Institute of
Hydrology

Natural Environment Research Council

Ecologically Acceptable Flow Regimes:

River Bray at Leehamford
River Barle at Perry Weir

Final Report to National Rivers Authority
South Western Region

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Executive Summary

This study forms part of an integrated assessment of the environmental impact of past and potential future abstraction regimes on the Rivers Bray and Barle by National Rivers Authority (NRA) South Western Region. A survey conducted by Halcrow & Partners (1991), commissioned by NRA South West, identified reaches of the River Bray at Leehamford and the River Barle at Perry Weir as being ranked within 20 sites in the region requiring assessment due to the impact of local abstraction at low flows on migratory fish species. The reaches lying downstream of the Leehamford abstraction on the River Bray and the Perry Weir abstraction on the River Barle were ranked tenth and eleventh in the 1991 Halcrow Low Flow Study. Both the Bray and the Barle were ranked as first class migratory fish rivers. The impacts of the abstraction noted at low flows include "drying out or virtually so, of significant reaches of nursery area, and/or: reach or weir impassable to migratory fish at times, and/or: major smolt or kelt entrainment at times".

The objective of this study is to assess the impact of the existing licensed abstraction regimes upon the availability of physical habitat to individual life-stages of selected target species. The methodology used for this assessment is the Instream Flow Incremental Methodology (IFIM), (Bovee, 1982), which is implemented using the Physical Habitat Simulation (PHABSIM) computer model. To meet the study objectives NRA South Western Region staff proposed that a PHABSIM study reach should be selected on the River Barle, between the Perry Weir abstraction and the confluence with the River Exe, approximately 1km downstream. On the River Bray the study reach was to be chosen to represent habitat types present in the vicinity of the Leehamford abstraction.

In liaison with NRA South Western Region target species for IFIM habitat simulations were selected as brown trout (adult, fry, juvenile and spawning), salmon (parr, young of year and spawning) and three macroinvertebrate target species; the freshwater shrimp *Gammarus pulex* and the stoneflies *Leuctra fusca* and *Isoperla grammatica*. For life-stages of trout generalised habitat suitability curves from the U.S.Fish & Wildlife, and habitat utilisation curves produced by NRA Wessex Region service were used in IFIM simulations. IFIM simulations for life-stages of salmon used generalised habitat suitability curves developed from studies in Norway and other published studies by Jan Heggenes (except for spawning salmon where Wessex NRA data was used). Invertebrate habitat suitability data were developed by the Institute of Freshwater Ecology.

In order to assess the impact of the abstractions at each site, PHABSIM WUA vs discharge relationships for individual target species life-stages were combined with records of historical and natural daily mean flows, to give the corresponding habitat (WUA) time series. For the River Bray site the flow record was naturalised using gauged daily abstraction data over the period 1980-1992. For the River Barle site the natural flow record (1981-1993) for the study reach was generated by adjusting the natural record from the nearby Brushford gauging station by assuming uptake of the maximum licensed daily abstraction (a "worst case" scenario). Habitat time series (all months, summer months and winter months) for individual target species were analysed using a conventional duration curve program.

At both sites time series simulations showed significant reductions in summer habitat availability for life-stages of trout and salmon. In both cases predicted reductions are greatest for the fry life-stage of trout and for salmon parr. Impact upon invertebrate habitat availability is limited relative to that upon habitat for the fish species.

Results of habitat simulations for trout suggest that the US habitat suitability curves are more appropriate for this application than the Wessex NRA curves. The generalised US curves for trout and Heggenes' generalised salmon curves are fairly broad-banded hence their transferability should be fairly good. Although it would clearly be beneficial to develop habitat utilisation data based on direct observations of trout and salmon in rivers similar to those studied here, it is likely that any curves produced would fall within the range of the generalised curves used here. This would result in an increase in the predicted impacts on habitat availability. Some additional simulations are recommended, particularly in the case of the Barle where the "worst case" scenario may not be a very realistic representation of actual abstraction over the period considered.

Acknowledgements

We would like to acknowledge the use of habitat suitability data developed by Dr Graham Lightfoot, Andy Strevens, Dave Bird and others from NRA South Western Region, Dr Patrick Armitage and colleagues from the Institute of Freshwater Ecology Riverlab, Wareham, the U.S.Fish & Wildlife Service & Dr Jan Heggenes. We also acknowledge the U.S Fish and Wildlife Service for their work in developing the PHABSIM system.

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1 Introduction

1.1 INSTREAM FLOW INCREMENTAL METHODOLOGY

The Instream Flow Incremental Methodology (IFIM) has been developed as a tool for environmental impact assessment since 1976, by the Aquatic Systems Branch of the U.S. Fish & Wildlife Service (Bovee, 1982). The IFIM allows the quantification of a measure of physical habitat area ('Weighted Usable Area') available to target aquatic species. The IFIM is implemented using the Physical Habitat Simulation (PHABSIM) computer model. Calibration of hydraulic models within PHABSIM on the basis of field observations of microhabitat variables depth, mean column velocity and substrate type facilitates the prediction of change in physical habitat area with discharge. Evidence based on IFIM predictions has frequently been upheld in disputes over water resources in the USA where it is by far the most commonly preferred method for assessing minimum acceptable flows.

The IFIM using PHABSIM has been assessed for use in the UK under national NRA R&D Project B2.1 Ecologically Acceptable Flows (Johnson *et al*, 1993(1)), by application at eleven study sites on a wide range of different types of rivers. The first application of the IFIM to a current UK operational water resources problem was carried out in 1992 at sites on the River Allen in Dorset by the Institute of Hydrology and National Rivers Authority Wessex Region (Johnson *et al*, 1993(2)). The IFIM is currently being employed by NRA Thames Region as part of an investigation into the impact of groundwater abstraction upon the ecology of the River Kennet. A flow chart giving an outline of the steps involved in applying the IFIM using PHABSIM to assess the impact of a historical abstraction regime upon the availability of physical habitat to selected target species is shown in Figure 1.1 below.

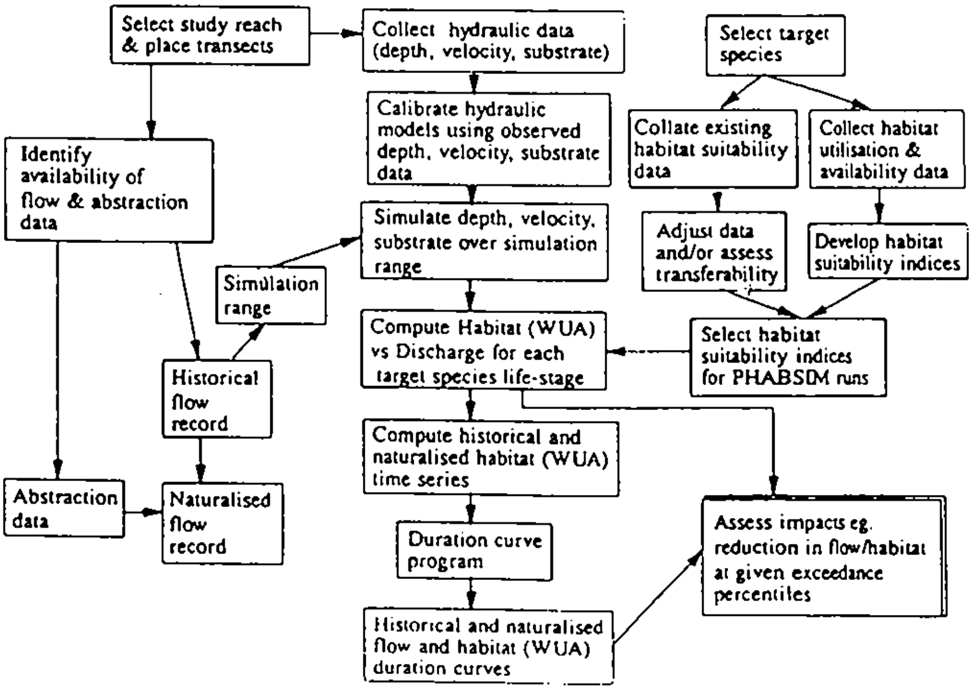


Figure 1.1 Procedure for IFIM assessment of impact of abstraction upon habitat availability.

1.2 THE RIVER BRAY AT LEEHAMFORD

The Leehamford bridge is situated on the River Bray (see Figure 1.2) approximately 2.5 km to the south west of the village of Challacombe where the Challacombe-Bratton Fleming road crosses the river. At this point the Bray has a relatively small catchment area of 17.6 km². The catchment, which drains Exmoor, is relatively flashy with the natural Q95 (0.083 cumecs) representing approximately 12% of the natural ADF (0.700 cumecs) for the period 1980-1992. In the headwaters of the catchment there is a small, disused reservoir (Challacombe reservoir). The catchment is subject to two principle abstractions for public water supply, from the Bray at Leehamford and from one of its tributaries the Brockenbrow. The Brockenbrow abstraction operates in winter only (November-March). It is operated in conjunction with the Leehamford abstraction and is relatively small. The principle abstraction at Leehamford operates mainly in the summer months.

The Leehamford abstraction lies immediately to the south of the bridge (grid ref. SS678399). At this point water is abstracted directly from the river for public water supply. The 'original' abstraction license restricted abstraction to not more than half of the natural flow in the Bray (50% take). Daily abstraction was not to exceed 34,095m³/day with an annual total of 4,023,270m³/year. However, in the summer of 1992, SWWSL voluntarily adopted a 'gentlemans agreement' which consisted of a prescribed minimum flow of 0.079 cumecs (natural flow) and a 50% take above that (other license conditions remained the same). This agreement was later encompassed in a temporary license variation which is due to end in July 1996.

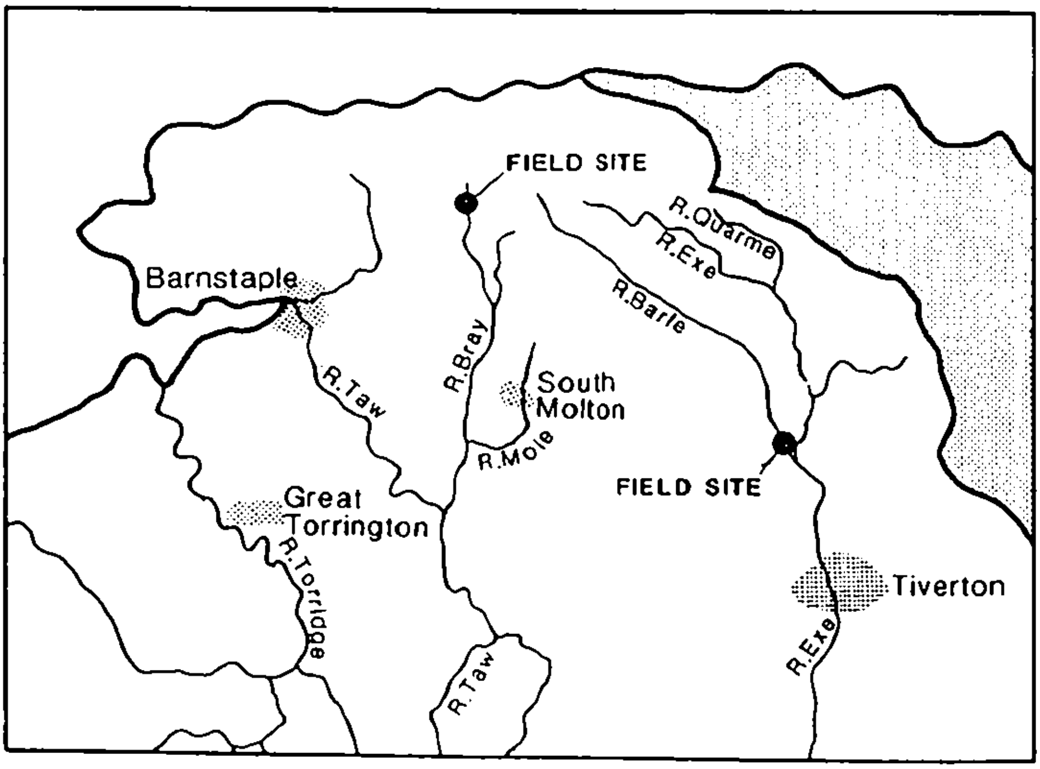


Figure 1.2 Location of R.Barle and Bray study sites within the S.W. Region.

Habitat time series simulations in this assessment are based on a record of daily mean flows from the NRA Leehamford gauging station which lies immediately downstream of the abstraction point (Station No. 050821). The measuring weir is sound with no significant drift; the last rating was done in 1982. The period of record used is from 1/1/80-31/12/92. Since the abstraction is upstream of the measuring weir the Leehamford gauged flow record is influenced by the abstraction.

The river reach immediately downstream of the abstraction was ranked tenth in the Halcrow Low Flow Study (1991) and was graded as a first class migratory fish river. The Halcrow study lists perceived impacts of the abstraction at low flows including "great reduction in nursery production potential due to reduced flow; passage for migratory fish difficult or discouraging at times; significant but not major smolt/kelt entrainment problems" and "dried out river length or severely depleted river length significantly reducing production of juvenile salmonids".

1.3 THE RIVER BARLE AT PERRY WEIR

The Barle catchment (see Figure 1.2) is relatively large, with a catchment area of 128km^2. Like the Bray it drains Exmoor and is relatively flashy, with the natural Q95 (0.65 cumecs, gauged at Brushford), representing approximately 11% of the ADF (5.843 cumecs) for the period 5/10/81-8/2/93. The Barle catchment is subject to relatively few artificial influences. Perry Weir (grid ref. SS931256) is situated on the Barle approximately 1.2 km north of Exebridge, 500m north of its confluence with the River Exe. At this point a system of weirs diverts a proportion of the river flow into a leat abstraction for fish farming, the water being returned to the Exe downstream of the confluence (approximately 1km downstream of the abstraction). The current abstraction licence allows a maximum daily abstraction rate of 0.770 cumecs. There is potential for the deprived stretch below the abstraction to dry out at times of very low flow (SW NRA Water Resources Planning 1993). The closest flow gauging station (Station No. 045011) to Perry Weir is situated at Brushford, some 500m upstream. The Brushford station is operated by Exeter University. A summary sheet for the station, covering the period of record from 1968-1981 is included in Appendix A. (Note that for the habitat time series analysis in this assessment a record of daily mean flows over the period 5/10/81-8/2/93 was used - this period is not covered by the summary sheet).

The river reach lying downstream of the abstraction was ranked eleventh in the 1991 Halcrow Low Flow Study. It was ranked as a first class migratory fish river but the impact of the abstraction at low flows was noted to cause "drying out or virtually so, of significant reaches of nursery area, and/or: reach or weir impassable to migratory fish at times, and/or: major smolt or kelt entrainment at times". Further fisheries problems identified by the low flow study include: "dried out river length or severely depleted river length significantly reducing production of juvenile salmonids", "obstruction caused by river reach with low flow, causing restricted distribution of fish for angling" and "abstraction of major part of flow, inadequately screened, leading to entrainment of downstream migrating smolt of kelts at times of low flows".

2 PHABSIM study sites and calibration data

2.1 LOCATION OF STUDY SITES

To meet the study objectives of assessing the impact of the operation of the abstraction schemes upon the availability of physical habitat to life stages of migratory fish species and selected invertebrates, NRA South Western Region staff (Tom Buckley, Alan Rafelt & Alan Burrows) proposed that:

(1) A PHABSIM study reach on the River Barle should be selected to represent habitat types present between the Perry Weir abstraction and the confluence with the River Exe, approximately 1km downstream.

(2) A PHABSIM study reach on the River Bray should be selected to represent habitat types present in the vicinity of the Leehamford abstraction.

After visual assessment of habitat types present, two PHABSIM representative reaches (120m long on the Bray and 240m long on the Barle) were selected. Transects were placed along each reach to sample the habitat types present and satisfy the data requirements of PHABSIM hydraulic and habitat models (Johnson *et al*, 1992). The chosen study reach on the River Bray is some 100m downstream of the Leehamford abstraction (grid ref. SS678399) as shown in Figure 2.1 below. The study reach on the River Barle lies immediately downstream of the Perry Weir abstraction as shown in Figure 2.2. At each location positions of transects were marked on left and right banks using permanent survey markers. The locations of transects for field sampling of microhabitat variables depth, mean column velocity and substrate type are shown in Figures 2.3 and 2.4 below, for the Bray and Barle sites respectively.

For both the Bray and the Barle the choice of study site location was driven primarily by the identification, by NRA SW, of reaches downstream of the abstraction points where problems of low habitat availability are perceived. In both cases the total stream length surveyed before selecting transect locations to define the study reach was around 500m. The study reaches selected represent habitat types present within these 500m long stretches. It is clear that any attempt to extrapolate results from the study sites must pay regard to possible change in channel form and habitat characteristics, particularly given the fact that in the South West region such changes may be large over relatively small distances. Details of a 'habitat mapping' extrapolation procedure used on the River Allen in Dorset are given by Johnson & Elliott (1993(2)).

2.2 PHABSIM FIELD SURVEY DATA

At each of the chosen study reaches field surveys were conducted to meet the data requirements of the PHABSIM model. The essential steps in this procedure were as follows:

(i) Elevations of the head-pins marking the transects were surveyed relative to a fixed datum level.

(ii) Inter-transect distances (reach lengths) were measured on the left and right bank and as triangulations. These data are given in Tables 2.1, 2.2 below, for the River Bray and River Barle sites respectively.

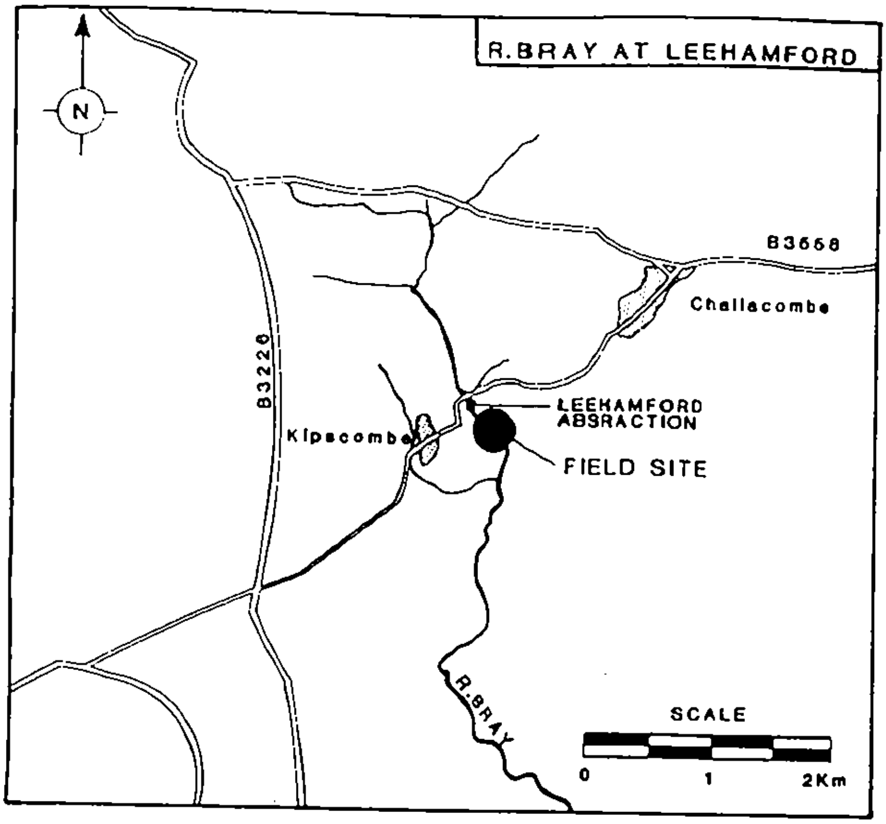


Figure 2.1 *R.Bray: Location of PHABSIM Field Study Site*

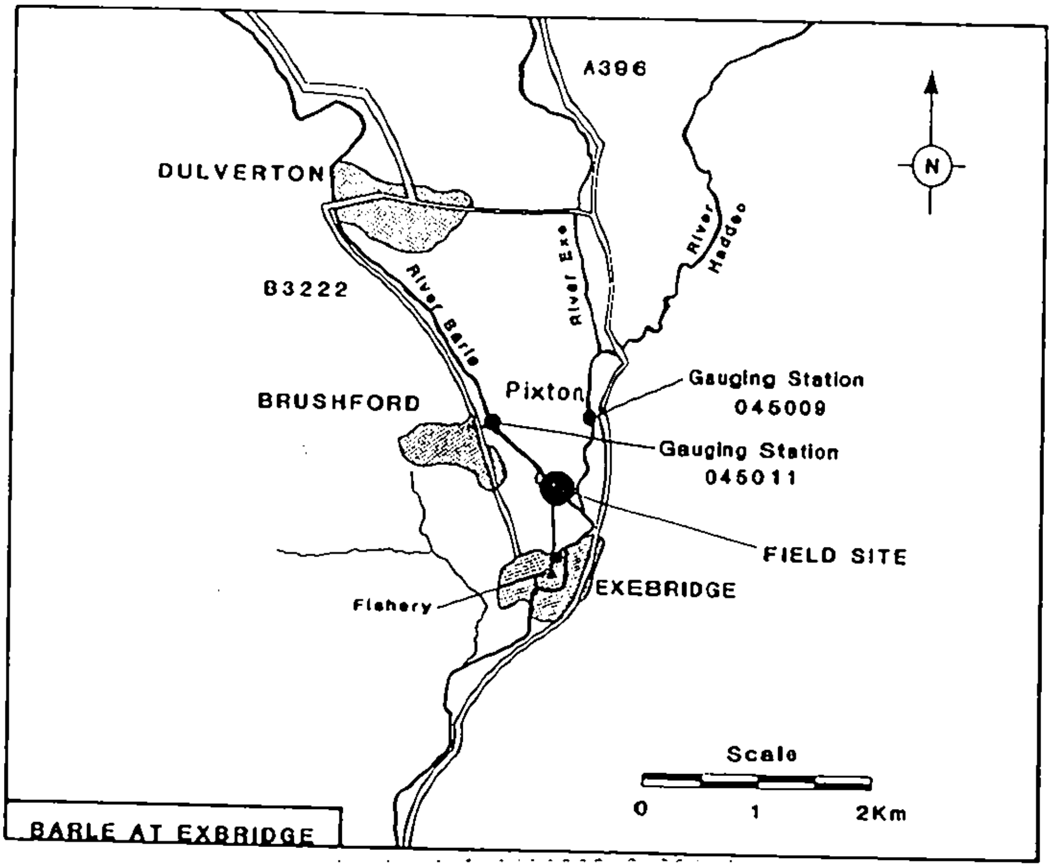


Figure 2.2 *R.Barle: Location of PHABSIM Field Study Site*

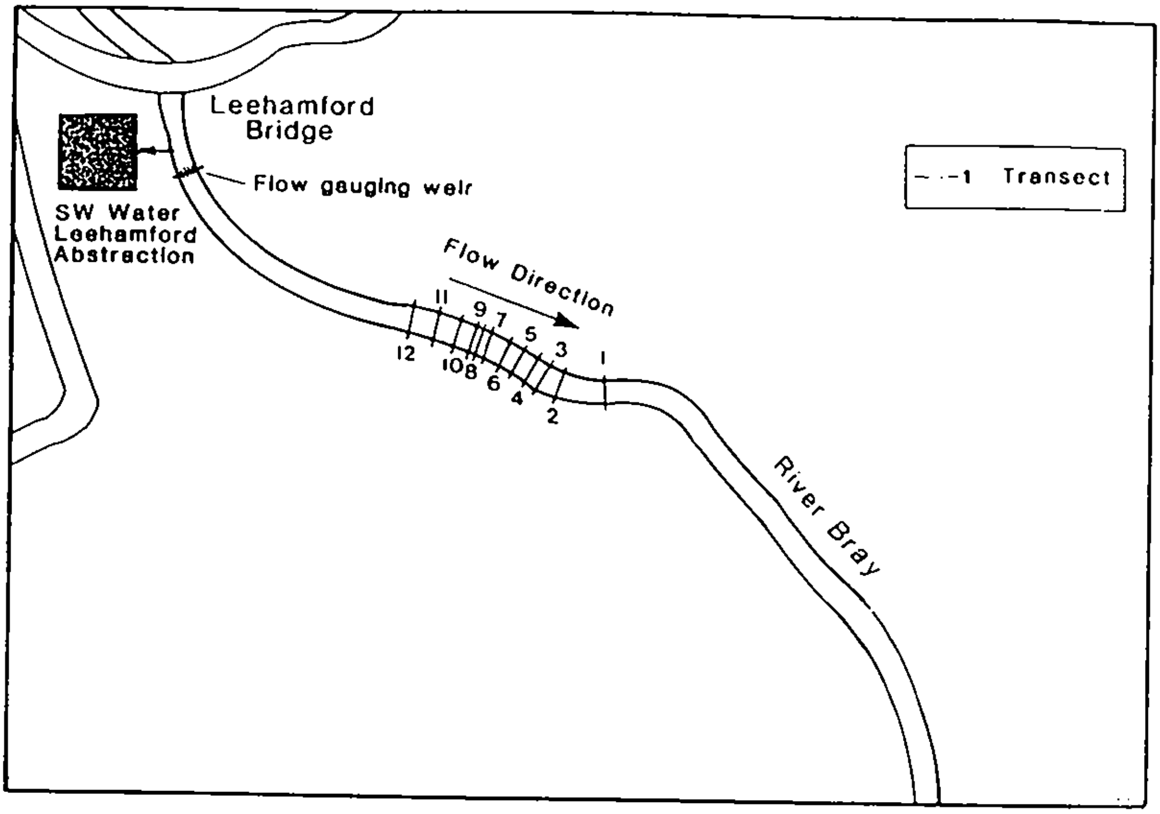


Figure 2.3 *R.Bray Site: Transect Placement*

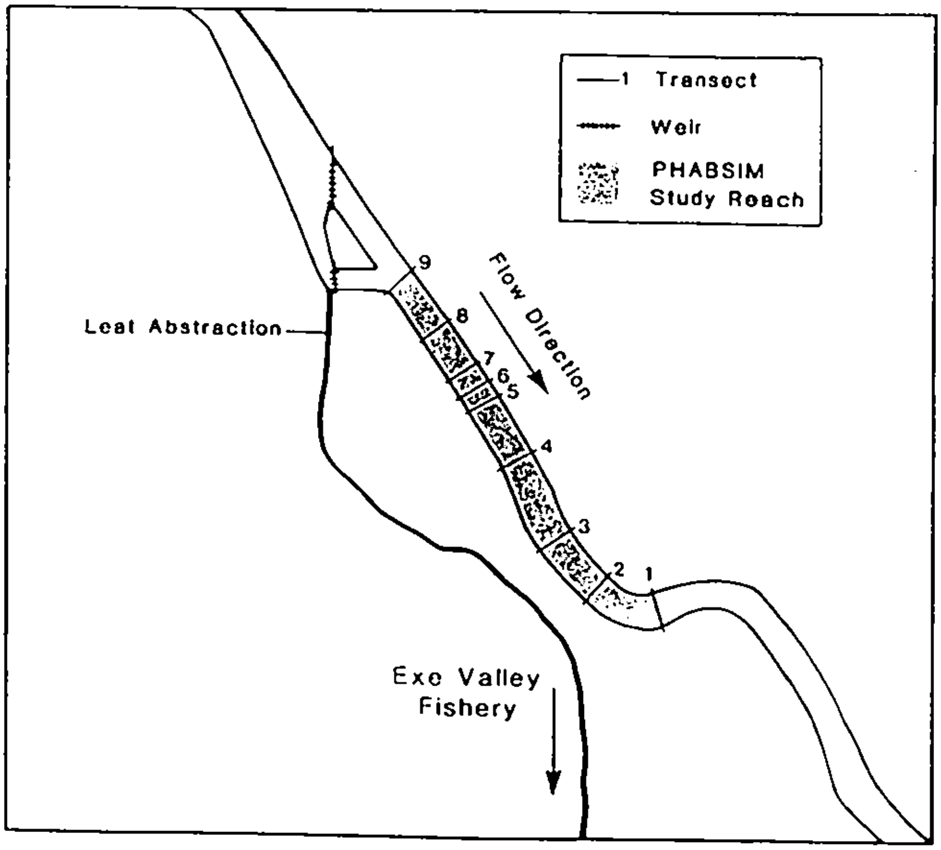


Figure 2.4 *R.Barle Site: Transect Placement*

(iii) Observations of dominant substrate in the immediate vicinity of each data point were made using the particle size classification system based on the Wentworth scale given in Table 2.5 at the end of this sub-section.

(iv) Mean column velocity was measured at each data point using an electromagnetic current meter averaging over a 30 second time interval. At each data point a single measurement at 0.6 x depth was taken.

(v) Water surface elevations were surveyed relative to the fixed head-pins at each transect. Measurements were made at left, right and centre of the stream then averaged.

(vi) Steps (iv) and (v) were repeated on two further occasions chosen to give the widest possible range of flow calibration data. Where river flow conditions did not allow discharges to be measured at all the cross sections within a study reach, discharge measurements were made at selected transects only and full sets of water surface elevations taken.

In addition to the observations made in (iii), additional observations were made of the following: subdominant substrate, substrate packing, small and large object cover (on the river bed), overhead vegetation cover, instream vegetation cover, and the presence or absence of undercut banks. Although these measurements were not used in model simulations for this assessment, they may be used in future simulations, given appropriate habitat suitability data. Summary plots showing surveyed cross-sectional profiles, observed water surface elevations and velocities are given in Appendices B and C for the River Bray and River Barle study sites respectively. A complete record of all field data gathered is given for both sites in Appendix D.

Tables 2.3 and 2.4 below give the dates when each set of hydraulic calibration data was measured, together with the mean measured discharge through the reach, for the River Bray and Barle study sites respectively. For the Bray the figures in Table 2.3 are taken from the Leehamford gauged flow record. For the Barle the figures refer to the average of the discharges measured at transects in the study reach (in this case daily abstraction data required to adjust the natural flow record from the Brushford gauging station was not available to calculate the flow through the study reach).

Table 2.1 *R.Bray Site: Reach Length Measurements*

	Inter-Transect Distances (m)		
C/S nos.	Left Bank	Right Bank	Average
1-2	20.35	27.0	23.675
2-3	8.80	8.85	8.825
3-4	7.29	8.26	7.775
4-5	8.90	9.28	9.090
5-6	8.67	8.52	8.595
6-7	11.20	11.54	11.370
7-8	5.63	4.65	5.140
8-9	4.05	4.95	4.500
9-10	9.67	9.60	9.635
10-11	11.57	12.15	11.860
11-12	12.75	13.86	13.305

Table 2.2 *R.Barle Site: Reach Length Measurements*

	Inter-Transect Distances (m)		
C/S nos.	Left Bank	Right Bank	Average
1-2	28.50	33.85	31.175
2-3	26.76	41.80	34.280
3-4	46.34	50.80	48.570
4-5	33.94	35.00	34.470
5-6	11.73	9.98	10.855
6-7	11.25	14.00	12.625
7-8	28.94	26.90	27.920
8-9	32.74	30.10	31.420

Table 2.3 *R. Bray Site: Measured Calibration Flows*

Survey No.	Date	Mean Discharge (cumecs)
1	25.2.93	0.17
2	15.6.93	1.25
3	10.9.93	0.43

Table 2.4 *R.Barle Site: Measured Calibration Flows*

Survey No.	Date	Mean Discharge (cumecs)
1	9.2.93	1.79
2	16.6.93	5.65
3	10.9.93	3.59

Table 2.5 *Substrate Classification Scheme*

1.	Organic detritus	
2.	Clay	(< / = 0.004mm)
3.	Silt	(0.004 - 0.0625mm)
4.	Sand	(0.0625 - 2mm)
5.	Gravel	(2 - 64mm)
6.	Cobble	(64 - 256mm)
7.	Boulder	(> 256mm)
8.	Bedrock	
9.	Terrestrial Vegetation	
10.	Man Made Bank Material	

2.3 PHABSIM HYDRAULIC MODEL CALIBRATION AND SIMULATIONS

PHABSIM contains a choice of three models for hydraulic simulations, IFG4, MANSQ and WSP. For this assessment hydraulic simulations were run using the IFG4 model. IFG4 simulates water surface elevations using a stage-discharge regression technique and simulates velocities using an approach based on Manning's equation and a simple mass balancing. The procedure used for hydraulic model calibration was the same for the data sets from each of the two study sites and is summarised below:

(i) Calibrate the IFG4 model for the full set of transects in the reach using the three measured stage/discharge sets. (For the Barle site discharges were taken as the mean measured discharge for the whole reach at each calibration flow. On the Bray the mean daily flow measured at the Leehamford gauging station on the day of each survey was used as the mean discharge for each calibration flow).

(ii) Check the accuracy of the water surface levels predicted by the IFG4 model with those observed when measuring the calibration flows.

(iii) Input one of the complete sets of measured velocity data into the IFG4 model and simulate velocities at the other two calibration discharges.

(iv) Check the accuracy of the water velocities predicted by the IFG4 model with those observed when measuring the calibration flows.

(v) Simulate water surface profiles and velocities, using the IFG4 model, for selected flows over the full range of discharges obtained from the gauged flow records at each site.

The measured water surface profiles (OBS1/2/3) and the simulated profiles (SIM1/2/3) generated by the IFG4 model at the measured calibration discharges are shown in Figures 2.5, 2.6 below, for the River Bray and River Barle study sites respectively (in Figures 2.5, 2.6 distance on the x axis is measured as the distance upstream from the most downstream transect (no.1) in the study reach). The flow exceedance percentiles represented by the observed discharges, based on records of historical flows (including effects of abstraction) through the study reaches are as follows :

River Bray

Obs No	Survey Date	Flow (cumecs)	Percentile
1	25.2.93	0.17	Q81
2	15.6.93	1.25	Q15
3	10.9.93	0.43	Q52

River Barle

Obs No	Survey Date	Flow (cumecs)	Percentile
1	9.2.93	1.79	Q60
2	16.6.93	5.65	Q28
3	10.9.93	3.59	Q41

The US Fish & Wildlife Service (Milhous *et al* ,1989) give guidelines for estimating the range of discharges over which observed calibration data may be reliably extrapolated. They recommend extrapolation limits of 0.4 x lowest - 2.5 x highest measured discharge. In this assessment the outputs of PHABSIM hydraulic and habitat simulations are to be combined with records of historical (effects of abstraction included) and natural flows (without abstraction). The limits of extrapolation implied by the U.S. Fish & Wildlife Service guidelines, as values in cumecs, and as exceedance percentiles of the historical flow records to be applied at each study reach are as follows :

	Lower limit	Upper limit
River Bray :	0.068(Q90)	3.12 (>Q2)
River Barle :	0.72 (Q78)	14.12(Q8)

In both cases it is necessary to extrapolate beyond the US guidelines in order to represent habitat conditions for the full range of discharges in the record. Extrapolation to flows higher than the upper limit has little influence on habitat time series outputs as the frequency of occurrence of such flows is very low. For flows lower than the recommended lower limit some increased errors in hydraulic modelling may be expected. In the case of the Barle it should be noted that (assuming maximum abstraction) historical flows are zero for 7% of the record, hence it is not necessary to extrapolate beyond Q93. If flow values of zero are excluded from the record , the lower limit of 0.72 cumecs corresponds to the Q84. In both cases the possibility of increased errors in hydraulic modelling should be considered when analysing outputs for flows in the 90-99 percentile range.

Simulated water surface profiles (output from the IFG4 model) at selected discharges over the chosen simulation ranges are given in Figures 2.7, 2.8 below for the River Bray and River Barle study sites respectively.

Outputs of PHABSIM hydraulic model simulations in the form of point values of predicted depths and velocity are combined with coded observations of substrate type (assumed to be independent of discharge) for entry into the PHABSIM habitat simulation model HABTAT. The HABTAT model combines these hydraulic data with habitat suitability index data for each target species life-stage. We shall now proceed to discuss the target species selected and the habitat suitability data available.

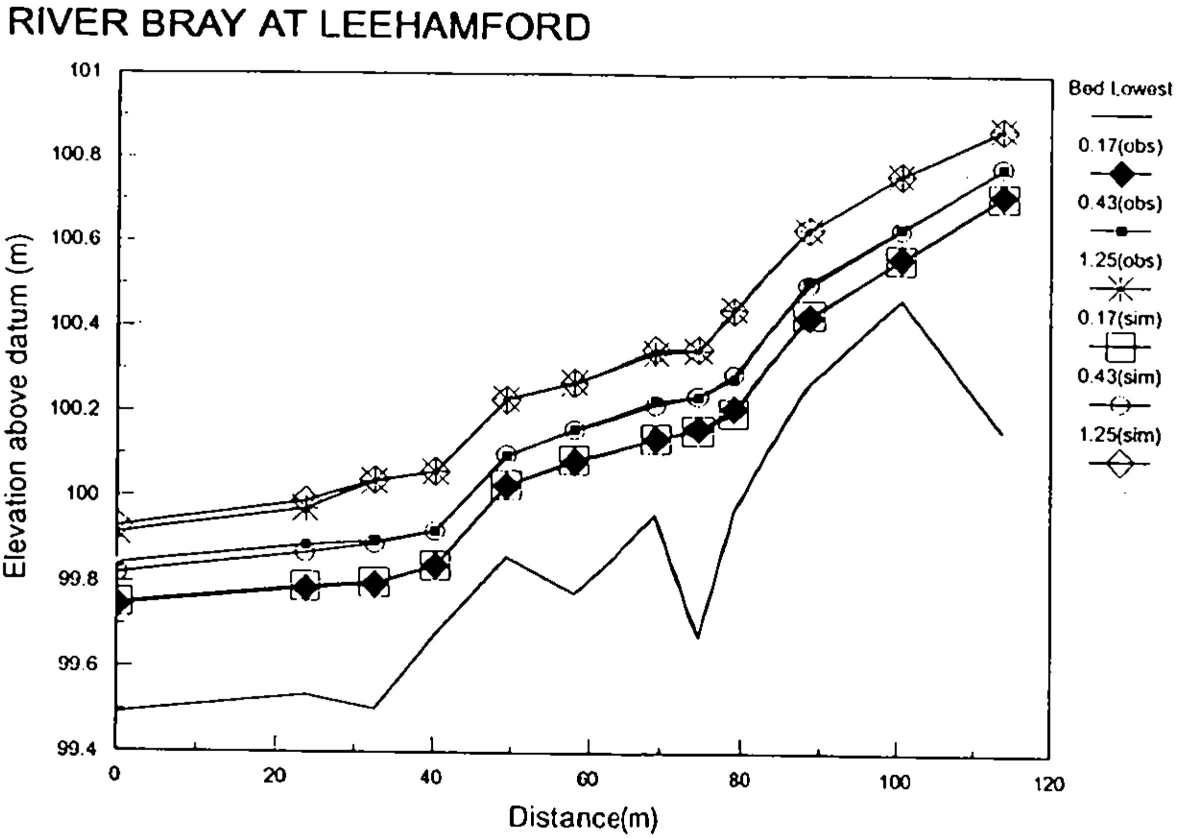


Figure 2.5 *River Bray: Observed and simulated water surface profiles calibration discharges*

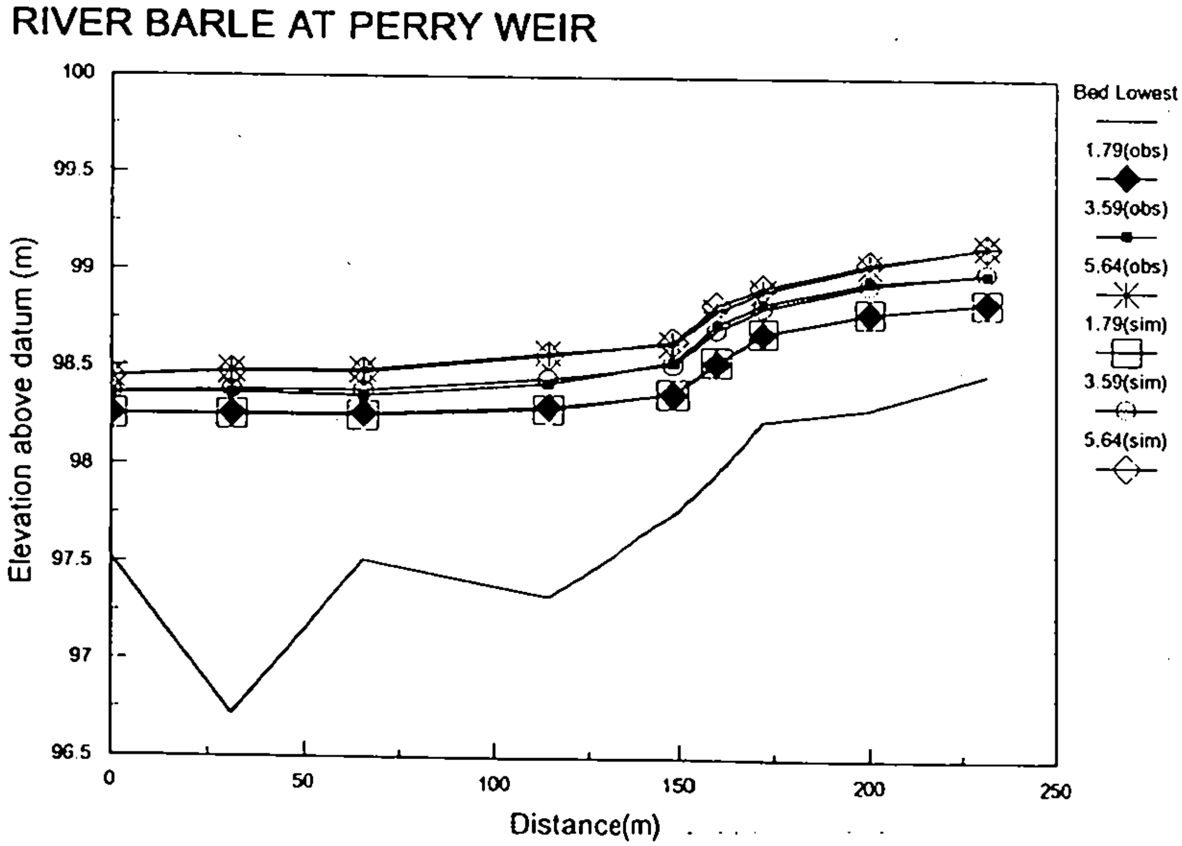


Figure 2.6 *River Barle: Observed and simulated water profiles at calibration discharges*

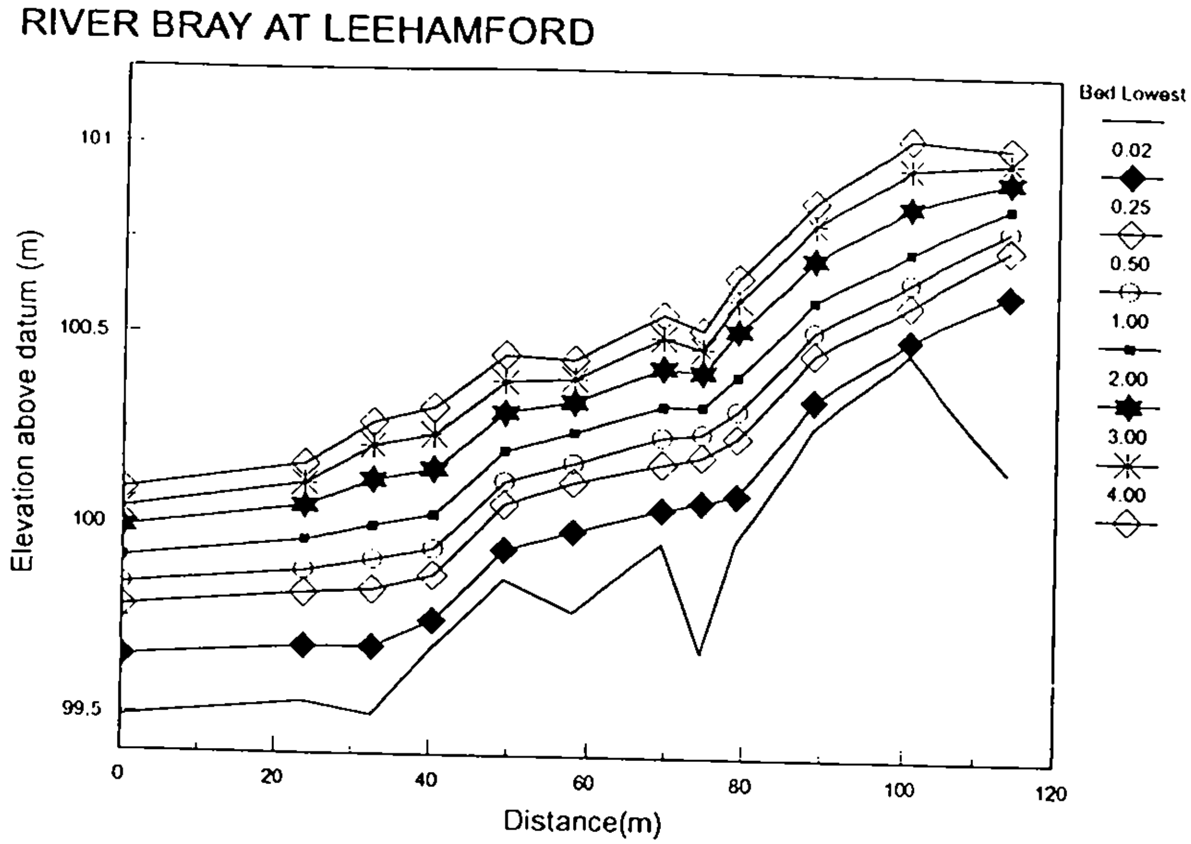


Figure 2.7 *River Bray: simulated water surface profiles at selected simulation discharges.*

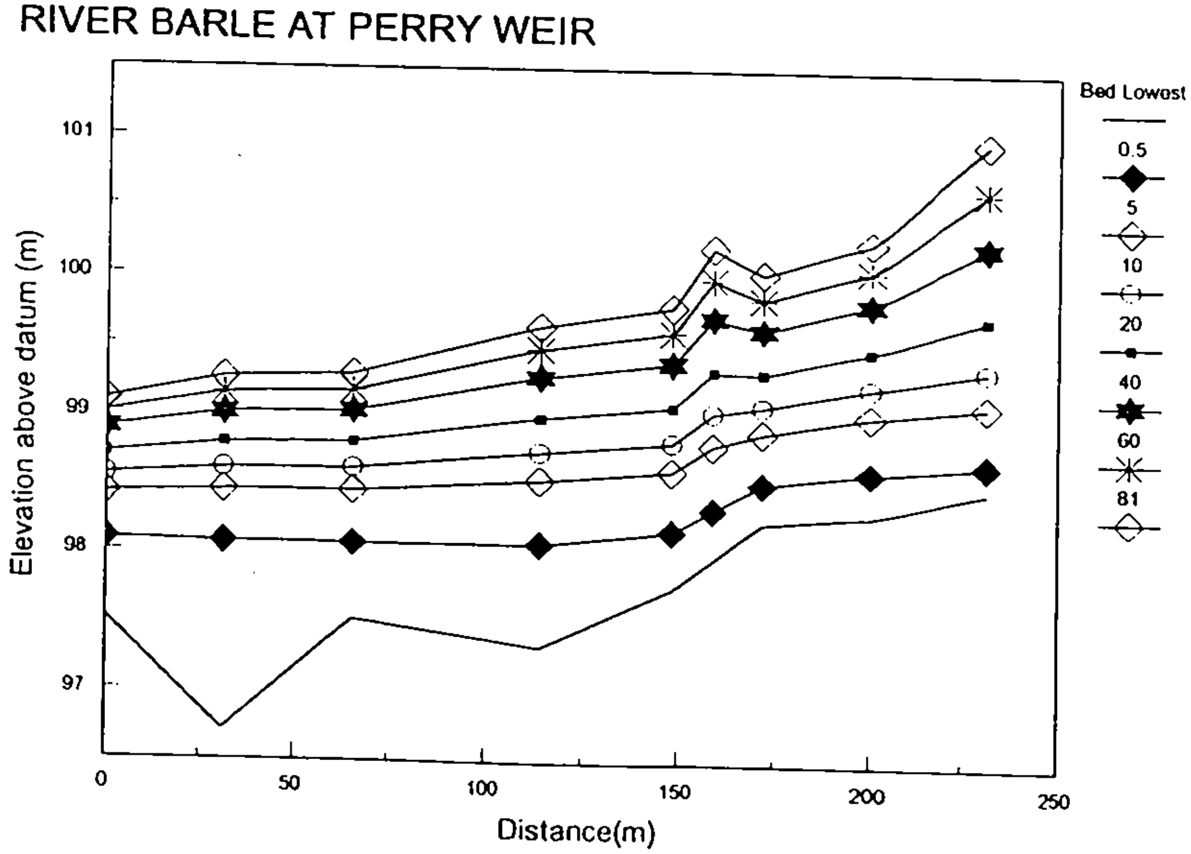


Figure 2.8 *River Barle: simulated water surface profiles at selected simulation discharges.*

3 Habitat suitability data

3.1 SELECTION OF TARGET SPECIES

The target species life-stages selected by NRA SW for this assessment are as follows:

Fish
- brown trout (all life-stages)

- atlantic salmon (parr, young of year and spawning)

Invertebrates
- *Gammarus pulex*

- *Leuctra fusca*

- *Isoperla grammatica*

In the next section we describe the form in which habitat suitability data enters the IFIM modelling procedure before discussing data available for those target species listed above.

