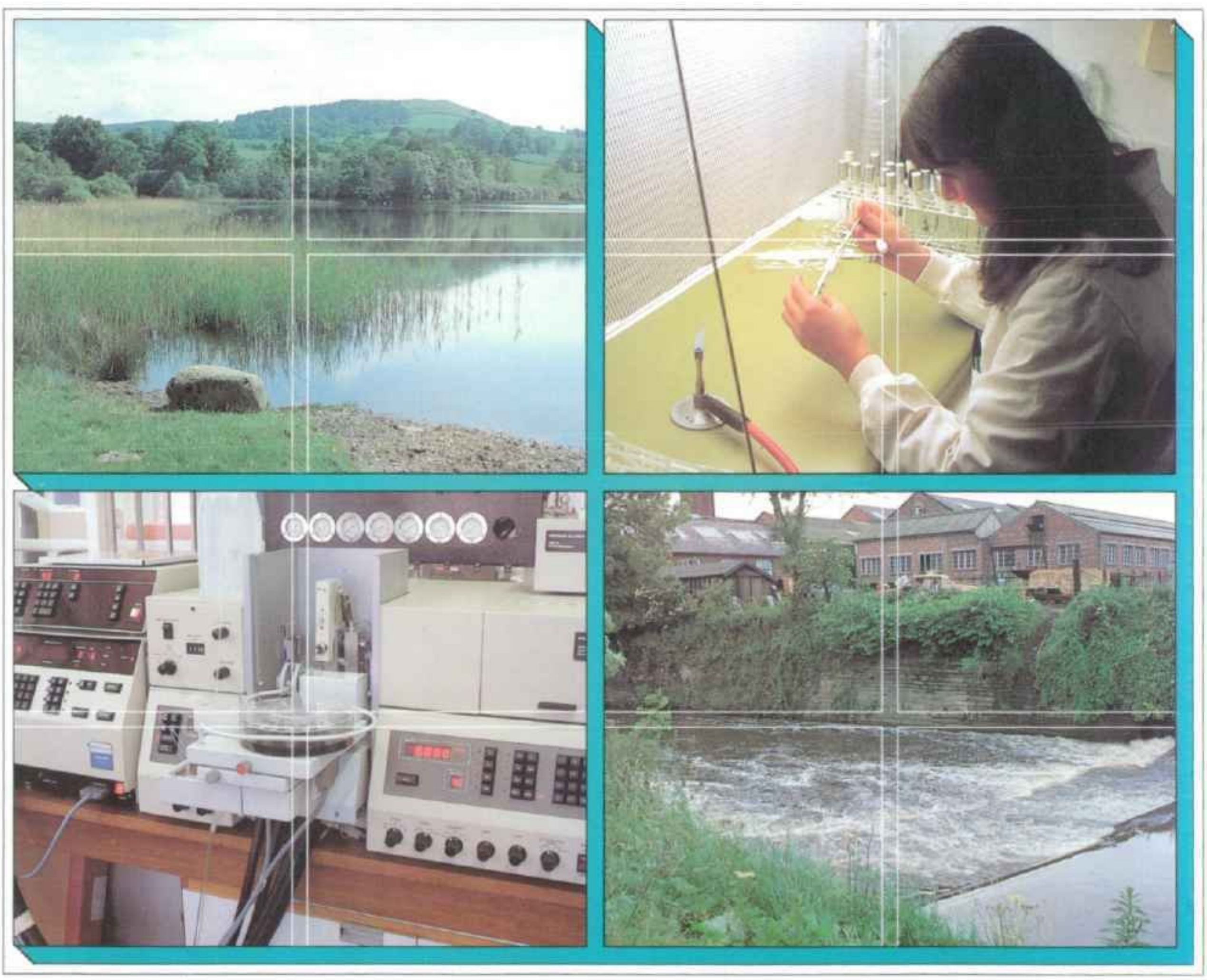
Institute of Freshwater Ecology

The Proposed Severn-Thames Transfer: Summary of Investigations (1995-1997)

Institute of Freshwater Ecology
Report to The Environment Agency (Thames Region)
June 1997



Natural Environment Research Council

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Dissemination Status

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Statement of Use

This document is one in a series of reports which investigate various aspects of a proposed Severn to Thames Transfer.

