THE LOWERMOOR ENVIRONMENTAL REPORT

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This report is in two parts:-

PART A - The environmental impact of a pollution of the River Camel on 6/7 July 1988.

PART B - Proposals for re-instatement.

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SUMMARY

This report has been prepared by Mr Gordon Bielby, Regional General Manager of the future South West Unit of the National Rivers Authority, with the assistance of specialist staff and external consultants. It describes the investigations which have been carried out into the impact of discharges of contaminated water on the plants and animals of the River Camel and other streams, following an incident at Lowermoor Water Treatment Works on 6/7 July.

It is concluded that the only identifiable impact is on fish stocks with an estimated loss of between 43,000 and 61,000 juvenile salmonids. A consequence of this mortality will be a reduction of several hundred adult salmon and sea trout returning during the next three years.

Further monitoring of the plants and animals of the River Camel will take place to test this conclusion including :

* Monitoring of the recovery of fish stocks
* Monitoring of aquatic insects
* An assessment of the status of aquatic birds by the RSPB
* An assessment of the status of otters by the Vincent Wildlife Trust.

The results of these studies will be made available to the public.

RECOMMENDATIONS OF THE REPORT

To ensure the earliest possible recovery of fish stocks it is proposed, subject to consultation with riparian and fishing interests, to :

* increase the escapement of salmon and sea trout to the River Camel by negotiating with the seven licensed commercial netsmen to cease fishing for a three year period from 1989-91;

* improve the habitat in salmon and sea trout spawning and rearing areas by clearance of debris and silt;

* put more effort into the control of illegal fishing and the carrying out of habitat improvements by employing trained, part-time, fisheries assistants recruited from the local community;

* investigate the feasibility of building fish passes at weirs to allow salmon and sea trout access to additional spawning areas;

* monitor the progress of the recovery of the fish stocks.

South West Water will finance the work which arises from the above programme.

During the next three months there will be a programme of consultation which will include :

Riparian and fisheries interests

Vincent Wildlife Trust

Royal Society for the Protection of Birds

Cornwall Trust for Nature Conservation

Camel Valley and Bodmin Moor Protection Society

A copy of this report has been sent to Her Majesty's Inspectorate of Pollution.

PART A

1. INTRODUCTION

On Wednesday 6 July 1988 an incident took place at South West Water's Lowermoor Water Treatment Works, near Camelford, Cornwall, which resulted in contaminated water entering the local distribution system. The circumstances surrounding this incident were investigated by Dr John Lawrence and he made public his report on 15 August 1988. Dr Lawrence did not deal with the environmental aspects resulting from some of the contaminated water being flushed out into the Rivers Camel and Allen and other local watercourses. These aspects are now the subject of this report.

2. THE RIVER CAMEL

The catchment of the River Camel covers an area of 457 km^2 to the west of Bodmin Moor. The shape of the drainage area is roughly circular, with the principal watercourses of the Rivers Camel and its major tributary the Allen rising in the north of the catchment east of Tintagel and flowing south south west towards Bodmin. The main river then flows in a north westerly direction to outfall through a long tidal estuary to Padstow Bay, as shown in Map 1.

The River Camel rises on Hendraburnick Down at an altitude of 280 metres and flows for 37 kilometres through agricultural land and woodland via Camelford to Wadebridge. The eastern part of the catchment lies on the higher parts of Bodmin Moor which rise to an altitude of 420 metres.

The River Allen rises between Delabole and Camelford at an altitude of 200 metres and flows for 17 kilometres through agricultural land and woodland to join the River Camel in the tidal reaches upstream of Wadebridge.

The River Camel is a game fish river supporting populations of salmon, sea trout and brown trout. It is best known for its run of winter salmon, most of which are late-running grilse, but there are significant earlier runs of grilse and two-sea-winter fish. There is also a good run of sea trout throughout the summer. Other fish such as eels, bullheads and brook lampreys abound and are widely distributed throughout the catchment.

The flow of the River Camel is measured at Denby (NGR SX 017 682). The catchment down to the gauging station is $209km^2$ which represents 46% of the total area. The average daily flow (ADF) at this gauging station for the period 1965 to 1986 is 5.88 m^3/s (112 m.g.d.) and the flow exceeded for 95 percent of the time (Q95) for the same period is 0.81 m^3/s (15 m.g.d.). The River Allen has a catchment area of $64km^2$ which represents 14% of the total catchment. There is no gauging station within this catchment.

3. INCIDENT ON 6/7 JULY 1988

On Thursday 7 July, at 0915 hours, Camelford Police telephoned the Authority's office at Bodmin to report that members of the public had seen dead and dying fish in the River Camel at Pencarrow Bridge (NGR SX 104 827) (see Map 2). The police also asked if there was a problem at Lowermoor Water Treatment Works. After reporting the substance of the call to his colleagues at Bodmin an Assistant Pollution Inspector responded to the incident and arrived at Pencarrow Bridge at 1010 hours.

At 0920 hours the Environmental Protection Officer, who was visiting the Authority's office at Launceston, was contacted. He decided that the incident seemed to be of a serious nature and, as the senior manager for environmental matters in the West Area, he returned to Bodmin to take charge.

On arrival at Pencarrow Bridge, the Assistant Pollution Inspector noticed 200-300 dead juvenile salmon and brown trout with surviving fish in a distressed state and this was reported to staff at Bodmin. Another Assistant Pollution Inspector now joined him at the confluence of the Tregoodwell Stream and the River Camel (NGR SX 108 833) where they found dead fish in the River Camel upstream of the confluence, but only live fish in the Tregoodwell Stream.

The inspectors proceeded to trace the fish mortality to a point in Camelford where a surface water drain enters the River Camel 15 metres downstream of Camelford Bridge (NGR SX 106 837). Dead and dying fish were observed at this point and an apparently healthy fish population was observed upstream of it. The dead fish were covered in mucus and their gills were bright red: these observations are consistent with exposure to water of low pH and high aluminium concentration.

The inspectors visited the adjacent industrial estate, part of which drains to the same surface water outlet. No evidence of accidental spillage was found. On returning to the town centre at 1130 hours, information was obtained from the public that the water distribution system had been flushed during the previous night because of a problem at Lowermoor Water Treatment Works.

The inspectors contacted Bodmin and reported that the fish mortality was likely to be related to a flushing out of the water distribution system. The Environmental Protection Officer was able to confirm this by virtue of information which, by then, he had received.

Prior to these enquiries, Environmental Protection staff had not been informed of the decision to undertake a flushing programme nor had advice been sought on the environmental consequences of the release of this contaminated water.

Water samples were collected from the River Camel downstream to Wenford Bridge (NGR SX 085 752). During this exercise many distressed fish were observed in the section between Trecarne Bridge (NGR SX 097 806) and Gam Bridge (NGR SX 089 779) and this information was passed to the Bodmin office. Samples of river water were delivered to the Authority's Truro Laboratory for analysis.

At 1500 hours staff inspected the River Allen and reported to the Bodmin office that there was also a major fish mortality between Newhall (NGR SX 070 823) and Knightsmill (NGR SX 072 806) and from Treforda (NGR SX 078 814) to Knightsmill.

On return to the River Camel the downstream extent of the fish mortality was ascertained. Then, from 1800 hours, another series of water samples was collected from the Rivers Camel and Allen; these were also delivered to the Truro Laboratory for analysis.

Based on reports of the extent of this fish mortality and the fact that some fish were still distressed it was decided to attempt a rescue of the surviving fish. A team of six staff arrived at Trecarne Bridge on the River Camel at 1500 hours and, with the help of Mr Ruscombe King, a local fish farmer, began the rescue attempt. Some of the severely distressed fish died immediately; others did not recover from the stress of electrofishing and transfer to a holding tank. It was therefore decided to abandon the operation because surviving fish were too stressed to be moved; their best chance was to be left to recover in the then improving water quality.

Selected sections of the Rivers Camel and Allen were then electrofished to determine whether any fish remained alive and to confirm the extent of the fish mortalities in both rivers. The information from these inspections was collated and an inspection of all the affected reaches was planned for Friday 8 July to assess the number of dead fish.

During the afternoon the Environmental Protection Officer made arrangements with Operations staff for the release of compensation water from Crowdy Reservoir. This was released via a pipe to Lowermoor Water Treatment Works and thence via the Greylake Stream and the Tregoodwell Stream to assist in the dilution and attenuation of the pollution in the River Camel.

During the afternoon the Environmental Protection Officer was told that a further flushing of the water distribution system would be necessary. He informed the District Manager that the contents of the water distribution system should not be allowed to enter the watercourses of the Rivers Camel and Allen. The Environmental Protection Officer agreed flushing arrangements with the staff of the Water Operations Controller by reference to a map of the distribution system. The agreement was :-

(a) Not to use hydrants or washout valves draining directly to the Rivers Camel and Allen.

(b) To maximise the use of hydrants and washout valves draining directly to the sea or to harbours, including those which would drain to small watercourses discharging directly to the sea. This excluded the watercourse flowing through Trebarwith Strand because of its popularity with children.

(c) To maximise the use of hydrants and washout valves draining over land provided there was sufficient capacity to absorb the discharged water.

Flushing, from fifteen hydrants and washout valves, continued throughout the night of Thursday 7 July and early morning of Friday 8 July in accordance with these rules and inspected by Environmental Protection staff.

During Thursday 7 July a number of interested people and organisations were informed of the fish mortality and the environmental investigations that were taking place. Staff also dealt with numerous enquiries from riparian owners and members of the public.

4. INVESTIGATIONS

4.1 Sources of Pollution

Although Operations staff were monitoring the quality of treated water at certain points in the distribution system, monitoring of the quantity and quality of the contaminated water was not undertaken at any of the sites prior to its discharge to the River Camel and tributaries.