3.2 HABITAT MODELLING: INTRODUCTION

PHABSIM modelling comprises two key elements; hydraulic simulation using IFG4, and habitat simulation using the HABTAT model. For a given simulation discharge values of mean column velocity, depth and substrate type are given as output from the hydraulic model(s), calibrated, as described in the previous section, using observed field data. The next stage in the simulation process is to assign to each of the simulated values of depth, velocity and substrate a habitat suitability value between 0 and 1, describing their relative value to the particular target species life-stage. This is achieved within PHABSIM by the use of "Habitat Suitability Indices". For each target species life-stage a habitat suitability index, in the form of a univariate curve taking values between 0 and 1, must be defined for each of the microhabitat variables velocity, depth and substrate.

Bovee (1986) defines three types of suitability index curves which may be used for IFIM simulations using PHABSIM. The distinction between the different types of habitat suitability criteria is in the way they are derived. The three types are defined as follows:

Category I: The habitat criteria are derived from life history studies in the literature or from professional experience and judgement, and are based on the adjudged suitability of physical habitat variables for target species life-stages.

Category II: The habitat criteria are based on frequency analysis of microhabitat conditions utilised by different life-stages and species identified by field observations. These criteria are termed "habitat utilisation curves" because they depict the conditions that were being used when the species were observed. Utilisation functions may not always accurately describe a species' preference because the preferred physical conditions may be absent or limited at the time of observation.

Category III: These are Category II curves in which the criteria are corrected for bias by factoring out the influence of limited habitat availability. This correction is aimed at increasing the transferability of the criteria to streams that differ from those where the criteria were originally developed. Category III curves are referred to as "habitat preference curves". Habitat preference for values of a given microhabitat variable is defined as the ratio of habitat utilisation to habitat availability. In general the greater the diversity of habitats present in the stream used for sampling the closer together will be the Category II and III curves derived from the utilisation and availability data.

3.3 HABITAT SUITABILITY DATA SOURCES

Applications of the IFIM in the UK under a number of R&D studies have used Category I habitat suitability curves for fish, macroinvertebrate and macrophyte species, produced by the Institute of Freshwater Ecology and Institute of Terrestrial Ecology. The first Category II and III curves for use in a UK IFIM application were developed by NRA Wessex Region as part of a catchment based study to address operational water resources problems on the River Allen in Dorset. Over a two year period a team led by Dr.Graham Lightfoot made observations of trout and salmon by snorkelling, diving and wading in a number of Dorset chalk streams similar in character to the Allen. From these data Category II habitat utilisation curves were developed for life-stages of trout (adult, fry/juvenile and spawning) and salmon (fry/juvenile and spawning). Curves for substrate were adjusted using habitat availability data and are thus Category III. The curves were used in an IFIM assessment (Johnson *et al* 1993(2)) of the impact of the historical groundwater abstraction regime upon seasonal habitat availability for trout and salmon.

For this assessment Category II or Category III habitat utilisation curves developed specifically for either the Barle or the Bray are not available. It has been necessary therefore to assess data available from previous IFIM applications and from published studies in the literature to select those most appropriate for this study. This assessment has taken into account those comments raised by NRA SW fisheries staff. A decision, on the basis of the information available, as to which curves are most appropriate for this application must ultimately be subjective, since it is not based specifically on analysis of either habitat availability or habitat utilisation data from the Bray, Barle or any similar rivers in NRA SW Region.

The transferability of the Wessex NRA curves to the Bray and Barle has not been assessed and it is clear that they may not be ideally suited for this application, given the difference in river type and habitat conditions present. This is particularly true of the Category II curves for depth and velocity which are based on utilisation data and were not adjusted by habitat availability. It is likely that habitat availability distributions for the Bray and Barle would be quite different to those in the Dorset chalk streams where the Wessex NRA observations were made. The substrate curves were adjusted for habitat availability and are thus Category III curves - this should increase transferability relative to the depth and velocity curves. Observations for the Wessex NRA study were made predominantly in the summer period, which may also increase errors in simulations for higher winter discharges (although summer low flows are of primary interest here). Heggenes (1990) noted seasonal changes in habitat selection by young atlantic salmon in a number of Norwegian streams. Wessex NRA suitability curves were developed for populations of trout and salmon living in sympatry, as is the case on the Bray and Barle (several authors have noted differences in habitat selection in young salmon between allopatric populations and those living in sympatry with brown trout populations).

The U.S. Fish & Wildlife Service have developed a library of habitat suitability curves ranging from Category I to Category III, for a wide variety of species. Category I curves for adult, fry, juvenile and spawning brown trout, based on habitat utilisation observations made in a number of US studies were developed by Raleigh, Zuckerman and Nelson (1986). In the development of these curves Category II data from various sources was collated along with information from published studies. The Category I curves produced from a synthesis of this information are fairly broad-banded, which enhances there transferability, relative to the more focused Category II utilisation curves, such as those produced by Wessex NRA. The authors state that "investigators who feel that the SI curves do not accurately reflect habitat utilisation at their study site are encouraged to gather information specific to their area and modify the curves or develop new curves as needed". For the simulation results presented here the U.S curves have not been adjusted.

Heggenes (1990(1)) gives Category I habitat suitability curves for parr and young of year salmon. Like the U.S. curves above the curves represent a synthesis of information from a number of other studies. The curves are presented as "generalised" habitat suitability curves - it is acknowledged by the author that various factors may influence habitat selection in individual cases. As in the case of the U.S. trout suitability curves, these generalised Category I curves are more readily transferable to the rivers studied here than the Wessex NRA Category II curves. We have normalised the curves so that they take values between 0 and 1.

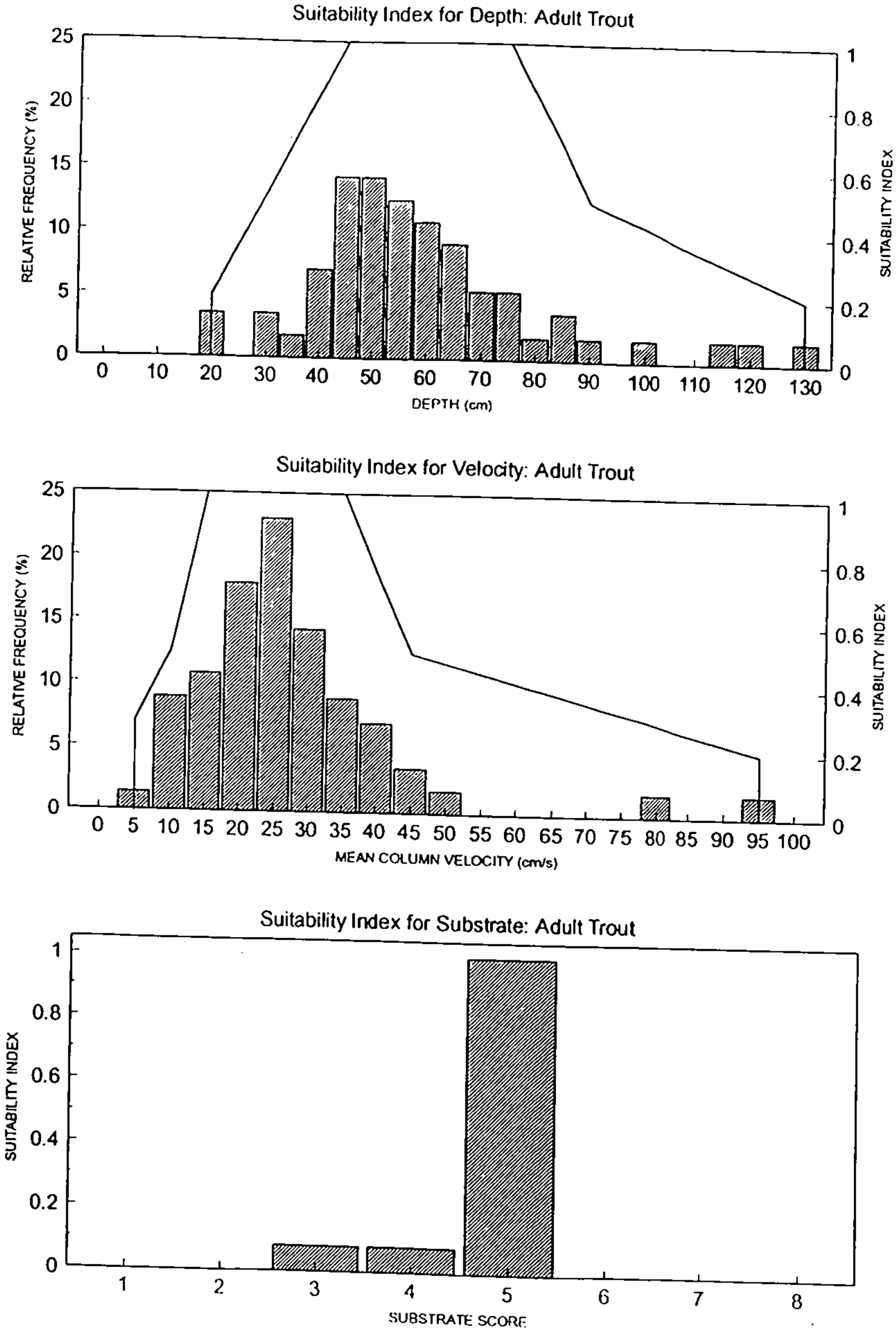
Habitat suitability curves for the three macroinvertebrate target species were developed by the Institute of Freshwater Ecology under NRA R&D Project B2.1 Ecologically Acceptable Flows. Curves are based on analysis of data from the RVPACS database. As noted in R&D Project B2.1 the lack of focus in these curves means that, relative to salmonid fish species, these species are very insensitive as target species in an IFIM study. It is clear in a study such as this that impacts predicted for the invertebrate species will be less than that for the fish species. Simulations were run, and results included here for the sake of completeness, but it is acknowledged that these are of secondary interest and will not contribute to the conclusions and recommendations of the study. The primary focus of this study is in any case with the fish species since it is for these species that the impact of the abstractions at both sites is perceived to have the greatest effect and gives the most cause for concern due to the potential loss of angling success.

3.4 HABITAT SUITABILITY INDICES FOR PHABSIM SIMULATIONS

The habitat suitability indices for life-stages of trout and salmon which (in liaison with SW NRA fisheries officer Kelvin Broad) were selected for use in PHABSIM habitat simulations for this assessment are listed in Table 3.1 below. The corresponding figures, listed in Table 3.1 are given on subsequent pages in this section. As discussed above habitat suitability curves for the three macroinvertebrate curves were provided by the Institute of Freshwater Ecology. Habitat suitability curves for *Gammarus pulex*, *Isoperla grammatica* and *Leuctra fusca* are shown in Figures 3.9-3.11 respectively.

Table 3.1 Habitat suitability indices selected for PHABSIM simulations for fish

Species	Life Stage	HSI Data Source	Figure No
Trout	Adult	Wessex (SW) NRA	3.1
Trout	Adult	US F& WS	3.2
Trout	Fry/Juvenile	Wessex (SW) NRA	3.3
Trout	Juvenile	US F& WS	3.4
Trout	Fry	US F&WS	3.4
Trout	Spawning	Wessex (SW) NRA	3.5
Trout	Spawning	US F&WS	3.6
Salmon	Parr	Heggenes	3.7
Salmon	Young of Year	Heggenes	3.7
Salmon	Spawning	Wessex (SW) NRA	3.8



Suitability Index for Depth: Adult Trout

Suitability Index for Velocity: Adult Trout

Suitability Index for Substrate: Adult Trout

Figure 3.1 *Habitat suitability data: adult brown trout (SW NRA)*

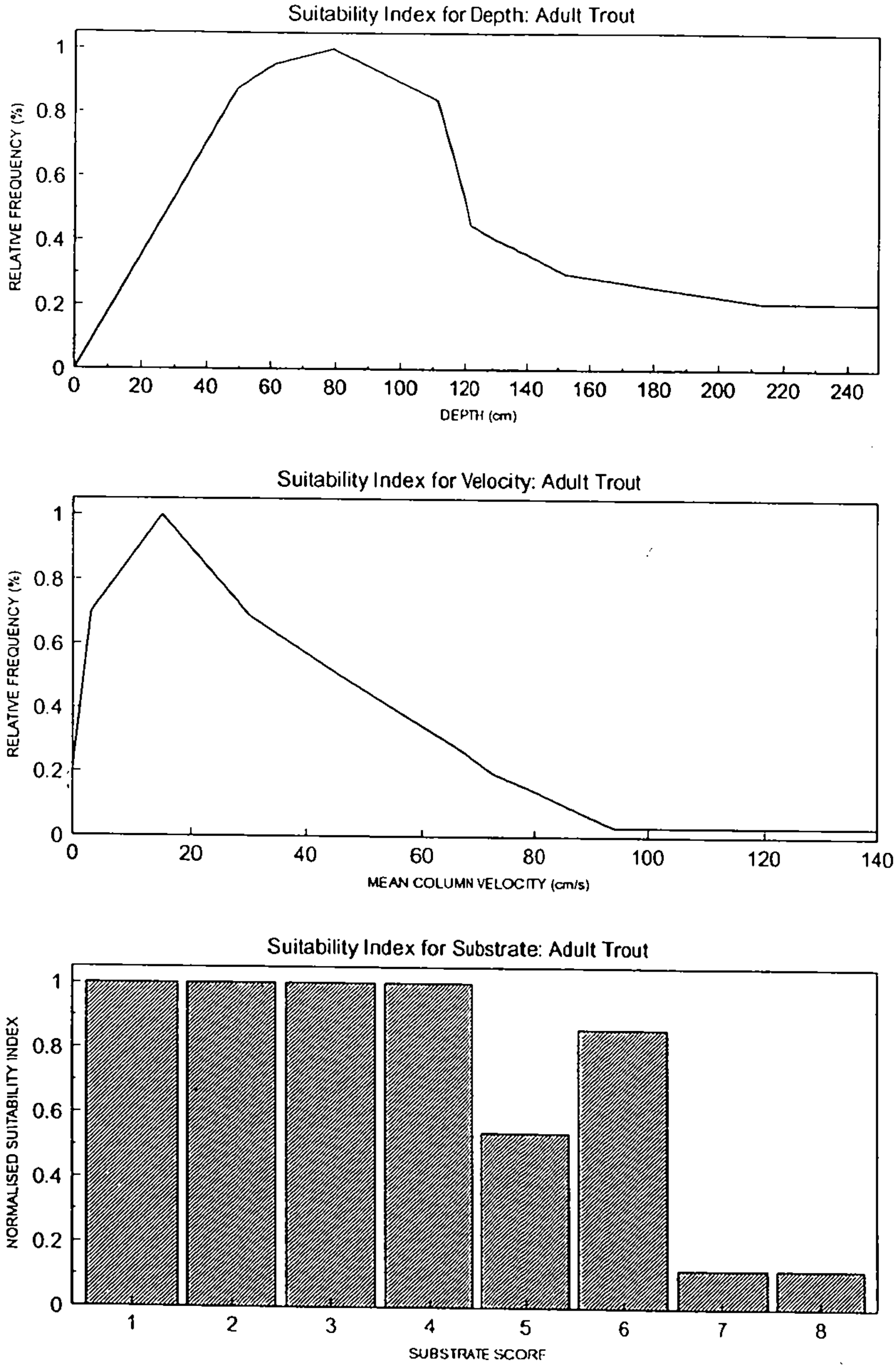


Figure 3.2 *Habitat suitability data: adult brown trout (US F&WS)*

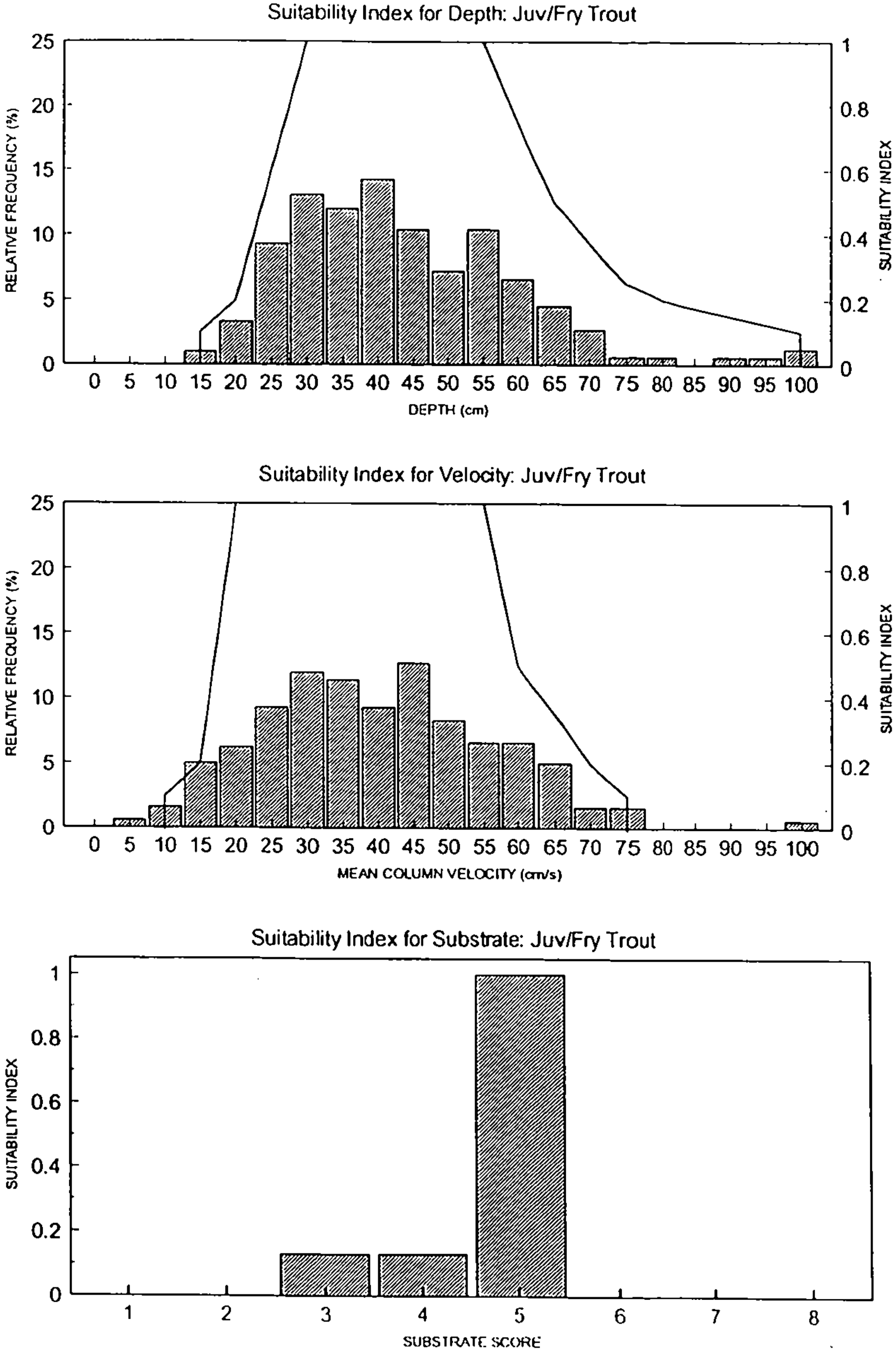


Figure 3.3 *Habitat suitability data: fry/juvenile brown trout (SW NRA)*

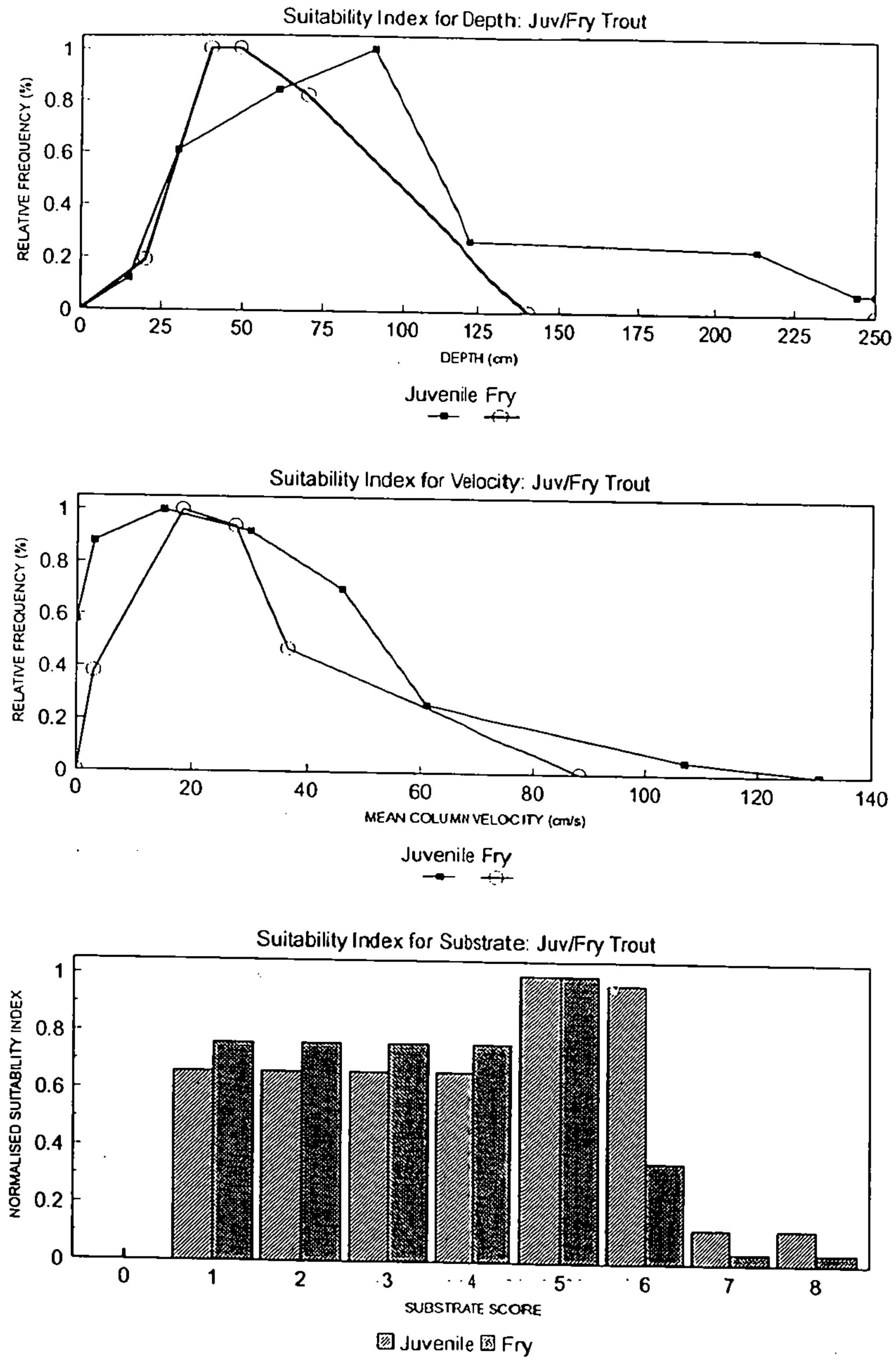


Figure 3.4 *Habitat suitability data: fry/juvenile brown trout (US F&WS data)*

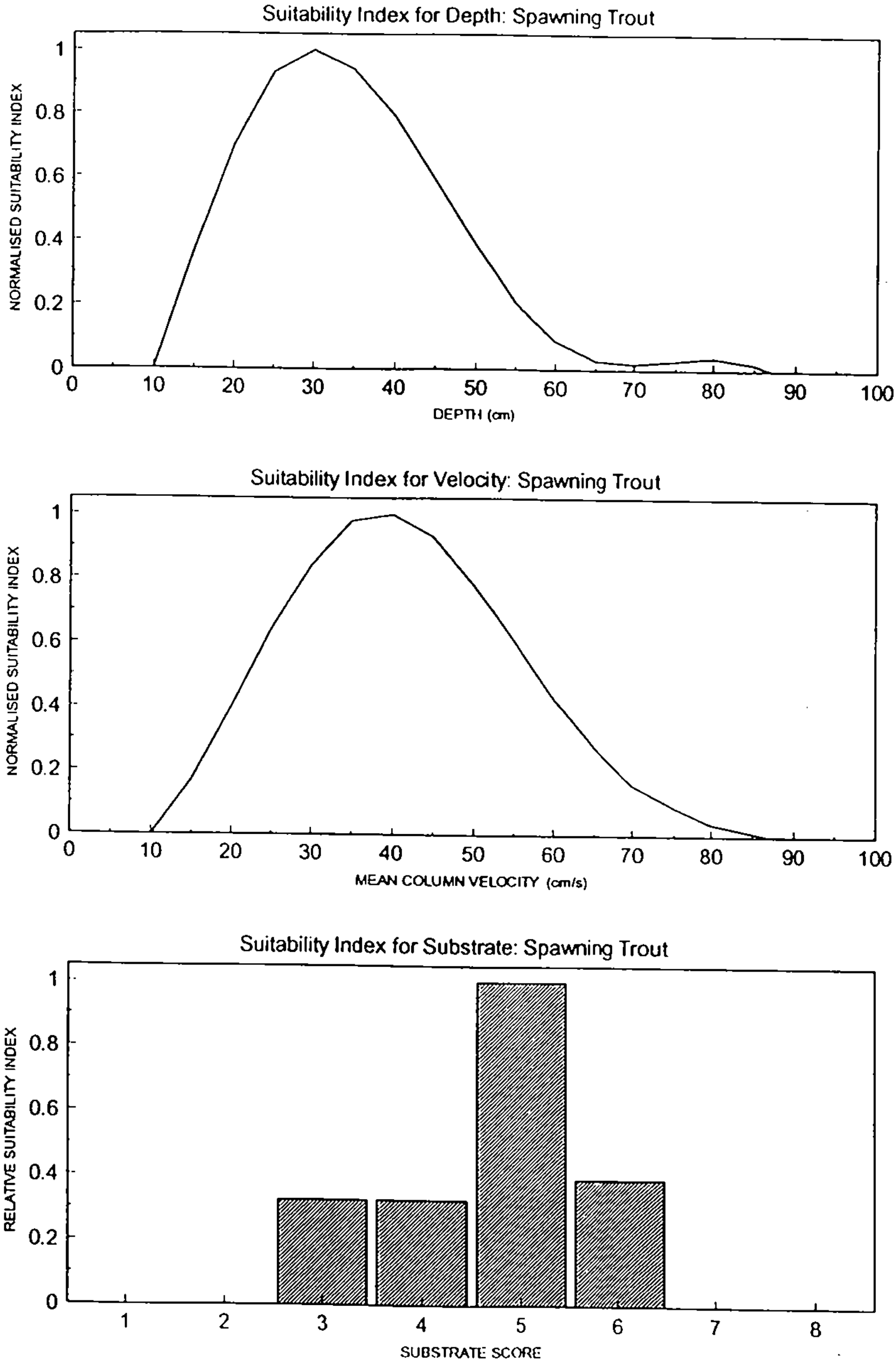


Figure 3.5 *Habitat suitability data: spawning brown trout (SW NRA data)*

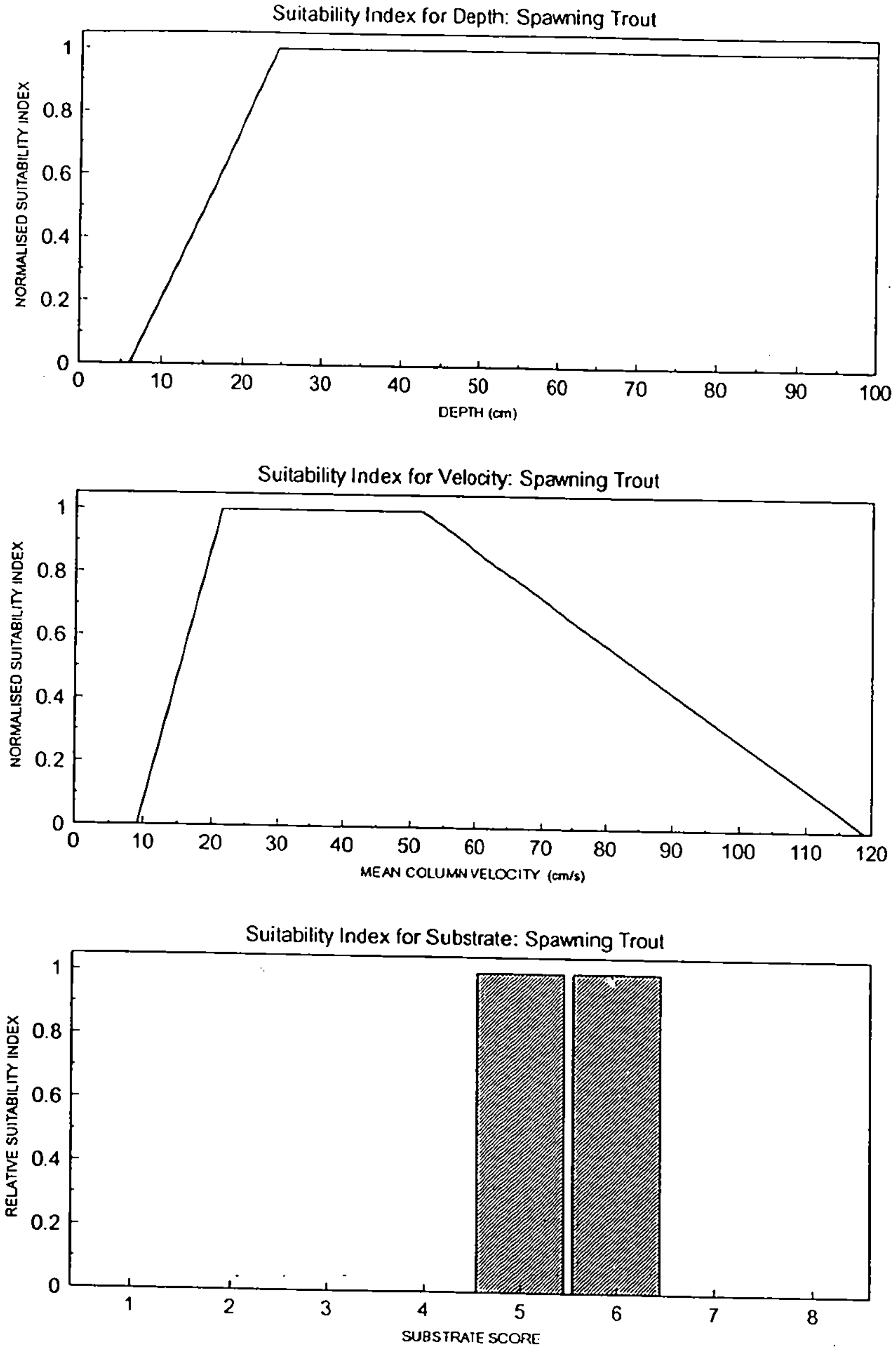


Figure 3.6 *Habitat suitability data: spawning brown trout (US &FWS data)*

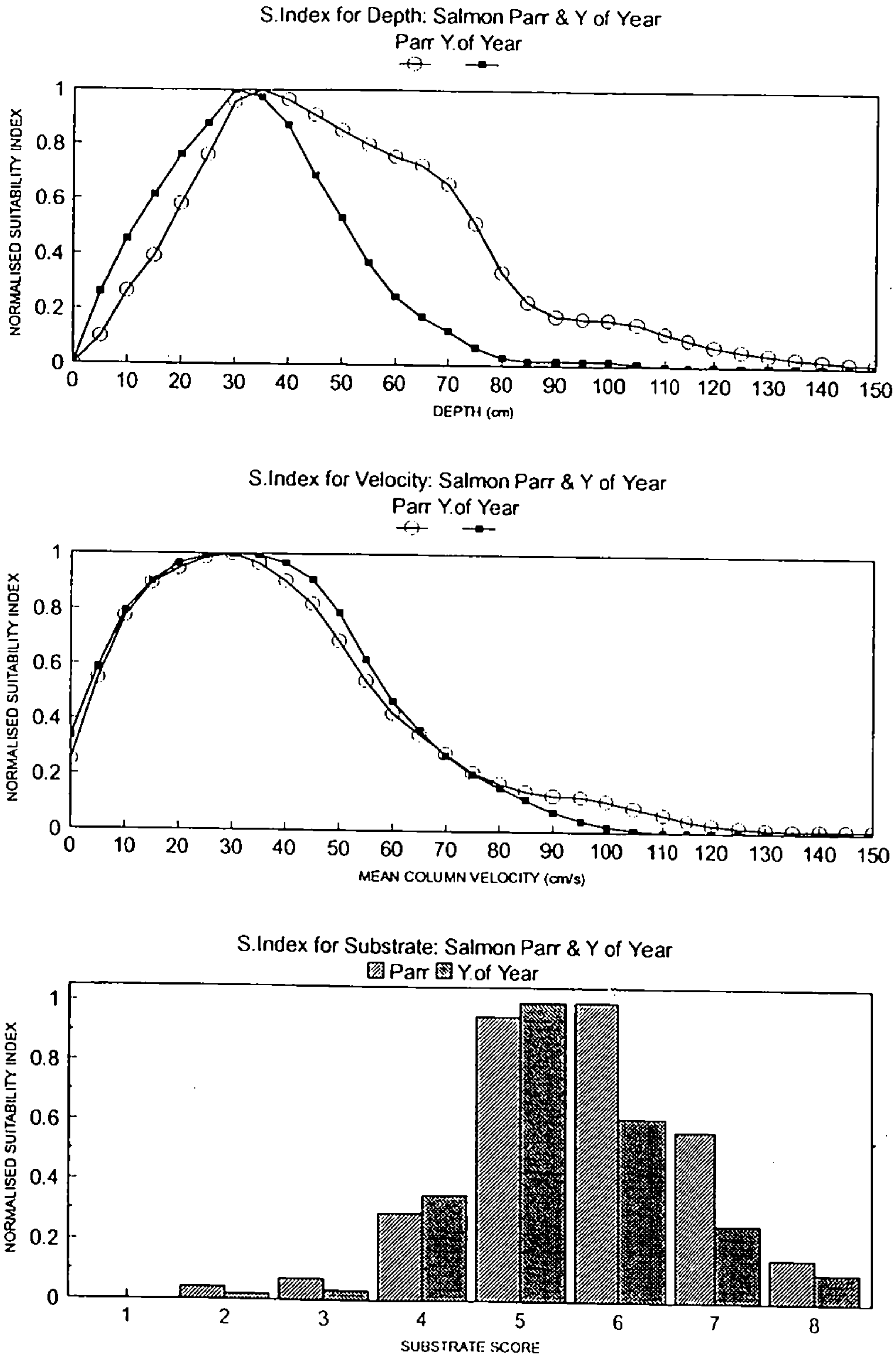


Figure 3.7 *Habitat suitability data: parr and young of year salmon (Heggenes data)*

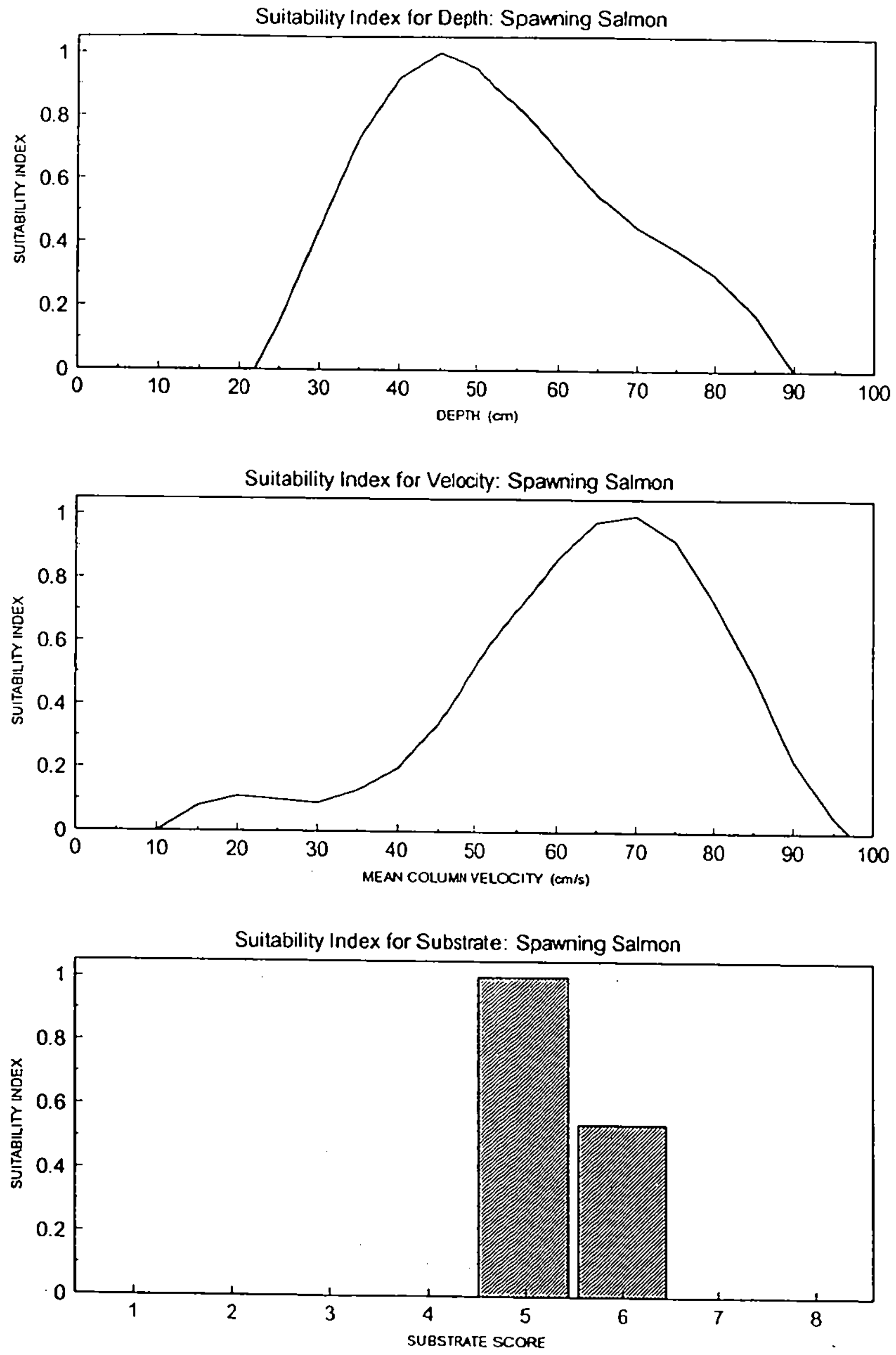


Figure 3.8 *Habitat suitability data: spawning salmon (SW NRA data)*

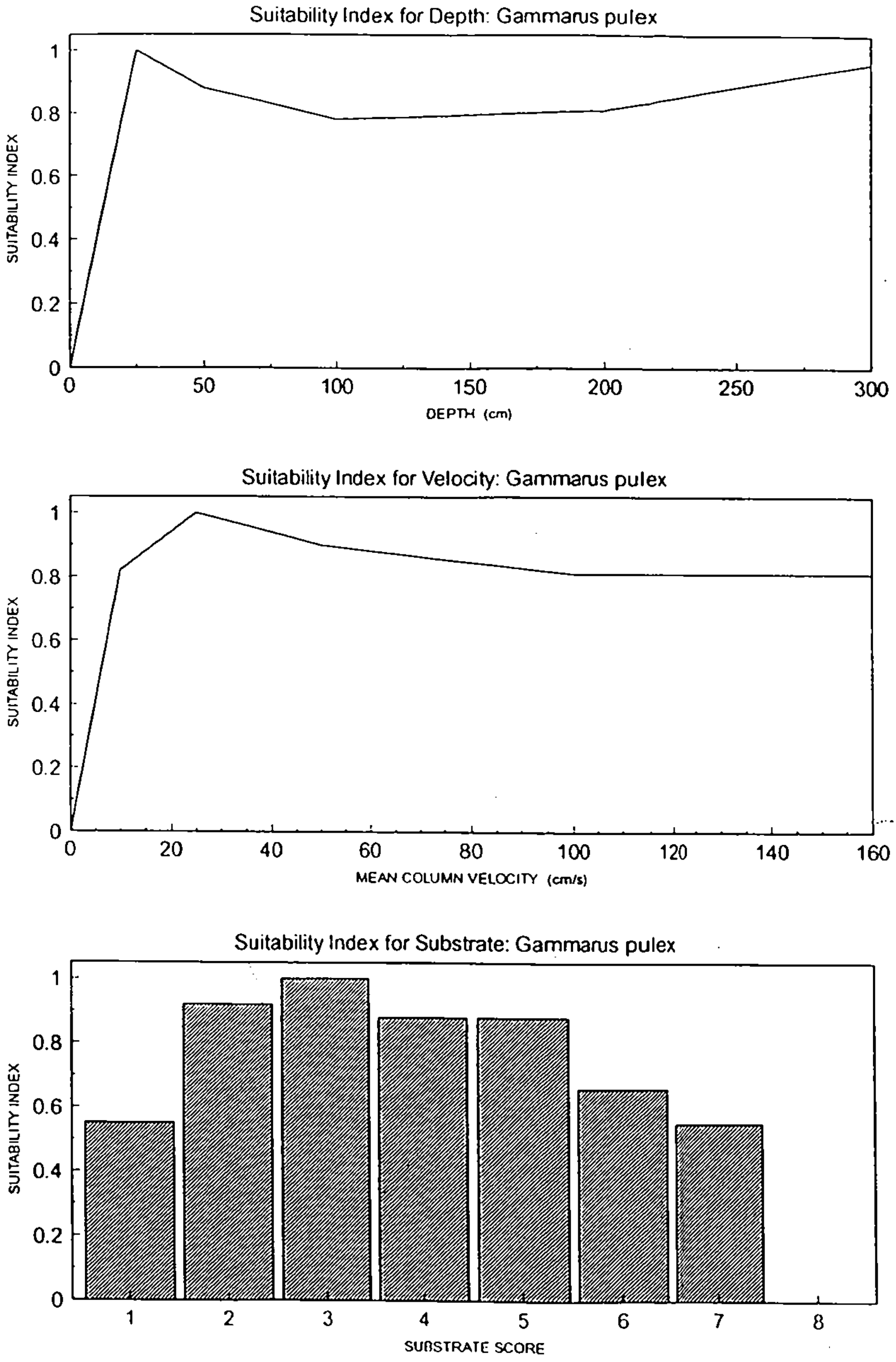


Figure 3.9 *Habitat suitability data: Gammarus pulex (IFE data)*

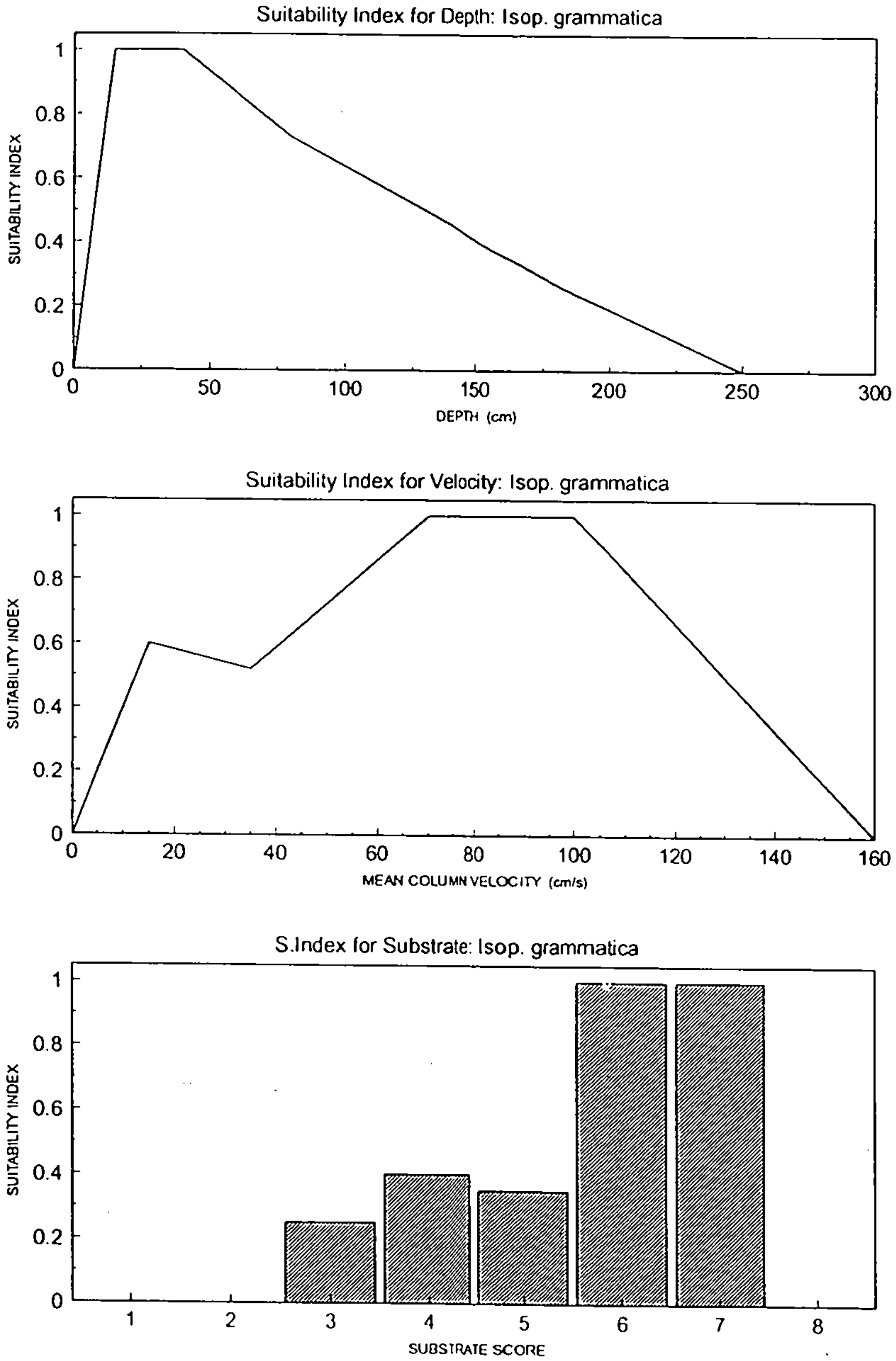


Figure 3.10 *Habitat suitability data: Isoperla grammatica (IFE data)*

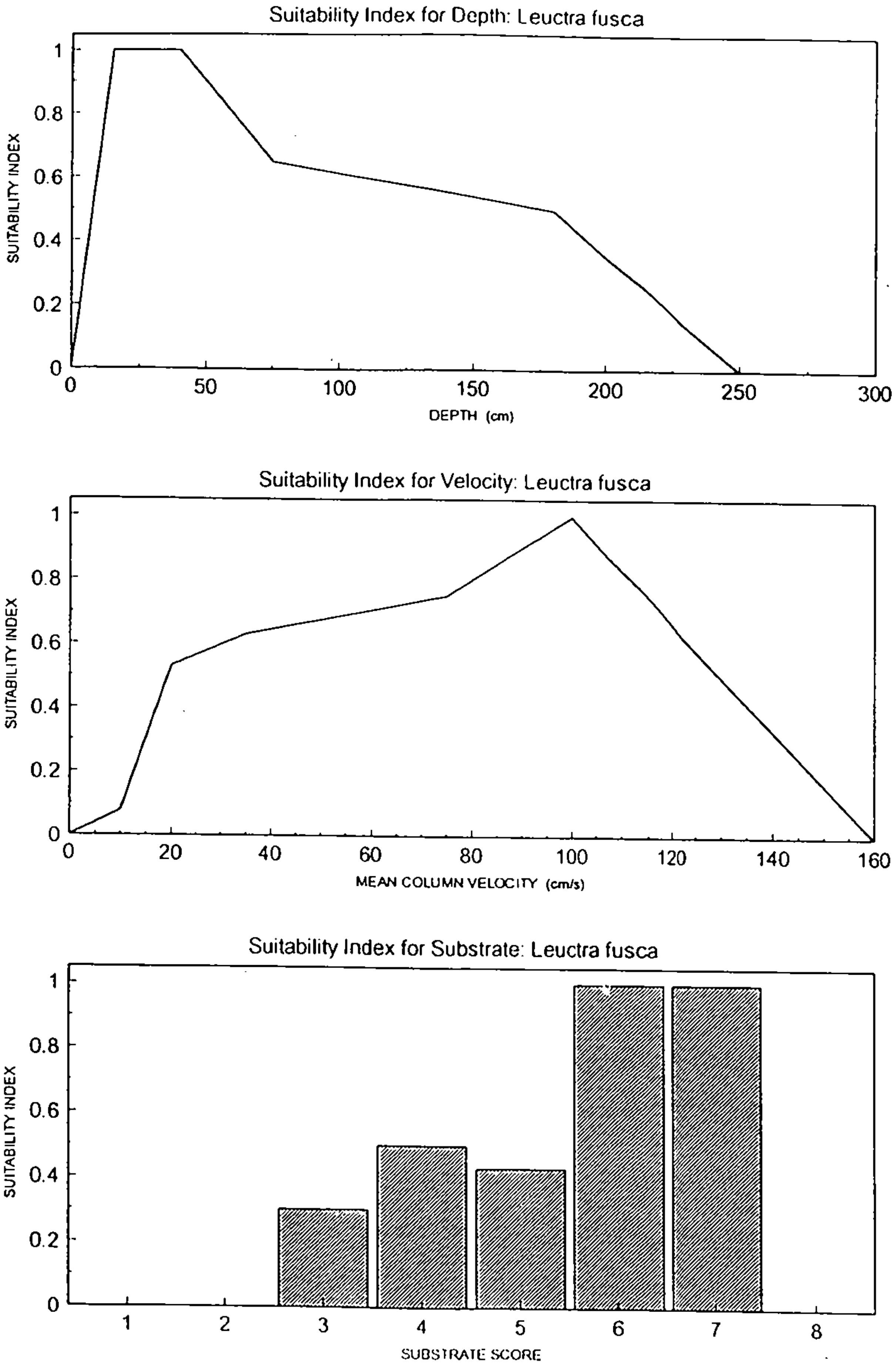


Figure 3.11 *Habitat suitability data: Leuctra fusca (IFE data)*

4 PHABSIM habitat simulations

4.1 COMPUTATION OF WEIGHTED USABLE AREA

The principle output of the PHABSIM habitat simulation model HABTAT is a relationship (for each target species life-stage) between Weighted Usable Area (WUA) and discharge. The WUA is a weighted measure of the habitat area available to a given target species life-stage. In the computation of the WUA the total available habitat area is weighted by its relative suitability to the target species life-stage. This weighting is defined by the relative suitability of the predicted values of the microhabitat variables depth, velocity and substrate at the given simulation discharge.