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1. Executive Summary

This document presents the conclusions from a series of recent studies (1995-1997) which establish baseline conditions in the middle reaches of the River Thames. They also include preliminary assessments of changes in the River Thames that might result from a Severn-Thames transfer. The main aim was to set the scene for policy decisions within the Environment Agency with particular regard to:

- assessment of the overall viability and desirability of promoting a Severn-Thames transfer
- the appropriate limitations under which such a transfer would operate

A matrix is presented (Table 1, page 3 & 4) depicting the major features that may be impacted or altered by a Severn-Thames transfer, under a limited range of prescribed transfer conditions. It includes assessment of the scale of change anticipated or, alternatively, states where the consequences are currently unknown. Assessments are on the basis that the transferred water would be released at a constant rate equivalent to 200Ml day^{-1} and during periods of low baseline discharges in the River Thames.

Listed below are the general topics covered in the recent studies and their location within this document (Summary of Investigations).

Topic	Report	Page No.	Appendix No.
Literature reviews			
River transfers -	Mann & Bass (1995)	5	Appendix I
River zooplankton -	Bass & May (1996)	7	Appendix IV
Assessment of existing Environment Agency information			
Biological data -	Furse *et al.* (1997)	13-16	Appendix IX
River zooplankton -	Bass *et al.* (1996)	8	Appendix V
Thames Soundings -	Bass & Collett (1997)	11	Appendix VIII
Water quality data -	House *et al.* (1996)	5	Appendix II
	Talbot *et al.* (1997)	6	Appendix III
Laboratory and field investigations			
Water and sediment chemistry -	House *et al.* (1996)	5	Appendix II
	Talbot *et al.* (1997)	6	Appendix III
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River zooplankton -	Bass *et al.* (1996)	8	Appendix V
Food utilised by juvenile fish -	Mann *et al.* (1995 & 1996)	9-11	Appendices VI & VII
Within-river habitat structure -	Bass & Collett (1997)	11	Appendix VIII

2. Summary of outstanding concerns

Minor **chemical changes** are predicted as a result of mixing water from the River Severn and River Thames under the typical river discharge conditions prevailing when the proposed transfer would operate. However, during the winter months high flow rates would cause the River Severn to lose some of its hardwater character. **Further assessment of the possible transfer of micro-organics, including pesticides and herbicides in the water and entrained sediment is recommended.**

Transfer of **suspended clay** in water from the River Severn would alter light conditions for plant/plankton development in the River Thames. Though such changes may be minor when compared with natural fluctuations. **Information should be obtained on the seasonal turbidity of River Severn water and considered in relation to the proposed settlement/retention period prior to release.**

Changes in water velocity, associated with operation of the transfer in early summer, **may impact young fish** by downstream displacement and modification of their food resources. Similar perturbations occur during unseasonable floods, but such effects are normally short-lived. **Further information is required on the prevailing water velocities and conditions controlling fish recruitment in the River Thames adjacent to the proposed discharge point for water from the River Severn.**

The **phytoplankton and zooplankton population size and community structure will be modified in the middle reaches of the River Thames during May-July** if water is transferred from the River Severn. Increases or decreases will depend on downstream loss-processes (increased flow) and the prevailing densities within the transferred water. **It is perceived that algal biomass within the River Thames is constrained by channel depth ('light climate') and the loss-processes that operate rather than the nutrients available.** There is the possibility of transfer of algal parasites and diseases, also other micro-organisms which are currently not present in the River Thames but the consequences are not currently predictable.