Subsequent investigation by Environmental Protection staff has enabled the maximum rate of flow from hydrants to be obtained although the rate of flow from washout valves on 6/7 July is unknown.

From Dr Lawrence's report it is known that 20 tonnes of 8% w/w aluminium sulphate (as $Al_2 O_3$) were discharged into the treated water reservoir at Lowermoor Water Treatment Works. The reservoir is believed to have held about 1.35 million litres (300,000 gallons) of treated water. If the aluminium sulphate had been uniformly mixed then this would have led to a concentration higher than 600 mg/l aluminium (as Al) with a pH value of 3.3. As a solution of 8% w/w of aluminium sulphate (as $Al_2 O_3$) is denser than the treated water the process of dispersion and transport through the mains would have been more complicated since full mixing would not have taken place. It is likely that at times the contaminated treated water, flushed from the distribution system, contained high concentrations of aluminium and was more acidic than pH 4.2 which was recorded in the treated water reservoir.

Environmental Protection staff subsequently visited each of the ten hydrants and washout valves used for flushing on the night of 6/7 July as indicated on Map 3. For each location, an inventory of site information was prepared and an assessment was made of the likelihood of discharged water entering a watercourse. From these inspections it was established that at locations R3 to R8 the discharges to watercourses probably contributed to the fish mortalities. It was considered that discharges from the distribution system at locations R1, R2, R9 and R10 probably did not so contribute.

4.2 River Water Quantity

The flow pattern of the River Camel can change rapidly in response to rainfall. During June, the river flow at Denby Gauging Station receded to 1.32 m^3/s (25 m.g.d.) after a period of dry weather. On 6/7 July river flows had increased to 2.00 m^3/s (38 m.g.d.) following several days of intermittent rainfall. On the days following, rainfall increased each day until 24 millimetres were recorded at Camelford on Sunday 10 July with a corresponding peak river flow of 10.00 m^3/s (190 m.g.d.). These increases in river flow probably scoured the catchment of any aluminium that may have settled on the river bed and washed away the remaining dead fish. Higher river levels also delayed certain environmental surveys because of the difficulty of working in the river.

The relevant rainfall data for Michaelstow shows a similar pattern to that recorded at Camelford and it is likely that similar flows occurred in the River Allen.

Time-of-travel calculations indicate that first-flushed water discharged to the River Camel at Camelford at 2300 hours on Wednesday 6 July would have reached Gam Bridge by approximately 0300 hours on Thursday 7 July, a distance of approximately 6 kilometres.

Excluding any effects of attenuation, it is probable that the main body of polluted river water reached Denby, 23 kilometres from Camelford, by approximately 1400 hours and entered the estuary at Wadebridge, 29 kilometres from Camelford, by approximately 1800 hours on the evening of Thursday 7 July.

Dilution of the polluted river water in the River Camel by two east bank tributaries was important in minimising the extent of the fish mortality. The Tregoodwell Stream which enters the River Camel 0.6

kilometres downstream of Camelford is calculated to have contributed 43% of the river flow below their confluence: the Stannon Stream, which enters the river 3.8 kilometres downstream of Camelford, is calculated to have contributed 42% of the river flow below their confluence.

It has not been possible to undertake similar estimates for releases to the River Allen catchment, but it can reasonably be assumed that the body of polluted river water had entered the estuary at Wadebridge by the late afternoon of Thursday 7 July.

4.3 River Water Quality

No samples were collected of the discharged water so the quality of this and the receiving waters at the time of discharge is unknown.

River water samples were collected from the Rivers Camel and Allen on 7, 8 and 14 July. Two surveys of the River Camel and one of the River Allen were undertaken on 7 July in the parts of the catchment where the fish mortalities had occurred. The pH values and total aluminium concentrations found in these samples are included in Appendices 1 and 2.

River Camel

Samples of river water collected on Thursday 7 July in the areas of the fish mortalities confirmed that the quality was by then almost back to normal. The first samples collected before 1100 hrs from the River Camel at Pencarrow Bridge and upstream of Camelford Sewage Treatment Works had pH values of 6.8 and 7.1 respectively and total aluminium concentrations of 0.63 mg/l Al and 0.21 mg/l Al respectively. A sample collected at 1340 hours at Trecarne Bridge had a pH value of 6.3 and a total aluminium concentration of 0.35 mg/l Al.

Results of 39 routine samples collected during the period 1983-87 from the River Camel at Trecarne Bridge have shown a range of pH values from 6.6 - 7.7 with a mean value of 7.2. Aluminium concentrations have not been monitored routinely in the River Camel.

However, a catchment study carried out from April 1984 to March 1986 provided pH values and total aluminium concentrations from samples collected in the River Camel at Pencarrow Bridge. A range of pH values from 6.6 - 7.6 with a mean value of 6.9 was recorded from 24 samples. A range of total aluminium concentrations from 0.01 - 0.71 mg/l Al with a mean value of 0.09 mg/l Al was recorded from 23 samples.

Comparison of the results for mid-morning Thursday 7 July with this baseline indicates that the polluting effects were no longer significant.

Results of samples taken from Trecarne Bridge for other determinands over the same period show that the river is free of organic contamination. It has a moderately low soluble solids content as reflected by the conductivity value and a relatively low buffering capacity as indicated by low total alkalinity and total hardness.

River Allen

Samples collected from the River Allen at Knightsmill Bridge on Thursday 7 July had a pH value of 7.1 and a total aluminium concentration of 0.30 mg/l Al. A sample collected 5.8 kilometres further downstream at Kellygreen (NGR SX 045 758) had a pH value of 7.4 and a total aluminium concentration of 0.13 mg/l Al.

Results of 22 routine samples collected from the River Allen during the period 1983-87 at Knightsmill Bridge have shown a range of pH values from 6.7 - 8.0 with a mean value of 7.5. Aluminium concentrations have not been monitored routinely in the River Allen. Results from samples taken at Knightsmill Bridge for other determinands over the same period show indications of slight organic pollution with a medium soluble solids content and a moderate buffering capacity. The chemical composition of River Allen water is anyway different to that of the River Camel because of the different geological formations within its catchment.

Comparison of the results of pH analysed from samples taken from the River Allen during the evening Thursday 7 July with the longer term data for Knightsmill Bridge indicates that the polluting effects were no longer significant.

4.4 Licensed Water Abstractions

The locations of licensed river abstractions were assessed on 7 July in relation to the extent of the fish kill, and the results of water quality sampling of the Rivers Camel and Allen.

Records indicated that there were only two licensed abstractions downstream of the releases from the water distribution system. They were a fish farm located at Dunmere, Bodmin (NGR SX 047 678) on the River Camel and an abstraction on the River Allen, for spray irrigation, at Benbole Farm, St Kew (NGR SX 032 740).

It was concluded that, since the polluted water was by then clearing the catchment, there would be no risk to the abstractors using the river water.

4.5 Fish

Assessment of the Loss

As noted above, sections of the River Camel upstream of Gam Bridge were electrofished to determine whether any fish remained alive. About 15 metres of the river, across its whole width, were fished at Trecarne, Kenningstock, and Pencarrow. Live fish were found at all these sites although numbers were low. A similar exercise was carried out on the

River Allen at Knightsmill, Trewalder and Lanteglos. Live fish were caught at all sites but dead fish were also observed.

A full inspection of the extent and magnitude of the fish mortality was undertaken on Friday 8 July and Saturday 9 July. Staff were assigned lengths of watercourse to walk on the River Camel between Gam Bridge and Camelford, on the River Allen between Knightsmill and Lanteglos and on the Delabole Stream from its confluence to Delabole. Dead fish were removed where possible and totals are given in Table 1.

TABLE 1 DEAD SALMONIDS COUNTED OR ESTIMATED, 8 AND 9 JULY 1988

	SALMONID FRY	SALMON PARR	TROUT
	ESTIMATED	COUNTED	
RIVER CAMEL	4,200	946	1,579
RIVER ALLEN	3,150	2,015	2,431
TOTAL	7,350	2,961	4,010

Many dead fish remained in deep pools where accurate counting and/or recovery were not possible. Large numbers of fry were killed and the reported totals are considered to be conservative because of the difficulties of recovering all fish. Although losses were not counted it was clear that the bullhead, eel and brook lamprey populations were badly affected over the same lengths as the salmonids. The extent of the fish mortality is indicated on Map 2.

As already noted, a spate on Sunday 10 July washed away most of the dead fish which had not by then been recovered. Consequently, immediate follow-up work in the Rivers Camel and Allen and investigative work in minor watercourses was deferred until September when a quantitative salmonid population survey of the River Camel and tributaries was carried out to determine the extent of the fish losses and to place them in the context of the whole population.

This survey was carried out at 41 sites as indicated on Map 4. When data from this survey are compared with all previous data for the affected reaches, from surveys in 1972, 1980 and 1985; they provide estimates of the probable fish losses in September. These are shown in Table 2.

TABLE 2 ESTIMATED LOSSES ADJUSTED TO SEPTEMBER 1988

AGE GROUP	MOST LIKELY RANGE
SALMON UNDER 1 YEAR	20,000 - 25,000
SALMON OVER 1 YEAR	4,500 - 9,500
TROUT UNDER 1 YEAR	11,000 - 19,000
TROUT OVER 1 YEAR	7,500
ESTIMATED TOTAL LOSS	43,000 - 61,000

The mortality of salmon aged one year and older represents about 19% of the whole stock of these age groups in the River Camel catchment whilst that of trout of one year and older represents about 8 - 11%.