At a given simulation discharge Q, the total plan area of the reach is given by

$$A(Q) = \Sigma_i A_i (Q) \tag{4.1}$$

where the individual cell areas A_i are defined by the positions of the data points across each transect and by the distances between adjacent transects, as shown in Figure 4.1 below.

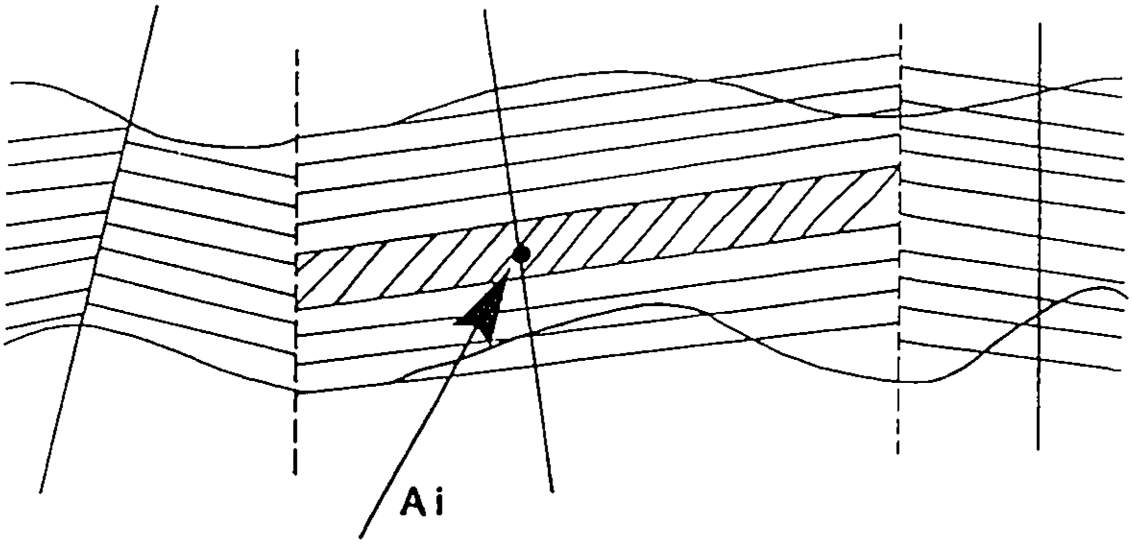


Figure 4.1 Individual cell area for WUA calculation

For a given simulation discharge Q, values of predicted cell depth, d_i, velocity, v_i and substrate code s_i are available as output from the hydraulic modelling phase of the simulation.

In the habitat simulation model the weighted usable area for a reach of total length L is defined by the equation

$$WUA(Q) = \Sigma_i WUA_i(Q) = \Sigma_i WUA_i(d_i,v_i,s_i) \times \frac{1000m}{L} \tag{4.2}$$

where the individual cell values WUA_i are defined by

$$WUA_i(d_i,v_i,s_i) = A_i(Q) \times SID(d_i) \times SIV(v_i) \times SIS(s_i) \tag{4.3}$$

Where SID, SIV, SIS are the habitat suitability indices for the microhabitat variables depth, velocity and substrate discussed in the previous section

4.2 PHABSIM HABITAT VS DISCHARGE OUTPUTS FOR TARGET SPECIES

The results presented below give values of total available habitat area A (defined by equation (4.1)), and WUA (defined by equation (4.2)) for individual target species life-stages, over the range of simulation discharges of interest. For the sake of clarity of presentation the results are plotted over a restricted portion of the complete simulation range. Figure 4.2 below shows total available habitat area vs discharge for the River Bray and River Barle sites. Figure 4.3 gives WUA vs discharge for life-stages of salmon, trout and the three species of invertebrates at the River Bray site. Corresponding results for the River Barle site are given in Figure 4.4 . Following convention in IFIM studies all habitat areas are scaled to give the value per 1000m of stream length (note that, for the sake of clarity, these outputs have been plotted using different y axis scales according to the maximum habitat values achieved).

In order to assist in comparison of results for different species life-stages and different habitat suitability data sets, the WUA vs discharge results may be normalised by their maximum value over the simulation range. The corresponding 'normalised WUA' ($WUA(Q)/WUA_{max}$) vs discharge (Q) results for the River Bray and River Barle sites are given in Figures 4.5, 4.6.

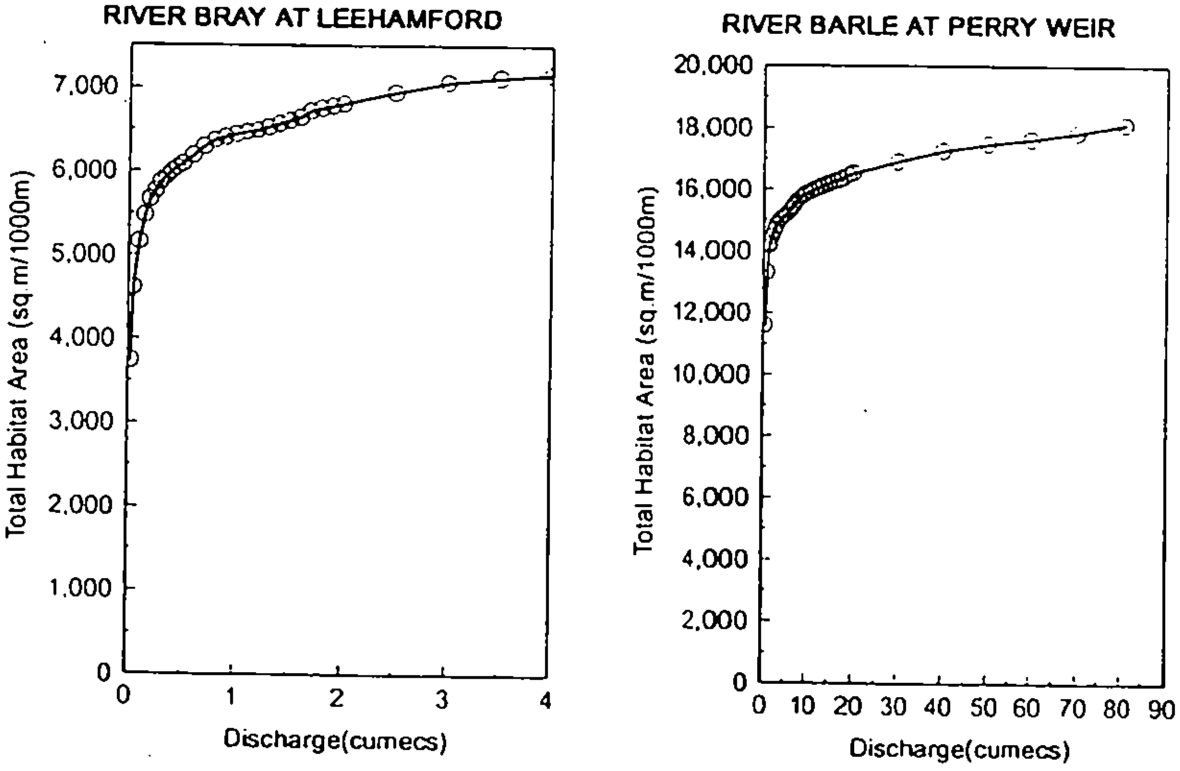


Figure 4.2 R.Bray and R.Barle: PHABSIM total habitat area vs discharge

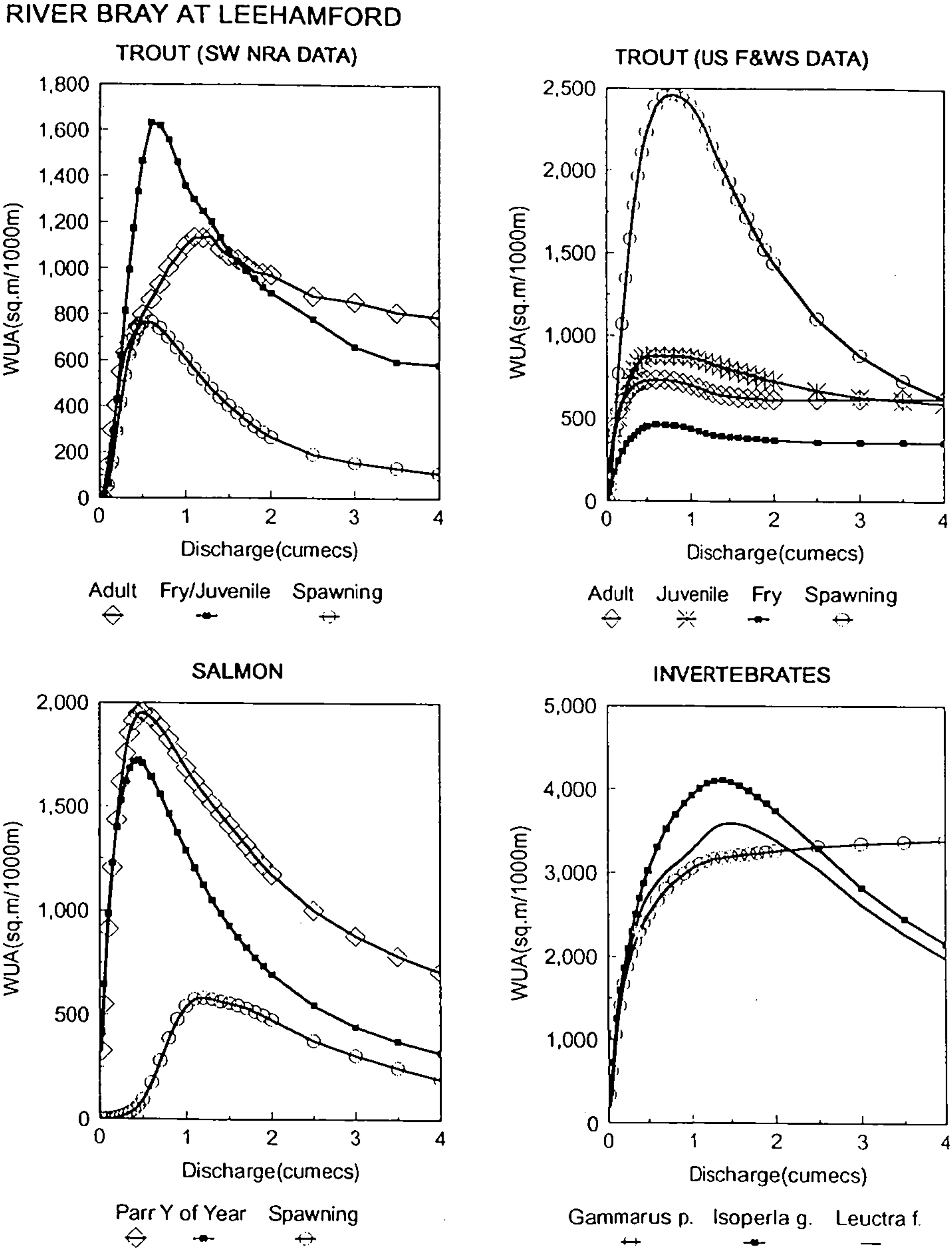


Figure 4.3 *R.Bray: PHABSIM WUA vs discharge habitat simulation outputs*

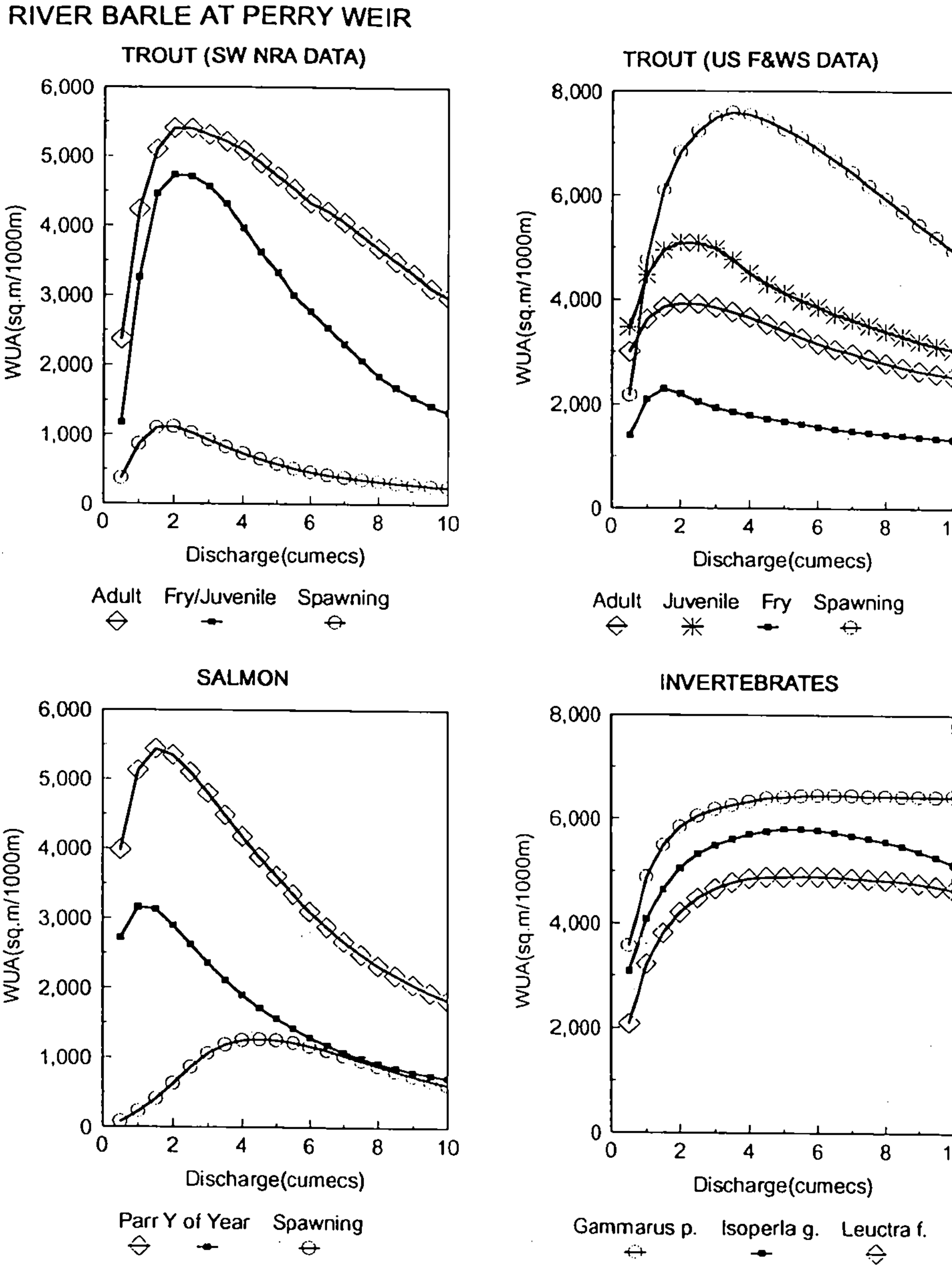


Figure 4.4 *R.Barle: PHABSIM WUA vs discharge habitat simulation outputs*

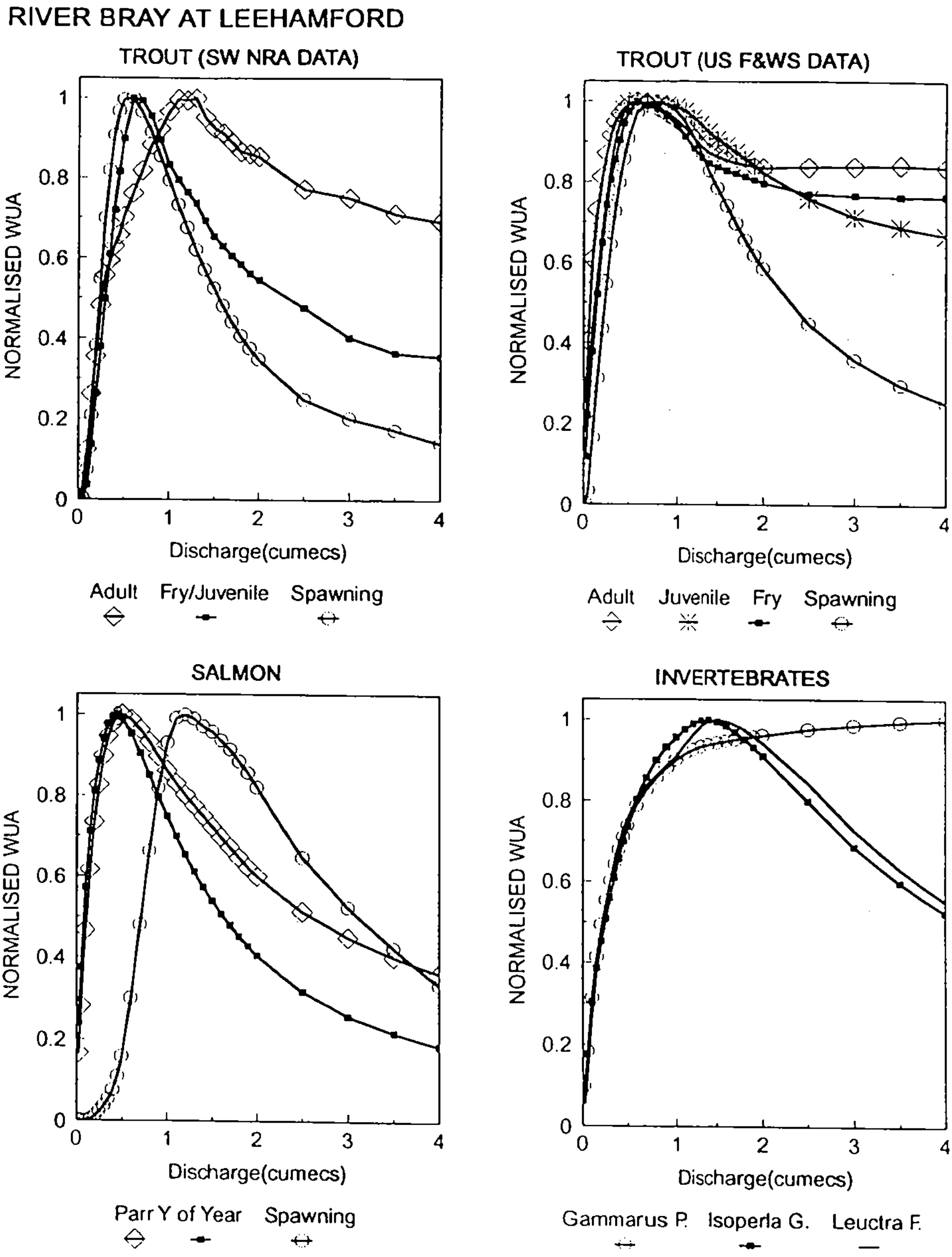


Figure 4.5 *R.Bray: PHABSIM normalised WUA vs discharge habitat simulation outputs*

RIVER BARLE AT PERRY WEIR

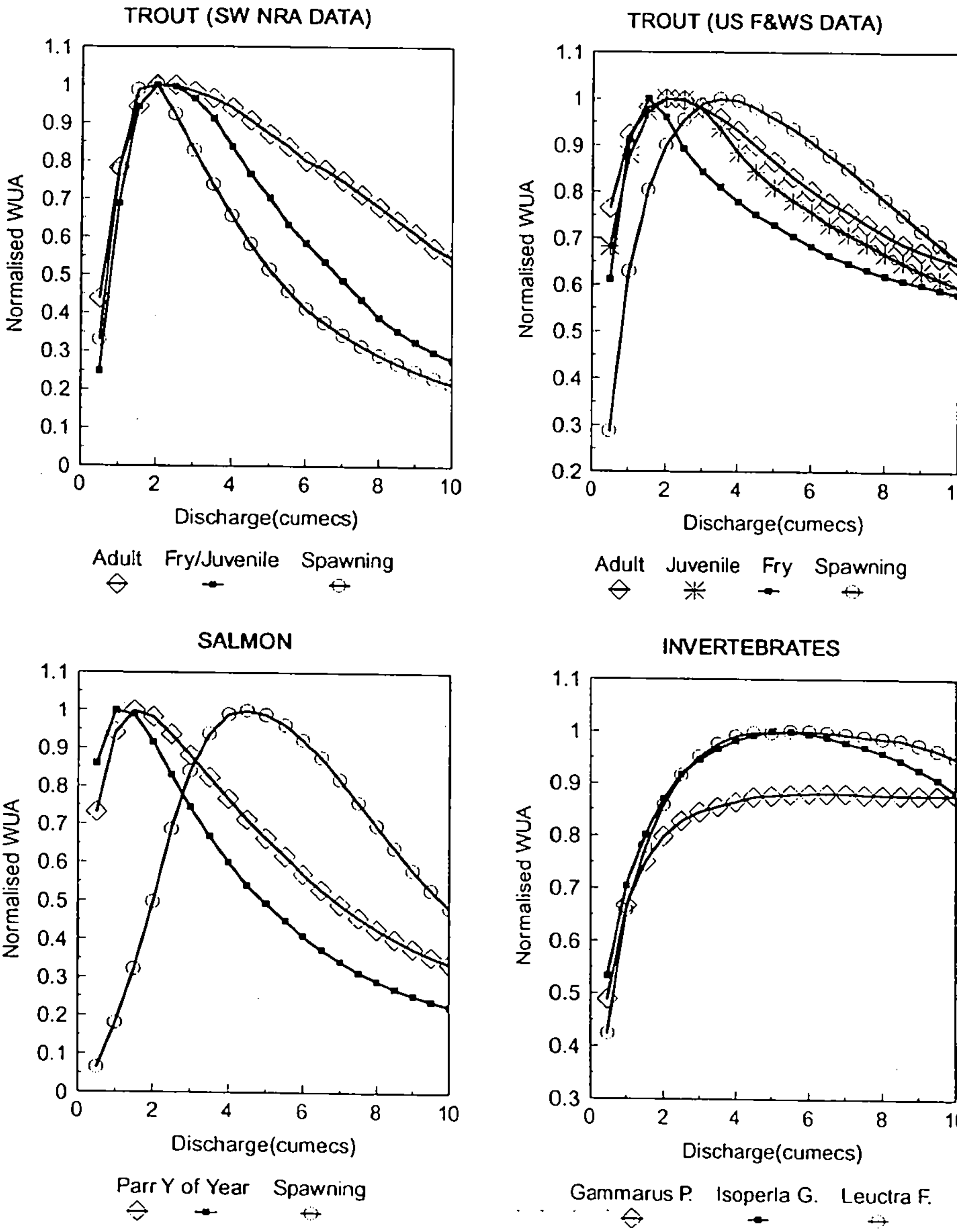


Figure 4.6 *R.Barle: PHABSIM normalised WUA vs discharge habitat simulation outputs*

5 Habitat time series simulations: River Bray

5.1 FLOW DATA AND METHODOLOGY

The results presented in the previous section demonstrate how the habitat area available to target species changes with discharge. In order to assess the impact of abstraction upon the variation of habitat availability over time it is necessary to combine WUA vs discharge outputs with the relevant flow records. As stated in Section 1, gauged records of historical flows are available from gauging stations close to each study site. We may generate corresponding habitat time series using the WUA vs discharge relationships given in the previous section using the transformation

$$WUA(T) = WUA(Q(T))$$

where T refers to a particular time (or day, in the case of a record of daily mean flows). For different species life-stages the appropriate functional form of the WUA is used.
In order to examine the relative impact of the abstractions on the availability of physical habitat to target species, habitat time series produced using flow records, with, and without the effects of abstraction may be compared.

For the R.Bray site the nearest gauging station is the Leehamford gauge (station no. 050821) which lies 100m upstream from the study reach. The abstraction lies upstream of the flow gauging station, hence the Leehamford gauged flow record includes the effects of abstraction. The measuring weir is sound with no significant drift; the last rating was done in 1982. The period of record used for the time series presented here is complete from 1/1/80-31/12/92. A natural flow record was constructed by adding an estimate of daily abstraction to the gauged daily mean flow. Abstraction data was obtained from SWWSL by NRA SW. Daily abstraction values were estimated as the average of 7 day totals.

Since the emphasis of this study is upon the availability of habitat under low flow conditions we have conducted separate summer (April-Sept) and winter (Oct-March) analyses in addition to analysing the full annual time series.

5.2 FLOW AND HABITAT DURATION CURVES

Historical and natural flow duration curves (for daily mean flows) for all months, summer months and winter months for the River Bray at Leehamford are given in Figure 5.1 below. The corresponding duration curves for total available habitat area are given in Figure 5.2. Habitat (WUA) duration curves for life-stages of trout and salmon are given in Figures 5.3-5.11 and those for the three invertebrate species in Figures 5.12-5.14.

RIVER BRAY

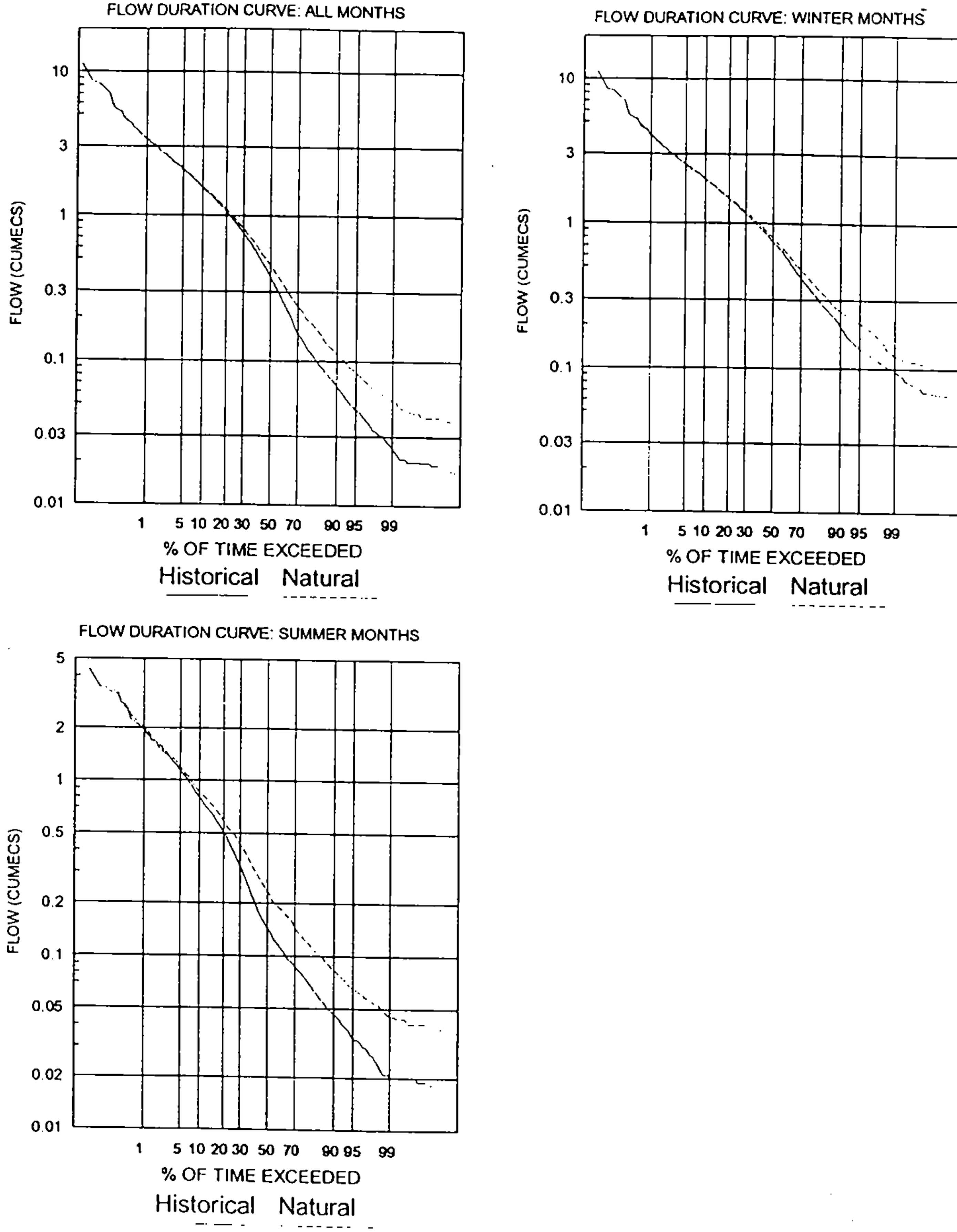


Figure 5.1 *R.Bray: Flow duration curves*

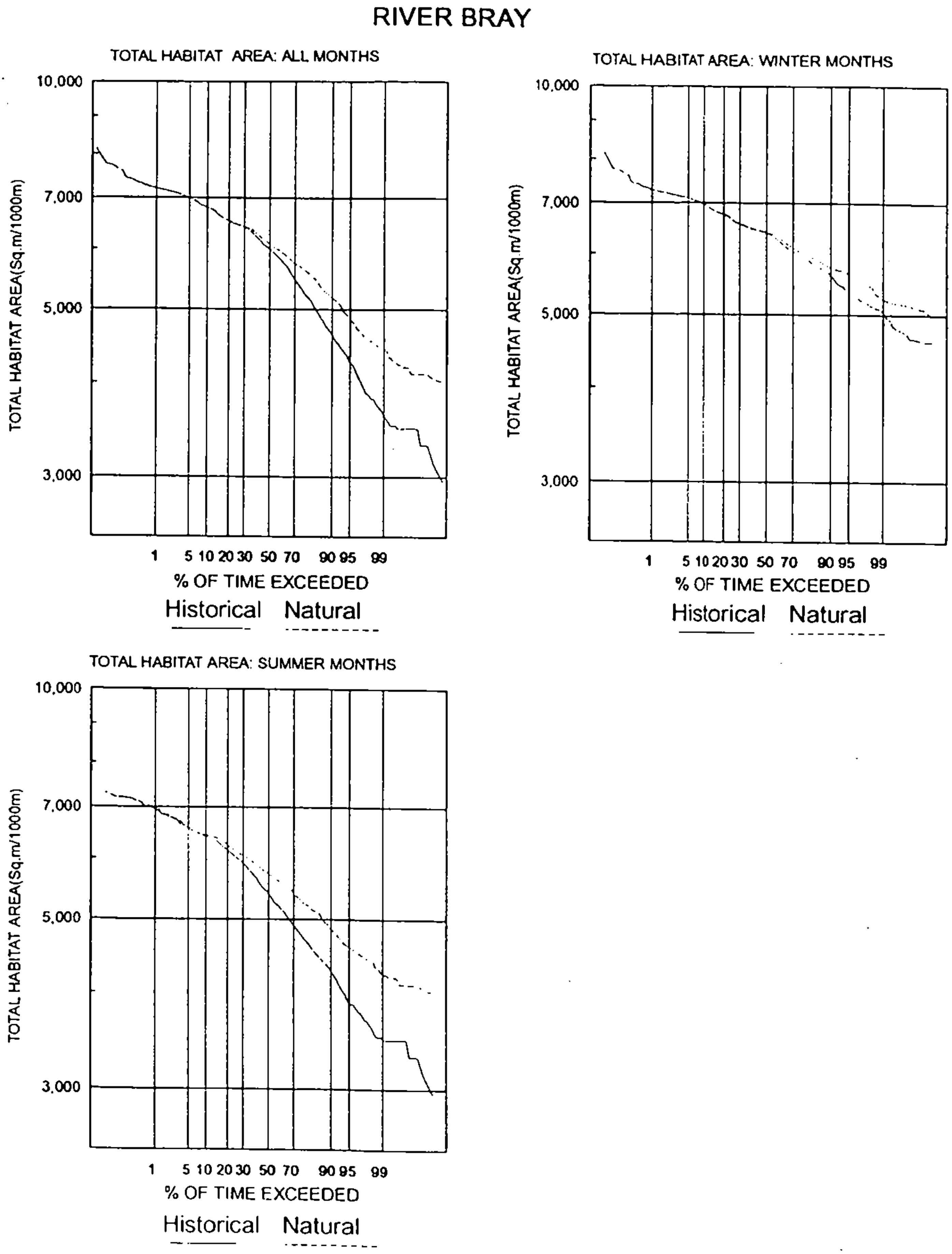
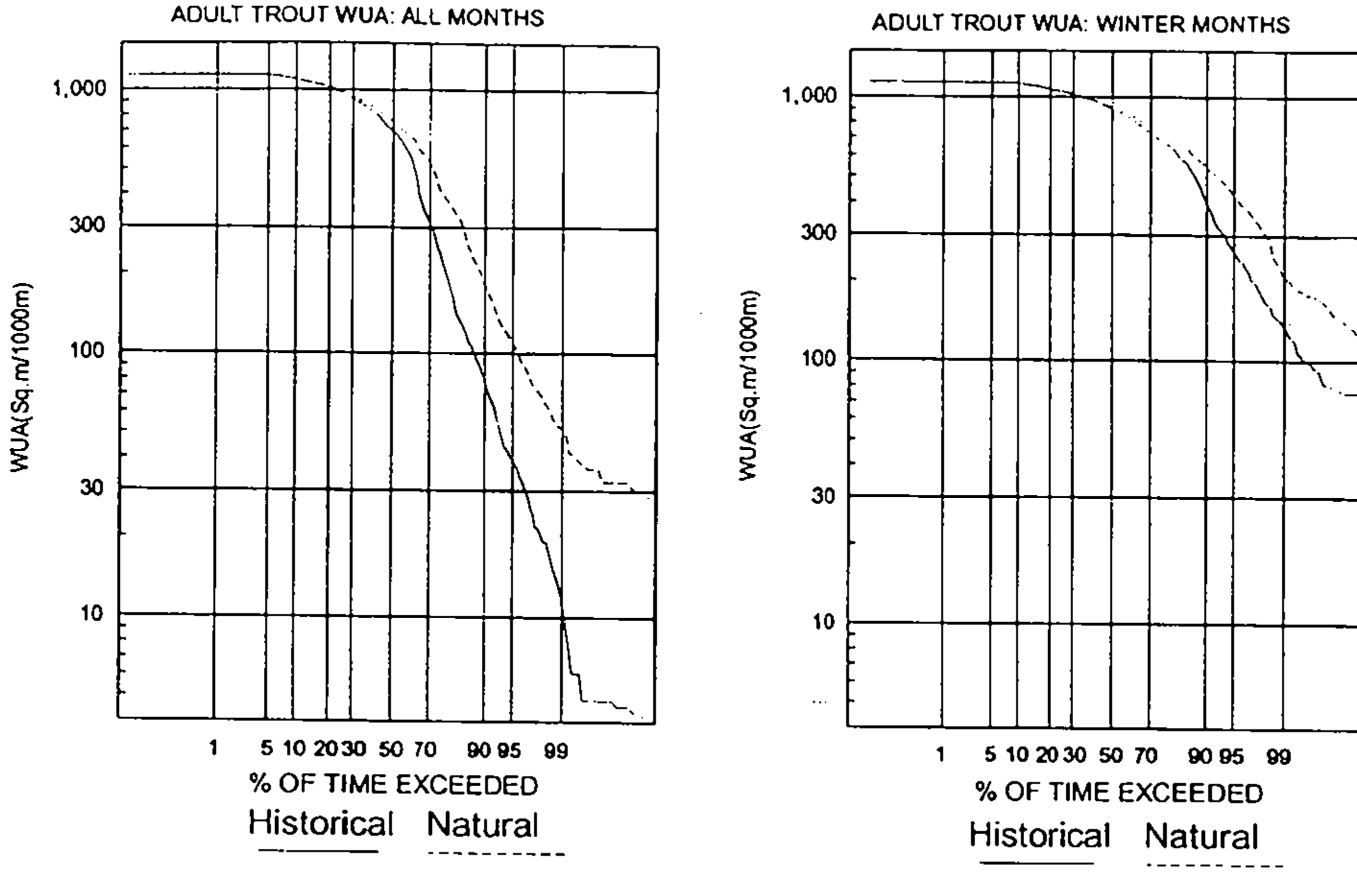


Figure 5.2 *River Bray: Duration curves for total habitat area*

RIVER BRAY



ADULT TROUT WUA: SUMMER MONTHS

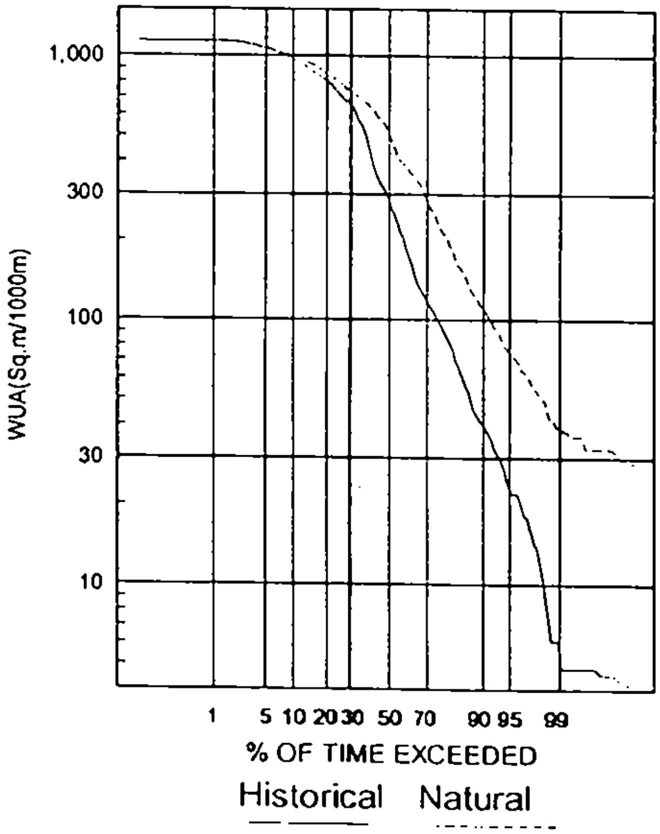


Figure 5.3 *R. Bray: Duration curves for adult trout WUA (SW NRA SI data)*

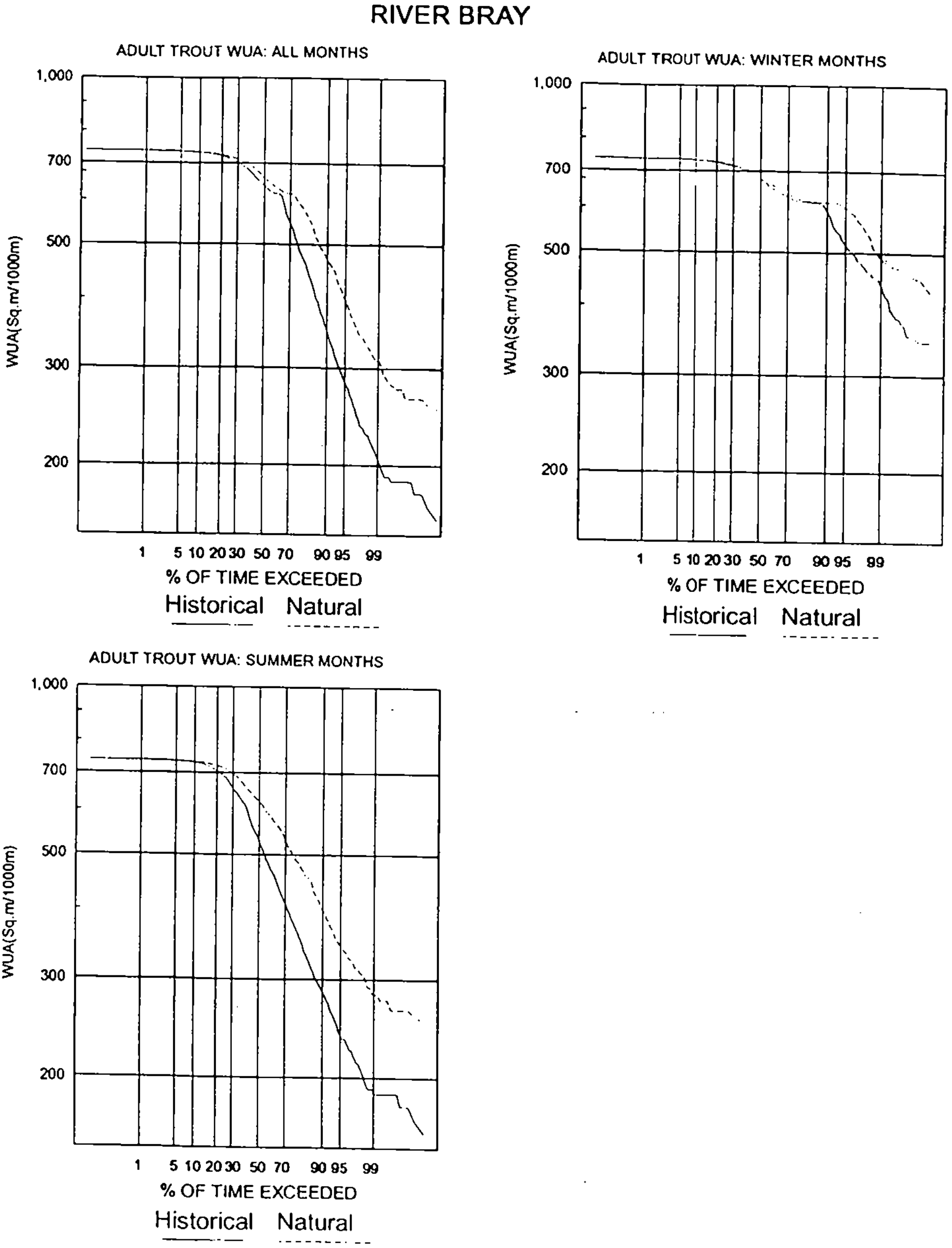
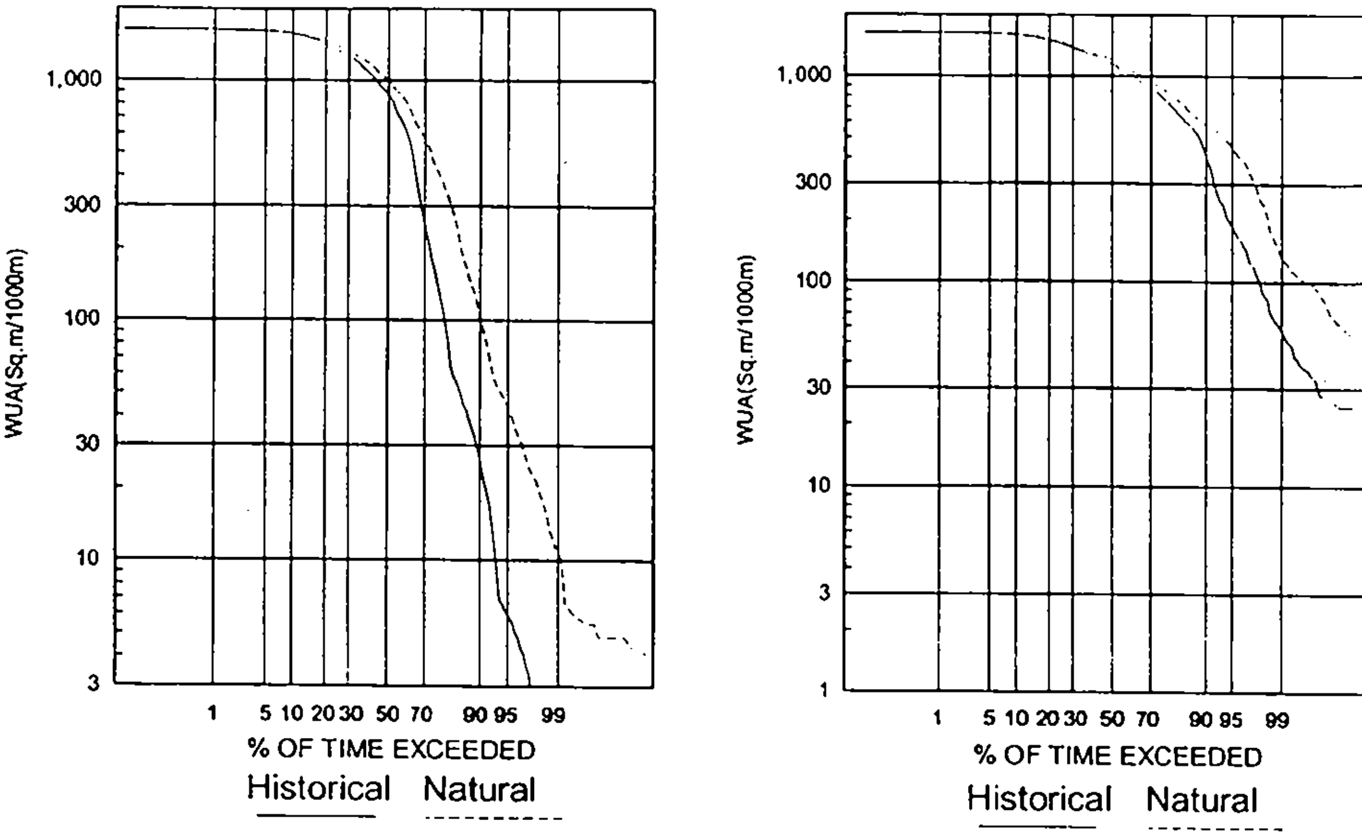


