish species in the lower Ure were supported by a strong 1995 year-class; notably, bream of this year-class were present at Aldwark Bridge. At Langthorpe, the 1995 year-class of bleak was particularly strong compared with other sites. Ruffe were not captured in sufficient numbers to indicate relative strengths of recent recruitment, apart from at Aldwark Bridge where a small number from that cohort of 1995 was present. Pike were mostly represented by fish from 1994 and 1992 and, as with perch, the older fish were from,1989-1992 year-classes.

Compared with previous years, the growth rates of most fish were greater than those observed in 1993. Fry survey reports (FSR 17/91 and 49/96) demonstrate that their relatively faster rates of growth were related to very good growth in their first year, with fry in 1995 attaining greater mean lengths than those in 1990.

High densities of 0+ trout occurred in both Swan and Apedale Becks, but >0+ fish were observed in very low numbers. The number of 0+ trout gave the highest densities on record for these becks and yet the number of older fish were the lowest. This indicates very good conditions for recruitment, as a result of adult fish ascending the streams from the Ure, in the autumn/winter of 1995. The very low numbers of >0+ fish may have occurred as a result of escapement to the Ure of juveniles in 1995, poor recruitment in 1994 or high mortality or emigration in the drought conditions of 1995. Results from the Wharfe drought survey (FSR 14/97) and the low numbers of 1+ trout in the Ure support the theory that the 1995 year-class of brown trout was relatively poor, with a strong year-class from 1996.

The high densities of 0+ brown trout (1996 year-class) in Swan and Apedale Becks gave rise to mean lengths 1cm smaller than previous figures, and by comparison trout fry in the main river at Clifton Castle were also larger, indicating a density dependant effect upon growth in the two tributaries.

The fry of four species (chub, roach, bream and minnow) were recorded in 1996 compared with a further four species (dace, bleak, gudgeon and three-spined stickleback) in 1995. Dace were the most notable species by their absence, as they have been present in every sample, except 1989, since fry monitoring began in 1981. Roach were numerically dominant, with chub, minnow and bream also present. Bream have only been recorded on four occasions, 1983 and 1984 and recently in 1995 and 1996. Recruitment in 1983 resulted in a strong year-class that has supported angling catches in the Ouse system. The relatively large number of 1+ bream (1995 year-class) sampled at Aldwark Bridge suggests that this year-class will support angling catches in the future.

The mean lengths of each species were slightly above the long-term values, but not as high as those observed in 1995, and it is unlikely that the 1996 year-class will be particularly strong.

(iii) Angling catch returns

Detailed analysis of catch returns are available in FSR 11/97. Very few matches were reported from the Spennithorne to Boroughbridge stretches but, in spite of this, the classification has remained relatively stable, with an increase from D to C during the warm summers of 1989-91, a return to D in the following years and back to a C in 1996. A more detailed examination of individual returns from the Dunsforth to Linton section indicates that catches were generally good throughout the summer and early winter but declined thereafter when anglers usually expect catches in this section to improve. Although not analysed, results from some winter league matches reported in the angling press highlighted relatively poor results. The species composition of angler catches has not changed greatly in recent years, with roach and perch being the most recorded species. Bream were not recorded from club matches in 1996 but chub were observed to increase slightly.

(iv) Angler reports

In the upper river, reports were received indicating that filamentous algal blooms were evident. An angler reported poor fly hatches at Jervaulx, whilst another had observed large hatches at Tanfield in 1996. Most anglers expressed concerns about the rapid rise and fall in river level in recent years and the exceptionally low levels observed in the last few years. Concern has been expressed over the lack of flow, which is insufficient to"clean" the river, and the appearance of stagnant areas where "sludge and algae" (diatom mats) build up. Reports were received from anglers expressing concern over the colour of the river. The river was reported as having a green/grey tinge to it, whilst other reports related to the river being much clearer than normal.

Agency Fishery Inspectors were notified of good catches of trout and some grayling in the upper Ure during May and June. At the start of the coarse fishing season, chub, dace and barbel were reported in catches in the river around Ripon and Boroughbridge and a 13lb salmon was taken by rod and line at Ripon during June. Inspectors were informed of poor catches in the lower Ure, notably Dunsforth to Linton during the winter of 1996.

Inspections during the winter revealed salmon redds at Middleham, Clifton Castle and Jervaulx. Brown trout redds were observed at Middleham. A follow-up survey in April 1997 revealed that the salmon redds at Clifton Castle and Middleham were still covered by flowing water, but some of the redd observed at Jervaulx was exposed. The tail water behind this particular redd was almost stagnant with mats of diatoms rising to the surface. The area at Middleham where brown trout redds were observed was relatively dry with much exposed gravel. An examination of the exposed redds failed to reveal any eggs or alevins.

(v) Key issues/impacts

The production of brown trout in Apedale Beck does not appear directly related to flow in the catchment measured at Kilgram Bridge. Low flows in September through to December would most likely impact on adult access from the Ure to the nursery streams, which does not seem to be the case in Apedale Beck, and the large numbers of fish evident in Swan Beck further support this; certainly, the apparent reduction in wetted area of the streams as a result of the drought cannot account for such a large increase in density.

It is noticeable that the growth rate data show that the mean length of 0+ fish was much lower at the higher densities observed in 1996 than in previous years, which suggests that fish are more concentrated, possibly as a result of low flows. This has possible implications of reduced fish survival resulting from the increased susceptibility to disease, predation and the lethal effects of high temperatures in shallow water. Brown trout are thought to be less susceptible in the main river than in tributaries because of relatively higher flows and a wider availability of habitat. However, at lower flows, especially if reduced by abstraction, trout could become subject to higher temperatures and disease, with any crowding in pools leading to an increased susceptibility to predation.

A description of salmon smolt production is available in FSR 4/96. From 1990, the number of smolts has declined markedly, which coincides with the low flows and hot summers of 1989-1991. Loss of production in the tributaries as a result of low flows is highlighted in FSR 4/96 but reduced flow in the main river will also account for some loss of production, particularly as it appears that some redds may become exposed as a result of low flows, which will be most critical between October and May. This clearly needs addressing in relation to abstraction rates.

Another serious threat, and possibly the most significant to continued breeding of salmon in the Ure, is the poor water quality of the lower, tidal Ouse, in particular the low dissolved oxygen levels and high temperatures during hot summers. Smolts are at greater risk than adults due to their lower swimming capabilities, but their migration to sea occurs in early spring when river levels should be higher and, along with lower temperatures, should assist in their survival. If conditions prevail whereby river levels are low during smolt migration then increased mortality would be expected. Adults returning in spring are also at risk at low flows but, what is more important, late run fish would run an even higher risk as a result of low summer flows, increased water temperatures and low dissolved oxygen acting as a block to migration, as expected in the drought years. Returning adults during late summer and autumn would also have to negotiate weirs and passes under sub-optimal flow conditions and therefore increased mortality could arise. **If salmon runs do increase significantly in the near future a similar scenario to that observed on the Tyne may arise whereby poor water quality during hot drought years may cause large mortalities of returning adults.**

Low flows were not thought to be directly correlated to successful recruitment of coarse fish in the Ure, rather the associated high water temperatures during drought conditions showed a strong positive effect. Notable increases in fry growth rates were observed.

At this stage in the study there are no clear indications that the drought has caused any deleterious effects to coarse fish populations or marked changes in species composition, with evidence of good recruitment by several species. However, the indication that dace did not benefit as much as other coarse fish under these conditions of higher temperatures may suggest some species are affected more than others. **The strong recruitment of most coarse fish suggests that in future fisheries will be supported by the 1995 year-class.**

10.6.4 Birds

Although many birds species are associated with water, discussions with the British Trust for Ornithology (BTO) indicate that only two bird species may be critically affected by prolonged low flows: dipper (*Cinclus cinclus*) and grey wagtail (*Motacilla cinerea*). A review of available data was carried out to determine whether there have been any significant changes in bird populations along the Ure over the last fifteen years, during which time low flows and droughts have occurred. Reference was made to data from BTO's surveys on the Ure, which covered a 7.2km section from North Stainley and Hutton Mill Dam between 1981-1993. The method of assessment used was the BTOs standard River Bird Survey, which is a variation on their Common Bird Census technique. Although these data to not relate directly to the drought of 1995-96, the droughts of 1989-91 would be in context.

These surveys indicate that, whilst grey wagtail populations during 1981-93 remained stable, dipper populations declined, although the significance of this not known. The mean population density for grey wagtail was 4.6 breeding pairs per 10 km and for dipper 1.4 pairs. Of the other birds recorded during the survey period, the following showed a population increase:

Greylag goose (*Anser anser*) - the native population is being augmented by feral birds, thus the population is increasing. The Ure population seems comparatively large.

Teal (*Anas crecca*) - thinly distributed nationally with a declining lowland population, they first appeared on the Ure in 1993 (two breeding pairs) hence the "increase".

Mallard (*Anas platyrynchos*) - the most commonly reported bird during the Ure survey, it is increasing nationally and is encouraged by human feeding in many areas.

Tufted Duck (*Aythya fuligula*) - this species colonised Britain about 100 years ago and has been expanding its population ever since; numbers on the Ure are comparatively high.

Goosander (*Mergus merganser*) - another colonist which arrived in Scotland in 1871 and has been expanding its population and range ever since. The Ure supports a comparatively high population, as do many Yorkshire rivers. It nests "semi-colonially", and being a fish eater it is of increasing concern to fisheries interests .

Little ringed plover (*Charadrius dubius*) - another colonist, having first nested in Britain in 1938. Its numbers are increasing and the Ure birds represent an important population locally.

Redshank (*Tringa totanus*) - this species is in decline nationally, but shows a local increase in the Ure catchment.

Pied wagtail (*Motacilla alba*) - this species has shown a slight decline nationally, but is increasing in the catchment. Although closely associated with water, it is not apparently vulnerable to decreased flow, as is the grey wagtail.

Whitethroat (*Sylvia communis*) - this species is often found in riverside scrub, and as a migrant is subject to occasional population crashes. It has expanded its population spectacularly on the Wharfe, but the situation on the Ure is not clear.

The following showed a population decrease:

Common sandpiper (*Actitis hypoleucos*) - closely associated with upland rivers, the national population is stable, but prone to local fluctuations due to excessive disturbance and changes in river flow. The population on the Ure was high, but has declined. This may simply be a natural adjustment to a more sustainable level.

The BTO considers that the Ure catchment supports an important population of birds, both in terms of species diversity and population sizes, some populations being above the national average. Most of the species for which the populations are increasing are ones which are increasing nationally or are subject to fluctuations. Migratory species may be subject to population pressures throughout their range, and so fluctuations may be due to factors in their wintering or summering grounds or on their migration route.

The two which are declining are both sensitive, to some degree, to changes in river flow: common sandpiper and dipper. Whilst the former is migratory, and therefore subject to external influences, the latter over winters in Britain. As with the grey wagtail, both of these species are insect feeders and require fast running water during the breeding season in order to provide food for their young. The months April - June is the critical period. Given their need for fast flowing water and exposed rocks, both these species are generally confined to the type of river habitat which is associated with upland rivers, but which occurs on the Ure as far down stream as Ripon.

Recent evidence suggests that weather conditions, including the drought, had a devastating effect on breeding populations (not necessarily those associated with the aquatic environment) in 1996. However, bird populations are not particularly sensitive indicators of changes in river flows, and thus not a suitable subject for monitoring to detect environmental change, but they are a high profile group in terms of public interest and perception.

10.6.5 Mammals

Two mammal species for which the Agency has particular responsibility are the European otter (*Lutra lutra*) and the water vole (*Arvicola terrestris*). The former is fully protected under the Wildlife and Countryside Act 1981, and the latter is likely to be so protected in the near future. Both are short listed under the UK Biodiversity Action Programme and the Agency has taken on the role of Contact Point for both species, and in addition is joint Lead Partner (along with the Wildlife Trusts) for the otter.

The Ure has been surveyed for otters on several occasions in the past, and reports of signs (eg spraint, tracks and sightings of individuals) have been verified on a number of occasions. The river is very difficult to survey systematically since the extreme variations in flow mean that spates wash away all signs, whilst low flows leave large areas of substrate exposed and consequently a large area to be searched for signs, which can easily be missed. It is also a matter of conjecture as to what size of population is present from the spraint and other signs. Whilst the Ure has a resident breeding otter population, other individuals may pass through the catchment.