From the losses of fry and parr identified in September 1988 the number of smolts which will not now be produced can be estimated for salmon in 1989 and 1990 and for sea trout in 1989-92 inclusive. The effect on the smolt run of both species will be most marked in 1989 and 1990.

Allowing for a 90% natural and fishing mortality at sea the estimated reductions in the number of returning adults are shown in Table 3.

TABLE 3 ESTIMATE OF ADULTS LOST FROM 1989 ONWARDS

	1989	1990	1991	1992	1993
SALMON	0	110 - 233	155 - 329	47 - 99	2 - 3
SEA TROUT	96 - 132	96 - 132	small numbers		

Salmon parr which were lost and which would otherwise have returned in 1990 would have been grilse and a significant proportion (about 70%) of those lost from adult runs in 1991 would also have been grilse. The majority of sea trout lost would have been returning first in the same year as they migrated as smolts - such fish being known locally as 'school peal'.

Toxicity of contaminated discharges to fish

A solution of 8% w/w aluminium sulphate (as Al_2O_3) has a pH of 2.5 and a concentration of soluble aluminium of about 55,000 mg/l Al. Dilution within the treatment works and distribution system probably resulted in the water discharged to the environment being at about pH 4.5 and 100 mg/l Al although this is likely to have been quite variable. As noted above, natural water quality in the River Camel tends to be slightly acid to neutral, relatively soft and poorly buffered, whilst the River Allen tends to be neutral with a greater buffering capacity. Such waters, receiving an acidic discharge, would be expected to remain relatively acid for several kilometres until dilution by tributaries and improved buffering took effect further downstream.

Low pH is itself toxic to fish and several mechanisms have been cited as causing death. These include disruption of the gill epithelium, production of mucus on the gills, inability to osmoregulate and acidosis of the blood. The effects of acidic water on salmonid fish are given in Table 4.

TABLE 4 EFFECTS OF ACID WATER ON FISH

pH Range	Effect
3.0 - 3.5	Unlikely that any fish could survive for more than a few hours.
3.5 - 4.0	Lethal to salmonids.
4.0 - 4.5	Harmful to salmonids not previously acclimated.
4.5 - 5.0	Harmful to salmonid fry and to adults in soft water.

The toxicity of aluminium is complex being influenced by several environmental factors of which pH is the most important. In acid water, aluminium is generally most toxic over the pH range 4.4 - 5.4 with a peak around pH 5.0 - 5.2. It can be acutely toxic to fish at concentrations as low as 0.1 mg/l.

The mode of action of aluminium is imperfectly understood. Mucus accumulation on the gills and gill damage are typical of fish which have died from aluminium poisoning. Impaired osmoregulation has been cited with loss of plasma sodium and chloride, similar to the effect of low pH. Reduced oxygen tension in venous blood has also been observed. A combination of these factors may be operating.

It is possible that the addition of contaminated treated water of pH 4.2 - 4.5 with a total aluminium concentration of 100 mg/l Al could have lowered the pH value of the River Camel and possibly the River Allen to pH 5.0 - 5.2. Total aluminium concentrations would have been considerably in excess of 0.63 mg/l Al which is the maximum level previously found in the rivers. Whatever the concentration of aluminium and the pH of the river water the combination was sufficient to cause extensive fish mortalities.

Consultation with the Water Research Centre has failed to locate reliable short-term toxicity data of pH and aluminium on European salmonids for a period of fewer than five hours.

Since the cause of death was quickly established no samples of fish were taken for autopsy by staff but a member of the public collected a sample of dead fish and preserved them in formalin. A sub-sample of two fish was made available and these were sent to Welsh Water for autopsy. Both fish were trout and had been feeding normally before death and the onset of death was rapid. The opercula of both fish were open in the coughing position, the normal response to gill irritation. The aluminium content of the gills was 76 times higher than in gills from control fish preserved in formalin. The formalin had had no major effect on gill metal concentrations. The level of aluminium found is comparable to that found in fish in the River Tywi known to have died as a result of aluminium poisoning.

The conclusion reached is that the high concentration of aluminium in the gills and the coughing position of the opercula are consistent with death from aluminium poisoning.

4.6 Invertebrates

River conditions on Thursday 14 July allowed an invertebrate fauna survey to be undertaken. It was accepted that the high flow over the previous four days would have flushed any dead or weakened invertebrates from the areas in which fish mortalities had occurred. This may have been partly balanced by a downstream drift of invertebrates (a well-known natural phenomenon) which may have contributed to recolonisation of previously affected areas.

Samples were taken from riffle areas and identified. From these data Biological Monitoring Working Party (BMWP) scores were calculated and associated Average Scores Per Taxon (ASPT) were determined: both of these indices are routinely used in the biological assessment of river water quality.

Nine locations on the River Camel were sampled and eight locations on the River Allen as indicated in Map 5.

The most recent invertebrate survey on the River Camel was carried out in 1983 and on the River Allen in 1984 although three locations in the vicinity of Camelford were sampled in June 1988. The BMWP scores and ASPT scores obtained in 1983 and 1984 were compared (at co-incident sites) with the survey on 14 July 1988 and the taxa found in 1983 and 1984 have been compared with those found in 1988.

Examination of the data indicates that there have not been any gross effects on the invertebrate fauna of the Rivers Camel and Allen resulting from the incident.

In order to identify any specific or longer-term effects, an additional survey was carried out beginning on 25 August. Samples were obtained from 14 locations (6 in the River Camel catchment and 8 in the River Allen catchment). These sites were selected to assess the effects of discharges known to have caused the fish mortalities. An additional 18 locations were sampled in the vicinity of flushing points where fish mortalities did not occur. These locations were selected to record any possible effects resulting from the flushing. Further locations were sampled in those watercourses which received discharges as part of the controlled flushing programme after the initial release. These locations are indicated on Map 5.

<u>These studies confirm that there has not been any damage to the invertebrate fauna of the Rivers Camel and Allen as a result of the incident and consequently that there is no need to take any steps to influence the recovery of invertebrates in the affected rivers.</u>

If any small community imbalance has resulted immediately downstream of discharges of contaminated treated water then this will be rapidly corrected by downstream drift and increases due to the natural productivity of the rivers.

4.7 Plants

A survey of sites upstream and downstream of flushing points on the Rivers Camel and Allen and the Tregoodwell Stream was carried out, for the Authority, by Alconbury Environmental Consultants in early September 1988 at the points shown on Map 6.

These areas are naturally poor in aquatic flowering plants (macrophytes) and large algae. Their scarcity is not attributed to flushing with contaminated water. Aquatic mosses (bryophytes) occur wherever the substrate is stable and, at sites upstream and downstream of flushing points, moss communities were similar. Overall there was no evidence of any impact on plant community structures.

Some species of bryophytes are known to accumulate metals and are useful indicators of metal pollution. Since acidic water could have resulted in some metals naturally present in the environment being dissolved and hence made available for accumulation, samples of bryophytes were analysed for lead, copper and zinc as well as aluminium.

There was no evidence of lead concentrations being different upstream and downstream of the points where contaminated water had been discharged. Only two sites had elevated lead levels, one of which was attributable to emissions from car exhausts, the site being in close proximity to a public highway. There was no evidence of increased copper. There was however a consistent increase in zinc concentrations at sites downstream of discharge points on the Tregoodwell Stream and at Camelford. These increases were consistent at about 30% and were found in all three bryophyte species sampled. At other sites downstream of discharge points, zinc levels were comparable to those found at control sites.

On the River Allen and on the Delabole Stream upstream of Delabole Quarry, the same effect was observed i.e. a 30% increase in zinc downstream of the flushing points. However, at four sites on the River

Allen system downstream of Delabole Quarry zinc levels were ten times higher than found elsewhere. This may be due to discharges from the quarry and not to the flushing of contaminated water and will be the subject of further investigations.

The flushing programme resulted in changes in zinc concentrations which were relatively insignificant on the Delabole Stream downstream of the Quarry because the levels were already elevated, although the changes were significant elsewhere.

Without exception where samples were taken upstream and downstream of flushing points, aluminium levels showed an increase of 30% at the downstream sites. On the Tregoodwell Stream samples of the moss *Rhynchostegium riparioides* from the road drain which carried the contaminated water had 14,000 mg/kg Al dry weight, more than double the concentration found at any other site.

The levels of aluminium found in bryophytes at downstream sites are not considered to be toxic to these plants. The metals accumulated in bryophytes will be released to the water slowly over a period of some months and eventually levels will return to normal.

Since the higher levels were observed only immediately downstream of the flushing points and the diet of most animals contains aluminium without detriment to them, the effect on invertebrates grazing on bryophytes is considered to be minimal or non-existent.

4.8 Birds

No wild birds were reported dead or stressed by the discharges.

Since the impact on invertebrates seems to have been slight, it is considered that no detriment will have been caused to birds which consume them. Since the incident, dippers have been seen feeding at many locations in the Rivers Camel and Allen by several observers.

The loss of substantial numbers of fish, especially salmonids and eels, may have had an effect on fish-eating birds such as kingfishers and herons. However, it is known that some fish survived and that kingfishers often take invertebrate prey. Consequently there should have been no impact on this species; indeed, kingfishers were observed in the affected reaches a few days after the incident.

Herons preferentially take eels and whilst some eels were killed in July their densities in September in the Rivers Camel and Allen were similar to or greater than those observed at control sites. Some eels probably survived the pollution; others have probably moved into the affected reaches. The period of significantly reduced eel densities is likely to have been short. In the event of a local food shortage herons would probably move to another part of their range and as a result are unlikely to have been affected.

The Royal Society for the Protection of Birds (RSPB) has agreed to undertake a survey of aquatic birds within the affected river corridors of the Rivers Camel and Allen to assess their population status. Because of the autumn movement in juvenile birds and the need to obtain results by reliable recording of breeding populations, a survey of dippers, wagtails and kingfishers will be undertaken by the RSPB during the 1989 breeding season.

