

South West Water Services Ltd
and
National Rivers Authority
South West Region

Roadford Operational and Environmental Study

Interim Report

Volume 1 - Main Report

April 1990
Sir William Halcrow & Partners Ltd

HALCROW

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National Rivers Authority
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ENVIRONMENT AGENCY



129254

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KEY

- Water Treatment Works
- River Intake
- Gauging Station
- Treated water main
(South Devon Main will carry raw water until high level T.W. built).
- Devonport Leat
- New works in red

10 km

THE ROADFORD SUPPLY SYSTEM

THE ROADFORD STUDY TEAM

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REPORT STATUS

The report is intended as a working document for use during the remaining part of the study. For members of the study team it represents the first opportunity to collate the detailed findings of all the many varied facets of the work. Inevitably, there will be areas where different parts of the report are not fully consistent with each other. This applies particularly to the technical annexes. Any such inconsistencies will be addressed during the production of the Final Report.

The Interim Report is also intended as a document for use in consultation with riparian owners, nature conservation interests and staff of the NRA and the Company. At this stage, there is nothing in the report in terms of either the assessment of environmental impact or the proposals for operating rules which should be taken as conclusive. It is anticipated that all aspects of the report will be subject to careful scrutiny and discussion by the many interested parties before the study is finished.

1. INTRODUCTION AND SUMMARY

1.1 Introduction

Roadford reservoir follows Wimbleball and Colliford as the third reservoir to be built under South West Water's three reservoir strategy, which will meet the region's water demands into the 21st century. Construction of the reservoir started in 1986 and the dam was completed in October 1989, when filling of the reservoir started.

Roadford reservoir lies in the centre of a complex water resource development which is shown schematically on Figure 1. The reservoir is designed to operate in conjunction with abstractions from the rivers Tamar, Tavy, Dart, Torridge and Taw, as well as with Burrator and Meldon Reservoirs. The concept of the scheme is that abstraction from the various rivers is substantially increased from present levels at times when there is sufficient water in the rivers; during dry periods, the river abstraction is reduced and the increased supplies are obtained instead from Roadford. The operating rules needed to control the amount of abstraction from the rivers and the use of the reservoirs will have a profound influence on the drought reliable yield of the scheme, its operating costs and its environmental impact.

In recognition of the potential environmental impact of the scheme, South West Water undertook an extensive programme of environmental investigations, mainly in the period 1986 to 1989. These studies were aimed at assisting derivation of operating rules for the scheme, monitoring its environmental impact and designing measures to alleviate adverse effects and promote benefits. The work was carried out by various organisations who produced reports on many different aspects of the scheme. However, when the reservoir neared completion in 1989, there was a need for an overview of all the environmental work with the aim of bringing the data collection to a conclusion and making plans for operating the scheme in an environmentally sensitive manner. This overview was carried out by Sir William Halcrow & Partners Ltd in early 1989. The Overview Report confirmed that the operation of the scheme would have an impact on all the rivers subjected to increased abstraction, but that the severity of the impact would be highly dependent on the precise details of the operating rules. The Overview Report concluded that an operational and environmental study was needed to propose the detailed operating rules for the scheme.

In August 1989, Sir William Halcrow & Partners Ltd were appointed by South West Water Services Ltd (the Company) in collaboration with National Rivers Authority SW Region (NRA) to undertake the Roadford Operational and Environmental Study. The terms of reference for this work are given in Appendix A. The objectives of the study can be summarised as:

- i) assessing the environmental impact of the scheme;
- ii) making recommendations for the priorities for abstraction and the operating rules for the scheme;

- iii) obtaining the optimum balance between environmental impact and operating costs;
- iv) proposing the terms of a reservoir operating agreement;
- v) making detailed recommendations for environmental monitoring once the scheme is commissioned.

The study was to be undertaken in two phases. Phase 1 was to involve:

- consultations between the study team, the Company, the NRA and outside interested parties including the riparian owners;
- preliminary choice of operating rules;
- and preliminary assessment of environmental impact.

Phase 2 would then involve further consultations and refinement of operating rules, including the rules to be adopted in the early years of scheme operation when water demands will be less than its ultimate capacity. This Interim Report describes the findings of Phase 1 of the studies.

The members of the study team are listed on the fly-sheet of this report. In addition to Halcrow's own staff and consultants, staff of the Company and NRA have played a major part in the work. However, the study has been managed by Halcrow and this report represents their views rather than those of the Company or NRA.

1.2 The Purpose of the Interim Report

This Interim Report describes the findings of Phase I of the studies. It includes a preliminary assessment of the environmental impact of the scheme when operating at its ultimate capacity. Conclusions are drawn about the relative effectiveness of different operating rules and suggestions are made for how further improvements could be achieved. However, as yet no firm recommendation has been made for operating rules for the scheme running at its ultimate capacity.

The report is in four volumes:

Volume 1	Main Report
Volume 2	Annexe A (Hydrology), B (Water Quality), C (Consultation), D (Ecology) and E (Recreation)
Volume 3	Annex F (Fisheries)
Volume 4	Hydrographs

The report is intended as a working document for use during the remaining part of the study. For members of the study team it represents the first opportunity to collate the detailed findings of all the many varied facets of the work. Inevitably, there will be areas where different parts of the report are not fully consistent with each other. This applies particularly to the technical

annexes. Any such inconsistencies will be addressed during the production of the Final Report.

The Interim Report is also intended as a document for use in consultation with riparian owners, nature conservation interests and staff of the NRA and the Company. At this stage, there is nothing in the report in terms of either the assessment of environmental impact or the proposals for operating rules which should be taken as conclusive. It is anticipated that all aspects of the report will be subject to careful scrutiny and discussion by the many interested parties before the study is finished.

1.3 Summary of Findings

1.3.1 Operating Rules Considered

The Interim Report has included a preliminary assessment of the environmental impact of the scheme operating under two scenarios:

- (i) The Base Case. These are the operating rules put forward by the Company to optimise the drought reliable yield and operating cost of the scheme, whilst complying with all the various undertakings given during its promotion.
- (ii) The Environmental Case. These are the operating rules proposed by the study team to minimise the environmental impact of the scheme whilst still enabling it to meet its water supply objectives in terms of drought reliable yield and reasonable operating costs.

The impact of the scheme has been assessed for each scenario in operation at its ultimate capacity which has been equated to the forecast demand level in the year 2014.

It is accepted that some of the abstraction conditions used to formulate the Base Case may not be acceptable under current NRA Policy.

1.3.2 Impact of the Base Case

The Base Case operating rules include a number of features which will lead to environmental improvements relative to the present situation. The reduction in hydro-electric abstraction for Morwellham and the increased prescribed flow at Lopwell will benefit the Tavy. For the River Dart, the introduction of a prescribed flow on the Devonport Leat abstraction and the higher prescribed flow at Littlehempston will benefit the river throughout its length. The higher prescribed flow at Torrington will lead to some improvement to the Torridge. The presence of Roadford will obviate the need for potentially damaging drought orders on the Rivers Tamar, Tavy, Dart and Torridge. The use of the Roadford fisheries bank for freshets should reduce the danger of fish mortalities in the Tamar estuary.

There would be three main drawbacks to the Base Case operating rules. Firstly, abstraction of water during minor spates is likely to affect migration of salmon

on the Rivers Tamar, Tavy, Dart and Torridge. Secondly, abstraction at times of low flow is likely to have an adverse effect on the fisheries and water quality of the Torridge and, to a lesser extent, the Dart and Tavy. Thirdly, draw-down in Burrator Reservoir would be substantially more than takes place at present. Even in non-drought years, the reservoir would be drawn down to levels similar to those experienced during the drought of 1989.

1.3.3 Impact of the Environmental Case

To avoid the adverse effects of the Base Case, an improved set of operating rules termed the Environmental Case have been proposed. The main features of the Environmental Case are:

- (i) Prescribed flows in all the rivers which vary according to the amount of water remaining in Roadford Reservoir. In non-drought years, this will allow prescribed flows to be higher than for the Base Case.
- (ii) For the Rivers Dart, Torridge and Taw only 50% of flows above prescribed flows would be abstracted, as compared with 100% for the Base Case.
- (iii) Rules have been devised to avoid potentially damaging abstraction of water during minor spates in summer. These rules which are termed "spate sparing" are intended to preserve flows which are important to the migration of salmon.

In general, the Environmental Case would achieve the objectives stated above. The adoption of higher prescribed flows in non-drought years will have a substantial benefit to the River Torridge and a lesser benefit to the Rivers Tamar and Taw. The spate sparing rules would reduce the potentially damaging effect of abstraction during minor spates in summer in all the rivers. The most significant benefit of the Environmental Case would be the avoidance of the potential major adverse effects of the Base Case on water quality, ecology and fisheries in the Torridge, and indeed some improvements over present conditions are anticipated.

The operating costs of the Environmental Case would be about £31,000 per year more than for the Base Case.

It has been concluded that the Environmental Case represents a significant improvement over the Base Case but that there is still room for further refinement by:

- modifying the spate sparing rules;
- making more use of the water stored in Roadford in non-drought years;
- Improving the continuity of autumn spillage for Burrator.

It is proposed that these further improvements in the Environmental Case operating rules should be considered in detail during the next phase of the study.

1.3.4 Phase 2 of the Study

In addition to seeking further improvements to the operating rules with the scheme at its ultimate capacity, the next stage of the work will examine in detail the operating rules during the next twenty years when the scheme will be building up from relatively low water demands towards its ultimate capacity. It is anticipated that this work will involve finding a balance between further reduction in environmental impact to the scheme and reducing operating costs, whilst allowing use to be made of the hydroelectricity generation potential.

Once the proposals for scheme operating rules have been determined, the terms of a Roadford reservoir operating agreement will be drawn up and recommendations for environmental monitoring will be made.

2 THE SCHEME

2.1 Scheme Description

The Roadford Scheme comprises the main reservoir formed by a dam on the River Wolf, new water treatment works and extensions to existing works, new raw and treated water mains and various water distribution improvements. The new works are shown in red on the Frontispiece. The system will provide supplies for the three zones of Plymouth, North Devon and South West Devon.

Existing supplies for Plymouth consist of a gravity supply from Burrator Reservoir and a pumped supply from Lopwell on the River Tavy. At present these sources feed water to Crownhill Water Treatment Works. Under the Roadford scheme, the supplies will be increased by pumping from the River Tamar at Gunnislake supported by releases from Roadford and by increased abstraction from the River Tavy. The supplies will be treated at the existing Crownhill works and a new high level treatment works to be constructed to the north of Plymouth.

In South West Devon, water is abstracted from the River Dart just upstream of Totnes through the Littlehempston intake. Under the Roadford scheme, abstraction from the Dart will be increased and treated at an extended treatment works at Littlehempston. In addition, water from the new high level treatment works at Plymouth can be transferred to the South West Devon area via a new trunk main to Littlehempston. Thus South West Devon can be supplied from Burrator Reservoir, and abstractions from the River Tamar, with or without supporting releases to the Tamar from Roadford Reservoir.

The North Devon area is at present supplied by Meldon Reservoir, Wistlandpound Reservoir, intakes on the Rivers Torridge and Taw and a variety of other small sources. In future, abstraction from the Torridge will be increased and treated at an enlarged works at Torrington. When there is insufficient flow in the River Torridge, the area can be supplied from Roadford via Northcombe Treatment Works and a new main to Torrington. As an alternative to the increased abstraction from the Torridge, the increase can be shared between the Rivers Torridge and Taw.

Two hydro-electric turbines have been installed at Roadford dam. The turbines can pass a combined flow of up to 320 Ml/d and generate 1 MW of power for local use or sale to the national grid. The turbines can be used when water is released from the reservoir to regulate flows in the Tamar, or when the reservoir would otherwise be spilling. There is also scope for making special releases of water for power generation, particularly during the early years of scheme operation when demands for water supplies have not yet reached the ultimate capacity of the scheme. These special releases could be made in the winter months when power tariffs are higher. However, matching the hydro-electric releases to the daily tariff variations would produce large daily variations in flow in the Wolf.

2.2 Scheme Operation

2.2.1 Evolution of Base Case Operating Rules

The operating rules for the scheme have evolved as a continuing process through the design of the scheme, its promotion through three Public Inquiries, and during its detailed design and construction. Since the Public Inquiries, the proposed method of operating the scheme has changed in a variety of ways including:

- direct supplies from Gunnislake to the new high level treatment works, rather than via the River Tavy to support the abstraction at Lopwell;
- a direct supply to North Devon rather than an inter-catchment transfer via the River Torridge;
- direct supply to South West Devon rather than the redeployment of Burrator Reservoir to regulate the River Dart;
- introduction of hydroelectric generation at Roadford.

These changes in the concept of the scheme have required continuous updating of its operating rules. The operating rules proposed by the Company take account of the following factors:

- i) where still applicable, operating rules put forward at the time of the Public Inquiry should be used;
- ii) the operating rules should take into account any undertakings given during the Public Inquiry;
- iii) after meeting the criteria in i) and ii) above, the operating rules should be designed to minimise the costs of operation of the scheme whilst maintaining its ability to give the required drought reliable yield.

The operating rules derived in this way are referred to in this report as the Base Case and were the starting point for the detailed examination of operating rules required for the Operational and Environmental Study. The Base Case operating rules are described in detail in the following sections.

2.2.2 Abstraction Conditions Generally

The amount of abstraction from rivers is controlled in three ways. Firstly, there is maximum amount of abstraction. This is normally set as a daily amount in MI/d often with an instantaneous maximum rate. Secondly, a prescribed flow is set for each river below which no abstraction can take place. Thirdly, the amount of water which can be abstracted when river flows are just above prescribed flows are restricted by "percentage takes". For example, if the prescribed flow in a river is 200 MI/d and the percentage take is 50%, then if the river flow is 236 MI/d the maximum amount abstractable is 18 MI/d. The

maximum abstraction, prescribed flow and percentage take are defined in each abstraction licence.

2.2.3 Resource Priorities

The Base Case resource priorities for supplying Plymouth would be:

- i) Burrator Reservoir for Plymouth;
- ii) direct supply from the River Tavy;
- iii) natural flows from the River Tamar;
- iv) River Tamar supported by releases from Roadford.

For supplying south west Devon the first priority would be abstraction from the river Dart and secondly transferring water from Burrator, followed by the river Tamar, supported by Roadford if necessary.

For supplying North Devon, the priorities would be firstly abstractions from the Rivers Taw and Torridge and, secondly, transfers from Roadford via the Northcombe Treatment Works.

The philosophy behind these priorities was to call first upon water in Burrator Reservoir which is the cheapest in terms of operating costs, but keeping some storage in reserve for droughts. The next priority was to use direct abstraction from the various rivers as long as there is sufficient river flow. This would then leave Roadford Reservoir as the main reserve for times of drought. Keeping Roadford as the last resort has the added advantage that it is the most expensive water in terms of operating costs of both water treatment and of pumping.

2.2.4 Compensation Releases From Roadford Reservoir

The compensation release from Roadford Reservoir as agreed at the Public Inquiry would be a constant 9 MI/d throughout the year.

2.2.5 Supplies to Plymouth Area

The priority source for Plymouth would be water supplied by gravity from Burrator Reservoir. The second priority would be abstraction from the River Tavy at Lopwell. This would be made at a rate of 50% of the excess flow above a prescribed flow of 73 MI/d. The maximum abstraction from the Tavy would be 91 MI/d.

When insufficient flow is available in the Tavy, water would be abstracted from the River Tamar at Gunnislake. This abstraction would be limited to 50% of the excess flow above a prescribed flow. Originally the prescribed flow was set at 245 MI/d. However, in accordance with an undertaking given at the Public Inquiry the scheme would be operated with a prescribed flow of 477 MI/d for the first ten years of operation. When there is insufficient flow in the river to

supply the required rate of abstraction, the flows in the Tamar would be augmented by releases from Roadford Reservoir. For the Base Case operating rules it has been assumed that the prescribed flow will be reduced to 245 MI/d after the first ten years of operation.

2.2.6 South West Devon Supply Area

The existing licence at the Littlehempston intake allows 9 MI/d to be abstracted from the river at all times and a further 18 MI/d to be abstracted subject to a prescribed flow of 68 MI/d. This is in addition to an abstraction of 24 MI/d through the radial collectors which is subject to a prescribed flow of 13 MI/d down the fish-pass at Totnes weir. The total existing licensed abstraction is thus 51 MI/d. The proposed Base Case operating rules would allow the total abstraction at Littlehempston to increase to 69 MI/d with 100% take above a prescribed flow of 122 MI/d. When there is insufficient flow in the River Dart or other local sources in south west Devon water would be supplied to Littlehempston from the new high level treatment works at Plymouth.

2.2.7 North Devon Supply Area

The Base Case rules for abstraction from the River Torridge at Torrington would allow 100% of the flow above a prescribed flow of 80 MI/d to be taken up to a maximum of 81 MI/d. There would also be an abstraction of 17.5 MI/d from the River Taw, as at present, with a prescribed flow of 195 MI/d and 100% take. When there is insufficient flow in the Rivers Torridge and Taw or other local sources in North Devon, demands would be met from Roadford via the Northcombe treatment works and the new main to Torrington.

2.3 Previous Environmental Studies

The environmental investigations carried out by SWW and a range of consultants over the past four years have concentrated on the River Tamar catchment where an extensive environmental database has been established. The locations of these investigations are shown on Figures 2 and 3. This work is described in more detail in the Overview Report (1). The Overview Report included a preliminary Environment Impact Assessment (EIA) based on the data available and the Base Case operating rules. The conclusions of the preliminary EIA were:

- i) Roadford dam would have a substantial effect on the flows in the Wolf catchment and on its salmon spawning and nursery areas. However, the Wolf spawning areas contribute only about 2% of the Tamar salmon stock.
- ii) The effect of the scheme with Base Case operating rules on the flow regime of the Lower Tamar would be slight, and little affected by the choice of prescribed flow at Gunnislake.
- iii) What limited effects there would be on flows entering the Tamar estuary would occur at the time of year of peak salmon runs and angling

success ie May to August. Thus a slight, but barely significant, reduction in salmon movement and angling success was foreseen.

- iv) Water quality in the Tamar and its tributaries would not be significantly affected. The destratification equipment installed at Roadford Reservoir would ensure that reservoir water quality was at least as good as quality in the river.
- v) Apart from localised effects in the River Wolf, minimal ecological impact was expected in the Tamar system.
- vi) Under the Base Case operating strategy, the impact of the scheme on the river flows, fisheries and estuaries of the Rivers Tavy, Plym, Dart, Torridge and Taw is likely to be greater than the impact on the Tamar.
- vii) The impact on these other rivers would depend on the operating strategy for the scheme and the detailed operating rules selected. The reduction in flow entering the estuaries could affect water quality, migration of salmonids and other plants and animals. The Taw/Torridge estuary is a SSSI, and the Tamar/Tavy is being considered for notification.
- viii) Any delay in spilling from Burrator could have a significant impact on the important salmon spawning and nursery areas in the River Meavy and also some effect on the late-run salmon fishing of the River Plym.
- ix) The method of operation of the scheme would influence the amount of draw-down in Burrator and Roadford reservoirs. This would have implications for the ecology and recreational use of the reservoirs and should be taken into account in determining the scheme's operating strategy.
- x) The proposal to generate hydro-electric power at Roadford Dam during the winter months, with large daily flow changes, would have marked effects on the flow regime of the Wolf during such periods.

2.4 Undertakings Given During Scheme Promotion

During the promotion and construction of the scheme a number of undertakings were made by South West Water to riparian owners on the affected rivers and other interested parties. These undertakings related mainly to measures to reduce the effect of the scheme on fisheries and water quality. A full list of the undertakings is given in Appendix B.

The Overview Report reviewed these undertakings and reached the following conclusions:

- i) The undertaking to maintain the Gunnislake prescribed flow at 477 Ml/d for the first 10 years of operation could be accommodated without difficulty. However, a reduction in the prescribed flow would make little

difference to the Tamar, but could enable flows in the Tavy, Dart and Plym to be improved.

- ii) The prescribed flow for abstraction from the River Dart to Burrator Reservoir via the Devonport Leat should be introduced as soon as possible.
- iii) The provision of a hatchery within the Wolf catchment was considered inappropriate. Immediately below the dam, water quality may be doubtful at times. The small numbers of fish required to satisfy any reasonable mitigation commitment could easily be reared from local broodstock in existing hatcheries.
- iv) The suggestion that fish are netted in the Tavy estuary and released upstream of Lopwell Dam should be resisted as there would be serious risk of damage to the fish.
- v) Installation of a full-river fish counter on the Tamar to obtain a full count would be very expensive and an efficient operation would not be certain. In any event, such an installation would not be necessary for the effective completion of the Roadford investigation. However, a fish counter on the fish pass exit at Gunnislake weir was recommended as a cost effective contribution to the investigation of movements around the tidal limit.
- vi) The use of the 2270 MI fisheries storage reserve needed detailed investigation.
- vii) A decision on installation of electronic fish counters in the Torridge should be delayed until the operating strategy for the scheme has been finalised and the likely impact on the Torridge fishery has been assessed.
- viii) The undertaking not to restrict agricultural practices in the Roadford reservoir catchment could, in the long term, have implications for water quality in both the reservoir and receiving water courses. A review of the farming practices should be undertaken.

3. CHOICE OF OPERATING RULES

3.1 Objectives

3.1.1 Water Resources

The main water resource objective of the Roadford scheme is to meet the forecast rising demands in the Plymouth, South West Devon and North Devon zones until well into the twenty first century, even under drought conditions. For the purposes of comparing options for scheme operating rules in this report, this general objective is defined in more specific terms below:

- i) Any new set of operating rules should be able to meet the same demands that can be supplied by the Base Case operating rules. The Base Case can meet demands as forecast for the year 2014 as shown in Table 1.

Table 1

FORECAST 2014 DEMANDS

Zone	Demand (Ml/d)
Plymouth	126
North Devon	94
South West Devon	<u>107</u>
TOTAL	327

The forecast demands quoted above are daily demands averaged over a year. The scheme should be capable of meeting fluctuations in this demand based upon the present seasonal pattern.

- ii) The scheme should be able to meet these demands under design drought conditions. The design drought is defined for the purpose of this report as the period 1975/76 which corresponds approximately to a 1 in 50 year event. It is assumed that for three months in 1976, demands would be reduced by 10% by hosepipe bans and other demand restriction measures. The system must be able to meet these demands during the design drought with all the reservoirs in the system just drawing down to 20% of total capacity, which would be retained as a reserve against occurrence of an even more severe drought.

When changes to the operating rules are being considered, they are designed so that the drought reliable yield of the scheme is still able to meet 2014 demands as defined above.

Keeping operating costs for the water supplies to within acceptable limits is also an important water resource objective, although of lower priority than the

need to maintain the drought reliable yield. The scheme operating costs can be expressed in annual terms for pumping and water treatment.

3.1.2 Water Quality

The operating rules which are adopted should cause no deterioration in water quality and should be of demonstrable benefit to water quality wherever possible. These primary water quality objectives should be viewed in the context of the published environmental quality objectives. Those of particular significance are:

- i) The river and estuary quality classifications defined by the National Water Council.
- ii) The European Community (EC) directive on the quality of fresh waters to support fish life.
- iii) The EC directive concerning the quality of bathing water.

For the Tamar, there are two main areas of concern. Firstly, water released from Roadford reservoir to the river Wolf and thence to the Tamar should cause no deterioration in river water quality. Secondly, abstraction of water at Gunnislake should cause no deterioration in quality of water below the abstraction point and entering the estuary. Regarding this latter point, there is at present concern that poor water quality in the upper estuary is at times causing fish kills. This is believed to be due to oxygen deficiency occurring when mud in the upper estuary is brought into suspension. Acute dissolved oxygen conditions are associated with spring tides, hot weather and prolonged periods of low river flow. It is important that the operation of the scheme should not aggravate this problem and if possible should improve it.

For the river Tavy, the main objective is that there should be no deterioration in water quality below Lopwell dam, entering the estuary. There are at present no known water quality problems in this area. Further up the Tavy, below Tavistock, there are potential polluting discharges from the sewage works, sausage factory and refuse tip. The water supply scheme itself has no effect on dilution of effluents from these sources, but there will be an indirect effect when the operation of the hydroelectric abstractions are changed in conjunction with the new water supply abstractions. In this case the objective is to improve river flows at times when dilution of the effluents from the sources is likely to be critical.

There are two problem areas on the River Torridge. Firstly, there have been widely reported fish mortalities in the River Okement below Meldon dam. Although this area is not directly affected by Roadford, any associated change in the operation of Meldon reservoir should aim to alleviate the problem in the Okement. The second problem area for the Torridge is the reach below the abstraction at Torrington down to the estuary. Here the problems are discharges of domestic and trade effluents from the sewage works and warm waste water from the creamery. In the upper estuary the situation is exacerbated by discharges from Weare Giffard sewage works. The objective

should be to avoid any deterioration in water quality at times of low flow when existing problems are acute.

For the River Dart, the increase in abstraction at Littlehempston could reduce the flow of freshwater entering the Dart estuary. This could cause an increase in the salinity of the upper estuary at high water although the effect at other states of the tide would be less significant. The reduction in freshwater flow would imply a reduction in the dilution available for the discharge of treated effluent from Totnes sewage works. An increase in local concentrations of ammonia and BOD, accompanied by a decrease in concentrations of dissolved oxygen, could occur. The operating rules should aim to minimise aggravation of these problems, particularly at times of low flow.

All the rivers affected by the scheme suffer to some degree from agricultural pollution. In general, the operation of the scheme will have no effect on this, either beneficial or adverse. However, there is some scope for alleviating agriculture pollution by making releases from Roadford or Meidon reservoirs to provide increased dilution of agricultural pollutants. The scheme operating rules should seek to maximise such potential benefits.

3.1.3 Fisheries

The main potential environmental impact of the Roadford scheme is on the salmon and sea trout fisheries of all the rivers involved. The specific areas where the scheme could adversely affect the fisheries are:

- i) Abstraction at low (but not very low) river flows, just above the prescribed flow has greatest relative effect on river flow and could influence fish migration.
- ii) Abstraction during minor spates could affect the movement of salmon and angling prospects. This would be felt most in dry years.
- iii) The presence of Roadford dam on the River Wolf will drown out some spawning and nursery ground and have a major effect on the flow regime of the Wolf and its potential for salmon and sea trout spawning.

The objectives of the operating rules from the fisheries viewpoint are to minimise the effects listed above.

The Rivers Tamar, Torridge, Tavy, Taw and Dart will all be affected to some extent by increased abstraction in the lower reaches of the rivers with a potential effect on fish migration. Here the objective should be to minimise the effect of abstraction both at times of low flow and during minor spates. The potential effects on water quality, need to be taken into account as described in 3.1.2.

In the River Plym catchment, the main potential effect of the scheme is due to changes in the pattern of spillage from Burrator reservoir. The operating rules should be designed to allow spillage from the reservoir on a reliable basis, particularly during the late autumn salmon spawning season.

For the River Wolf below Roadford dam, the aim should be to realise the excellent potential of salmonid juvenile production. Dispersion of stock is critical and this can be achieved by arranging flows that optimise spawning when water is available, resorting to restocking as appropriate. Some restocking will be taking place anyway to mitigate for drowned-out and cut-off spawning and nursery areas.

On the Tamar between the dam and Gunnislake, low flows will be enhanced by regulation releases for abstraction. This is likely to represent a significant benefit for angling for salmon, trout and sea trout at such times, so a high level of regulation would be desirable.

3.1.4 Ecology

The primary objective in the design of operating rules from the ecological point of view is to maintain the biomass and species diversity of plants and animals in the river channel. In particular, the creation of good conditions for invertebrates and plant life will maintain the food chain for birds and fish.

The scheme could affect the amount of flooding on wetlands in the bottom of river valleys. The operating rules should be designed to minimise such effects which are only likely to be significant when the frequency of spillage from dams is affected. It should be noted that it is also important to maintain the frequency of winter spillage for the benefit of aquatic life below dams.

In the estuaries, changes in the river flow regime could affect the zone of mixing of fresh water and sea water as well as physical features such as sandbars and mudflats. The operating rules should be designed to minimise such effects. The Taw/Torridge and Tamar estuaries are of national, perhaps international, importance for birds.

In addition to the avoidance of damage to the different parts of the river system mentioned above, there is a general objective to minimise the impact of the scheme on species of local, regional or national importance, particularly those already at risk. Where possible, improvements in conditions for the river and estuary should be incorporated into the scheme if they do not have a major resource implication in terms of scheme yield and cost.

3.1.5 Recreation

The operation of the scheme will affect the amount of draw-down in the existing reservoir at Burrator as well as the draw-down regime at Roadford. Burrator and Roadford could offer water sports such as sailing, board-sailing, canoeing and rowing in future, and both are important in visual terms for walkers, birdwatchers and picnickers. Water supply reservoirs are by their nature designed to be drawn down during dry periods. However, the amount and timing of the draw-down is to some extent governed by scheme operating rules, particularly in non-drought years. The operating rules now under consideration for Roadford reservoir are in general proposed to make more use of water in the reservoir in non-drought years so as to alleviate the impact on

river flows. Clearly there is a potential conflict of interests between this and the desire to keep reservoir levels high for the benefit of recreational users.

The objectives of the operating rules from the recreational view point are:

- i) In non-drought years, to restrict the amount of draw-down to a level which will permit appropriate and safe recreational use of the reservoirs and for visual amenity.
- ii) In drought years at Burrator to restrict the amount of draw-down to a level that will not unduly impair appropriate recreational use or visual amenity.

The assessment of acceptability of draw-down is very subjective. It is important that this matter should be considered in consultation with organisations such as the Countryside Commission, the Nature Conservancy Council and Dartmoor National Park Authority.

3.2 Choice of Operating Rules for the Environmental Case

3.2.1 General Principles

The objectives of the improved Environmental Case operating rules as described in Section 3.1 can be summarised as:

- i) Reduction or suspension of abstraction at times of low river flows to avoid adverse water quality effects and delayed migration of salmon and sea trout.
- ii) Avoidance of abstraction during minor spates at times of otherwise low flow; such spates are important for migration of salmon.
- iii) Allowing Burrator reservoir to spill in the autumn and winter for the benefit of salmon and sea trout spawning in the river Meavy, and salmon angling.
- iv) Avoiding excessive reservoir draw-down.
- v) Improved conditions below abstraction points for biota in the lower reaches of rivers and their estuaries.