The larger **aquatic plants** (macrophytes) are well represented in the River Severn and River Thames. **The possibility of the development of invasive hybrids and introduction of plant pests and diseases from the River Severn was raised but no previous similar incident was quoted.**

Macroinvertebrates and adult fish were considered to be resilient to the changes associated with the proposed transfer rate, as no alterations to the distribution of the major physical habitats were likely. However the introduction of species, not thought to occur in the River Thames near Buscot, was considered possible. This was raised as a **potential problem in the case of the zebra mussel, which is capable of colonising intake pipes and the zander, a predatory fish viewed with mixed feelings by fishery interests.**

3. The Proposed Severn-Thames Transfer

3.1 Background

From the mid-1970's a series of investigations were commissioned by the Environment Agency, Thames Water (and their predecessors) to assess the viability of a possible Severn-Thames transfer scheme. These have primarily been desk studies and literature reviews but water quality in the River Severn and baseline conditions in the River Thames were also addressed. Initially several alternative transfer routes, transfer rates, off-take and input points were considered. Modes of transfer included direct pipelines and combinations of pipeline/canal and pipeline/Thames tributary.

In summary it was concluded that the most economic option was a direct pipeline from an off-take point on the River Severn, near Haw Bridge, to the vicinity of Buscot on the River Thames. Short retention storage (between one and five days) in lagoons at each end would be required to intercept sediment from the River Severn and facilitate controlled rates of discharge into the River Thames. Transfer rates of 200Ml to 400Ml per day were envisaged with the transfer operating when resources in the Thames region were exceptionally low. Such transfers would also depend on maintaining prescribed minimum flows in the River Severn to safeguard access for migratory fish. The prescribed minimum flow in the River Severn would be in the order of 2500-4000 Ml day^{-1} (28.3-46.2 cumecs). All year generally.

The transfer would be designed to operate during periods when water resources are scarce, for example, periods of excessive drought. The transfer would be triggered when storage in London's reservoirs dropped below a predetermined level for the time of year. Additional reservoir releases from the upper catchment of the River Severn would be necessary to permit the transfer to operate when river flows are universally depleted. Preliminary modelling results by the Environment Agency indicate the transfer would be needed about one year in six for an average of five months, most commonly in July-November. In major drought years the transfer would be required earlier (May or June) and in some years it might be required after November.

3.2 Recent Studies

Further investigations into the viability and consequences of a Severn-Thames transfer were considered appropriate in the mid-1990's, as both an alternative to the development of a proposed new reservoir in south west Oxfordshire or in conjunction with such a development. The Environment Agency (and formerly the National Rivers Authority) had commissioned a series of studies to provide baseline information on the reaches of the River Thames and tributaries that might be impacted by the development of a proposed new reservoir. The scope of investigations was extended upstream in 1995 to include reaches that would be impacted by a Severn-Thames transfer. Discussions between the Environment Agency and the Institute of Freshwater Ecology led to the development of a collaborative research programme. The Executive Summaries from specific investigations undertaken by the Institute of Freshwater Ecology (1995-1997) are provided in the attached Appendices (I-IX).

The Environment Agency's overall objective was to investigate in more detail the environmental risks and benefits associated with such a transfer. This included identifying the key environmental implications arising from each study: where possible quantifying the estimate of change and finally assessing the potential risks to the water environment which might arise from such a transfer.

3.3 Rivers as dynamic systems

The potential impacts of a Severn-Thames transfer should be considered against a background of broad seasonal changes within rivers. Superimposed on seasonal changes are variations occurring over a range of timescales (minutes-years). Extensive information on the River Thames is currently available for a limited range of physical parameters (eg, temperature and river discharge) with other variables measured at comparatively infrequent intervals (some components of water chemistry and river biota) or not at all (eg, sediment translocation and the majority of micropollutants).

The river biota includes organisms preadapted in different ways to perturbations. At alternative extremes they may be physically resilient to change or respond with a rapid population recovery. Seasonal occurrence and synchronised life stage development are commonplace and known for a wide range of organisms. Less well understood are changes at the community level, where interactions between species and prevailing conditions can generate large year to year differences. It is against this backdrop that the consequences of a Severn-Thames transfer are assessed.