Otters are most frequently reported in the area of Ripon Parks, where a breeding population has been known of for many years. This is thought to be a population which survived the decline of the 1960-70s. Signs and sightings have also been regularly reported at High Batts, Yorkshire Wildlife Trust's nature reserve near North Stainley, but this site has a high number of visits by experienced naturalists who keep a particular watch for signs. Signs of this species have been reported and confirmed as far up stream as Kilgram Bridge (although some reports suggest sightings as far upstream as Hawes), but few if any records have been confirmed downstream of Ripon (although reports have come from as far downstream as Newby).

The decline of otters in the 1960-70s has been shown to be related to the use of organochlorine pesticides, and the withdrawal of these chemicals has marked a recovery of the otter population, which is now returning to a number of its former haunts. The question of agricultural chemicals is still an issue, however, and concerns have been expressed over sheep dips, particularly the new generation of synthetic pyrethroids and the impact they may have directly upon the otter or on its prey species. Reduced flows might serve to concentrate such chemicals.

Food supply is a crucial factor since otters require a sustainable population of fish and invertebrates (particularly crayfish), in order to keep them on a particular catchment and to enable them to breed. All the indications from fisheries and biological information are that food is plentiful, and they will not need to move in search of a more rewarding area, which may result in road casualties.

Under low flow conditions it is likely that prey is easier to catch, being confined to a smaller volume of water, but if stocks become depleted due to increased hunting success of a range of predators, and those predator populations then rise as a consequence, then a population crash may follow. Prey species which are crowded together may also suffer from an increased incidence of disease and parasite infections, or at least display reduced growth and condition due to greater intraspecific competition.

Disturbance by humans and dogs and road casualties are other issues. In this respect the Ure is a relatively secluded river with limited access and few major roads nearby, the A6108 being a relatively quiet road which keeps away from the river for most of its length. For otters attempting to move between the Ure and the Swale the A1 proves a major barrier. Otters are at their most vulnerable when moving between catchments, which they may be forced to do when the young disperse or if conditions do not favour them remaining on the Ure.

Whilst the decline in the water vole population has been a cause of concern in recent years, this was previously thought to be such a common mammal that little systematic survey work was carried out, and consequently little baseline data are available. No such detailed surveys or regular monitoring appears to have been undertaken for water voles on the Ure. Such surveys would involve the location of burrows, latrines and live trapping by qualified experts. The river, with its major variations in flow, does not generally seem a very suitable habitat for water voles, since sudden floods drown them out whilst low flows leave them high and dry away from the water for considerable periods. They are also vulnerable to predators such as birds of prey, foxes and mink, particularly if they are away from their burrows or away from the water. Nevertheless, increased surveying effort could be made in the ponded stretches, where conditions may be more favourable.

Whilst it is unlikely that increased abstraction will have an immediate and dramatic effect on either of these species, it is valuable to continue collating records of the status of the otter population and of prey species throughout the duration of the Time Limited Licence.

11.0 RIVER WHARFE CATCHMENT

11.1 Background and issues

A typical Pennines river, the Wharfe has a varied and rich ecology and shows a distinct zonation in character and habitats from the upper fast flowing and boulder-strewn stretches to the meandering reaches influenced by tidal water downstream of Tadcaster. The highly spatey nature of the river, with its associated fluctuations in the extent of wetted and exposed areas, probably accounts for some of the biological diversity and annual variability in long term data.

The biological quality of the Wharfe can be described as excellent or good, but the invertebrate faunas have regularly suggested that the middle and lower reaches are slightly influenced by organic enrichment, rather than by negative impacts from elevated levels of BOD or ammonia. The Wharfe also holds populations of native white-clawed crayfish (*Austropotamobius pallipes*), a species that is under threat nationally from introduced signal crayfish (*Pacifastacus leniusculus* - also present in the Wharfe from Kilnsea to Burnsall). A rare, and possibly threatened, species of pea mussel (*Pisidium tenuilineatum*) has been recorded at Grassington. The river itself is an SSSI from Buckden to Kettlewell, in the upper reaches.

The change in the river's character is also reflected in the fish communities, with trout being augmented by grayling, and then giving way to coarse fish down the system. Many of the tributaries are also important spawning grounds for trout.

With the onset of the 1995/1996 drought and the introduction of Drought Orders and a TLL, the ecology of the Wharfe has been perceived to be under threat and vulnerable to damage as a result of extreme low flows, loss of habitat and water quality changes. Unprecedented low flows were experienced over long periods by the aquatic communities during this period, especially during the autumn of 1995 through to early spring in 1996. In addition to the impact of the natural drought and the potential effect of increasing abstractions at lower river flows from Lobwood, The Hollins and Arthington, the issue of compensation releases has also given rise to concern, particularly in relation to the perceived changes to the Wharfe downstream of the River Dibb.

11.2 Purpose

Unprecedented low flows and drought in the Wharfe catchment during 1995 and 1996, together with the granting of a TLL to YWS for the operation of their abstraction at Lobwood and Arthington, required detailed investigative and monitoring work to be carried out by both YWS and the Agency. This covered aspects of hydrology, water quality, river habitat and macrophytes, invertebrates and fisheries and studies on potentially affected birds and mammals (**Figure 11.2a**).

11.3 Hydrology and water resources

The Wharfe is dependent on summer rainfall to maintain flows, given the relatively small input from groundwater derived baseflow. The Wharfe reacts very quickly to rainfall, quite unlike rivers such as the Derwent or Hull which derive a greater proportion of their flow from aquifers. In simplistic terms, however wet the preceding winter, if there is very little rain during the summer then flows in the Wharfe will also be very low. In contrast, there is a good correlation on the Derwent between summer flows and rainfall during the preceding winter.

This report is based on the best available hydrometric data from the Wharfe for the years 1995 to 1997, in relation to data collected in previous years. Information is available for rainfall and river flows, but the Agency does not have access to any rainfall records in the Wharfe catchment which predate 1960. The closest long period record is from the gauge at Harlow Hill WTW in Harrogate, which goes back to 1920. **Figure 11.3a** indicates the month on month cumulative surplus or deficit of rainfall, when compared to the 1961-1990 LTA for Harlow Hill. (In concise terms, when the graph is on a downward trend then rainfall is less than average, and when it is wetter than average, the graph climbs). Between 1920 and 1960, annual rainfall was on average 14mm greater than between 1961 and 1990. This is represented by the surplus of 570mm, shown at the start of the average period in 1961. Also shown is the overall deficit in rainfall since the late 1980s, halted temporarily by wetter than average conditions in the early 1990s. Prior to 1989, there had been twelve to thirteen years of generally wetter than average conditions in the Wharfe area.

Analysis of averaged rainfall totals for five raingauges in Wharfedale from 1961 to 1990 (**Figure 11.3b**) shows that since March 1995 very few months have been wetter than average, and this has had a marked impact on flows in the Wharfe, as there is very little groundwater storage in the system.

Observed river flow curves, one for each of the last three years for each of the principal gauging stations in the Wharfe catchment, namely Grimwith, Addingham and Flint Mill, are shown in **Figures 11.3c-e**. Grimwith GS measures the release from the reservoir down the River Dibb; Addingham GS is between the Lobwood and The Hollins abstraction points. Flint Mill GS is downstream of Wetherby, and will in time be replaced by the ultrasonic gauge at Tadcaster.

River level data are also available, at fifteen minute time intervals, for the following sites:

1992 to 1997	*1996 to 1997*
Otley Weir	Hubberholme
Arthington Nunnery	Starbotton
Collingham	Skirfare Bridge
Thorp Arch	Grassington

Each of the **Figures 11.3c-e** describes daily mean flows for a given year in relation to maximum, minimum and median flows for the time of year. Median, rather than mean, is used to describe the 'average' flows, as mean flows are deceptively high due to the large volumes of flow during high flow events. By definition, median flows are those exceeded for 50% of the time (also described in hydrological jargon as Q50).

It is clear that Grimwith was used heavily for much of 1995, but releases were not significantly higher than the median, and they were much reduced after the Drought Order in September. In contrast, releases for 1996 were more varied, given the minimal replenishment of reservoir stocks during the winter of 1995/6. During the very driest periods, releases from Grimwith of 100 tcmd can equal the natural flow of the River Wharfe. The natural Q95 of the Wharfe at Addingham is approximately 150 tcmd.

Observed flows at Addingham during 1995 describe the effect of the rainfall pattern over the catchment during the year. During the first three months of 1995, flows were above average, most notably during the large flood events at the end of January and beginning of March. During the summer, flows were below average but not at the minimum for the time of year, apart from a short period in July. For most of this time the compensation releases from the Dibb were at least equal to or in excess of the abstractions from Lobwood and The Hollins, so the flows in the Wharfe downstream of the Dibb (and particularly the Bolton Abbey section) were in fact artificially high, even though abstraction at Lobwood was intense from April 1995 onwards.

However, for long periods between September 1995 and April 1996, flows were the lowest measured for the time of year (ie. since 1970), the lowest being 64.3 tcmd on 6 September 1995. Throughout the summer of 1996, flows were generally below average but, as in 1995, not as low as during the drought of the late 1980s and early 1990s. Flows during the winter of 1995/6 fluctuated around the average, in a manner which could be expected from a flashy river such as the Wharfe.

Further downstream, flows for the first three months of 1995 at Flint Mill were above average. For extended periods between April 1995 and September 1996 flows were at their lowest recorded for the time of year. During the latter part of 1996, flows recovered due to the first significant rainfall for eighteen months. In order to protect this part of the river, there is a requirement on YWS to ensure a compensation release of 18 tcmd from Lindley Wood Reservoir into the River Washburn (at the confluence with the Wharfe, 18 tcmd represents approximately 10% of the Wharfe flow under Q95 conditions). This requirement remained in force throughout 1995 and 1996, but YWS did apply to abstract the Washburn 'compensation' water at Arthington.

The amount that can be abstracted from Lobwood and The Hollins is dependent on the flow of the river and the amount of water released from Grimwith on the previous day. This policy assumes a travel time of 24 hours from Grimwith to Lobwood. Fluctuations in the hydrograph at Addingham suggest otherwise. Study of the relationship between the releases, abstractions and natural flow of the river was carried out for the period of 14 to 28 June 1996. This period was chosen for the following reasons:

- The release from Grimwith was gradually increased during the period.
- There was no rainfall during the period until the 25 June: therefore, the river could be expected to be in a state of steady recession.
- The 'observed' hydrograph from Addingham was quite variable, suggesting that releases from Grimwith and abstractions at Lobwood were not synchronised.

Data for the Grimwith releases and observed flows at Addingham were retrieved from the Agency hydrometric database, while Lobwood abstractions were supplied by YWS. The results indicate that the time of travel between Grimwith and Lobwood was 7.5 hrs, with a further 1.5 hrs to Addingham GS.

Daily abstraction figures for Lobwood, The Hollins and Arthington have been received from YWS for November 1994 to date. This information (**Figure 11.3f**) illustrates the extra pressure on the Wharfe through the increased take from Lobwood and use of the Arthington abstraction from early 1996, although the former declined somewhat during the summer and autumn of 1996.

11.4 Water quality

During 1995, the NRA's GQA water quality sampling programme (twelve sites on the non-tidal Wharfe) was supplemented by an additional eighteen sites dealt with by YWS, for a limited suite of determinands, between August and December. These included longitudinal and transverse surveys from Addingham to Pool.

The frequency of sampling at the GQA sites was doubled from the mandatory twelve occasions to twenty-four (effectively once a fortnight) from 1 April 1996, and final effluents at seven major sewage and trade discharges have been sampled concurrently at normal frequencies (Ilkley, Burley-Menston, Otley, Pool, Thorp Arch, Wetherby and Tadcaster).

Changes in general water quality classifications in the Wharfe over the period 1993 to 1995 were examined (**Figures 11.4a-g**). Chemical GQA grades for the period 1992-96 fluctuate between A (*very good*) and B (*good*), but this does not necessarily correlate with flows. The grades for 1991 were C (*fairly good*)/D (*fair*), depending on the sample point, and therefore worse than 1995/96. However, the lower GQA in 1991 does not mean that the drought had a more significant impact on water quality in that year. The STWs on the Wharfe underwent some improvements in the early 1990s, with a resultant improvement in effluent quality.

1996 was a very poor year for ammoniacal nitrogen in the tidal Wharfe at Ryther, and it is believed that this was linked to intermittently high ammonia discharges from Tadcaster Trade STW, combined with low dilution in the Wharfe. The situation at the works has now been rectified. At Tadcaster Weir quality was only grade D in 1996, but this is probably due to a single spurious result from the autumn of 1996 skewing the statistics rather than a drought impact.