Reduction in the amount of abstraction in non-drought years can be achieved by making more use of the water stored in Roadford, Burrator and Meldon reservoirs. This can be arranged by adopting operating rules which allow the prescribed flows at the abstraction points to be increased when there is sufficient water in Roadford reservoir. The prescribed flows can be reduced when the storage left in Roadford reservoir starts to fall towards levels which indicate that water supply problems are approaching. In this way the prescribed flows in all rivers can be kept high at most times, but as a drought approaches the reliable yield of the scheme is safeguarded by reduction of the prescribed flows to lower levels.

Protection of minor spates against abstraction can be achieved by spate sparing rules. In these rules a spate is defined as a flow which gives a daily mean value (dmf) of at least two times the lowest dmf in the previous seven days. When such a spate occurs, abstraction from the river would be suspended for a few days and the water supplies would instead be maintained from one of the reservoirs, or by abstraction from the Tamar supported by Roadford releases.

Spilling of Burrator reservoir during the autumn can be achieved under most circumstances by reducing supplies from Burrator in the late summer. The catchment area of Burrator is large in relation to the reservoir size, so the reservoir will generally fill rapidly as soon as supplies from the reservoir are reduced. The timing of the reduction of supplies from Burrator can be determined by control rules within Burrator reservoir combined with the Roadford reservoir control rules.

3.2.2 Roadford Reservoir Control Rules Governing Prescribed Flows

The reservoir control zones proposed for improved operation of the scheme are shown on Figure 6. When the amount of storage in Roadford reservoir is in Zone A, which would be under average or wet conditions, generous prescribed flows and other operating rules can be allowed. If the storage remaining is in Zone B, the possibility of a drought is starting to loom and prescribed flows must be reduced. When the remaining storage is in Zone C, prescribed flows must be further reduced to levels which still enable the drought reliable yield of the scheme to be maintained. The Zone C control line has been derived to ensure that in the 1975/76 design drought, the reliable yield of the scheme will be approximately the same as for the Base Case, corresponding to the 2014 demand level.

The prescribed flows applicable to each river for the three reservoir zones are compared with the Base Case prescribed flows and the Q95s in Table 2 below:

Table 2

VARIATION OF PRESCRIBED FLOWS (MI/d)

River	Base Case	Environmental Case			Q95
		Zone A	Zone B	Zone C	
Tamar	245	304	220	90	152
Tavy	73	73	73	41	73
Dart	122	122	122	80	122
Torridge	80	200	150	80	80
Taw	195	208	150	104	104

Some comments on the rationale behind the choice of prescribed flows in Zones A, B and C are given below.

- i) The prescribed flows historically adopted by SWW as matter of policy were based on the Q95s, that is the flow which on average is exceeded for 95% of the time. Abstraction licensing policy required these to be weighted to take account of environmental, fisheries and water quality factors and existing protected abstractions. However a lower prescribed flow than that defined by the policy would be considered if acceptable supportive evidence was provided. Roadford studies are designed to enable the latter route to be followed where appropriate.
- ii) The adoption of prescribed flows of less than Q95 for periods during extreme droughts is considered justified where
 - it still leads to higher residual flows than occurred historically; and
 - present low-flow conditions do not have any known impact on water quality, fish movement or wellbeing; and
 - such a measure allows more optimal environmental use of water at other times or in other places.

Adoption of a 50% take also reduces the effect of a lowered prescribed flow.

- iii) The Torridge and Taw do exhibit a problem with fish movement at very low flows; prescribed flows have therefore been kept at Q95 in Zone C, with more generous values in Zones A and B. These figures also reflect the low Q95 level relative to average daily flows in these rivers.

3.2.3 Percentage Takes

The percentage takes proposed for the Environmental Case operating rules are 50% for each of the river abstractions. The Base Case values were 50% for the Tamar and Tavy, and 100% for the Dart, Torridge and Taw.

3.2.4 Spate Sparing

For the purpose of the improved operating rules, a spate is defined as a daily mean flow which is more than double the lowest daily mean flow in the previous seven days. As the spate sparing is only needed to protect small spates at times of low flow, a "top level" can be applied above which abstraction is not affected. Provided the flow after abstraction is greater than the spate top level no reduction in abstraction is required. To avoid excessive loss of water at times when spates are occurring frequently, a delay period is built into the rules so that no spate is spared within 14 days of commencement of sparing an earlier spate.

The duration of the spate sparing can vary from river to river depending on the type of catchment and spate characteristics, location of abstraction and any perceived water quality problems. The magnitude of the spate top level and the duration of spate sparing proposed for each river are shown in Table 3 below.

Table 3**SPATE SPARING CHARACTERISTICS**

River	Spate Top Level MI/day	Days of Sparing
Tamar	500	5
Tavy	450	3
Dart	244	3
Torridge	300	5
Taw	390	5

An example of the spate sparing rules showing their effect on abstraction from the Tavy in September 1987 is shown in Figure 7. The spate sparing rules would operate during the period June to September inclusive when fish migration is dependent upon spates.

3.2.5 Use of Fisheries Bank

During the promotion of the scheme an undertaking was given that a "full-to-full" volume of 2270 MI (500 million gallons) would be reserved for fisheries purposes. For both of the Base Case and Environmental Case operating rules, it is proposed that this reserved storage should be used to alleviate the problem of low dissolved oxygen in the upper Tamar estuary at times of low flow which has caused salmon mortalities.

Analysis of fish movements at Gunnislake weir has indicated a marked tendency of salmon to run on the spring-neap and neap quadrants of the tidal cycle provided that there is sufficient fresh water flow over Gunnislake weir. During this part of the tidal cycle, the re-suspension of deposits in the upper estuary with consequent dissolved oxygen sag will be less. The records of fish deaths in the upper estuary indicate that they mainly occur during the neap-spring and spring quadrants of the tidal cycle. Therefore, the fisheries reserve could be used to make special releases from Roadford reservoir during periods when low river flows coincide with the spring-neap and neap phase. The aim would be to attract the salmon to run into the river during times when water quality in the upper estuary is good. This should increase the numbers of fish in the river whilst at the same time reducing the numbers of fish waiting in the upper estuary at times when water quality is bad.

It is anticipated that releases from Roadford reservoir of 300 MI/d for two days would be sufficient to attract salmon into the river. It has been assumed that these releases would be made once a month in July and August giving 1200 MI per year.

In years when no danger of a water quality problem in the estuary is perceived, a more effective use of the fisheries bank water might be the creation of good spawning conditions in the Wolf in the autumn. This will be considered further in the next phase of the work.

3.2.6 Spillage from Burrator Reservoir

The Burrator control rules have been designed to ensure that the reservoir is if possible spilling no later than 1st December and that there is reliable spill totalling at least 280 Mi/week throughout the critical salmon spawning period December and January. This also covers the peak salmon angling period in December.

3.2.7 Abstraction from the River Taw

For both the Base Case and the Environmental Case it has been assumed that abstraction from the River Taw would continue at a maximum of 17.5 MI/d as for the existing temporary licence, but without supporting transfers from the River Exe. In this way the burden of public water supplies would be shared between the Rivers Taw and Torridge. The intention was that this assumption would be reviewed if the impact assessment indicated excessive effects on either the Taw or the Torridge.

4. IMPACT OF NEW OPERATING RULES

4.1 River Flows and Reservoir Levels

4.1.1 Simulation of Scheme Operation

The Company has developed a comprehensive simulation model of the operation of the Roadford scheme. The model provides an excellent tool for use in assessing the environmental impact of the scheme, and refining its operating rules. The schematic arrangement of the model, termed PG 400, is shown in Figure 1. The model covers the whole of the supply areas of Plymouth, North Devon and South West Devon. The model simulates the operation of the scheme on a daily basis to meet all the zonal water supply demands.

The input data to the model can be summarised as:

- daily flow data for the rivers which are affected by abstractions and impoundments;
- zonal water supply demands predicted for a given year in the future; the variation in demand throughout the year is allowed for by weekly factors which are different for each zone;
- system control rules which cover factors such as compensation flows, prescribed minimum flows at abstraction points, maximum amounts of abstraction, pumping capacities, treatment works capacities, reservoir level controls, and so forth.

The model simulates the operation of the system at the given level of demand for the period 1957 -1987. The output from the model is available in a wide variety of tabular and graphical forms covering such parameters as amounts of abstraction, reservoir levels and river flows before and after abstraction.

The model is capable of producing a large range of output data for an infinite range of schemes. However, running of the model and processing and interpretation of the output are very time consuming. The schemes to be simulated and the output data must, therefore, be carefully selected to provide pertinent information for specific purposes.

For this Interim Report, the impact of the scheme has been examined when it is operating at its full capacity which is nominally taken as the 2014 demand level (see Section 3.1.1). Two operating scenarios have been considered:

- i) The Base Case, which is the operating rules originally prepared by the Company to comply with undertakings given at the Public Inquiries whilst minimising operating costs.
- ii) The Environmental Case, which is the rules proposed by the Study Team to reduce the environmental impact of the scheme, as described in Section 3.2.

The remaining parts of Chapter 4 of the Report examine the impact of the Base Case and Environmental Case. The effect on river flows and reservoir levels has been considered for two years of simulated scheme operation:

- 1984, which was a very dry summer equivalent to a drought of about 1 in 10 years, followed by a wet autumn;
- 1987, which was an unremarkable year in terms of river flow extremes.

A comparison of historic monthly flows for these two years is given in Table 4 below.

Table 4
MONTHLY FLOW IN RIVER TAMAR AT GUNNISLAKE, 1984 AND 1987
(flows in MI/d)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1984												
Flow	5702	3283	1123	665	328	190	112	130	328	1987	5011	4147
% of Mean	145	106	50	46	33	32	21	17	34	80	160	107
1987												
Flow	1814	1642	2506	1901	458	579	449	233	233	3802	3283	2074
% of Mean	47	54	114	134	47	97	85	31	24	153	104	54

The simulated flows and reservoir levels for the Base Case and Environmental Case for the years 1984 and 1987 are shown in Hydrographs 1 to 12 which are bound as a separate volume.

4.1.2 Draw-down of Roadford Reservoir

The simulated draw-down of Roadford reservoir is shown on Hydrograph 1. In 1984, for the Environmental Case the reservoir level would have dropped into Zone B in mid-May and Zone C at the end of August. The level would have returned to Zone B in early November 1984 and to Zone A in early January 1985. In 1987 the reservoir would have been in Zone A throughout.

Figure 8 shows the simulated monthly zone state of the reservoir for the period 1957 to 1987. For the 31 years of simulation, the reservoir would have been in Zone C in only 3 years: 1959 for 4 months; 1976 for 9 months (including January and February 1977); and 1984 for 4 months. For 9 years the reservoir would have been in Zone A throughout. For the remaining 19 years, the reservoir would have been in Zones A and B throughout.

The implications of reservoir draw-down on recreational use of the lake are discussed in Section 4.5.1.

4.1.3 Flows in the River Tamar

Hydrograph 2 shows how flows will be affected in the River Lyd at Lifton and Hydrograph 3 shows flows in the River Tamar at Gunnislake.

In the early part of the year there is no change to the flow at Lifton or below Gunnislake because Roadford is spilling and there is no abstraction at Gunnislake. In the spring, as river levels and reservoir levels elsewhere in the system start to fall, abstraction starts at Gunnislake. Initially when the Gunnislake flow is above the prescribed flow, the abstraction is not supported by releases from Roadford.

At times when regulation releases are being made from Roadford, the flow downstream of Gunnislake is increased by the extent to which the 9 MI/d compensation release exceeds the natural discharge of the Wolf. Thus for example on Hydrograph 3 between mid-June and the end of August 1984, the flow below Gunnislake is up to 9 MI/d higher than the natural flow would have been. This applies to both the Base Case and the Environmental case. It is arguable whether this increase in low flows above the natural condition is the optimal use of water at a time when water resources generally are critical. This matter has not yet been investigated in detail but will be considered further in the next phase of the study.

The use of the Roadford fisheries bank can be seen on the hydrographs for the Base Case and Environmental Case. In 1984 and 1987 releases are made in both July and August.

The main effects of the Environmental Case operating rules as compared with the Base Case are described below:

- i) The spate sparing rules proposed for the Environmental Case are not at present functioning effectively for the Tamar. For the two sample years of 1984 and 1987, most minor summer spates are not protected because they do not meet the criteria of the flow being double the dry weather flow. On the other hand, the fisheries bank releases do create significant spates. Possible improvements to the spate sparing rules will be considered further in the next phase of the work.
- ii) In the typical year of 1987, regulation releases for the Environmental Case would be larger and of longer duration than for the Base Case. This can be seen particularly by comparing the 1987 flows for the River Lyd shown on Hydrograph 2. In 1984, the situation is reversed and the regulation releases for the Environmental Case are for a shorter duration than for the Base Case. This is because of the lower prescribed flows at Gunnislake when the reservoir drops in to Zones B and C.
- iii) For the Environmental Case in 1984, when Roadford falls into Zone C at the end of August, flows below Gunnislake are reduced below the natural flow for a period of about four weeks whilst abstraction continues. The reduction in flow is generally about 10%.

4.1.4 Flows in the River Tavy

The effect of the scheme on flows in the River Tavy is shown on Hydrograph 4. The most striking effect of the scheme is the improvement in flows at Lopwell due to the reduction in hydro-electric abstraction at Morwellham. At

present the operating rules for the hydro-electric abstraction allow about 106 MI/d to be abstracted at Tavistock subject to a prescribed flow at Tavistock of 77 MI/d. During the promotion of the scheme, it was agreed with CEEB that the prescribed flow at Tavistock would gradually be increased to 147 MI/d by the year 2011. Thus, when operating at the 2014 demand level the prescribed flow at Tavistock will be at the much higher level of 147 MI/d. The effect of this can be seen by comparing the flow upstream of the abstraction (the blue line on Hydrograph 4) with the historical flow (the black line). When the natural flow is less than about 250 MI/d, the Morwellham abstraction ceases and flows are improved by up to 106 MI/d. This effect applies equally to both the Base Case and the Environmental Case.

An improvement in flows in the Tavy will be achieved by raising the prescribed flow from its present level of 41 MI/d to 73 MI/d, except when Roadford is in Zone C (ie during droughts) when it reverts to 41 MI/d. However a further marked improvement occurs during droughts when the presence of Roadford will obviate the need for a drought order on the Tavy. This can be seen by looking at the historic flows in August and September 1984, which at times dropped to almost zero because of the combination of hydro-electric abstraction at Morwellham and water supply abstraction with a very low prescribed flow of 2.2 MI/d due to the drought order. Again the improvement in flows as a consequence of the Roadford scheme applies for both the Base Case and the Environmental Case.

The effects of the Roadford scheme on flows at Lopwell can be seen on Hydrograph 4. During the early part of the year when there is plenty of water in Burrator reservoir, no abstraction takes place at Lopwell. In the spring as levels in Burrator reservoir start to fall, abstractions of up to the maximum allowable 90 MI/d take place. Occasionally, these abstractions are more than the water saved by the reduction in hydro-electric abstraction for Morwellham. Examples of this are seen in February and March 1987. However, generally the amount of the abstraction for water supply is substantially less than the water saved by the reduced hydro-electric abstraction.

The cutting in and out of Lopwell abstractions in March and April is controlled by the state of Burrator Reservoir. There is clearly a need for a refinement of the control rules to prevent this happening too frequently.

During the summer, as the natural flow drops towards the prescribed flow of 73 MI/d, the water supply abstraction is reduced with only 50% of the flow above the prescribed flow being abstracted. When the flow falls below the prescribed flow abstraction ceases.

The differences in flows between the Base Case and Environmental Case operating rules are:

- i) Some spates are spared. This can be seen clearly in Figure 7 which shows the three small spates which occurred in September 1987. The first spate is spared. The second occurs within 14 days of the first spate and so it is not spared. The third spate occurs more than 14 days after the first spate but is not spared because the spate flow is not more than

twice the previous low flow. There is a need for further refinement of the spate sparing rules. For example in September 1984 a small spate would have been preserved at the expense of a much larger one a few days later (Fig 13).

- ii) In 1984 when Roadford reservoir drops into Zone C towards the end of August, the prescribed flow for the Environmental Case drops to 41 MI/d and the abstraction increases. This can be seen in the Environmental Case for Hydrograph 4.

In general, when the Roadford scheme is operating at its ultimate capacity its impact on flows in the River Tavy will be a substantial improvement at most times during the spring and summer.

4.1.5 Levels in Burrator Reservoir

The effect of the scheme on the amount of water stored in Burrator reservoir is shown on Hydrograph 5. Comparing the predicted reservoir levels for 1984 and 1987 with the historic levels it can be seen that the effect of the scheme is to increase the amount of drawdown substantially. The increase is slightly more for the Environmental Case than for the Base Case. The significance of the increased drawdown for recreational use of the lake is discussed further in Section 4.5.2 of this report.

Flows in the River Meavy downstream of Burrator dam and in the river Plym downstream of the Meavy confluence are affected by the timing and amount of spillage from Burrator reservoir. This is discussed further in section 4.1.6 below.

4.1.6 Flows in the Rivers Meavy and Plym

Flows in the River Meavy upstream of the Plym confluence are shown in Hydrograph 6 and for the River Plym at Carnwood in Hydrograph 7. In each case flows with Roadford in operation (the red line) are compared with historic flows (the black line) i.e. the flows which actually took place in 1984 and 1987 with Burrator reservoir in operation. Where the Roadford scheme results in an increase in flow the area is hatched in red and where Roadford results in a drop in flow the area is hatched in blue.

For both the Base Case and the Environmental Case spillage would start several weeks earlier in the autumn. Furthermore subsequent extended periods of non-spillage such as occurred historically in December 1987 would be avoided. Nevertheless there is scope for further refinements to the Environmental Case to improve the continuity of autumn spillage.

4.1.7 Flows in the River Dart

The effect of the scheme on flows in the River Dart at Littlehempston are shown on Hydrograph 8. With the Roadford scheme in operation, flows in the River Dart at Littlehempston during the summer will be higher than those historically recorded for three reasons:

- i) The introduction of a prescribed flow on the abstraction from the headwaters of the Dart into the Devonport Leat.
- ii) The application of prescribed flows to all of the abstractions from the River Dart at Littlehempston. Under present conditions up to 24 MI/d can be abstracted through the radial collectors at Littlehempston subject to a prescribed flow of only 13 MI/d in the River Dart. Under the new operating rules 90% of the abstraction through the radial collectors will be considered part of the Littlehempston abstraction and subject to the same prescribed flow rules.
- iii) The prescribed flow will be raised from its present level of 68 MI/d to 122 MI/d (except when Roadford is in Zone C when the prescribed flow drops to 80 MI/d for the Environmental Case).

The effect of these prescribed flow changes can be seen clearly on Hydrograph 8 which shows that flows downstream of Littlehempston from June to September are generally substantially more than historic flows.

The flow improvements described above apply equally to the Base Case and the Environmental Case. Further improvements are obtained for the Environmental Case operating rules as described below:

- i) The 50% take rule reduces the amount of abstraction as flows approach the prescribed flow.
- ii) The spate sparing rule allows some spates to be saved. An example is shown on Hydrograph 8 in the second half of August 1984. However, the spate sparing rules are not yet functioning satisfactorily so that, for example, none of the three spates which occurred in September 1984 would have been saved. This is because the spate cut-off level of 244 MI/d has been set too low. This matter will be further investigated in the next stage of the study.

The Environmental Case operating rules lead to flows slightly worse than the Base Case flows when Roadford reservoir drops into Zone C in August and September 1984. However, the amount of abstraction during this period is relatively small due to the 50% take rule.

4.1.8 Flows in the River Torridge

The effect of the scheme on flows in the river Torridge at Torrington are shown in Hydrograph 9.

For both the Base Case and Environmental Case there is some improvement in flows for three reasons:

- i) The compensation flow from Meldon reservoir is to be increased to 7.3 MI/d.

- ii) The prescribed flow at Torrington is to be increased to 80 MI/d as compared to 68 MI/d at present.
- iii) There will be no need for drought orders once the Roadford scheme is in operation, so a situation such as 1989 when the prescribed flow was reduced to 25 MI/d under the drought order, will not occur.

The improvements in flows due to the first two causes above can be seen clearly on the hydrographs, particularly in August and September 1984 when flows with the Roadford scheme in operation are seen to be higher than the historic flows.

The suggested Environmental Case operating rules lead to a marked further improvement in flows during the summer. These are described below:

- i) The increased prescribed flows and lower percentage take for the Environmental Case will mean that flows in the Torridge with the scheme in operation will actually be greater than historic flows for virtually the whole of the period from April to September. This applies equally to a dry year like 1984 and a typical year like 1987.
- ii) This situation compares with the Base Case where flows would be reduced by up to 25% at most times throughout the summer.
- iii) An example of spate sparing can be seen in the spate which occurred towards the end of August 1984. However the spate sparing rules at present would not save any of the other spates occurring in 1984 and some further refinement of the rules may be necessary during the next stage of the work.

The hydrographs show that even when the Torridge flow is below the prescribed flow abstraction of 9 MI/d continues at times. This is when Torridge flows are being supported by releases from Meldon Reservoir. This occurs when the storage in Meldon is above the lower control line shown in Hydrograph 10. Thus in 1984 the abstraction supported by Meldon continues until mid-August for the Base Case or mid-July for the Environmental Case.

4.1.9 Flows in the River Taw

The effect of the scheme on flows in the river Taw is shown on Hydrograph 11. For the purposes of this report it is assumed that the existing temporary licence for abstraction of 17.5 MI/d at Newbridge would become a permanent feature and that the abstraction would not be supported by transfers from the River Exe. However, it is understood that the possibility of the Exe-Taw transfer being made permanent is still being considered. The way in which supplies to North Devon would be shared between the Taw, the Torridge and Roadford is shown on Hydrograph 12. In general abstraction from the Taw continues throughout the year at the level of 17.5 MI/d until the natural flow drops below the prescribed flow, when abstraction ceases.

With the Environmental Case operating rules the abstraction continues for slightly longer in 1984 due to the lower prescribed flow when Roadford reservoir is in Zones B and C. However, during the summer of 1984 the flows in Taw would generally be well below the Zone C prescribed flow of 104 MI/d so no abstraction would take place.

It can be seen from Hydrograph 12 that at present the arrangement of prescribed flows in the Torridge and the Taw tends to make the Torridge carry a larger share of abstraction than the Taw when river flows are low. This effect is particularly marked for the Base Case, for example in weeks 18 to 30 in 1984 as shown on Hydrograph 12. There may well be a case for adjusting the prescribed flows so that the abstraction is shared evenly between the two rivers. This will be further investigated in the next phase of the study.

The headwaters abstractions in the Taw catchment at Leahamford Bridge and Taw Marsh are to be reviewed, in line with an undertaking given to the River Taw Riparian Owners Association. This will marginally increase low flows in both the Base Case and the Environmental Case.

4.2 Water Quality

4.2.1 Tamar Catchment

A summary of water quality for all of the rivers under consideration is given in Table 5. The quality classifications shown are based on an assessment of the data on a rolling three year basis, using NRA's standard river quality classification system.

The Tamar catchment is typically of class 1B/2A quality. It usually supports a high quality fishery. Fish mortalities have occurred in the upper Tamar estuary, caused by the re-suspension of anoxic sediments in the zone of maximum turbidity at the tidal limit downstream of Gunnislake, at times of spring tides, warm weather and low freshwater discharge. The more significant point source polluting inputs are the effluents from:

- Holsworthy sewage treatment works (average 0.7 MI/day), which enters the Tamar at North Tamerton via the River Deer;
- Launceston sewage treatment works (average 1.7 MI/day), which enters the Tamar 3 km upstream of the Lyd confluence.

Thus there is relatively little sewage effluent in the freshwater Tamar. The origins of the estuarine quality problem may lie with natural influences such as the accumulation and settling of organic detritus of algal or planktonic origin. The volume of sewage effluent discharged into the estuary is insignificant when compared to the tidal flux of the estuary (about 50,000 MI/day).

The main feature of the various scheme options is that the flows above Gunnislake will be increased in the summer. In a dry year, the Base Case leads to a more prolonged period of elevated flow than does the Environmental Case. In a typical year, the situation is reversed, with the Environmental Case resulting in higher flows than the Base Case.

Below Gunnislake flows will not be affected significantly except for the occasional periods when abstraction takes place without supporting releases from Roadford reservoir. The impact of these flow changes upon water quality is expected to be as follows:

(a) Lyd Subcatchment

The increased flux of good quality water due to releases from Roadford Reservoir will have a substantial and beneficial effect. The temperature buffering effects of reservoir releases, combined with the potentially substantial volume of water entering the River Wolf due to leakage, will tend to reduce the summer temperature of the Lyd by up to 2 degrees Celsius, and increase the winter temperature by a similar amount.

There are two counteracting mechanisms which determine the impact of increased flows upon re-aeration characteristics:

- increase in the rate of mass transfer of oxygen across the air/water interface due to increased velocity; and
- decrease in the overall re-aeration rate due to increased depth and the consequent increase in the volume of water which the surface mass transfer is required to support.

Where the increase in depth is large compared to the original depth of water, the second mechanism is dominant. During the summer months, there is very little natural flow in the Wolf. Releases will have a profound impact upon the depth of the water. (However, the resulting summer flows will be no higher than those which occur naturally in the winter). Therefore during the summer a reduction in the re-aeration rate should be expected at times of release. Figure 9(a) shows how these mechanisms are likely to cancel one another out during a typical year in the Lyd. In a dry summer, the water depth in the Lyd will be increased from about 10cm to about 60cm, reducing the overall re-aeration rate.

The increased flows could also have a significant impact upon turbidity. The current velocity which is predicted in the Wolf for flows in excess of 150 MI/day (about 0.8 m/s) is verging on that which is required to scour the river bed. Previous studies performed by Halcrow on the relationship between releases from Wimbleball Reservoir and suspended solids concentrations in the River Haddeo concluded that suspended solids concentration on any day is a function of both the river flow and increases in flow which have taken place since the previous day.

It is proposed that a similar analysis for the River Wolf should be undertaken in the next stage of this study.

There will be no other significant impacts upon water quality in the Lyd subcatchment.

(b) Tamar : Lyd to Gunnislake Abstraction

Increased flows in the Tamar will be proportionally less than those in the Lyd subcatchment. In the Environmental Case the impact will be beneficial, and is illustrated in Figure 9(b). There will be a significant improvement in water quality at those times of the summer when the Tamar would otherwise have tended to form ponds, with long retention times, due to low flow. This is expected to result in a decrease in the levels of nutrients available which should prevent the build-up of filamentous algae and the depletion of phytoplankton due to zooplankton grazing.

(c) Gunnislake Abstraction to Gunnislake Weir

Downstream of the Gunnislake abstraction, there will be no change in flow when abstractions are supported by regulating releases. Water quality should be improved by the improvements induced upstream of the abstraction. Retention times will be unaffected, and so the

significance of any improvement at times of low flow will be comparatively less than that expected upstream of the abstraction.

On the few occasions when the abstraction is unsupported, there will be significant decrease in flow. If this situation were to occur in a dry year during a period of intense sunlight, it is possible that eutrophic conditions may develop.

(d) Tamar Estuary

No deleterious effects are foreseen for either the Base or Environmental Cases upon the estuary. There is presently a transfer of water from the River Tavy (see 4.2.2 below) into the Morwellham canal. This water is channelled through Morwellham power station and enters the Tamar estuary approximately 3km downstream of the normal tidal limit. It is understood that abstraction to the power station in summer is to be reduced as water supply abstractions are increased. Therefore there will be a small decrease in the flux of non-saline water into the upper Tamar estuary. This will result in a small increase in the salinity of the upper estuary at high water.

At times of unsupported abstraction, it is likely that the position of the zone of maximum turbidity will be moved slightly further up the estuary. This can be expected to cause a problem only if the abstraction remains unsupported during the period from 2 hours before high water to 1 hour after high water. At other times these effects are not likely to result in any significant deterioration.

Special releases of 300 MI/day are proposed to take place for 2 days consecutively, twice a year, to encourage fish migration. Suspended solid concentrations may increase if such releases are not allowed to build up gradually, but otherwise there should be no deleterious effects.

4.2.2 Tavy Catchment

The Tavy and its tributary the Lumburn, are of fair to high quality. The Tavy upstream of the Lumburn suffers from the impact of the effluent from Crowndale STW (9.7MI/day), which forces the river into Class 2 (Table 5). In addition, the catchment features two consented fish farm discharges (totalling 5.7 MI/day flow through the fish farm) and a factory which manufactures sausage skins. At times of drought, water could previously be transferred from the River Tamar at Gunnislake into the Lumburn near the village of Lumburn itself, but this was not a permanent arrangement.

Table 5
SUMMARY OF EXISTING WATER QUALITY

RIVER	REACH	EC FISHERY STATUS	QUALITY				
			Year	84	85	86	87
Tamar	Gunnislake	salmonid	2	2	2A	2A	2A
Tavy	Lopwell Dam	salmonid	1B	1B	1B	1A	1B
	Shillamill	salmonid	2	1B	2A	2A	2A
Lumburn	Shillamill	salmonid	1B	1B	2A	1B	1B
Meavy	Shaugh	salmonid	1A	1A	1A	1A	1A
Plym	Shaugh Bridge	salmonid	1A	1B	3A	1B	1A
	Plym Bridge	salmonid	1A	1A	1A	1A	1B
Dart	Totnes Weir	salmonid	1A	1A	2A	1B	1B
Torridge	Beam Weir	salmonid	2	2	2A	2A	2A
	Torrington	salmonid	1B	2	2A	1B	1B
Okement	Iddesleigh	salmonid	1B	2	1B	1B	1B
	Bridge, Woodhall Bridge	salmonid	1A	1B	1B	1B	1A
Taw	New Bridge	salmonid	1B	1B	1B	2A	2A

The Lumburn, and the Tavy itself downstream of the Lumburn confluence, are typically of 1B quality. The Tavy is impounded by Lopwell Dam at its tidal limit.

The impact of the various scheme proposals upon water quality in the Tavy is expected to be as follows:

(a) Morwellham Canal to Crowndale Sewage Treatment Works

The reduction of the Morwellham flow diversion will result in a very significant increase in the flows in the Tavy downstream of Tavistock. This will reduce slightly the range of temperature and suspended solids variations in the river. There will be no discernible impact upon re-aeration.