Figure 5.4 *R.Bray: Duration curves for adult trout WUA (US F&WS SI data)*

RIVER BRAY


FRY/JUVENILE TROUT WUA: ALL MONTHS

FRY/JUVENILE TROUT WUA: WINTER MONTHS

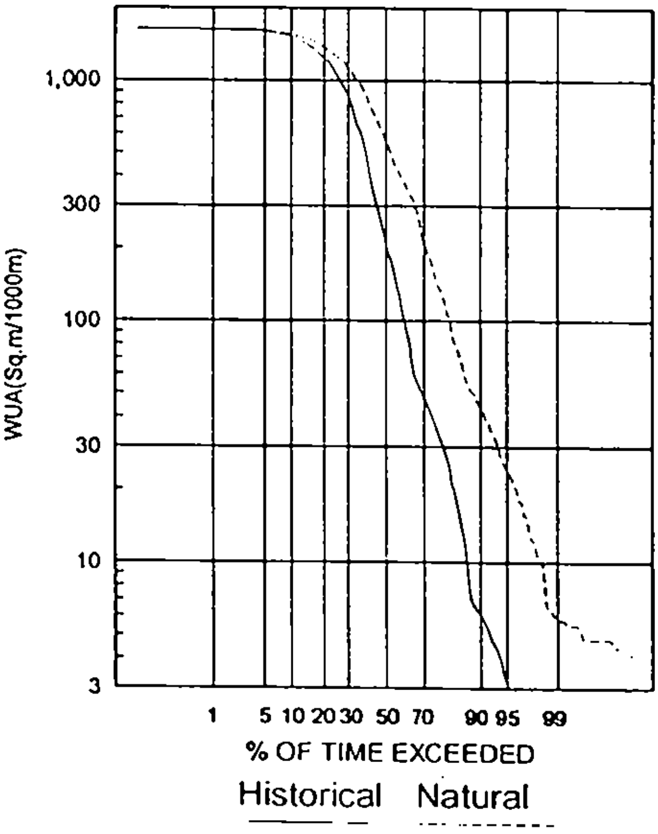
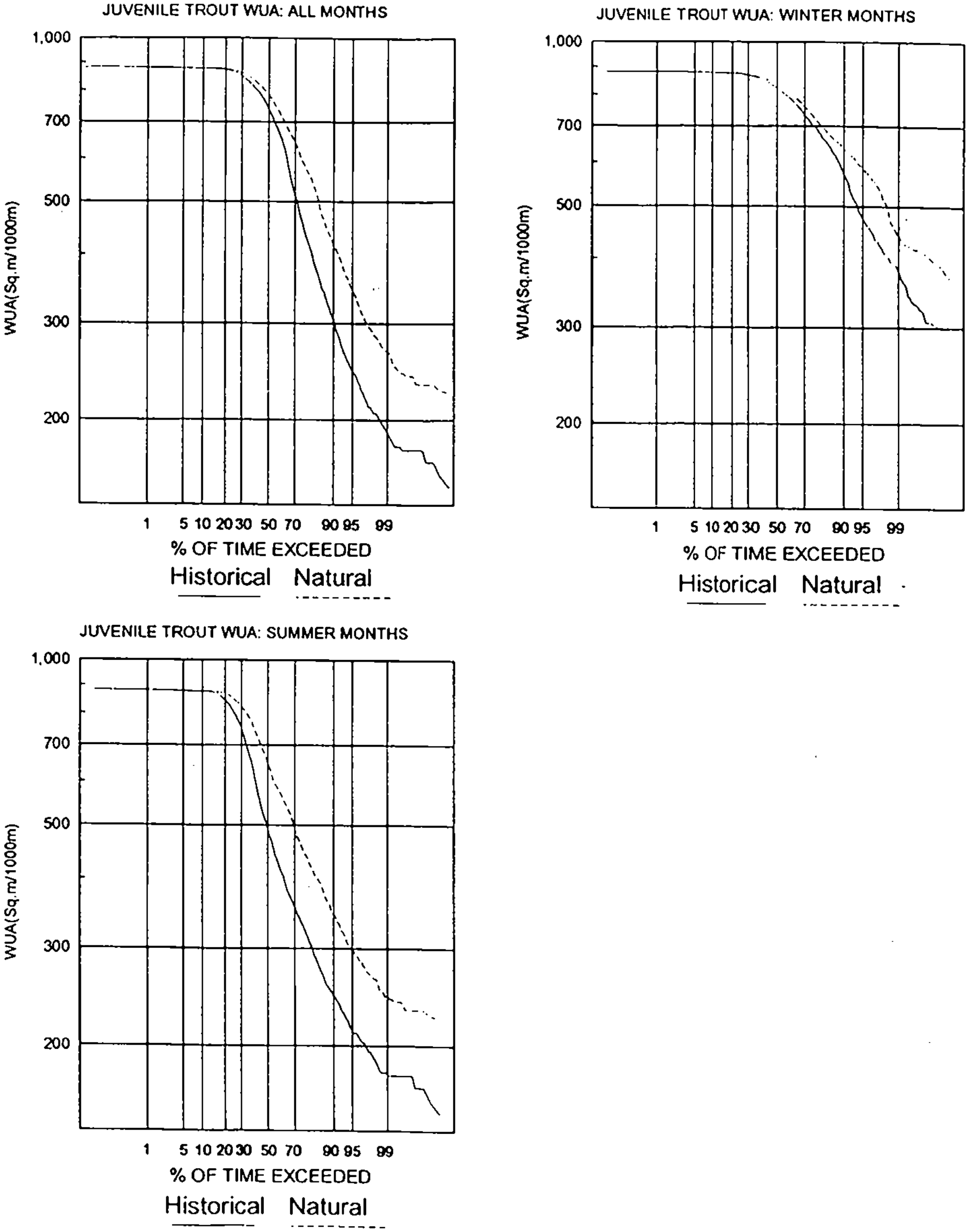

FRY/JUVENILE TROUT WUA: SUMMER MONTHS

Figure 5.5 *R.Bray: Duration curves for fry/juvenile trout WUA (SW NRA SI data)*

RIVER BRAY


JUVENILE TROUT WUA: ALL MONTHS

JUVENILE TROUT WUA: WINTER MONTHS

JUVENILE TROUT WUA: SUMMER MONTHS

Figure 5.6 *R.Bray: Duration curves for juvenile trout WUA (US F&WS SI data)*

RIVER BRAY

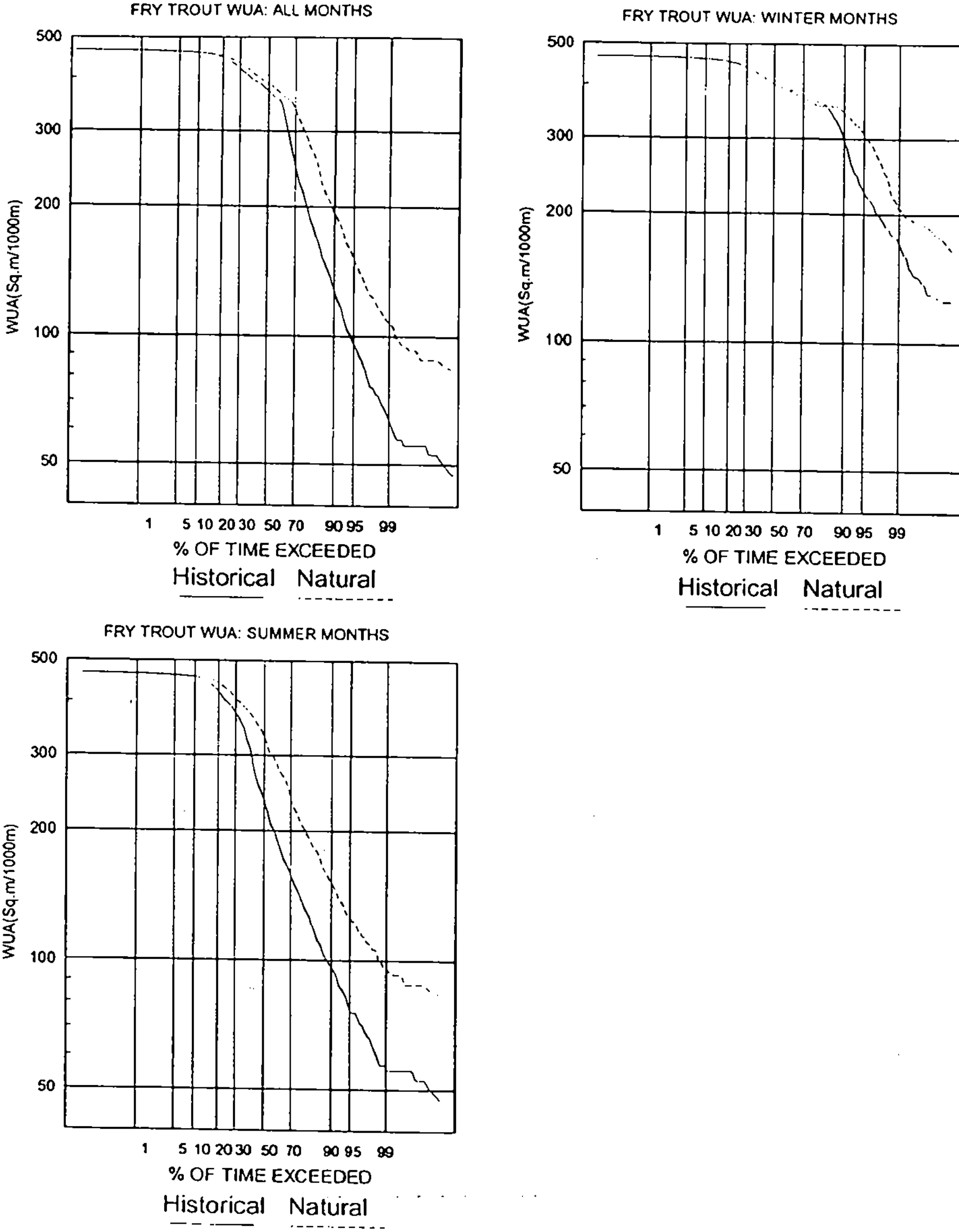


Figure 5.7 *R. Bray: Duration curves for fry trout WUA (US F& WS SI data)*

RIVER BRAY

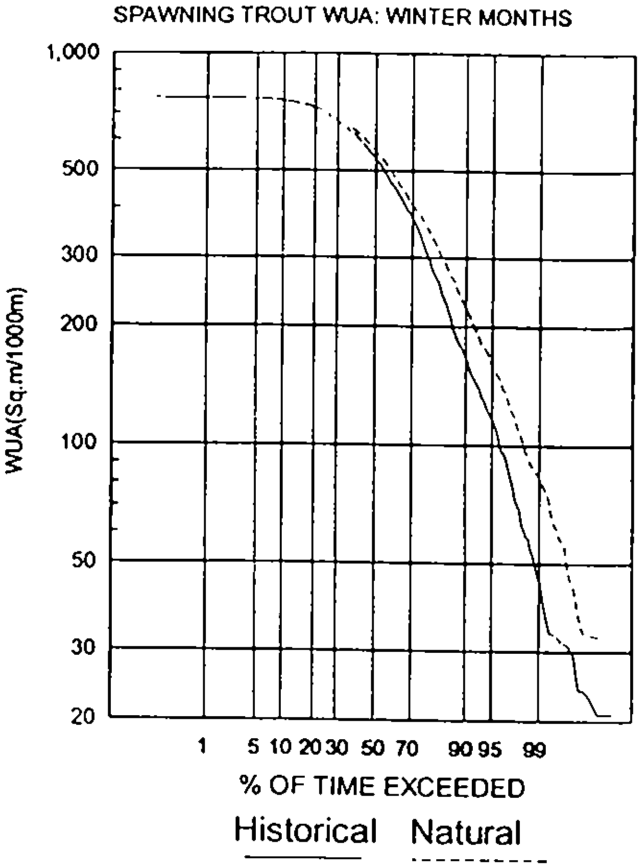


Figure 5.8 *R.Bray: Duration curves for spawning trout WUA (SW NRA SI data)*

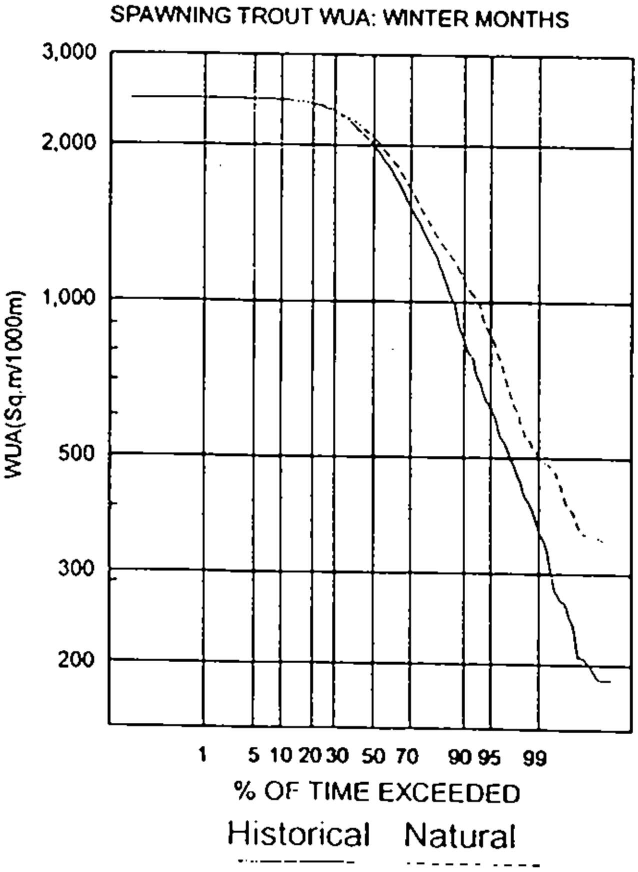
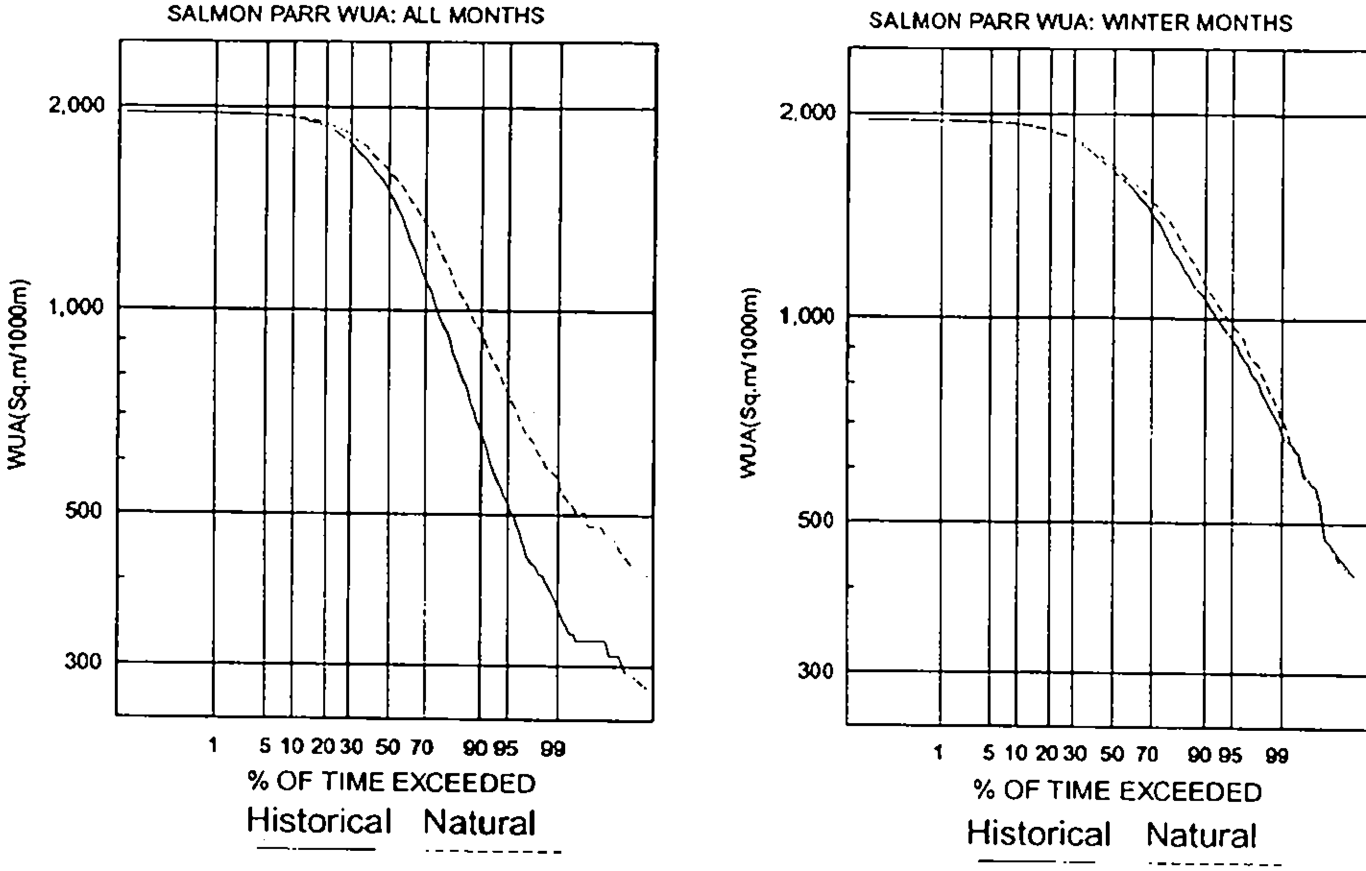


Figure 5.9 *R.Bray: Duration curves for spawning trout WUA (US F& WS SI data)*

RIVER BRAY


SALMON PARR WUA: ALL MONTHS

SALMON PARR WUA: WINTER MONTHS

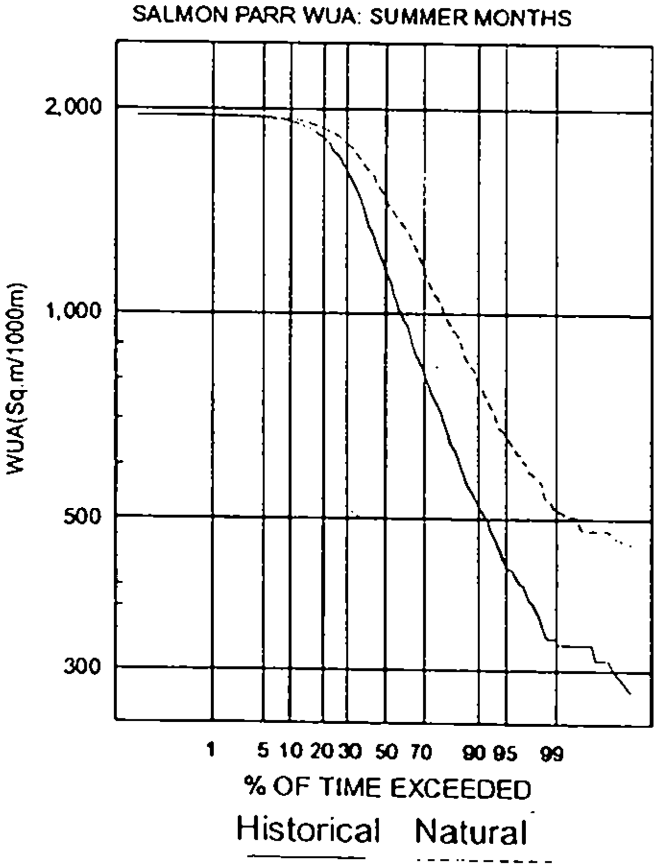

SALMON PARR WUA: SUMMER MONTHS

Figure 5.10 *R.Bray: Duration curves for salmon parr WUA (Heggenes data)*

RIVER BRAY

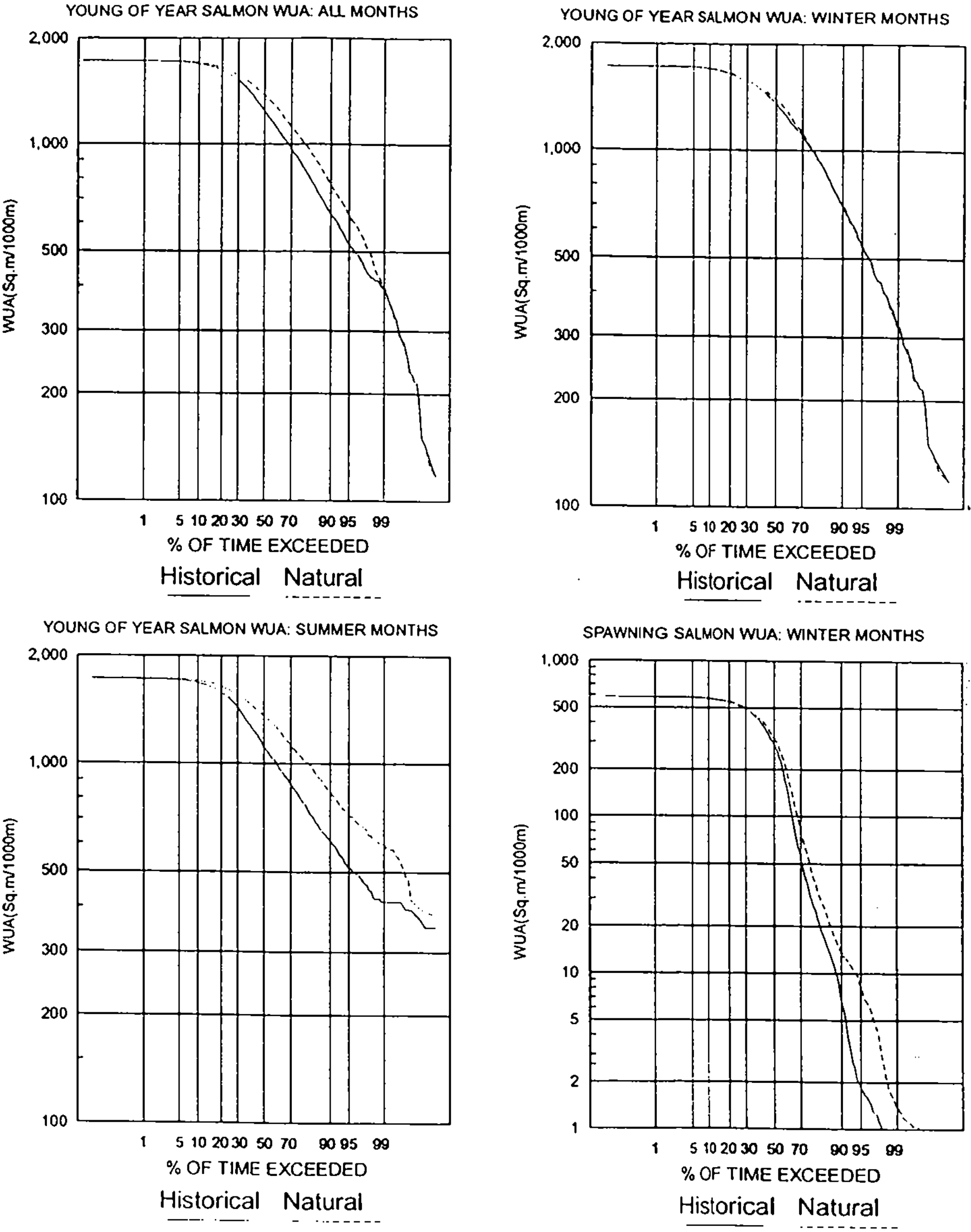


Figure 5.11 *R.Bray: Duration curves for young of year (Heggenes data) and spawning (SW NRA data) salmon*

RIVER BRAY

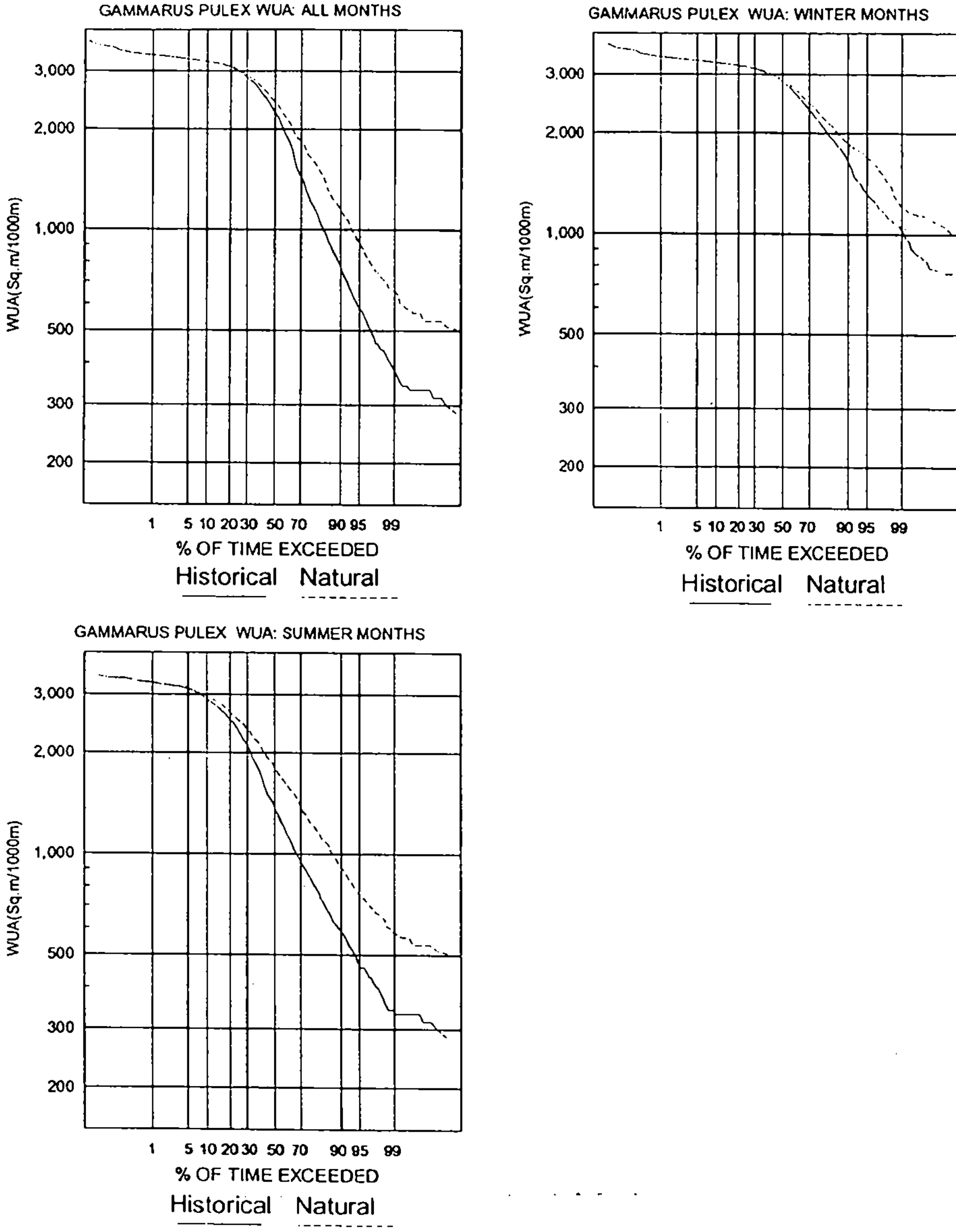
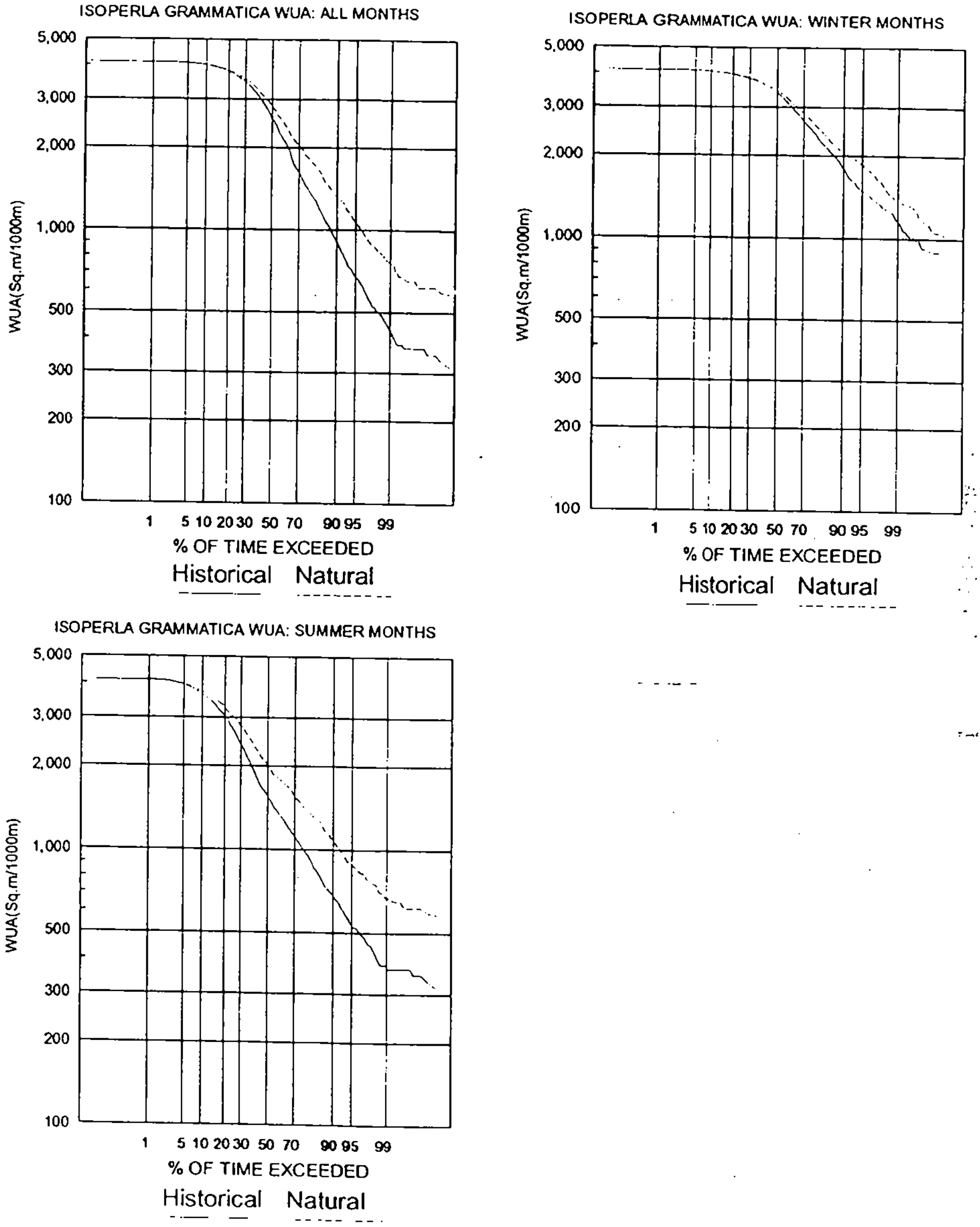


Figure 5.12 *R.Bray: Duration curves for Gammarus pulex WUA*

RIVER BRAY



ISOPERLA GRAMMATICA WUA: ALL MONTHS

ISOPERLA GRAMMATICA WUA: WINTER MONTHS

ISOPERLA GRAMMATICA WUA: SUMMER MONTHS

Figure 5.13 *R.Bray: Duration curves for Isoperla grammatica WUA*

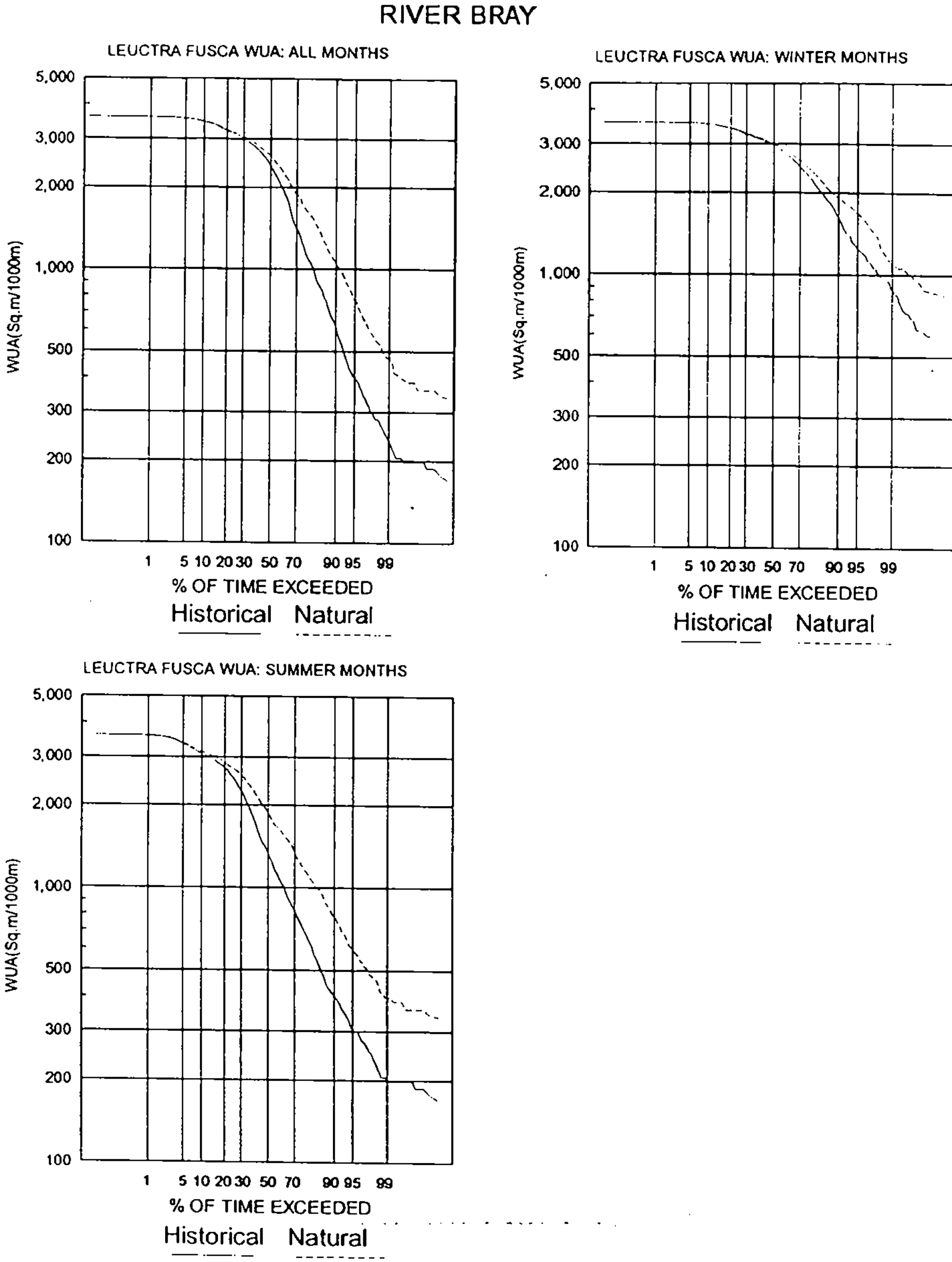


Figure 5.14 *R.Bray: Duration curves for Leuctra fusca WUA*

6 Habitat time series simulations: River Barle

6.1 FLOW DATA AND METHODOLOGY

The closest flow gauging station (Station No. 045011) to Perry Weir is situated some 500m upstream, at Brushford. This station is operated by Exeter University. Flow data used in the time series analysis presented here cover the period of record from 5/10/81-8/2/93 (these data were obtained from Exeter University via NRA SW). Five short gaps, totalling 86 missing days in all were present in this flow record. Comparisons between a flow duration curve based on a record with the missing days removed, and another duration curve, based on a record in which the gaps were infilled using a regression relationship (supplied by NRA SW) are as follows:

Flow	Gaps Removed	Gaps Infilled
Mean	5.843	5.886
Q50	3.44	3.5
Q70	1.86	1.9
Q95	0.65	0.63

It can be seen that infilling the missing days makes a negligible difference to the flow duration curve. All time series analysis for this assessment is based on the record in which the missing days are removed.

Since the Brushford gauging station lies upstream of the Perry Weir abstraction, the gauged flow record at Brushford represents the natural flow through the study reach (ie. the case of zero abstraction). Gauged abstraction data for the Perry Weir leat abstraction is not available, hence it is not possible to adjust the Brushford flow record to represent the actual (influenced by abstraction) historical flows through the study reach. For this reason we have chosen to model a "worst case" scenario, in which it is assumed that the daily abstraction rate was constant over the period of record used for time series simulations, and equal to the maximum licenced daily rate of 0.77 cumecs. Hence the time series of 'historical flows', used in the simulations presented below, refers to the adjusted record, ie:

historical DMF (study reach) = DMF (Brushford) - 0.77 cumecs

In practice daily abstractions may be below the licenced maximum, hence the outputs here will overestimate the impact of historical abstractions and will represent the worst case in terms of negative impacts on flows downstream. As discussed in the recommendations section additional modelling of the distribution of flows across the weirs and along the leat to the fishery are required to model the historical abstraction regime more realistically.

6.2 FLOW AND HABITAT DURATION CURVES

Historical and natural flow duration curves (for daily mean flows) for all months, summer months and winter months for the River Barle Perry Weir study site are given in Figure 6.1 below. The corresponding duration curves for total available habitat area are given in Figure 6.2. Habitat (WUA) duration curves for life-stages of trout and salmon are given in Figures 6.3-6.11 and those for the three invertebrate species in Figures 6.12-6.14.