In the previous *Interim Report,* the YWS monitoring (reported in more detail in their Drought Order submission) indicated that the levels of dissolved oxygen remained high, even where continuously monitored at critical points on the Wharfe during 1995. Oxygen saturation remained above 80% from October to November 1995, even with a photosynthesis-induced diurnal variation of 10%. Levels did not fall below the value requiring oxygen to be injected into the river. A reduction in the level of sampling carried out by YWS was renegotiated as a result.

Temperatures of 20-25°C were recorded in August 1995 when the river was still being fully supported by compensation releases from the Grimwith-Dibb system. Cusum analysis showed that significant changes in levels of other water quality determinands may be linked to the drought period in some instances (**Table 11.4a**). As in the Ouse and Ure, pH values were generally higher during the drought (eg **Figures 11.4h-i**), probably as a result of less runoff from acidic moorland areas. Dissolved oxygen was also lower at a few sites in both the upper and lower parts of the river during late 1996 (**Figures 11.4j-k**), although this is not easily explained. There was little evidence of trends in ammonia levels apart from increases at Burley Weir and Ryther, but levels fell again in late 1996 at the latter site. Nutrients (nitrates and phosphates) were also recorded in higher concentrations during the drought, but not evenly down the system (**Figures 11.4l-m**). Reduced dilution is a likely explanation, and consequences may have been increased primary productivity in the system (ie growth of algae and higher plants).

Impacts from individual STWs varied from fairly localised (ie within 500 m) to 1.5 km (eg Otley STW), evident in reductions in dissolved oxygen of up to 10% below background. Dissolved oxygen level sags recovered downstream, often with assistance from the Wharfe's many weirs. Almost all the effluent samples were within both the standard consent limits and the more stringent limits set by the Drought Order conditions, and only six samples exceeded the temporary BOD and ammonia consents (at Ilkley, Ben Rhydding and Wetherby). *It is concluded that YWS operated these installations very effectively during the drought.*

An additional focus of concern regarding water quality has been the impact of the compensation releases from Grimwith Reservoir via the River Dibb. Worries have been expressed about long term effects of acidity (and suspended solids) on the receiving ecological communities of the Wharfe. Analysis of long term monitoring data (since 1978) has shown that, while there have been statistically significant periods of different pH values at Hartlington Bridge on the Dibb, there have been no instances since 1983 when the recorded pH fell below 7 (neutral). This pattern has been mirrored by the pH values recorded in the Wharfe at Bolton Bridge, downstream of the Dibb confluence. No impact from the drought has been observed, and indeed lower pH values appear to be related to high winter flows rather than low flow period with compensation releases.

Other influences on the Wharfe, such as colour and turbidity, were also higher downstream of the Dibb during the period by a factor of two to four, because of the Grimwith releases, but this is much less than the impact from rainfall, when turbidity in the Wharfe rises by several orders of magnitude. Colour measurements of raw water at

Lobwood have also been taken since late 1994 and, because concerns have been raised, additional monitoring of this determinand was instigated in the early summer of 1996 at Burnsall and Bolton Bridge on the Wharfe, and Hartlington Bridge on the Dibb.

11.5 Ecology

11.5.1 River Habitat Survey

In 1996, river habitat surveys were carried out at eighteen sites on the Wharfe between Starbotton and Tadcaster Weir in response to the TLL applications from YWS. The aim of the surveys was to provide the Agency with background physical information on which to evaluate the potential changes that might take place with a revised abstraction/compensation scheme.

The sites (500 m long) were upstream and downstream of YWS abstraction points, as well as fairly evenly distributed to gain information about longitudinal changes in river habitats. Most of the surveys were completed between 30 July and 4 August 1996, with three sites having been dealt with in 1995 as part of the Agency's national RHS survey.

The eighteen sites showed a range of physical features and habitats. The upper reaches displayed features typical of an actively eroding, fast flowing upland river, with frequent side bars, point bars and mid channel bars, eroding cliffs and a cobble/bedrock and boulder substrate. Further downstream, areas with glides, runs and smooth boundary flow, no perceptible flow, ponding, deeper water and a more silty substrate were more typical

Many of the upper reaches showed areas of actively eroding earth banks, but these were also present in the lower reaches, in conjunction with gentler banks and stable cliffs. There were a number of bank protection reinforcements, mostly associated with bridge crossings, although some of the upper reaches also had old stone pitching on the bank toe.

The survey also showed that the river generally had moderate to high degree of cover and shade provided by bankside trees. These also provided instream habitat through underwater roots. Bankside ground cover vegetation tended to consist of tall herbs and shrubs in the lower reaches, with a tendency towards shorter grasses in the upper Wharfe, where stock grazed to the water's edge.

As there is only a set of RHS data from one year, this means that only a description of the river can be given at the present time, and no comment can be made on the impact of increased abstractions and altered compensation releases.

11.5.2 Aquatic macrophytes

Macrophyte surveys undertaken on the Wharfe form a part of the monitoring programme associated with YWS TLL and Drought Orders and were carried out at eighteen sites between Starbotton and Tadcaster Weir (ie those used for the RHS, see above). These were carried out by Scott Wilson Research Consultancy in the summer of 1996. These sites lie upstream and downstream of YWS abstraction points at Lobwood, The Hollins and Arthington.

Records of mosses, algae and higher plants were also collated from NRA/Agency biology site sheets from 1975-96, but this provided only a very general indication of the status and trends of Wharfe macrophytes.

The upper reaches from Starbotton to The Strid at Bolton Abbey displayed features, flows and community types typical of an upland river flowing over Carboniferous Limestone. Mosses were locally abundant on side bars, point bars and boulders (emergent and submerged). With more shade, bryophytes such as *Thamnobryum alopercurum* were found. The species diversity in these reaches reflected the habitat diversity and generally high water quality. Higher plants tended to be limited, probably as a result of suitable substrate and disturbance during high flows. Filamentous algae were present at many of the sites, especially in the shallow slacks in the river margins.

Near Lobwood the species composition changed to reflect a flora more typical of middle reaches of a river. Filamentous algae were common, dominating some reaches, and were only absent from faster riffles and the deep main channel where the flow was stronger. At Ilkley, the last records of upland mosses were obtained. This site, and those downstream, also had more plants typical of a slower-flowing and more nutrient-rich river.

Upstream of Riffa Beck, the flora was dominated by submerged higher plants such as *Elodea* sp., *Potamogeton perfoliatus* (perfoliate pondweed), *Ranunculus penicillatus* (stream water crowfoot). Slower flows and higher nutrient loading compared to upstream stretches was indicated by the presence of the floating *Enteromorpha* (blanketweed) and *Lemna minor* (common duckweed), along with abundant filamentous algae.

Upstream of Collingham was the first locality where lowland *Sparganium erectum* (branched bur-reed), *Typha latifolia* (reedmace) and *Alisma plantago-aquatica* (water plantain) were recorded, and no bryophytes were noted. Further downstream at Tadcaster the flora reflects the high nutrient levels and slower flows of a large lowland river.

Any reduced flows are likely to favour those species tolerant of higher siltation and slow current speeds. The survey provides a good baseline for the sites recorded and is being repeated to assess any changes brought about by changes to flows and abstractions. Because the Wharfe is so spatey and prone to low flows, this intense physical variability is likely to result in highly dynamic macrophyte communities. The link with flow data needs to be explored more fully.

Besides this scientific survey of the Wharfe's macrophytes, other information was received by the Agency during the period from Fisheries Inspectors, anglers and other member of the public. These mostly concerned the luxuriant growths of filamentous algae and the apparent decline of *Ranunculus* in favour of species typical of slow-fowing water such as *Elodea*, *Potamogeton* spp. *Lemna* and *Myriophyllum* (water milfoil).

A further event was the discovery of blue-green algae (Cyanobacteria) in the Wharfe at Tadcaster on 16 August 1996. Identified as *Microcystis* (which can cause severe illness in humans and even death in domestic animals), relevant health departments were notified by the Agency and the situation was monitored over the following six weeks. The source of the algae was not the Wharfe itself, but Harewood Lake and its downstream outlet, Stank Beck. In this beck, the number of colonies/ml of the alga fell from just over 1000/ml on 19 August to none on 30 September. The low flows in the Wharfe undoubtedly allowed the retention of this species in sufficient amounts for it to be observed.

11.5.3 Aquatic macro-invertebrates

The NRA's national GQA survey was carried out in 1995 and included thirteen biology sites on the main River Wharfe, with additional sites on tributaries. Biological samples were collected in spring and autumn. In 1996 these sites were supplemented by two on the upper Wharfe at Hubberholme and Kettlewell to provide data relevant to the natural drought - and sampling was carried out by YWS and the Agency in spring, summer and autumn. Identification of the fauna was to mixed taxonomic level (ie species level wherever practicable). Some groups, such as oligochaetes, simuliids and chironomids, remain to be dealt with, but a small proportion of the difficult *Pisidium* species was identified by a recognised national expert, largely to determine if *P. tenuilineatum* was present in the samples. So far none have been found.

A primary concern of the Agency, and others, has been the possibility that low flows can adversely impact on water quality, with its knock-on effect on ecological or biological quality. This is relevant to the Wharfe since it receives the discharges from numerous STWs, mainly in the Ilkley to Wetherby section, as well as a few organic effluents from trade discharges such as Pool Paper Mills and the Tadcaster breweries. The biological GQA grades for the Wharfe sites during the years 1990-96 are shown in **Table 11.5a,** alongside the independently derived YII. In general, there was no significant deterioration during 1995, although the autumn samples showed a greater influence of organic enrichment than those in the spring, which was preceded by a very wet period.

(i) Long term changes and drought impact

In the section on macro-invertebrates in the first *Interim Report,* the Wharfe was split into two zones, largely on pragmatic grounds. With the inclusion of more sites in the higher reaches of the Wharfe, together with a site on the Skirfare as a 'control', it was necessary to examine longitudinal zonation in the Wharfe in more detail. The longitudinal pattern was very clear (**Figure 11.5a**), but for the purpose of analysing the drought impact four zones were recognised, based on coherent site-groupings:

- A 'higher' Wharfe site-group including Hubberholme and the Skirfare at

Hawkswick, together with Kettlewell (although this site is somewhat transitional with the next group).

- An 'upper' Wharfe site-group including Grassington, Burnsall, Bolton Bridge, Addingham and Ilkley; the last is also slightly transitional with the next group.

- A 'middle' Wharfe site-group including sites at Burley Weir, Otley, Castley, Harewood and Boston Spa. There is still some residual heterogeneity and zonation.

- A 'lower' Wharfe site-group consisting only of the site at Tadcaster Weir.

The aims of this classification included the assumption that samples within each zone could be treated as replicates in various statistical analyses. In fact, these zones may truly represent ecological sectors in the river, as they coincide very well with macrophyte and fish distribution patterns (see report BD 5/97).

With the availability of historical data from the thirteen Wharfe monitoring sites, the events of 1995-96 could be put in some context, even though causal relationships between flow patterns and faunal changes are difficult to establish and remain to be studied more rigorously. Univariate biotic scores provide a general indication of the status of freshwater invertebrate communities but over the period 1984-96 few readily discernible patterns are evident, although the expected longitudinal changes in *BMWP score* and *ASPT* are clear (**Figure 11.5b**). The highest *BMWP score* measured during the period was from Tadcaster in the autumn of 1996, and at the same time the lowest was recorded from the higher Wharfe. The *ASPT* was also the lowest ever in these higher reaches of the river, linked to possible pollution incidents during the summer and early autumn of 1996. The only long term trend is that of increasing faunal richness in the upper Wharfe, as measured by the *no. of BMWP taxa* (**Figure 11.5c**). An interpretation of these results is that the increased frequency of low flow events in the latter half of the 1985-96 period has led to an increase in biological richness in the upper section of the Wharfe, concomitant with similar responses in the Ouse and Ure.

No long term changes can be discerned in the biological data from the **higher Wharfe**. A few macro-invertebrates appear to be associated more strongly with drought periods, notably leeches, planariid flatworms, psychodid midges and gammarid shrimps. Low flows may encourage these groups, and allow more effective upstream migration of species, such as the shrimp *Gammarus pulex*, into this zone where they are not regularly recorded. Of interest is the strong showing of lepidostomatid caddis flies after the summer of 1990, with no records in the previous three years. Historical data from 1971-76 show that they were present in the Skirfare, and in the Wharfe from Grassington downstream. In the first *Interim Report* it was suggested that this caddis fly responded well to the drought in 1995 in the upper and lower Wharfe.