4.9 Otters

There have been no reports of dead or distressed otters associated with the incident.

Otters frequent the River Camel catchment and normally occupy extensive ranges. Any otters with a home range which included part or all of the streams where eel or salmonid populations were affected may have had to seek some unaffected reaches. In the short-term the loss of fish is unlikely to have had any effect on otters and long-term effects are likely only if there is intensive competition for space and the food resource in the River Camel and if the recovery period of the fish populations is prolonged.

A preliminary survey by the Vincent Wildlife Trust in September 1988 indicated that otters were using the sections of the River Camel which were polluted in July. Further detailed survey work and spraint analyses (to assess diet) have been commissioned by the Authority.

4.10 Subsequent Flushing Programme

Following the flushing programme of the night of 6/7 July, nineteen hydrants and washout valves were used, according to agreed rules (Section 3), to release contaminated treated water from the distribution system. Fifteen of these were used between Thursday 7 July and Sunday 10 July and were inspected by Environmental Protection staff during this period. Fourteen of these were used between Thursday 21 July and Monday 25 July and these were supervised by Environmental Protection staff. These hydrants and washouts are indicated on Map 7.

A further nine hydrants and washout valves were used, without supervision by Environmental Protection staff, between Thursday 7 July and Sunday 10 July. These hydrants and washouts are indicated on Map 7.

Where hydrants and washout valves were used after 7 July, the rate of discharge was controlled to ensure minimal impact on watercourses. Some discharges did reach a watercourse, others soaked away into land. Staff recorded the pH of the discharges. At three locations acidic water with a pH in the range 4.0 - 5.0 was recorded during the first few minutes of controlled discharge. Within minutes pH values greater than 7.0 were recorded, and generally in the range 8.0 - 9.0 for all locations as discharges continued.

4.11 Assessment of Disposal Options

On the late evening of Wednesday 6 July, the Treatment Scientist reported that water being released from the treated water reservoir at Lowermoor Water Treatment Works had a pH of around 4.2, with an elevated aluminium level and he believed that this was as a consequence of lime dosing plant failure that afternoon. Staff were also aware that some of this water had entered the distribution system and reached at least as far as the Camelford area.

Based on the limited information available to Operations staff and Treatment Scientists on the night of 6/7 July, the health risks to customers were not considered such as to require a supply shutdown, although action was considered necessary to deal with potential effects on customers in certain areas.

In considering options, staff were aware of the consequences of isolating and depressurising the distribution system which, even if it occurs for a short period, can result in backsiphonage and the ingress, though leak points, of bacterial and chemical contamination from the surrounding groundwater. The possibility of creating a serious health risk had therefore to be weighed against the risks to customers of not turning off the water supply at source. There were also potential operational problems such as mains bursts which can arise when supplies are resumed.

Staff decided not to shut down the water supply to customers since it was believed that there was an acceptable alternative i.e. to lessen the problem by flushing the mains overnight.

In the extreme and extended pressures of the incident, with immediate attention focussed on the protection of water supply customers, the potential effects on watercourses and aquatic life were not given any consideration.

Similar incidents have occurred previously and Environmental Protection staff have been called upon to advise on disposal options. These staff are trained and experienced in effluent disposal practices. Their attendance in the early hours of Thursday 7 July would have provided Operations staff and Treatment Scientists with a chance to re-appraise the disposal options available and would have alerted them to possible consequences.

With the decision not to shut down the distribution system, the question arises - could pollution of the Rivers Camel and Allen have been avoided? To answer this question it is necessary to consider, albeit with hindsight, whether practical options were available. The possibilities were :-

i) <u>Neutralisation of the water stored in the treated water reservoir, followed by disposal to land, temporary storage or controlled discharge to watercourses</u>.

This seems to have been a practical option to reduce the volume of highly contaminated water to be dealt with through the distribution system, which was the main cause of the pollution of the River Camel.

However, it would have required the closure of the works and this was discounted for the reasons given previously and because the full extent of the contamination was not known at that time.

ii) <u>Controlling the rate of discharge to watercourses according to their capacity to accept the contaminated water without damage</u>.

This appears to have been a practical option and could have limited the pollution.

However, this action would have considerably delayed completion of flushing which would have led to an increase in the number of customers who received contaminated water and the level of contamination to which some were exposed.

iii) Treatment of the contaminated water immediately prior to discharge to watercourses.

This is not considered to have been feasible for a number of practical and logistical reasons.

iv) Concentrating the discharge of contaminated water at selected points.

This would have protected the more important watercourses at the expense of others and by discharging to the sea.

The use of such discharge points would however, inevitably, have resulted in wider distribution of highly contaminated water within the system with consequences to customers already referred to.

v) Careful choice of discharges, away from watercourses or where adjacent land could be used as a soakaway.

This could have significantly reduced the impact on some watercourses.

It would not have been possible in all cases and since it would have delayed the completion of flushing it would also have increased the impact upon customers.

A number of these options were successfully used during the controlled programme of flushing which followed, demonstrating that if consultation with Environmental Protection staff had taken place it would have been practicable to reduce the impact on watercourses.

However it should be noted that this prolonged the period of retention of the remaining contaminated water within the distribution system.

The only solution to protect the customers and avoid damage to the environment, appears to have been to close the whole system whilst controlled decontamination took place.

In the circumstances which prevailed on the night of 6/7 July, especially with the then limited knowledge of the extent of the contamination and in the absence of contingency plans for controlled use of the available discharge points, the outcome of resorting to any of these options would have been much less clear. Certainly it should have been possible to reduce the impact upon key watercourses. However any delay to determine what steps to take and any resultant action would have increased the impact upon customers, unless consultation with Environmental Protection staff had itself led to closure of the distribution system.

In terms of limiting the period of high acid concentration in the supply system it is apparent that the urgent flushing on the night of 6/7 July was direct and effective.

4.12 Future Monitoring and Work Programmes

Further sampling of water chemistry, invertebrates and fish and special investigations into aquatic birds and otters are planned and the results will be made public.

The proposed programme for these tasks is outlined in Appendix 3.

PART B

1. REHABILITATION

1.1 DISCUSSION

As far as can be ascertained, and subject to further surveys, only the fish stocks of the affected stretches of the Rivers Camel and Allen suffered significantly. It follows that action to mitigate the damage must focus upon those stocks.

No direct action can be taken to reinstate stocks of non-salmonid species although their recolonisation will be monitored until the populations return to normal.

It is fortunate that salmon and sea trout are adaptable and capable of withstanding impacts such as the one under discussion. Reduced mortality and increased growth of survivors, with the probability of a high proportion of those survivors becoming smolts earlier than usual, is one compensatory mechanism. The phenomenon of divided migration and return is another. Similarly, the great fecundity of salmon and the ability of sea trout to spawn in several consecutive seasons give both species considerable powers of population regeneration.

This means that, left alone, stocks of both species would eventually return to the pattern and level of abundance exhibited before the pollution. It is prudent however to assist and accelerate this process.

For salmon and sea trout stocks, various courses of action can be taken to mitigate for the loss of juveniles and the effects of the resultant reduction in the number of returning adults which is expected to be most significant in the period 1989-91.

Possibilities include encouraging natural recovery, reducing the licensed rod, net and illegal catch and restocking, either separately or in combination. In addition, a sustainable increase in natural production could be achieved by habitat improvement measures and by providing or improving access to presently-unused (or little-used) spawning and rearing areas.

1.2 Controlling Catches

Since, for several years, the number of returning adult salmon and sea trout will be reduced, this may reflect in catches and spawning escapement. A controlled reduction in catches to compensate for this would ensure that sufficient adults escape to spawn in the catchment (including in any new spawning areas which are opened-up) and still enable part of the catch to be maintained at a satisfactory level.

The net fishery is primarily commercial and a reduced catch might be compensated for by payment of a sum related to the direct loss of income. If the net catch was significantly reduced more salmon and sea trout would become available to run the river and the rod catch and spawning escapement would remain at normal levels.

Some controls on rod catches may also be desirable.

Whatever is agreed, it would be necessary to exercise catch controls in the years 1989-91 inclusive. In the absence of powers which would allow legal action within this timescale it would be necessary to proceed on the basis of negotiation and agreement.

1.3 Artificial Propagation

The salmon and sea trout populations of the River Camel have for a number of years been, and indeed still are, very buoyant and it has not been necessary to provide artificial support to the very adequate natural production.

In any event no suitable artificially-reared juvenile fish are immediately available and the earliest that smolts could be reared would be the spring of 1990. This in itself makes restocking an inadequate answer to the rehabilitation needs of this incident. Further, there are good reasons for the view that, with a basically buoyant fish population, protection and improvement of the natural habitat and, where necessary, increased escapement of adult spawning stocks will provide the soundest, most economic long-term benefit.

1.4 Habitat Improvements

Several habitat improvements are possible and these include increasing the access to potential spawning areas and enhancing the quality of spawning gravels where this is recognised as a limiting factor. Also the risk of pollution can be reduced by a programme of catchment investigation and community involvement.

These actions form part of the catchment management approach which is being introduced progressively to rivers in the region. Whilst early action will be taken to determine the basis of such a plan for the River Camel, this would not in itself bring about improvements early enough to mitigate for losses.

2. CONCLUSIONS

Successful action to rehabilitate the fishery will need the close co-operation of the community and especially the riparian and fisheries interests.