(b) Crowndale Sewage Treatment Works to Lopwell Dam

The increase in flow resulting from the reduction of the Morwellham abstraction will provide additional dilution for the 9.7 MI/day of sewage effluent from Crowndale STW, resulting in a significant improvement in water quality from Class 2 to Class 1B. It is possible that this may have the knock-on effect of improving parts of the lower Tavy to Class 1A.

(c) Tavy Estuary

The Tavy estuary covers an area of approximately 2 square kilometres, with a tidal range of approximately 5 metres. At least 80% of its area is inter-tidal. The volume of tidal flushing at each tidal cycle can be estimated (very approximately) to be 3,750,000 cubic metres, which is equivalent to 7250 MI/day. The prescribed flows at Lopwell are insignificant compared to this tidal flux in both the Base and Environmental Case. Therefore the actual impact upon the Tavy estuary will be insignificant.

4.2.3 Plym Catchment

The Plym is a moorland river. It receives settled effluent from the mica settling lagoons at china clay works in the area around Shaugh. This effluent causes an increase of between 10 and 20 mg/l in suspended solids concentrations. However these solids are predominantly micaceous residue, and are neither toxic nor de-oxygenating. The resulting turbidity levels do not pose a threat to algal activity. The upper Plym is typically a Class 1A quality, although failures have occasionally resulted from low pH values.

The Meavy is a tributary of the Plym, joining it at Shaugh. It is consistently of Class 1A quality. Burrator reservoir is situated on the Meavy headwaters.

Upstream of Shaugh the pH of both the Plym and the Meavy is lower than that observed in the other rivers covered by this study. The pH of the upper Plym (minimum 4.2) is sufficiently low to cause periodic deterioration to Class 3A. These low pH values reflect the relatively large proportion of the catchment area which lies on acid moorland.

(a) Meavy Subcatchment

There will be no significant change in the timing and extent of spills from Burrator reservoir to the Meavy. Consequently, the impact of the scheme upon water quality in the Meavy will be negligible.

(b) Plym: Meavy Confluence to Marsh Mills

The Plym upstream of the Meavy confluence is unaffected by the scheme proposals. The quality of the Plym downstream of the Meavy will be unaffected because the Meavy itself will not be affected significantly.

It is recommended that the biota of the Meavy and the Plym at Shaugh should be monitored to provide early warning of any potential problems arising from the low pH of these waters.

(c) Plym Estuary

The Plym estuary will be unaffected by the scheme proposals.

4.2.4 Devonport Leat

The Devonport Leat connects the West Dart with Burrator reservoir, and is located entirely within the Dartmoor National Park. The scheme will have no impact upon the quality of water in the Devonport Leat.

4.2.5 Dart Catchment

The Dart is typically of Class 1A/1B quality. It receives the effluent from Ashburton and Buckfastleigh STW (3.9 MI/day average), but this has only a minimal impact upon water quality. The Base Case will result in a very substantial increase in flow for a period of about 3 months in a dry summer, in the reach between the abstraction at Littlehempston and Totnes Weir. The Environmental Case will result in an increase in flow of similar or slightly greater magnitude, over about 3.5 months. This short reach (about 1 km) receives no significant effluent discharges and lies upstream of the town of Totnes itself. The flow increases will reduce considerably the summer residence time of water in the reach. The overall impact upon water quality of both cases will be highly beneficial, virtually guaranteeing Class 1A quality.

Totnes STW discharges 5 MI/day of treated sewage effluent into the Dart estuary a short distance below Totnes weir. The prescribed flows which are proposed (all 122 MI/day, except Zone C for the Environmental Case which is 80 MI/day) are well in excess of this sewage effluent flow, and so the impact arising from any changes in dilution will be insignificant. Furthermore, the effluent cannot be carried upstream on a rising tide, and so there is no risk of an accumulation of effluent over successive tidal cycles causing any problems. The Dart estuary provides the equivalent of approximately 8,000 MI/day by tidal flushing. Thus the flow of both river water and sewage effluent can be seen to be a very minor factor in determining the quality of the Dart estuary. The fact

that there have been no recently reported water quality problems in the upper Dart estuary lends weight to this conclusion.

The increased summer flux of non-saline water into the upper Dart estuary will lead to reductions of approximately 3 parts per thousand in salinity at high water. This impact will be of transient duration, and is not considered to be significant.

4.2.6 Torridge Catchment

The Torridge and its tributary the Okement have suffered from occasional pollution incidents resulting in fish mortalities. At the tidal limit of the Torridge estuary the resuspension of sediments caused by a rising tide has resulted in local sags in dissolved oxygen, particularly in the vicinity of Weare Giffard. Such conditions are stressful to fish, and the passage of migratory fish in particular appears to be disrupted. The quality of estuarine water is further prejudiced by the generally high bacterial levels which are an accumulation of the substantial volume of sewage effluent discharged into the estuary itself and the high bacterial concentrations in the freshwater entering the estuary downstream of Beam Weir. (In this connection it should be noted that the Company is already taking steps to reduce the volume of sewage effluent which is discharged directly into the estuary, and this can be expected to improve the quality of estuarine waters very substantially).

The specific impacts are described below:

(a) Okement Subcatchment

The Okement is a semi-moorland river, with a pH intermediate between that of a lowland river and a true moorland stream. It is typically in Class 1B. It is susceptible to pollution caused when sulphide ore outcrops on Dartmoor are leached by heavy rainfall after prolonged dry periods; this leads to the presence of sulphuric acid in the Okement, and hence abnormally low pH values, resulting in fish mortalities.

(b) Torridge: Okement to Great Torrington Abstraction

The Torridge downstream of the Okement confluence is typically in Class 1B.

Both the Base Case and the Environmental Case will provide a slight benefit to this reach when compensation flow from Meldon reservoir is increased from 3.8 to 7.7 MI/d in 1993. This will give a slight reduction in the background temperature, pH and phosphate concentration.

(c) Torridge: Great Torrington Abstraction to Tidal Limit

The abstraction at Great Torrington lies immediately upstream of the effluent discharges from Great Torrington STW and the Torridge Vale Creamery. Great Torrington STW discharges an average of 2.8 MI/day

of treated domestic sewage and trade effluent. The minimum dilution of this effluent ranges from 7:1 in a dry year to 25:1 in a typical year.

The Torridge Vale Creamery, previously owned by Unigate Foods Limited, is now owned by Dalry Crest Limited. Consent to discharge cooling water with traces of solids settled from river water, boiler blow-down and condensate was granted in 1972. The maximum discharge permitted is:

- 4.5 MI/day (May to October inclusive), and
- 3.2 MI/day (November to April inclusive).

It is understood that the Torridge Vale Creamery discharge consents are currently under review.

The minimum dilution of this effluent ranges from 4:1 in a dry year to 16:1 in a typical year. Consequently in dry years the discharge can be expected to cause a maximum temperature rise of approximately 2 degrees Celsius in the river.

The combined impact of the abstraction and the two effluents which have been described is to cause a deterioration in the quality of the Torridge from 1B to 2A.

The impacts upon the diluting flows in dry weather are as follows:

- Environmental Case, typical year - a sustained increase in flow of between 8% and 25% between mid-May and September;
- Environmental Case, dry year - a sustained increase in flow of between 8% and 20% between May and June;
- Base Case, typical year - a sustained reduction of between 9% and 30% between May and September, interrupted by about 2 weeks in August when the flow is increased by about 25% while the prescribed flow is in operation.
- Base Case, dry year - a sustained reduction of between 8% and 33% during May and early June, followed by a sustained increase of between 4% and 35% during late June and July.

The effects of this upon water quality in the summer months are summarised in Table 6.

Table 6
IMPACTS ON THE TORRIDGE AT ROTHERN BRIDGE

DETERMINAND	CHANGES IN CONCENTRATION			
	ENVIRONMENTAL CASE		BASE CASE	
	Typical	Dry	Typical	Dry
Phosphate (95th %ile)	+0.2 mg/l	N/S	+0.05 mg/l	+0.03 mg/l
Ammonia (N) (95th %ile)	-0.1 mg/l	N/S	+0.03 mg/l	+0.01 mg/l
Nitrate (N) (95th %ile)	-0.2 mg/l	-0.1 mg/l	+0.2 mg/l	N/S
Temperature (95th %ile)	-0.5deg.C	N/S	+1.0deg.C	+0.5deg.C
pH (5th %ile)	N/S	N/S	N/S	N/S
pH (95th %ile)	-0.01*	N/S	+0.02*	+0.01
Silicate (95th %ile)	marginal decrease	N/S	marginal increase	N/S
N/S = not significant * = very approximate estimate				

The Environmental Case is therefore slightly beneficial. In the Base Case the Torridge can be expected to fall consistently in Class 2A with occasional excursions into Class 3A on account of high temperatures.

(d) Torridge Estuary

The Base Case impacts described in (c) above are likely to lead to increased planktonic and macrophytic production during the summer months. This may lead to an increase in the number of occasions on which the conditions are not conducive to the passage of migratory fish. This is based upon the hypothesis that a major factor in the problems of the upper Torridge estuary is the steady deposition of

planktonic and macrophytic detritus at the tidal limit, and the oxygen demand exerted by the subsequent processes of decomposition and resuspension. Such an impact would be avoided by adopting the Environmental Case operating rules, which would be of marginal benefit to estuarine quality.

Reduced dilutions for Torrington STW resulting from the Base Case will cause a periodic increase of about 10% of bacterial levels in the Torridge influx to the estuary. However it is highly likely that this impact will be offset by the improvements brought about by the Company's proposals for improvements to the sewerage and sewage disposal facilities in and around the Torridge (and the Taw) estuaries.

The Torridge catchment as a whole exhibits several characteristics which suggest that a detailed study of chemical/biochemical/bioecological dynamics is required in order to identify the key factors which determine its water quality. For example:

- The range of pH variation is unusually large.
- Phosphate concentrations are 3 to 4 times higher than those in the other rivers covered by this study.
- There is no simple explanation for the occasional apparent unsuitability of the upper Torridge estuary for fish migration (Section 4.3.6).

4.2.7 Taw Catchment

The changes to the flow regime of the River Taw resulting from both the Base Case and the Environmental Case are small compared to the river flows themselves. Therefore the impact of either case upon water quality in either the River Taw or the Taw estuary will be negligible.

4.3 Fisheries

4.3.1 Introduction

The fisheries aspects of the scheme, including much background detail, are discussed at length in Annexes F1 to F6. Only a brief summary is presented here, concentrating on:

- a description of the relationship between fisheries, and fishing, and river flow,
- identification of the critical hydrological aspects for fisheries, including where relevant the associated relationship of water quality,
- a description of how the above were translated into realistic operating rules,
- consideration of the impact of existing abstractions,
- a summary of the likely impact of Base Case operating rules,
- a summary of the likely impact of Environmental Option operating rules,
- a consideration of possible mitigation measures, and the requirements for future work.

4.3.2 River Tamar

The fisheries of the Tamar have been the subject of considerable investigation in connection with the Roadford scheme (section 2.4). This is reported in Annex F1.

Salmon movement past the tidal limit and Gunnislake intake site is mainly associated with spates. In dry summers small spates can be very important in stimulating movement into fresh water. Some fish migrate on steady flows, of 300 MI/d or less. As flows recede, the numbers of fish migrating fall, but occasional movements have been recorded at flows of less than 100 MI/d. Sea trout appear to enter the river at all discharges, with no evidence of low flows being inhibitory.

Water quality can deteriorate in the upper estuary to the extent that salmon are killed. Mortalities occur in hot, dry summers, associated with spring tides, high water temperatures and low freshwater discharge.

The Base Case rules are a 50% take, subject to a prescribed flow of 245 MI/d, of up to 148 MI/d. Abstractions at flows below the p.f. are allowed if supported by a commensurate release from Roadford. The compensation flow from the reservoir is a constant 9 MI/d.

The potential environmental impact of the Base Case is ameliorated by the priority afforded to abstraction from Burrator and Lopwell. This greatly reduces the extent of unsupported abstraction from Gunnislake and thus the impact on residual flows downstream. However, these rules allow abstraction from small summer spates which would be detrimental to the fishery.

Operating rules for the Environmental Case therefore aim to:

- maintain the protection of low flows, by a prescribed flow which varies according to Roadford storage (Zone A 304 MI/d; Zone B 220 MI/d; Zone C 90 MI/d).
- prevent depletion of the most critical small summer spates (spate-sparing).
- create occasional artificial freshets to lead fish from the estuary at potentially dangerous times.
- create conditions suitable for salmon spawning in the Wolf when Roadford storage permits.

It is considered that operation of the scheme by these rules would have minimal detrimental effect on fish movement and fishing downstream of the abstraction point. The freshets to allow emigration from the estuary represent a significant improvement on present conditions.

Enhanced flows between the dam and Gunnislake while releases are being made, which is of course at times of low natural flow, are likely to cause an improvement to salmon and sea trout angling by distribution of stock and by creating good fishing conditions. The Environmental Case involves releases over a longer period than the Base Case in most years, thereby increasing this potential benefit. The greatest improvement is likely to be felt on the Lyd sub-catchment, where summer fishing is often adversely affected by low flows. Examples of streams elsewhere in the region with enhanced flows exhibiting significantly improved angling for migratory salmonids are the St Neot River (Fowey tributary receiving regulating releases from Colliford Reservoir) and the Mole (Taw tributary receiving water transferred from the Exe in 1989). No more fish will be induced to enter the river by the releases, however, as the residual flow downstream of Gunnislake remains unchanged.

Before construction of the dam, it was estimated that about 2.5% of salmon production in the Tamar catchment was supported by the Wolf. The lack of high flows in the Autumn is likely to reduce greatly the salmon spawning potential of the stream. Juvenile salmonid productivity is likely to be potentially high, however, due to the regulated flow (c.f. River Meavy). The salmon production potential could be realised by appropriate restocking with eggs or young fish. Further, it is likely that adequate storage in most years would allow appropriate releases to encourage immigration and spawning by salmon.

4.3.3 River Tavy

Assessment of the potential impact of the scheme on the rivers other than the Tamar is based upon sparse and frankly inadequate data. In particular, the assumption that the timing and distribution of angling catches can be used as an indicator of fish migration while probably broadly valid, lacks precision. The impact assessments should therefore be considered interim in nature, and should later be validated and developed by more direct investigation.

The Tavy is a small, productive salmonid river which is heavily exploited. There is some evidence that exploitation by the nets, enhanced by delayed migration due to high abstraction and the presence of Lopwell Dam, has hastened a shift to later timing of runs of salmon. Existing abstraction for both hydro-electric power water and supply are considerable and are believed to be having a significant effect on salmon fisheries, but little effect on sea trout fishing.

The effect of the scheme on flows at Lopwell is shown in Hydrograph 4. Figure 13 shows river flows and salmon catches during the angling seasons of 1984 and 1987. This demonstrates clearly the strong influence of spate flows on salmon catches. Figure 14 shows how flows in September 1987 were affected by abstractions at Lopwell and for the Morwellham power station and demonstrates how the existing low flows are considerably reduced by abstraction.

The Base Case operating rules, although allowing a higher total take at Lopwell than at present (91 instead of 41 MI/d), do include a higher prescribed flow (73 MI/d) and a 50% take. While these rules represent a significant enhancement of low residual flows, such conditions are not in fact considered limiting either for sea trout (which appear to enter the river at almost any flow) or salmon (whose migrations are associated with rather higher flows, especially spates). A greater contribution in fisheries terms is conferred by the gradually increasing prescribed flow for the Abbey Weir abstraction for Morwellham, which will improve low flow conditions between Tavistock and Lopwell.

The main adverse impact of the Base Case lies in the significant depletion of medium flows, including small spates, that this abstraction added to the Morwellham take represents. For example, at a natural flow of 450 MI/d (equivalent to a highly effective small summer spate), nearly 200 MI/d (45%) could be removed by the two abstractions.

The Environmental Case involves a lower prescribed flow (41 MI/d) under Zone C conditions, and a spate sparing rule. The lower prescribed flow at times is considered to be of little consequence as low flow conditions are generally not critical, as discussed above. Residual flows even with Zone C rules are generally considerably higher than under existing rules, largely because of the higher Morwellham p.f., but also because drought orders, such as obtained in 1976, 1984 and 1989, will not be necessary in such years. The spate sparing is considered to be a significant contribution in principle, though effective operating rules that optimise the use of available water are still being developed.

Both sets of rules fail to deal with two major problems of the Tavy, which are:

- heavy net exploitation of salmon held up below Lopwell Dam
- depletion of medium flows, when salmon might be moving, by the abstraction for Morwellham power station.

It is therefore recommended that action is taken to reduce these impacts. Details are given in section 3.4 of Annex F2.

4.3.4 River Plym

The Plym is an unusual river in that the main salmon nursery area on the Meavy, having been considerably reduced in extent by the construction of Burrator Dam, is highly productive probably largely as a result of the regulated flow regime. Salmon angling is effectively limited to the autumn months, and good fishing is generally coincident with spill from Burrator, particularly for the Meavy but also for the main River Plym. It is not certain for the Plym whether this is a true causal relationship, or whether Burrator spill is just a symptom of the high river discharges necessary to initiate salmon migration and dispersion. There is no doubt, however, that effective penetration of the Meavy by spawning salmon is dependent upon Burrator spill, and it is believed that this was compromised in the autumns of 1987, 1988 and 1989. The existing compensation flow of 2.6 MI/d is clearly adequate to support a high rate of juvenile production. Sea trout angling does not appear to be influenced to any extent by the present resource operation.

Figure 15 shows river flows and salmon catches in the autumn of 1984 and 1987. Figure 16 shows how salmon and sea trout catches have varied since 1952 and also demonstrates the timing of the runs. Hydrograph 5 shows how the storage in Burrator and, particularly, its spillage would be affected by the scheme, Hydrographs 6 and 7 show the effect on flows in the Meavy and Plym.

The Base Case operates with similar rules to present i.e. the same compensation flow. However, operational considerations are different, and in order to ensure that Burrator fills completely each winter abstraction from the reservoir would be greatly reduced in the autumn. This generally results in earlier spill from Burrator, which is likely to benefit both fishing and salmon spawning. For example, in 1984 Burrator spilled about November 12; with Base Case operating rules, spill would first occur about October 22. Equivalent figures for 1987 are about October 26 and October 18. However, heavier abstraction while the reservoir was full or almost so changes the pattern of spill, in some years making it less continuous; this could have an adverse effect upon spawning.

The only changes for the Environmental Option concern the timing, reliability and extent of reservoir spill. The operating rules require "guaranteed" spill by December 1, and spill of at least 280 MI/week during December and January. (The guarantee is of course subject to adequate rainfall). In most years these rules result in little difference to the Base Case, with more favourable

conditions obtaining as earlier and greater spill is occurring anyway. However, in dry years they should help considerably, for example by improving the very poor angling and poor spawning penetration observed in 1987, 1988 and 1989.

With the Plym stock so totally dependent upon the Meavy it is recommended that the relationships between timing and extent of Burrator spill, and successful spawning and juvenile recruitment, are carefully studied.

4.3.5 River Dart

The Dart is similar in many ways to the Tavy, being a small productive salmonid river with salmon angling heavily dependent upon spates. Over the past thirty years the run has swung from mainly spring/summer salmon to grilse, with the peak months being July to September. Dry summers lead to poor salmon fishing, with activity centred on the few spates. Wet summers with a succession of spates are associated with first class fishing. This is shown on Figure 17. Generally, any spate that effectively doubles the prevailing flow and which exceed about 200 MI/d appears to be successful at stimulating movement and good fishing.

Sea trout angling does not appear to be influenced by freshwater flows, with good catches often being taken at the lowest flows (see Figure 18). Indeed, wet summers with high flows do not appear to be good for sea trout fishing.

Of the licensed existing abstraction up to 51 MI/d at Littlehempston, a maximum of 24 MI/d can be taken via the radial collectors subject to a prescribed flow of 15 MI/d down the fish pass. Of the remaining 27 MI/d, 9 MI/d can be abstracted at all times and the rest is subject to a prescribed flow of 68 MI/d. It is considered that this abstraction is having a limited effect on fisheries. Sea trout runs and fishing appear to be unaffected by low flows (at least within the range experienced in recent years) and good salmon fishing is dependent upon high flows which are relatively unaffected by the existing scale of abstraction. The main way in which the Littlehempston abstraction may be affecting fishing is by reduction of some small spates of critical size in dry summers, and are associated with fair fishing. The Devonport Leat abstractions also contribute to this effect (see below).

Abstraction to the Leat, from the West Dart, Blackbrook and Cowsic, presently occurs without a prescribed flow condition. In addition to causing a depletion in flows down to the estuary, it has a considerable effect on the value of these tributaries as nurseries. The Cowsic is frequently dry downstream of the intake.

The Base Case operating rules (100% take up to 60 MI/d, including the radial collectors, subject to a prescribed flow of 122 MI/d) make a considerable contribution to the low flow situation compared with present practices. However, this is a limited contribution to fisheries because, as was concluded above, present reduction of low flows is not considered to significantly affect migration or catches. The depleting effect on minor spates is maintained. The adoption of a prescribed flow and 50% take for the Devonport Leat is seen as a significant contribution, however, in terms of increased juvenile production.

The Environmental Case maintains the Improved situation regarding the Devonport Leat abstraction. It introduces a 50% take and spate sparing concept at Littlehempston, but incorporates a lower prescribed flow of 80 MI/d during Zone C Roadford storage. This occurs for less than 5% of the time in the 31 years modelled at full yield, and is considered to be of negligible adverse impact in view of the relationship between flow and catches discussed above. Residual low flows would remain well above present levels at all times. Ensuring that small spates of critical character for salmon movement are protected is, on the other hand, seen as a significant beneficial contribution. The spate sparing rule as presently modelled is relatively ineffective and requires further development. Assuming this can be done, the Environmental Case is considered to be a modest improvement over the Base Case, which is in turn a significant improvement over present operating conditions.

4.3.6 River Torridge

The Torridge is a potentially marvellous salmon and sea trout river suffering considerable decline - mainly, it is believed, because of water quality problems. It has a very low summer base flow compared to its average flow, which has tended to split the salmon run into spring and autumn factions, with only poor summer runs. Water quality problems and a heavy netting pressure have compounded this situation.

Spring and autumn runs of salmon are generally associated with considerable river flow which are unlikely to be significantly affected by abstraction. This is shown on Figure 19. Runs of salmon in the summer occur when flows exceed about 250 MI/d, either as high base flow or as spates. In the absence of such flows, salmon fishing simply does not exist; for example, not a single salmon was caught on rod between April 20 and September 20 1984. In contrast to the Tavy and Dart, sea trout fishing also appears to be adversely affected by low flows. Good steady catches were maintained in 1987 when residual base flows were of the order of 80 MI/d, but in 1984, considerable periods of poor fishing were associated with base flows around 60 MI/d (see Figure 18). It is assumed that this was caused by a reluctance or inability of fish to ascend into the river from the estuary.

The Base Case operating rules, incorporating an increased prescribed flow of 80 MI/d, protects this apparently vulnerable range of flows for sea trout movements to some extent. For example, in 1984 the number of days with a dmf below 80 MI/d would have been reduced from 82 to 72, and in 1987 from 17 to 6. However, the greater take (up to 50 MI/d peak, 100% take) would increase the number of days that residual flows lay at or close to the prescribed flow, and could reduce the effectiveness of some small summer spates around the apparent critical dmf level of 250 MI/d. Thus the Base Case operating rules should represent a minor improvement in sea trout fishing in very dry years, but a minor deterioration in salmon angling. Little or no effect upon stocks is foreseen.

Because of the significant problems facing the Torridge, in which residual flows below Torrington play an important part, the changes from the Base Case to

the Environmental Case are greater here than on the other rivers. The changes are:

- considerably higher prescribed flows when Roadford storage allows (200 MI/d in Zone A, 150 MI/d Zone B) with Zone C p.f. remaining at the Base Case level of 80 MI/d.
- a spate sparing rule.

Overall, it is considered that the Environmental Case removes the limited adverse impact that the present operation has on sea-trout movements at very low flows, while itself having minimal impact. It is considered that there is scope for further fine tuning of operating rules on the Taw and the spate sparing rules on the Torridge to optimise the proposals for the latter river.

4.3.7 River Taw

The Taw is unique among the Devon rivers in having major headwaters on both Exmoor and Dartmoor. Like the Torridge, dry summer base flows are low compared to the average flow and runs of both salmon and sea trout are adversely affected at such times. The spring run of salmon, still fairly plentiful though considerably depleted compared to thirty years ago, enters the river on the prevailing high flows up to the end of April. Good catches from then on are dependent on elevated flows in excess of about 250 MI/d (see Figure 20). Fishing was therefore poor in, for example, 1984, when only a single spate of effective proportions occurred between the end of April and late September. In average and wet years sea trout catches are consistent and build to a peak in late July. In dry years, however, catches are poor and only improve after flow events exceeding about 100 MI/d.

The Base Case assumes a continuation of the existing temporary licence to take up to 17.5 MI/d at Newbridge, subject to a prescribed flow of 195 MI/d at Umberleigh. The effects of this operation are considered minimal in view of the small take and high p.f.

Operating rules for the Environmental Case were basically designed to ease the load on the Torridge while not causing any significant deterioration in conditions on the Taw. The lower prescribed flows in Zone B (150 MI/d) and Zone C (104 MI/d) are unlikely to have any significant effect on either salmon or sea trout fishing. The incorporation of a spate sparing rule reduces any theoretical impact on spates of critical size for salmon movement, though this is seen as a minor gesture to a minimal impact.

It is likely that some further adjustment of the Taw operating rules will be proposed to balance the impact on the Torridge, but these are unlikely to change the implications for the Taw to a significant extent.

4.4 Ecology

4.4.1 Introduction

The assessment of the impact of Roadford on ecological interests needs to consider freshwater reaches of the Tamar, Tavy, Plym, Dart, Torridge and Taw catchments, six estuaries, the Devonport Leat, as well as three reservoirs. Sixteen areas of potential impact have been identified and a brief assessment of existing interests and possible affects are outlined in Sections 4.4.2 to 4.4.17. Details are given in Annex C.

The study so far has gathered ecological information for all the rivers, estuaries and reservoirs potentially affected. The data collection has involved consultation with interested local, national, statutory and voluntary bodies with a professional interest in ecology. The requirement has been to ensure that they have been given an opportunity to present for consideration data they hold; the objectives thereafter are to aim to devise operating scenarios which protect the most important habitats and features identified. Scenarios are also considered which offer improvements to degraded sites or ones most at threat.

Data relevant to the investigation have been rather disparate. For some areas affected there are large amounts available whilst for others there is virtually nothing.

For aquatic invertebrates the best source of information has been data collected by the previous Water Authority. They also hold the majority of data on fish. Most other data have come from external sources. The estuaries have been well surveyed in recent years and wildfowl and wader counts are available. River plants have been adequately covered in most of the affected catchments because of either NCC work or specially commissioned surveys by the Water Authority in relation to Roadford. Data on river birds is covered in a general way by a recent DBWPS breeding atlas but greater detail is available through a 1987 survey of breeding kingfishers, grey wagtails and dippers. Unfortunately otters have not been adequately considered thus far because of the recent resignation of the Otters and Rivers Project Officer.

Terrestrial habitats have not been considered in any detail since Roadford operations will not have any material effect on them.

4.4.2 Wolf, Thrushel and Lyd

This section of river faces the greatest potential impacts, both adverse and beneficial, since the valley has been impounded and augmentation releases are planned. However there is also a much better database to predict impacts than in other river or estuary sections.

Although in general this report has not considered the impact of the early years of operation, some mention is made here for the Lyd sub-catchment because it will be affected substantially by the initial impoundment. Effects of hydro-electric generation will not be considered until the next stage of the work.

Invertebrates will be affected considerably since individual taxa respond differently to changes in temperature, flow, substrata, extent of vegetation and water chemistry. In the Wolf the key changes affecting all biota are: minimum flow increasing from 1-9Ml/d, improved water quality, temperature changes, bed stability and its effect on increased plant biomass, increased silt in the early years, and artificially high summer levels when Tamar abstractions are being supported.

Surveys indicate that the invertebrates of the system are typical of similar rivers in south west England. Two regionally important species were found:

- i) The stonefly, *Amphinemura standfussi*; recorded in the middle reaches of the River Wolf and the Kellacott Stream. The operation of Roadford Reservoir should not pose a major threat as it is a summer growing species. However long periods of releases in the Environmental Case might have some impact.
- ii) The caddisfly, *Athripsodes bilineatus*, recorded in the lower reaches of each of the rivers Wolf, Thrushel and Lyd. It is a species which inhabits tree roots and as such will benefit from the increase in minimal flow. This benefit far exceeds any disbenefits which might occur due to releases.

A more constant flow and siltier conditions will characterise the Wolf in the early years of operation. Detrimental impacts on invertebrates will be greatest near the reservoir and affect taxa which require fast flows and clean stones ie *Hydropsychidae* caddis and blackflies (*Simuliidae*). Stoneflies are also generally sensitive to increased siltation and constant flows and are likely to decline. The exceptions will be *Leuctra geniculata*, *L fusca* and *L nigra*. Several taxa are likely to be unaffected or thrive (ie the mayfly *Caenis rivulorum*, the caddis *Polycentropus flavomaculatus*, water-mites such as *Hydrocarina* and bivalve molluscs *Sphaeriidae*). Siltation is considered to be a temporary problem as long as releases are made to flush out accumulated sands and silts within the first 18 months of impoundment. Without this compaction of the sediments will reduce diversity.

When fully operational there will be considerable differences in the Wolf depending on whether the Base or the Environmental Case is adopted. However the differences for invertebrates (and for plants) are minimal compared with the effects resulting from reduced scour and a nine-fold increase in low flows. The following assessments assume no major differences in impacts between the two scenarios unless stated.

The abundance of mayflies could increase downstream of the reservoir but the species diversity will probably be reduced. *Heptageniidae* are the group most likely to suffer; they are negatively affected by high densities of macrophytes.

Leuctridae (stoneflies) and *Elminthidae* (riffle beetles) are characteristic of rivers with irregular flow fluctuations. The riffle beetles live in the interstitial spaces within the substrate and avoid exposure to the full force of the current.

The number and range of taxa collected in tree roots was significantly higher than in the pools or the submerged macrophytes. The compensation flow will increase water depths and increase the surface area of the valuable tree root habitat available to the fauna. Gradual increase in supported releases will result in a maximum depth change of 30cm and this will benefit the majority of the invertebrate fauna.

Filter-feeders will benefit from both increased baseflow and augmentation. Examples include *Hydropsychidae*, *Polycentropodidae* and *Brachycentridae*. For both filter-feeders and species of tree roots the Environmental Case is likely to produce most benefit.