In spring 1996 the Kettlewell and Skirfare faunas were again somewhat distinct from previous results, but the Hubberholme sample was very poor and grouped with similar samples from the autumn of 1996. In the intervening summer season rich faunas were observed in the higher Wharfe, typical of what had been recorded in previous years.

At the time, it was considered that the 1996 spring sample from Hubberholme was indicative of a probable toxic impact, and this was reinforced by the similarity of the autumn 1996 samples from the three sites, which had the lowest-ever values for *BMWP*, *number of taxa* and *ASPT* indices. These samples were dominated by non-insect (ie molluscs and worms) groups, and most of the sensitive mayflies, stoneflies and caddis flies normally expected were entirely absent or in very low numbers (**Table 11.5b**). The few exceptions were riffle beetles and small tipulid larvae. It is believed that, **while a drought impact is shown by the higher than average abundance of leeches and earthworms, a significant impact from pesticide (sheep-dip?) was responsible for these drastic faunal changes**. Corroboration for this is available from the 'upper' Wharfe faunal zone.

The data from the **upper Wharfe** zone show a strong degree of structure related to seasonality and drought impact (**Figure 11.5d**). The samples from the autumn of 1995 were grouped on the edge of the variation seen previously, and the spring 1996 faunas also formed a coherent group with these. The autumn 1995 fauna was also largely distinct from that in 1996, although three samples from Addingham in 1989, 1990 and 1992 also grouped here. Out of thirty-one common or frequently recorded taxa, nineteen were more abundant in the autumn of 1995 compared with previous years (**Figure 11.5e**). Conversely, three were not recorded at all: leuctrid and nemourid stoneflies and ephemerellid mayflies. However, in the Wharfe, both leuctrid and ephemerellid nymphs are strongly associated with the summer months and the warm period preceding the autumn sampling may have led to their earlier emergence.

Even allowing for chance occurrences and absences among the rare or infrequently recorded taxa, much higher than average abundance values of earthworms, pea mussels, leeches, nematodes and owl midges (Psychodidae) were obtained. Among the taxa newly recorded for the autumn period, the most significant may be the planorbid snails.

One of the main concerns about the impact of the 1995 drought was that continued low flows during the winter and spring period of 1995/96 would not allow any 'recovery' of the invertebrate populations. Winter washout is believed to be a major factor in structuring the invertebrate communities in spatey rivers such as the Wharfe, so it was important to determine how the faunas appeared in the spring of 1996. As shown in **Figure 11.5d**, they did in fact group most strongly with the autumn 1995 samples and were on the edge of the previous spring faunal variation. Comparison with the 1985-1994 long term average indicates that out of the twenty-seven common or frequently recorded macro-invertebrate families, eighteen were recorded in higher numbers in spring 1996, with only three appreciably lower or absent: leuctrid, nemourid and taeniopterygid stoneflies (**Figure 11.5f**). The lack of scouring action is most evident with respect to the normally rare or infrequently recorded spring families. At least six were present in much higher numbers than average: whirligig beetles, earthworms, roundworms, owl midge larvae, pond snails and shrimps (*Crangonyx*, not *Gammarus* - the former is more characteristic of slow-flowing and still waters). Three spring families were newly recorded for the upper Wharfe zone: nerite and ramshorn snails, and pea mussels. All of these are usually associated with lower flows and are more prevalent in autumn samples.

Upper Wharfe summer 1996 samples retained their seasonal character (including a strong showing by the mayfly *Ephemerella ignita*) but were grouped on the edge of variation (**Figure 11.5c**). Out of twenty-six common or frequently occurring taxa, seventeen were recorded in higher numbers than the average value (**Figure 11.5g**). As would be expected, other groups, such as leeches, dipteran fly larvae and snails, were also apparently favoured. Conversely, leuctrid and perlid stoneflies and polycentropid caddis were less abundant than the average. Among the rare or infrequently recorded taxa a few were present in much higher numbers than expected (hydrophilid beetles, pond snails, pea mussels, fly larvae and earthworms). Two new taxa were recorded for the summer period: *Crangonyx pseudogracilis* and *Ephemera*. Absences among the remaining taxa may or may not be significant because of their general rarity in this section of the Wharfe.

In the autumn of 1996, the samples had the lowest *BMWP score* since autumn of 1990, and the lowest *ASPT* since the autumn of 1985, but the *number of taxa* was not significantly affected. Other taxa not recorded that had been fairly common in 1995 and in previous years included water mites and perlodid stoneflies. The possible toxic impact was not as severe as in the higher Wharfe and Skirfare, but could be readily seen in the paucity or absence of sensitive insect groups. The exceptions were riffle beetles, blackflies and small craneflies. The last two taxa may have escaped the incidents during their aerial stage and reproduced afterwards. Molluscs, leeches and worms seem to have been unaffected by this event and actually appeared to be in higher numbers than the previous autumn (**Table 11.5c**), corresponding to a 'typical' drought response.

A clue to the origin of the dramatic faunal deterioration in the higher and upper Wharfe before the autumn of 1996 comes from the mortality of large numbers of signal crayfish near Grassington during mid August. Acting on information supplied by members of the public, surveys carried out by Agency and YWS biologists on 20 and 21 August revealed numerous dead and moribund as well as live signal crayfish in the stretch from Gaistrill's Strid to just downstream of Grassington. These deaths occurred largely coincidently with the known population limits of this species. No native crayfish were found dead or alive, although it is known that a small population persists in this section, in company with the signals. No signs of disease were observed but some had reddish mottling. Kick samples taken at the time showed a very sparse aquatic insect fauna present, except at Conistone Bridge where there were good numbers of heptageniid mayflies, indicating, along with the absence of any dead crayfish, that this was upstream of the source of any pollution, which may have occurred on or about 19 August. Heat stress was suggested as a cause, but this can be ruled out by the localised impact, coincident decline in other sensitive insect life, and the fact that more severe conditions had occurred during 1995.

With this information and the the poor autumn faunas recorded in both the Skirfare and higher Wharfe, it is postulated that three toxic pollution incidents occurred during the late summer and early autumn of 1996:

- Entering the Wharfe downstream of Conistone Bridge but upstream of Gaistrill's Strid on or about 19 August.

- Entering the Skirfare after this date but before 2 October.

- Entering the Wharfe upstream of Hubberholme (but downstream of Beckermonds) after 22 August but before 2 October.

The Agency is actively following up these suspected incidents, and is engaged at national level in developing strategies to limit the environmental impact of sheep-dipping on nearby watercourses, as sheep farmers increasingly switch from using organo-phosphate agents to safer (for vertebrates) synthetic pyrethroids that are 100-1000 times more toxic to insects and crustaceans.

Concerns about the impact of the compensation releases from the River Dibb on the ecology of the Wharfe are not borne out by examination of faunal data from Burnsall, upstream, and Bolton Bridge, downstream. While there could be a more localised impact from the lower pH and high turbidity closer to the Dibb/Wharfe confluence, there is no significant difference ($p = 0.901$) between the two sites, based on the data used in this study.

Further downstream, the **middle Wharfe** receives more discharges from STWs and trade effluents than the upper zone, and it is more lowland in character. As would be expected, the faunal richness is usually higher but, because it is more lowland and enriched, the ASPT index is generally lower as more groups such snails, leeches and flatworms flourish and still-water types such as waterbugs, diving beetles and damselflies are recorded more frequently, (see **Figure 11.5b**).

No long term trends are evident in the univariate scores, but the impact of the 1995 and 1996 drought is clear with use of multivariate analyses (**Figure 11.5h**). As mentioned in the *Interim Report*, the autumn 1995 fauna was easily discriminated from previous data, and this was repeated again in 1996. Of note was the similarity of the spring 1996 samples to the previous autumn. When this group (autumns 1995 and 1996, spring 1996) is compared to previous spring/autumn data, several observations can be made. Of the thirty-seven common families (**Figure 11.5i**), twenty-eight were recorded in higher numbers in the drought period. More dramatic changes are seen in the rare or infrequent families where, even allowing for chance presences and absences, several were far more abundant in the drought period.

The summer fauna from the middle Wharfe did not conform to the autumn/spring/autumn pattern, but was clearly grouped and distinct from the main group of previous examples (**Figure 11.5h**). Most of the taxa discriminating between the 1996 and previous data were recorded in higher numbers during the drought period, with the exception of leuctrid stoneflies, heptageniid and baetid mayflies and neritid snails.

Any effect of the Arthington abstraction is not clear from the data currently available.

Significance tests between the Castley and Harewood faunal data show that, while there is an overall difference, none of the seasonal comparisons (notably summer and autumn) indicate that the faunas can be discriminated easily (**Table 11.5d**), although the last two seasons are more likely to be different than the spring samples.

The **lower Wharfe** zone is represented by the site at Tadcaster, downstream of the weir. The substrate is sandier than at any of the sites upstream, but it is a biologically rich location. There is very little apparent structure in the faunal data from 1984-96 apart from some seasonality in that summer faunas are strongly grouped. The 1995 autumn fauna was within the range of variation but the 1996 results indicated an 'extreme' form. The sample taken in October 1996 had the highest *BMWP score* and *number of taxa* in the period 1984-96, although the *ASPT* was average. Taxa such as bladder snails, coenagrid damselfly nymphs and sialid larvae were recorded in 1996 for the first time since 1990, and *Molanna* (a cased caddis) was a new record for this site. Others were present in 1996 in higher than average numbers, in particular *Asellus*, caenid mayflies, hydropsychid caddis, pond snails and spire snails (Bithynidae).

It is apparent that the 1995-1996 drought had relatively little impact on the lower Wharfe apart from a slight enrichment or 'enhancement 'effect, and there is no evidence for long term change at this site. This weak faunal response is similar to that seen in the non-tidal Ouse upstream of York and in the lower Ure.

In general, many of the Wharfe's macro-invertebrate families with altered abundance values appear to be associated more strongly with low-flow periods than at other times, notably molluscs, flatworms, dipteran larvae, waterbugs and diving beetles, which is to be expected. Initially more surprising is the increased frequency and abundance of cased caddis flies. Lower current speeds and perhaps a greater availability of sand for case construction may be factors responsible for this phenomenon. Similarly, hydropsychid caddis flies (especially *Cheumatopsyche lepida*) may also be favoured by a better flow-distribution pattern for their net-spinning activities and higher levels of suspended food materials.

Overall, the drought impact on the Wharfe's invertebrate fauna has been the promotion of faunal diversity and abundance throughout most of its length. Coupled with this has been the suppression of seasonal change (notably between autumn and spring), because of the relative lack of flushing spates, and some evidence of decline in a few flow-loving types such as leuctrid stoneflies. All of these changes are reversible with the onset of more normal flow patterns.

11.5.4 Fisheries

Several surveys were undertaken to provide information on fish stocks and angling activity on the Wharfe during 1996 in relation to the drought and, in particular, flows as influenced by Drought Orders and TLLs. A detailed report on which this summary is based is available as Fishery Science Report D14/97.

(i) Sites and methods

On the Wharfe, twenty sites were selected for electro fishing. These ranged from Conistone, well above any major abstractions, down to Ulleskelf, in the tidal reaches and well below any major abstractions. On the tributaries, ten sites were sampled.

Each site was sampled once or twice over the June to September period during low flow conditions. On the main river, semi-quantitative sampling was carried out with variations in methodology appropriate to each site. On the tributaries, a single run was carried out by wading upstream with a single anode. At some of the main river sites downstream of Ilkley, eel sampling was carried out.

It was initially envisaged that three lengths might be suitable for surveying by sonar but, on examination, macrophyte growth was too abundant at two of these and it was only carried out at Smaws Ing (from Tadcaster railway viaduct to Easedike), on 3 September 1996 using Simrad split beam scanning sonar.

Other fisheries data were gathered from a variety of sources.

(ii) Main observations

In the main river, both the fish populations and individual fish appeared to be in good condition and only limited changes had occurred since earlier, pre-drought surveys. Overall, along the length of the Wharfe, survey catches were as great as, or greater than, in 1993 or whenever sampling had previously been carried out. Particularly good catches were obtained from shallow, fast reaches. Such lengths can be sampled relatively efficiently during low flows and are also likely to be the areas where fish congregate during hot, dry summers to take advantage of the relatively high and stable oxygen levels. If anything, the concentration of fish in fast water was more pronounced for large, rather than small fish, which appeared to be more dispersed along the river.