It is proposed, subject to consultation, that the most effective course of action would be to :

(i) increase the escapement of salmon and sea trout to the River Camel by negotiating with the seven licensed commercial netsmen to cease fishing for a three year period from 1989-91;

(ii) improve the habitat in salmon and sea trout spawning and rearing areas by clearance of debris and silt;

(iii) put more effort into the control of illegal fishing and the carrying out of habitat improvements by employing trained, part-time, fisheries assistants recruited from the local community;

(iv) investigate the feasibility of building fish passes at weirs to allow salmon and sea trout access to additional spawning areas;

(v) monitor the progress of the recovery of the fish stocks.

3. FINANCE

South West Water will finance the work which arises from the above programme.

4. CONSULTATION

During the next three months there will be a programme of consultation which will include :

Riparian and fisheries interests
Vincent Wildlife Trust
Royal Society for the Protection of Birds
Cornwall Trust for Nature Conservation
Camel Valley and Bodmin Moor Protection Society

MAPS

1. River Camel Catchment.

2. Investigations on 7 July 1988.

3. Hydrants and Washout Valves used on 6/7 July 1988.

4. Locations of Fish Population Survey Sites.

5. Location of Sampling Points of Invertebrates.

6. Location of Sampling Points for Aquatic Plants.

7. Hydrants and Washout Valves used after 6/7 July 1988.

APPENDICES

1. Analytical Results for Samples collected in the River Camel Catchment.

2. Analytical Results for Samples collected in the River Allen Catchment.

3. Monitoring and Work Programmes.

APPENDIX 1

ANALYTICAL RESULTS FOR SAMPLES COLLECTED IN RIVER CAMEL CATCHMENT

RIVER CAMEL - morning of 7 July 1988

	Time	pH	Total Aluminium mg/l	Suspended Solids mg/l
Camelford Weir (upstream of incident)	1130 hrs	7.2	0.01	2.0
Upstream of Camelford Sewage Works	1030 hrs	7.1	0.21	3.2
Tregoodwell Stream	1045 hrs	7.1	0.01	3.2
Pencarrow Bridge	1015 hrs	6.8	0.63	8.4
Trecarne Bridge	1340 hrs	6.3	0.35	5.2
Gam Bridge	1520 hrs	6.6	0.03	1.0

RIVER CAMEL - evening of 7 July 1988

	Time	pH	Total Aluminium mg/l	Suspended Solids mg/l
Camelford Weir	1830 hrs	7.2	0.01	2.8
Upstream of Camelford Sewage Works	1835 hrs	7.3	0.12	6.2
Trecarne Bridge	1840 hrs	6.8	0.15	6.8
Gam Bridge	1850 hrs	6.9	0.03	2.2

RIVER CAMEL - morning of 8 July 1988

	Time	pH	Total Aluminium mg/l
Camelford Weir	1055 hrs	7.2	0.01
Upstream of Camelford Sewage Works	1045 hrs	7.2	0.04
Pencarrow Bridge	1030 hrs	7.0	0.12
Trecarne Bridge	1025 hrs	7.0	0.09
Gam Bridge	1010 hrs	7.0	0.05

APPENDIX 1 (cont)

RIVER CAMEL - 14 July 1988

	Time	pH	Total Aluminium mg/l
Camelford Weir	1155 hrs	7.3	0.02
Upstream of Camelford Sewage Works	1210 hrs	7.3	0.02
Pencarrow Bridge	1240 hrs	7.4	0.07
Trecarne Bridge	1345 hrs	7.2	0.05
Gam Bridge	1330 hrs	7.4	0.05

APPENDIX 2

ANALYTICAL RESULTS FOR SAMPLES COLLECTED IN RIVER ALLEN CATCHMENT

RIVER ALLEN - evening of 7 July 1988

	Time	pH	Total Aluminium mg/l	Suspended Solids mg/l
Knightsmill Bridge	1910 hrs	7.1	0.30	16.0
Kellygreen	1920 hrs	7.4	0.13	6.0