The predicted increase in standing crop of benthic mosses, algae and macrophytes due to the stabilised flow regime will generally be favourable to the invertebrates eg *Oligochaeta*, *Chironomidae*, grazing snails such as *Lymnaea*, the mayflies *Ephemerella ignita* and *Caenis rivulorum*, the caddis *Hydropsychidae* and the shrimp *Gammarus*. However certain taxa will suffer and this change in habitat and flow regime will be detrimental to the filter feeding *Simuliidae* (blackflies) and to *Heptageniidae* (mayflies).

Overall the increased abundance of those species adapted to the new environment would be at the expense of a reduction in species. The probable reduction in species should be restricted to immediately downstream of the reservoir. Although species diversity and abundance may change, the differences between the impacts of the Environmental Case and the Base Case will be minimal.

Although the invertebrate surveys were the most detailed investigations of biota executed, other important surveys have been undertaken.

Surveys of terrestrial habitats in the river corridors of the Wolf, Thrushel and Lyd indicated that few sites of key nature conservation interest abut the rivers. Of those identified, none are regarded as being dependent for their existence on the present regime of the river. As such it is not considered likely that, however operated, Roadford will have an impact on the sites.

The absence of water voles and water shrews make otters the only mammal of note. This important animal uses the rivers regularly. The operation of Roadford is unlikely to have any adverse effect on the otter since the operating regime will not make them more prone to disturbance and other surveys suggest that their food will not be materially affected in the reach as a whole; habitats associated with the reservoir itself may be beneficial providing sufficient effort is made to create them correctly.

Although heron feed in the rivers, the three most important birds of the rivers are the dipper, grey wagtail and kingfisher. The potential impacts on these birds relates to the availability of their food. Dippers are unlikely to be affected and will thrive in the increased summer flows. Grey wagtails might be affected severely in very dry summers when the heavily augmented river will drown their shingle-bed feeding areas. There will be adverse impacts too in normal years if the Environmental Case operates and flows are regularly augmented to a high

degree. In average and wet summers they will benefit. Kingfishers should not be adversely affected since their food should remain available to them and not decrease. However, deeper water, resulting from the operation of the Environmental Case may reduce feeding success. Since the regulated Wolf should not freeze, even in the severest winters, this will provide a very important feeding area when others are unavailable.

Both toads and frogs breed in the river corridor, but only the former breeds in the river. In normal and wet years they will benefit greatly from not being washed downstream whilst in drought years, particularly if the dry period is early in the season, they will be adversely affected -by- being washed downstream. The Base Case would be less damaging.

Botanical surveys of the Wolf, Thrushel and Lyd indicated a paucity of truly aquatic higher plants. Only one bankside plant, Wood Club-rush, was recorded which is relatively rare in Devon. However, although sparse, it is widely distributed and occurs in the Thrushel upstream of the influence of Roadford. An intensive survey of aquatic and bankside bryophytes indicated that the Wolf supports a rich and varied community. Many are characteristic of moist and shaded conditions (oceanic). None are rare nationally but many are confined to western Britain. The regulation effect of Roadford is bound to exert, in time, a major change in the flora of the Wolf. There will be limited changes in the Lyd whilst in the Thrushel changes will be transitional. In general many species will increase in abundance and some new species will invade to take advantage of the more stable environment. Edge bryophytes may be at risk in the Wolf as their previously scoured habitats become vegetated by higher plants. For macrophytes there will be little difference in the Base and Environmental Cases; the main effect will come from impoundment influencing natural spates.

4.4.3 Tamar; Lydfoot to Gunnislake Newbridge

This section of river has received less attention than the Lyd sub-catchment despite the fact that it will be considerably affected by Roadford. Macrophytes generally occur in more diverse communities and in greater abundance than in the Lyd or Torridge. No very rare species have been recorded but the presence of Small Pondweed and the nationally rare alga *Cladophora aegagropila* is noteworthy. Due to its larger size, the non-salmonid fish are thought to be more diverse than in many other local rivers. The grey wagtail is the only bird to breed in large numbers down the river but dippers, kingfishers and sand martins do breed in places. Compensation flow is deemed to have either a minimal beneficial effect or no effect at all. Augmentation releases are, overall, predicted to be beneficial for the general well being of the river because it will improve water quality considerably. However in some very dry years the augmentation may be so great, and for so long, that for those years there may be an adverse effect on coarse fish recruitment and less feeding areas exposed for grey wagtails. By the same token, the Environmental Case will also have greatest affect. The improvements resulting from water quality changes makes this a favourable option.

4.4.4 Tamar from Gunnislake Newbridge to Gunnislake Weir

This short ponded section supports few plants and there is little information on animals. The effect of Roadford should be beneficial due to improved water quality and no change in flow volumes. Greatest benefits would result from the Environmental Case due to greater dilution of 'natural' Tamar water.

4.4.5 Tamar Estuary Downstream of Gunnislake Weir

The principal interest of the estuary is the waders which feed on the mudflats. Avocets and black-tailed godwits are of national importance. It is primarily because of the birds that the section of estuary from Tamar Bridge to Gunnislake Weir is being considered for notification as a SSSI. For the same reasons given in 4.4.4, any effects from Roadford's operation are likely to be beneficial.

4.4.6 Tavy downstream of Lopwell

The Tavy estuary has some ornithological interest but this is not dependent on enhanced river flows. At times the mudflats are used by avocets, a bird which has made the Tamar famous amongst ornithologists. For this reason, primarily, the estuary is being considered as a SSSI. Despite this it is not suggested that Roadford's operation will have material effects on the biota. Roadford's operation, through the partial buy-out of Morwellham hydro-electric generation, provides much improved flows in the Tavy.

4.4.7 Burrator Reservoir

Botanically the reservoir is best known for the carpets of Shoreweed which occur along its margins and for the presence of Quilwort. Its ornithological interest is limited; few passage birds or waders use the margins but goosander now have their main roost in Devon established here. Greater draw-down will have some effect potentially putting at risk the extent of Shoreweed and the Quilwort. The winter roost of the goosanders should not be affected since it is planned to have the reservoir spilling by late autumn.

4.4.8 Meavy and Plym downstream of Burrator

The Plym estuary has some wader interest but poor wildfowl. Grey wagtails and dippers breed successfully down the whole of the Meavy and Plym whilst kingfishers breed only in the lower Plym. The Plym has an exceptionally noteworthy breeding duck, the mandarin. Botanically the Meavy is most interesting with its very luxuriant growth of rooted macrophytes and unusual community structure. The presence of Filmy Fern in the wooded banks below Burrator is noteworthy. Invertebrates indicate a very clean system in the Meavy with this quality of water helping to improve the Plym. Although spilling from Burrator may change to some degree, the maintenance of intermittent spilling and the existing compensation flow will ensure that neither the interest of the river nor the estuary are affected.

4.4.9 Dart Downstream of Littlehempston

A very short stretch of freshwater river will be affected below the intake, but the main area of potential impact is the estuary. The surveys and literature reviews of OPRU (1988) (see Annex D) concluded that neither the habitats nor the species of the Dart estuary are diverse or special. Wader and wildfowl data also suggest that the estuary affected by river flows is not special but a good range of species is counted regularly. No details of plants and animals in the short stretch of fresh water river above Totnes Weir are available. The impact of the Base Case is to increase the take from the river during moderately low flows so that about a third of the water will be abstracted when flows are in the order of 150-250 MI/d. Under very low flows there is an improvement. The Environmental Case reduces considerably the take in the moderately dry periods. There is no reason, apart from maintaining water quality, to suggest that the latter option is an ecological priority.

4.4.10 Devonport Leat

Little is known about the biota of the leat, but the information available suggests that it does not support anything special. Providing some flow and reasonable levels are maintained, no adverse impacts are expected.

4.4.11 Meldon Reservoir

This has little known animal or plant interest. As such, therefore, greater usage of it for water supply is not deemed harmful.

4.4.12 Okement Downstream of Meldon

Biota of special note have not been reported from the Okement. Periodically, after drought periods, acid runoff containing high levels of some metals occurs and causes fish and invertebrate mortalities. These events have far more significance for river biota than anything which is planned in terms of water resource changes. Ways in which water in Meldon could be handled to protect the river biota might be considered.

4.4.13 River Torridge from Okement to Taddipport Bridge

This section of river has been shown to support few river plants due to the instability of the bed. A hybrid Pondweed occurs in the river in this section; in south west England it is confined to the Torridge. Kingfishers, dippers, grey wagtails and sand martins all breed along this section of river. Some invertebrates occur here which are rare locally. The potential for adverse or beneficial impact is minimal.

4.4.14 River Torridge from Taddipport Bridge to Beam Weir

This short section of the Torridge has reduced flows due to abstraction of water at Torrington; it also receives effluent outfalls. Nothing of special note has been reported although Small Pondweed has recently been recorded. The channel flora is dominated by filamentous algae and there are indications that

this is due to water quality changes. This section of river has, for a long time, been subject to major abstractions with a very low prescribed flow in relation to mean discharge. Roadford provides an opportunity to reduce abstractions as flows approach the prescribed flow. Since base flows are so small in this river compared with average flows, any improvement will be desirable. This section of river appears to be the one which requires most support to improve the general environment for river biota. The Base Case proposes to improve conditions for biota under low flows but makes things worse during moderately low flows. Thus for a year such as 1987 abstractions would be greater in the future and dilution of effluents much reduced for virtually the whole of the summer. For a year such as 1984 an improvement would occur for at least half the summer period. The Environmental Case provides very significant improvements in dilution for both low and moderately low flows. As such it is likely to reduce the occurrence of smothering blanketweed algae in this section of river. Its benefits cannot be overstated and this element of the Environmental Case deserves highest priority for adoption.

4.4.15 Torridge Estuary Below Beam Weir

The greatest interest is centred on the winter waders of the estuary. The Taw-Torridge estuary is a SSSI. In the section of tidal (but freshwater) river below Beam Weir the rare hybrid Pondweed is also present. It is unlikely that the effect of the operation of Roadford will be detected in the most interesting areas of the estuary. However any improvements to water quality will reduce the risk of adversely affecting the invertebrates of the mud flats on which the birds feed.

4.4.16 Taw Estuary Below Newbridge

Apart from the birds of the open estuary and the salt marsh communities of plants, little is known about the biota of the upper estuary most affected by freshwater flows. The Taw-Torridge Estuary is a SSSI; however the main area of interest is well down from the upper tidal limit so that little effect is expected from Roadford. Both the Base and Environmental Cases would result in similar abstractions from the Taw as takes place now under the temporary licence; however since the river has such a high prescribed flow and a relatively small take abstractions are likely to be virtually undetectable.

4.4.17 Roadford Reservoir

The reservoir is now filling and already attracts reasonable numbers of wildfowl. Surveys through the winter 1989/90 suggest it will be of regional importance. Habitat improvements and a quiet area for wildlife are planned. Depending on the extent, and successful implementation of these, the impacts of various operating scenarios will be different. A clearer picture should be available for assessment in the Final Report.

4.5 Recreational Use of Reservoirs

4.5.1 Roadford Reservoir

Roadford reservoir will have a surface area of 300 hectares when it is full. It will be the second largest area of inland water in the south west region, surpassed only by Colliford lake on Bodmin Moor with an area of 360 hectares. At the Public Inquiry In 1980, the Inspector's Report indicated that initially provision would be made only for a few recreations compatible with the rural character of countryside, such as fishing, walking and passive enjoyment of the lake's special character. Therefore, initial provision of recreational facilities would be limited car parking together with some toilet facilities. Footpaths are to be established around the waters edge when the reservoir is full as shown on Figure 21. A brown trout bank fishery is planned. Assuming initial stocking takes place in the autumn of 1991, the fishery will open in the spring of 1993.

Following the 1980 Public Inquiry, the Roadford Water and Land Use Consultative Group (RWLUG) was formed to advise the water authority on recreational use. Recently the Company has employed the Pleda Consultancy to provide a strategy for recreation and leisure development at Roadford, but the findings of their work are not yet available. It is intended that any development would be of the highest quality in keeping with the atmosphere and environment of the site. Draft proposals are to be discussed with the two district planning authorities and the RWLUG.

Simulated drawdown of the reservoir with the scheme operating at its ultimate capacity is shown in Hydrograph 1. The amount of drawdown for the Base Case and Environmental operating rules are compared in Table 7 below.

Table 7
DRAW-DOWN OF ROADFORD RESERVOIR

Year	Operation	Minimum Storage (%)	Draw-down Depth (m)	Minimum Area (ha)
1984	Base Case	42	9.0	175
	Environmental Case	41	9.1	173
1987	Base Case	90	1.8	277
	Environmental Case	82	2.9	265

It can be seen that the main effect of the Environmental Case is to increase the amount of drawdown in typical years by about 1m. The consequences of this for possible recreational uses would be:

- (i) Some unsightly shoreline would be visible. For recreational developments this effect could be reduced by siting accommodation with a view mainly of the water body rather than the shoreline.

- (ii) For people using the cycle track there would be more temptation to cycle by the water's edge. This effect could be reduced by good sign boards.
- (iii) For sailing, rowing and canoeing the water would be typically about 50 metres further away and there would be wider bodies of exposed mud in creeks. Access to the water could be improved by siting slipways in a location least affected, possibly with floating pontoons and steps. The potential danger of the exposed mud could be reduced by restricting the sailing area for beginners.
- (iv) For trout fishing, experience at Wimbleball reservoir suggest that the increased drawdown may reduce the number of anglers wanting to fish, but that the average catch per rod would be unaffected.

In a dry year such as 1984, the amount of drawdown in the reservoir would be approximately the same for either the Base Case or the Environmental Case.

It is concluded that the effects of the increased drawdown for the Environmental Case would be comparatively minor and would not prejudice the role of Roadford as a centre for recreation.

4.5.2 Recreational Use of Burrator Reservoir

Burrator reservoir has a surface area when full of 60 hectares. There is no designated public area in the vicinity of the lake, but there is general access to over 2,000 hectares of land with good access by paths. Six small car parks accommodate 40 cars with 200 additional spaces in informal parking areas. The area of the lake is used mainly for casual recreation by walkers and sightseers. Horseriding takes place on the open moorland and various tracks. Bird watchers have access to 5km of shoreline. There is a low key bank fishery for trout. Diving, canoeing and climbing licences are issued occasionally and there are one or two orienteering events held annually. There are no regular boating activities on the lake and the local people are resistant to such proposals.

Burrator reservoir is at present heavily used for recreation. There are about 800,000 visitors each year. This is more than twice the number at any of the other Company's sites. About 3,000 visits are for birdwatching and 2,000 to 4,500 for the trout fishing.

The effect of the possible change in operating rules on drawdown in the reservoir is shown on Hydrograph 5 and in Table 8 below.

Table 8
DRAW-DOWN OF BURRATOR RESERVOIR

Year	Operation	Minimum Storage (%)	Draw-down Depth (m)	Minimum Area (ha)
1984	Historic	51	4.0	45
	Base Case	18	8.2	24
	Environmental Case	13	9.0	21
1987	Historic	58	3.4	47
	Base Case	36	5.6	38
	Environmental Case	30	6.6	32
1989	Historic	37	5.5	39

It can be seen that the amount of draw-down would be very similar for either the Base Case or the Environmental operating rules, but for both the amount of draw-down would be substantially more than took place historically in 1984 and 1987 and would be worse than the 1989 draw-down level of 37%.

The experience of 1989 suggests that draw-down does not significantly affect the number of people visiting the reservoir nor the number of trout fishermen. However, for a very dry year like 1984, for either set of operating rules the draw-down would be about 3m more than actually took place in 1989, reducing the water surface area to just 21ha as compared with the 1989 minimum of 39ha (see Figure 22). Clearly there is a danger that the greatly increased draw-down in Burrator reservoir in both typical and dry years would in the long term deter recreational use of the area. Bearing in mind that Burrator is a much smaller reservoir than Roadford, it should be possible to adjust the scheme operating rules so that draw-down in Burrator in non-drought years remains similar to that which takes place at present, with the water required being drawn instead from Roadford. Adjustment to the operating rules will be considered further in the next stage of the study.

4.6 Operating Costs

4.6.1 Calculation of operating costs

The annual average operating costs for the scheme can be calculated using the Company's computer program PG413. The program includes the cost of pumping the raw water to the treatment works, the treatment costs at Crownhill and Roborough WTW's and the benefit of hydro-electric generation from Burrator and Roadford.

in the Base Case there would be potential to make specific releases from Roadford for hydro-electric generation during the winter months in wetter years when there would be spare water in Roadford. With the current SWEB tariff structures, there would also be greater financial benefit by generating during the winter months. However, for the purpose of this report the Base Case runs have not included these specific hydro-electric releases and hydro-electric power has only been generated on Roadford compensation releases, water supply/fisheries releases and spill water.

The treatment costs for Crownhill and Roborough WTW's have been included because this is where there is greatest cost difference depending on the type of water that is being treated. Tamar/Roadford water is more expensive to treat than River Tavy water, which is more expensive than Burrator water.

More details of the calculations are given in Annex A.

4.6.2 Effect of Environmental Case on Operating Costs

The annual average cost of running the scheme under the Environmental Case set of operating rules is on average about £31,000 per year higher. Increased costs occur in the wet and typical years when Roadford reservoir is in Zones A and B - the higher prescribed flows on the rivers force more water to be taken from Roadford and hence give increased pumping and treatment costs. Some of these increased costs are offset by the hydro-electro generation from the extra Roadford releases; these have been included in the calculation.

In very dry years such as 1984 the operating costs are lower with the Environmental Case. When Roadford reservoir falls into Zone C, lower prescribed flows are set on the Tavy and Dart so less water will be pumped at Gunnislake and across to SW Devon.

If there are specific releases from Roadford for hydro-electric generation or the value of hydro-electric power changes then the cost difference is likely to be higher.

5. CONCLUSIONS

5.1 Preliminary Environmental Impact Assessment

5.1.1 Impact on the River Tamar

- i) During the summer flows in the Tamar system between Roadford and Gunnislake would generally be increased by releases from Roadford reservoir. In most years these releases would be slightly larger and of longer duration for the Environmental Case than for the Base Case. In a very dry year the situation would be reversed.
- ii) The effect of the flow increases due to regulation will be generally beneficial to water quality, ecology and angling conditions. It is likely that the change in summer flow regime will have some effect on the distribution of species of flora and fauna but no adverse effect on the overall biomass.
- iii) When regulation releases from Roadford are being made, there would be an increase in flow of up to 9 MI/d at times, below Gunnislake due to the additional release for compensation water. It is doubtful whether this 9 MI/d increase below Gunnislake is a good use of the water in environmental terms.
- iv) Unsupported abstractions at Gunnislake are confined mainly to the spring. There would be a slight reduction in flow below Gunnislake at these times. The reduction would be somewhat less for the Environmental Case in most years.
- v) The slight reductions in flow below Gunnislake are not expected to have any adverse impact on water quality, fisheries or ecology.
- vi) The proposed use of the fisheries bank is to make two freshets of 600 MI each in July and August each year. The timing of the freshets would be aimed to attract fish into the freshwater river to prevent a build-up of fish at times of poor water quality in the estuary. This benefit would be felt equally for the Base Case and the Environmental Case.
- vii) The introduction of a spate sparing rule for the Environmental Case would provide an improvement in conditions for salmon migrating into the river, compared to the Base Case.

5.1.2 Impact on the River Tavy

- i) The Base Case operating rules would lead to a substantial increase in low flows below Lopwell due to:
 - the reduction in hydro-electric transfers to Morwellham
 - an increase in the Lopwell prescribed flow from 41 to 73 MI/d
 - avoiding the need for drought orders.

- ii) The reduction in hydro-electric abstraction at Tavistock will benefit the river below Tavistock in terms of water quality, ecology, fisheries and angling conditions.
- iii) The main adverse impact of the scheme lies in abstraction of medium flows (in the region of 200 to 500 MI/d) when the water supply abstraction would be superimposed on the existing hydro-electric abstraction. This has its greatest potential fisheries impact during summer, by reduction of high base flows in wet years and depletion of spates in dry years.
- iv) Further improvements to the River Tavy fishery could be obtained by limiting the netting in the upper estuary below Lopwell dam and by further reducing the Morwellham hydro-electro abstraction, so that it takes place only during the winter months.
- v) The Environmental Case will give some improvement to migration conditions for salmon although further refinement of the proposed spate sparing rules is necessary.
- vi) The occasional reduction under the Environmental Case of the prescribed flow to 41 MI/d when Roadford is in Zone C will have no significant adverse effect.

5.1.3 Impact on the River Plym

- i) The operation of the Roadford scheme will generally allow Burrator reservoir to spill in the autumn up to several weeks earlier than takes place at present. However, there would continue to be frequent short periods in the autumn when the reservoir was not spilling. This applies equally to the Base Case and the Environmental Case. The impact on the river flows and fisheries of the Plym system is, therefore, that the benefits of the earlier spilling are offset to some extent by the subsequent unreliability of spillage. There is some scope for further development of operating rules to optimise the situation in fishery terms.
- ii) There is scope for further improvement in the Environmental Case by revising the rules to ensure that adequate spilling continues through the critical period of salmon migration and spawning in the late autumn and winter. Alternatively, releases could be made through the reservoir draw-off systems.

5.1.4 Impact on the River Dart

- i) The Base Case will give a substantial improvement to the flow regime in the river Dart due to:
 - the introduction of a prescribed flow on the abstractions to the Devonport Leat from the headwaters of the Dart; this will increase summer flows throughout the river between the abstraction point and Littlehempston;

- application of the prescribed flow at Littlehempston to all water supply abstractions from the river;
 - raising of the prescribed flow at Littlehempston from its present level of 68 MI/d to 122 MI/d.
- ii) The introduction of the prescribed flow to the Devonport Leat abstraction will benefit the nursery conditions for young fish below the abstraction point and will also give a slight improvement in angling conditions in the River Dart.
 - iii) During the spring, abstraction will generally cause a slight reduction in flows below Littlehempston to below their historic levels. At most other times the flows with the scheme in operation will be significantly greater than historic flows.
 - iv) The changes in the flow regime below Littlehempston are not expected to have any significant impact, either adverse or beneficial, on fisheries, ecology or water quality.
 - v) Under the Base Case, the peaks of some minor summer spates are reduced by abstraction. This would probably have some adverse effects on the migration of salmon. There would be some improvement in this situation by the adoption of the Environmental Case spate sparing rules, but further work on the rules is needed to get full benefit from this.

5.1.5 Impact on the River Torridge

- i) For both the Base Case and the Environmental Case there is some improvement in very low flows due to:
 - increased compensation flow from Meldon
 - raising the Torrington prescribed flow from 68 to 80 MI/d
 - obviating the need for drought orders.
- ii) At other times with the Base Case, flows will be reduced to significantly below historic levels, mainly during the spring and early summer. This is likely to have an adverse effect on water quality, ecology and migration of salmon and sea trout. In view of the present tenuous state of the Torridge fishery, this effect is considered to be highly undesirable.
- iii) With the Environmental Case, flows below Torrington would be greater than historic flows at almost all times in the spring and summer. This will give a substantial improvement over Base Case conditions and some improvements on the existing situation.

- iv) The spate sparing rules incorporated in the Environmental Case would avoid abstraction during some minor spates, but further refinement of the rules is needed.

5.1.6 Impact on the River Taw

- i) Both the Base Case and the Environmental Case assume that the existing temporary arrangements for abstraction of 17.5 MI/d from the river Taw are made permanent.
- ii) The adoption of comparatively high prescribed flows for the Taw means that the effect on river flows, water quality, fisheries and ecology are minimal. This applies equally to the Base Case and the Environmental Case.

5.1.7 Impact on Draw-down of Roadford Reservoir

- i) Draw-down under the Environmental Case would be more than the Base Case in most years but would not be to the extent that would have any significant impact on recreational use of the reservoir.
- ii) In view of the above, there would be scope for making more use for the water stored in Roadford in non-drought years for the possible benefit of rivers or for hydro-electric generation.

5.1.8 Impact on Burrator Reservoir

- i) Under both the Base Case and the Environmental Case annual maximum draw-down of Burrator reservoir would be substantially greater than historic levels and, indeed, would be more than the maximum draw-down experienced during the drought of 1989.
- ii) The level of draw-down experienced in 1989 does not appear to have influenced the numbers of visitors to Burrator nor had any adverse effects on specific recreational activities. Nevertheless, this amount of draw-down on a regular annual basis would probably have an adverse impact on recreation in the long term.

5.1.9 Impact on Operating Costs

- i) The adoption of the Environmental Case operating rules would increase the annual average operating cost from £623,000 to £654,000. This represents an increase of £31,000 or 5% of the annual average operating costs.
- ii) The above conclusion does not take account of potential hydro-electric benefits from Roadford. These are likely to increase the additional operating costs associated with the Environmental Case.

5.2 Conclusions on the Operating Rules

5.2.1 The Base Case

- i) The Base Case operating rules include a number of features which will lead to environmental improvements:
 - the use of the fisheries bank for freshets should reduce the danger of fish mortalities in the Tamar estuary;
 - reduced hydro-electric abstraction for Morwellham will improve conditions in the River Tavy;
 - the increased prescribed flow at Lopwell will benefit the Tavy;
 - the prescribed flow on the Devonport Leat abstraction will benefit the River Dart throughout its length;
 - the higher prescribed flow at Littlehempston will benefit the Dart;
 - the higher prescribed flow at Torrington will benefit the Torridge;
 - the presence of Roadford will obviate the need for potentially damaging drought orders on the Rivers Tamar, Tavy, Dart and Torridge.
- ii) Despite the improvements listed above, the Base Case will still have a number of adverse impacts:
 - abstraction of water during minor spates is likely to affect migration of salmon on the Rivers Tamar, Tavy, Dart and Torridge;
 - abstraction at times of low flow is likely to have a major adverse impact on the fisheries, ecology and water quality of the River Torridge and, to a lesser extent, the Rivers Dart and Tavy;
 - the amount of draw-down in Burrator reservoir will generally exceed 1989 levels and could adversely affect recreational use of the reservoir.
- iii) It is concluded that the Base Case whilst incorporating many features designed to reduce environmental impact does still include some effects which could be avoided by careful design of operating rules.

5.2.2 The Environmental Case

- i) The Environmental Case would allow a number of improvements over the Base Case operating rules:

- spate sparing rules would reduce the potentially damaging effect of abstraction during minor spates in the summer; however the rules considered to date still leave some room for improvement
 - the adoption of higher prescribed flows dependent upon the state of Roadford reservoir will have a substantial benefit to the River Torridge and a lesser benefit to the Rivers Tamar, Tavy and Dart.
- ii) The proposed abstraction rules for the River Torridge would avoid the potential major adverse effects of the Base Case on water quality, ecology and fisheries and would in fact lead to some slight improvements over present conditions.
 - iii) For the thirty one years of simulated operation of the Environmental Case Roadford reservoir storage would fall into Zone C in 3 years; 1959, 1976 and 1984. The prescribed flows in Zone C, which are lower than for the Base Case would be applicable at times of natural low flows and indeed at times when historically some much lower prescribed flows would have been applied through drought orders. No adverse effects of the lower Zone C prescribed flows are anticipated.

5.2.3 Potential for Further Improvements

- i) The proposed Environmental Case would preserve the advantageous aspects of the Base Case while reducing some of its adverse effects.
- ii) Further refinements are needed to the spate sparing rules to make them more effective in protecting spates which are of significance to fisheries.
- iii) There is scope for making more use of Roadford storage in non-drought years for the benefit of the rivers and to reduce the amount of draw-down in Burrator, or for generating hydro-electric power.
- iv) The present arrangement of continuing to release the full 9 MI/d of compensation water from Roadford in addition to regulation releases should be reviewed to see if an alternative use which is more beneficial to the environment can be found.

5.3 Recommendations for Further Work

- i) To date the study has concentrated upon finding the best operating rules for when the scheme is working at its ultimate capacity. Further work on refinement of these rules is recommended as described in section 5.2.3 above.
- ii) In the next stage of the work emphasis should be turned to the operating rules during the early years of scheme operation. Here there is scope for:

- further improvements for the benefits of the rivers and their fisheries
 - optimising benefits from the hydro-electric generation whilst avoiding adverse environmental impact
- iii) Following the work on refining the operating rules for the scheme as in i) and ii) above, the terms of a reservoir operating agreement should be proposed.
- iv) The next stage should include the development of recommendations for environmental monitoring.
- v) Consultation on the findings of this report with riparian owners, nature conservation interests and staff of the Company and the NRA will be of paramount importance during the next stage.

Appendix A

Terms of Reference

APPENDIX A

ROADFORD RESERVOIR OPERATIONAL AND ENVIRONMENTAL STUDY

TERMS OF REFERENCE FOR CONSULTANCY SERVICES

1. INTRODUCTION

The operation of the Roadford scheme will affect the rivers Tamar, Tavy, Torridge, Taw, Plym and Dart. The environmental impact of the scheme will depend upon the priority given to the various sources of abstraction and the operating rules adopted. The drought reliable yield of the scheme and its operating costs will depend upon these same factors. An investigation is needed to address the inter-relationship between the environmental impact of the scheme and its drought reliable yield and operating costs.

The objectives of the Roadford Operational and Environmental (ROE) Study are:

- i) Assessing the environmental impact of the scheme.
- ii) Deciding upon the priorities for abstraction and the operating rules for the scheme.
- iii) Obtaining the optimum balance between environmental impact and operating costs.
- iv) Proposing the terms of a Reservoir Operating agreement.
- v) Making detailed recommendations for environmental monitoring once the scheme is commissioned.

2. TECHNICAL STUDIES

2.1 General

The Operational and Environmental Study should be an iterative process involving:

- setting of operating rules;
- simulation of scheme operation and determination of its effect on river flows and operating costs;
- assessment of impact on water quality, fisheries and ecology;
- consultation with SWW staff (both NRA and Plc) and with outside interested parties;
- revisions to operating rules;
- simulation of operation, and so forth.

In addition to the above study, a programme of field investigations and monitoring will continue. These aspects should be integrated so that the investigations are properly aligned to the proposed scheme operation.

2.2 Operational Modelling

Operational modelling of the scheme should be carried out using the Authority's existing PG300 model.