Initial indications are that recruitment of brown trout, which might be predicted to decline during the drought, held up reasonably well through 1995 and 1996 and major effects on angling for the next few years are unlikely. As expected, brown trout were numerous in the upper reaches and where riffles and fast runs were present. Growth rates were generally moderate to fast, although some of the larger fish displayed scale edge erosion indicative of poor habitat condition prior to sampling. Recent recruitment appeared to differ markedly between the two upstream main river sites, where the 1996 year class was abundant and the 1995 year class sparse, and the downstream sites, where the 1995 year class rather than that of 1996 was dominant. Severe spates in the upper catchment in spring 1995 may have adversely affected the survival of eggs and small fry in the vicinity. Relatively few of the large brown trout could, from their scales, be clearly identified as fish stocked at takeable size. However, some of the trout, which could not be aged due to the samples consisting entirely of regenerated scales, were probably stocked fish.

Apart from Capelshaw Beck, which was completely fishless, brown trout occurred at all the tributary sites. The populations in Skyreholme, Kex and Bow Becks were dominated by small, young fish indicating that, even through 1995 and 1996, these becks were acting as valuable spawning and nursery areas. The recruitment of brown trout fry in Barden Beck was relatively poor in 1996 and this could be an effect of the drought exacerbated by the absence of compensation releases from Lower Barden Reservoir and reduced leakage via the dam. Either reduced egg deposition due to impaired access for spawning trout, or reduced survival of deposited eggs as a result of drying out or siltation of spawning gravels, could be the reason for the poor recruitment. The brown trout populations of Hundwith Beck displayed a marked deterioration since 1988. Low flows during the drought may have exacerbated the adverse effects of channel management and enrichment. The brown trout populations of the River Washburn displayed clear indications of being adversely affected by flow reductions during the drought.

Grayling have usually been considered to be in decline in the Wharfe, but catches were larger than in 1993 and significant recruitment had occurred during 1995 and 1996. Growth was fast and better than in earlier samples. Warmer water, increased invertebrate productivity and decreased intraspecific competition may have been causative factors.

Recruitment of most coarse fish had been particularly good in 1995, promoted by high summer water temperatures, but relatively poor in 1996, following the same pattern as in the 1989 to 1991 drought. These fish should form a major contribution for coarse angling over the next few years. In particular, the 1995 year class of chub should be prominent in catches well into the next decade. In comparison, the contributions of the 1996 coarse fish year classes are likely to be relatively modest. This appears to conform to a general pattern observed during the course of previous droughts. In addition, growth rates of the small and medium sized fish had been fast but, during 1996, some of the large, old fish displayed reduced growth, possibly as a result of competition in the areas where such fish were aggregated.

Chub numbers have been high in recent years, and the 1996 results indicate that the 1995 year class should maintain the stocks by entering the fishery during the next few years as the early 1980s year classes and those of 1989 and 1991 decline. Small specimens were found in accessible tributaries downstream of Ilkley (as were dace and gudgeon).

In recent years, anglers have complained of a drop in dace catches, and electric fishing catches of larger dace were also low in 1996. However, the successful 1995 year class should improve the stocks available to anglers during the next few years. Judging from electric fishing catches, barbel stocks appear to be low in the river and successful recruitment occurs only in hot, dry summers, but the summer of 1995 appears to have produced only a moderately successful year class. Ruffe, perceived to be a declining species in Dales Area rivers, were captured at three sites.

Some fish favoured by low flows, especially perch, were more prominent in 1996. Perch, which have generally been relatively scarce in the Wharfe, have tended to increase in recent years and this trend seems to have been accelerated with the success of the 1995 year class. Low flows, increased macrophyte growth and increased availability of cyprinid fry have probably favoured this species. Perch also appear to have become more numerous in the River Washburn during recent years, and low flows during 1995 and 1996 may have exacerbated this effect. In order to restore the fish populations to a more natural state, with brown trout dominating the stocks of larger fish, greater minimum flows need to be provided.

Pike have continued to spread upstream in the main river, and this has been of particular concern to angling clubs with trout fisheries in the middle reaches. However, catches of this species, which is particularly susceptible to electric fishing, were modest and growth rates were high, suggesting that this species is not likely to impact prey species severely. Three pike were captured at Knotford and this is the furthest upstream that this species has been recorded in surveys, not having been recorded in 1987. In recent years, pike have been regularly reported from the Wharfe in the Otley area, where they were formerly absent. It is possible that the pike originally entered the Wharfe from adjoining gravel pits. Their establishment may have been assisted by increased stands of macrophytes which act as spawning and nursery areas. Inappropriate culling programmes may also have aided the survival of young fish.

Generally, eel numbers increased downstream, with very few individuals present at sites upstream of Addingham and moderate numbers at most sites downstream of Tadcaster Weir. The numbers present appeared, if anything, to be greater than in 1993. This would be against the general trend in Western Europe, where elver runs have been in decline.

The sonar survey at Smaws Ings indicated that fish stocks were similar to those in other good coarse fisheries in the region. Fish numbers were greater along the left margin than along the right margin, and were consistently high upstream of Newton Kyme, consistently low between the village and the main powerlines, and variable in the vicinity of, and downstream of, the gauging station. Overall, the numbers of fish were similar to those observed in other good riverine coarse fisheries.

Electric fishing sampling in selected tributaries revealed a more complex situation than in the main river. Brown trout stocks and recruitment were good in Skyreholme, Kex and Bow Becks. Stone loach were numerous in Bow Beck, indicating the likelihood of some organic inputs. The presence of two small chub in this site in June indicates that coarse fish can enter the lower end of this beck from the main river. Poor trout fry production in Barden Beck was probably the result of low flows exacerbated by lack of a compensation release from Lower Barden Reservoir. The June sampling produced a reasonable catch of small to medium sized trout, but no trout fry, whilst under yearlings were present, along with the larger fish, in September. This suggests either that the fry had not emerged from the gravels in June or that spawning occurred elsewhere on the beck and fry dispersed from the spawning area to the sampling site between June and September.

Recent deterioration of trout stocks in Hundwith Beck was probably due to enrichment and physical habitat damage as well as low flows. Hundwith Beck contained a sparse brown trout population in both June and September, with most fish belonging to the 1995 year class. Only one 1996 year class brown trout was captured. This represented a marked deterioration in the trout population since 1988 (FSR 52/89). Both the visual appearance of the site and the abundance of stone loach indicate that organic inputs may have adversely impacted trout stocks. However, low drought flows and channel dredging since 1988 may also have had detrimental effects. A few chub and many minnows populated the site between June and September, probably as a result of immigration from the main river.

Severely reduced trout stocks but increased numbers of perch in the River Washburn between Thruscross and Lindley Wood Reservoirs were probably associated with very low flows. The River Washburn, downstream of Thruscross Reservoir, had a fish population dominated by 0+ (1996 year class) brown trout, with very few larger trout and no other species present. Although flows were relatively high at the time of sampling, flows may have been much lower previously. Further downstream, a site near the A59 road bridge held only sparse brown trout stocks, considerably reduced since 1988. Low numbers of stone loach and minnows were present, but considerable numbers of perch, which had not been captured in 1988, were caught. Low river flows may have favoured this species at the expense of trout.

(iii) Condition of fish in the Wharfe and tributaries

Only the condition of brown trout was examined in detail. Body condition and gonad development of those from the main river were not adversely impacted by the drought. Overall, the mean relative condition of those electro fished from the main river was 99.7%, very similar to that in 1982 (FSR 37/83). Nine of these trout were considered"thin", whilst eleven were "fat". Differences between sites were modest, although trout condition appeared to be relatively good at Conistone and Addingham but relatively poor at Appletreewick and at the Nunnery. Therefore, there was no indication that the drought as a whole, or particular augmentations or abstractions, had adversely impacted trout condition.

Some brown trout captured from spawning becks in autumn were relatively thin, but it is uncertain whether this is a drought effect. Brown trout electro fished from the spawning becks, Hebden Beck, River Dibb and Pickles Beck, had mean conditions that were considerably less than 100%, indicating that they were generally rather thin. This might indicate that some had spawned prior to capture, but it could suggest that riverine conditions for trout had been poor in late summer. The brown trout from Hambleton Beck had relatively high condition factors, possibly reflecting delayed spawning

Macroparasite incidence and infestation levels did not appear to be elevated in 1996. The large fish louse, *Argulus coregoni,* was recorded at several sites although infestation levels were, generally, low. Such infestations have been regularly recorded from the Wharfe, including during the 1993 survey. "Stumpy" chub, with scoliosis or lordosis, have been recorded on several occasions from the Wharfe previously. Examination of fry displaying this condition has indicated that it is probably linked to infestations of a myxosporidian parasite. Overall, the incidence and severity of these conditions did not appear to have been affected by the drought.

(iv) Fish mortalities

Amongst factors which could result in increased mortality of fish during the drought are water quality deteriorations, parasites and disease, predation and impingement on screens. Generally, water quality remained good despite low flows. No fish mortalities directly attributable to the drought were recorded for the Wharfe or its tributaries, although reduced dilution may have increased the severity of pollution mediated mortalities, but the numbers of fish killed in such incidents have been relatively low. Only one such mortality occurred in 1996, compared to five in 1995. Parasite and disease incidence, where investigated, did not increase during the drought, and mortality as a result does not appear to have risen.

High abstraction rates at the Lobwood intake were associated with two incidents of fish impingement (along with native crayfish) and found to be related to the continued use of the old intake and band screens during Drought Order Number 3. Following liaison with YWS, their staff acted to prevent further incidents at Lobwood, and the new screens at Lobwood and Arthington should prevent such problems in the future.

(v) Habitat observations and remedial works

During summer, fish were concentrated in deep pools and in shallow, well-oxygenated water below weirs, on riffles and in fast runs. Many of the slow, relatively shallow runs were sparsely populated with fish. Angling activity and success were affected by the distribution of fish and environmental conditions, particularly high summer temperatures and low, clear water. Angling activity was targeted on relatively short lengths where there were dense concentrations of fish. Early morning and evening were even more favoured than usual for angling during the summer months, with little angling activity during the day. The patchy distribution of fish adversely affected match angling, since only a few pegs in most lengths provided significant catches.

There was concern that the dense concentrations of fish made them more vulnerable to predation, especially from pike, herons and goosanders.

On occasions, the river was peaty coloured, especially just downstream of the Dibb, whilst the lower reaches were often unusually clear. The reduced flows in the river resulted in the exposure of large areas of gravel, including potential spawning areas. Some silt deposition occurred, but this was largely removed by spates in autumn 1996.

During autumn 1995, clearance of boulders was successfully carried out at the confluence of several becks with the Wharfe in order to improve access for spawning trout. It was not necessary to repeat this work in 1996 since the beck confluences remained free of obstructions and flows were, generally, higher in autumn 1996 than in autumn 1995.

(vi) Anglers' reports

During 1996, three evening liaison meetings were held. In July, discussions were held between the Agency and representatives of interested angling organisations at Bolton Abbey, concentrating on trout and grayling, and at Wetherby, concentrating on coarse fish. Various issues relating to the prevailing drought were explored, and particular attention was paid to improving cooperation and exchange of information between angling interests in the catchment and the Agency. Requests at these two meetings for angling organisations to apprise the Agency of data, including catch and stocking records held by them, resulted in several useful responses.

In August, a meeting was held at Otley involving a wide range of groups with interests in the catchment and focussing primarily on water resource and quality issues in relation to the drought and drought orders. Environment Agency Officers disseminated information gathered from monitoring of the riverine environment and answered questions raised by the audience.

In addition to the Agency initiatives, the Anglers Conservation Association carried out consultations, involving a questionnaire, with angling clubs in the catchment regarding adverse effects on angling. Various correspondence was also received by the Agency concerning the effects of the drought.

Anglers expressed concern about the general state of the river habitat, changes in the fish community and difficult conditions for angling. Other concerns included a lack of fly life, abundant weed growth, exposure or siltation of spawning gravels and inaccessibility of spawning areas on tributaries. Sightings of fish predators, including goosanders and cormorants, had increased.

Reports were received that trout, including those about to spawn in autumn 1995, were in poor condition; that trout angling was poor early in the 1996 season; that the continuing declines of dace and grayling had accelerated; that pike and bream had increased in number and that more wounds on fish, consistent with predator damage, were evident. Entrainment of fish, actual or potential, at Lobwood and Arthington intakes was a concern.