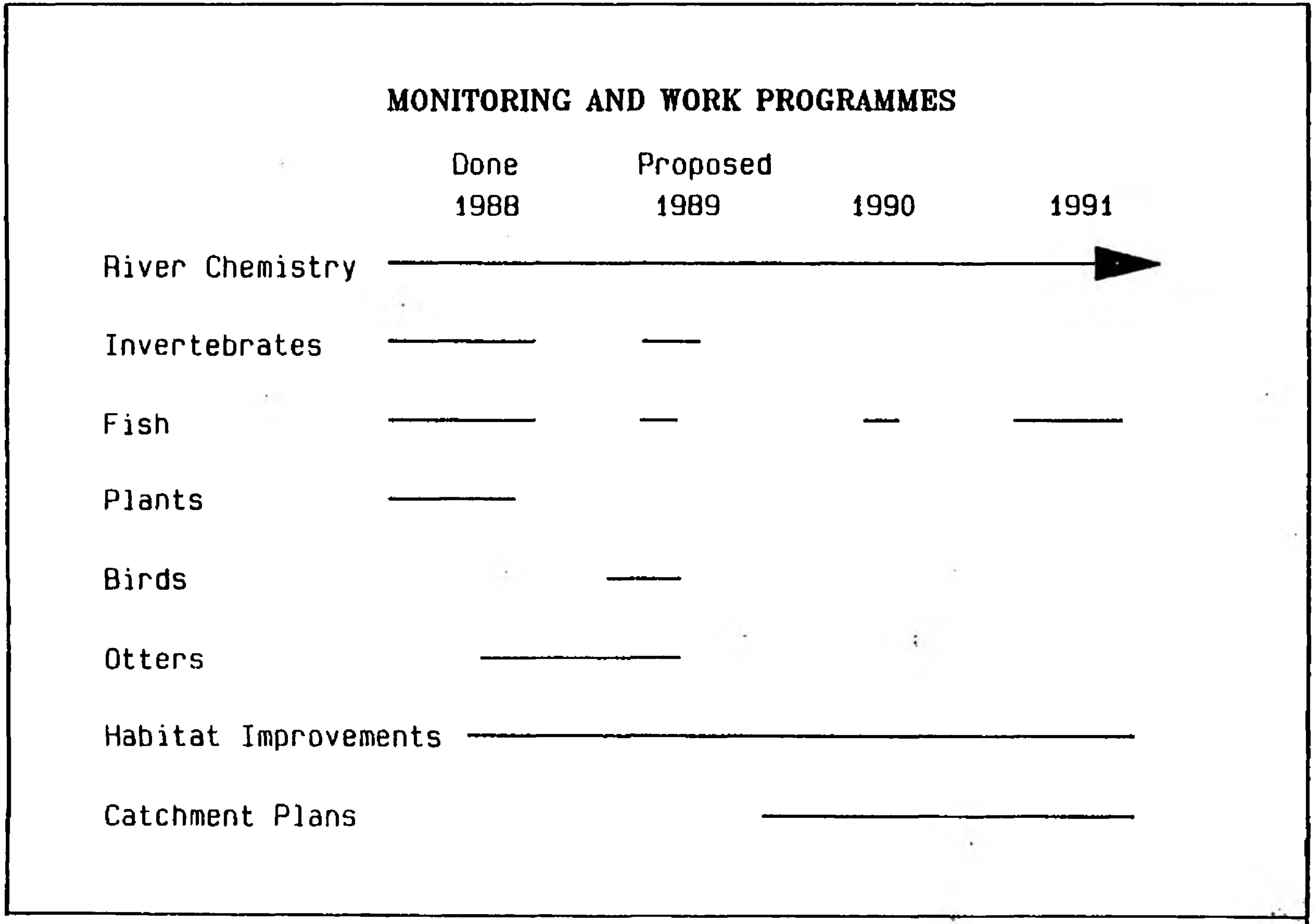
RIVER ALLEN - morning of 8 July 1988

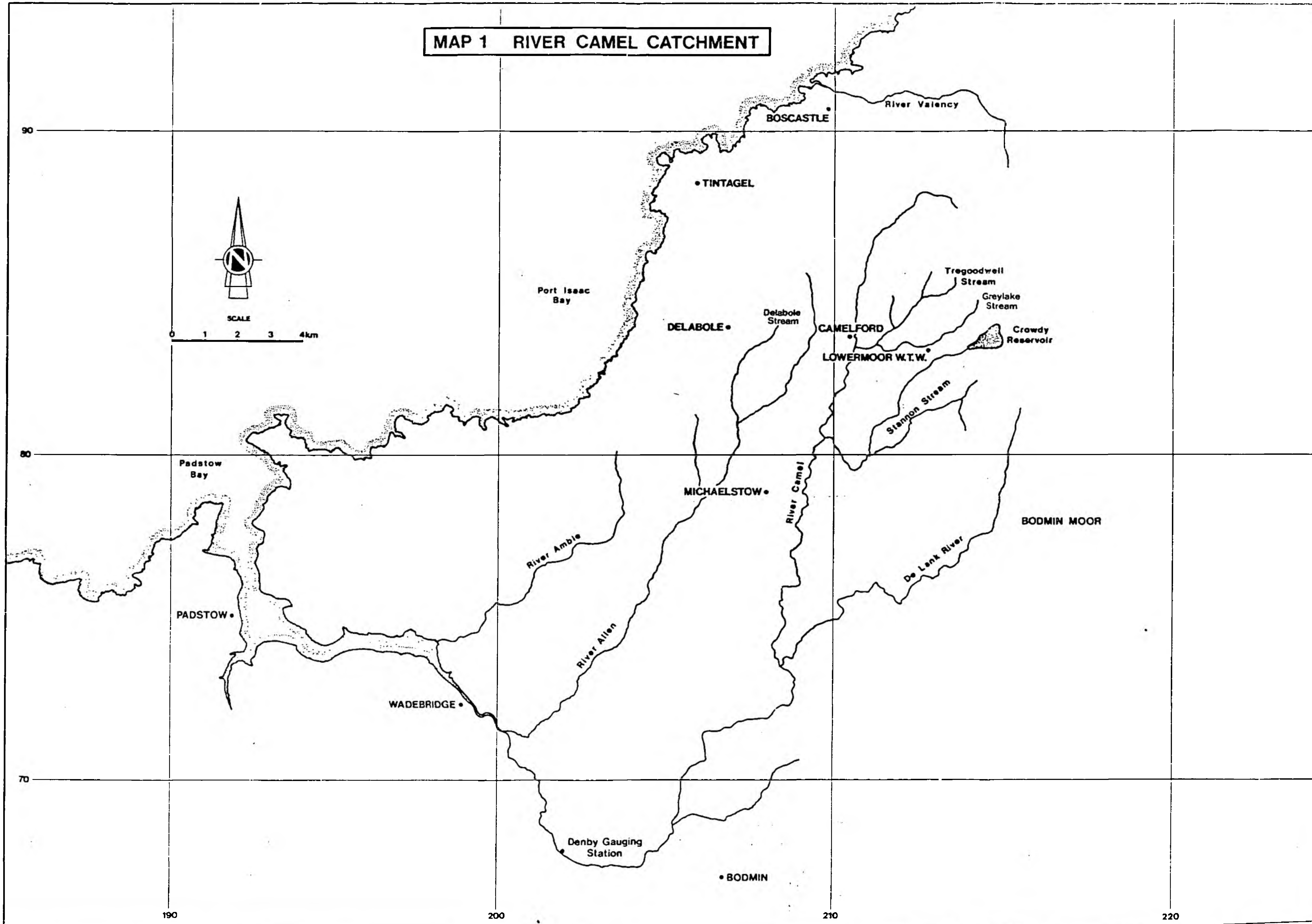
	Time	pH	Total Aluminium mg/l
Lanteglos Church	1110 hrs	7.5	0.06
Knightsmill Bridge	1125 hrs	7.3	0.10
Tributary at Whitewells	1135 hrs	7.2	0.06
Tributary below Treburgett	1120 hrs	7.7	0.07
Penvcse	1150 hrs	7.6	0.14
Kellygreen	1200 hrs	7.7	0.05

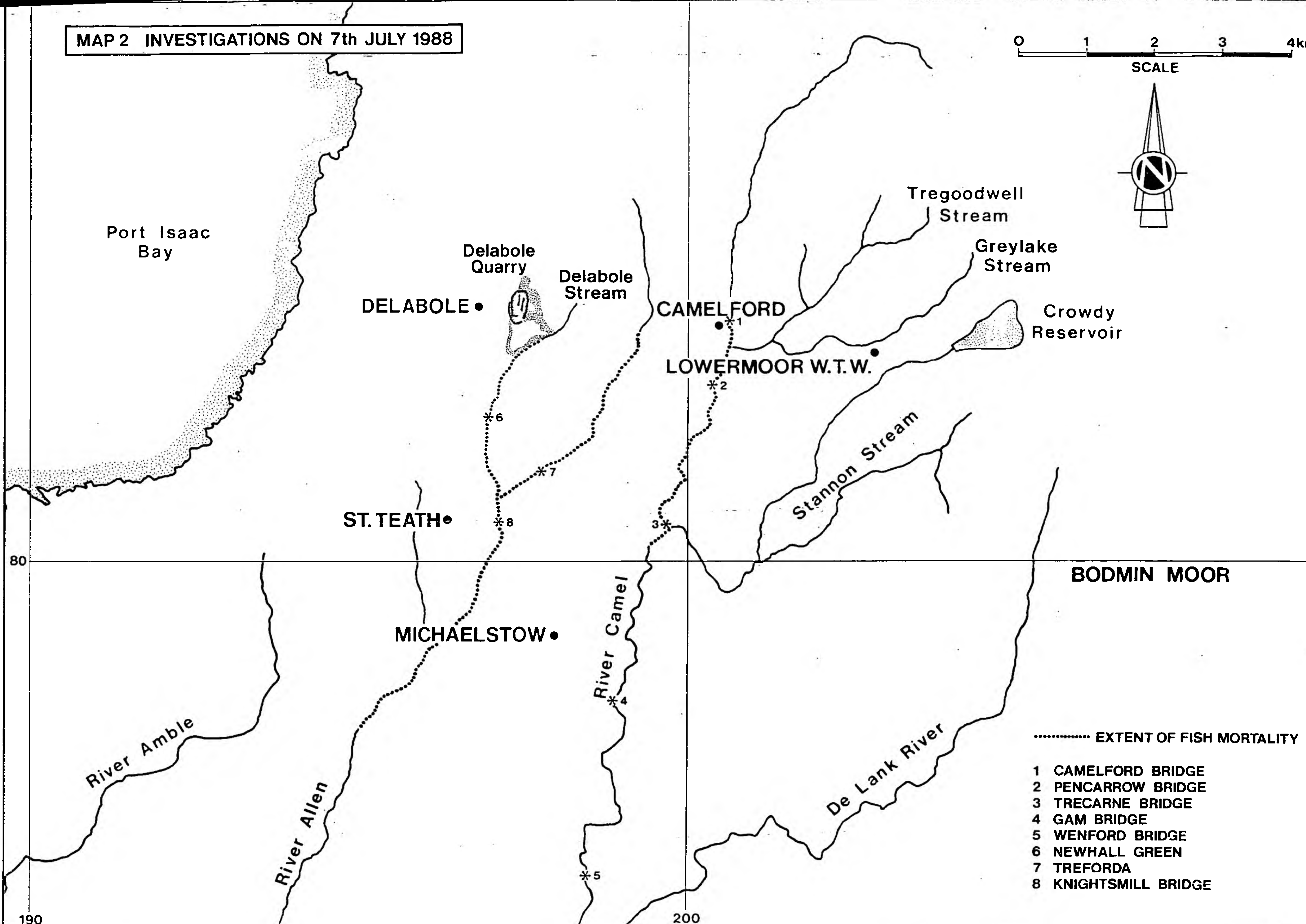
RIVER ALLEN - 14 July 1988

	Time	pH	Total Aluminium mg/l
Lanteglos Church	1250	7.6	0.02
Knightsmill Bridge	1100	7.4	0.02
Penvose Farm	1050	7.7	0.02
Kellygreen	1040	7.7	0.04
Dinham's Bridge	1030	7.7	0.02