The first priority of the operational modelling should be to investigate the drought reliable yield of the scheme and its dependence upon the priorities for abstraction from each potential source and the individual abstraction rules adopted in each case. The effects of varying the prescribed flows and percentage takes at each of the abstraction points should be investigated. The best method of operation of the scheme at its ultimate output should then be determined using the iterative process described in Section 2.1 above. Once the overall operating strategy for the scheme at its full output has been determined, its operation should be considered in detail for a number of stages of scheme development:

- i) During first filling of the reservoir.
- ii) After first filling but before the demands reach the drought reliable yield.
- iii) At the drought reliable yield.

The level of investigation for these various stages should vary. A detailed working plan for the operation of the scheme during first filling is needed as soon as practicable. The subsequent stages can be investigated in progressively less detail, although some consideration should be given to each stage so that its possible influence on earlier operating strategy can be assessed. At each stage the various factors likely to influence the environmental impact of the scheme need to be taken into account.

Operational studies of the filling process should address inter alia:

- the undertaking that no abstraction will be made at Gunnislake during the filling process;

- timing and magnitude of releases for fishery purposes; this may be influenced by lake water quality predictions;
- the date at which hydro-electric generation can commence;
- the ability of the partially filled reservoir to meet drought demands;
- the influence on planned recreational use of Roadford and Burrator reservoirs;
- filling control rules to govern the use of the reservoir for water supply and power generation, taking account of the probabilities of refill.

Once the reservoir has filled, its operation should strike a balance between minimising operating costs and maximising environmental benefits. The issues to be considered should include:

- hydro-electric power generation and its influence on river flows and reservoir levels; this will effect ecology, fisheries and recreational use;
- use of the spare capacity at Roadford and the fisheries reserve to reduce the impact of abstractions at Gunnislake, Lopwell, Torrington and the Dart system.

Once demands have reached the reliable yield of the system, the operating rules should be designed to allow the scheme to produce its full yield under drought conditions. Control rules should be derived to strike the correct balance between operating costs and environmental impact under non-drought conditions. The issues will be similar to those outlined above for the early years of reservoir operation.

2.3 Water Quality Investigations

Although the impact of the scheme upon the River Tamar, and in particular upon the Tamar Estuary, is expected to be minimal, it is nevertheless required that the ROE Study should examine these effects.

The objectives of the present study, with regard to water quality, should be as follows:

- i) To predict changes in water quality in those rivers and estuaries which are likely to be affected, and to comment on the significance of these changes, as part of the Environmental Impact Assessment;
- ii) To consider how these changes and their impact may be minimised by the adoption of appropriate operating rules;
- iii) To consider the level of monitoring which would be appropriate to the continued assessment of these changes, and to recommend a suitable monitoring programme.

The unusually low rainfall in the South West Water region in 1989 has led to the development of a drought situation. A programme of intensive monitoring of flow, chemical and biochemical quality, and ecology is currently being proposed, which will generate a substantial database of conditions under low river flows. The water quality investigations should be based on an analysis of this data supplemented with calculations made using an analytical method for performing statistical mass balance calculations by combining distributions. The need for numerical modelling should then be assessed.

2.4 Fisheries

There are two distinct but inter-dependent aspects of the fisheries investigation. One is the ROE Study; the other is the continuing monitoring and development of EIAs and operating rules.

The ROE Study should include the following:

- i) Analysis of the existing data obtained for the Tamar catchment by the Roadford Fisheries Investigation Team, and other relevant data held by the Authority.
- ii) Analysis of existing data held by SWW on the Rivers Tavy, Plym, Torridge, Dart and Taw, to the extent that they are relevant to the scheme operation.
- iii) Preparation of initial environmental input assessments based upon i) and ii) above, for the scheme operation as currently proposed.
- iv) Preparation of recommendations for modification to the scheme operating strategy, and proposals for scheme operating rules, to minimise any adverse impacts identified by iii) above.
- v) Preparation of a final EIA for each river affected based upon the modified operating strategy being recommended.
- vi) Recommendations for future fieldwork on each affected river, to further identify likely impact, to monitor effects of the scheme, and to provide a basis for mitigation.

- vii) Recommendations for action to mitigate for the impact of the scheme.

2.5 Ecology

The ROE Study should include an assessment of the impact of the scheme on ecology. This should involve:

- i) A thorough assessment and analysis of all the data which has been collected in recent years.
- ii) Discussion with specialists and a review of available literature on the impact of impoundment and river regulation on aquatic life.
- iii) An impact assessment for the Tamar based on predicted changes in flow and water quality, the analysis of ecological data in i) above and the literature review in ii) above.
- iv) Proposals for modification of the scheme operating rules on ecological grounds.
- v) Preliminary EIA's for the other rivers and estuaries affected and recommendations for further studies in these areas.

2.6 Recreation and Amenity

2.6.1 Introduction

To-date the environmental studies undertaken for Roadford Reservoir have not addressed the potential recreational use of the

reservoir in any detail, nor have they considered how the operating strategy for this reservoir might affect the existing recreational use of Burrator Reservoir.

The ROE Study should examine the effects of the scheme on:

- the potential amenity and recreational use of Roadford Reservoir;
- the existing and potential amenity and recreational use of Burrator Reservoir;
- the existing and potential recreational use of the rivers affected by the scheme, namely, the rivers Tamar, Tavy, Torridge, Taw (possibly), Plym and Dart.

The specific objectives of this part of the study should be:

- to set out the amenity/recreational parameters which should, as far as possible, be taken into account when formulating the operating rules for Roadford Reservoir;
- to evaluate the recreational constraints imposed and opportunities offered by the final agreed operating rules which will need to ensure a viable scheme which balances all environmental needs, not just of Roadford Reservoir, but also of Burrator Reservoir and the rivers affected.

Base data gathering should be undertaken with the aim of establishing:

- the existing amenity and recreational context and value of Burrator Reservoir and affected rivers;

- the recreational context of Roadford Reservoir;
- demands for new recreational facilities covering water-based recreation, informal land-based recreation and existing and potential tourist needs.

Statistical data on the existing use and popularity of Burrator Reservoir should also be collected. This should be backed by site visits during the remaining summer months to judge the number and distribution of visitors.

Information should also be collected on how recreation use has been managed on other reservoirs with major drawdown.

Using the above data, an outline recreation and tourism strategy should be developed for the two reservoirs.

Following review of the outline recreation and tourism strategy the study should assess the tourism & recreation impacts of the initial operating rules put forward by the study as a whole, including a period of iteration with other team members and SWW staff, ending with identification of the preferred operating rules and associated impacts.

Appendix B

List of Undertakings

APPENDIX B
LIST OF SWW UNDERTAKINGS

SOUTH WEST WATER

CHIEF EXECUTIVE'S COMMITTEE - 2 DECEMBER 1988

ROADFORD SCHEME - UNDERTAKINGS GIVEN IN RELATION TO FISHERIES MATTERS

REPORT OF HEAD OF ADMINISTRATION

During the promotion of the Roadford Scheme, and at the time of the Public Inquiry, a number of undertakings were given to organisations and individuals representing fisheries interests in respect of the construction and operation of the reservoir. In the ten years which have since elapsed, the proposed operation of the scheme has been revised and a new concept - hydrogeneration - has been added. There is now a clear need to revise the undertakings in the light of these new proposals, to amalgamate those which duplicate each other and, if possible delete those which now appear impracticable.

It is therefore proposed to seek the agreement of the Roadford Fisheries Liaison Committee at their meeting on 13 December 1988 that the attached revised set of undertakings (Appendix A) should now replace the original undertakings (see Appendix B).

ROADFORD - PROPOSED NEW UNDERTAKINGS

<u>REFERENCE NO</u>	<u>NEW UNDERTAKING</u>	<u>REPLACING UNDERTAKING</u>
1	<p>COMPENSATION WATER</p> <p>Compensation flows of 2 mgd will be discharged to the River Wolf below the dam at all times irrespective of whether water is being discharged for ultimate abstraction at Gunnislake or not. This compensation water will form part of the prescribed flow at the intake.</p>	2
2	<p>RELEASES</p> <p>(a) Releases and abstractions will be phased in and out to eliminate sudden fluctuations in river level and to cause as little damage to fisheries and disturbance to fishing as possible within the operational limits of the scheme.</p> <p>(b) Discussions to be held with the Tamar and Tributaries Fishing Association to reach agreement as to the best use of the 500 mg in the reservoir for fisheries purposes.</p>	3,4,7(A),7(B), 10(B),25,4/51/V
3	<p>WATER QUALITY</p> <p>Equipment has been installed immediately downstream of the dam and water quality is being, and will continue to be, monitored to ensure water quality is maintained.</p>	6(B),7(C)
4	<p>HOTEL INDUSTRY</p> <p>Everything possible will be done by the Authority to minimise damage to the local hotel industry and its links with fishing.</p>	5
5	<p>FISHERIES MITIGATION</p> <p>The Authority will compensate for lost fisheries production (both salmon and sea trout) by means of a fish rearing programme, details of which will be submitted to the Roadford Fisheries Liaison Committee.</p>	7(C),8,9,16, 21,22
6	<p>ELECTRONIC FISH COUNTERS</p> <p>(See separate report)</p>	1,11(A),4/51/D
7	<p>PRESCRIBED FLOW - RIVER TAMAR</p> <p>For a period of ten years from the first certification of the reservoir, the Authority</p>	10(C),13(A),4/51/

a 105 mgd prescribed flow at the abstraction point at Gunnislake. Thereafter, before any changes are made in that flow, they will apply to the Secretary of State for a formal variation in the abstraction licence to drop the prescribed flow by 1 mgd from 54 to 53 mgd. It is recognised that this is a device whereby discussion of the proper prescribed flow can be brought before the Secretary of State for consideration.

8

ABSTRACTION AT GUNNISLAKE

13(B), 23, 4/51/9

No abstraction will take place at Gunnislake at less than the prescribed flow unless a corresponding release has first been made from the reservoir. Effective screens will be provided at the intake point to prevent fish losses.

9

ROADFORD FISHERIES LIAISON COMMITTEE

13(D)

The terms of reference of the Committee are as follows:-

- (a) To consider and advise the Authority upon any programme or scheme of investigation into the effects on the fisheries of the region of the Roadford scheme and to advise on actions and policies as a result.
- (b) To consider and advise the Authority prior to the implementation of any proposals for varying the abstractions from the relevant rivers dependent upon the Roadford scheme.
- (c) To consider and advise the Authority on the best disposal of the water held in the Roadford Reservoir and identified as being for fishery purposes.
- (d) To consider and advise on any aspect of the scheme and its operation during construction and after completion of the dam which could have an effect on the well-being of fisheries.

10

RIVER TORRIDGE

11(B), 11(C), 4/51

- (a) Full consultations will be held with all parties affected by the changes to the scheme relating to the River Torridge.
- (b) Effective screens will be installed and maintained at the Torridge intake so that there will be no loss of smolts or other fish at this point.
- (c) The Authority will continue with its programme to rehabilitate the River Torridge.

- 11 DEVONPORT LEAT 15
The Authority is committed to setting prescribed flows on the Devonport Leat intakes as soon as Roadford water is available.
- 12 FISHERIES INVESTIGATIONS 26
The programme of investigations to monitor ~~all~~ aspects of the scheme and to provide information on which to base future decisions will continue. Progress on and revisions to the programme will continue to be reported to the Roadford Fisheries Liaison Committee.
- 13 WATER CONSERVATION 22/35/E
The Authority has commenced a programme of leakage control schemes and will continue to investigate water conservation measures.
- 14 ASSURANCES GIVEN ON FISHERIES MATTERS 14
The Authority will not alter, modify or withdraw any of the proposals or assurances or evidence relating to fisheries matters given at the Inquiry or to riparian owners without the agreement of the Roadford Fisheries Liaison Committee.

UNDERTAKING

1. Full consultation with all interests before installing electronic fish counters. Nothing will be done by the Authority which would inhibit the movement of fish upstream.
2. Compensation flows of 2mgd to be discharged to the River Wolf below the dam at all times irrespective of whether water is being discharged for ultimate abstraction at Gunnislake or not. This compensation water to form part of the prescribed flow at the intake.
3. During the early years of the scheme there would be sufficient water available in the reservoir for experimental releases, including the 500mg special reserve for fisheries purposes.
4. Releases and abstractions to be phased in and out to eliminate sudden fluctuations in level.
5. (a) Consideration being given to reserving the 500mg fisheries storage for release at times when salmon mortalities likely to occur in Tamar Estuary.
- (b) Releases from reservoir to be subject to close monitoring both in relation to quality and such aspects as timing and pattern of release. Within operational limits of scheme and as experience is gained, releases will be so arranged as to cause as little damage to fisheries and disturbance to fishing as possible - this will be a management objective of the scheme.
- (c) There are likely to be multiple draw-off arrangements so that water can be taken from several different levels in the reservoir and equipment will be incorporated, immediately downstream of the dam, to monitor water quality aspects of the releases. Further discussion to be entered into on the question of a stocking programme. The need to compensate fully for any damage to sea trout stocks accepted, and is implicit in any proposals of the Authority for mitigation or damage to salmon stocks.

ORIGIN OF UNDERTAKING	COMMENTS
Letters 8.5.77 from Director of Fisheries and Recreation (DoRF) to P.D. Tuckett and Lord Trenchford. Also meeting at Endsleigh House 28.6.77.-	Report on fish counters to be submitted to RFLC - 13.12.88.
Letter 16.5.77 from Director of Resource Planning (DRP) to Lord Trenchford.	
Meeting held on 28.6.77 at Endsleigh House attended by Dr. E.R. Merry and Mr. R.S. Hobbs on behalf of S.W.W.A.) 500mg reserve currently the subject of HEP discussions. Agreement required as to best use of this water.
As 3 above.) Guidelines for the operation of experimental releases and releases for HEP generation to be agreed.
Letter 7.12.77 from DoFR to Mr. P.D. Tuckett.	
	Water released from Roadford will be controlled via the valve tower. In addition to the scour valve, there will be three separate draw-offs at differing depths.

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UNDERTAKING

5. Everything possible to be done by the Authority to minimise damage to the local hotel industry and its links with fishing.
6. (a) Not possible for Authority to abstract maximum requirement of 32.5mgd for many years, as pumping station at Gunnislake will be constructed in stages to meet demand requirements. Similar situation will apply in the case of the River Torridge transfer. Maximum quantities likely to be abstracted in 1991 and 2001 are 14.8mgd and 18.9mgd respectively.
- (b) Authority do not envisage any adverse changes in quality of river water. Quality aspect will be fully investigated.
- (c) There would be the fullest consultation and discussion with various interests in connection with the development of the scheme.
8. Possible re-introduction of the old Cornwall River Authority salmon stocking scheme to be considered and Tamar and Tributary Fisheries Association to be advised of the Authority's views in due course.
9. Indicated that the Authority planned to compensate for the lost fisheries production by means of a fish rearing programme, although not in advance of the scheme and that the Authority would consider the possible introduction of the Cornwall River Authority salmon stocking programme, but not as part of the mitigation for the scheme.
10. (a) The Authority will be prepared subject to liaison with the other riparian owners associations involved, to establish a Roadford scheme Fisheries Liaison Committee.
- (b) The Authority undertake to consult with the Tamar and Tributaries Fisheries Association representative on the Liaison Committee upon the best disposal of the water held in the Roadford Reservoir and identified as being for fishery purposes.

ORIGIN OF UNDERTAKING	COMMENTS
Letter 16.8.77 from DoFR to Lord Trenchford.	<p>The Authority will have the capacity to abstract the maximum of 32.5mgd at Gunnislake - the pumping station will not be constructed in stages.</p> <p>Water quality aspects under review.</p>
Letter 21.11.77 from D&P to Mr. P.D. Tuckett.	<p>Roadford Fisheries Liaison Committee established as a result of this and similar undertakings.</p>
Meeting with Tamar and Tributaries Fisheries Association (TTFA) 15.12.77.	<p>Stocking policy currently under review.</p>
Letter 18.1.78 from Director of Admin. (DoA) to Mr. P.D. Tuckett.	<p>Report on fisheries mitigation to be submitted to RLFC on 13.12.88.</p>
Letter 10.2.78 from DoA to Mr. P.D. Tuckett.	<p>RLFC established in 1983.</p>
	<p>See comments under 3 and 7(a) above.</p>

UNDERTAKING

- (c) The Authority undertake to review the prescribed flow rules on the Tamar after the initial experimental period of 10 years in the light of experience of the operation of the scheme.

13. The Authority undertake:-

- (a) That for a period of 10 years from the first filling of the reservoir the Authority will operate an experimental regime with a 105mgd flow at the abstraction point at Gunnislake. Thereafter, before any changes are made in that flow they will apply to the Secretary of State for a formal variation in the abstraction licence to drop the prescribed flow by 1mgd from 54-53mgd. It was recognised that this is a device whereby discussion of the proper prescribed flow can be brought before the Secretary of State for consideration.

- (b) Before and during the first filling of the reservoir no abstraction will take place at Gunnislake except in case of emergency, in which case the maximum take would be the throughput of the existing emergency pipeline i.e. 3.5mgd.

- (c) To accept liability in respect of discolouration of the river during the construction period subject to the conditions:-

- (i) that compensation shall only be made if water remains unfishable for three or more days on any one occasion;
- (ii) that an arbiter agreed by both the Authority and the Association shall be appointed whose task it will be to inspect the water on any occasion of complaint and then, if the water is unfishable, determine whether the cause is attributable to the date construction works;
- (iii) that compensation shall be assessed by agreement or in default by arbitration subject to the Authority not paying compensation exceeding £10,000 in aggregate in any one year of the contract.

ORIGIN OF UNDERTAKING	COMMENTS
<p>Letter 24.4.78 from DoA to Mr. P.D. Tuckett incorporates all Authority's undertakings to TTFA in one letter. In respect of (a) see also transcript 21/11/F.</p>	<p>) To be interpreted as a review of all) prescribed flows, with the objective) of setting a prescribed flow that) will have minimal environmental and) fisheries effects while optimising) the water resource benefit.) 10 year experimental period to) commence from date of first) certificate? Date needs to be agreed.</p>
	<p>Emergency pipeline will become non-operational when work on the new intake commences. First filling may not be complete before first abstraction or release.</p>
	<p>Original undertaking modified by agreement with the TTFA and being carried out.</p>

UNDERTAKING	ORIGIN OF UNDERTAKING	COMMENTS
<p>The Authority accepted that points (i) and (i) above are negotiable.</p> <p>(d) Roadford Scheme Fisheries Liaison Committee to be set up with following terms of reference:-</p> <p>(i) The Committee shall comprise three members appointed by the Tamar and Tributaries Fisheries Association, three members appointed by the River Tavy Riparian Owners' Association, three members appointed by the River Torridge Riparian Owners' Association and three members appointed by S.W.W.A.</p> <p>(ii) The Committee shall elect its own Chairman and Vice Chairman, each to hold office for three years. The secretary shall be the Director of Admin. of the S.W.W.A and S.W.W.A. will provide technical advice and assistance from its staff.</p>		<p>RFLC now comprises 4 members appointed by TTEA, 2 members appointed by River Tavy Riparian Owners Association, 2 members appointed by the River Torridge Riparian Owners Association and 2 members appointed by S.W.W.A.</p>
<p>(iii) The objects of the Committee will be:-</p> <p>(a) to consider and advise the Authority upon any programme or scheme of investigation into the effects on the fisheries of the region of the Roadford scheme;</p>		<p>Terms of reference amended (see Appendix A).</p>
<p>(b) to consider and advise the Authority prior to the implementation of any proposals for varying the abstractions from the relevant rivers dependent upon the Roadford scheme;</p> <p>(c) to consider and advise the Authority upon the best disposal of the water held in the Roadford reservoir and identified as being for fishery purposes.</p> <p>(iv) The Committee shall meet not less than annually at a time and place to be determined by themselves.</p>		
<p>11. (a) Part of the proposed comprehensive monitoring programme will involve two electronic fish counters installed on the Torridge.</p>	<p>Letter 16.2.78 from DoFR to Mr. R.A.L. Waller Clinton Devon Estates.</p>	<p>No longer applicable?</p>

UNDERTAKING

- (b) Effective screens to be installed and maintained at the Torridge intake so that there will be no loss of smolts or other fish at this point. Consideration also to be given to the installation of electronic fish barriers should they prove necessary to regulate the distribution of fish within the Torridge catchment.
- (c) If it appears that there is any indirect loss of salmon and sea trout production of the Torridge arising from the operation of the Roadford scheme it would be possible to rear some smolts for release in the Torridge.
12. The Authority would not object to imposition of a condition on the planning consent relating to water quality, although the Authority doubted whether the DoE would consider it a proper condition to impose on a planning consent.
14. Assurance given that the Authority would not propose to alter, modify or withdraw any of the proposals or assurances or evidence relating to fisheries matters given at the original Inquiry or to change the assurances given to riparian owners.
15. For fisheries purposes the partial redeployment of the Burrator leat should take place as soon as possible, although this is not envisaged for water supply purposes until 1993.
16. Fish hatchery at Roadford to be designed and operated to rear as many salmon and sea trout smolts as it was necessary to rear to safeguard the fishery and second to that would be trout production for the reservoir itself.

ORIGIN OF UNDERTAKING	COMMENTS
	Screens will be installed. Electronic fish barriers - try to take out this undertaking.
	No longer required.
Letter 23.2.78 from DoA to Mr. P.D. Tuckett.	
Letters 16.2.82 from DoCS to Mr. P.D. Tuckett and from CE to Mr. Craig-Mooney.	Undertaking affected by alterations to the research investigations, proposed operation of the scheme etc. All changes have and will continue to be made by discussion and agreement with interested parties.
DoFR in cross-examination by Mr. Horton (transcript 4.61/C).	S.W.W.A. are still committed to meeting prescribed flow on Devonport least intake as soon as Roadford water is available.
DoFR in cross-examination by Mr. P.D. Tuckett (transcript 4/66/D).	No hatchery will be constructed at Roadford. Report on fisheries mitigation to be submitted to RFLC on 13.12.88.

UNDERTAKING

17. The Authority would like to agree with the TTFA a way of ensuring that the Arbiter appointed to inspect the water on any occasion of complaint reaches the scene quickly.
18. The Authority is willing to negotiate on the wording of the undertaking given to TTFA that "compensation shall only be made if water remains unfishable for three or more days on any one occasion", although this may have to be discussed by Members of the Authority.
19. Authority prepared to reflect the effect of inflation upon the proposed £10,000 limit upon compensation in any one year of the contract for discolouration of the river during the construction period.
20. Consideration to be given to Mr. Craig-Mooney's suggestion that netmen could net salmon in the Tavy estuary for return to the river above Loppwell Dam.
21. Provision of a fish trap, hatchery and snolt rearing facilities to compensate for lost spawning and rearing area and any other indirect losses to production.
22. The redistribution of excess spawners from the fish trap to the natural catchment.
23. The provision and maintenance of effective screens at the intake and discharge points to prevent fish loss.
24. Consideration to be given to the installation of fish barriers, should they prove necessary, to redistribute fish within the catchment.
25. The management of the timing and duration of regulation releases to cause the least possible interference with angling.
26. The introduction and operation of a comprehensive programme (including the provision of electronic fish counters) to monitor all aspects of the scheme and to provide information on which to base future decisions.

ORIGIN OF UNDERTAKING	COMMENTS
Mr. Widdicombe in reply to Lord Trenchard (transcript 21/16/A).	See undertaking 13(c) above.
Mr. Widdicombe in reply to Lord Trenchard (transcript 21/16/B).	
Mr. Widdicombe in reply to Lord Trenchard (transcript 21/16/G).	
Mr. Widdicombe in reply to Mr. Craig-Mooney (transcript 25/11/D).	
Mr. G.H. Bielby in evidence (proof of evidence paras. 4.6.1 to 4.6.4 and 4.6.6 to 4.6.8).	Report on fisheries mitigation to be submitted to RFLC on 13.12.88.
Mr. G.H. Bielby in evidence (proof of evidence para. 4.6.5).	
Mr. G.H. Bielby in evidence (proof of evidence para. 4.7.13).	Screens will be provided.
Mr. G.H. Bielby in evidence (proof of evidence para. 4.7.14).	See comment on undertaking 11(b).
Mr. G.H. Bielby in evidence (proof of evidence para. 4.2, 4.3, 4.7.7, 4.7.9, and 4.7.10).	Operational rules will be designed to cause minimum damage to the fishery and least possible interference with angling.
	Programme of investigations constantly under review and progress and changes reported to Committee.

SCOTT WELSH WHITE ENTERPRISE, TEL: 0392-349900

29.11.88 15:05 NO.006 P.11

UNDERTAKING	ORIGIN OF UNDERTAKING	COMMENTS
4/51/D Undertaking to mitigate any unacceptable damage to fisheries installation of electronic fish counters.	Given by Mr. Bielby to Mr. Widdicombe.	See undertaking 1 above.
4/51/F Flows to be in excess of those specified in abstraction licence, for at least the first ten years of operation of reservoir.	Given by Mr. Bielby to Mr. Widdicombe.	See undertakings 10(c) and 13(a) above.
4/51/G Fish screens at all water intakes and discharge points and consideration to be given to installation of fish barriers if prove to be necessary.	Given by Mr. Bielby to Mr. Widdicombe.	See undertaking 11(b) above.
4/51/V Everything possible to be done, within operational limits of scheme, to minimise damage to angling.	Given by Mr. Bielby to Mr. Widdicombe.	Everything possible will be done, within the operational limits of the scheme, to minimise damage to angling.
4/52/A Safeguard against pollution downstream during construction period.	Given by Mr. Bielby to Mr. Widdicombe.	Pollution control commitment undertaken.
21/17/F Authority to act, by imposition of obligations in the contracts and by inspections, to safeguard against pollution of water downstream of dam site during construction.	Mr. Bielby.	Pollution control commitment undertaken.
21/17/G During construction stage discharge tunnel to be used for river diversion so that dam can be built under the most favourable conditions "in the dry". This method of construction will have incidental benefit of minimising possible risks of pollution to river.	Mr. Fraser.	Pollution control commitment undertaken.
21/18/B Conditions to be attached to contract to ensure that no polluting discharge is made to any watercourse and that no work carried out in any watercourse is done in such a manner as to cause pollution.	Mr. Widdicombe.	Pollution control commitment undertaken.
22/3/A Agreement with CEEB re. River Tavy least abstractions:- (i) present prescribed flow at Abbey Weir to be raised from 12agd to 32.4agd in 6 steps 1981-2011. First increased to 17agd in 1981; thereafter four steps of 3agd and one of 3.4agd; (ii) from 1981 onwards Authority to compensate CEEB for loss of power generation arising from this agreement.	Mr. Bielby in evidence.	Commitment undertaken.

ROADFORD - UNDERTAKINGS GIVEN BY THE AUTHORITY IN RELATION TO FISHERY'S MATTERS

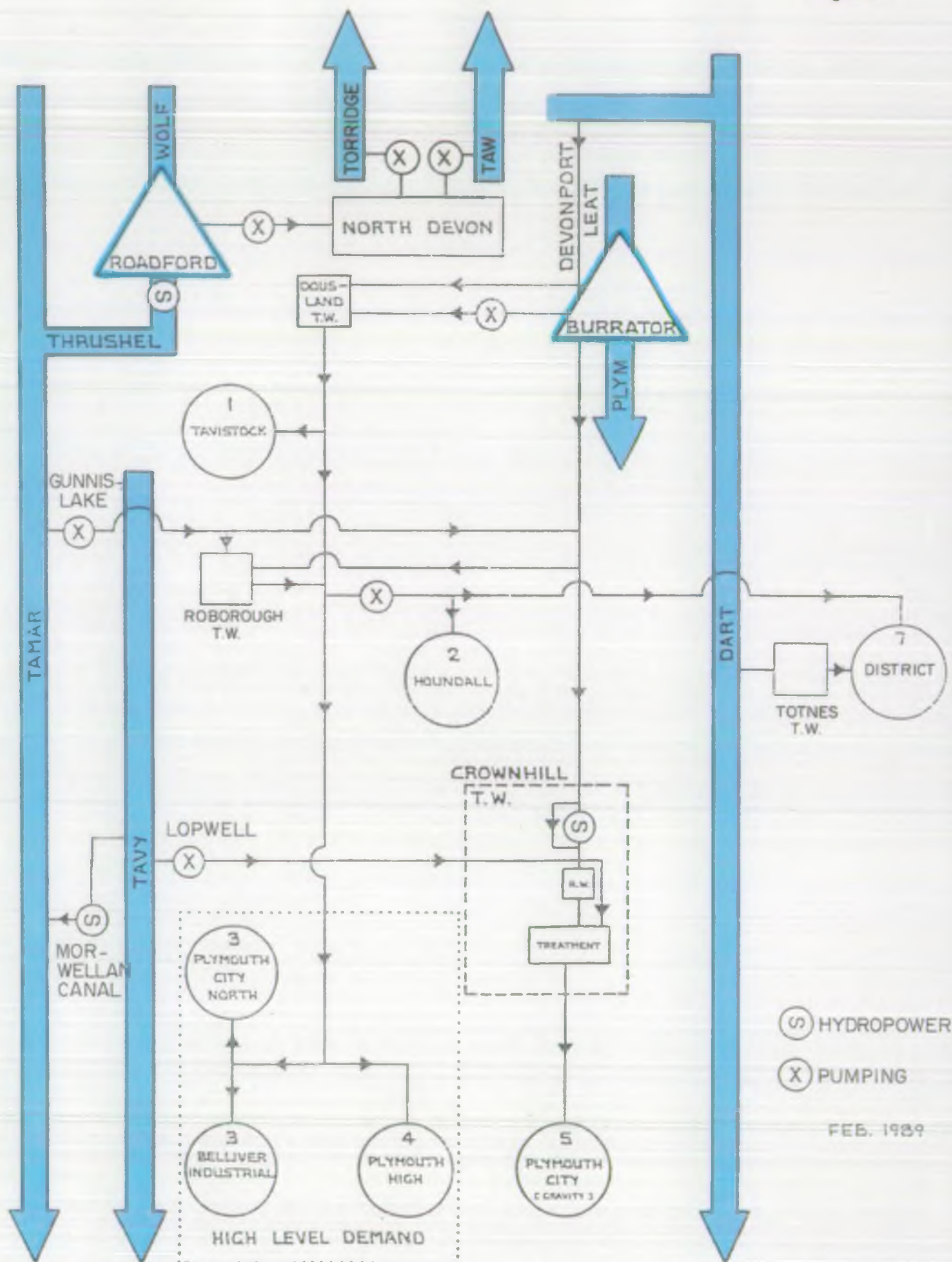
APPENDIX B

UNDERTAKING	ORIGIN OF UNDERTAKING	COMMENTS
22/4/B Agreement with Fara Industries Ltd. for imposition of 9mgd prescribed flow at Evans Weir. Authority to cancel annual abstraction charge.	Mr. Bielby evidence in chief.	The ownership of the weir has changed hands and the abstraction point to the least blocked. It is believed that the abstraction will not be used again.
22/35/E Authority will apply itself to investigation of water conservation measures.	Given by Mr. Battersby to Mr. Pearson.	
23/32/B S.W.W.A. may consider drawing up a code of conduct for construction and operation of reservoir.	Given by Mr. Battersby to Mr. Fookes.	
25/11/D Undertaking to consider Mr. Craig-Mooney's suggestion that wetsmen should net Tavy salmon in estuary for return to the river above Lopwell Dam.	Given by Mr. Widdicombe to Mr. Craig-Mooney.	