The effects of a Severn-Thames transfer are considered with respect to a combination of current knowledge and the perceived risks/benefits, with emphasis placed on the perceived risks which require further evaluation.The spreadsheet summary (Table 1A & B, pages 3 & 4) highlights the anticipated main changes/impacts resulting from the proposed transfer. It should be noted that the majority of changes outlined already occur from time to time as a result of exceptional weather conditions. The remaining changes associated with a river transfer would result from the introduction of novel chemicals, fauna and flora (including pathogens and parasites).

(TABLE 1A)	KEY:	....perceived risk of impact....		
		changes will occur	no significant change or impact anticipated	consequences unknown ○
Potential change in:	Potential effects:	seasonal transfers: .....May/June	.....July-October	.....November-April
1. temperature	LITTLE CHANGE			
2. river discharge	RAISE THE LOW FLOW BASELINE IN THE RIVER THAMES	...MIGHT INCREASE c.50%	...MIGHT INCREASE UP TO 100%	...MIGHT INCREASE UP TO 100%
3. water velocity	SMALL INCREASE AS THE RIVER THAMES IS IMPOUNDED	...POSSIBLE IMPACT ON FISH FRY	...LITTLE CHANGE	...LITTLE CHANGE
4. water chemistry	UNCHANGED EXCEPT WHEN THE RIVER SEVERN HAS A HIGH DISCHARGE			...CONDUCTIVITY MAY DECREASE
5. range of trace pollutants	UNKNOWN AS DIFFERENT COMPOUNDS MONITORED IN EACH RIVER ○	○	○	○ ...movement of sediment-bound compounds
6. turbidity	transferred suspended clay may alter growing conditions for algae and submerged plants ○	○	○	...highest translocation period
7. fauna/flora (new)	some new introductions will occur, mostly as seeds/eggs or juvenile forms	...plankton and fish eggs/fry	...a range of species	...few species
8. phytoplankton/zooplankton	dilution of resident population or additions may occur ○	○	○	ABSENT IN AUTUMN/WINTER
9. submerged plants	little change without large increase in turbidity	loss or gains possible		
10. emergent plants	change possible during growing season			
11. macroinvertebrates	MAJOR CHANGES UNLIKELY			
12. adult fish	MAJOR CHANGES UNLIKELY			
13. juvenile fish	POTENTIAL DISPLACEMENT AND ALTERED FOOD SUPPLY	FISH EGGS AND FRY VULNERABLE	MODIFIED PLANKTONIC FOOD SUPPLY	
14. pest & diseases	unknown scope for pests/diseases ○	a rise or decline possible	a rise or decline possible	○

TABLE 1A & 1B: An evaluation of the consequences of operating a proposed transfer of 200 Ml day^{-1} from the River Severn to the River Thames. It is assumed that conditions prevail which reflect low (seasonal) discharge in the River Thames, triggering the full transfer volume at a constant pumping rate. Predictions are made on the basis of the reports summarised in the text. Seasonal influences are covered in (A) and storage conditions in (B) . Conclusions supported by data are in upper case, whilst aspects lacking firm data or with inconclusive data are in lower case.

(TABLE 1B)	KEY:	....perceived risk of impact....		
		changes will occur	no significant change or impact anticipated	consequences unknown
Potential change in:	conditions in storage: (period unspecified)	.....settlement period	.....storage prior to release	.....rate of release
1. temperature				
2. river discharge				...control abrupt changes
3. water velocity				...control abrupt changes
4. water chemistry				...control abrupt changes
5. range of trace pollutants	...depends on type of compounds	...depends on affinity with sediment	...depends on stability of compounds	
	potential resuspension	...clay may not settle out	...potential further settlement	...potential resuspension
6. turbidity	potential for interception	possible growth and reproduction	possible growth and reproduction	
7. fauna/flora (new)				
8. phytoplankton/zooplankton	potential for interception			
9. submerged plants	potential for interception			
10. emergent plants	potential for interception			
11. macroinvertebrates	potential for interception	possible growth and reproduction	possible growth and reproduction	
12. adult fish	limited potential for interception	possible growth	elevated or reduced food supply	...control abrupt changes
13. juvenile fish				
14. pest & diseases				