RIVER BARLE

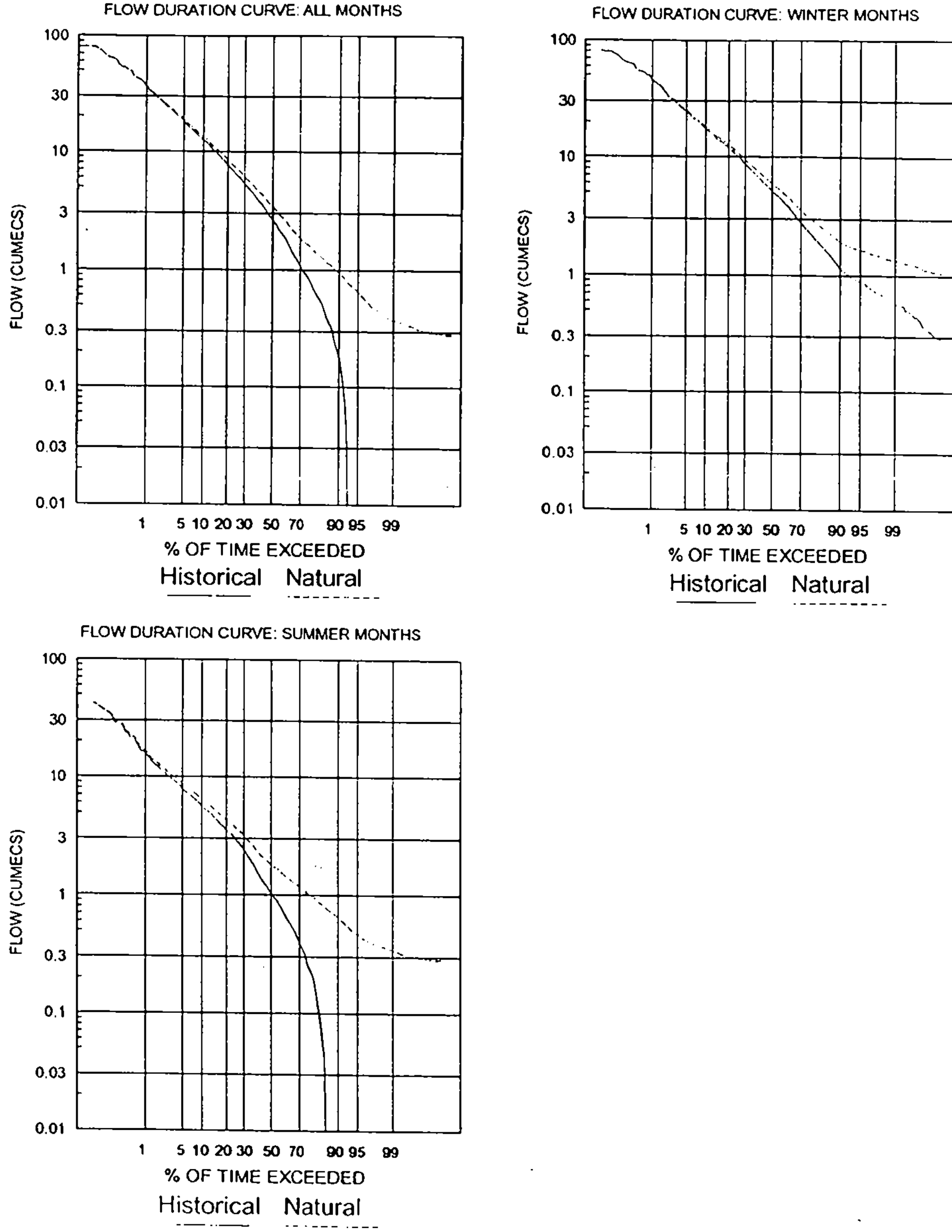


Figure 6.1 *R. Barle: Flow duration curves*

RIVER BARLE

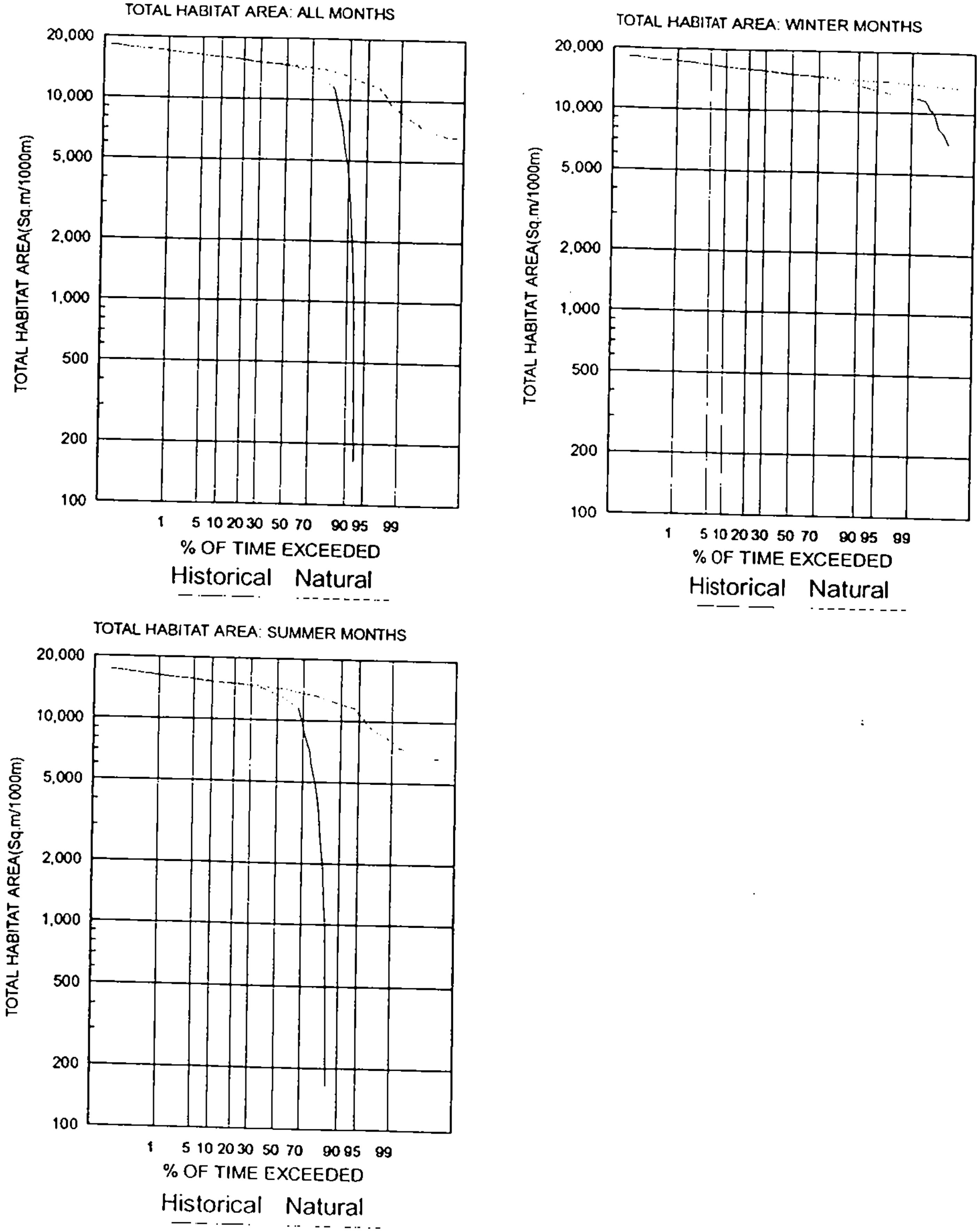


Figure 6.2 *R.Barle: Duration curves for total habitat area*

RIVER BARLE

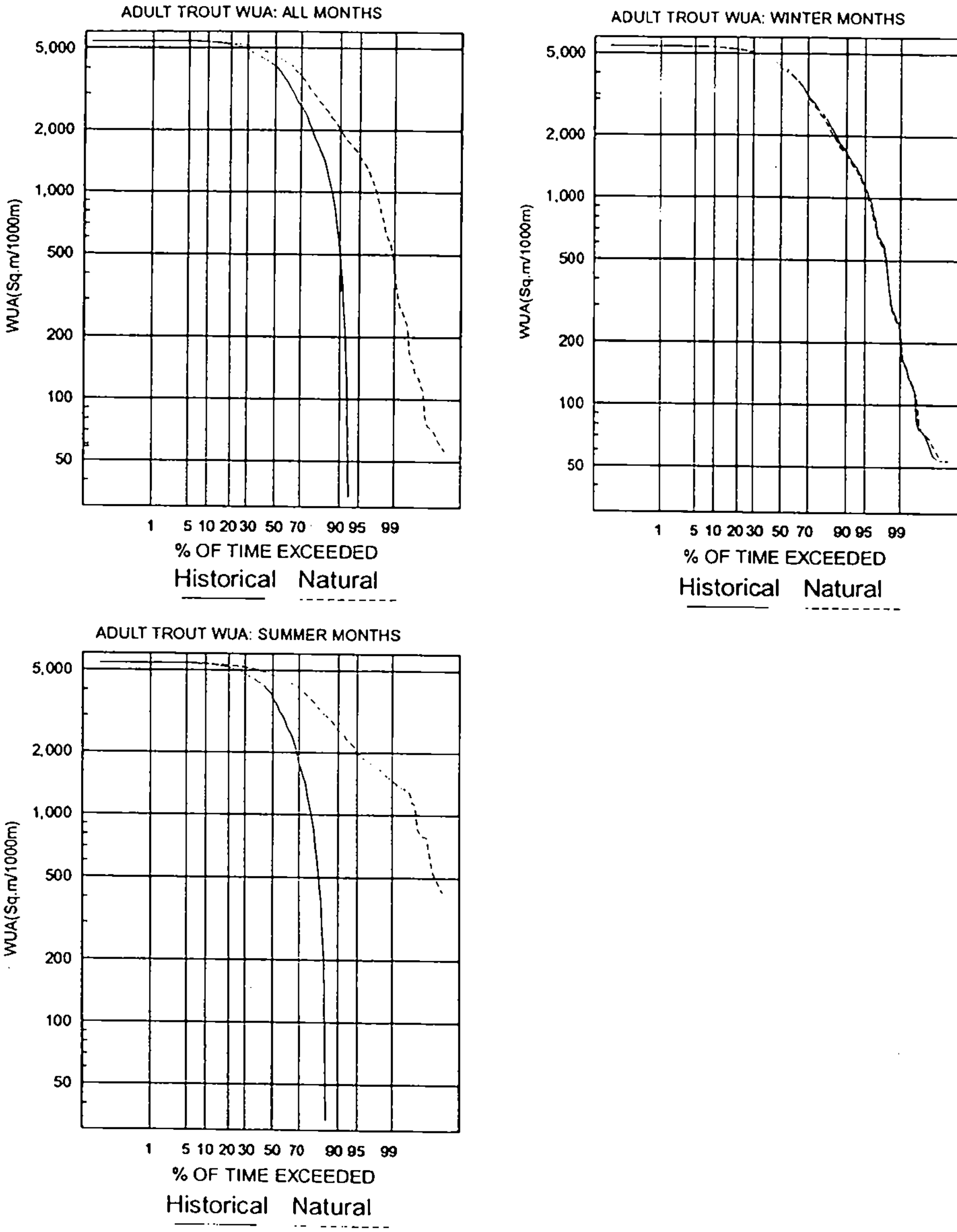


Figure 6.3 *R.Barle: Duration curves for adult trout WUA (SW NRA SI data)*

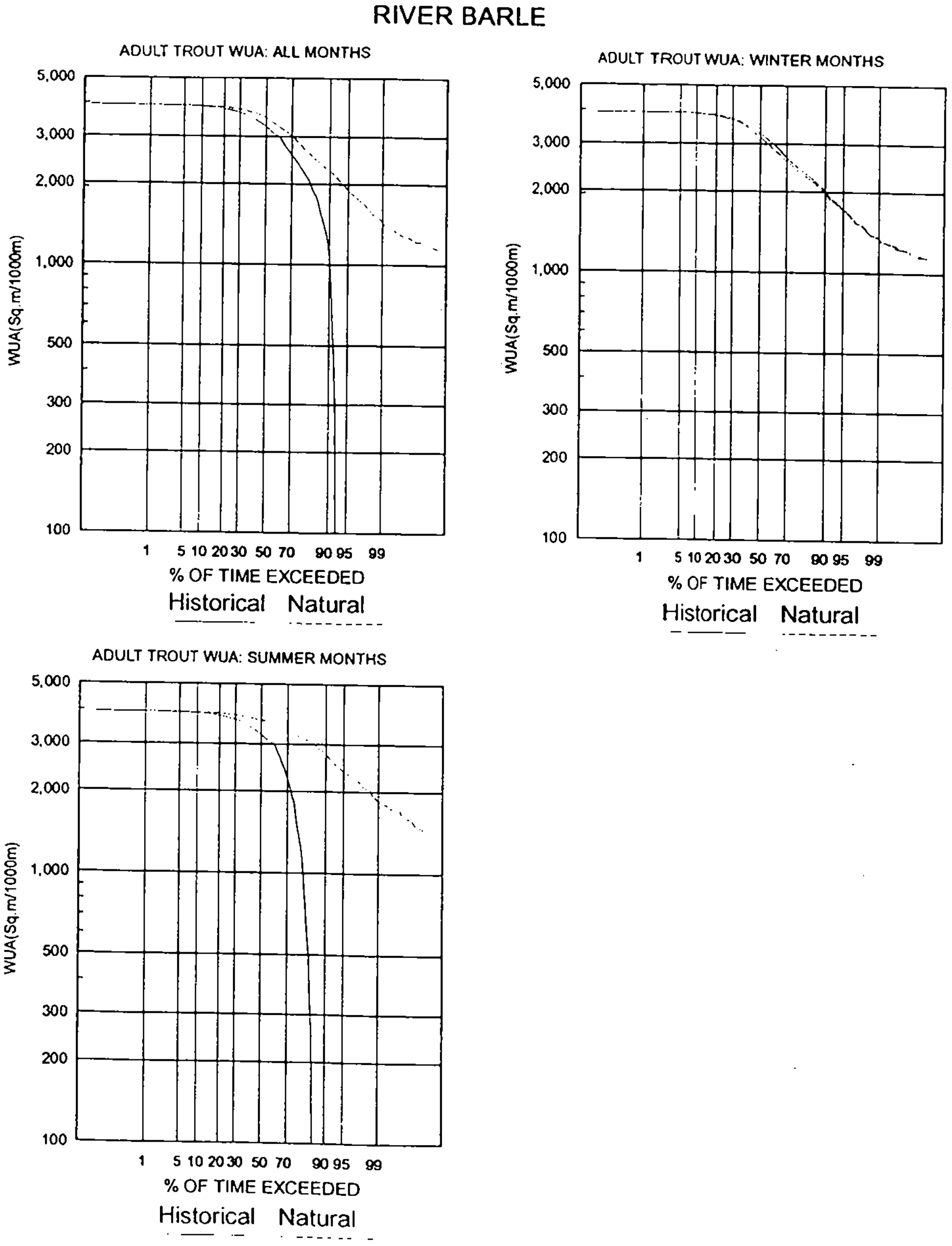


Figure 6.4 *R.Barle: Duration curves for adult trout WUA (US F&WS SI data)*

RIVER BARLE

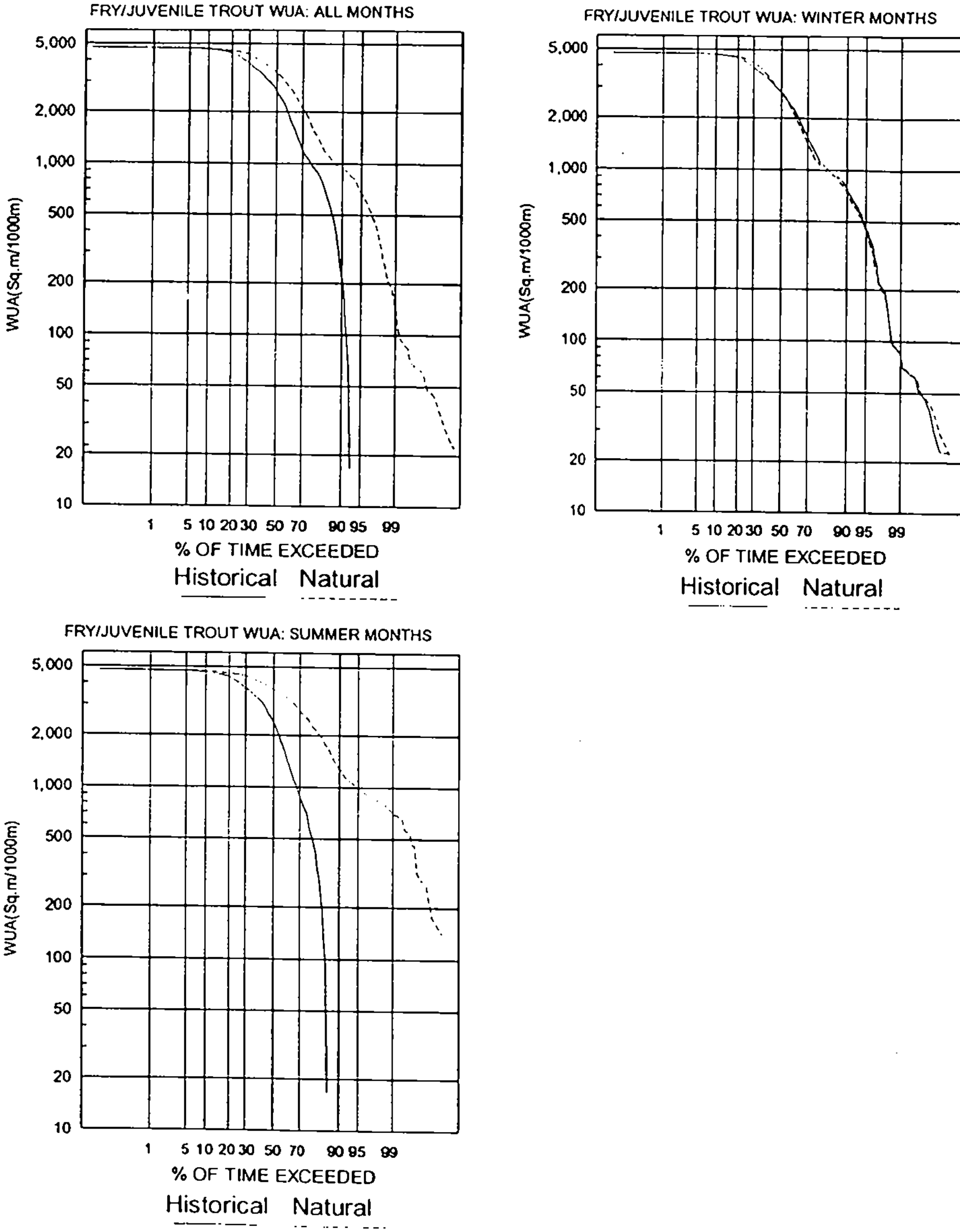


Figure 6.5 *R. Barle: Duration curves for fry/juvenile trout WUA (SW NRA SI data)*

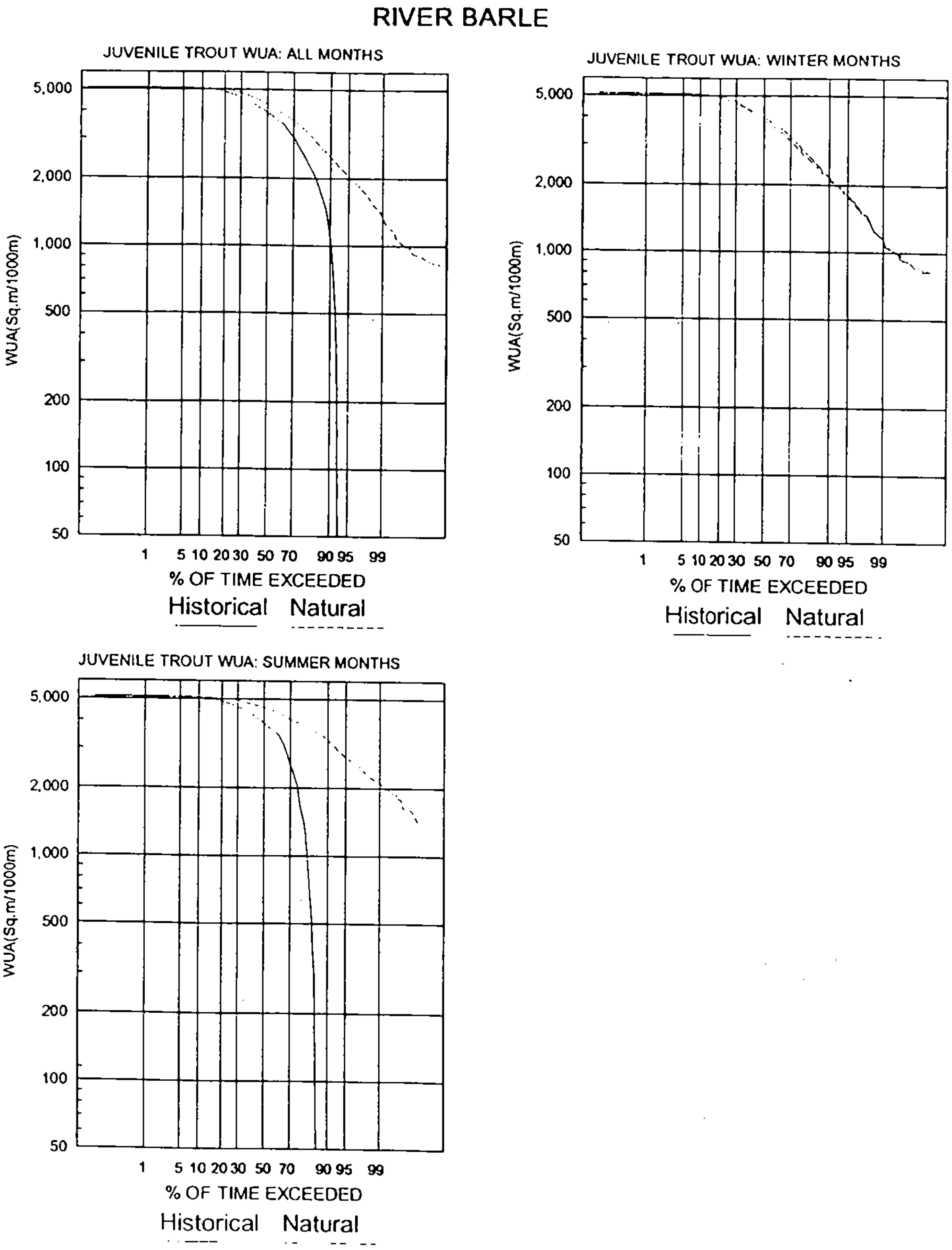


Figure 6.6 *R.Barle: Duration curves for juvenile trout (US F&WS SI data)*

RIVER BARLE

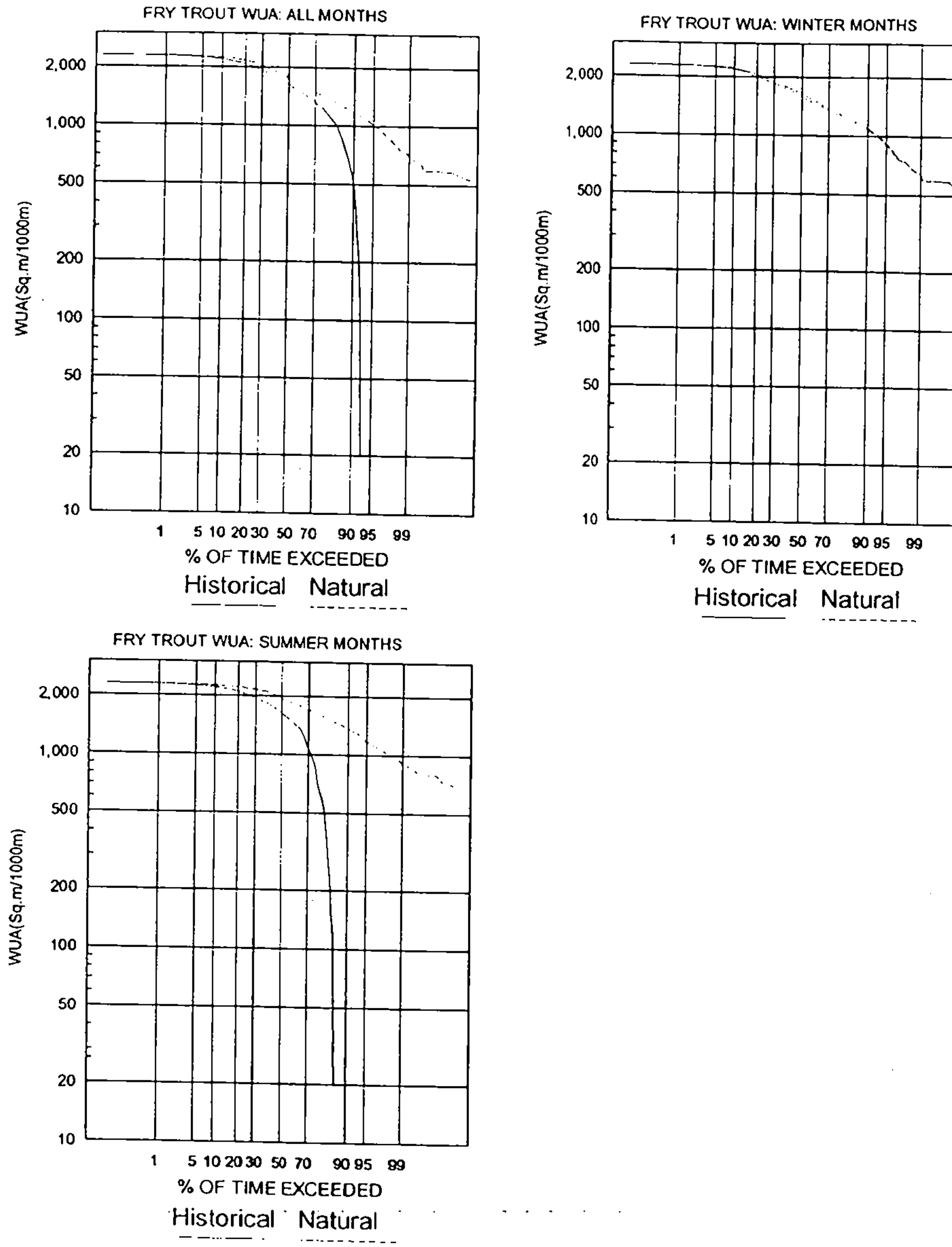


Figure 6.7 *R. Barle: Duration curves for fry trout WUA (US F&WS SI data)*

RIVER BARLE

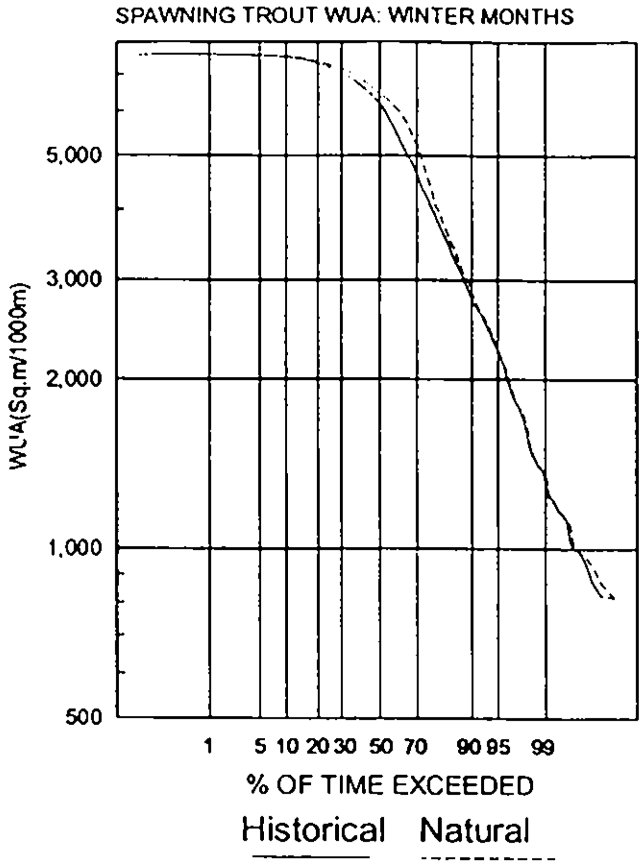


Figure 6.8 *R.Barle: Duration curves for spawning trout WUA (SW NRA SI data)*

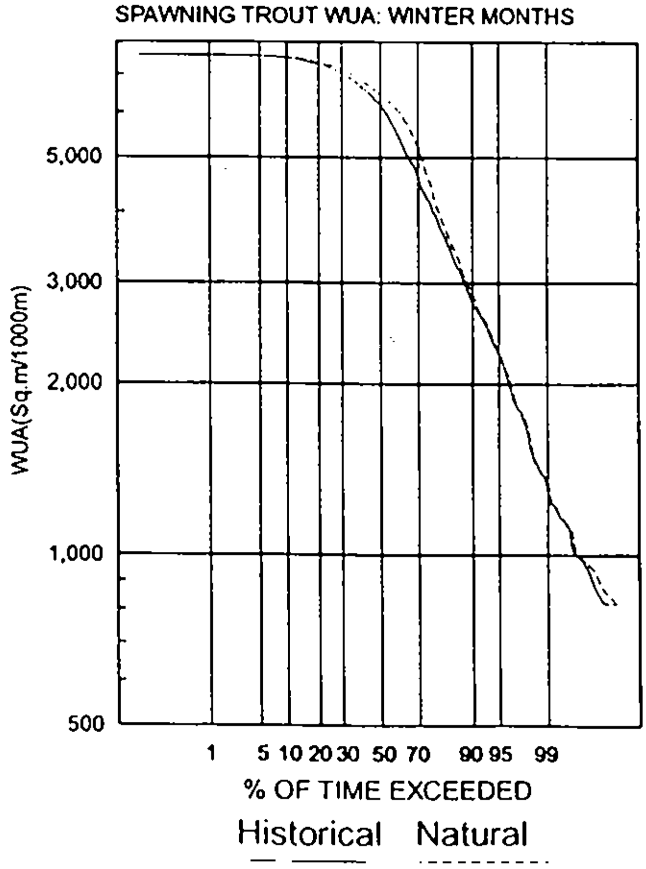


Figure 6.9 *R.Barle: Duration curves for spawning trout WUA (US F& WS SI data)*

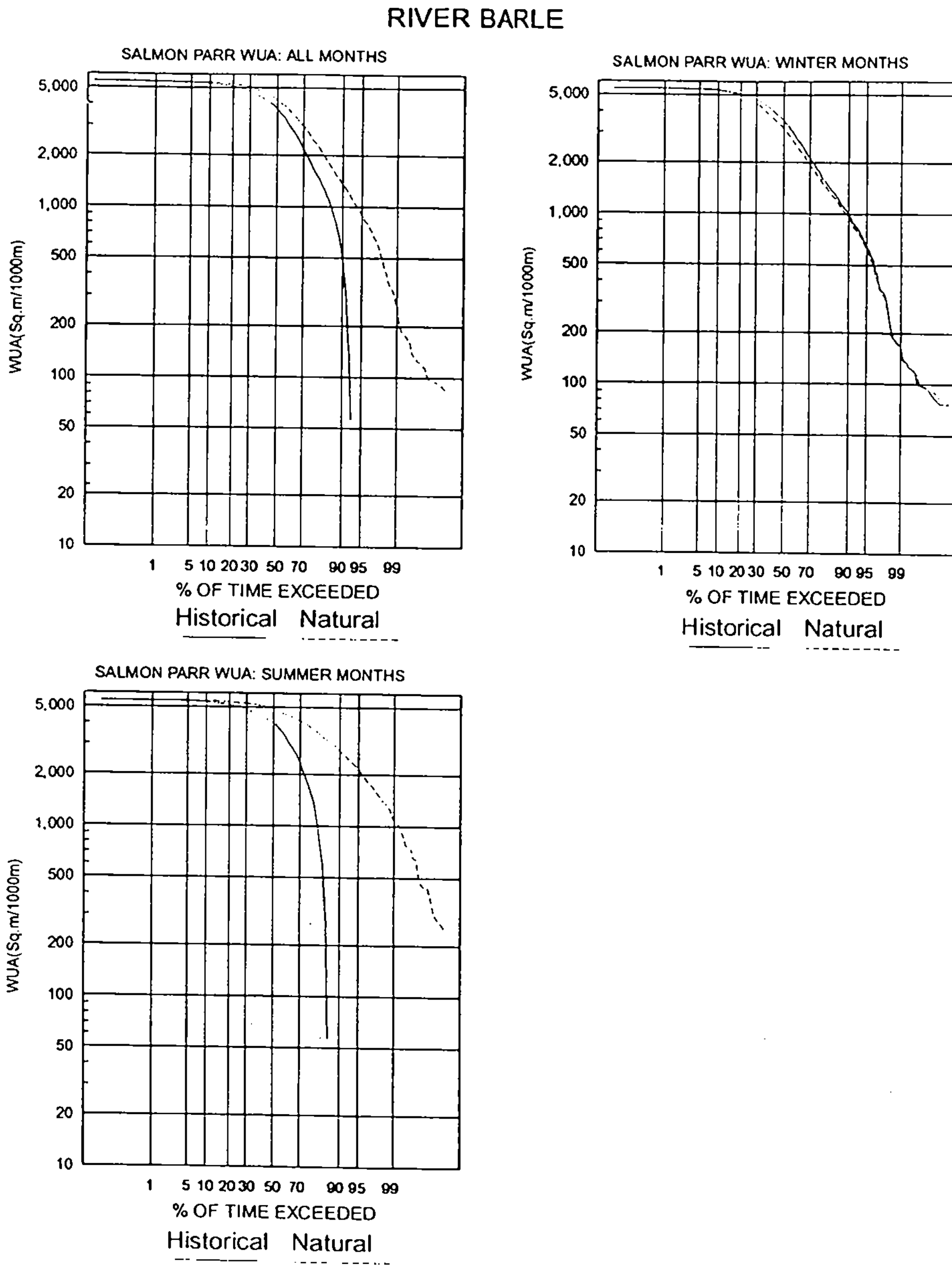


Figure 6.10 *R. Barle: Duration curves for salmon parr WUA (Heggenes data)*

RIVER BARLE

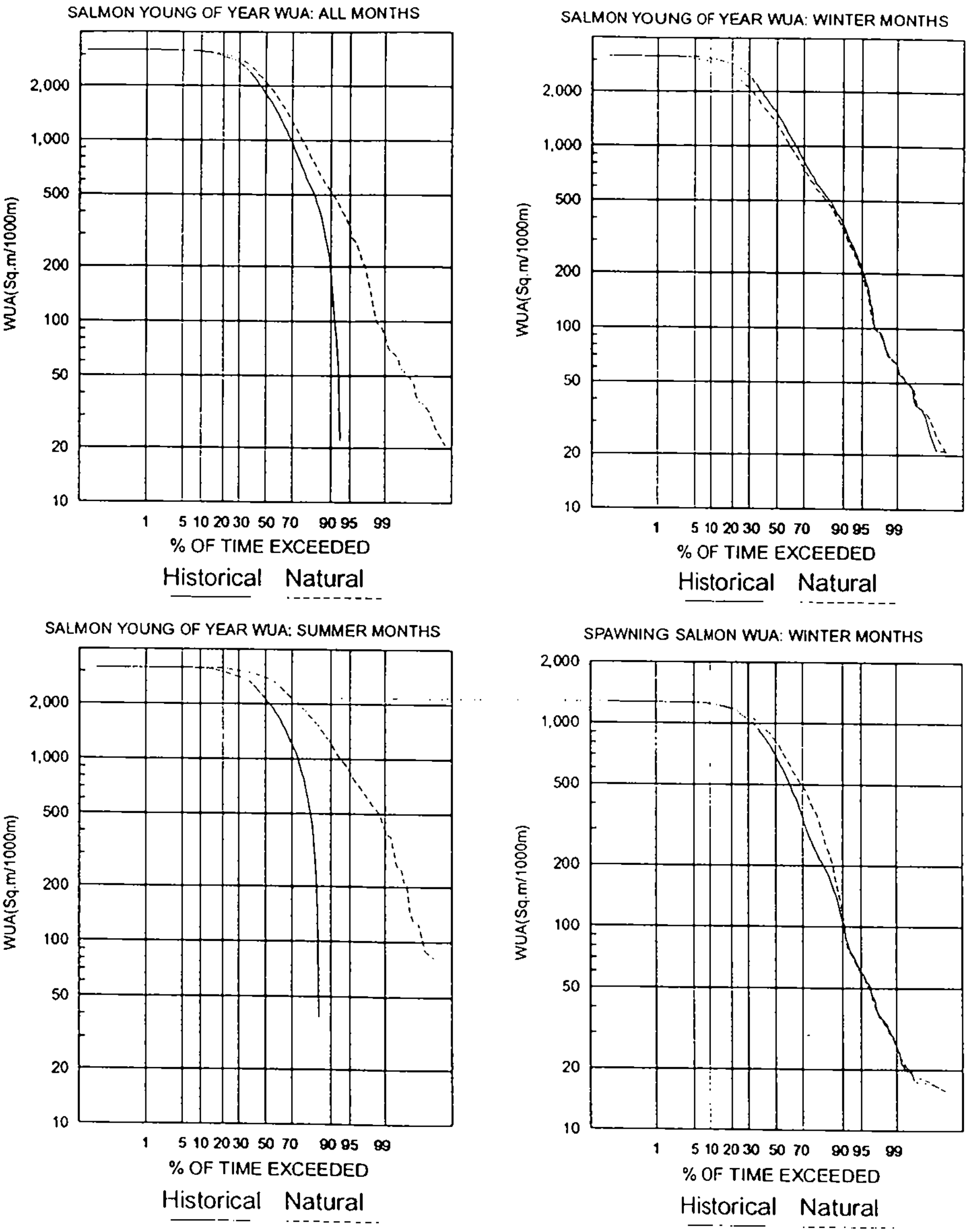


Figure 6.11 *R.Barle: Duration curves for young of year (Heggenes data) and spawning (SW NRA data) salmon WUA*

RIVER BARLE

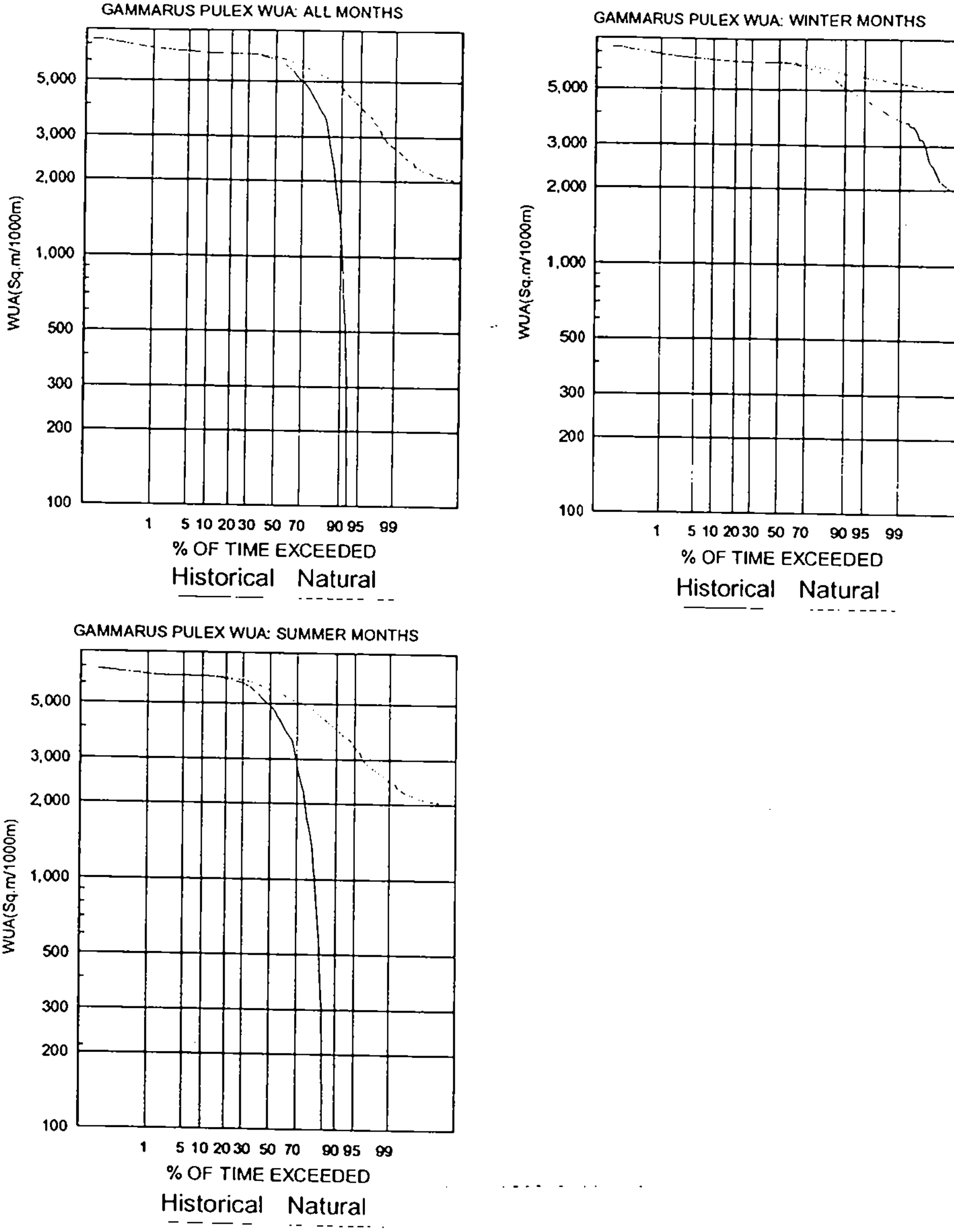


Figure 6.12 *R.Barle: Duration curves for Gammarus pulex WUA*

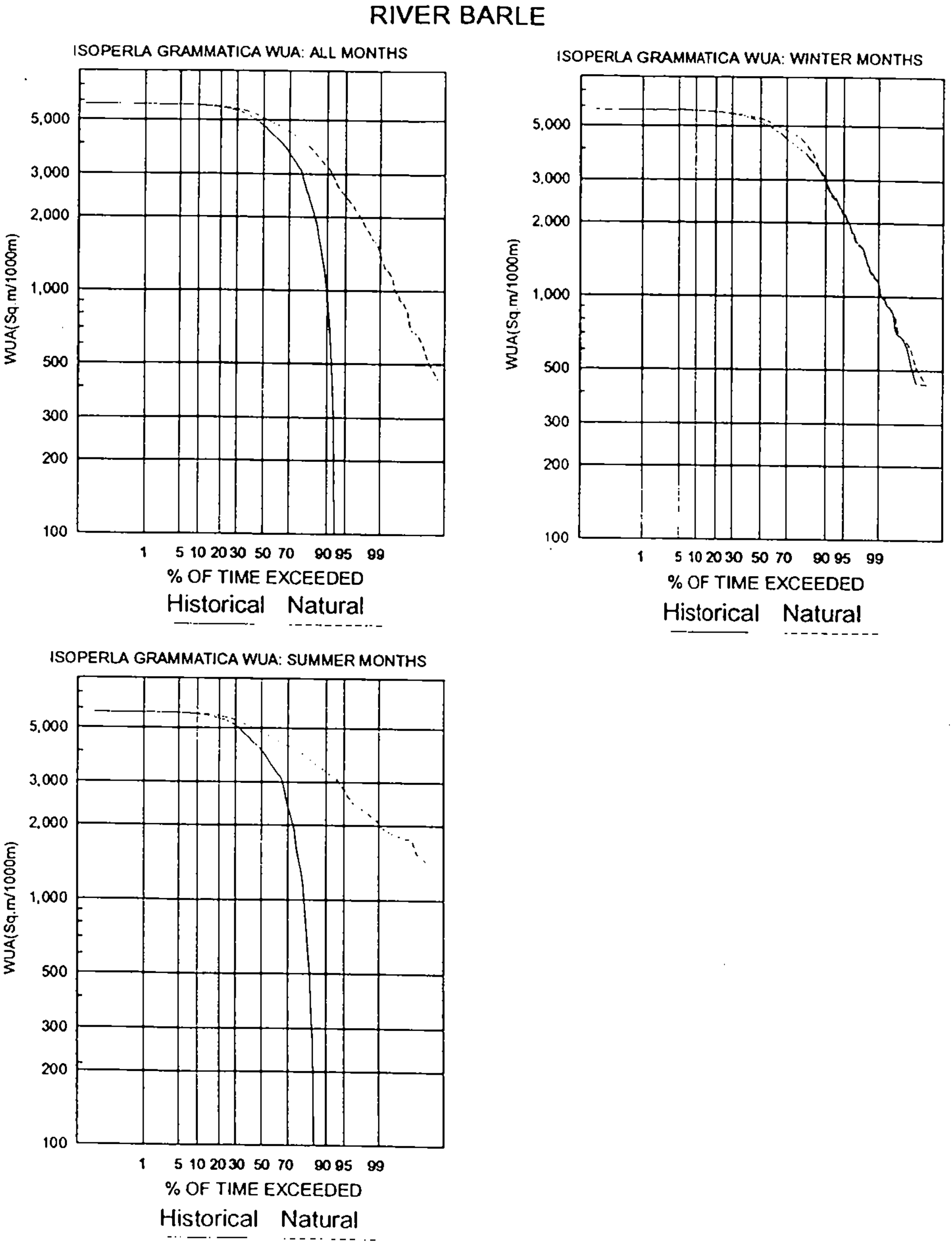


Figure 6.13 *R.Barle: Duration curves for Isoperla grammatica WUA*

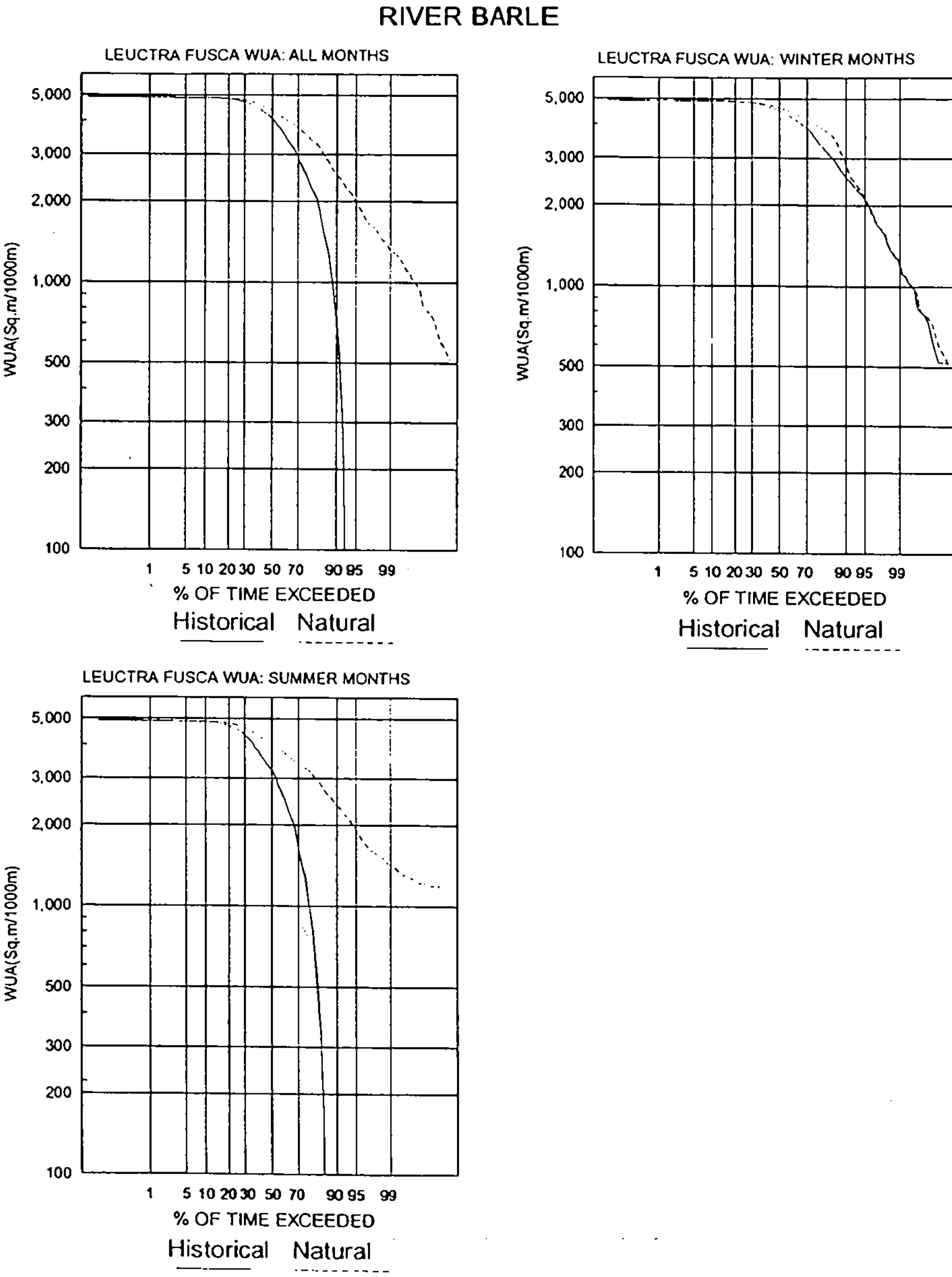


Figure 6.14 *R.Barle: Duration curves for Leuctra fusca WUA*

7 Assessment and interpretation of results

7.1 RIVER BRAY AT LEEHAMFORD

7.1.1 WUA vs discharge outputs

PHABSIM WUA vs discharge results for target species at the Leehamford study site were given in Figures 4.3,4.5.

Trout

For life-stages of trout, simulated WUA vs discharge curves from the two different habitat suitability data sets are substantially different. In the corresponding results for normalised WUA vs discharge (Figure 4.5) differences are reduced. This may be attributed largely to the differences in suitability data for substrate. Since substrate is not treated as being discharge dependent, the difference in substrate suitability data tends to produce a largely discharge independent scaling of absolute values of WUA. The differences in outputs from the two different habitat suitability data sets is most evident for the adult life-stage.

Using the US F&WS habitat suitability data WUA vs discharge for adult fry and juvenile life-stages all peak at around 0.6 cumecs. For this data set spawning WUA peaks at 0.8 cumecs. With the US data WUA for juveniles is around 70% greater than that for fry, but the shape of the curves is very similar. This is demonstrated in Figure 4.5 where the fry and juvenile curves for the normalised WUA are very similar. For the NRA SW suitability data WUA vs discharge curves for the fry/juvenile and spawning life-stages peak at around 0.6 cumecs. The adult WUA curve from this data set peaks at 1.3 cumecs.

On the whole the US data seems to produce the more realistic results, particularly for the adult life-stage. This reflects opinions expressed about the transferability of the habitat suitability data sets which were expressed in Section 3.

Salmon

WUA (based on Heggenes habitat suitability data) for parr and young of year salmon peak at around 0.5 cumecs. The spawning WUA curve (based on SW NRA habitat suitability data) peaks at around 1.2 cumecs. WUA curves for parr and young of year (Figure 4.3) have a very similar shape in the 0-0.5 cumecs range, with a slight scaling in absolute terms. In Figure 4.5 the normalised WUA for parr and young of year is almost identical over this range of discharges.

Invertebrates

For the three invertebrate species WUA vs discharge curves show a much reduced level of sensitivity of WUA to changes in discharge when compared with the corresponding outputs for the fish species. This reflects the much less finely focused habitat suitability data for these species. *Gammarus pulex* in particular is extremely tolerant to a wide range of discharges. For both *Isoperla grammatica* and *Leuctra fusca* WUA peaks at around 1.5 cumecs, falling off gradually at higher discharges.