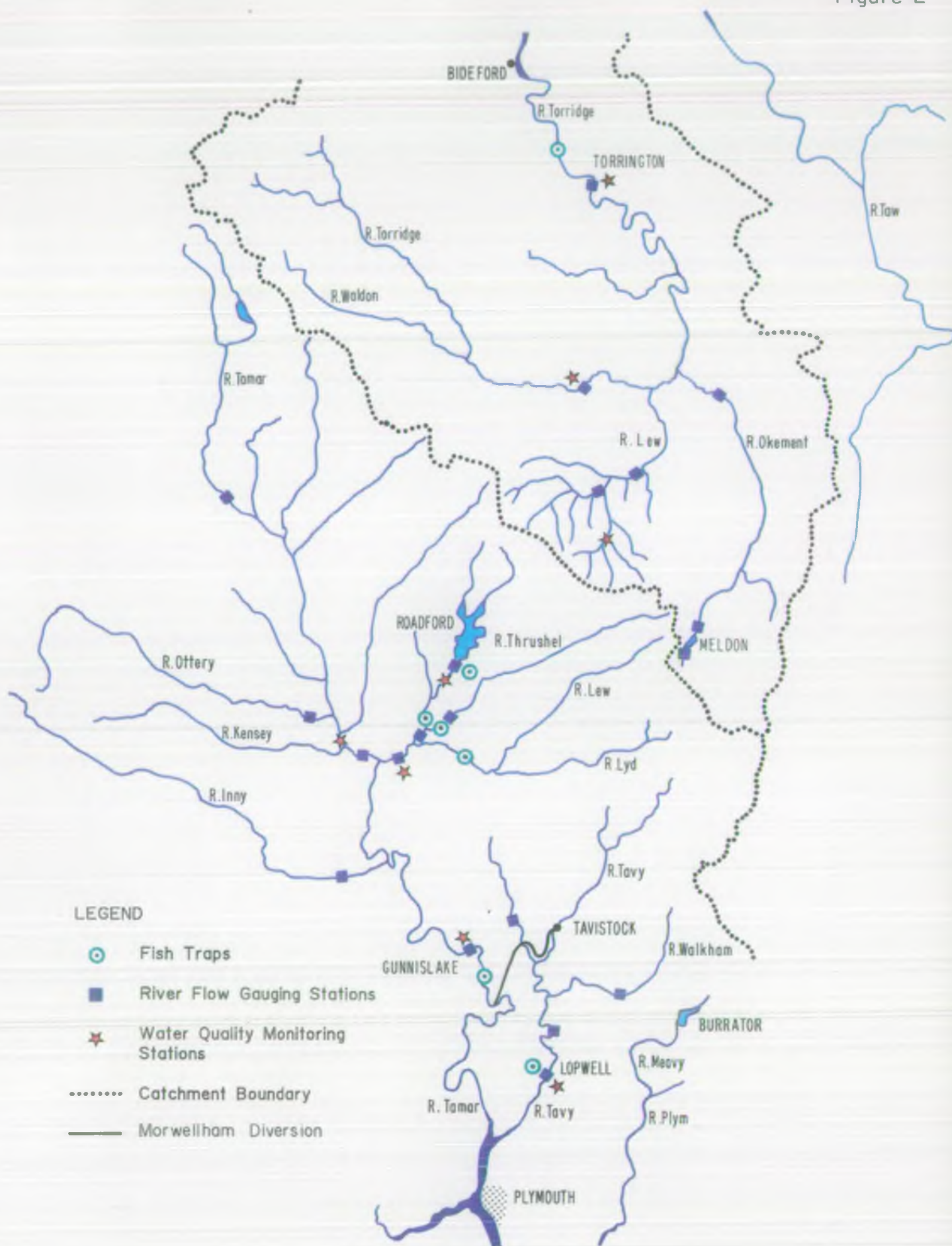
Figures

- 1 Schematic Layout of PG400 Simulation Model
- 2 Location of Monitoring Stations
- 3 Roadford Reservoir Project Area
- 4 Lower Tamar and Tavy
- 5 Lower Torridge
- 6 Roadford Reservoir Control Zones
- 7 Example of Spate Sparing
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- 9 River Tamar Water Quality - Sheet 1
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- 11 River Tamar Salmon Catches and Flows
- 12 River Tamar Sea Trout Catches and Flows
- 13 River Tavy Salmon Catches and Flows
- 14 River Tavy Flows and Abstractions September 1987
- 15 River Plym Salmon Catches and Flows
- 16 River Plym Rod Catches 1952-1988
- 17 River Dart Salmon Catches and Flows
- 18 River Dart and Torridge Sea Trout Catches and Flows
- 19 River Torridge Salmon Catches and Flows
- 20 River Taw Salmon Catches and Flows
- 21 Proposed Recreation at Roadford
- 22 Burrator Reservoir Draw-down September 1989

Figure 1

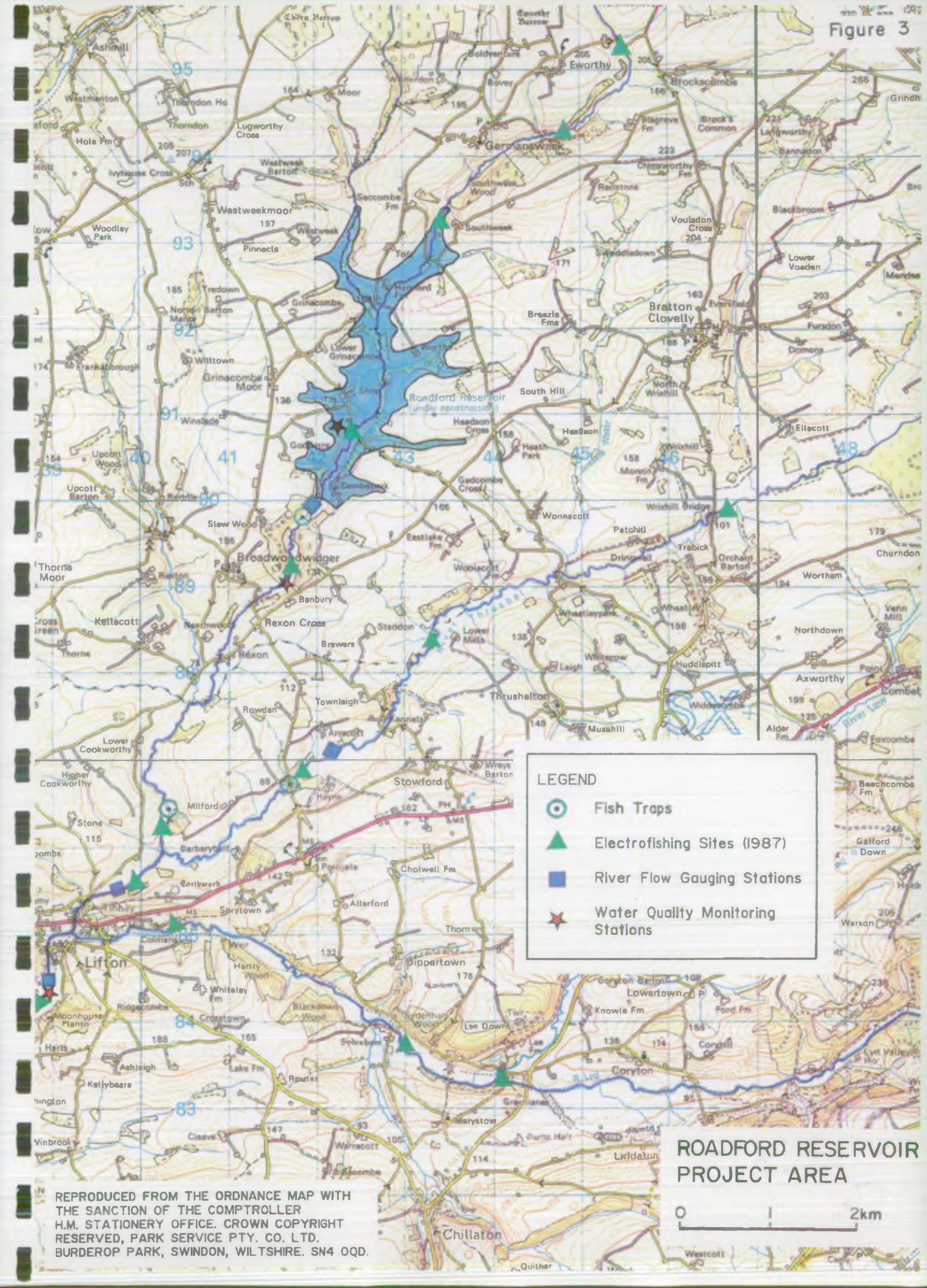


SCHEMATIC OF PG400 SIMULATION MODEL







LOCATION OF MONITORING STATIONS

Figure 3



LEGEND

-  Fish Traps
-  Electrofishing Sites (1987)
-  River Flow Gauging Stations
-  Water Quality Monitoring Stations

**ROADFORD RESERVOIR
PROJECT AREA**

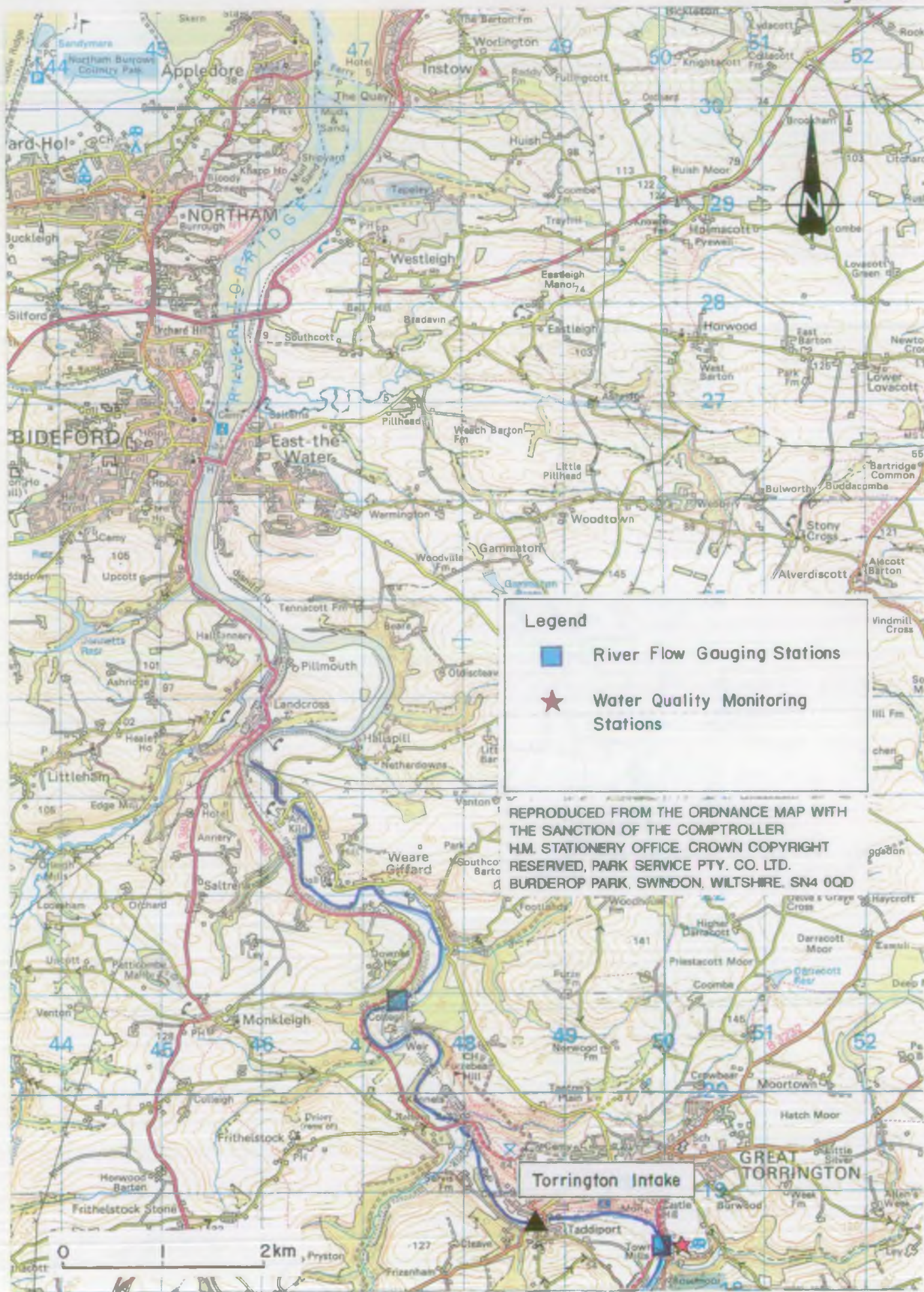
0 1 2km

REPRODUCED FROM THE ORDNANCE MAP WITH
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BURDEROP PARK, SWINDON, WILTSHIRE. SN4 0QD.

TAVISTOCK



Figure 5



ROADFORD STORAGE

2014 DEMANDS

1975 1976

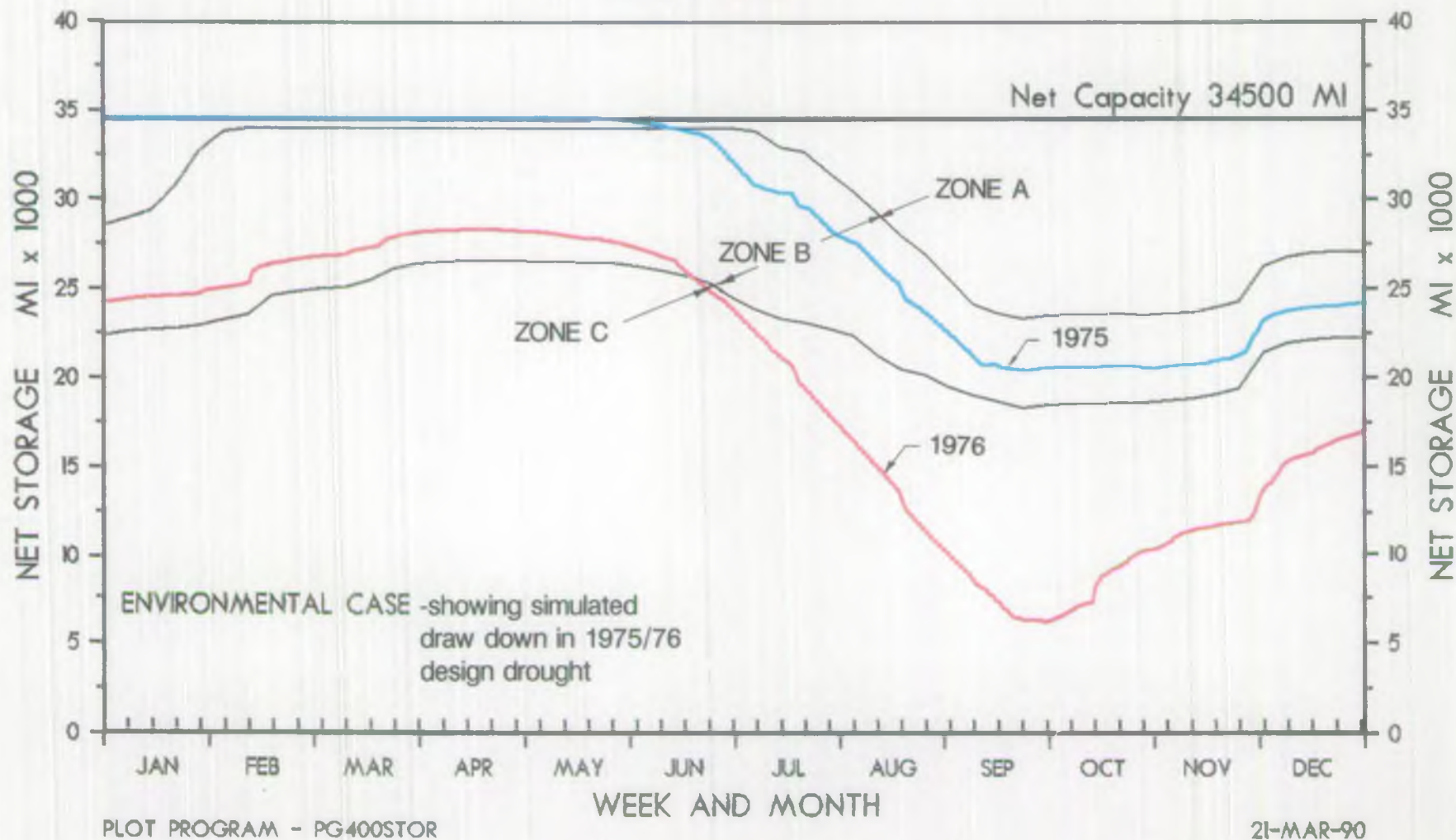
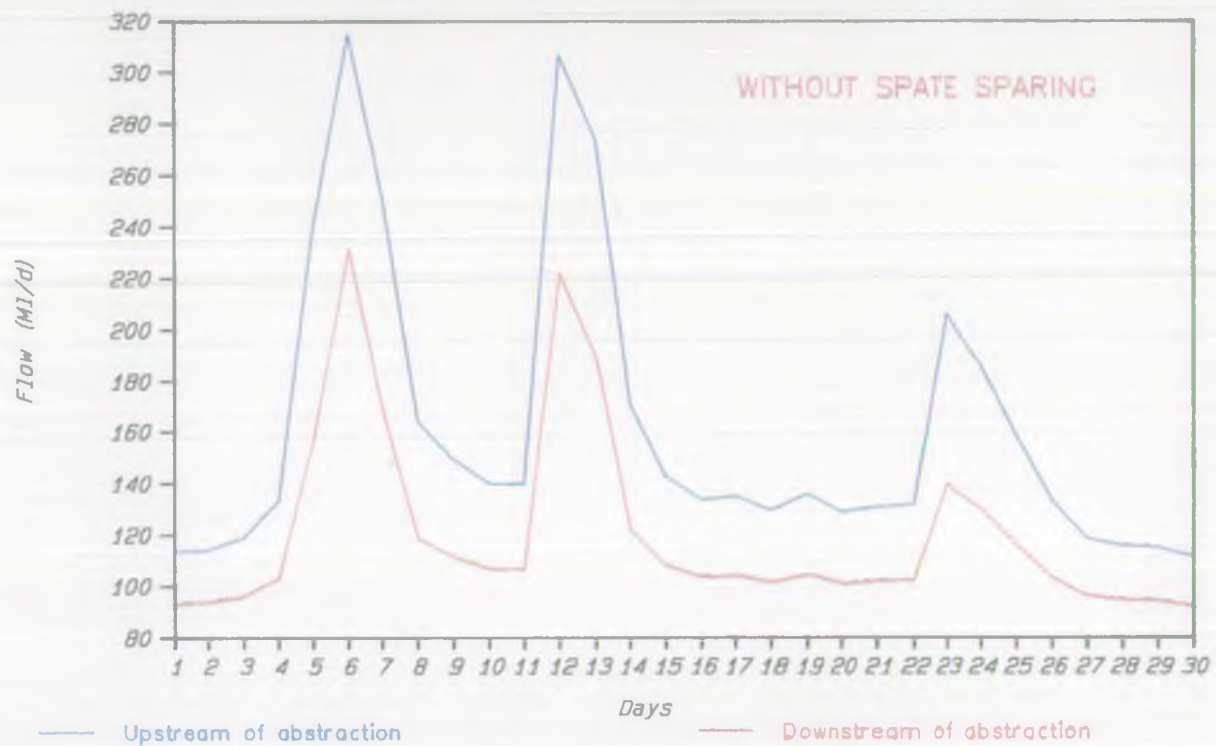


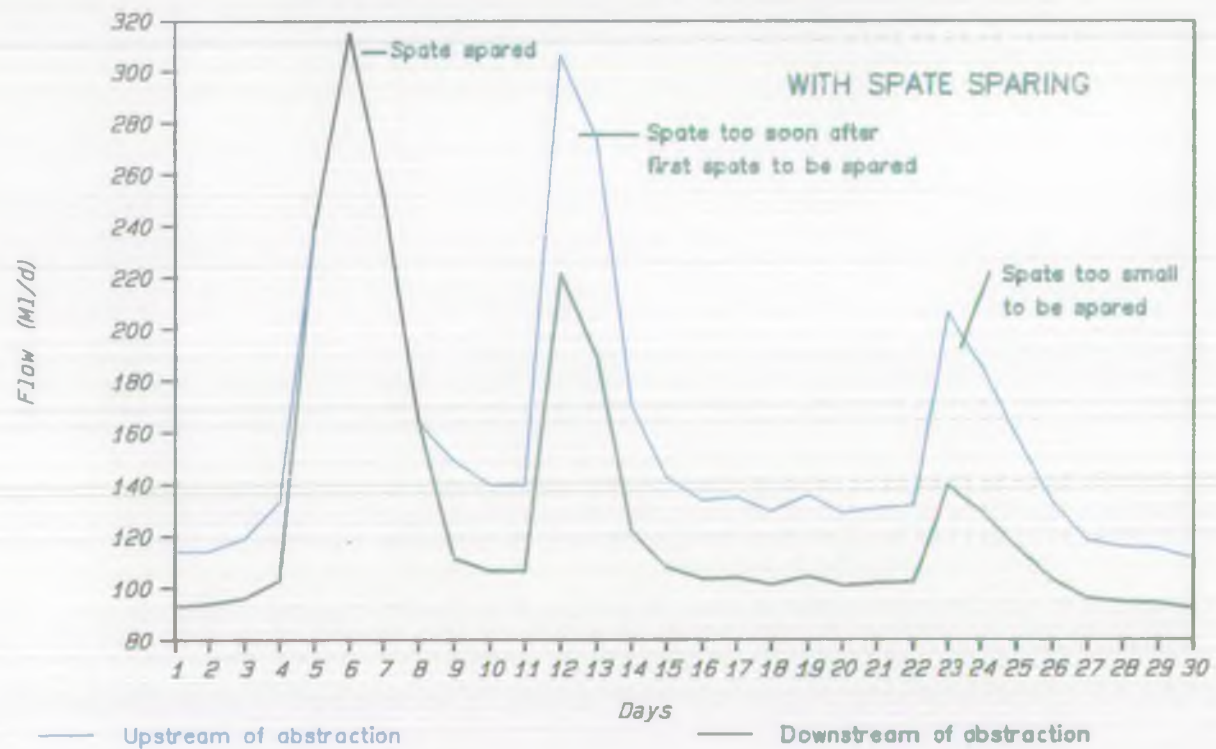
Figure 7

Example of Spate Sparing: Simulated flows in the River Tavy at Lopwell at 2014 Demand

a) Base Case for September 1987



b) Environmental Case for September 1987



Example Of Spate Sparing

MINIMUM MONTHLY STATE IN ROADFORD RESERVOIR
ENVIRONMENTAL CASE - 2014 DEMANDS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1957	A	A	A	A	A	B	B	B	A	A	A	A
1958	A	A	A	A	A	A	A	A	A	A	A	A
1959	A	A	A	A	A	B	B	B	C	C	C	C
1960	B	B	A	A	A	B	B	A	A	A	A	A
1961	A	A	A	A	A	B	B	B	B	B	A	A
1962	A	A	A	A	A	B	B	B	A	A	A	A
1963	B	B	B	A	A	B	B	A	A	A	A	A
1964	A	A	A	A	A	A	B	A	A	A	A	A
1965	A	A	A	A	A	A	A	A	A	A	A	A
1966	A	A	A	A	A	A	A	A	A	A	A	A
1967	A	A	A	A	A	A	B	A	A	A	A	A
1968	A	A	A	A	A	A	A	A	A	A	A	A
1969	A	A	A	A	A	A	A	A	A	A	A	A
1970	A	A	A	A	A	B	B	A	A	A	A	A
1971	A	A	A	A	B	B	A	A	A	A	A	A
1972	A	A	A	A	A	A	A	A	A	A	A	A
1973	A	A	A	A	A	B	B	A	A	A	A	A
1974	A	A	A	A	A	B	B	B	A	A	A	A
1975	A	A	A	A	A	B	B	B	B	B	B	B
1976	B	B	B	B	B	C	C	C	C	C	C	C
1977	C	C	B	B	B	B	B	B	B	B	B	B
1978	B	B	A	A	A	B	B	A	A	B	B	C
1979	B	B	B	B	A	A	A	A	A	A	A	A
1980	A	A	A	A	B	B	B	A	A	A	A	A
1981	A	A	A	A	A	A	A	A	A	A	A	A
1982	A	A	A	A	B	B	B	B	A	A	A	A
1983	A	A	A	A	A	A	B	B	B	B	B	B
1984	A	A	A	A	B	B	B	C	C	C	C	B
1985	B	B	B	B	A	B	B	A	A	A	A	A
1986	A	A	A	A	A	A	A	A	A	A	A	A
1987	A	A	A	A	A	A	A	A	A	A	A	A

KEY

ZONE A
ZONE B
ZONE C

Environmental Case
Roadford State 1957-87



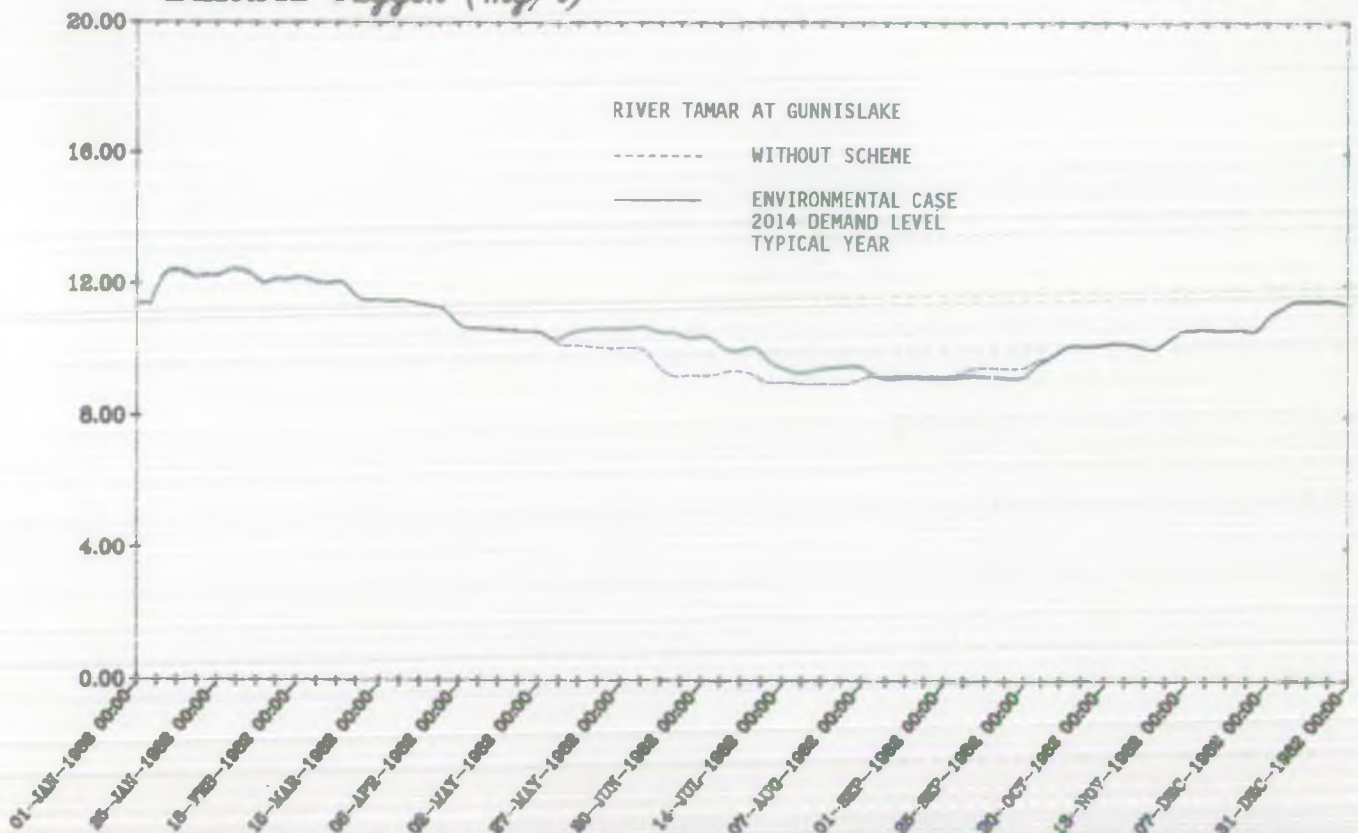
Gunnislake

Temperature (celsius)