Access to the areas of river where fish were concentrated was often difficult, especially for disabled and elderly anglers. Often wading was necessary in order to reach deeper water. Factors such as prolific weed growth and extensive shallow water limited the use of certain angling techniques. Fly fishing was particularly difficult in many areas. The utilisation of keepnets, without adversely affecting retained fish, became extremely difficult. As a result, angling activity on the river had declined, resulting in losses of income for clubs which issued day or other short period permits or arranged matches. In the longer term, clubs largely dependant on river fisheries were likely to experience falls in membership. The unpopularity of river angling under the prevailing conditions had intensified angling pressure on local stillwaters.

Match angling overall was not influenced significantly in terms of **total** catch weights, but was adversely affected by the patchy fish distribution and difficult river condition. In 1996, very few match returns were received by the Agency for analysis, due mainly to poor responses from match organisers rather than a reduction in the number of matches.

(vii) Main issues and impacts

Apart from impingement of fish at Lobwood, no effects of abstraction could be distinguished from 'natural' drought effects, although any unsupported abstractions are likely to exacerbate drought effects.

The main **short term effects** of the drought have been alterations in fish distribution and behaviour, with consequent effects on angling activity and success. All of the available information indicates that the drought has been associated with increased aggregation of fish, especially relatively large individuals, in fast water, including riffles and fast runs, during the summer months, with correspondingly reduced stocks in slower flowing water. Both electric fishing and sonar surveys indicated that smaller fish were, generally, more evenly distributed than large fish. Concerns regarding the possible inaccessibility of some spawning becks to adult trout were addressed by clearing obstructions, and fry production indicates that, with the possible exception of Barden Beck, egg deposition did not limit recruitment in 1996.

Reduction in available habitat and concentration of the fish into shallow, fast water could render fish more susceptible to predators. The main fish predator, pike, did not appear to be present in large numbers relative to prey fish, and would not be expected to have had a major effect. Both goosanders and cormorants have increased in number in this catchment, but it is difficult to assess their effects on fish stocks.

The major **medium term effects** have been adverse impacts on trout stocks in tributaries downstream of reservoirs without the provision of compensation releases, increased growth of small and medium size fish and the production of successful 1995 year classes of most coarse fish.

Over a period of months, the drought could potentially affect total stocks, growth and fry production. None of the data available indicated a decline of stocks in the Wharfe, implying that the drought had not adversely impacted stock overall, directly or indirectly. In the tributaries, low flows in Barden Beck and in the River Washburn, between Thruscross and Lindley Wood Reservoirs, had adversely impacted trout stocks, although populations in Skyreholme, Kex and Bow Becks were fully satisfactory. Factors other than flows had adversely impacted the brown trout populations in Hundwith Beck.

Generally, the drought has been beneficial to growth. Growth rates of trout and coarse fish were greater than normal in 1995. In 1996, small trout and coarse fish continued to grow rapidly, but some fry and some of the large old fish displayed reduced growth. Increased temperatures and increased food productivity per unit area appear to have more than compensated for the reduction in wetted area.

In 1995, brown trout production appeared to be relatively low in the Wharfe upstream of the Dibb confluence compared to both downstream sites and other years including 1996. A similar, but less marked, phenomenon was observed in some tributaries in the upper catchment (FSR D42/96 and ABCS "*Ecological surveys of Linton Beck sub-catchment likely to be affected by the operations of the Swinden Quarry*"). It is considered that this relatively poor recruitment of brown trout of the 1995 year class in the upper catchment is more likely to be the result of severe spates in early 1995, with consequent increased mortality of eggs or fry, than the subsequent low flow conditions associated with the drought.

It is too soon to assess the **long term effects** of the drought on fish stocks although their overall composition as observed in 1996 will, together with previous data, provide a baseline against which changes can be assessed. However, some suggestions can be made concerning possible long term trends. The likelihood of such trends emerging will increase if the drought extends into summer 1997, and beyond, and if further, unsupported, abstractions are made.

The drought and associated reduced flows will reduce habitat availability, but this will only adversely affect fish stocks if space is the main determining factor. If food production is the main limiting factor, increased production per unit area may well compensate for any reduction in productive area. Early indications do not indicate that total stocks have generally declined in the main river, and indeed the high growth rates indicate that reduced habitat availability is not adversely affecting fish stocks. It may be tentatively concluded that total fish stocks are unlikely to decline as a result of the drought.

If the drought continues, reduced flows, and associated habitat changes such as increased summer temperatures, increased siltation and enhanced macrophyte growth would be expected to **influence the composition of the fish community**. It would be expected that brown trout and grayling might become less abundant, both in the middle reaches relative to larger coarse fish, and in the upper reaches relative to minor species such as stone loach and minnows. However, in the case of brown trout such an effect may be partially counteracted by the stocking of fish for angling.

Coarse fish species typical of slow, lowland rivers such as roach and perch will probably increase relative to species typical of fast flowing rivers such as dace and barbel. Therefore, roach and perch are likely to become more numerous at sites where they are already present, and extend their distribution upstream and into reaches of fast flow. There is some indication that such an increase in perch abundance has been initiated already. However, expansion of the stocks of such species may be limited due to their inability to cope with the severe winter spates which occur in the Wharfe.

The prominence of chub both in electro fishing surveys and in angling catches during recent years, both in the Wharfe and other Yorkshire rivers, indicates that this species may be able to flourish under the prevailing flow conditions. Thus, this species is likely to become even more dominant, especially in the middle reaches of the Wharfe, if the recent regime of very low summer flows and severe winter spates continues.

11.5.5 Mammals

Three national otter surveys have been carried out on the Wharfe, covering Grassington to Bolton Abbey, and then from Tadcaster to the confluence with the Ouse. The most recent positive data for the whole river are those provided by the Yorkshire Otters and Rivers Project, collected in August/September 1994. This survey showed recent evidence that otters are still using the catchment but in small isolated areas. The lack of otter signs (spraints/footprints) does not necessarily mean they are not using the rest of the river, but it is likely that their populations are fragmented and vulnerable. It is also possible that otters are using the Wharfe's tributaries (which are not visited as often in surveys) more than the main river.

The limited amount of evidence of otters using the catchment would indicate that there is, in parts, an adequate food supply and sufficient bankside habitat for them to lie up in and breed. Where signs are scarce or absent, it needs to be established whether food or habitat, in addition to factors such as water quality, is the limiting factor, or a combination of both.

With many potential influences on their populations, it is very difficult to ascertain whether low flows will affect otters in the Wharfe catchment, although the fish and supporting invertebrate populations (including signal and native crayfish) seem mostly adequate and not adversely impacted by the recent drought.

12.0 KEY ISSUES/IMPACTS

Even with an absence of abstractions and extra pressure placed on rivers by drought orders and time limited licences, there has been considerable public interest in the ecological consequences of the 1995-96 drought. Many of the predictable environmental responses to drought and low flows have been observed across a wide range of Yorkshire's river systems during 1995 and 1996. These could be classified as either detrimental or beneficial, at least at face-value:

Detrimental impacts:

- Decreases in chemical and biological water quality, some downstream of effluent discharges (STWs, industrial), due to lack of dilution.
- Decreases in dissolved oxygen and increases in pH in rivers not influenced by abstractions/compensations/discharges, ie natural drought impacts.
- Lack of dilution for pollution incidents.
- Abundant algal growth, both filamentous species and epilithic diatoms, due to higher temperatures and nutrient levels, and longer retention time.
- Decline in some flow-loving invertebrates, such as stoneflies, due to low flows and higher temperatures.
- More entrainment of fish and crayfish on to intake screens.
- Some movement of flow-loving fish into remaining stretches of faster water
- Some downstream displacement of fish populations.
- Blockage to side streams, preventing access for spawning salmonids.
- Excessive exposure and siltation of spawning redds.
- Changes in angling activity, both in timing and distribution, due to weather conditions and movement/aggregation of target fish.

Beneficial impacts:

- Improvements in chemical water quality in some areas due to less frequent operation of storm overflows, and operation of STWs by YWS voluntarily to stricter consent standards during the drought.
- Increased macroinvertebrate diversity and productivity in grayling and coarse fish zones of good quality rivers.

- Increased growth rates and fry survival of coarse fish and brown trout.

- Support for future angling fisheries with strong year-class of several fish species.

The detrimental impacts have been localised, although it is too early to say with certainty that some river stretches have not been affected. For example, in the upper tributaries and upper reaches of the main River Aire, there was a noticeable deterioration in chemical quality. Many stretches declined from GQA grade A or B to GQA grade C - in most cases this was attributable to lower dissolved oxygen levels. The reasons for this have not been established, but as these tributaries are not impounded and have not been subjected to compensation reductions, the natural effects of the drought may be a strong contributory factor. Investigations of these changes and comparisons with other un-impounded catchments may show similar conclusions.

Where water quality deteriorations did occur in the Calder catchment during 1995 and 1996 these were either due to known pollution occurrences or single 'rogue' samples. It could be argued that low river flows limit the dilution available to absorb one-off pollution incidents, which therefore tend to be more significant in their effect. The possible exception is the River Ryburn downstream of Ripponden Wood STW, where lower available dilution is likely to have contributed to the marginal grade change in 1995. The very low dissolved oxygen levels recorded in the mid-reaches of the Calder at Brookfoot, Brighouse, are believed to be due to a combination of low river flows, a high proportion of treated sewage effluent, the fact that the stretch of river affected is essentially split into a series of 'pounds' separated by weirs, high temperatures and excessive weed growth.

Even so, some water quality improvements have been recorded in spite of the drought, and reflect YWS achieving improvements in effluent treatment at several STWs. All the improvements in river quality in the Calder catchment are in reaches receiving inputs from combined sewage overflows (CSOs), and can therefore be attributed to their less frequent operation in drought conditions. Two of the improved reaches were also downstream of STWs where recent capital expenditure has resulted in significant diversions of effluent out of the catchment (Meltham and Huddersfield- Deighton).

Streams receiving compensation releases were of particular concern during the drought. In some situations, where compensation releases have been reduced, or where effluent discharges compromise water quality, environmental impact has been observed. Although the drought did not appear to have had as much of an impact on water quality as had been feared on the Don catchment, it is quite possible that, when the water quality results are looked at in context with flow data and results from biological and fisheries surveys, it may be seen that the drought has had an impact. It is important not to look at data in isolation.

The drought has highlighted many anomalies in the compensation regimes operated by YWS. Some of the releases originated from bygone industrial demands, and are inappropriate for protecting the environment. In addition, some of the compensation agreements in practice result in higher levels of compensation water being released in the winter months, when it is least needed. A regime where higher levels of compensation water are discharged in the summer months (as is currently the case with Winscar) and where winter rainfall is conserved would be more appropriate. The compensation releases are shortly to be reviewed jointly by YWS and the Agency.

In areas free from effluent influences, reductions in compensation releases or increased abstraction, it is evident that the natural drought has had an impact on the aquatic environment in Yorkshire. For example, the significant ecological changes in the Wharfe seen in the autumn of 1995 were just as marked upstream of the Lobwood abstraction as downstream. During the period preceding the biological sampling, compensation releases from Grimwith were normal and provided a net flow surplus to the river. Even though an ecological response can be demonstrated for the other 'clean' Pennine rivers, complete drought, or stream-bed drying, is not an ecological disaster for many stream systems, as it can be a regular feature of their dynamics (eg winterbournes on the Chalk of southern England) or is intermittent and coincident with drought periods. In these situations, the fauna and flora change according to the prevailing conditions and, with the onset of flow, rapidly recolonise. This also happens in the limestone streams of Wensleydale (and, no doubt, in other Pennine systems) and various tributaries of the upper Derwent, notably the River Riccall and the Rye at Helmsley.

In this context, the reservoired catchments in the Pennines are not 'natural', and have a more stable flow regime; the aquatic communities are possibly not used to periodic drying and may have developed accordingly. Analysis is required to establish whether they actually support a different community structure to the more naturalised headwaters of catchments that are unregulated. Comparisons between reservoired catchments and rivers with abstraction points from the mid-reaches will be difficult.