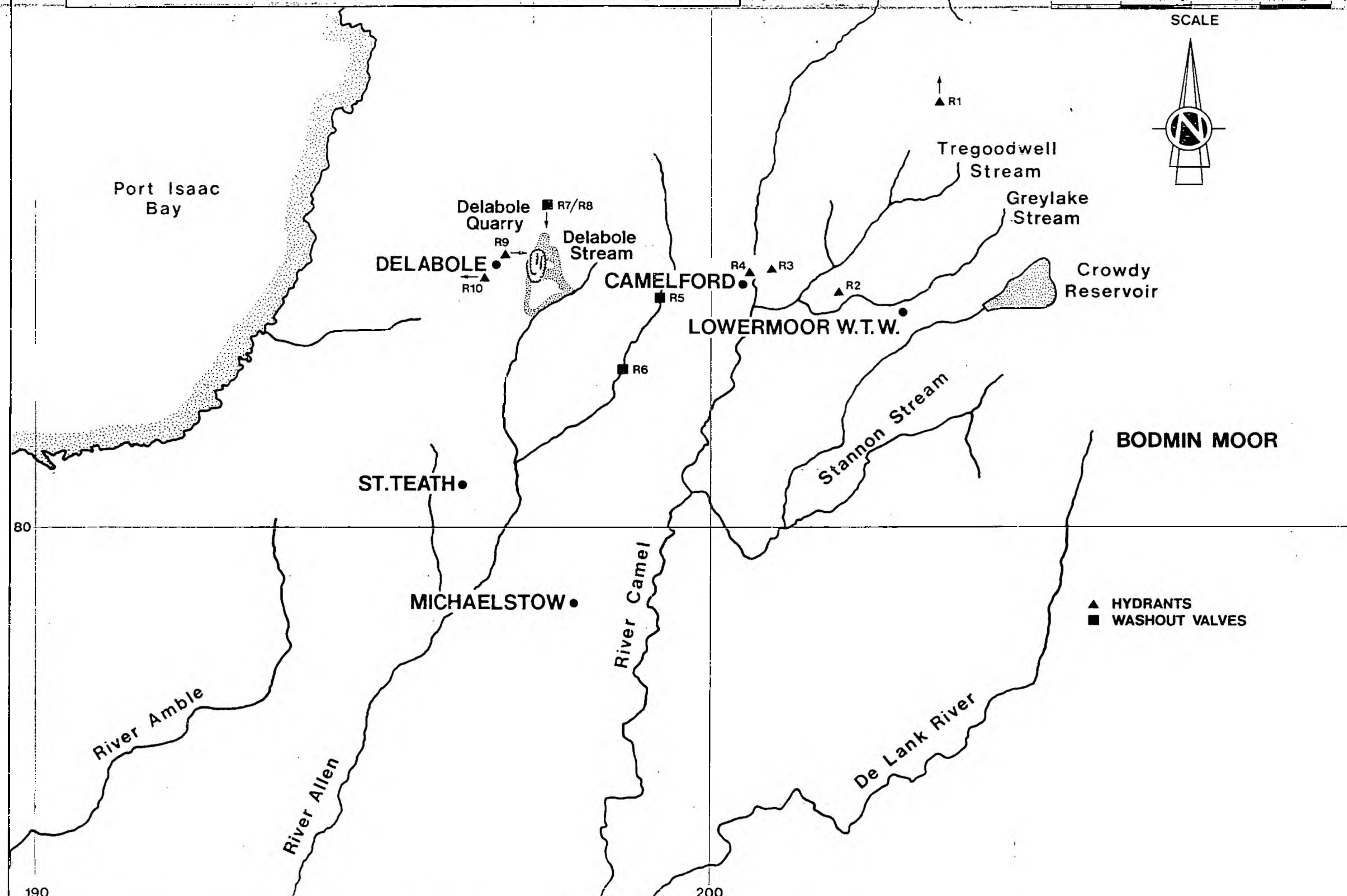
APPENDIX 3

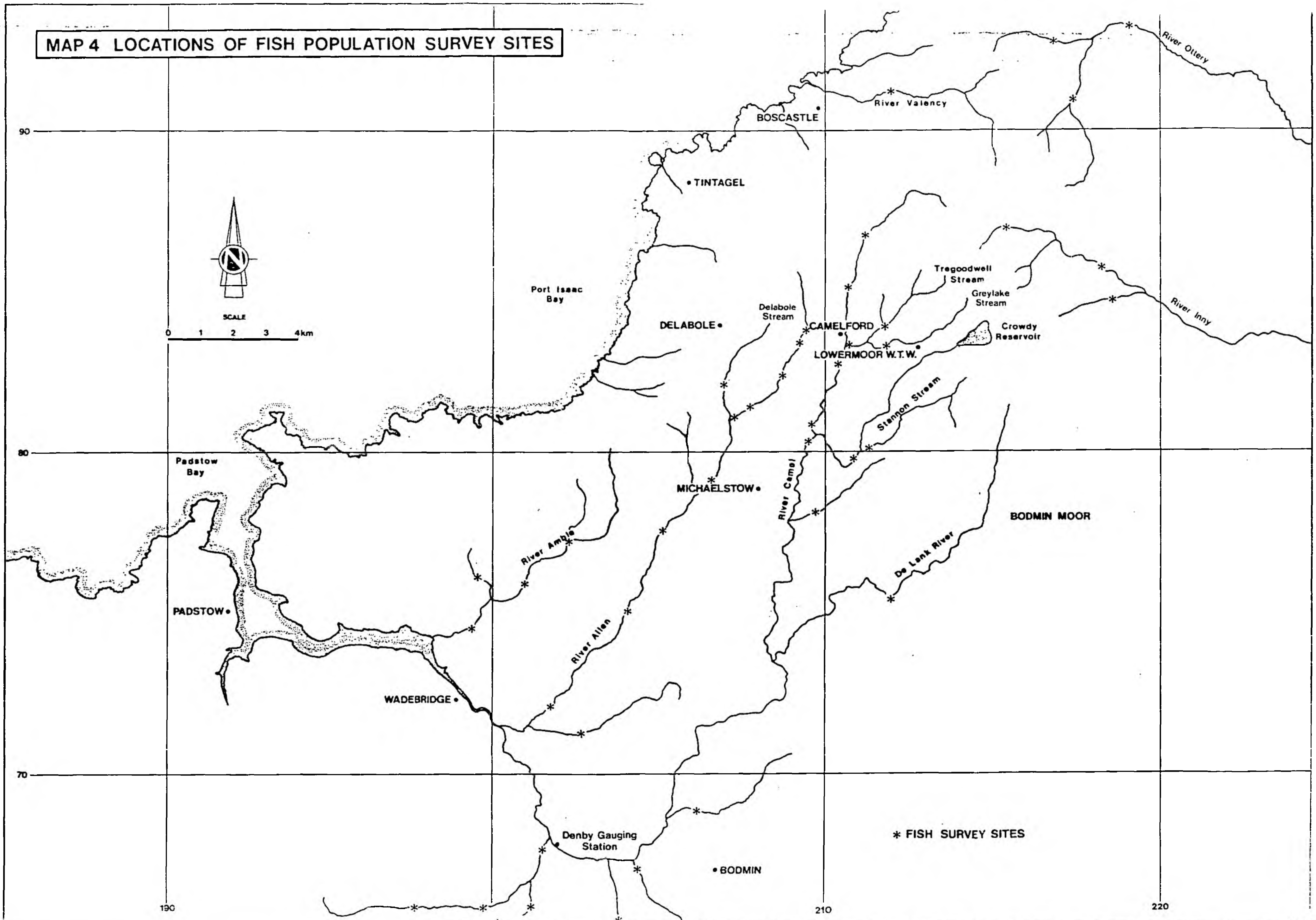

MONITORING AND WORK PROGRAMMES
Done
Proposed
1988
1989
1990
1991
River Chemistry
Invertebrates
Fish
Plants
Birds
Otters
Habitat Improvements
Catchment Plans


MAP 1 RIVER CAMEL CATCHMENT
River Valency
BOSCASTLE
90
TINTAGEL
SCALE
0 1 2 3 4km
Port Isaac Bay
DELABOLE
Delabole Stream
CAMELFORD
Tregoodwell Stream
Greylake Stream
Crowdy Reservoir
LOWERMOOR W.T.W.
Stannon Stream
80
Padstow Bay
MICHAELSTOW
River Camel
BODMIN MOOR
River Amble
De Lank River
PADSTOW
River Allen
WADEBRIDGE
70
Denby Gauging Station
BODMIN
190
200
210
220

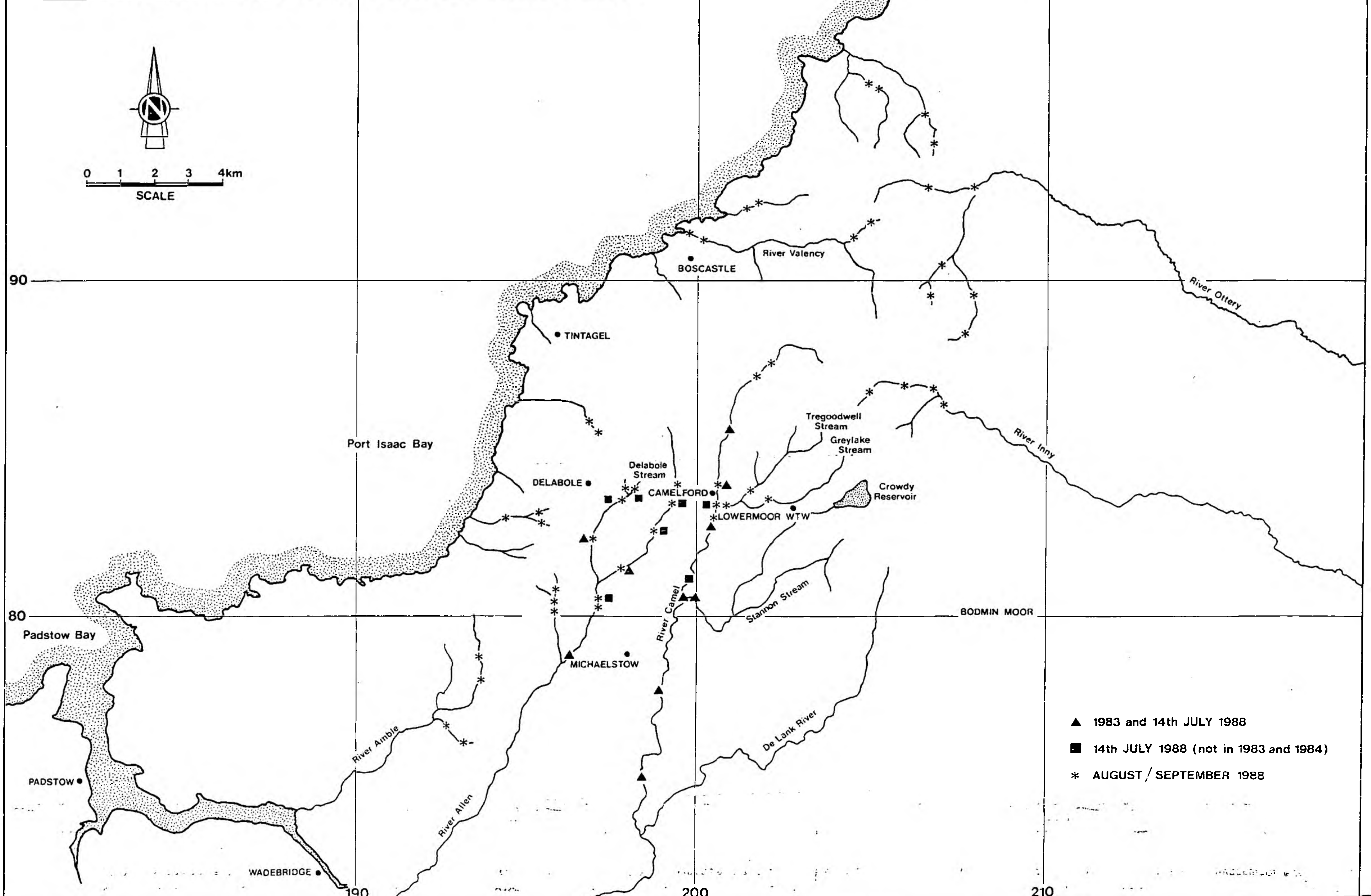

MAP 2 INVESTIGATIONS ON 7th JULY 1988
0 1 2 3 4km
SCALE
N
Port Isaac Bay
Delabole Quarry
Delabole Stream
DELABOLE
CAMELFORD
Tregoodwell Stream
Greylake Stream
Crowdy Reservoir
LOWERMOOR W.T.W.
Stannon Stream
ST. TEATH
80
BODMIN MOOR
MICHAELSTOW
River Camel
River Amble
River Allen
De Lank River
190
200
1 2 3 4 5 6 7 8
EXTENT OF FISH MORTALITY
1 CAMELFORD BRIDGE
2 PENCARROW BRIDGE
3 TRECARNE BRIDGE
4 GAM BRIDGE
5 WENFORD BRIDGE
6 NEWHALL GREEN
7 TREFORDA
8 KNIGHTSMILL BRIDGE