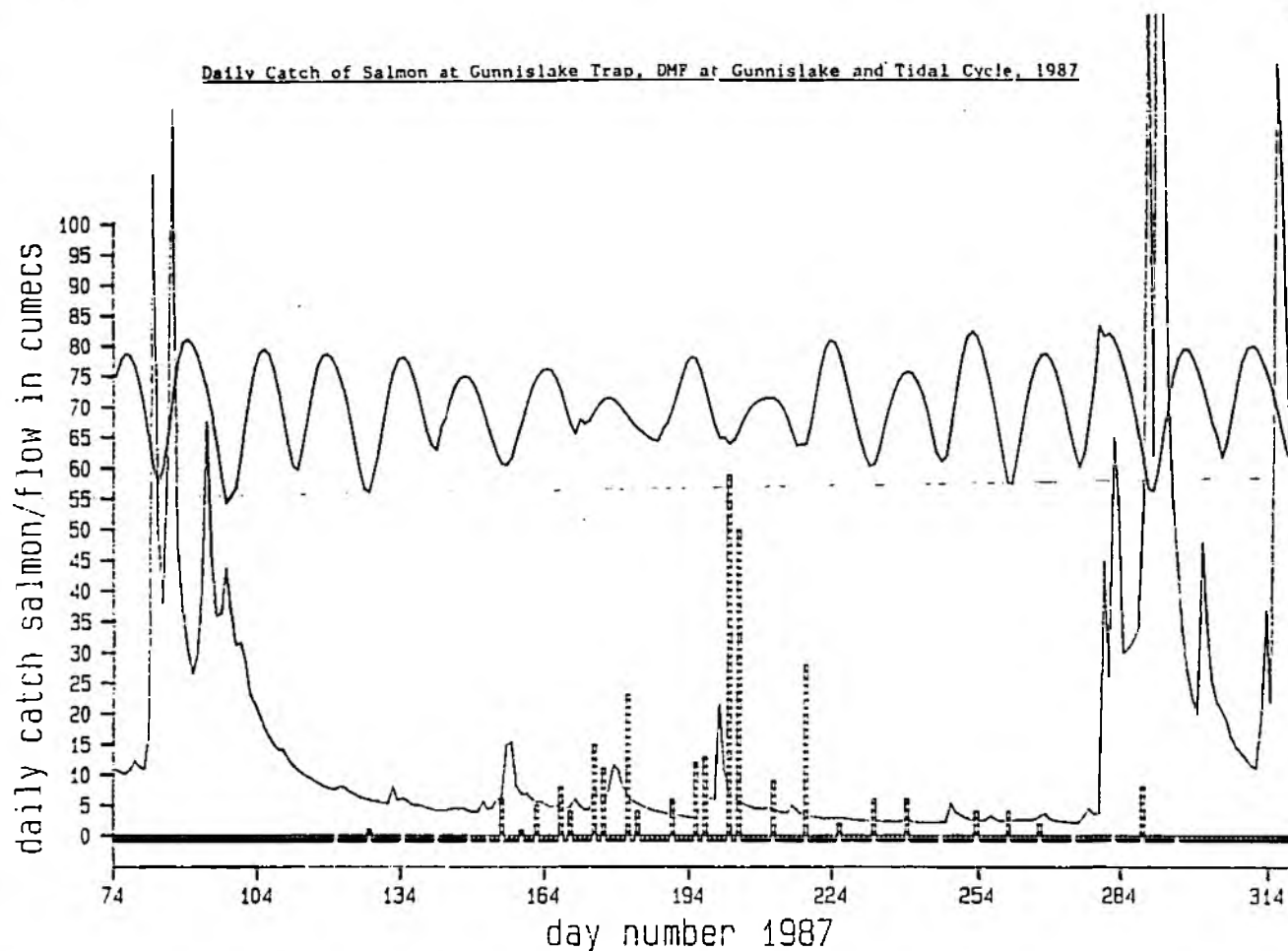


Gunnislake

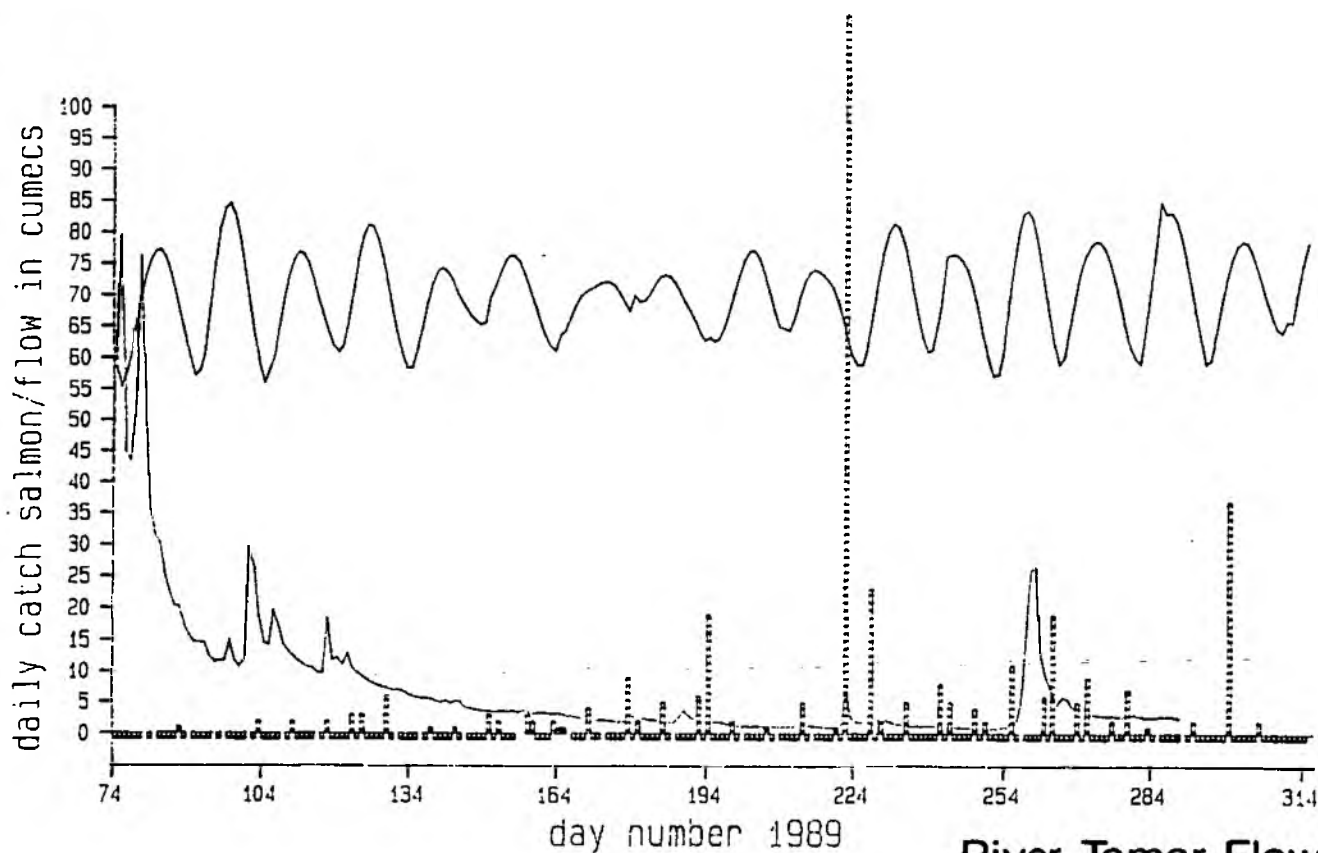
Dissolved Oxygen (mg/l)



Daily Catch of Salmon at Gunnislake Trap, DMF at Gunnislake and Tidal Cycle, 1987

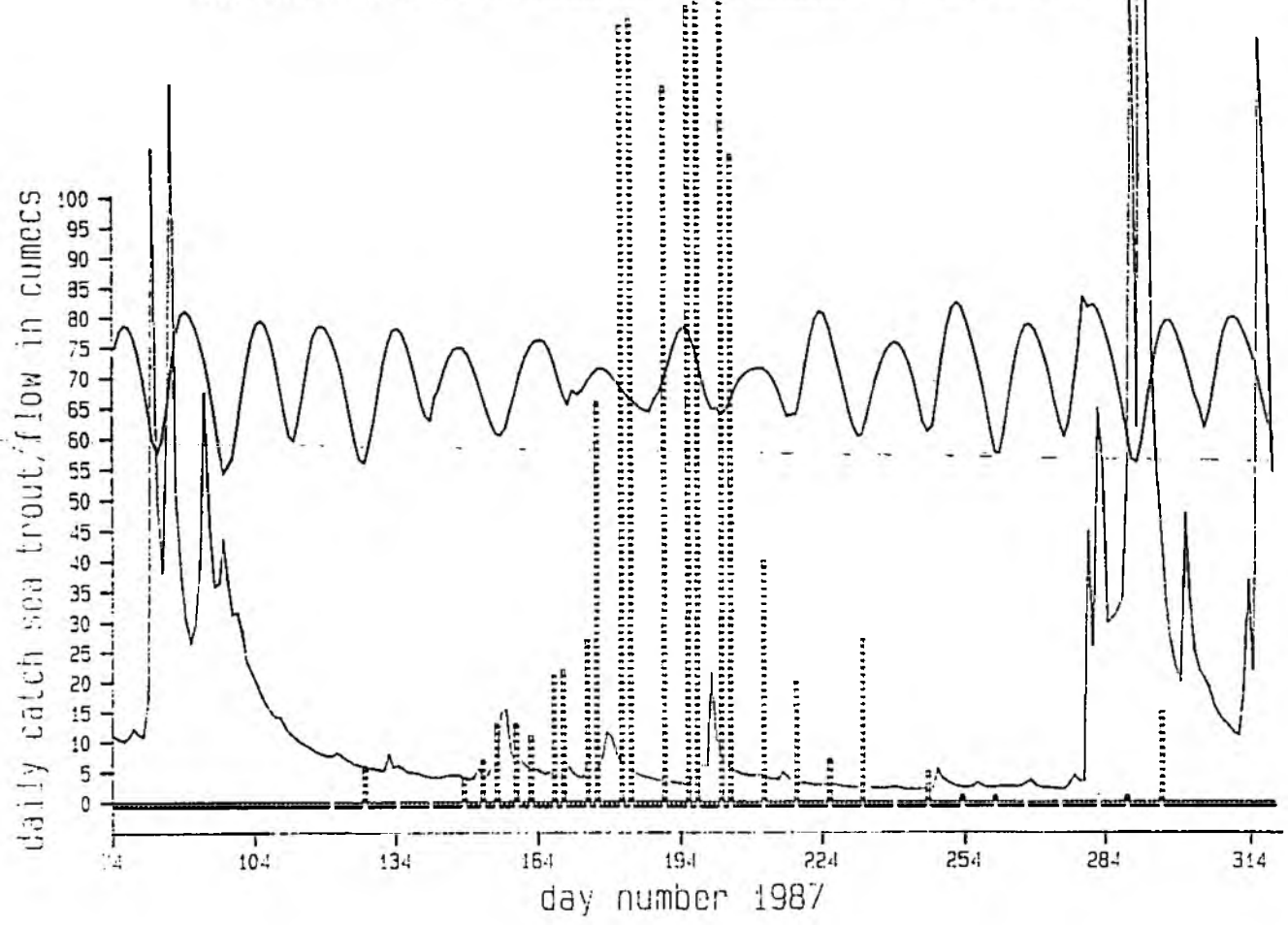


Daily Catch of Salmon at Gunnislake Trap, DMF at Gunnislake and Tidal Cycle, 1989

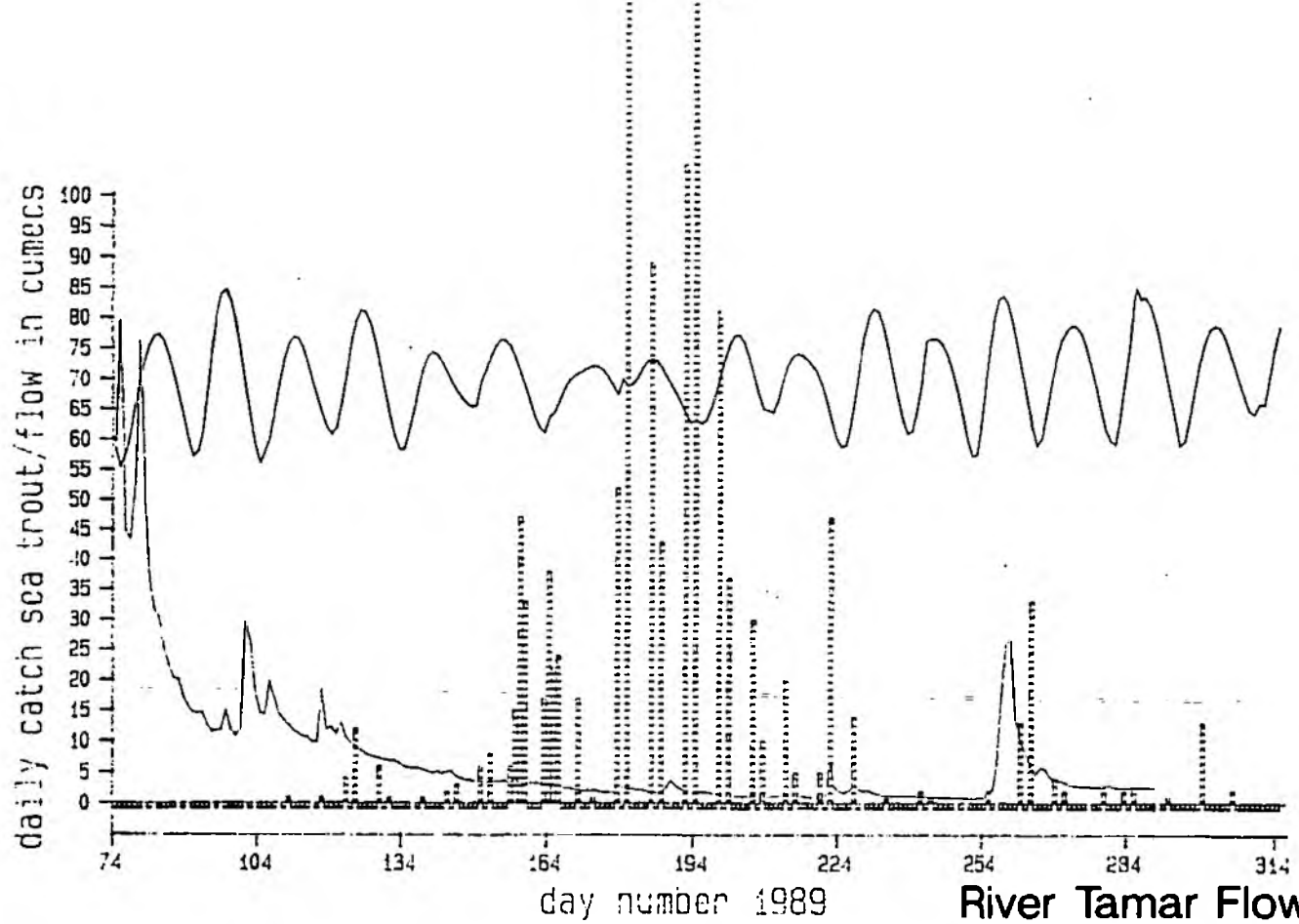


River Tamar Flows
and Salmon Catches

Daily Catch of Sea Trout at Gunnislake Trap, DMF at Gunnislake and Tidal Cycle, 1987

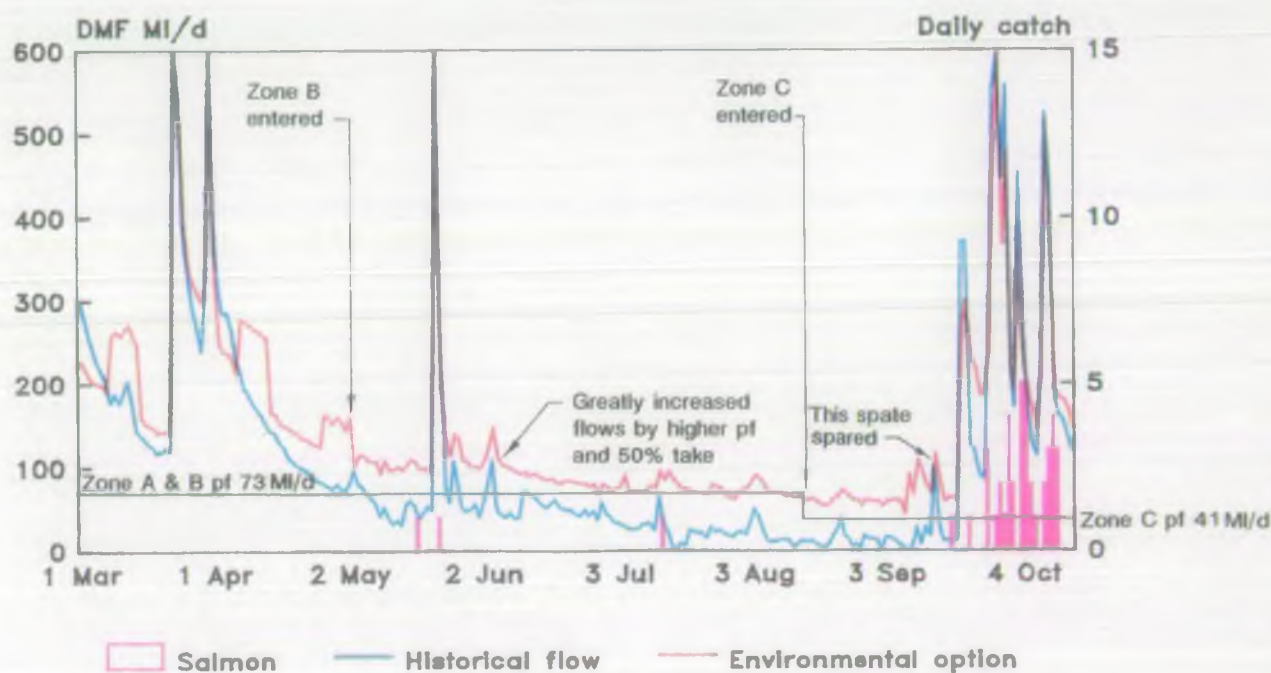


Daily Catch of Sea Trout at Gunnislake Trap, DMF at Gunnislake and Tidal Cycle, 1989

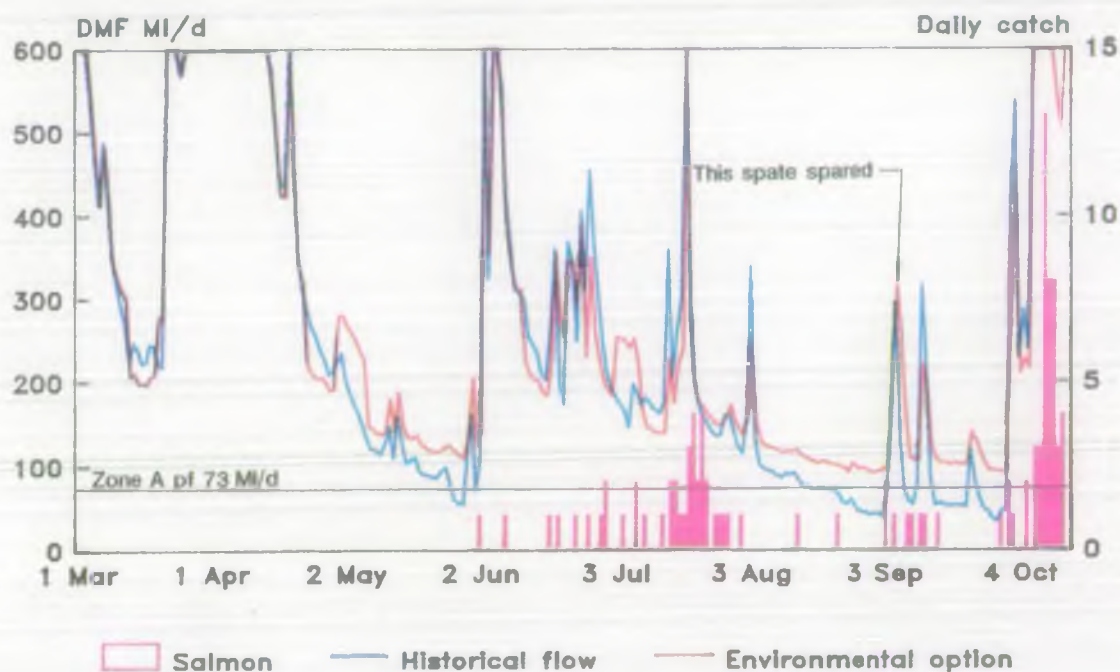


River Tamar Flows
and Sea Trout Catches

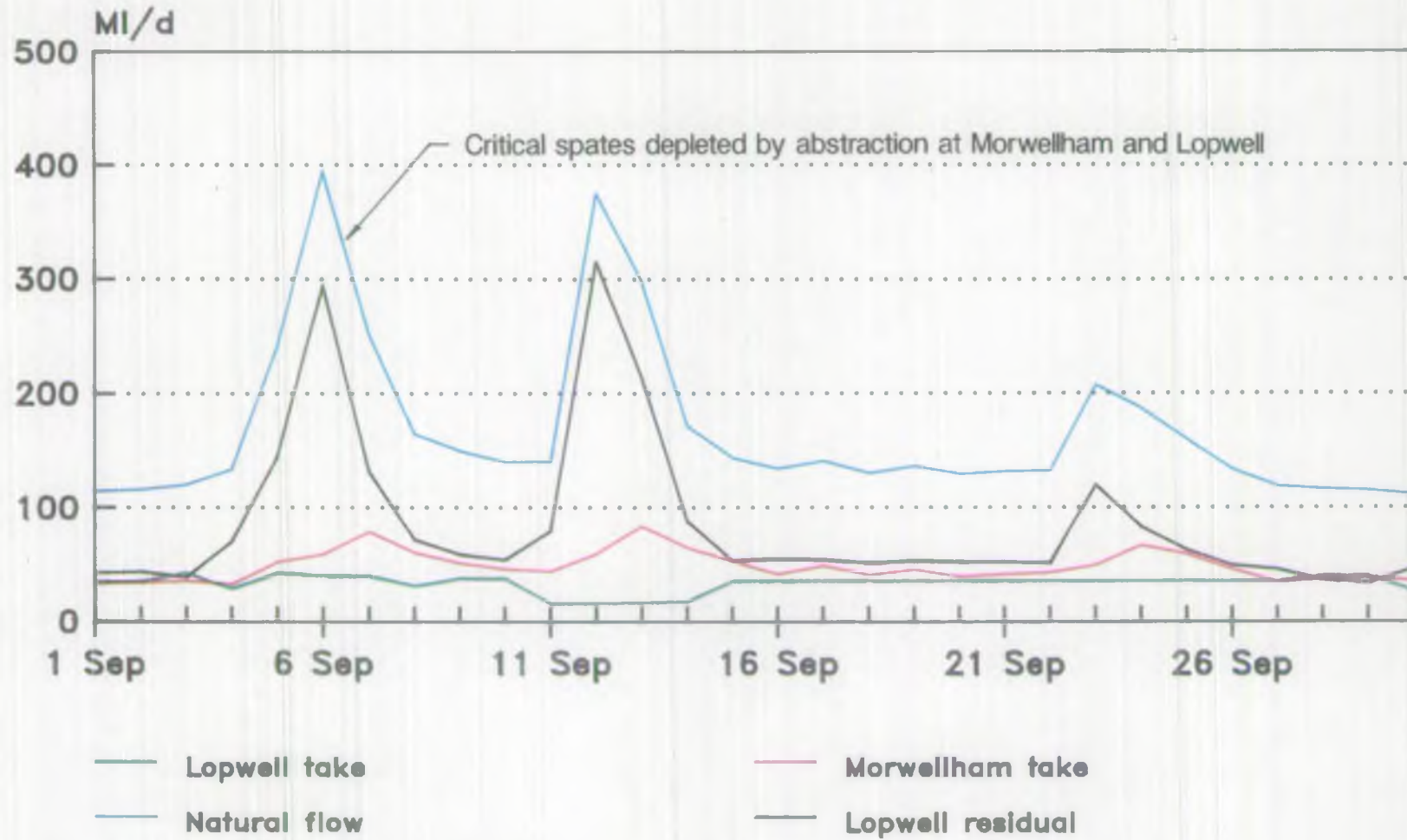
Tavy Salmon 1984
Historic and Predicted flows, d/s Intake



Tavy Salmon 1987
Historic and Predicted flows, d/s Intake

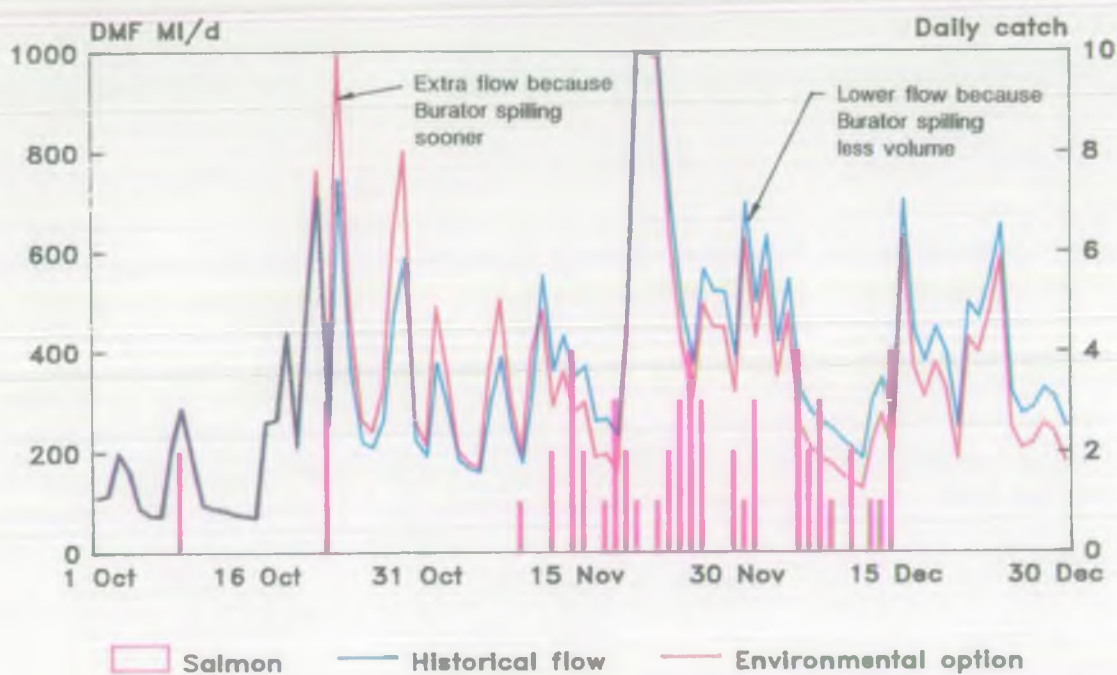


Tavy Flows and Abstractions September 1987

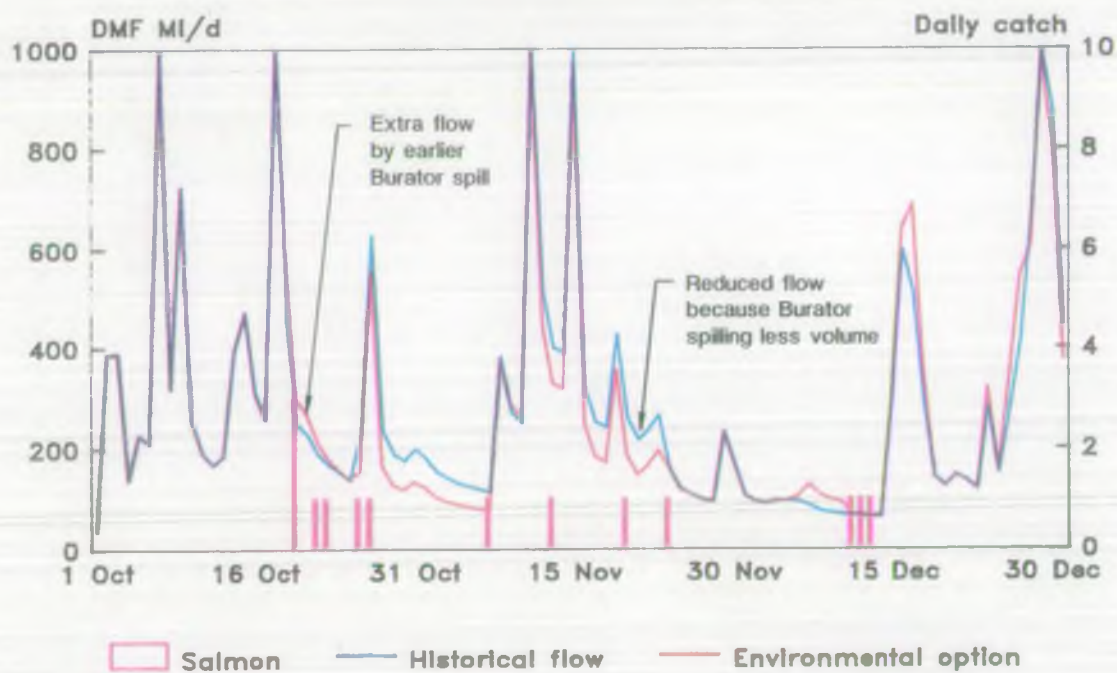


Historic flows and abstractions
(This shows how existing scheme is hitting both spates and low flows)

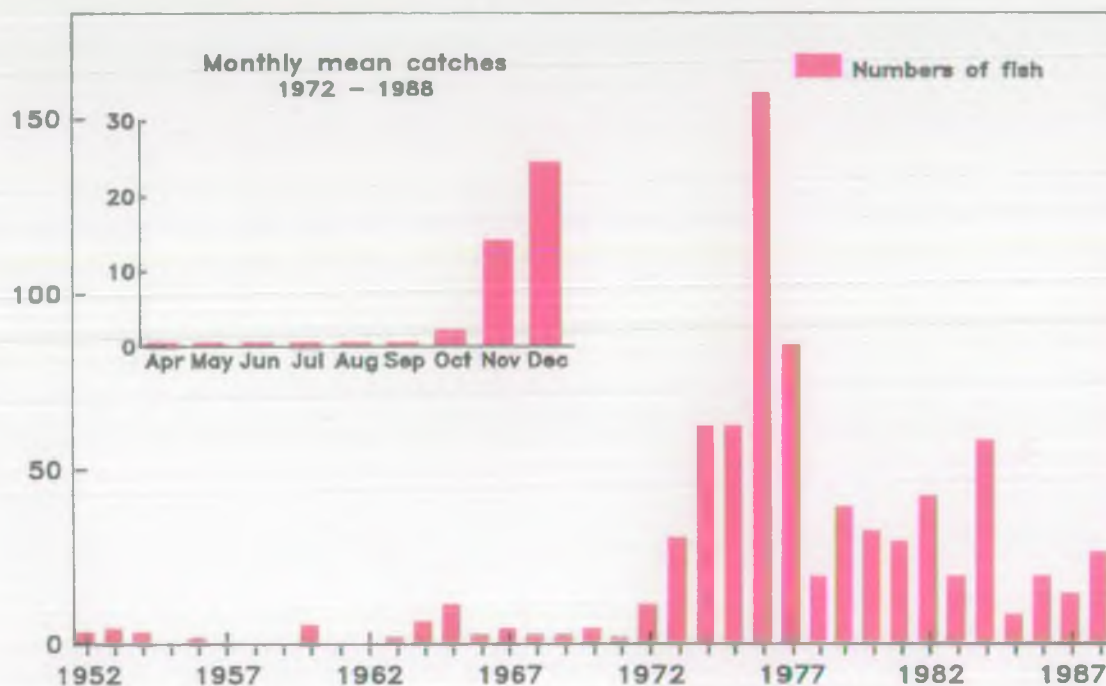
Plym Salmon 1984
Historical and Predicted flows, Carnwood