From the evidence and analyses available so far, the ecological condition of the upland rivers in Yorkshire, and their sensitivity to impact, differs from the situation faced by lowland streams and rivers (notably chalk streams), where drought and low flows have more far-reaching and long term impacts. The Pennine rivers' highly variable flow regimes, characterised by occasional summer as well as winter spates, tends to lead to a physically controlled ecosystem. Support for this hypothesis comes from several studies in the USA and elsewhere (Poff & Ward 1989, Poff & Allan 1994) where a classification of stream flow regime versus principal controlling factors (abiotic/biotic) has been put forward. Catastrophic floods can have dramatic and long-lasting impacts on macroinvertebrate communities, especially if they occur in summer months (Giller *et al*, 1991) and it may take several years for recovery to take place. Fish populations are also susceptible and fry numbers can be severely depleted as they are displaced downstream and often lost from the system; adults can often regain their favoured reaches.

In the Wharfe, and other spatey Pennine rivers such as the Aire, Ure and Swale, when flows are more stable during the late spring to early autumn, this allows biological interactions to develop and time for additional species, usually dependant on slow flows, to build up populations. In normal years, this rich autumn fauna (as well as algal colonies) will be dispersed during the winter spates and the biological clock reset for the following spring. In late 1995 and early 1996, the winter floods were not sufficient to disturb the stable-flow community and build up of taxa continued, at least until the autumn of 1996. Monitoring of the situation in 1997 will discover if a normal pattern, or cycle, is resumed, and it is recommended that testing of the hypothesis about river spatiness and biological richness/stability/drought impact is done through examination of long term data from the Dibb and Washburn, both subject to compensation releases.

The observed patterns of change in the invertebrate and fish communities in the relatively unpolluted rivers of North Yorkshire form a coherent and parallel response which accords with the view expressed by Everard (1996) that drought can have a beneficial effect on freshwater ecosystems: in general, biodiversity and productivity has been maintained and even enhanced, and several species, including many coarse fish, have had better than average recruitment and growth, as well as expanding their range.

Ironically, it appears that droughts in upland and spatey rivers lead to the formation of biological communities which, although taxonomically richer and more productive than 'normal', are actually more susceptible to flows (ie spates) than would be the case otherwise. This conclusion leads to the confident prediction that, providing drought does not continue year after year, recoverability of the normal pattern is assured and the potential elimination of some flow-loving (and cool-water) species (mostly stoneflies) will be averted. Evidence does indicate that some of these species have, contrary to the main pattern, not fared well during the drought period and that some other tolerant and unspecialised species have expanded their range upstream (eg in the Wharfe), although this hold may be precarious. Consistent long-term climatic change, with warmer, drier summers, would speed up this process, but there is a limit to the process on island Britain, as sources of potentially colonising species are limited. The return of wetter conditions in 1997 may also have drawn a line under the environmental drought responses.

In spite of high variability in much of the ecological data already analysed, it is still possible to discern significant changes apparently linked to the drought and low flows. The distinction between 'short', 'medium' and 'long term' effects on fish populations outlined in section **11.5.5(vii)** helps to clarify and weight the measured or observed drought responses. At what point is change in excess of 'normal' variability *impact* and when can it be regarded as *environmental damage* in instances of perceived or measured impact (or change) on the various components of the river system?. Variability is a reflection of the unstable physico-chemical regime in spatey rivers and may actually be protection against environmental damage in the short term.

In these instances (as in the Wharfe's invertebrate faunas in 1995/96), even extreme variability cannot be considered to be 'environmental damage' if it can be demonstrated that a return of normal flows will lead to a brisk response in the aquatic communities. Disturbance to the general pattern can be significant *if it is maintained,* and if ecological successional changes occur which are non-reversible (or very slow to do so).

These difficulties in making assessments about environmental impact are, in part, due to the problem of classifying ecological communities (through to species and populations) on the basis of their 'value', sensitivity to drought impact and their ability to recover subsequently. Not only is assigning significance to observed ecological changes as a result of drought clouded by value judgements, the determination of abstraction impacts over and above natural drought can be difficult to do because effects can be subtle, or even delayed, especially in the case of fisheries.

These issues are currently being examined by, and on behalf of, the Agency. Other initiatives to refine and increase the sensitivity of environmental scoring methods, such as SWALP, are ongoing. With a more refined environmental evaluation system in place, and with promising leads being found in current analyses, it may be possible in the near future to detect subtle ecological influences of **individual** Drought Permits and Time Limited Licences on rivers such as the Wharfe, in addition to the small streams in southern Yorkshire where drastic changes in flow regimes have occurred. Evaluation of the consequences of Drought Orders/Permits and TLLs continues, and three years' monitoring will take place before final judgement will be attempted.

13.0 LIMITATIONS

By its nature an interim report such as this cannot be expected to answer all environmental questions posed by the 1995-96 drought and the ensuing changes in the management of Yorkshire's water resources. It may, however, serve to inform on the current status of monitoring programmes and ongoing analyses and also highlight issues related to the understanding of causation, linkages and damage assessment.

A significant factor hindering the production of rapid and well-founded answers is simply the wide geographic area covered, including a diversity of ecosystem types experiencing a broad range of natural and artificial influences, not just those related to changes in abstraction regimes and compensation releases. Confounding manmade impacts are common, especially those related to river habitat and water quality. Linking the various components (from unicellular diatoms to piscivorous mammals and birds) in a particular ecosystem is difficult in any case, and requires a solid understanding of the mechanisms operating within each level, even before the connections can be made, if only tenuously. A totally holistic view of the drought and low-flow impact is probably not realistic.

Linkage between physico-chemical parameters (ie. the drought's actual manifestation) and biota also remains problematical, even though some general responses are known.This is at the heart of the task faced by technical teams in the Agency who are appraising the relative impacts of particular Drought Orders/TLLs versus natural drought and background variation in river flows. Given the observed relationship between high flows (spates) and instream effects in the Pennine rivers it is clear that simplistic correlations with periods of *low* flows will not suffice. Flow variability, extremes, duration of threshold flows, timing of events and the nature of the 'starting point' characteristics of the ecological community being monitored, are all features that need to be critically reviewed.

A further problem in relating observed ecological changes to drought effects is that chemical water quality monitoring is routinely based on a relatively small number of spot checks throughout the year which, almost inevitably, introduces a large amount of variability in the data that can be increased during low-flow conditions. This can make interpretation difficult and reliant on powerful statistical techniques. More frequent sampling may overcome these limitations, and has been applied in several instances during the drought period, particularly in the Ridings Area of western and southern Yorkshire, where water quality problems are more prevalent and acute.

In addition, very few chemical GQA monitoring stations exist in the cleaner upper river catchments (especially in the Dales Area), because the primary sanitary determinands do not usually show any changes in these stretches. The GQA classification currently excludes nutrient and pesticide determinands. This is significant because, apart from small sewage works in the upland areas over which the Agency has some control, nutrients enter the Pennine rivers from more diffuse sources, such as runoff from improved grassland and areas where there is intensive stocking of cattle and sheep. This leads to eutrophication and growths of filamentous algae and diatoms. Pesticides (notably sheep-dip) can also enter the river unnoticed unless there is a significant mortality of fish or large invertebrates such as crayfish. Both eutrophication and toxic pollution are exacerbated by low-flow conditions, and can have far more significant ecological impacts than mere drought alone.

The two components of river ecosystems that form the bulk of the drought monitoring effort are macroinvertebrates and fish. Monitoring of macroinvertebrates has a few limitations which are well-understood, particularly: the level of taxonomic discrimination used for analysis of biological quality and environmental impact, apparent discrepancies between the various biological quality scoring systems, and lack of an adequate system of assessing drought impact compared with organic pollution or other toxic effects. Details of these and other limitations are given in the technical report BD 5/97.

Similarly, fisheries surveys also have limitations, often in connection with the actual sampling methods. A comparison of the effectiveness and efficiency of various techniques can be found in FSR 21/97. Possibly because of this, significant differences were found between the results of the fisheries surveys on the Don and Calder. These could be real differences between the catchment, or could be artifacts related to the use of different survey contractors.

One-off surveys in themselves cannot contribute to assessment of change but are useful in defining current status or providing a baseline for future work. In order to demonstrate change or impact, it is necessary to have a good basis with which to compare current data. This requires more than one previous example as impact needs to be shown to exist outside of the range of natural variability. Long term data sets, especially for aquatic macroinvertebrates and fish, are especially lacking for many of the upper catchment and headwater streams influenced by compensation releases in the Aire, Calder and Don systems. Other priorities, and a focus on water quality issues, has meant that those interpreting results from the drought monitoring in these areas will have to wait three years before obtaining sufficient information.

Lessons being learned as part of this process and emerging from R&D projects (eg Armitage *et al*, 1997) emphasise that a high degree of focus on particular habitats is required: the distinction between the assessment of general quality and site-specific/habitat specific impacts is often not clear in sampling programmes. This is especially relevant to upland rivers where exposure of particular areas of riverine sediments at the wrong time may be catastrophic for spawning fish (or developing eggs), but of no real consequence for aquatic macroinvertebrates. Appreciation of the *scale*, process rates and spatial integrity of the various aquatic systems in Yorkshire (and indeed elsewhere) is still underdeveloped but is fundamental in putting observed environmental impact into perspective.

As mentioned in section **13**, assigning judgemental terms to the observed changes in aquatic ecosystems is a problematical area in the absence of strong guidelines and knowledge about the sensitivity and resilience (ie ability to recover) of different communities and species. Parameters such as rarity and conservation value are relevant and contribute to the debate, but are nevertheless influenced by natural as well as anthropogenic events. Further research and assessment is needed in drawing up a classification scheme for freshwater ecosystems and their component biota.

14.0 RECOMMENDATIONS

14.1 General

This report has highlighted similarities but also some anomalies in the conclusions of the various specialist functions. When all the data from the joint YWS/Agency monitoring programmes become available, it will be essential to examine all of the findings in context. Integrating these results requires knowledge and understanding of individual catchments; this rests with the specialist staff involved. **It is recommended that this detailed knowledge is fully utilised in the process of collation.**

The final Drought Report will include more results, particularly from fisheries surveys and aquatic macroinvertebrate monitoring. Because of the large amount of data and analyses involved, **it is recommended that the final Drought Report is built upon a series of more detailed individual catchment reports.**

Other relevant ecological information exists outside of the both the Agency and YWS and but this has been largely ignored (Magee, 1997). It **is recommended that better liaison and contacts are made with local environmental and naturalist groups, such as the Yorkshire Dales National Park, Yorkshire Naturalists' Union, Yorkshire Wildlife Trust and English Nature.**

The data from the monitoring programmes will provide a valuable resource for specialist and in-depth studies of drought impact and for those who may want to carry out independent evaluations and analyses. **It is recommended that data in easily understandable format on a CD-ROM (or floppy discs) is produced by the Agency, for use by external parties such as academics, students and interest groups.**

Other, more specific, recommendations are grouped under appropriate topics.

14.2 Hydrology and water resources

In order for the full impact of the abstractions on river flows to be quantified, it is vital that good abstraction records are kept, with daily volumes made available. This will allow assessment of the impacts over the next two years. It will also give a better picture of the way the sources are operated with respect to timing of abstractions. This information should then be used to analyse the long term naturalised flow records for the Ouse, Ure and Wharfe under the Time Limited Licence conditions..

It is recommended that work on flow-naturalisation is progressed to facilitate the evaluation of the Drought Orders and TLLs.

14.3 Water Quality

As the drought developed and continued through the winter of 1995, the situation on the Don catchment grew critical and reservoir recharge did not occur. With hindsight, it is apparent that YWS should have applied for drought orders on the Don catchment earlier. It would have been of benefit if YWS had introduced more modest reductions in compensation releases at an earlier stage. The experiences also indicated that More Hall Reservoir is one of the most vulnerable compensation releases. This is both in terms of the levels to which stocks dropped, and the effect on the effluent from Jamont. **It is recommended that, in the event of future drought conditions, reductions in this compensation release beyond 7.2 tcmd should be strongly resisted by the Agency.**

Preliminary analysis of water quality data for the Aire catchment, which was not subjected to drought orders and therefore influenced by the natural drought, suggests a widespread deterioration in quality. **It is recommended that further investigations in this area are carried out by the Agency.**

The Brookfoot area on the Calder suffered very low dissolved oxygen levels in both 1995 and 1996, and should be investigated. The problems experienced in this location may well be ongoing problems even in non-drought years, and **it is recommended that a routine sampling point is reintroduced in this area to monitor the situation.** Mitigation measures may also be necessary.