7.1.2 Habitat time series simulation outputs

The historical and natural flow duration curves (Figure 5.1) using gauged abstraction data (1980-1992) show significant levels of impact from the historical abstraction, concentrated in the summer months. The relative impact of abstraction on discharges at given exceedance percentiles for the summer and winter periods is shown in Figure 7.1 below. For the summer months the natural 95 percentile flow (Q95) was reduced by 48%, with reduction remaining as high as 25% at the 30 percentile exceedance level. For the winter months low flows were still reduced significantly (33% reduction for the winter (Q95)) but flows exceeded 70% of the time or less were reduced by less than 10%. Reductions in flows percentiles and the corresponding reductions in WUA for the fish species, for the summer months are given in Table 7.1 below.

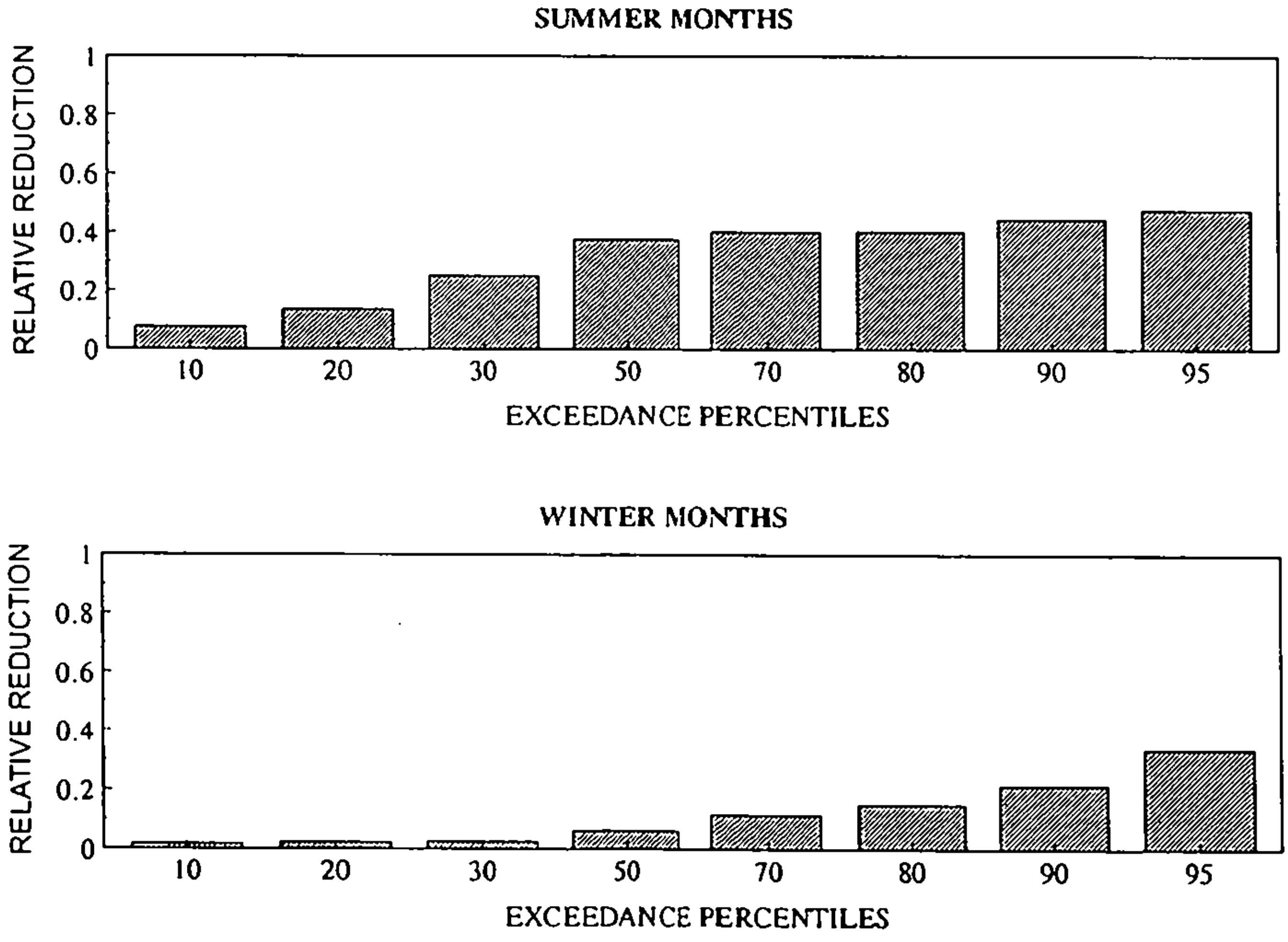


Figure 7.1 Reduction in flow at selected exceedance percentiles by abstraction.

Table 7.1 *Reduction in flow and habitat values by abstraction: summer months.*

Perc. of Time	Flow	Total Habitat	Trout WUA			Salmon WUA	
			Adult	Juv	Fry	Parr	Y of Y
95	47.7	15.1	30.3(68.4)	27.9(86.3)	37.9(86.3)	34.6	28.8
90	44.6	12.2	28.8(64.1)	28.6(86.2)	36.5(86.2)	34.2	27.4
80	40.4	10.7	25.7(57.1)	27.7(75.2)	33.9(75.2)	31.3	26.2
70	40.1	9.2	22.6(58.7)	27.8(77.4)	33.6(77.4)	29.3	21.7
50	38.0	5.7	14.9(43.7)	24.1(62.4)	28.7(62.4)	21.5	18.1
30	25.1	2.2	5.9(11.4)	8.7(23.2)	7.1(23.2)	8.9	7.7
20	13.5	1.6	2.0(5.6)	4.7(10.8)	2.7(10.8)	3.1	3.9
10	7.5	0.4	0.2(4.0)	0.4(2.1)	0.0(2.1)	0.8	1.4

Total available habitat area duration outputs (Figure 5.2) show a reduced sensitivity to the effect of abstraction, relative to the impact on the flow. For the summer months total available habitat area is reduced by 15% at the 95 percentile exceedance and by 6% at the 50 percentile exceedance level. For the winter months reduction in total available habitat area is negligible.

Weighted usable area duration curve outputs (Figures 5.3-5.14) show high levels of impact due to abstraction, concentrated in the summer months. As anticipated from the habitat suitability data, predicted impacts are more severe for the fish species than for the relatively tolerant invertebrate species. Reductions (by abstraction) in summer WUA values at selected exceedance percentiles for life-stages of trout and salmon are given in Table 7.1 above (for trout WUA, figures from simulations using SW NRA data are included in brackets). As mentioned in the discussion of WUA vs discharge results, the PHABSIM outputs seem more realistic using the US data, and it is likely that predictions using SW NRA data are overestimating impacts. These results are displayed graphically for adult trout in Figure 7.2, for fry and juvenile trout in Figure 7.3, and for parr and young of year salmon in Figure 7.4. Impact upon the spawning life-stages of trout and salmon is relatively limited since abstraction has limited impact upon flows in the winter spawning period.

Using the US F&WS habitat suitability data, predicted reductions in adult trout WUA for the summer months are 30% at the 95 percentile exceedance level and 15% at the 50 percentile level (corresponding reductions predicted using the SW NRA data are 68% and 44%). For the fry and juvenile life-stages, using US F&WS suitability data, predicted reductions in summer WUA at the 95 percentile exceedance level are 38% and 28% respectively. At the 50 percentile level the corresponding reductions are 29% and 24% (using NRA SW suitability data for the combined fry/juvenile life-stage gives reductions of 86% and 62% at the 95 and 50 percentile levels respectively).

From Figure 7.4 it may be seen that predicted reductions in WUA for parr and young of year salmon are very similar, with slightly greater reductions predicted for the parr. For

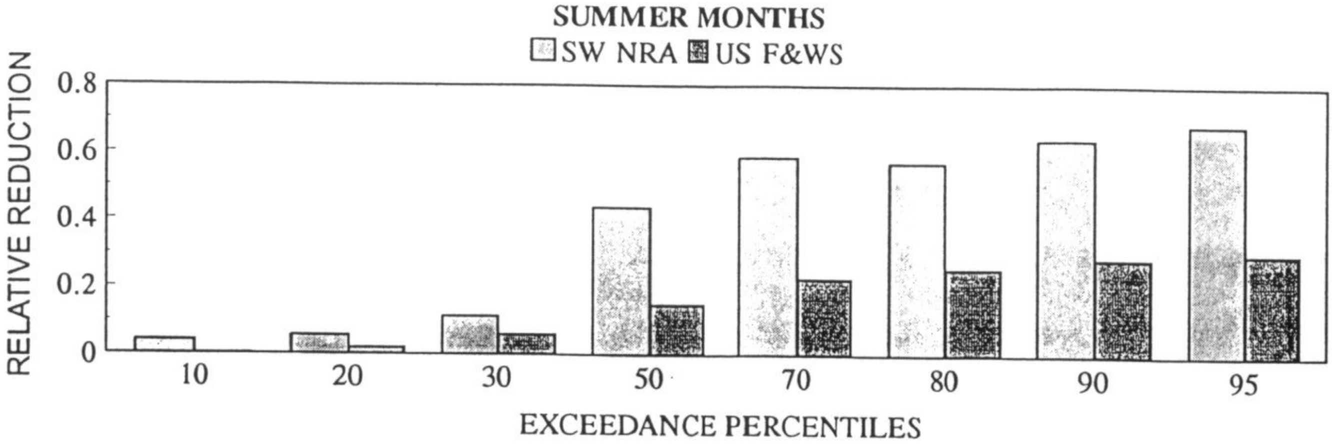


Figure 7.2 *Reduction in adult trout WUA at selected exceedance percentiles.*

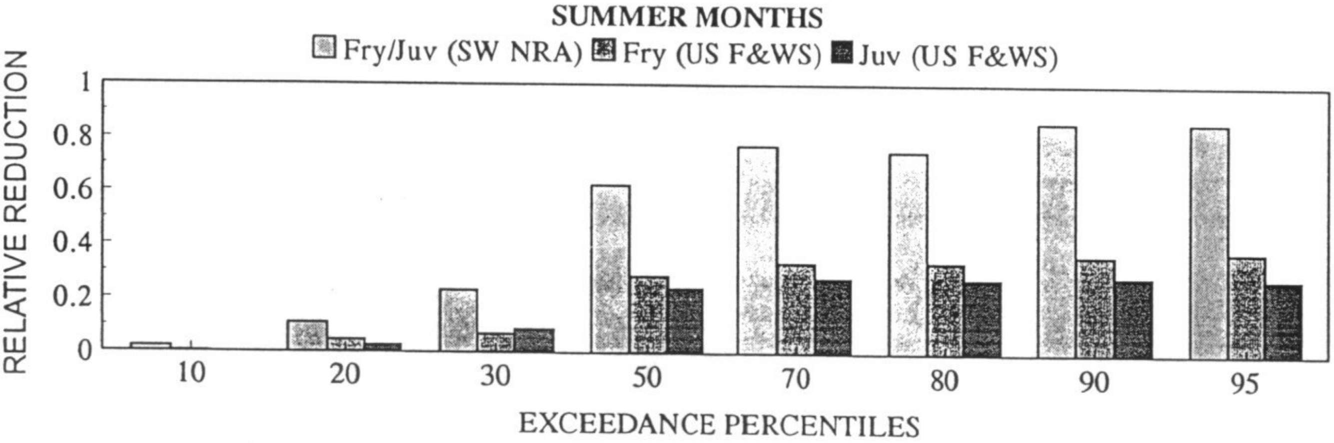


Figure 7.3 *Reduction in summer fry and juvenile trout WUA at selected exceedance percentiles.*

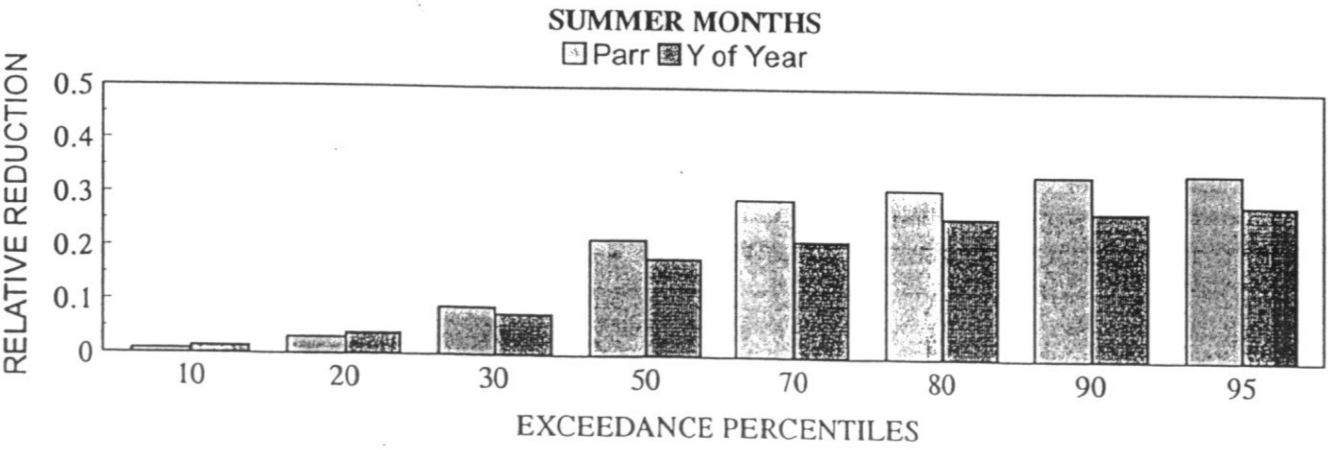


Figure 7.4 *Reduction in summer parr and young of year salmon WUA at selected exceedance percentiles.*

the summer months salmon parr WUA is reduced by 35% at the 95 percentile exceedance level and by 22% at the 50 percentile level. Corresponding reductions predicted for the young of year are 29% and 18%. Predicted reductions in WUA for both parr and young of year salmon are very similar to those predicted for adult trout using US Fish & Wildlife service suitability data, reflecting the similarity in the corresponding WUA vs discharge curves over the 0-1 cumecs range. As in the case of spawning trout, reduction in salmon spawning salmon WUA is limited since abstraction has a relatively limited impact upon winter flows.

7.1.3 Additional time series simulations: temporary licence scenario

Before gauged daily abstraction records were available to run habitat time series simulations, some preliminary analysis was conducted using a scenario based on uptake of the maximum abstraction rate permitted by the temporary licence variation agreed in 1992. This variation specified a prescribed minimum flow of 0.079 cumecs, below which abstraction is not permitted. This value approximates to the 95 percentile exceedance value for the natural flow record constructed using gauged abstraction data (as used to produce the results in Figures 5.1-5.14). The 1992 licence variation permits abstraction of half the remaining flow above 0.079 cumecs up to a daily maximum of 0.394 cumecs.

The abstraction scenario which was modelled was based on uptake of the maximum abstraction permitted by the 1992 licence variation. Assuming this scenario a 'natural' flow record was constructed for the period 1980-1993. Figure 7.5 below gives the 'natural' and summer flow duration curves and fry trout WUA duration curves (using US F&WS data) based on this abstraction scenario, for the period of record 1980-1993 (it must be stressed that this is not a real scenario, since the licence variation was not agreed until 1992).

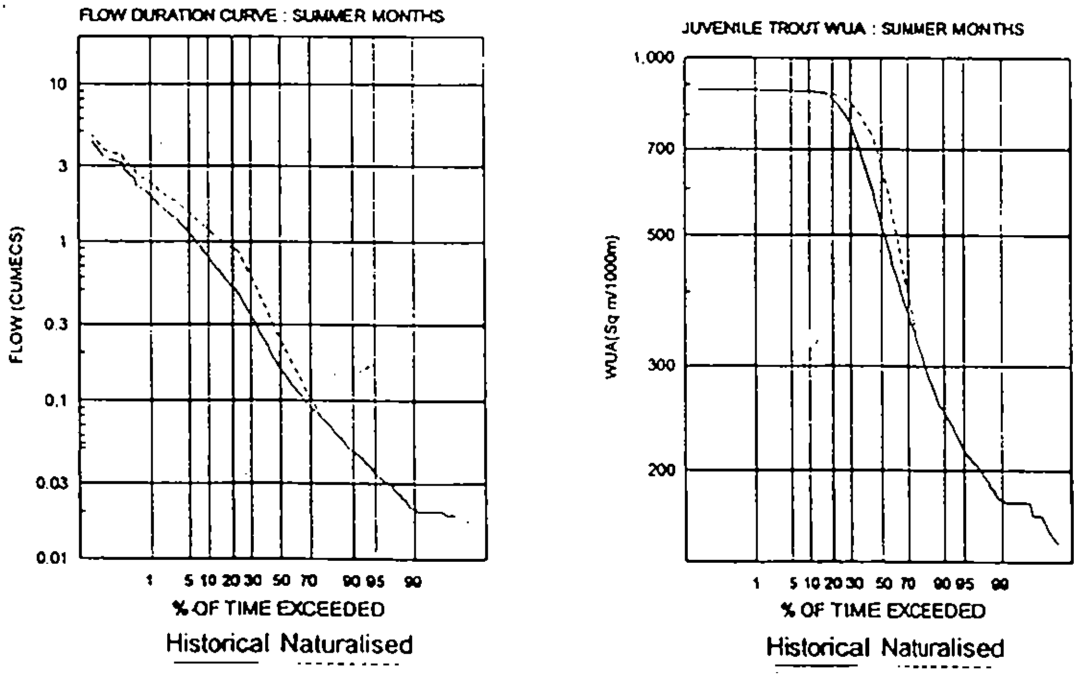


Figure 7.5 *Simulated historical and 'natural' flow and juvenile trout WUA duration curves under '1992 abstraction licence scenario' (1980-1993).*

It may be seen from Figure 7.5 that, under this abstraction scenario, summer flows over the period 1980-1993 fell below the prescribed minimum flow of 0.079 cumecs for around 25% of the time. Consequently, under this scenario, natural and historical flows in the 75-99.9 percentile exceedance range would be identical. It follows that summer habitat values in the 75-99.9 percentile exceedance range (ie. the lowest 25% of habitat values) for all target species would be unaffected by abstraction. Comparing Figure 7.5 with Figure 5.7 it may be seen that for this scenario, the half-take condition for flows above the relatively high prescribed minimum flow ensures a relatively low level of impact upon summer habitat availability, when compared with outputs using gauged abstraction data under the original licence.

7.2 RIVER BARLE AT PERRY WEIR

7.2.1 WUA vs discharge outputs

Trout

PHABSIM WUA vs Discharge results for target species at the Perry Weir study site were given in Figures 4.4 and 4.6. As in the simulations conducted on the R.Bray study site, the simulation outputs for the two different habitat suitability data sets for trout are very different. As in the case of the R.Bray the US F&WS seem to produce the more realistic results.

The WUA vs discharge curves produced using the US F&WS habitat suitability data for the juvenile and adult life stages of trout both peak at around 2 cumecs. The fry and spawning curves produced from the same data set, reach optimum levels at 1.5 and 3.5 cumecs respectively. The curves produced from the NRA SW data predict that WUA for all three life stages peaks at 2 cumecs.

Salmon

WUA for salmon parr and young of year reach peak levels at 1.5 and 1 cumec respectively. For spawning salmon (using from SW NRA data) peak habitat is reached at 4.5 cumecs. The normalised WUA curves for salmon parr and young of year (Figure 4.6) show that young of year salmon are slightly more sensitive to increases in flow above the peak then those for parr. In absolute terms optimum WUA levels for young of year salmon are 40% less than those for salmon parr.

Invertebrates

The three invertebrate species WUA vs discharge curves show reduced levels of sensitivity to changes in flow in a similar way to those produced for the R.Bray site. All three species reach high WUA levels at 4.5 cumecs with *Gammarus pulex* showing slight increases in habitat with flow above this level. WUA for *Isoperla grammatica* and *Leuctra fusca* both begin to decline with flow above 4.5 cumecs but are far less sensitive to changes in flow than the fish species examined above.

7.2.2 Habitat Time Series Simulation Outputs

The flow duration curves (Figure 6.1) produced using gauged flow data (1981-1982) show that the maximum licenced uptake of the abstraction has the potential to have a significant impact the natural flow, especially in the summer months. The relative impact of the abstraction on discharges at selected exceedance percentiles is shown in Figure 7.6 below. The potential impact during the summer months is such that there is a 100% reduction in flow at exceedances above 90%, since the abstraction has the potential to take up all of the available flow at low flows. Even at the 30 percentile exceedance level the abstraction could potentially reduce the flow by 24.1%. In the winter there is still potential for the abstraction to have a significant impact. At the 50% exceedance level the potential reduction in flow is 13% rising to 57% at the 95% exceedance level. The reductions in flows at selected percentiles and the corresponding reductions in WUA for the fish target species for the summer months are given in Table 7.2 below.

The total habitat area duration curves (Figure 6.2) show that total habitat area has a reduced sensitivity to the effect of abstraction relative to the impact on flow. For example, the

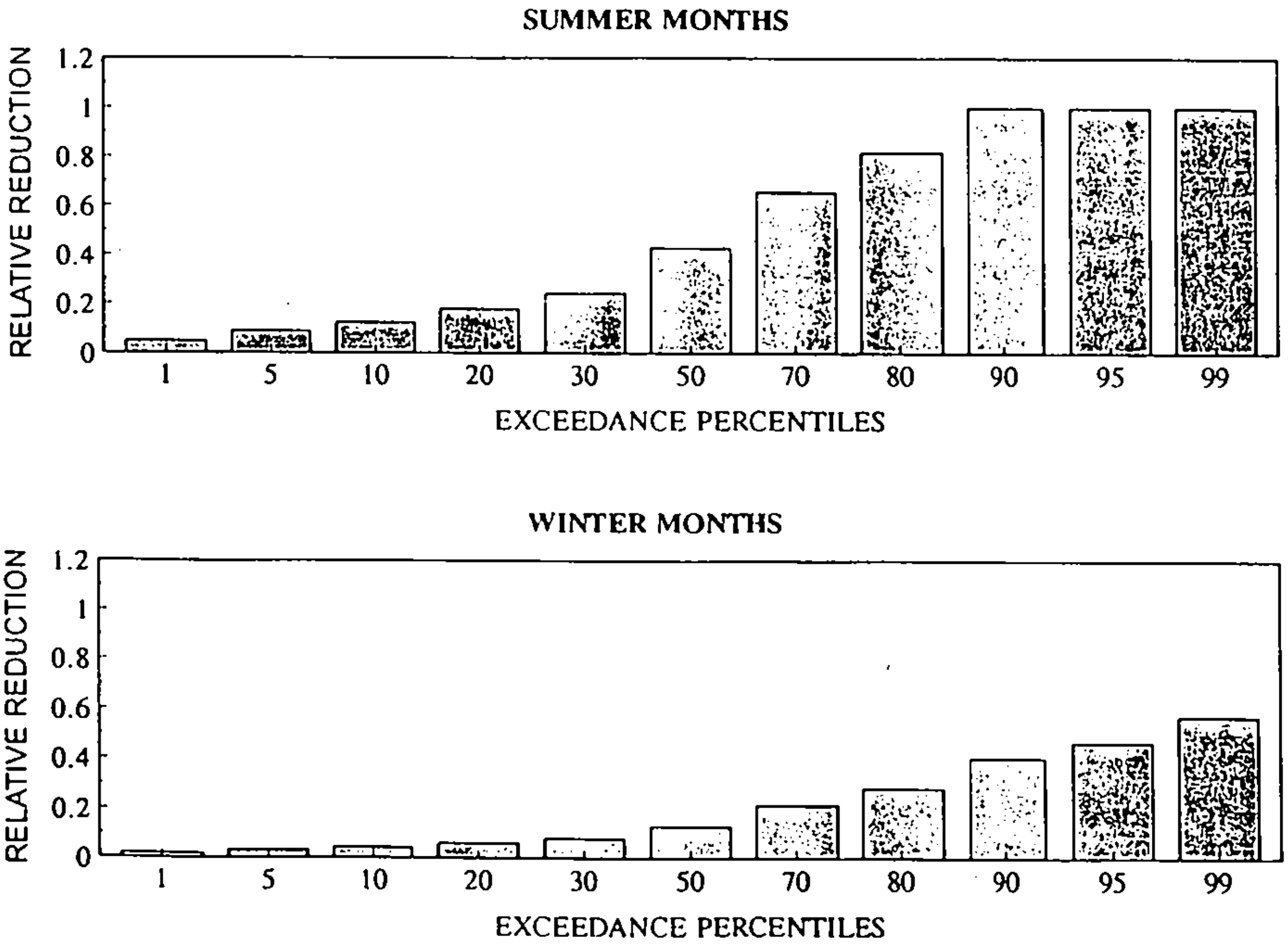


Figure 7.6 *Reduction in flow at selected exceedance percentiles by abstraction*

reduction in total habitat at the 70 percentile is 31.7% whereas the flow is reduced by 65.8% at the same percentile. For the winter months the reduction in total habitat area is negligible in comparison.

Table 7.2 *Reduction in flow and habitat values by abstraction: summer months*

Perc. of Time	Flow	Total Habitat	Trout WUA Adult	Juv	Fry	Salmon WUA Parr	Y of Y
95	100	100	100(100)	100(100)	100(100)	100	100
90	100	100	100(100)	100(100)	100(100)	100	100
80	81.7	69.6	67.1(77.5)	68.3(82.1)	69.1(82.1)	68.8	66.5
70	65.8	31.7	34.1(56.6)	37.1(68.4)	36.9(68.4)	42.2	43.7
50	42.8	6.9	11.8(22.1)	14.9(35.5)	15.6(35.5)	16.7	23.9
30	24.1	1.5	3.8(7.7)	6.6(14.9)	10.0(14.9)	7.9	7.4
20	17.8	0.8	1.9(2.3)	2.9(4.5)	5.1(4.5)	3.5	4.6
10	12.2	0.6	0.6(0.9)	0.8(1.4)	2.3(1.4)	1.4	0.4

The WUA duration curves shown in Figures 5.3 to 5.14 show high levels of impact if the maximum level of abstraction is applied. Impact is concentrated during the summer months. For maximum levels of abstraction the potential reductions at selected exceedance percentiles for fish species are given in Table 7.2, above (figures for simulations for trout using SW NRA data are included in brackets). As in the simulations for the R.Bray the PHABSIM outputs seem more realistic using the US data, with the SW NRA data probably overestimating the impacts. These results are also displayed graphically in Figures 7.6, 7.7, and 7.8. The potential impact of the abstraction during the winter months for all the species and life stages of fish is negligible since low flows likely to cause detrimental impacts occur rarely, whilst flows above those giving optimal WUA for each target species are much more common and any reduction in flow will increase WUA in these circumstances.

The potential impact during the summer on invertebrates is, perhaps unexpectedly, similar to that on the fish species. This is because optimum WUA levels for these target species is achieved at relatively high discharges which occur infrequently in the summer (eg *Leuctra fusca* at 4.5 cumecs a flow which is exceeded less than 20% of the time in the summer) and below these levels the invertebrates are sensitive to reductions in flow.

Using the US F&WS data, the predicted reductions in adult trout WUA in the summer months is 67% at the 80 percentile exceedance level and 11% at the 50 percentile exceedance level. The equivalent figures for the juvenile life stage are 68% and 15%. Those for the fry life stage are 69% and 16% respectively. The predicted reductions in WUA for salmon parr and young of year are similar to those for trout with slightly greater reductions at lower percentile exceedances. At the 80 percentile exceedance level the reduction for parr is 69% and young of year is 66.5 whilst the reduction at the 50 percentile exceedance level is 17% for parr and 23.9% for young of year.

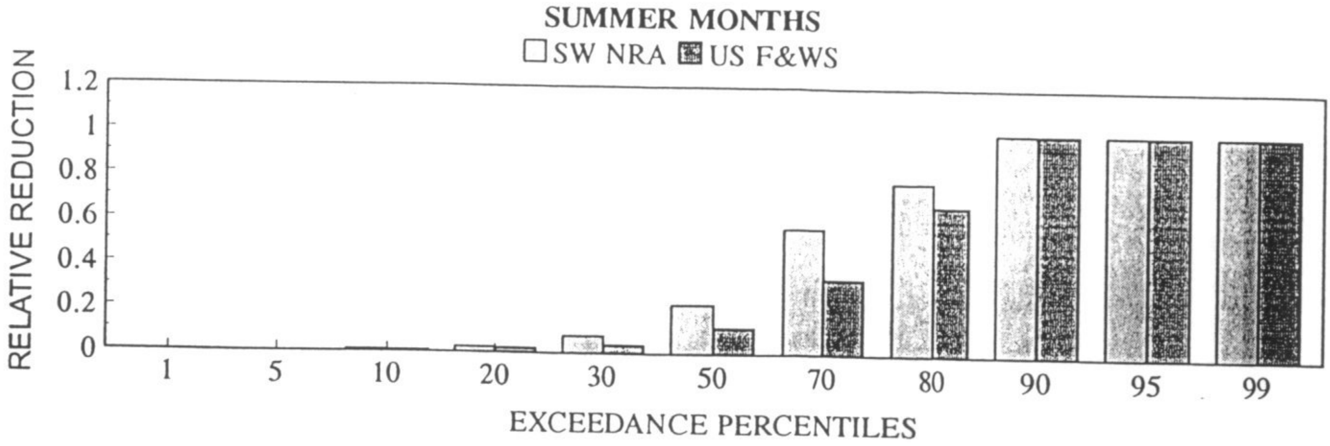


Figure 7.7 *Reduction in summer adult trout WUA at selected exceedance percentiles.*

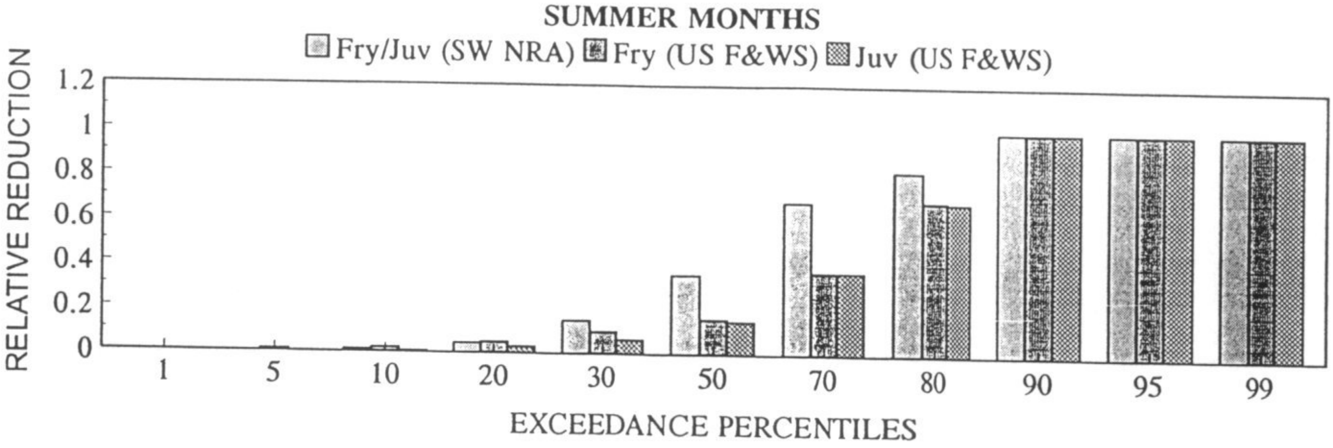


Figure 7.8 *Reduction in summer fry and juvenile trout WUA at selected exceedance percentiles.*

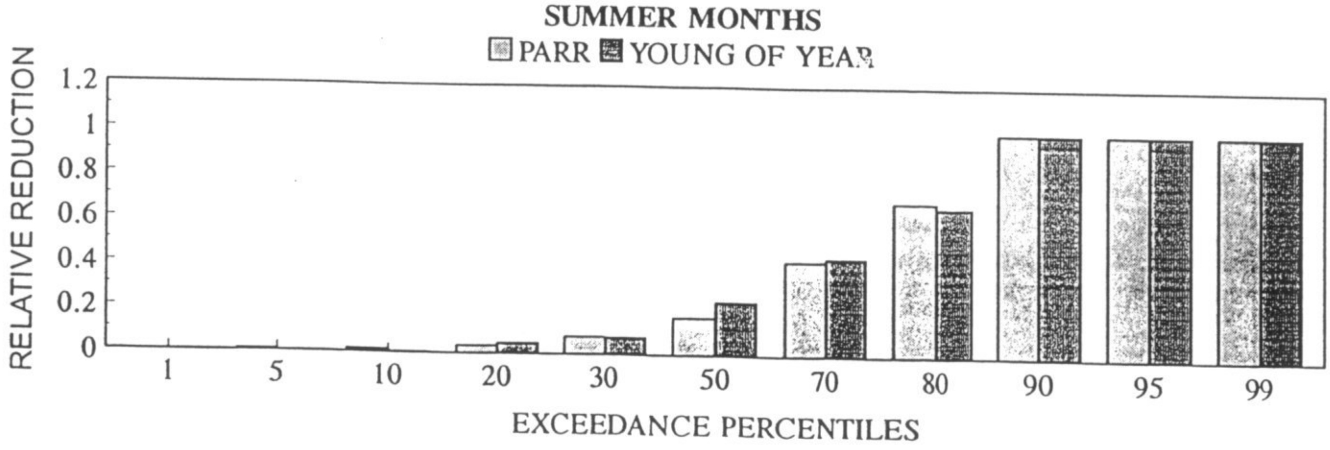


Figure 7.9 *Reduction in summer parr and young of year salmon WUA at selected exceedance percentiles.*

8 Conclusions and recommendations

8.1 RIVER BRAY AT LEEHAMFORD

Analysis of historical and natural flow duration curves (using gauged abstraction data) over the period 1980-1992 suggest that the level of historical abstraction permitted by the 'original' licence conditions significantly reduced flows in the summer over a large portion of the flow range, with high impacts at low flows. The consequent reduction in total wetted stream area (total available habitat area) was less than that in the flow, but in contrast the Weighted Usable Area available to adult, fry and juvenile trout and salmon parr and young of year was reduced to a greater extent than the flow. Greatest impact was predicted for the fry life-stage of trout and for the salmon parr.

Doubts have been expressed about the transferability of the habitat suitability developed by NRA Wessex Region (now NRA SW), and as stated in the previous section it is our view that IFIM predictions using these data may overestimate the impact of abstraction upon habitat availability. In contrast, both the US Fish & Wildlife Service trout curves and the Heggenes salmon curves were specifically designed as 'generalised' curves and should transfer more readily. The curves are fairly broad-banded and it is likely that Category II utilisation curves developed specifically for the rivers studied here would be more focused and would fall within the range of these curves. If this were the case then it is likely that impacts from IFIM simulations would be greater than those predicted here. Following this line of argument we suggest that outputs from IFIM simulations presented here using the US trout data and Heggenes salmon data may underestimate impacts.

The only possible approaches to directly assessing the influence of the use of these generalised Category I habitat suitability curves upon the results of this assessment is to initiate a program of direct observations of trout and salmon in SW rivers similar in character to the Barle and the Bray. A sampling program along the lines of the Wessex NRA program for the River Allen study could be initiated and Category II/|III utilisation/preference curves developed. Clearly this approach is fairly resource intensive.

A less resource intensive approach is to test the curves used here following a technique recently developed by the U.S.Fish & Wildlife Service (Thomas & Bovee, 1993). The essence of this technique is to test (for a given species life-stage) the hypotheses that (i) 'optimal' habitats will be used more than 'suitable' habitats and (ii) 'suitable' habitat will be used more than 'unsuitable habitat'. It is suggested that statistically valid tests of these hypotheses can be achieved using significantly smaller data sets than those required to develop habitat utilisation criteria.

Considering that the levels of impact upon summer habitat availability for trout and salmon predicted using the generalised Category I habitat suitability curves are very significant for low flow periods, together with the fact that these (as a result of using generalised curves) may be under-estimates it is doubtful that further simulations using habitat utilisation data are justified, since the evidence already available from the results presented here would appear sufficient to warrant careful consideration of any return to the 'original' licence conditions.

Additional time series simulations, using an imaginary scenario based on the current (temporary) licence suggest that the prescribed minimum flow is set at a level high enough to ensure minimal impact upon summer habitat availability. Further simulations will be required to assess the impact of any alternative operating rules for the abstraction regime. In section 8.3 below we discuss the application of the IFIM to the formulation of such rules and assessment of their impact upon habitat availability.

8.2 RIVER BARLE AT PERRY WEIR

As for the R.Bray site above, analysis of historical (estimated using the maximum licenced abstraction uptake) and natural flow duration curves over the period 1981-1993 suggest that the level of abstraction permitted by the current licence conditions significantly reduced flows in the summer over a large portion of the flow range, with high impact at low flows. The consequent reduction in total wetted stream area (total available habitat area) and WUA available to adult, fry and juvenile trout and salmon parr and young of year was less than that for the flow. The greatest impact was predicted for the fry life stage of trout and salmon parr.

The doubts expressed about the transferability of the habitat suitability data developed by NRA SW to the R.Bray, as discussed above, may also be valid for this site and again the IFIM predictions using these data may overestimate the potential impact of abstraction on habitat availability. The US Fish & Wildlife Service trout curves and the Heggenes salmon curves should, again, transfer more readily to this site than those developed by NRA SW as they are more generalised. The suggestion that the outputs using these data may underestimate the potential impact of the abstraction on available habitat at this site are also valid for the reasons outlined above. The recommendation that the habitat suitability data be further developed or tested for use on the Barle and Bray, again outlined in the preceding section, would again allow the assessment of the influence on the results of the suitability curves used.

The levels of impact upon summer habitat availability predicted for trout and salmon indicate that the abstraction has the potential to have significant impact, even using the generalised Category I habitat suitability curves and the possible underestimates of habitat loss that may result. However, the results presented for this site are based on a 'worst case' scenario in which the licenced maximum uptake is abstracted from the river at all times. Further simulations will be required to examine the impact of the actual level of abstraction or any alternative operating rules for the abstraction regime.

8.3 USE OF IFIM OUTPUT FOR FORMULATING OPERATING RULES

The use of IFIM outputs for the prescription of operating rules for an abstraction which is perceived to be impacting upon habitat availability is discussed in NRA R&D Note 185 'Ecologically Acceptable Flows'. Although it is quite possible to recommend restrictions on abstraction which should ensure protection of 'natural habitats' at low flows (by setting a high enough minimum prescribed flow), it is difficult to estimate 'acceptable' levels of reductions in habitat values, or ranges (in terms of exceedance percentiles for example) over which given reductions are acceptable. In the absence of data to support any such estimates they are bound to be to some extent subjective. For this reason it is not possible, nor is it within the project brief to recommend operating rules for the two cases considered here.

To illustrate the mechanism described in R&D note 185 for assessing an ecologically acceptable flow we shall use the example of salmon parr on the River Bray. Figure 8.1 below gives the relevant WUA vs discharge relationship, summer flow and habitat duration curves for this example.

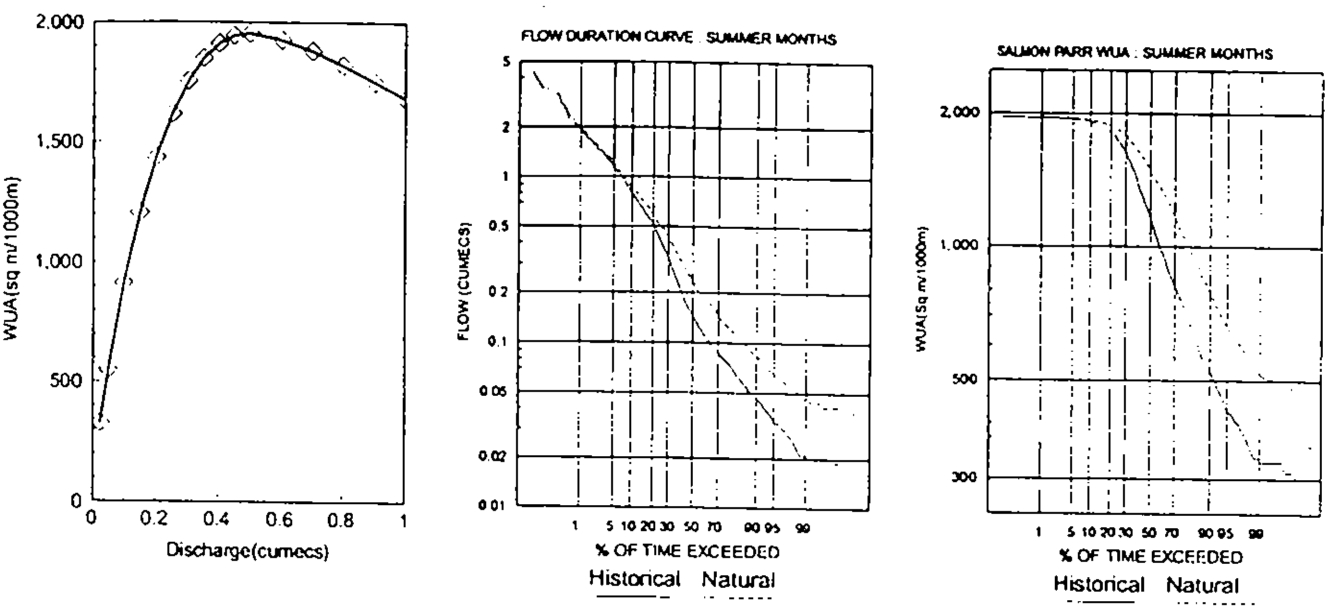


Figure 8.1 *R.Bray: IFIM outputs for salmon parr*

The WUA vs discharge curve in this example peaks at around 0.5 cumecs. From the natural flow duration curve it may be seen that a flow of 0.5 cumecs corresponds to around the natural Q50 flow. For flows less than 0.5 cumecs WUA will always be less than the peak value achieved at 0.5 cumecs. Consequently all WUA value in the habitat duration curve in the 50-99 percentile range correspond to flows of 0.5 cumecs or less.

Now suppose that we enforce a condition that flow should be regulated such that salmon parr WUA should be maintained (for the summer months) at a level above its 90 percentile exceedance value (for the natural flow regime). Reading from the habitat duration curve, the natural summer 90 percentile exceedance value for salmon parr WUA is approximately 800m^2/1000m. Referring to the WUA vs discharge curve it can be seen that for salmon parr this value of WUA corresponds to discharges of either 0.085 cumecs or 3.4 cumecs. Since we know that the discharge corresponding to the 90 percentile exceedance value of WUA must be less than 0.5 cumecs we reject the higher discharge from considerations.

We can now state that a minimum prescribed flow set at 0.085 cumecs would maintain salmon parr habitat above its natural 90 percentile exceedance value. A flow of 0.085 cumecs corresponds approximately to the naturalised Q95. The corresponding flow required to ensure no reduction at the 95 percentile level is 0.065 cumecs. This corresponds to the naturalised Q97. Clearly there are endless scenarios we could assess in this manner - others may include allowing a tolerance on levels of reduction at given percentiles, eg. we could insist that the maximum allowable reduction (between the historical and natural values from the simulations) in salmon parr WUA at the 90 percentile level is 20% etc.

The IFIM is designed as a tool for negotiation and it is clear that any alteration in existing licence conditions will involve a process of negotiation between the NRA and the licence holder. Results presented here can assist in developing proposals for such negotiation, but further simulations may be required to explicitly assess the impact of alternative abstraction regimes.

References

Bovee, K.D. 1982. A Guide to Stream Habitat Analysis Using The Instream Flow Incremental Methodology. U.S.Fish & Wildlife Service Instream Flow Information Paper No.12, FWS/OBS-82/26

Bovee, K.D. 1986. Development and Application of Habitat Suitability Criteria for Use in The Instream Flow Incremental Methodology, US Fish & Wildlife Service Instream Flow Information Paper No. 21.

Bullock, A., Gustard, A. & Grainger, E. 1991. Instream Flow Requirements of Aquatic Species. Institute of Hydrology Report No.115.

Halcrow & Partners 1991. Low Flow Study. Report to National Rivers Authority South West Region.

Heggenes J. 1990. Habitat utilisation and preferences in juvenile atlantic salmon. Regulated Rivers Research & Management, Vol 5,341-354.

Johnson, I.W., Elliott, C.R.N., Gustard, A., Armitage, P.D., Ladle, M., Beaumont, W. 1992. Data requirements and data collection procedures for application of the Instream Flow Incremental Methodology in the UK. Institute of Hydrology report to National Rivers Authority.

Johnson, I.W & Elliott, C.R.N. 1993. River Allen habitat mapping survey. Institute of Hydrology report to National Rivers Authority Wessex Region.

Johnson, I.W., Elliott, C.R.N., Gustard, A., Armitage, P.D., Ladle, M., Beaumont, W., & Dawson, F.H. 1993(1). National Rivers Authority Project B2.1 Ecologically Acceptable Flows. I Project Record 282/Wx. (and R&D Note 185)

Johnson, I.W., Elliott, C.R.N., Gustard, A.,& Clausen, B. 1993(2). River Allen Instream Flow Requirements. Institute of Hydrology report to National Rivers Authority Wessex Region, Final Report.

Johnson, I.W., Elliott, C.R.N., Gustard, A., Yaqoob, S., Fairhurst, A., Blackburn, J.H., Armitage, P.D., & Ladle M. 1993(3). MAFF Project FD0503 Quantitative Environmental Assessment of River Flood Defence Schemes, Final Report.