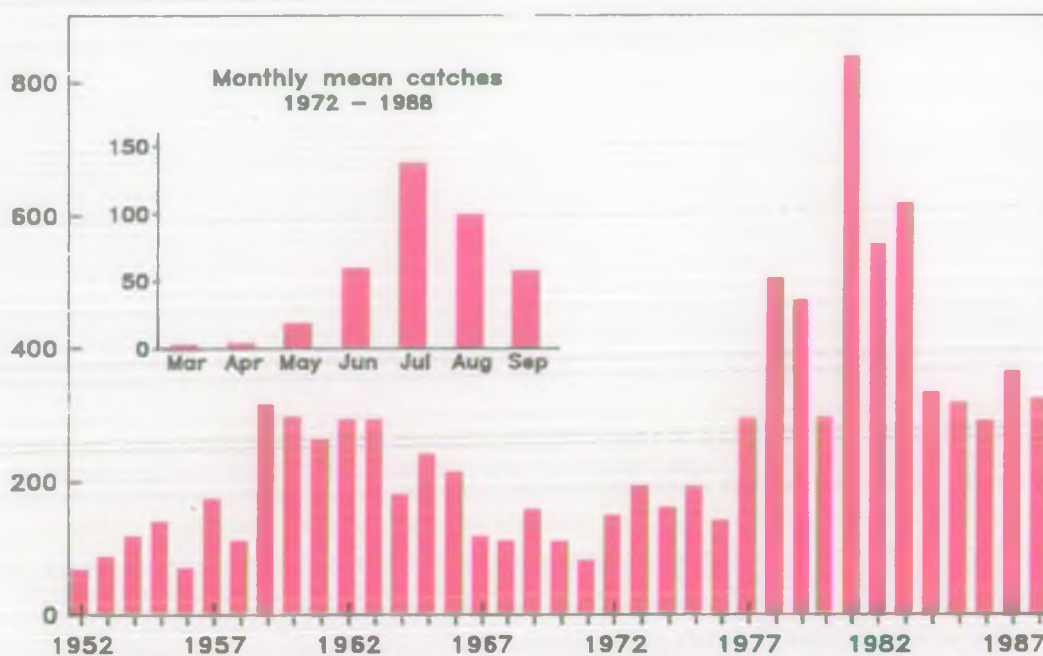
Plym Salmon 1987
Historical and Predicted flows, Carnwood



Plym Salmon Rod Catch

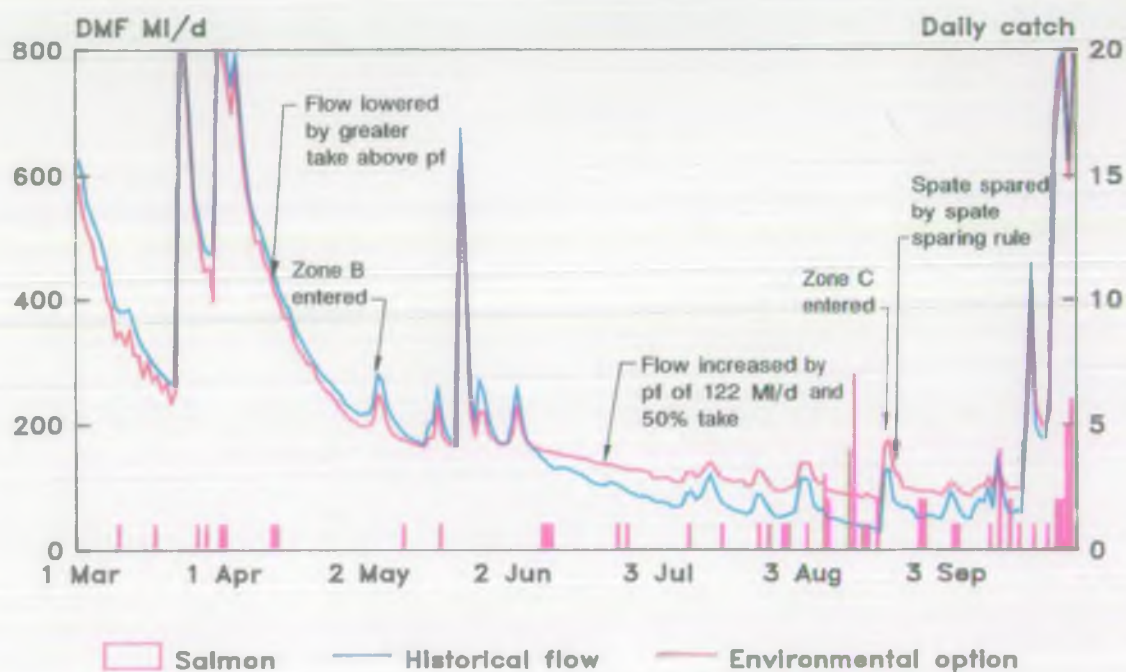


Plym Sea Trout Rod Catch

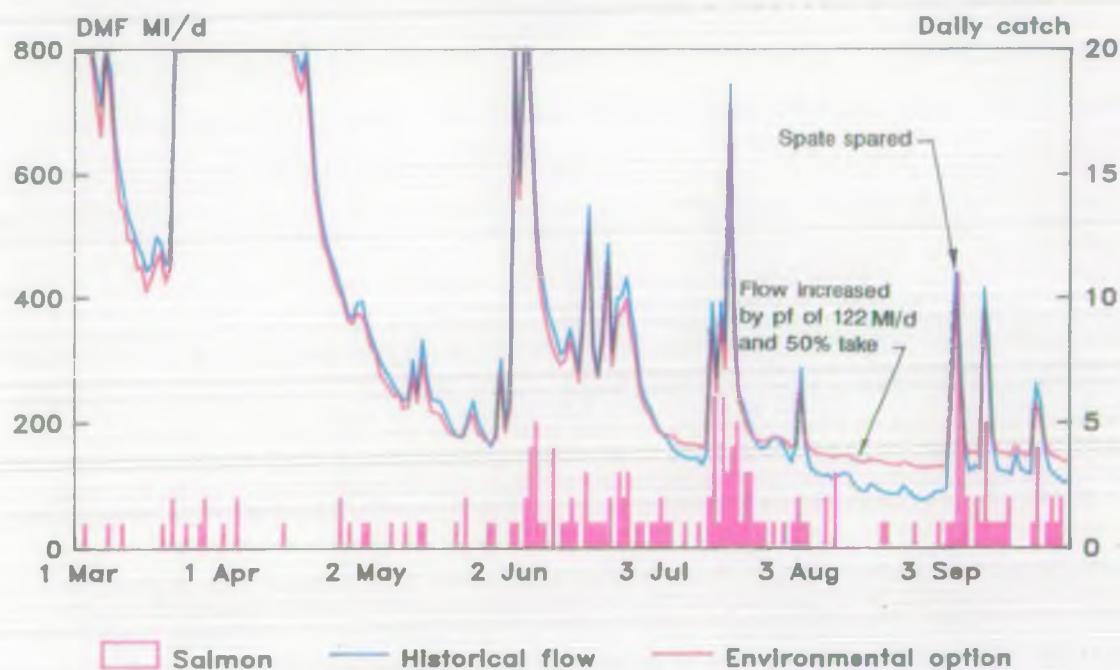


River Plym Rod Catches
1952-1988

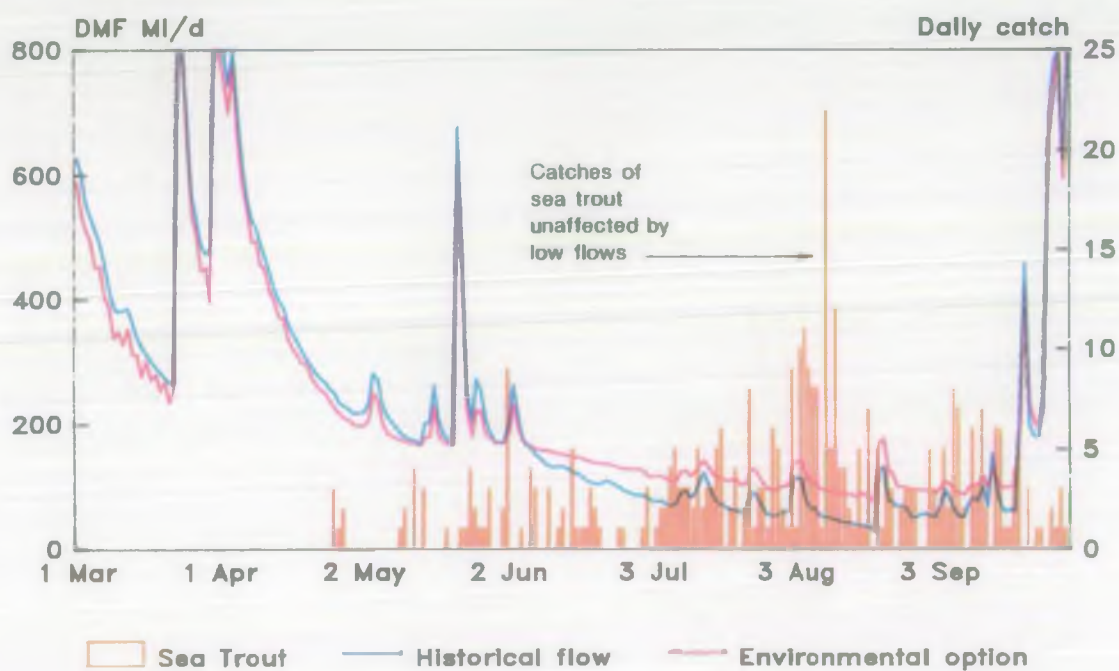
Dart Salmon 1984
Historic and Predicted flows, d/s Intake



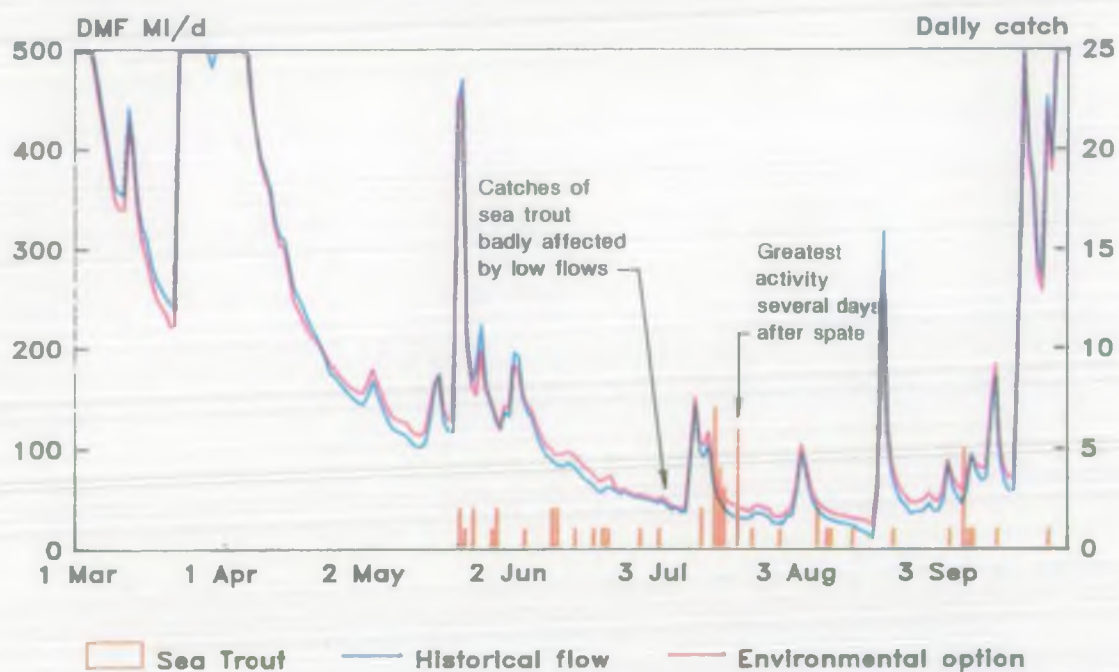
Dart Salmon 1987
Historic and Predicted flows, d/s Intake



Dart Sea Trout 1984
Historic and Predicted flows, d/s Intake

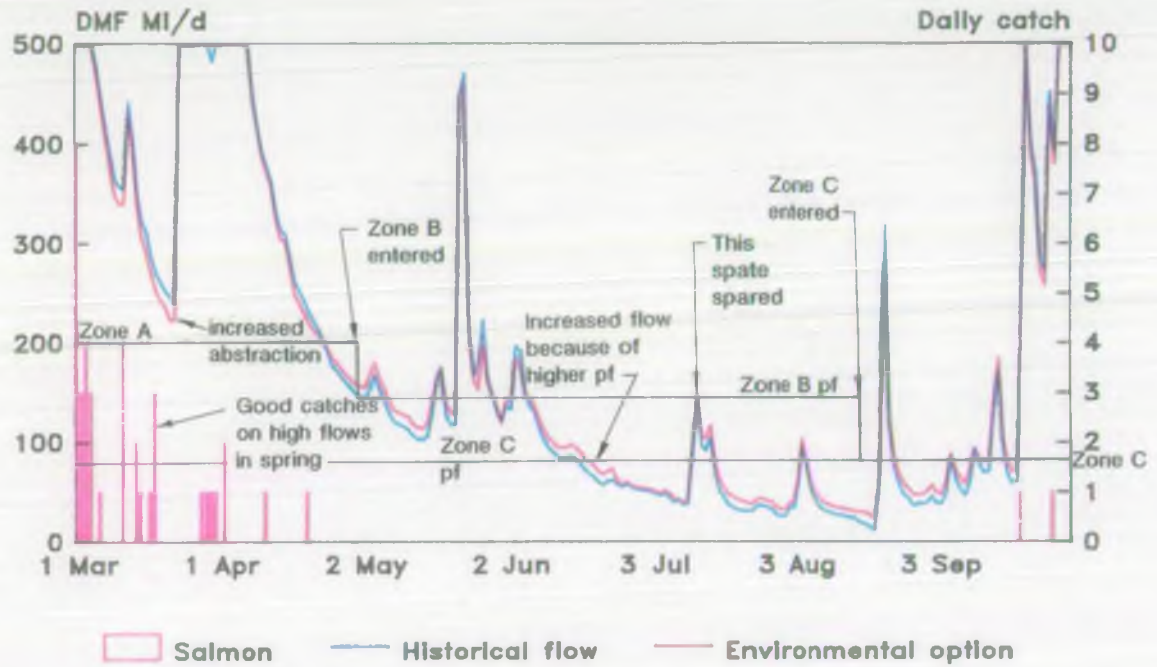


Torrige Sea Trout 1984
Historic and Predicted flows, d/s Intake

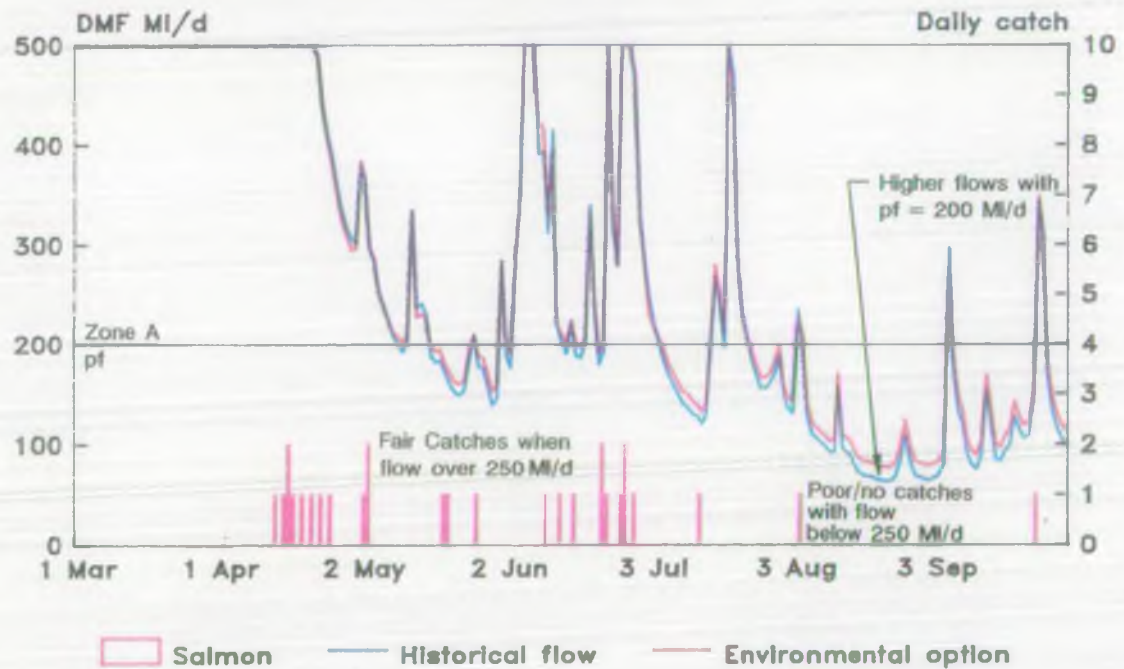


**Dart and Torrige Sea Trout
 Catches and Flows**

Torridge Salmon 1984
Historic and Predicted flows, d/s intake

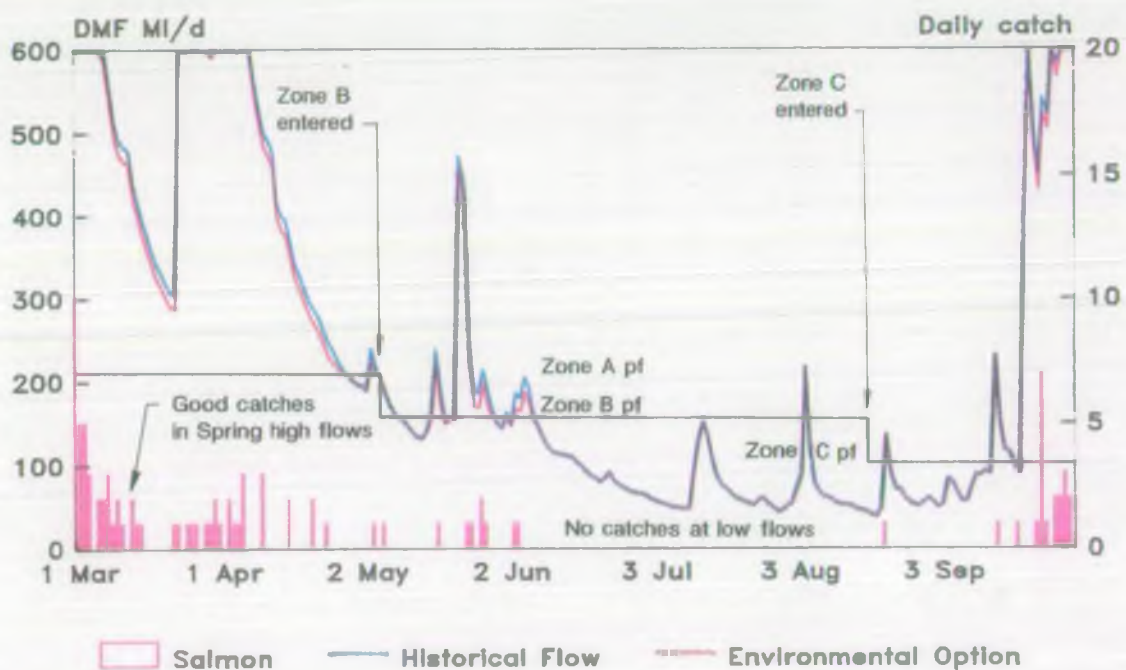


Torridge Salmon 1987
Historic and Predicted flows, d/s intake

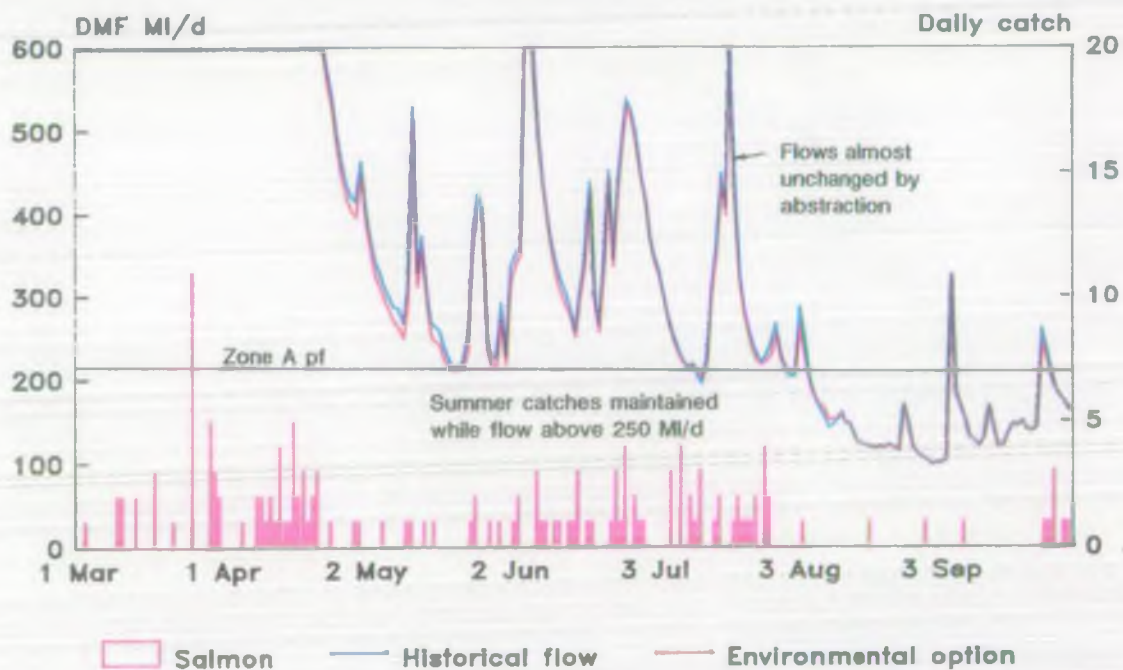


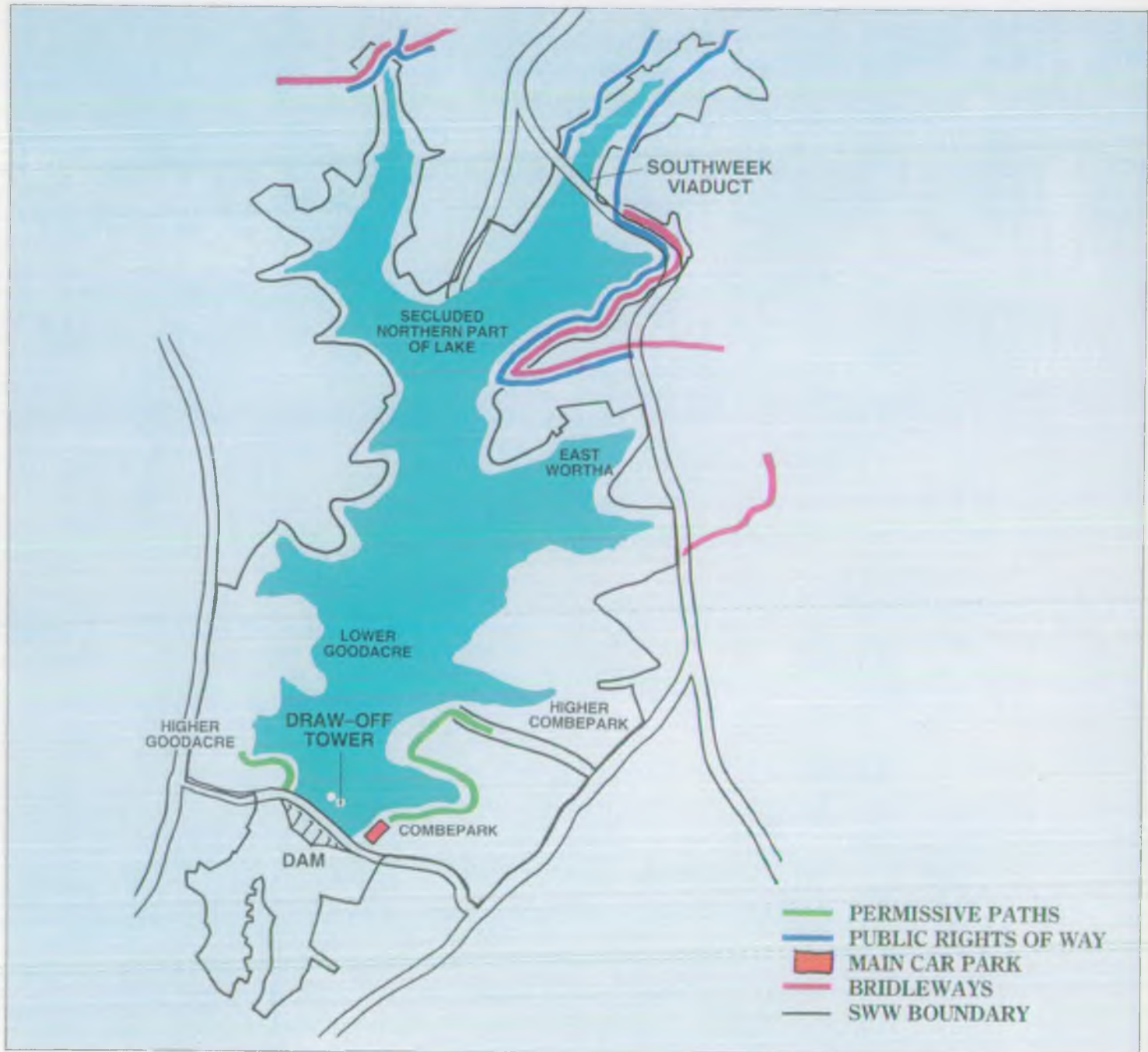
**River Torridge Salmon
 Catches and Flows**

Taw Salmon 1984
Historic and Predicted flows, d/s Intake



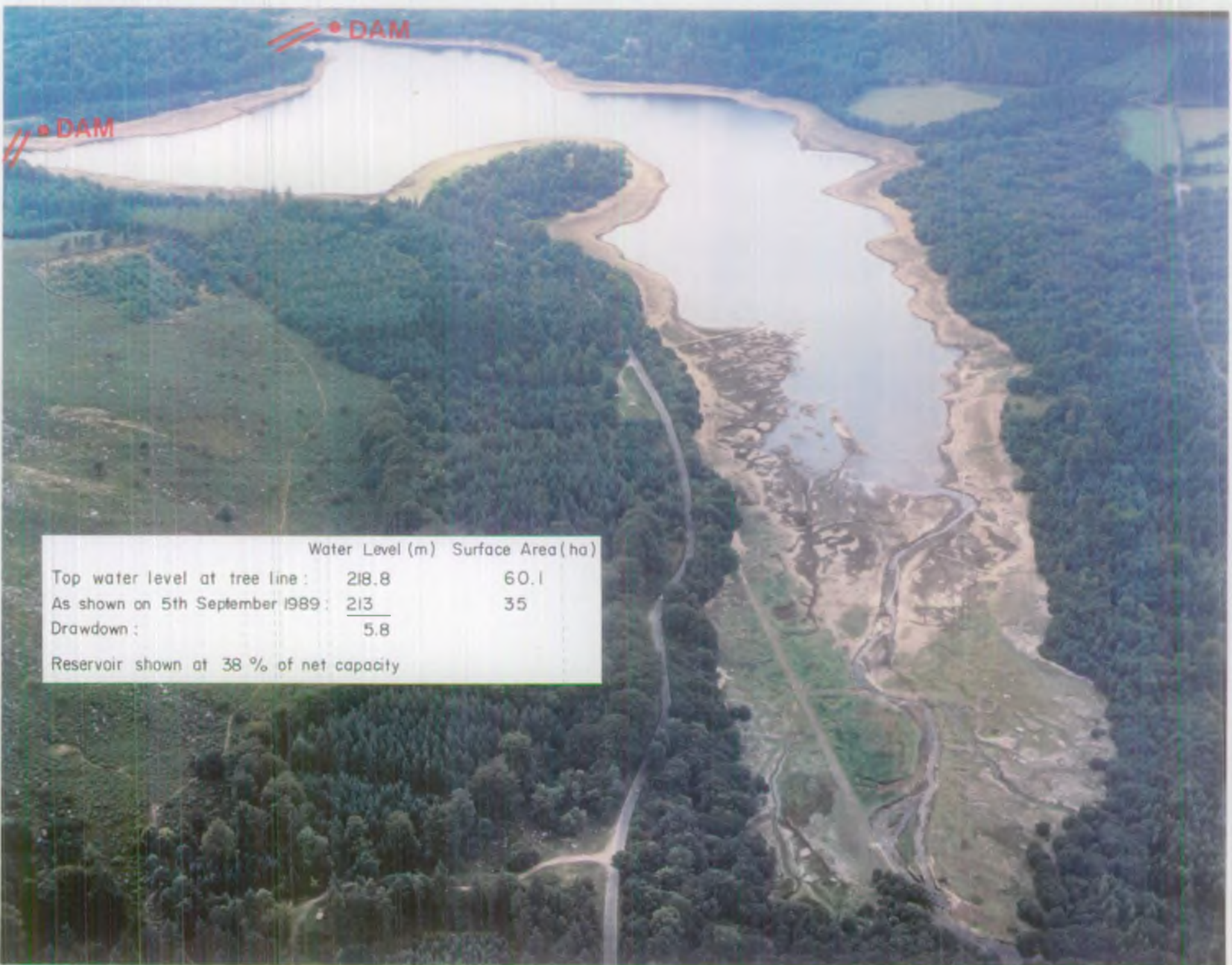
Taw Salmon 1987
Historic and Predicted flows, d/s Intake





By Courtesy of SWW Public Relations

Proposed Recreation at Roadford



Burrator Reservoir Draw Down
September 1989

HALCROW

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