When the dissolved oxygen levels dropped dangerously low, the methods of aeration employed were found to be of limited benefit to a riverine system. **It is recommended that other remedial options, eg peroxide dosing, are trialed.**

The chemical water quality analysis done for the drought sites in the Ridings Area concentrated mainly on sanitary parameters, eg BOD, dissolved oxygen and Ammonia. **It is recommended that an investigation into the effects of compensation release patterns on water quality *including list 1 & 2 substances* is carried out in future droughts.**

14.4 Ecology

As mentioned in earlier sections of this report, evaluating the nature and degree of ecological responses to low flows and drought is difficult, especially set against a background of high natural variability and fairly rapid rates of recovery when 'normal' conditions resume.

In addition, the assigning of terms such as 'damage' and 'harm' is not an objective science as this often depends on the perspective of the assessor, the timescale of the impact and the sensitivity or 'value' of the impacted species, habitat or community.

It is recommended that the Agency makes full use of the output from the current R &D project 'Environmental Evaluation Criteria for Water Resource Impact Assessment' being carried out on behalf of the North-East Region by Sir William Halcrow and Partners Ltd.

14.4.1 Macrophyte and algal surveys

As with one-off RHS, to gain a more representative picture of the possible impacts of low flows on instream macrophytes, **it is recommended that macrophyte surveys should be repeated annually, at the same time of year, for a number of years (5-10).**

In order to try to establish changes in plant communities in relation to flows (including spates) **it is recommended that flow data, covering the several years, should be analysed along with the macrophyte data**.

Because they may show more obvious responses to low flows than either macrophytes or macroinvertebrates **it is recommended that surveys of benthic algae (i.e. diatoms) should be included in future drought monitoring programmes, using recently developed methods.**

14.4.2 Aquatic macroinvertebrates

Much of the following relates to the analysis of the available data, rather than developing new methods for monitoring:

It is recommended that close attention is given to subfamilial and species patterns in groups such as Hydropsychidae and Simuliidae, which show strong longitudinal zonation, and Chironomidae and Oligochaeta, which respond to substrate and enrichment. (They may, however, not be needed in all cases).

It is recommended that findings should be extrapolated to other spatey Pennine rivers not included in the Drought Report to examine consistent trends and river specific faunal responses. Also, compare with analyses made on less spatey rivers (eg. Hull, Derwent, Rye, Cod Beck).

More detailed analysis of the relationship between river flows and invertebrate assemblages is required. **It is recommended that examination of the ecological significance of various flow parameters, such as average flows preceding the sampling period, extreme flows, variability and deviation from the mean is progressed.**

14.4.3 Fisheries

It is recommended that for future monitoring, the Agency should adopt a standard approach to Fisheries/Ecology surveys.

It is recommended that audit surveys should be carried out on the Don, Calder and Worth catchments.

As a mitigation measure in the Drought Orders, YWS were required to restock the rivers if damage to the fishery had occurred. The results of the fisheries surveys will be used to assess this, but maintaining the genetic integrity of natural stocks will need to be considered where appropriate. Any stocking programmes should take into account habitat availability. In particular, sudden, large influxes of takeable trout should be avoided. **It is recommended that, if necessary, several small introductions should be made over an extended period.**

To assess habitat changes that may impact on spawning success **it is recommended that spawning tributaries and spawning areas of the Don, Calder and Worth should continue to be examined for evidence of physical change.**

With regard to the Fisheries work on the Ouse and Ure **it is recommended that**

- **Monitoring of water quality in the tidal Ouse should be continued to determine the impact on salmon migration under low flow conditions.** The installation of a fish counter at Naburn Weir (part-funded by YWS) will assist in quantifying the numbers of adult salmon.

- **Future fish population survey programmes of the lower Ure and Ouse should adopt a multi-method approach as described above and further sites should be examined with a view to increase seine netting in relation to known aggregations of fish as identified from sonar surveys.**

- **Monitoring of fish entrainment at Drax Power Station should continue and be extended to include York Water Works' intake at Acomb Landing.**

- **Angling catch census be carried out during the 1997 coarse fishing season on York & District AA water at Beningbrough to monitor catches and species distribution, in order to follow up changes in fish communities seen during the 1995-96 drought.**

- **Monthly inspections and retention of photographic records at Newton-on-Ouse, Overton, Clifton Bridge and Acaster Malbis be carried out to assess seasonal trends in river conditions.**

- **A fish population survey on Swan and Apedale Becks at several sites in July 1997 should be done to determine the number of 1+ fish and current production in relation to flow and ameliorative works.**

- **The Agency undertakes quantitative fish population surveys at Jervaulx and Clifton Castle during July 1997 to establish baseline monitoring for salmon production in the Ure which can be used to examine drought impacts.**

- **Assessment of salmon production in the Ure's 'salmon becks' be done to help determine drought impacts.**

- **The Agency instigates a study during the autumn/winter of 1997-1998 to identify spawning sites, and to determine which may be at risk from low flows and desiccation.**

With regard to Fisheries work on the Wharfe **it is recommended that**

- **The Agency collects and analyse as many match returns as possible and continues to gather information from anglers, to help assess drought responses.**

- **The Agency carries out regular inspections and record observations (plus photographs), at fixed points. Particular attention to possible siltation of spawning gravels, location of spawning areas in main river, macrophyte growth, flows over obstructions and accessibility of tributaries for spawning.**

- **The Agency continues to remove obstructions, especially at the mouths of**

spawning becks, if necessary.

- **The Agency reviews the operation of Barden and Washburn Valley Reservoirs with YWS to improve fisheries.**

15.0 REFERENCES

(NB. This is not intended to be a definitive bibliography of drought-related publications)

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16.0 GLOSSARY OF TERMS

Abstraction	Removal of water from a source of supply (surface or ground water)
Airlift	A sampler in which material from the stream be and the animals associated with it are driven up a pipe and into a collecting net by the release of compressed air near to the base of the pipe.
Algae	Simple nonflowering plants including single-celled diatoms, filamentous 'blanket weed' and seaweeds.
ASPT	Average Score Per Taxon. A biotic score based on the BMWP score divided by the number of contributing invertebrate taxa (groups). It is a useful guide to the biological quality of a stream or river.
Ammonia	A chemical which is often found in water as the result of organic effluents. Widely used to characterise water quality. High levels adversely affect the quality of water for fisheries and abstractions for potable water supply.
BMWP score	Biological Monitoring Working Party. A biotic score based on the sensitivity/tolerance of a range of freshwater invertebrate groups; used to assist in classification of water quality.
BOD	Biochemical oxygen demand. A measure of the amount of oxygen consumed in water, usually by organic pollution. Widely used to characterise water quality.
Catch returns	Forms completed by anglers indicating locality, time spent fishing and fish caught, sent to the Environment Agency for data analysis.
Catchment	The total area of land which contributes surface water to a specified watercourse or water body.
Classification/ Classes	A method of placing waters in categories (classes or grades) according to assessments of water quality based, for example, on measurements of the amounts of chemicals in the water (especially BOD, dissolved oxygen and ammonia).
Cluster analysis	A computational technique with the aim of finding samples which group together that are more similar to each other (eg in faunistic terms) than those which are in different groups.
Compensation releases/flows	Water released artificially from reservoirs to augment river flows, usually to compensate for water abstracted for supply.

CSO	Combined sewer overflow - an overflow structure which permits a discharge from the sewerage system during wet weather conditions.
Cusum	A statistical technique for separating out periods over which a determinand has different underlying mean (average) levels. It is seen as a plot of the cumulative sum of deviations from a target value against the observation number.
Dissolved oxygen	The amount of oxygen dissolved in water. Oxygen is vital for life, so this measurement is an important, but highly variable, test of the 'health' of water; it is used to classify waterbodies.
Determinand	A general name for a characteristic or aspect of water quality. Usually a feature which can be described numerically.
Diatoms	Single celled algae with an interlocking pair of siliceous cases; often in the water as plankton but colonies also form brown or blackish deposits on hard surfaces in rivers and streams.
DoE	Department of the Environment.
Drought Order	A change in conditions with regard to abstraction rates, abstraction points, prescribed flows or other matters relating to the use of water by a water company, or by the regulator to protect the water resource and environment; granted by the DoE.
Drought Permit	Superseded Drought Orders after 1996.
Dry weather flow	As used in the Dales Area, the DWF is the average of the annual '7-day minimum flows' for all the years in the period of record. The 7-day minimum flow in a year is the average daily value of the lowest total flow over any seven consecutive days in the year.
Electro fishing	A sampling technique where an electrical current in water is used to draw fish towards an anode and temporarily stun them, enabling them to be captured, identified and measured.
Emergent	Used to describe plants/macrophytes which grow out of the water, usually in stream margins.
Face value GQA	A GQA grade based on the assessment of one year's water quality data, as opposed to the normal 3-year period.
Faunal assemblage	A group of animal species living in the same basic habitat, but not necessarily interacting (as in a 'community').

GQA	General Quality Assessment; a formal scheme for classifying controlled waters, ie rivers, lakes, canals, estuaries etc. based on chemical, nutrient, biological and aesthetic quality.
Hydro-acoustic survey	The use of high energy sound waves (sonar) to obtain echoes from targets such as fish in deep rivers where electrofishing may be less efficient.
Hydrograph	Plot of flow vs time.
Hydrology	The study of water resources, and the water cycle.
Kick sample	A biological sample taken by kicking the stream bed to disturb it, and collecting the organisms that are dislodged with a pond-net; it is the most widely used qualitative method for collecting macro-invertebrates from streams and shallow rivers.
Long term average	Description of the average (mean) condition over a set, or defined, period. Currently rainfall is averaged over the period 1961-1990 by the Meteorological Office. Similarly, a LTA macro-invertebrate fauna can be based on a series of samples from, for example, 1985-1994 to define the period before the drought of 1995.
Macro-invertebrate	Animal without a backbone; such as insects, worms, crustaceans, molluscs and spiders; usually retained on a sieve of mesh size 0.5mm. Widely used to assess the quality of aquatic ecosystems such as rivers, lakes and ponds.
Macrophyte	Large algae and higher plants visible to the naked eye, but commonly retained for mosses, liverworts, ferns and flowering plants.
Monitoring	Usually refers to the regular assessment by sampling or measurement of environmental quality in order to detect change, deviation from normal conditions, or attainment of stated conditions.
Multivariate analysis	Techniques of statistical analysis which deal with more than one variable (eg determinand values or species counts) simultaneously; often used with biological data involving numerous samples and species.
NRA	National Rivers Authority; existed 1989 to March 1996, now superseded by the Environment Agency.
Ordination	A computational technique for displaying the relationship between samples (eg of macro-invertebrates) on two or more axes (or dimensions).
%-tile (percentile)	The value below which falls a specified percentage of the statistical population (ie set of values).

Prescribed flow	A generic term for any flow 'prescribed' under statute or regulation.
Rheophilous	Flow-loving; usually occurring in areas of fast-flowing water.
Riparian owner	A person or organisation with property rights on a river bank.
River corridor	Land which has visual, physical or ecological links to a watercourse and which is dependent on the quality or level of water within the channel.
RIVPACS	A computer programme for classifying macro-invertebrate samples from watercourses based on a national community classification, and for predicting the macro-invertebrate fauna that any site should support under natural conditions, based on a limited number of environmental measurements.
Rolling programme	A monitoring programme designed to be spread over a period of time (such as three years), so that not all sampling points are dealt with simultaneously.
RSPB	Royal Society for the Protection of Birds.
SSSI	Site of Special Scientific Interest. A site given a statutory designation by English Nature or the Countryside Council for Wales because it is particularly important on account of its conservation value.
Standard deviation	A statistical term for the variation of a set of values (data).
Statistically significant	A description of a conclusion which has been reached after making proper allowance for the effects of random chance.
Stenothermal	Tolerance only to a narrow range of temperatures, whether cool or warm.
STW	Sewage treatment works. The term WWTW (waste water treatment works) is often now preferred by water companies.
Surber sampler	A device for obtaining semi-quantitative macro-invertebrates from stream beds, basically a metal frame or box, with a net to collect organisms dislodged from within box.
Surface water	Water in ponds, lakes, streams and rivers.
SWALP	Surface Water Abstraction Licensing Policy.
tcmd	Thousand cubic metres per day, a unit of flow, equivalent to a mega litre per day (Mld).

Time Limited Licence	Licence with a specified period of validity (eg.three years from date of issue).
WTW	Water treatment works.
Yorkshire Interpretative Index	A system of determining biological water quality based on the types, abundance and pollution sensitivity of freshwater invertebrates; conceived by the then Yorkshire Water Authority.