MAP 3 HYDRANTS AND WASHOUT VALVES USED ON 6th/7th JULY 1988

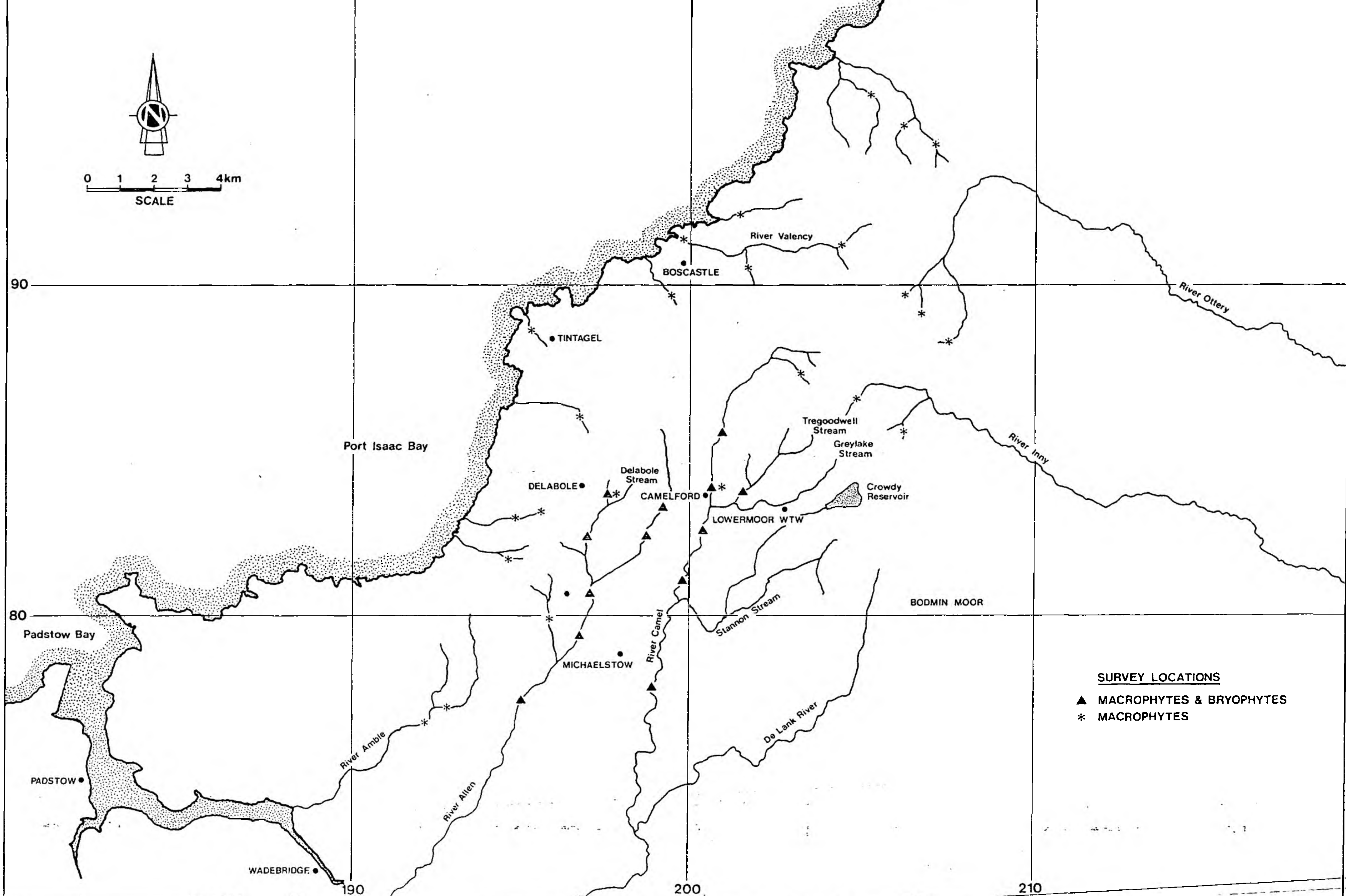


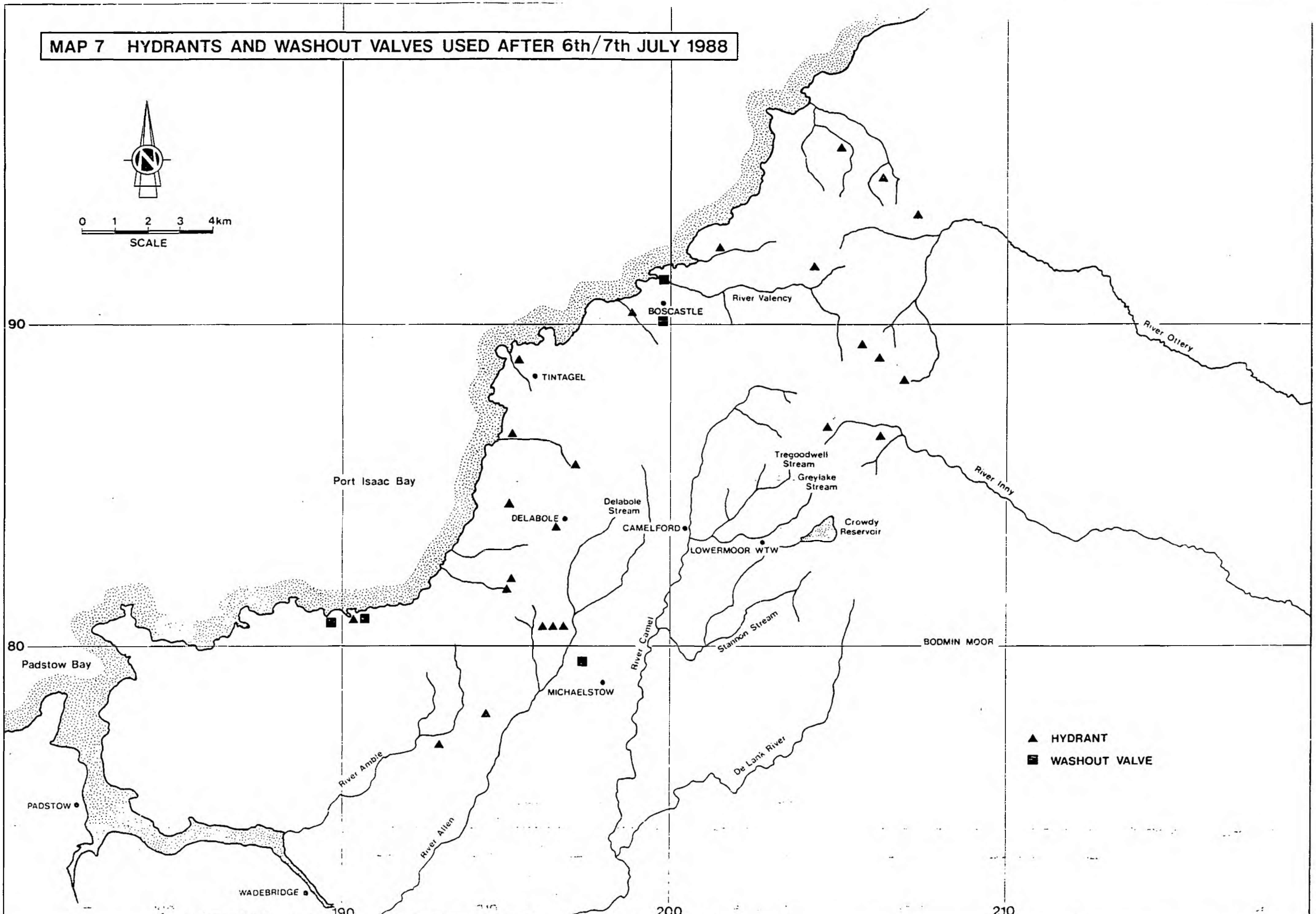

MAP 4 LOCATIONS OF FISH POPULATION SURVEY SITES
SCALE
0 1 2 3 4km
90
80
70
190
210
220
River Ottery
River Valency
BOSCASTLE
TINTAGEL
Port Isaac Bay
DELABOLE
Delabole Stream
CAMELFORD
Tregoodwell Stream
Greylake Stream
River Inny
Crowdy Reservoir
LOWERMOOR W.T.W.
Stannon Stream
Padstow Bay
MICHAELSTOW
River Camel
BODMIN MOOR
River Amble
De Lank River
PADSTOW
River Allen
WADEBRIDGE
Denby Gauging Station
BODMIN
* FISH SURVEY SITES

MAP 5 LOCATIONS OF SAMPLING POINTS FOR INVERTEBRATES



MAP 6 LOCATION OF SAMPLING POINTS FOR AQUATIC PLANTS




MAP 7 HYDRANTS AND WASHOUT VALVES USED AFTER 6th/7th JULY 1988
0 1 2 3 4km
SCALE
90
80
190
200
210
BOSCASTLE
River Valency
River Ottery
TINTAGEL
Port Isaac Bay
Tregoodwell Stream
Greylake Stream
River Inny
Delabole Stream
DELABOLE
CAMELFORD
Crowdy Reservoir
LOWERMOOR WTW
Stannon Stream
River Camel
BODMIN MOOR
Padstow Bay
MICHAELSTOW
HYDRANT
WASHOUT VALVE
De Lank River
River Amble
River Allen
PADSTOW
WADEBRIDGE