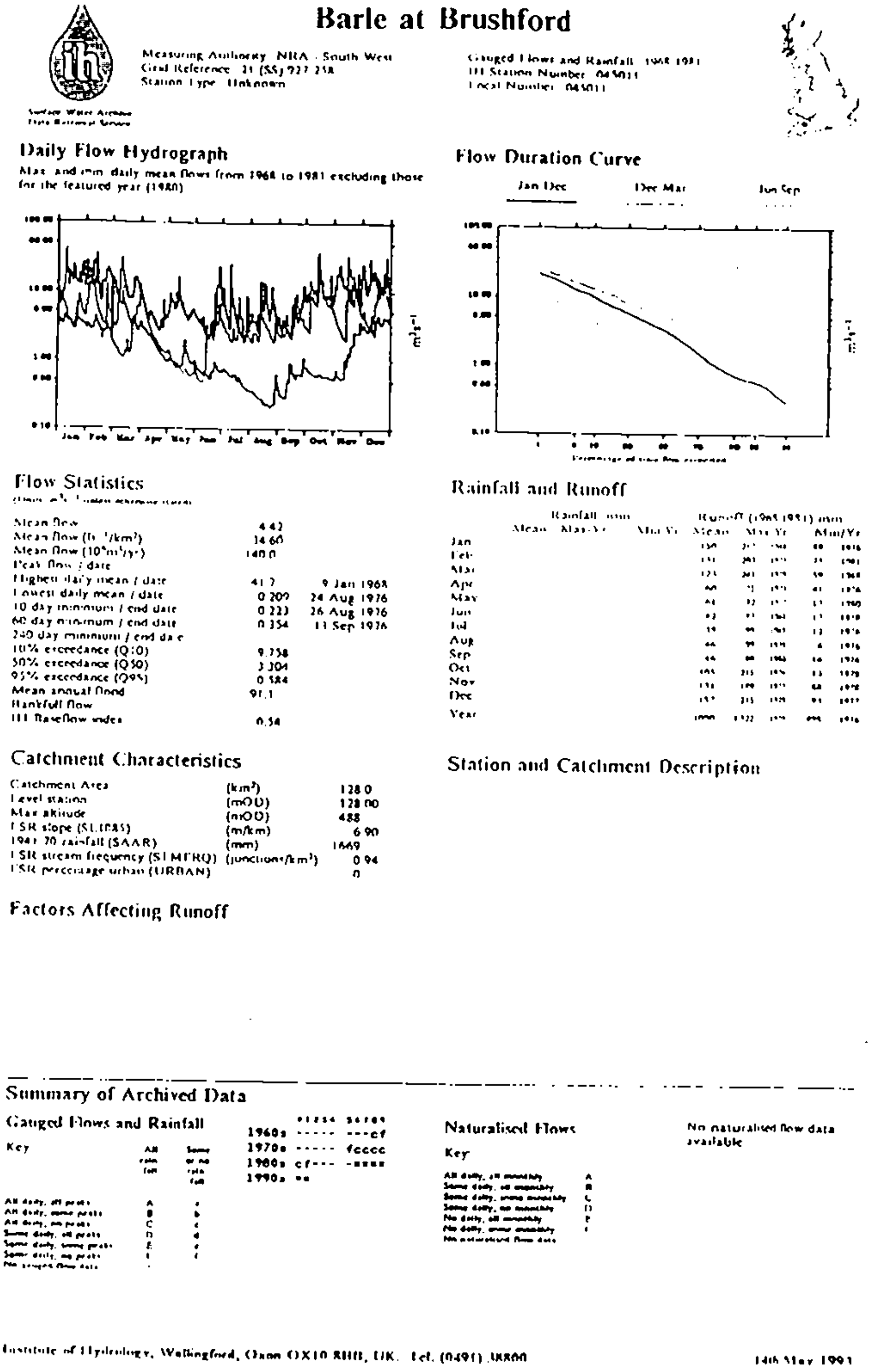
Milhous R.T., Updike, M.A. & Schneider, D. Physical Habitat Simulation System Reference Manual - Version II. U.S Fish & Wildlife Service Instream Flow Information Paper No. 26, Biol Rep 89(16).

National Rivers Authority South Western Region Water Resources Planning. 1993. Alleviation of Low Flows Phase 1A - Site Investigations River Barle, Hydrological Assessment, Water Resources Planning, August 1993. NRA South Western Region internal report..

Raleigh, R.F., Zuckerman, L.D. & Nelson, P.C. 1986. Habitat suitability models and instream flow suitability curves : brown trout, revised. U.S. Fish & Wildlife Service Biol.Rep 82(10.124).

Thomas, J.A. & Bovee,K.D. 1993. Application and testing of a procedure to evaluate transferability of habitat suitability criteria. Regulated Rivers Research & Management Vol 2.

Appendix A



Barle at Brushford

Surface Water Archive
Data Retrieval Service

Measuring Authority NRA - South West
Grid Reference 21 (SS) 927 258
Station Type Unknown

Gauged Flows and Rainfall 1968 1981
IH Station Number 045011
Local Number 045011

Daily Flow Hydrograph

Max and min daily mean flows from 1968 to 1981 excluding those for the featured year (1980)

Flow Duration Curve

Flow Statistics

Mean flow	4.42	
Mean flow (l s⁻¹/km²)	34.60	
Mean flow (10⁶m³/yr)	140.0	
Peak flow / date		
Highest daily mean / date	41.7	9 Jan 1968
Lowest daily mean / date	0.209	24 Aug 1976
10 day minimum / end date	0.223	26 Aug 1976
60 day minimum / end date	0.354	11 Sep 1976
240 day minimum / end date		
10% exceedance (Q10)	9.758	
50% exceedance (Q50)	3.304	
95% exceedance (Q95)	0.584	
Mean annual flood	91.1	
Bankfull flow		
IH Baseflow index	0.54	

Rainfall and Runoff

	Rainfall mm Mean	Max/Yr	Min/Yr	Runoff (1968 1981) mm Mean	Max/Yr	Min/Yr
Jan				[illegible]	[illegible]	[illegible]
Feb				[illegible]	[illegible]	[illegible]
Mar				[illegible]	[illegible]	[illegible]
Apr				[illegible]	[illegible]	[illegible]
May				[illegible]	[illegible]	[illegible]
Jun				[illegible]	[illegible]	[illegible]
Jul				[illegible]	[illegible]	[illegible]
Aug				[illegible]	[illegible]	[illegible]
Sep				[illegible]	[illegible]	[illegible]
Oct				[illegible]	[illegible]	[illegible]
Nov				[illegible]	[illegible]	[illegible]
Dec				[illegible]	[illegible]	[illegible]
Year				[illegible]	[illegible]	[illegible]

Catchment Characteristics

Catchment Area	(km²)	128.0
Level station	(mOD)	128.00
Max altitude	(mOD)	488
FSR slope (S1085)	(m/km)	6.90
1941 70 rainfall (SAAR)	(mm)	1669
FSR stream frequency (STMFRQ)	(junctions/km²)	0.94
FSR percentage urban (URBAN)		0

Station and Catchment Description

Factors Affecting Runoff

Summary of Archived Data

Gauged Flows and Rainfall

Key	All rain fall	Some or no rain fall
All daily, all peaks	A	a
All daily, some peaks	B	b
All daily, no peaks	C	c
Some daily, all peaks	D	d
Some daily, some peaks	E	e
Some daily, no peaks	F	f
No gauged flow data	-	

```
       01234 56789
1960s  ----- ---cf
1970s  ----- fcccc
1980s  cf--- -----
1990s  --
```

Naturalised Flows

No naturalised flow data available

Key	
All daily, all monthly	A
Some daily, all monthly	B
Some daily, some monthly	C
Some daily, no monthly	D
No daily, all monthly	E
No daily, some monthly	F
No naturalised flow data	

Institute of Hydrology, Wallingford, Oxon OX10 8BB, UK. Tel. (0491) 38800

14th May 1993

Figure A1 *R.Barle at Brushford - Gauging station summary sheet*

Appendix B
River Bray at Leehamford: PHABSIM hydraulic calibration data summary

RIVER BRAY AT LEEHAMFORD

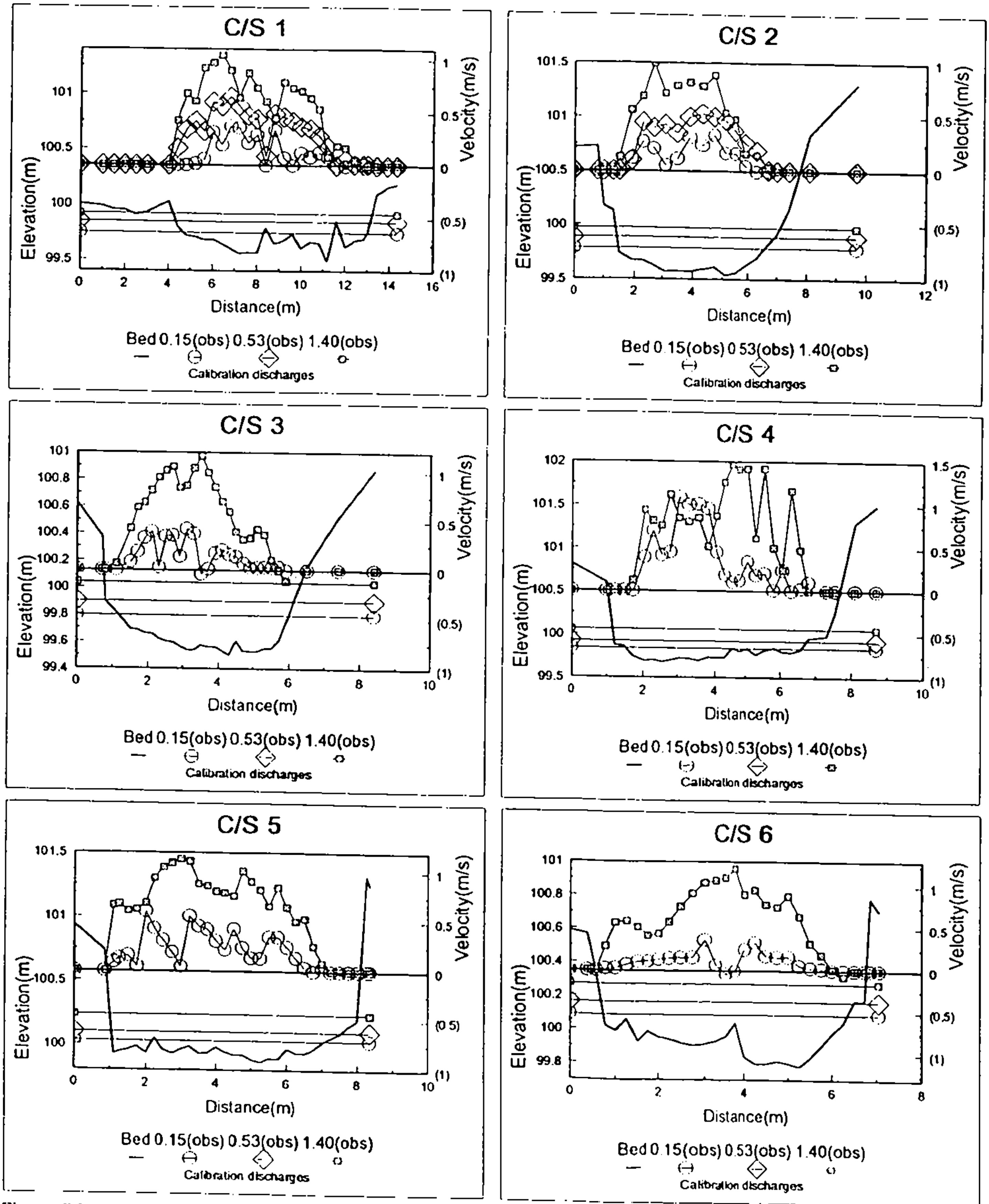


Figure B1 *R.Bray: Hydraulic calibration data C/S 1-6*

RIVER BRAY AT LEEHAMFORD

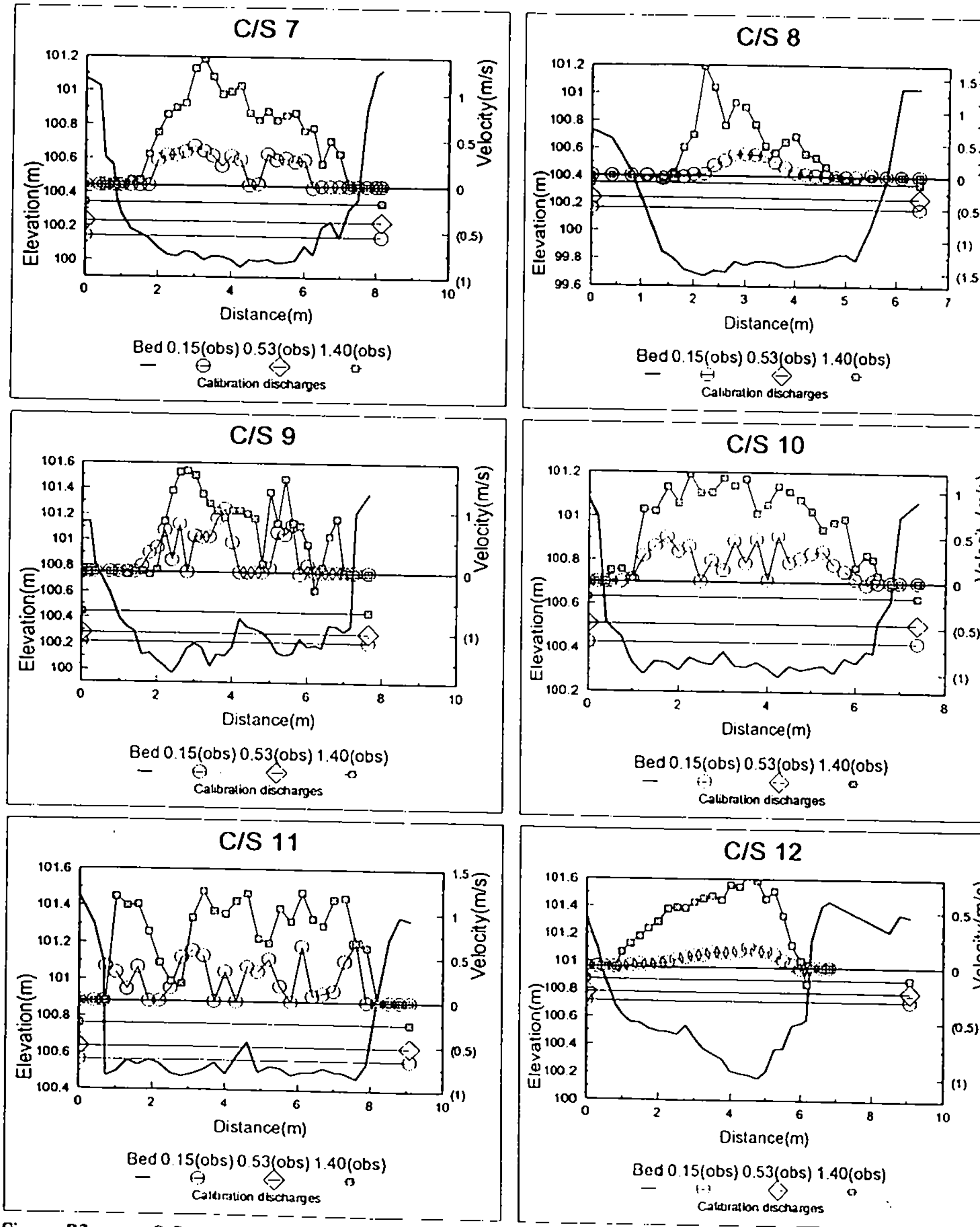


Figure B2 *R.Bray: Hydraulic calibration data C/S 7-12*

Appendix C
River Barle at Perry Weir: PHABSIM hydraulic calibration data summary

RIVER BARLE AT PERRY WEIR

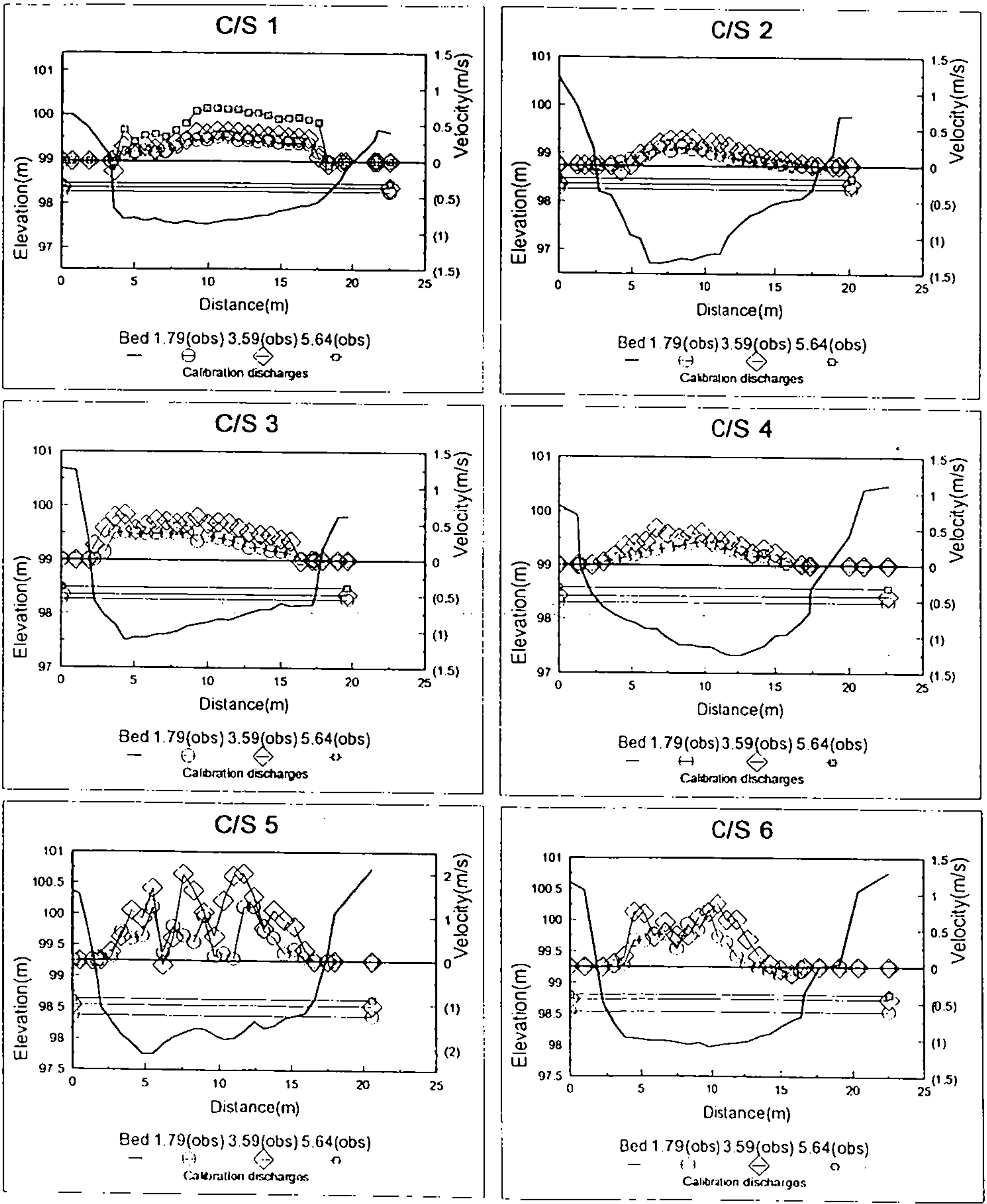


Figure C1 *R.Barle: Hydraulic calibration data C/S 1-6*

RIVER BARLE AT PERRY WEIR

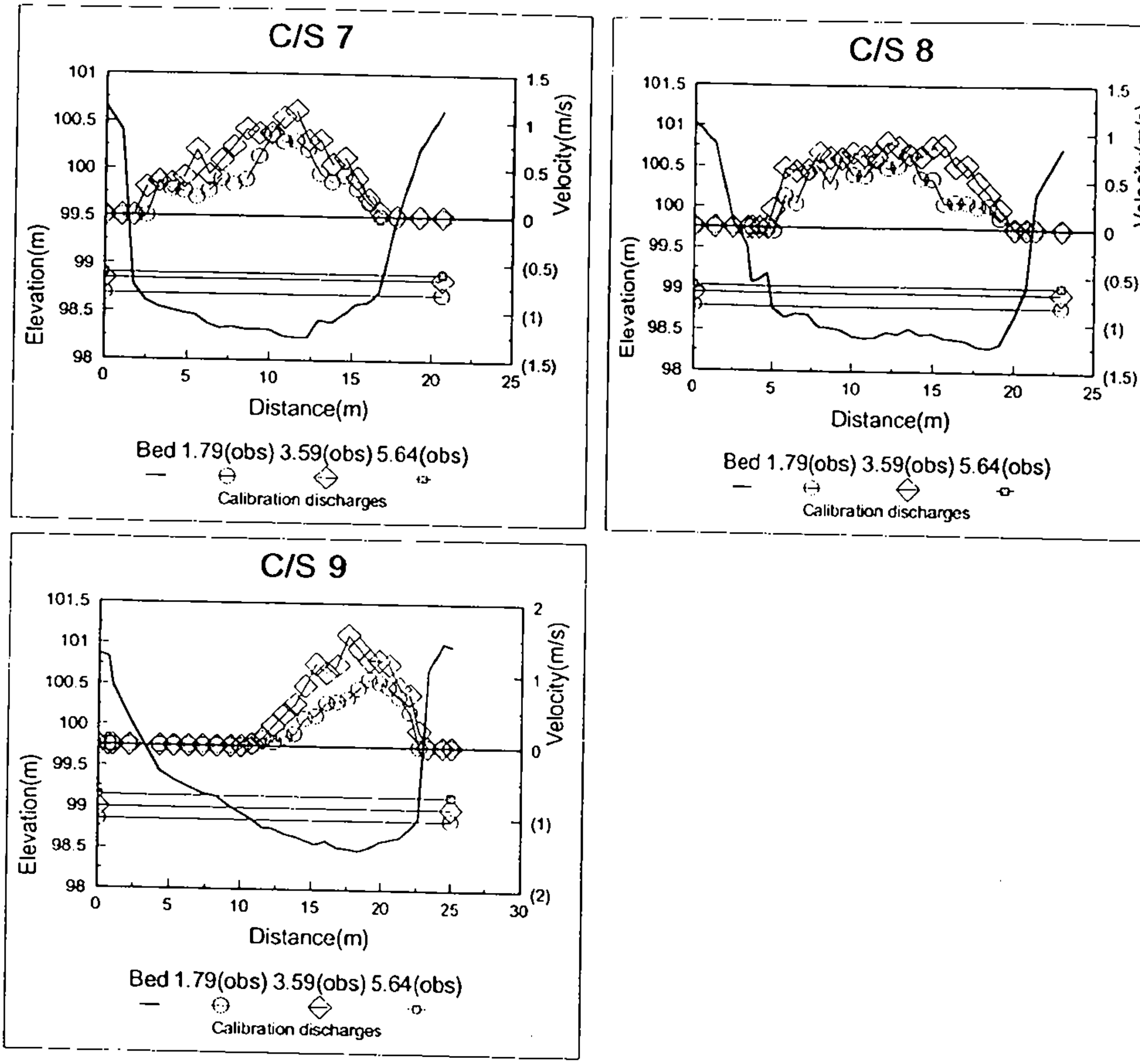


Figure C2 *R.Barle: Hydraulic calibration data C/S 7-9*

Appendix D

PHABSIM field survey data: River Bray at Leehamford and River Barle at Perry Weir.

CHANNEL INDEX DATA

Each of the following is estimated for each survey point.

Small objects (<200 mm)		percent	0 to 100
Large objects (>200 mm)		percent	0 to 100
Overhanging vegetation		percent	0 to 100
Instream vegetation		index	0 to 1000
Undercut bank		existance	0 to 1
Substrate size	- major	index	1 to 10
	- minor	index	1 to 10
	- % major	percent	0 to 100
Packing		index	0 to 100

The sustrate size uses the folllowing index:-

plant detritus/organic material		1
mud/soft clay	< / = 0.004mm	2
silt	0.004 - 0.0625mm	3
sand	0.0625 - 2mm	4
gravel	2 - 64mm	5
cobble	64 - 256mm	6
boulder	> 256mm	7
bedrock	> 256mm	8
Terrestrial vegetation	index	9
Built-up bank material	index	10

The substrate index is written in the form X0Y.Z; where X is the index to the most common material, Y is the index to the second most common, and Z is the percent the dominant is of the total surface. If only one substrate type is present then rather than X00.100, it should be recorded as X00.00.

The vegetation index includes the following:-

No instream vegetation	0
Streamer vegetation	1
Reed-type vegetation	2
Floating vegetation	3
Streamer/Reed	4
Streamer/Overhanging	5
Reed/Overhanging	6

The index is written as XYD.Z; where X is the dominant vegetation, Y is the subdominate, D is the total density of vegetation in units of 10 percent (range 0 to 1), and Z is the percentage of the dominate of the total. For example a cell with mostly streamer vegetation (60 percent of total) and the rest overhanging instream vegetation which covers 30 percent of the stream bed area has the values X=1, Y=3, D=3, and Z=60 for an index of 133.60. If there is only one type present then rather than X0D.100, it should be recorded as X0D.00.

R. BRAY: HYDRAULIC CALIBRATION DATA							
C/S 1							
WSL at 0.15 cumecs =		99.745					
WSL at 0.53 cumecs =		99.843					
WSL at 1.40 cumecs =		99.915					
		0.15 cumecs		0.53 cumecs		1.40 cumecs	
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)
0	100	0	0	0	0	0	0.000
1	99.984	0	0	0	0	0	0.000
1.5	99.948	0	0	0	0	0	0.000
2	99.947	0	0	0	0	0	0.000
2.5	99.904	0	0	0	0	0	0.000
3	99.929	0	0	0	0	0	0.000
4	100.026	0	0	0	0	0	0.000
4.4	99.803	0	0	7	0.16	15	0.423
4.8	99.721	2	0	12	0.343	21	0.676
5.2	99.708	5	0.014	15	0.424	24	0.604
5.6	99.679	5	0.058	15	0.324	26	0.920
6	99.686	6	0.311	19	0.604	26	0.971
6.4	99.65	3	0.193	20	0.56	30	1.044
6.8	99.603	10	0.369	25	0.646	33	0.900
7.2	99.562	15	0.356	26	0.556	34	0.640
7.6	99.568	19	0.212	25	0.473	38	0.874
8	99.565	12	0.29	28	0.435	34	0.734
8.4	99.79	0	0	28	0.09	37	0.605
8.8	99.649	14	0.335	20	0.488	33	0.448
9.2	99.676	8	0.073	20	0.457	26	0.791
9.6	99.739	2	0	10	0.42	30	0.732
10	99.609	17	0.119	15	0.366	25	0.705
10.4	99.666	10	0.082	16	0.35	25	0.641
10.8	99.658	13	0.123	17	0.276	36	0.536
11.2	99.492	7	0.084	14	0.178	35	0.082
11.6	99.851	0	0	0	0	20	0.186
12	99.619	15	-0.006	15	0.06	27	0.165
12.4	99.676	9	0.009	17	0.014	24	0.054
12.8	99.693	6	0.008	14	0.013	24	0.043
13	99.748	2	0	13	0.013	4	0.000
13.4	100.094	0	0	0	0	0	0.000
13.9	100.161	0	0	0	0	0	0.000
14.35	100.186	0	0	0	0	0	0.000

C/S 2							
WSL at 0.15 cumecs =		99.785					
WSL at 0.53 cumecs =		99.888					
WSL at 1.40 cumecs =		99.972					
		0.15 cumecs		0.53 cumecs		1.40 cumecs	
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)
0	100.717	0	0	0	0	0	0.000
0.8	100.73	0	0	0	0	0	0.000
1	100.18	0	0	0	0	0	0.000
1.3	100.132	0	0	0	0	0	0.000
1.5	99.742	1	0	0	0	23	0.128
1.9	99.673	9	0.113	20	0.096	23	0.560
2.3	99.67	15	0.268	20	0.447	34	0.693
2.7	99.626	15	0.205	26	0.4	43	0.999
3.1	99.566	21	0.052	29	0.434	47	0.718
3.5	99.577	21	0.114	31	0.351	45	0.793
3.9	99.569	21	0.308	24	0.501	45	0.818
4.3	99.594	20	0.238	30	0.533	43	0.787
4.7	99.613	14	0.329	29	0.499	40	0.884
5.1	99.535	23	0.164	36	0.47	45	0.536
5.5	99.56	21	0.163	32	0.373	45	0.482
5.9	99.625	20	0.047	28	0.263	40	0.162
6.3	99.698	10	-0.005	18	0.186	30	0.150
6.7	99.825	2	0	6	0.015	18	0.038
7	99.916	0	0	0	-0.003	5	0.000
7.4	100.153	0	0	0	0	0	0.000
8.1	100.838	0	0	0	0	0	0.000
9.68	101.304	0	0	0	0	0	0.000

C/S 3					
WSL at 0.15 cumecs =		99.795			
WSL at 0.53 cumecs =		99.897			
WSL at 1.40 cumecs =		100.037			
		0.15 cumecs		1.40 cumecs	
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)
0	100.626	0	0	0	0.000
0.7	100.376	0	0	0	0.000
0.8	99.903	0	0	0	0.000
1.1	99.816	0	0	10	0.066
1.5	99.691	10	0.08	28	0.424
1.7	99.687	11	0.184	35	0.641
1.9	99.663	12	0.33	35	0.693
2.1	99.658	16	0.394	36	0.817
2.3	99.623	16	0.026	35	0.946
2.5	99.603	16	0.347	41	1.021
2.7	99.597	21	0.355	46	1.057
2.9	99.566	21	0.14	50	0.842
3.1	99.542	20	0.423	46	0.867
3.3	99.54	20	0.372	42	1.043
3.5	99.573	20	-0.043	32	1.163
3.7	99.562	20	0.013	37	0.998
3.9	99.56	15	0.174	42	0.851
4.1	99.539	15	0.209	41	0.702
4.3	99.502	24	0.16	45	0.602
4.5	99.602	26	0.14	40	0.393
4.7	99.536	26	0.07	40	0.318
4.9	99.53	27	0.024	45	0.330
5.1	99.533	27	0.028	40	0.420
5.3	99.55	22	0.03	45	0.367
5.5	99.552	18	0.027	45	0.111
5.7	99.602	19	0.035	27	-0.004
5.9	99.733	1	0	15	-0.112
6.5	100.16	0	0	0	0.000
7.4	100.522	0	0	0	0.000
8.4	100.872	0	0	0	0.000

C/S 4					
WSL at 0.15 cumecs =		99.839			
WSL at 0.53 cumecs =		99.922			
WSL at 1.40 cumecs =		100.06			
		0.15 cumecs		1.40 cumecs	
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)
0	100.816	0	0	0	0.000
1	100.6	0	0	0	0.000
1.2	99.875	0	0	0	0.000
1.45	99.868	0	0	9	0.000
1.7	99.743	3	0	34	0.122
2.05	99.691	12	0.39	35	0.940
2.3	99.704	12	0.7	40	0.818
2.55	99.68	13	0.41	40	0.762
2.8	99.703	11	0.45	40	1.120
3.05	99.727	13	1.09	40	0.852
3.3	99.72	9	1	35	0.809
3.55	99.699	13	1.01	35	0.856
3.8	99.735	10	0.96	35	0.515
4.05	99.734	10	0.45	30	0.872
4.3	99.74	8	0.186	30	1.266
4.55	99.848	4	0.103	28	1.470
4.8	99.809	2	0.124	25	1.413
5.05	99.843	2	0.347	29	1.425
5.3	99.769	4	0.186	31	0.616
5.55	99.818	4	0.205	30	1.426
5.8	99.847	4	0.01	27	0.508
6.05	99.803	5	0.242	25	0.248
6.3	99.793	0	0	20	1.170
6.55	99.823	2	0.03	20	0.479
6.8	99.958	2	0.103	5	0.000
7.3	99.984	0	0	0	0.000
7.55	100.249	0	0	0	0.000
8.1	101.296	0	0	0	0.000
8.7	101.498	0	0	0	0.000

C/S 5							
WSL at 0.15 cumecs =		100.028					
WSL at 0.53 cumecs =		100.098					
WSL at 1.40 cumecs =		100.232					
		0.15 cumecs		1.40 cumecs			
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)		
0	100.934	0	0	0	0.000		
0.85	100.738	0	0	0	0.000		
1.1	99.925	16	0.088	30	0.667		
1.25	99.945	7	0.13	30	0.679		
1.5	99.956	7	0.159	25	0.609		
1.75	99.985	3	0.051	25	0.626		
2	99.933	8	0.606	27	0.689		
2.25	100.047	6	0.431	27	0.940		
2.5	99.956	6	0.31	30	1.049		
2.75	99.93	10	0.191	30	1.093		
3	99.962	9	0.048	29	1.135		
3.25	99.985	6	0.557	27	1.111		
3.5	99.93	6	0.457	29	0.884		
3.75	99.936	9	0.426	29	0.867		
4	99.978	7	0.306	26	0.811		
4.25	99.943	10	0.221	27	0.794		
4.5	99.918	12	0.43	32	0.763		
4.75	99.923	14	0.238	33	1.011		
5	99.883	14	0.136	30	0.908		
5.25	99.862	16	0.132	21	0.823		
5.5	99.895	14	0.348	34	0.659		
5.75	99.893	13	0.349	32	0.849		
6	99.968	12	0.247	29	0.651		
6.25	99.94	10	0.14	28	0.508		
6.5	99.932	10	0.042	27	0.537		
6.75	99.967	1	0	25	0.259		
7	100.02	3	0.031	20	0.087		
7.25	100.054	1	0	15	0.000		
7.5	100.091	0	0	10	0.012		
7.75	100.15	0	0	0	0.000		
8	100.191	0	0	0	0.000		
8.25	101.318	0	0	0	0.000		
8.34	101.248	0	0	0	0.000		

C/S 6							
WSL at 0.15 cumecs =		100.086					
WSL at 0.53 cumecs =		100.162					
WSL at 1.40 cumecs =		100.271					
		0.15 cumecs		1.40 cumecs			
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)		
0	100.589	0	0	0	0.000		
0.4	100.568	0	0	0	0.000		
0.6	100.336	0	0	0	0.000		
0.8	100.025	5	0.023	25	0.291		
1	99.988	7	0.024	30	0.570		
1.25	100.059	2	0.068	25	0.589		
1.5	99.928	15	0.106	35	0.518		
1.75	99.988	10	0.109	35	0.415		
2	99.952	13	0.133	40	0.438		
2.25	99.941	13	0.148	38	0.581		
2.5	99.92	16	0.154	40	0.762		
2.75	99.904	16	0.154	40	0.919		
3	99.913	20	0.364	37	1.049		
3.25	99.93	20	0.066	38	1.072		
3.5	99.956	13	-0.042	25	1.107		
3.75	100.036	14	-0.006	27	1.216		
4	99.838	25	0.25	35	0.907		
4.25	99.794	28	0.334	57	0.960		
4.5	99.795	28	0.173	52	0.788		
4.75	99.81	25	0.158	50	0.759		
5	99.796	30	0.165	52	0.892		
5.25	99.777	30	0.058	52	0.646		
5.5	99.831	27	0.032	46	0.325		
5.75	99.904	17	0.021	37	0.189		
6	99.976	10	0.005	27	0.014		
6.25	100.04	0	0	22	-0.068		
6.5	100.169	0	0	10	0.000		
6.73	100.171	0	0	0	0.000		
6.85	100.779	0	0	0	0.000		
7.04	100.707	0	0	0	0.000		

C/S 7					
WSL at 0.15 cumecs =		100.14			
WSL at 0.53 cumecs =		100.229			
WSL at 1.40 cumecs =		100.341			
		0.15 cumecs		1.40 cumecs	
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)
0	101.072	0	0	0	0.000
0.4	101.024	0	0	0	0.000
0.55	100.611	0	0	0	0.000
0.77	100.565	0	0	0	0.000
0.87	100.362	0	0	1	0.000
1	100.27	0	0	5	0.000
1.25	100.183	0	0	17	0.060
1.5	100.157	0	0	20	0.058
1.75	100.127	2	0	28	0.340
2	100.073	7	0.275	27	0.575
2.25	100.034	11	0.331	32	0.776
2.5	100.023	9	0.332	25	0.847
2.75	100.053	9	0.37	37	0.899
3	100.045	10	0.43	40	1.276
3.25	100.002	13	0.376	37	1.378
3.5	100.027	13	0.324	35	1.188
3.75	100.023	13	0.214	31	0.993
4	100.006	11	0.326	37	1.026
4.25	99.962	16	0.287	40	1.088
4.5	100.006	15	0.006	38	0.793
4.75	99.998	15	0.021	37	0.718
5	100.008	15	0.352	39	0.814
5.25	99.987	15	0.287	37	0.715
5.5	99.991	15	0.305	38	0.768
5.75	100.003	15	0.264	30	0.800
6	100.091	9	0.286	26	0.605
6.25	100.038	12	-0.02	25	0.638
6.5	100.198	0	0	30	0.247
6.75	100.234	0	0	13	0.498
7	100.137	0	0	10	0.358
7.25	100.306	0	0	4	0.000
7.5	100.365	0	0	0	0.000
7.75	100.902	0	0	0	0.000
8	101.102	0	0	0	0.000
8.15	101.13	0	0	0	0.000

C/S 8					
WSL at 0.15 cumecs =		100.164			
WSL at 0.53 cumecs =		100.239			
WSL at 1.40 cumecs =		100.347			
		0.15 cumecs		1.40 cumecs	
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)
0	100.73	0	0	0	0.000
0.4	100.665	0	0	0	0.000
0.8	100.432	0	0	0	0.000
1.1	100.14	10	0	20	-0.039
1.4	99.845	25	-0.05	45	-0.030
1.6	99.798	25	-0.002	55	0.014
1.8	99.718	40	-0.018	60	0.438
2	99.698	40	0.023	60	0.627
2.2	99.673	47	0.025	68	1.687
2.4	99.714	45	0.16	70	1.363
2.6	99.7	45	0.234	70	0.767
2.8	99.779	38	0.326	60	1.122
3	99.751	34	0.338	58	1.054
3.2	99.778	37	0.324	60	0.789
3.4	99.78	36	0.31	60	0.467
3.6	99.771	36	0.218	63	0.356
3.8	99.742	38	0.135	67	0.525
4	99.743	39	0.05	67	0.608
4.2	99.758	40	0.026	66	0.347
4.4	99.773	38	0.016	66	0.290
4.6	99.791	35	0.005	60	0.148
4.8	99.829	34	-0.005	57	-0.002
5	99.834	30	-0.005	50	-0.026
5.2	99.793	33	0.004	55	-0.035
5.5	100.042	3	0.027	10	0.000
5.8	100.368	0	0	3	0.000
6.1	101.04	0	0	0	0.000
6.45	101.037	0	0	0	0.000

C/S 9					
WSL at 0.15 cumecs =		100.211			
WSL at 0.53 cumecs =		100.281			
WSL at 1.40 cumecs =		100.444			
		0.15 cumecs		1.40 cumecs	
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)
0	101.135	0	0	0	0.000
0.2	101.144	0	0	0	0.000
0.35	100.814	0	0	0	0.000
0.75	100.596	0	0	0	0.000
1	100.39	0	0	4	0.000
1.2	100.324	0	0	7	-0.026
1.4	100.293	0	0	12	0.007
1.6	100.112	6	0.101	18	0.014
1.8	100.126	6	0.321	20	-0.036
2	100.07	9	0.403	32	0.045
2.2	100.026	9	0.691	38	0.838
2.4	99.97	10	0.203	37	1.342
2.6	100.048	7	0.791	39	1.650
2.8	100.161	1	0	29	1.669
3	100.199	6	0.602	32	1.597
3.2	100.167	5	0.576	37	1.286
3.4	100.025	16	0.583	40	1.136
3.6	100.12	12	0.89	45	1.015
3.8	100.104	10	1.051	44	0.908
4	100.171	13	0.499	40	1.019
4.2	100.393	0	0	39	1.021
4.4	100.33	0	0	25	0.972
4.6	100.315	0	0	28	0.888
4.8	100.295	0	0	17	0.147
5	100.23	7	0.082	30	1.321
5.2	100.132	6	0.666	35	0.809
5.4	100.114	6	0.629	34	1.540
5.6	100.129	3	0.784	30	0.814
5.8	100.24	7	-0.028	20	0.769
6	100.179	1	0.125	21	0.470
6.2	100.191	0	0	20	-0.285
6.4	100.171	0	0	23	0.096
6.6	100.346	0	0	9	0.605
6.8	100.34	0	0	11	0.890
7	100.297	0	0	10	0.000
7.17	100.341	0	0	0	0.000
7.3	101.217	0	0	0	0.000
7.65	101.368	0	0	0	0.000

C/S 10							
WSL at 0.15 cumecs =		100.424					
WSL at 0.53 cumecs =		100.508					
WSL at 1.40 cumecs =		100.63					
		0.15 cumecs		1.40 cumecs			
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)		
0	101.082	0	0	0	0.000		
0.2	100.997	0	0	0	0.000		
0.4	100.516	0	0	0	0.000		
0.5	100.492	0	0	17	0.129		
0.75	100.451	0	0	17	0.135		
1	100.334	9	0.029	30	0.036		
1.25	100.28	13	0.284	31	0.797		
1.5	100.341	10	0.391	32	0.776		
1.75	100.332	7	0.492	37	1.040		
2	100.3	11	0.333	34	0.867		
2.25	100.356	9	0.391	31	1.182		
2.5	100.337	9	0.005	32	0.980		
2.75	100.323	7	0.235	33	0.982		
3	100.383	1	0.13	35	1.138		
3.25	100.32	11	0.448	33	1.056		
3.5	100.314	12	0.207	33	1.128		
3.75	100.336	10	0.467	34	0.752		
4	100.307	13	0.022	36	0.851		
4.25	100.27	15	0.509	40	1.052		
4.5	100.319	8	0.216	33	0.995		
4.75	100.302	11	0.265	34	0.906		
5	100.312	11	0.32	33	0.780		
5.2	100.321	9	0.343	32	0.583		
5.5	100.29	9	0.198	30	0.662		
5.75	100.357	10	0.126	35	0.701		
6	100.333	9	0.035	32	0.168		
6.25	100.388	4	-0.026	25	0.308		
6.4	100.38	6	0.026	25	0.262		
6.5	100.52	0	0	8	0.083		
6.8	100.615	0	0	0	0.000		
7	101.003	0	0	0	0.000		
7.4	101.072	0	0	0	0.000		

C/S 11					
WSL at 0.15 cumecs =		100.563			
WSL at 0.53 cumecs =		100.634			
WSL at 1.40 cumecs =		100.76			
		0.15 cumecs		1.40 cumecs	
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)
0	101.455	0	0	0	0.000
0.4	101.302	0	0	0	0.000
0.67	101.093	0	0	0	0.000
0.72	100.474	11	0.392	0	0.000
1	100.498	6	0.326	28	1.184
1.3	100.56	1	0.136	25	1.080
1.6	100.536	2	0.386	25	1.094
1.9	100.564	0	0	21	0.788
2.2	100.543	1	0.003	16	0.440
2.5	100.49	8	0.151	19	0.229
2.8	100.475	9	0.5	26	0.203
3.1	100.49	8	0.574	27	0.946
3.4	100.512	6	0.518	27	1.248
3.7	100.55	0	0	23	1.023
4	100.49	8	0.34	31	0.993
4.3	100.582	1	0	19	1.139
4.6	100.663	2	0.398	24	1.225
4.9	100.498	7	0.339	25	0.718
5.2	100.53	8	0.483	25	0.666
5.5	100.523	6	0.177	24	1.060
5.8	100.484	8	-0.002	27	0.910
6.1	100.501	7	0.632	24	1.236
6.4	100.501	6	0.068	18	0.942
6.7	100.524	6	0.099	19	0.867
7	100.503	8	0.129	24	1.160
7.3	100.497	7	0.469	24	1.183
7.6	100.466	11	0.67	25	0.674
7.9	100.547	0	0	12	0.621
8.2	100.918	0	0	0	0.000
8.5	101.224	0	0	0	0.000
8.8	101.346	0	0	0	0.000
9.08	101.326	0	0	0	0.000

C/S 12							
WSL at 0.15 cumecs =		100.713					
WSL at 0.53 cumecs =		100.779					
WSL at 1.40 cumecs =		100.872					
		0.15 cumecs		1.40 cumecs			
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)		
0	101.32	0	0	0	0.000		
0.3	101.097	0	0	0	0.000		
0.5	100.894	0	0	0	0.000		
0.8	100.69	0	0	3	0.000		
1	100.615	7	0	24	0.139		
1.25	100.564	12	0.012	29	0.212		
1.5	100.558	16	0.029	34	0.278		
1.75	100.518	17	0.017	35	0.352		
2	100.496	20	0.032	40	0.407		
2.25	100.492	20	0.041	40	0.529		
2.5	100.474	25	0.071	42	0.541		
2.75	100.54	16	0.09	43	0.535		
3	100.449	25	0.106	47	0.590		
3.25	100.377	30	0.111	46	0.620		
3.5	100.336	36	0.134	55	0.641		
3.75	100.3	40	0.137	60	0.610		
4	100.212	47	0.133	60	0.743		
4.25	100.194	51	0.153	70	0.730		
4.5	100.187	49	0.183	69	0.839		
4.75	100.159	52	0.142	75	0.784		
5	100.211	55	0.147	74	0.622		
5.25	100.37	35	0.119	50	0.691		
5.5	100.38	34	0.068	54	0.470		
5.75	100.54	26	0.03	54	0.203		
6	100.559	29	-0.014	45	0.064		
6.17	100.586	12	-0.002	30	-0.150		
6.3	101.156	0	0	0	0.000		
6.6	101.409	0	0	0	0.000		
6.8	101.438	0	0	0	0.000		

R. BRAY: CHANNEL INDEX DATA

C/S 1

Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	0	0	0	309.8	70
1	0	0	0	0	0	309.8	70
1.5	0	0	0	0	0	309.8	70
2	0	0	0	0	0	309.8	70
2.5	0	0	0	0	0	309.8	70
3	0	0	0	0	0	309.8	70
4	0	0	0	0	0	309.8	70
4.4	0	0	0	0	0	309.8	70
4.8	10	0	0	0	0	506.8	80
5.2	20	10	0	0	0	605.6	80
5.6	20	10	0	0	0	605.6	80
6	20	10	0	0	0	607.7	80
6.4	30	30	0	0	0	706.7	90
6.8	10	10	0	0	0	607.6	80
7.2	10	0	0	0	0	605.7	80
7.6	10	30	0	0	0	706.6	80
8	10	40	0	0	0	706.8	90
8.4	10	40	0	0	0	705.7	90
8.8	20	50	0	0	0	705.8	90
9.2	20	50	0	0	0	706.8	90
9.6	10	30	0	0	0	706.9	10
10	10	30	0	0	0	706.9	10
10.4	10	30	0	0	0	706.9	10
10.8	10	30	0	0	0	706.9	10
11.2	10	30	0	0	0	706.9	10
11.6	10	30	0	0	0	706.9	10
12	10	30	0	0	0	706.9	10
12.4	10	30	0	0	0	706.9	10
12.8	10	20	0	0	0	703.6	70
13	0	0	0	0	0	309.8	70
13.4	0	0	0	0	0	309.8	70
13.9	0	0	0	0	0	309.8	70
14.35	0	0	0	0	0	309.8	70

C/S 2

Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	0	0	0	309.6	80
0.8	0	0	0	0	0	903.6	80
1	20	30	0	0	1	307.6	60
1.3	20	40	0	0	0	706.6	90
1.5	30	40	0	0	0	705.7	90
1.9	20	10	0	0	0	506.6	70
2.3	20	0	0	0	0	605.7	70
2.7	20	0	0	0	0	605.7	70
3.1	20	0	0	0	0	605.7	70
3.5	30	20	0	0	0	607.7	80
3.9	20	40	0	0	0	706.8	90
4.3	20	20	0	0	0	607.6	80
4.7	20	20	0	0	0	607.6	70
5.1	30	10	0	0	0	506.6	70
5.5	30	10	0	0	0	506.6	70
5.9	40	10	0	0	0	605.6	60
6.3	50	10	0	503	0	607.8	50
6.7	30	20	0	0	0	706.6	80
7	10	0	0	0	0	903.7	60
7.4	10	0	0	0	0	903.7	60
8.1	10	0	0	0	0	903.7	70
9.68	0	10	0	0	0	903.6	80

C/S 3							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	10	0	0	309.8	70
0.7	0	0	10	0	0	309.8	70
0.8	0	0	10	0	0	309.8	70
1.1	10	20	10	0	0	603.7	70
1.5	10	20	20	0	0	605.6	80
1.7	10	20	0	0	0	607.7	80
1.9	10	20	10	0	0	605.6	80
2.1	10	20	0	0	0	605.6	80
2.3	10	20	10	0	0	605.6	80
2.5	10	20	0	0	0	605.6	80
2.7	10	20	10	0	0	605.6	80
2.9	20	20	0	0	0	607.7	80
3.1	10	20	0	0	0	607.6	80
3.3	10	30	0	0	0	706.6	90
3.5	0	50	0	0	0	705.7	10
3.7	0	50	0	0	0	705.7	10
3.9	20	30	0	0	0	607.6	80
4.1	20	0	0	0	0	605.7	80
4.3	10	0	0	0	0	506.6	70
4.5	0	0	0	0	0	506.7	70
4.7	0	0	0	0	0	506.7	70
4.9	0	0	0	0	0	506.7	70
5.1	20	0	0	0	0	605.7	70
5.3	20	20	0	0	0	605.8	80
5.5	20	20	0	0	0	605.8	80
5.7	20	40	0	0	0	806.6	10
5.9	20	40	0	0	0	806.6	10
6.5	20	30	0	0	0	706.6	80
7.4	10	30	0	0	0	705.7	70
8.4	20	20	0	0	0	305.6	70

C/S 4							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	0	0	0	903.8	80
1	0	0	0	0	0	903.8	80
1.2	10	30	10	0	1	305.6	70
1.45	20	30	0	501	0	506.7	70
1.7	20	20	0	503	0	605.7	60
2.05	20	20	0	0	0	706.6	70
2.3	20	20	0	0	0	706.6	70
2.55	20	20	0	0	0	706.6	70
2.8	30	20	0	0	0	706.7	60
3.05	30	20	0	0	0	706.7	60
3.3	30	20	0	0	0	605.8	50
3.55	30	10	0	0	0	605.8	50
3.8	20	40	0	0	0	706.6	60
4.05	30	20	0	0	0	706.7	60
4.3	30	20	0	0	0	706.7	60
4.55	20	30	0	0	0	607.6	60
4.8	20	30	0	0	0	607.6	60
5.05	20	40	0	0	0	706.6	60
5.3	20	40	0	0	0	501	60
5.55	20	50	10	0	0	706	60
5.8	20	50	10	0	0	706	60
6.05	20	50	10	0	0	706	60
6.3	30	20	10	501	0	705.6	60
6.55	30	20	10	501	0	705.6	60
6.8	30	30	10	501	0	706.6	90
7.3	20	20	10	0	0	305.6	70
7.55	10	20	10	0	0	903.8	50
8.1	10	20	10	0	0	309.6	70
8.7	0	10	0	0	0	309.7	70

C/S 5							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	0	0	0	309.8	80
0.85	0	0	0	0	0	309.8	80
1.1	10	0	0	0	1	605.7	70
1.25	10	0	0	0	1	605.7	70
1.5	20	0	0	0	0	605.8	80
1.75	20	20	0	0	0	605.9	70
2	20	20	0	0	0	605.9	70
2.25	20	20	0	0	0	605.9	70
2.5	20	20	0	0	0	605.9	70
2.75	20	0	0	0	0	605.8	80
3	20	0	0	0	0	605.8	80
3.25	20	0	0	0	0	605.8	80
3.5	20	0	0	0	0	605.8	80
3.75	20	0	0	0	0	605.8	80
4	20	0	0	0	0	605.8	80
4.25	20	0	0	0	0	605.8	80
4.5	20	0	0	0	0	605.8	80
4.75	20	0	0	0	0	605.8	80
5	20	0	0	0	0	605.8	80
5.25	20	0	0	0	0	605.8	80
5.5	20	0	0	0	0	605.8	80
5.75	20	0	0	0	0	605.6	60
6	20	0	0	0	0	605.6	60
6.25	20	0	0	0	0	605.6	60
6.5	20	0	0	0	0	605.6	60
6.75	30	20	0	0	0	506.6	70
7	10	0	0	0	0	506.7	70
7.25	20	0	0	0	0	605.7	90
7.5	20	0	0	0	0	506.8	80
7.75	0	0	0	0	1	504.8	80
8	0	0	0	0	1	504.8	80
8.25	0	0	0	0	0	309.8	80
8.34	0	0	0	0	0	309.8	80

C/S 6							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	0	0	0	903.7	70
0.4	0	0	0	0	0	903.7	70
0.6	0	10	0	0	1	309.7	60
0.8	10	20	0	0	1	309.8	60
1	80	10	0	0	0	605.9	60
1.25	50	10	0	0	0	605.7	60
1.5	50	20	0	0	0	604.6	50
1.75	30	10	0	0	0	506.7	60
2	0	10	0	0	0	504.6	40
2.25	0	10	0	0	0	504.6	40
2.5	30	20	0	0	0	605.6	60
2.75	60	20	0	0	0	605.8	70
3	60	20	0	0	0	605.8	70
3.25	50	20	0	0	0	607.7	70
3.5	50	20	0	0	0	607.7	70
3.75	30	30	0	0	0	705.6	70
4	60	20	0	0	0	605.7	70
4.25	60	20	0	0	0	605.7	70
4.5	50	10	0	0	0	607.8	80
4.75	50	10	0	0	0	607.8	80
5	20	10	0	0	0	705.6	80
5.25	20	10	0	0	0	705.6	80
5.5	10	10	0	0	0	406.7	50
5.75	0	10	0	0	0	407.8	50
6	0	10	10	0	0	405.8	50
6.25	0	10	10	0	0	405.8	50
6.5	0	30	10	0	1	704.7	60
6.73	0	0	10	0	1	309.6	80
6.85	0	0	10	0	1	309.6	80
7.04	0	0	10	0	0	309.6	80

C/S 7							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	0	0	0	309.8	80
0.4	0	0	0	0	0	309.8	80
0.55	0	0	0	0	0	309.8	80
0.77	0	0	0	0	0	309.8	80
0.87	0	0	0	0	0	309.8	80
1	0	0	0	0	0	305.8	70
1.25	0	0	0	0	0	305.8	70
1.5	0	0	0	0	0	503.8	70
1.75	20	0	0	0	0	506.8	60
2	20	20	0	0	0	605.8	70
2.25	20	20	0	0	0	605.8	70
2.5	20	20	0	0	0	605.9	70
2.75	20	0	0	0	0	605.9	80
3	20	0	0	0	0	605.7	70
3.25	20	0	0	0	0	605.7	70
3.5	20	0	0	0	0	605.7	70
3.75	20	0	0	0	0	605.7	70
4	30	10	0	0	0	605.6	70
4.25	10	30	0	0	0	507.6	80
4.5	10	30	0	0	0	507.6	80
4.75	10	30	0	0	0	507.6	80
5	10	0	0	0	0	605.6	80
5.25	0	0	0	0	0	506.6	70
5.5	0	0	0	0	0	506.6	70
5.75	0	20	0	0	0	706.6	80
6	10	30	0	0	0	705.8	90
6.25	0	40	0	0	0	705.6	80
6.5	0	60	0	0	0	705.9	10
6.75	0	60	0	0	0	705.9	10
7	0	60	0	0	0	705.9	10
7.25	0	0	0	0	0	301.8	90
7.5	0	0	0	0	0	309.8	80
7.75	0	0	0	0	0	309.8	80
8	0	0	0	0	0	309.8	80
8.15	0	0	0	0	0	309.8	80

C/S 8							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	0	0	0	903.8	80
0.4	0	0	0	0	0	903.8	80
0.8	0	0	0	0	0	903.8	80
1.1	10	10	10	502	0	905.8	90
1.4	10	80	20	0	0	703.8	70
1.6	10	80	20	0	0	703.8	70
1.8	30	70	10	0	0	703.8	80
2	40	30	0	0	0	706.6	70
2.2	40	30	0	0	0	706.6	70
2.4	10	60	0	0	0	706.6	70
2.6	10	60	0	0	0	706.6	70
2.8	10	60	0	0	0	706.6	70
3	20	40	0	0	0	706.6	70
3.2	20	40	0	0	0	705.7	60
3.4	20	30	0	0	0	705.7	60
3.6	20	30	0	0	0	507.6	60
3.8	0	10	0	0	0	507.6	60
4	0	10	0	0	0	507.7	60
4.2	0	10	0	0	0	507.7	60
4.4	0	10	0	0	0	504.7	50
4.6	0	10	0	0	0	504.7	50
4.8	0	10	0	0	0	504.7	50
5	20	20	0	0	0	504.7	50
5.2	0	60	0	0	0	504.7	60
5.5	20	40	0	0	0	904.8	80
5.8	20	20	0	0	0	903.8	80
6.1	20	20	0	0	1	900	80
6.45	0	0	0	0	0	900	80
	0	0	0	0	0	103.8	60

C/S 9							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	0	0	0	309.8	80
0.2	0	0	0	0	0	309.8	80
0.35	0	0	0	0	0	309.8	80
0.75	0	0	0	0	0	309.8	80
1	20	0	0	0	0	603.7	90
1.2	20	0	0	0	0	603.7	90
1.4	30	0	0	0	0	605.8	80
1.6	40	20	0	0	0	605.7	80
1.8	40	20	0	0	0	605.7	80
2	20	10	0	0	0	600	70
2.2	20	20	0	0	0	605.8	70
2.4	20	0	0	0	0	605.6	70
2.6	20	30	0	0	0	605.7	70
2.8	20	50	0	0	0	706.7	80
3	20	60	0	0	0	706.9	90
3.2	0	50	0	0	0	700	60
3.4	30	30	0	0	0	607.7	90
3.6	20	20	0	0	0	600	70
3.8	20	30	0	0	0	607.6	70
4	20	40	0	0	0	706.6	10
4.2	0	80	0	0	0	700	10
4.4	0	90	0	0	0	700	10
4.6	0	90	0	0	0	700	10
4.8	0	90	0	0	0	700	10
5	20	70	0	0	0	706.8	10
5.2	10	20	0	0	0	706.6	90
5.4	30	40	0	0	0	705.8	10
5.6	20	30	0	0	0	705.6	90
5.8	20	20	0	0	0	506.6	80
6	20	30	0	0	0	506.6	80
6.2	0	40	0	0	0	805.8	10
6.4	0	70	0	0	0	800	10
6.6	0	70	0	0	0	800	10
6.8	0	70	0	0	0	800	10
7	0	70	0	0	0	800	10
7.17	0	20	0	0	1	305.8	80
7.3	0	0	0	0	0	309.8	80
7.65	0	0	0	0	0	309.8	80

C/S 10							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	0	0	0	903.6	70
0.2	0	10	0	0	0	903.6	70
0.4	0	10	0	0	1	105.6	40
0.5	0	10	0	0	0	105.6	40
0.75	0	10	0	501	0	306.6	70
1	10	20	0	501	0	704.6	80
1.25	30	20	0	0	0	605.6	70
1.5	30	20	0	0	0	706.7	60
1.75	30	20	0	0	0	706.7	60
2	30	20	0	0	0	605.8	60
2.25	30	20	0	0	0	605.8	60
2.5	20	40	0	0	0	706.6	60
2.75	20	40	0	0	0	706.6	60
3	30	30	0	0	0	605.6	50
3.25	30	30	0	0	0	605.6	50
3.5	40	20	0	0	0	507.7	70
3.75	40	20	0	0	0	507.7	70
4	20	30	0	0	0	705.7	70
4.25	30	40	0	0	0	605.7	60
4.5	30	40	0	0	0	605.7	60
4.75	30	40	0	0	0	507.6	70
5	30	40	0	0	0	507.6	70
5.2	10	30	0	0	0	506.7	80
5.5	10	30	0	0	0	506.7	80
5.75	10	20	0	501	0	407.6	90
6	10	20	0	0	0	407.6	90
6.25	30	20	0	501.2	0	704.7	50
6.4	10	40	0	501.2	0	703.7	50
6.5	10	10	0	0	0	309.8	60
6.8	0	0	0	0	0	903.8	60
7	0	0	0	0	0	903.8	60
7.4	0	0	0	0	0	903.7	80

C/S 11

Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	0	0	0	309.8	80
0.4	0	0	0	0	0	309.8	80
0.67	0	0	0	0	0	309.8	80
0.72	0	0	0	0	1	605.8	80
1	0	0	0	0	0	605.8	80
1.3	20	0	0	0	0	605.8	80
1.6	20	0	0	0	0	605.8	80
1.9	20	0	0	0	0	605.6	70
2.2	10	0	0	0	0	506.6	70
2.5	20	0	0	0	0	605.7	80
2.8	0	0	0	0	0	605.7	70
3.1	20	0	0	0	0	605.7	70
3.4	20	40	0	0	0	806.8	10
3.7	20	40	0	0	0	806.8	10
4	0	30	0	0	0	605.8	80
4.3	0	30	0	0	0	807.6	10
4.6	30	30	0	0	0	608.6	80
4.9	40	0	0	0	0	605.9	80
5.2	20	30	0	0	0	705.9	10
5.5	20	20	0	0	0	605.6	60
5.8	20	0	0	0	0	605.6	70
6.1	20	0	0	0	0	605.7	80
6.4	20	0	0	0	0	605.7	80
6.7	30	0	0	0	0	506.6	60
7	20	20	0	0	0	605.7	70
7.3	0	0	0	0	0	605.6	70
7.6	0	0	0	0	0	605.7	80
7.9	30	30	0	0	0	105.8	70
8.2	0	0	0	0	0	309.8	80
8.5	0	0	0	0	0	309.8	80
8.8	0	0	0	0	0	309.8	80
9.08	0	0	0	0	0	309.8	80

C/S 12							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	10	20	0	0	0	309.8	70
0.3	10	20	0	0	0	309.8	70
0.5	10	20	0	0	0	309.8	70
0.8	10	10	0	0	0	309.9	70
1	10	0	0	0	0	403.7	50
1.25	0	0	0	0	0	406.8	50
1.5	0	0	0	0	0	406.8	50
1.75	10	0	0	0	0	405.6	60
2	10	10	0	0	0	406.6	50
2.25	10	0	0	0	0	406.6	50
2.5	10	0	0	0	0	406.6	50
2.75	10	0	0	0	0	406.6	50
3	10	0	0	0	0	506.6	60
3.25	10	0	0	0	0	506.6	60
3.5	10	0	0	0	0	506.8	50
3.75	20	10	0	0	0	506.6	70
4	30	20	0	0	0	605.6	70
4.25	30	30	0	0	0	607.6	70
4.5	20	30	0	0	0	704.6	60
4.75	20	30	0	0	0	704.6	60
5	30	20	0	0	0	704.7	90
5.25	30	20	0	0	0	704.7	90
5.5	10	40	0	0	0	704.8	90
5.75	10	40	10	0	0	704.8	90
6	0	50	10	0	1	703.9	10
6.17	10	10	10	0	1	900	80
6.3	0	0	10	0	0	903.8	70
6.6	0	0	10	0	0	903.8	70
6.8	0	0	10	0	0	903.8	70

R. BARLE: HYDRAULIC CALIBRATION DATA							
C/S 1							
WSL at 1.79 cumecs =		98.257					
WSL at 3.59 cumecs =		98.357					
WSL at 5.64 cumecs =		98.448					
		1.79 cumecs		3.59 cumecs		5.64 cumecs	
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)
0	100	0	0	0	0	0	0
0.7	100.009	0	0	0	0	0	0
1.9	99.701	0	0	0	0	0	0
3.4	99.043	0	0	0	0	0	0
3.6	97.89	40	0.046	40	-0.14	50	-0.018
4.3	97.647	50	0.107	56	0.203	67	0.439
5	97.679	64	0.128	61	0.142	76	0.276
5.7	97.611	60	0.15	71	0.215	78	0.362
6.4	97.653	75	0.117	75	0.169	90	0.375
7.1	97.574	70	0.128	75	0.171	92	0.341
7.8	97.536	70	0.192	76	0.265	90	0.435
8.5	97.602	67	0.295	71	0.288	84	0.525
9.2	97.548	67	0.291	74	0.399	84	0.695
9.9	97.524	68	0.294	75	0.377	87	0.731
10.6	97.574	64	0.327	65	0.417	82	0.735
11.3	97.625	55	0.33	65	0.409	80	0.719
12	97.634	60	0.291	65	0.4	78	0.715
12.7	97.666	60	0.285	65	0.366	75	0.673
13.4	97.719	57	0.267	62	0.376	73	0.664
14.1	97.742	50	0.281	55	0.349	65	0.637
14.8	97.832	41	0.257	54	0.369	56	0.584
15.5	97.868	37	0.248	41	0.338	55	0.597
16.2	97.938	31	0.251	35	0.336	51	0.612
16.9	97.959	27	0.237	32	0.317	48	0.581
17.6	98.039	22	0.129	26	0.061	40	0.537
18.3	98.263	0	0	6	-0.04	28	-0.058
19.2	98.554	0	0	0	0	0	0
19.5	98.791	0	0	0	0	0	0
21.5	99.438	0	0	0	0	0	0
21.7	99.678	0	0	0	0	0	0
22.55	99.612	0	0	0	0	0	0

C/S 2							
WSL at 1.79 cumecs =		98.261					
WSL at 3.59 cumecs =		98.367					
WSL at 5.64 cumecs =		98.481					
		1.79 cumecs		5.64 cumecs			
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)		
0	100.821	0	0	0	0		
1.3	100.217	0	0	0	0		
1.8	99.813	0	0	0	0		
2.35	99.339	0	0	0	0		
2.7	98.44	0	0	0	0		
3.5	98.353	0	0	30	0.002		
4.2	97.977	84	0.048	60	-0.078		
4.9	97.533	92	0.092	100	0		
5.6	97.461	99	0.099	107	0.158		
6.3	96.969	135	0.193	157	0.2		
7	96.947	150	0.253	155	0.32		
7.7	96.99	150	0.207	155	0.363		
8.4	97.052	144	0.254	150	0.36		
9.1	97.019	144	0.223	150	0.377		
9.8	97.097	138	0.232	145	0.244		
10.5	97.145	133	0.167	140	0.33		
11.2	97.154	125	0.152	135	0.314		
11.9	97.539	95	0.109	115	0.271		
12.6	97.75	75	0.099	90	0.202		
13.3	97.942	57	0.072	65	0.168		
14	98.034	44	0.048	45	0.123		
14.7	98.165	33	0.037	40	0.092		
15.4	98.235	27	0.019	35	0.075		
16.1	98.276	20	-0.002	25	0.058		
16.8	98.311	17	-0.007	25	0.034		
17.5	98.474	4	0	12	0.011		
17.9	98.854	0	0	0	0		
18.9	99.216	0	0	0	0		
19.3	100.005	0	0	0	0		
20.14	100.017	0	0	0	0		

C/S 3					
WSL at 1.79 cumecs =		98.264			
WSL at 3.59 cumecs =		98.356			
WSL at 5.64 cumecs =		98.487			
		1.79 cumecs		5.64 cumecs	
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)
0	100.949	0	0	0	0
0.98	100.914	0	0	0	0
1.9	99.594	0	0	0	0
2.3	98.487	0	0	8	0.206
3	98.218	20	0.103	40	0.442
3.7	98.059	45	0.375	70	0.601
4.4	97.771	57	0.388	75	0.632
5.1	97.822	70	0.356	75	0.423
5.8	97.813	67	0.363	75	0.482
6.5	97.872	63	0.369	75	0.555
7.2	97.885	67	0.38	74	0.543
7.9	97.936	56	0.352	70	0.508
8.6	98.027	47	0.382	58	0.527
9.3	98.071	43	0.261	55	0.595
10	98.101	39	0.333	50	0.51
10.7	98.162	34	0.308	45	0.526
11.4	98.145	36	0.283	45	0.519
12.1	98.21	26	0.237	36	0.449
12.8	98.276	20	0.174	31	0.387
13.6	98.339	12	0.177	23	0.358
14.3	98.354	13	0.131	20	0.351
15	98.459	8	0.124	17	0.297
15.7	98.407	11	0.091	17	0.266
16.4	98.42	5	0.029	16	-0.014
17.2	98.42	0	0	5	0.005
17.4	98.629	0	0	0	0
17.9	99.47	0	0	0	0
19	100.069	0	0	0	0
19.66	100.073	0	0	0	0

C/S 4					
WSL at 1.79 cumecs =		98.301			
WSL at 3.59 cumecs =		98.421			
WSL at 5.64 cumecs =		98.578			
		1.79 cumecs		5.64 cumecs	
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)
0	100.303	0	0	0	0
1.35	100.112	0	0	0	0
1.5	99.189	0	0	0	0
2.25	98.654	0	0	0	0
3	98.411	10	0.038	15	0.042
3.75	98.275	21	0.076	30	0.133
4.5	98.179	30	0.109	40	0.279
5.25	98.119	38	0.142	50	0.305
6	98.014	50	0.185	59	0.338
6.75	98.022	60	0.216	70	0.518
7.5	97.851	64	0.245	75	0.437
8.25	97.724	70	0.277	85	0.382
9	97.718	78	0.303	85	0.435
9.75	97.679	79	0.328	90	0.463
10.5	97.679	82	0.316	94	0.324
11.25	97.589	90	0.242	105	0.349
12	97.529	94	0.227	105	0.353
12.75	97.535	97	0.175	105	0.278
13.5	97.622	90	0.125	98	0.173
14.25	97.704	50	0.134	62	0.239
15	97.901	56	0.06	60	0.183
15.75	97.913	55	0.025	62	0.074
16.8	98.165	31	0.006	37	0.018
17.3	98.324	15	0	23	0
17.4	98.762	0	0	0	0
20	99.764	0	0	0	0
21	100.609	0	0	0	0
22.66	100.677	0	0	0	0

C/S 5					
WSL at 1.79 cumecs =		98.371			
WSL at 3.59 cumecs =		98.439			
WSL at 5.64 cumecs =		98.631			
		1.79 cumecs		5.64 cumecs	
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)
0	100.252	0	0	0	0
5	100.196	0	0	0	0
1.4	99.321	0	0	0	0
1.75	98.813	0	0	0	0
2	98.38	0	0	0	0
2.7	98.163	10	0.066	18	0.19
3.4	97.948	34	0.656	42	0.536
4.1	97.808	40	0.491	50	1.151
4.8	97.64	55	0.552	60	0.955
5.5	97.642	45	1.223	55	1.662
6.2	97.799	37	0.173	46	-0.105
6.9	97.907	28	0.781	30	0.514
7.6	97.978	28	0.564	36	1.992
8.3	98.043	20	0.424	20	1.609
9	98.049	23	1.014	30	1.106
9.7	97.95	21	0.106	35	0.552
10.3	97.88	27	0.176	35	1.384
11	97.895	33	0.051	25	1.952
11.7	98.006	27	1.232	35	2.006
12.4	98.169	22	1.228	12	1.472
13.1	98.052	14	0.677	5	0.744
13.8	98.106	12	0.528	19	1.166
14.5	98.219	12	0.174	25	0.935
15.2	98.261	12	0.266	20	0.793
15.9	98.302	8	0.078	10	0.252
16.6	98.526	0	0	0	0
17.5	99.259	0	0	0	0
18	99.905	0	0	0	0
20.6	100.618	0	0	0	0

C/S 6					
WSL at 1.79 cumecs =		98.533			
WSL at 3.59 cumecs =		98.635			
WSL at 5.64 cumecs =		98.801			
		1.79 cumecs		5.64 cumecs	
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)
0	100.862	0	0	0	0
1.04	100.739	0	0	0	0
2.2	98.941	0	0	0	0
3	98.598	11	-0.001	38	0.046
3.75	98.378	21	0.024	55	0.14
4.5	98.361	37	0.364	55	0.751
5.25	98.343	34	0.354	55	0.727
6	98.325	44	0.452	60	0.406
6.75	98.324	43	0.452	60	0.609
7.5	98.299	53	0.246	60	0.43
8.25	98.264	49	0.588	65	0.425
9	98.294	52	0.496	65	0.675
9.75	98.224	58	0.785	65	0.745
10.5	98.258	55	0.416	72	0.868
11.25	98.278	52	0.333	60	0.642
12	98.288	50	0.147	62	0.65
12.75	98.321	41	0.026	55	0.376
13.5	98.395	38	-0.02	55	0.149
14.25	98.444	34	-0.067	45	0.042
15	98.556	22	-0.121	38	-0.035
15.75	98.656	13	-0.111	26	-0.091
16.4	98.711	10	-0.066	20	-0.025
16.65	99.094	0	0	0	0
17.7	99.511	0	0	0	0
19.1	99.561	0	0	0	0
20.4	100.726	0	0	0	0
22.56	101.019	0	0	0	0

C/S 7							
WSL at 1.79 cumecs =		98.683					
WSL at 3.59 cumecs =		98.742					
WSL at 5.64 cumecs =		98.901					
		1.79 cumecs		5.64 cumecs			
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)		
0	100.831	0	0	0	0		
1	100.572	0	0	0	0		
1.75	98.95	0	0	5	0		
2.5	98.782	5	-0.003	15	0.302		
3.25	98.724	13	0.362	18	0.364		
4	98.689	12	0.274	23	0.346		
4.75	98.658	16	0.261	33	0.412		
5.5	98.633	24	0.193	36	0.699		
6.25	98.542	33	0.266	45	0.433		
7	98.498	29	0.389	42	0.591		
7.75	98.515	38	0.33	45	0.736		
8.5	98.491	41	0.383	45	0.918		
9.25	98.493	42	0.63	57	0.873		
10	98.482	43	0.855	55	0.876		
10.75	98.425	40	0.78	60	1.043		
11.5	98.408	33	0.79	60	1.111		
12.25	98.407	33	0.696	55	0.802		
13	98.59	10	0.45	40	0.806		
13.75	98.567	8	0.361	45	0.548		
14.5	98.652	25	0.427	30	0.621		
15.25	98.755	7	0.289	25	0.408		
16	98.777	5	0.148	10	0.187		
16.75	98.888	0	0	9	0.046		
17.8	99.638	0	0	0	0		
19.2	100.397	0	0	0	0		
20.66	100.8	0	0	0	0		

C/S 8					
WSL at 1.79 cumecs =		98.788			
WSL at 3.59 cumecs =		98.852			
WSL at 5.64 cumecs =		99.033			
		1.79 cumecs		5.64 cumecs	
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)
0	100.142	0	0	0	0
1.3	99.882	0	0	0	0
2.5	98.93	0	0	0	0
3.5	98.62	0	0	0	0
3.75	98.189	0	0	0	0
4.2	98.216	0	0	0	0
4.7	98.296	0	0	0	0
5	97.879	5	-0.04	17	0.193
5.7	97.755	10	0.339	22	0.63
6.4	97.806	7	0.253	25	0.594
7.2	97.793	8	0.58	34	0.614
7.9	97.647	21	0.635	28	0.798
8.6	97.64	25	0.461	37	0.741
9.3	97.613	25	0.72	42	0.732
10	97.535	30	0.561	35	0.792
10.7	97.51	35	0.541	45	0.759
11.4	97.525	35	0.709	50	0.757
12.1	97.588	31	0.628	50	0.908
12.8	97.56	30	0.652	43	0.862
13.5	97.629	30	0.793	40	0.776
14.2	97.555	37	0.523	40	0.756
14.9	97.575	37	0.516	35	0.859
15.6	97.516	35	0.254	40	0.882
16.3	97.504	38	0.279	40	0.65
17	97.483	31	0.272	48	0.673
17.7	97.422	42	0.229	45	0.491
18.4	97.404	44	0.245	45	0.369
19.1	97.445	39	0.117	30	0.208
20	97.787	10	0	0	0
20.7	98.136	0	0	0	0
21.3	99.287	0	0	0	0
22.95	99.85	0	0	0	0

C/S 9							
WSL at 1.79 cumecs =		98.847					
WSL at 3.59 cumecs =		98.895					
WSL at 5.64 cumecs =		99.138					
		1.79 cumecs		5.64 cumecs			
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)	Depth (cm)	Vel. (m/sec)		
0	100.955	0	0	0	0		
0.7	100.913	0	0	0	0		
1	100.573	0	0	0	0		
2.2	100.165	0	0	0	0		
4.3	99.522	0	0	0	0		
5.3	99.42	0	0	0	0		
6.3	99.329	0	0	0	0		
7.3	99.255	0	0	0	0		
8.3	99.213	0	0	0	0		
9.3	99.09	0	0	0	0		
10	99.023	0	0	0	0		
10.75	98.945	0	0	10	0.028		
11.5	98.845	6	0.099	18	0.11		
12.25	98.83	12	0.048	20	0.291		
13	98.765	15	0.129	28	0.452		
13.75	98.737	20	0.171	30	0.592		
14.5	98.69	20	0.391	35	0.848		
15.25	98.642	26	0.424	35	1.159		
16	98.685	26	0.611	44	1.035		
16.75	98.6	30	0.626	50	1.142		
17.5	98.592	35	0.675	50	1.568		
18.25	98.563	40	0.815	57	1.375		
19	98.605	36	0.947	45	1.214		
19.75	98.67	33	0.902	45	1.211		
20.5	98.702	20	0.839	34	1.153		
21.25	98.727	21	0.696	35	0.833		
22	98.832	14	0.493	25	0.739		
22.68	98.96	3	0	20	0.228		
23.25	100.779	0	0	0	0		
24.35	101.103	0	0	0	0		
25	101.068	0	0	0	0		

C/S 10L			
WSL at 1.79 cumecs =		98.914	
Distance (m)	Elevation (m)	Depth (cm)	Vel.(m/sec)
0	100.072	0	0
2	99.9	0	0
3.3	99.631	0	0
3.65	99.266	0	0
4.3	99.159	0	0
5	99.107	0	0
6	99.06	0	0
6.4	99.037	0	0
6.8	98.003	1	0
7.2	98.921	6	0.028
7.6	98.876	7	0.036
8	98.869	8	0.071
8.4	98.824	13	0.07
8.8	98.803	20	0.13
9.2	98.774	21	0.115
9.6	98.759	19	0.172
10	98.752	26	0.181
10.4	98.691	27	0.153
10.8	98.677	30	0.27
11.2	98.643	33	0.316
11.6	98.601	36	0.197
12	98.622	36	0.335
12.4	98.616	37	0.25
12.8	98.675	35	0.328
13.2	98.604	36	0.247
13.6	98.665	32	0.113
14	98.637	26	0.114
14.4	98.776	19	0.134
14.8	98.772	17	0.097
15.2	98.766	7	0.099
15.25	99.704	0	0
16.2	100.777	0	0
17.75	101.301	0	0

C/S 10R			
WSL at 1.79 cumecs =		99.376	
Distance (m)	Elevation (m)	Depth (cm)	Vel.(m/sec)
0	100.811	0	0
1.4	100.547	0	0
2.05	100.202	0	0
2.1	99.418	0	0
2.4	99.237	17	0.443
2.7	99.214	21	0.655
3	99.246	18	1.004
3.3	99.13	34	0.658
3.6	99.11	42	0.978
3.9	99.098	38	1.044
4.2	99.082	42	0.819
4.5	99.103	34	1.334
4.8	99.123	36	1.187
5.1	99.094	30	1.43
5.4	99.172	26	1.095
5.7	99.138	30	0.852
6	99.197	21	0.652
6.3	101.241	15	0.54
6.6	99.223	18	0.66
6.9	99.226	16	0.36
7.2	99.293	12	0.299
7.5	99.399	2	0.054
7.8	99.794	0	0
9	100.011	0	0
10	100.143	0	0
12.1	100.072	0	0

C/S 11		
WSL at 1.79 cumecs =		100.867
Distance (m)	Elevation	
0	101.411	
1.25	102.081	
2.4	101.491	
2.9	101.357	
3.9	101.333	
4.9	101.334	
5.9	101.323	
6.9	101.299	
7.9	101.343	
8.9	101.342	
9.9	101.337	
10.9	101.339	
11.9	101.319	
12.9	101.309	
13.9	101.311	
14.9	101.322	
15.9	101.321	
16.9	101.374	
17.9	101.361	
18.9	101.349	
19.9	101.374	
20.9	101.349	
21.9	101.104	
22.8	101.399	
23.5	101.726	
24.9	101.774	

C/S 12L		
WSL at 1.79 cumecs =		100.881
Distance (m)	Elevation	
0	101.482	
4.6	101.225	
5.9	100.952	
9.1	100.884	
12.7	100.774	
16	100.753	
19.9	100.785	
23.5	100.797	
27.5	100.805	
30.9	100.804	
34.9	100.707	
37.8	100.565	
38.2	100.787	
42.1	100.704	
45.8	100.727	
49.6	100.745	
52.6	100.745	
56.2	100.709	
59.8	100.606	
62.7	100.785	
64	100.945	

C/S 12R			
Distance (m)	Elevation	Depth (cm)	Vel.(m/sec)
0		0	0
0.4		0	0
0.8		0	0
1.2		0	0
1.6		0	0
2		0	0
2.4		30	0
2.8		40	0.234
3.2		40	0.042
3.6		50	0.043
4		62	0.451
4.4		82	0.689
4.8		85	0.674
5.2		85	0.776
5.6		80	0.747
6		82	0.692
6.4		73	0.575
6.8		75	0.671
7.2		65	0.569
7.6		70	0.252
7.7		72	0.092
8.3		0	0

C/S 13							
WSL at 1.79 cumecs =		100.896					
Distance (m)	Elevation (m)	Depth (cm)	Vel. (m/sec)				
0	101.946	0	0				
2	101.902	0	0				
4	101.443	0	0				
4.5	101.004	0	0				
5.5	100.907	40	0				
6.3	100.33	70	-0.003				
7.1	100.027	113	0.015				
7.9	99.994	118	0.035				
8.7	99.963	122	0.07				
9.5	99.915	125	0.088				
10.3	99.9	122	0.097				
11.1	99.863	132	0.115				
11.9	99.791	147	0.122				
12.7	99.724	145	0.127				
13.5	99.664	153	0.147				
14.3	99.542	162	0.151				
15.1	99.456	170	0.166				
15.9	99.449	170	0.182				
16.7	99.616	158	0.134				
17.5	99.746	138	0.174				
18.3	99.862	127	0.146				
19.1	99.864	127	0.129				
19.9	99.767	132	0.103				
20.7	99.854	132	0.097				
21.5	100.029	110	0.081				
22.3	100.194	95	0.032				
23.1	100.373	74	0				
24.1	100.734	45	0.008				
24.25	101.538	0	0				
25	101.763	0	0				
27.5	102.298	0	0				
28.15	102.426	0	0				

R. BARLE: CHANNEL INDEX DATA

C/S 1

Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	80	0	0	902.9	90
0.7	0	0	80	0	0	902.9	90
1.9	0	0	80	0	0	902.9	80
3.4	10	0	80	0	0	209.8	70
3.6	30	0	80	0	1	605.6	80
4.3	30	10	80	0	0	605.8	80
5	30	20	80	0	0	605.8	80
5.7	50	10	70	0	0	607.8	90
6.4	50	10	70	0	0	607.8	90
7.1	50	10	70	0	0	605.8	90
7.8	40	0	70	0	0	605.6	80
8.5	40	0	70	0	0	605.6	80
9.2	40	0	60	0	0	605.6	80
9.9	40	0	60	0	0	605.6	80
10.6	30	0	60	0	0	605.5	80
11.3	30	0	50	0	0	605.3	90
12	20	0	50	0	0	506.5	90
12.7	20	0	30	0	0	506.5	80
13.4	20	0	20	0	0	506.7	80
14.1	30	10	20	0	0	506.8	80
14.8	30	10	10	0	0	506.8	90
15.5	0	0	0	0	0	506.9	90
16.2	0	0	0	0	0	506.8	80
16.9	30	0	0	0	0	506.8	80
17.6	30	0	0	0	0	506.5	90
18.3	30	0	0	0	1	906.5	80
19.2	0	0	0	0	0	901.9	80
19.5	0	0	0	0	0	901.9	80
21.5	0	0	0	0	1	902.7	80
21.7	0	0	0	0	0	902.7	80
22.55	0	0	0	0	0	900	80

C/S 2							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	0	0	0	900	80
1.3	20	40	20	0	0	900	80
1.8	20	40	50	0	0	900	80
2.35	20	40	60	0	0	900	80
2.7	20	40	40	0	0	900	80
3.5	30	70	50	0	1	709.7	80
4.2	20	30	30	0	0	700	90
4.9	20	70	20	0	0	700	90
5.6	0	80	10	0	0	706.7	90
6.3	0	50	0	0	0	706.7	90
7	20	50	0	0	0	607.7	70
7.7	20	30	0	0	0	607.7	70
8.4	20	30	0	0	0	607.7	70
9.1	20	30	0	0	0	607.7	60
9.8	40	30	0	0	0	607.7	60
10.5	40	10	0	0	0	607.7	60
11.2	40	10	0	0	0	607.7	60
11.9	30	10	0	0	0	605.7	60
12.6	30	0	0	0	0	506.7	60
13.3	30	0	0	0	0	506.7	60
14	0	0	0	0	0	504.8	70
14.7	0	0	0	0	0	504.8	70
15.4	30	0	0	0	0	603.6	60
16.1	30	0	0	0	0	306.6	50
16.8	20	0	0	0	0	103.7	40
17.5	20	0	0	0	1	306.6	60
17.9	0	0	0	0	0	903.6	70
18.9	0	0	0	0	0	309.7	80
19.3	0	0	0	0	0	903.9	90
20.14	0	0	0	0	0	903.9	90

C/S 3							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	0	0	0	900	80
0.98	0	0	0	0	0	900	80
1.9	10	0	80	0	1	304.8	90
2.3	20	0	80	0	1	500	90
3	10	30	80	0	0	700	90
3.7	10	30	80	0	0	705.5	90
4.4	10	0	80	0	0	605.6	80
5.1	10	0	80	0	0	605.6	80
5.8	10	0	80	0	0	605.6	80
6.5	10	0	60	0	0	605.6	80
7.2	10	0	40	0	0	605.6	80
7.9	10	0	10	0	0	605.6	80
8.6	10	0	10	0	0	605.7	90
9.3	10	0	0	0	0	605.7	90
10	10	0	0	0	0	506.6	80
10.7	10	0	0	0	0	506.6	80
11.4	10	0	0	0	0	506.7	70
12.1	10	0	0	0	0	506.7	70
12.8	10	0	0	0	0	506.7	70
13.6	10	0	0	0	0	605.7	70
14.3	10	0	0	0	0	605.8	70
15	10	0	0	0	0	605.8	70
15.7	10	0	0	0	0	605.7	70
16.4	10	0	0	0	0	109.8	60
17.2	10	0	0	0	1	309.5	60
17.4	10	0	0	0	0	904.6	80
17.9	0	0	0	0	0	902.8	80
19	0	0	0	0	0	902.8	80
19.66	0	0	0	0	0	902.8	80

C/S 4							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	0	0	0	903.9	80
1.35	0	0	0	0	0	903.9	80
1.5	0	0	0	0	1	903.9	80
2.25	0	0	0	0	0	903.7	70
3	40	0	0	0	0	603.7	60
3.75	40	0	0	0	0	603.7	60
4.5	40	0	0	0	0	605.6	60
5.25	40	0	0	0	0	605.6	60
6	50	0	0	0	0	605.8	60
6.75	50	0	0	0	0	605.8	60
7.5	50	0	0	0	0	605.8	70
8.25	50	0	0	0	0	605.8	70
9	50	0	0	0	0	605.8	70
9.75	50	0	0	0	0	605.8	70
10.5	30	0	0	0	0	605.6	70
11.25	20	0	0	0	0	506.6	60
12	20	0	0	0	0	506.6	60
12.75	10	0	0	0	0	406.8	40
13.5	10	0	0	0	0	406.8	40
14.25	20	20	0	0	0	704.6	90
15	20	30	0	0	0	703.7	90
15.75	10	40	20	0	0	503.6	60
16.8	10	40	50	0	0	305.6	50
17.3	20	10	70	0	1	506.7	50
17.4	20	10	70	0	0	506.7	50
20	20	30	60	0	0	305.7	80
21	0	0	30	0	0	903.8	80
22.66	0	0	0	0	0	903.9	90

C/S 5							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	30	0	0	900	80
0.5	0	0	30	0	0	900	80
1.4	0	0	30	0	0	902.9	80
1.75	0	0	30	0	0	902.9	80
2	0	0	30	0	1	902.9	80
2.7	10	0	50	0	0	600	90
3.4	10	0	60	0	0	605.8	90
4.1	20	0	50	0	0	600	90
4.8	0	0	30	0	0	600	90
5.5	0	0	20	0	0	700	90
6.2	10	0	10	0	0	607.8	90
6.9	10	0	0	0	0	607.8	80
7.6	10	0	0	0	0	607.8	80
8.3	10	0	0	0	0	607.8	80
9	10	0	10	0	0	607.8	90
9.7	10	0	10	0	0	706.8	90
10.3	10	0	30	0	0	706.8	90
11	0	0	40	0	0	800	90
11.7	0	0	40	0	0	800	90
12.4	0	0	40	0	0	800	90
13.1	0	0	60	0	0	800	90
13.8	0	0	50	0	0	800	90
14.5	0	0	70	0	0	800	90
15.2	0	0	70	0	0	800	90
15.9	0	0	70	0	0	800	90
16.6	0	0	70	0	0	501.6	80
17.5	0	0	70	0	0	209.6	80
18	0	0	30	0	0	209.6	90
20.6	0	0	0	0	0	900	90

C/S 6							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	70	0	0	903.8	90
1.04	0	0	70	0	0	903.8	90
2.2	20	50	60	0	1	903.8	80
3	20	40	50	0	0	508.6	90
3.75	30	10	50	0	0	800	90
4.5	20	0	40	0	0	608.6	60
5.25	20	0	30	0	0	608.6	60
6	20	20	20	0	0	806.6	80
6.75	20	20	20	0	0	806.6	80
7.5	30	10	10	0	0	608.6	70
8.25	30	10	10	0	0	608.6	70
9	30	20	10	0	0	706.7	90
9.75	30	20	10	0	0	706.7	90
10.5	30	20	10	0	0	706.7	90
11.25	30	20	10	0	0	706.7	90
12	30	20	0	0	0	706.6	60
12.75	30	20	0	0	0	607.6	60
13.5	30	10	0	0	0	607.6	60
14.25	30	0	0	0	0	605.8	60
15	40	0	0	0	0	604.7	70
15.75	40	0	10	0	0	604.7	70
16.4	30	20	20	0	0	604.7	70
16.65	30	30	50	0	0	903.9	80
17.7	50	30	20	0	0	903.9	80
19.1	0	0	0	0	0	903.9	90
20.4	0	0	0	0	0	903.9	90
22.56	0	0	0	0	0	903.9	90

C/S 7							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	70	0	0	900	90
1	0	0	70	0	0	900	70
1.75	0	0	70	0	1	605.5	70
2.5	20	0	30	0	0	605.6	80
3.25	20	0	30	0	0	605.6	80
4	10	0	30	0	0	800	90
4.75	0	0	0	0	0	800	90
5.5	0	0	0	0	0	800	90
6.25	0	0	0	0	0	800	90
7	0	0	0	0	0	800	90
7.75	0	0	0	0	0	800	90
8.5	0	0	0	0	0	800	90
9.25	0	0	0	0	0	800	90
10	0	0	0	0	0	608.5	80
10.75	0	0	0	0	0	608.5	80
11.5	0	0	0	0	0	800	90
12.25	0	0	0	0	0	800	90
13	0	0	10	0	0	800	90
13.75	0	0	30	0	0	805.9	90
14.5	0	0	50	0	0	805.7	90
15.25	0	0	60	0	0	805.5	80
16	10	0	60	0	0	805.5	80
16.75	20	0	70	0	0	509.5	90
17.8	10	0	90	0	0	902.5	80
19.2	0	0	90	0	0	902.9	80
20.66	0	0	50	0	0	902.9	80

C/S 8							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	40	0	0	903.8	80
1.3	0	0	40	0	0	903.8	80
2.5	0	0	40	0	0	903.8	80
3.5	0	0	40	0	0	903.8	80
3.75	10	80	40	0	0	801.8	90
4.2	10	80	40	0	0	801.8	90
4.7	10	80	40	0	0	801.8	90
5	10	80	40	0	0	801.8	90
5.7	0	0	40	0	0	804.9	90
6.4	0	0	40	0	0	804.9	90
7.2	0	0	40	0	0	804.9	90
7.9	20	0	40	0	0	608.7	50
8.6	40	0	40	0	0	605.7	60
9.3	40	0	40	0	0	605.7	60
10	40	0	40	0	0	605.7	60
10.7	40	0	40	0	0	605.7	60
11.4	30	20	40	0	0	607.6	60
12.1	30	20	40	0	0	607.6	60
12.8	30	20	40	0	0	607.6	60
13.5	30	20	40	0	0	607.6	60
14.2	30	20	40	0	0	607.6	60
14.9	30	20	40	0	0	607.6	60
15.6	30	20	10	0	0	607.6	60
16.3	30	20	20	0	0	607.6	60
17	30	20	40	0	0	607.6	60
17.7	30	20	60	0	0	607.6	60
18.4	30	20	80	0	0	607.6	60
19.1	30	20	80	0	0	607.6	60
20	30	20	80	0	0	903.7	80
20.7	30	20	40	0	0	903.7	80
21.3	30	20	40	0	0	903.7	80
22.95	30	20	40	0	0	903.7	80

C/S 9							
Distance	%Small	%Large	%OHC	Instream Veg.	Undercut bank	Substrate	Packing
0	0	0	0	0	0	903.9	90
0.7	0	0	0	0	0	903.9	90
1	0	0	0	0	0	903.9	90
2.2	0	0	0	0	0	903.9	90
4.3	0	0	0	0	0	903.9	90
5.3	0	0	0	0	0	509.6	60
6.3	0	0	0	0	0	509.6	60
7.3	0	0	0	0	0	509.6	60
8.3	0	0	0	0	0	509.8	70
9.3	10	0	0	0	0	509.8	70
10	10	0	0	0	0	509.8	70
10.75	0	0	0	0	0	506.6	70
11.5	30	0	0	0	0	506.7	60
12.25	40	0	0	0	0	605.6	50
13	40	0	0	0	0	605.6	50
13.75	40	0	0	0	0	605.7	50
14.5	40	10	0	0	0	607.6	50
15.25	40	10	0	0	0	607.6	50
16	40	10	0	0	0	706.7	50
16.75	40	10	0	0	0	706.7	50
17.5	40	10	0	0	0	706.7	50
18.25	40	10	0	0	0	706.7	50
19	40	10	0	0	0	706.7	50
19.75	40	10	40	0	0	706.7	50
20.5	40	10	40	0	0	706.7	50
21.25	40	10	40	0	0	706.7	50
22	30	0	60	0	0	603.6	60
22.68	30	30	70	0	1	306.7	70
23.25	0	0	30	0	0	903.8	80
24.35	0	0	30	0	0	903.8	80
25	0	0	30	0	0	903.8	80