TABLE 1A & 1B: An evaluation of the consequences of operating a proposed transfer of 200 Ml day^{-1} from the River Severn to the River Thames. It is assumed that conditions prevail which reflect low (seasonal) discharge in the River Thames, triggering the full transfer volume at a constant pumping rate. Predictions are made on the basis of the reports summarised in the text. Seasonal influences are covered in (A) and storage conditions in (B) . Conclusions supported by data are in upper case, whilst aspects lacking firm data or with inconclusive data are in lower case.

4. River Transfers

Mann & Bass (1995)(Appendix I) considered worldwide published information on the consequences of river transfers. Proposals for new studies were also formulated, in order to address remaining gaps in knowledge within topics of major concern to the Environment Agency.

The literature review revealed an abundance of general papers on potential ecological effects of water transfers, both on the donor and the recipient river. However, there were few documented case studies. Many schemes involved the transference of water volumes far greater than those envisaged in the Severn-Thames scheme.

The key issues identified were:

- changes in water chemistry.
- changes in flow regime and temperature.
- movement of sediments.
- transfer of algae and invertebrates.
- development of lentic populations of algae and nutrients in the Thames-side reservoir and their transference to the river.
- changes in micro-habitat distribution, growth and survival of newly-hatched fish.

A series of twelve new investigations were outlined, five of these were subsequently developed as collaborative studies with the Environment Agency and their conclusions are presented below and on the following pages.

5. Water Chemistry

These studies addressed changes in water chemistry resulting from mixing water from the River Severn and River Thames. Previous reviews and studies had raised the issue of changes in solubility which result in precipitation of entrained material and dissolution of metal pipework. These were sources of concern with regard to both conditions in the River Thames and in abstracted water intended for potable supplies.

Phase 1 -

House, Talbot, Smith, Sadak, & Lawlor (1996)(Appendix II)
investigated changes in the chemistry of water from the River Severn and River Thames during mixing. Changes are generally small for the major ions and this is predicted from theoretical calculations on the effect of mixing (WATEQ*). For the trace metals the effects appear to be greater for certain elements, notably for amphoteric metals

(aluminium/zinc) and for the transition metals (copper/nickel/vanadium). It must be emphasised that these results only pertain to one set of mixing trials.

To summarise, the chemical changes which occur are either predicted by WATEQ to a fairly good degree or - for some of the metals - they can be rationalised from a knowledge of their inorganic chemistry. This work has looked at mixing waters direct from the river and considered the conditions in a pipeline but not the effect of a variable (currently unknown) storage period for incoming waters before addition to the River Thames.

* WATEQ - a chemical speciation program used to calculate ion balances and all major thermodynamic equilibria both in solution and mineral phases. The program version used determines the potential stability of over one hundred chemical entities in water. Data on total calcium, magnesium, sodium, potassium, alkalinity (as bicarbonate), sulphate, chloride, nitrate, dissolved oxygen, silica, phosphate and ammonia were used. In some cases measurements of iron, fluoride, manganese, borate and aluminium were also available.

Phase 2 -

Talbot, House, Irons, Lawlor, & Clarke (1997)(Appendix III)
assessed the changes in chemical interactions of transferred suspended sediment from the River Severn when mixed with water from the River Thames. This aspect was investigated on four separate occasions (spring, summer, autumn and winter). Parameters considered in this work included 10 major ions, 13 metals, the particle size, mineral components and biological composition of the sediment and the organic content of the solution.

The chemical nature of the two waters appear largely similar (as discussed in the Phase 1 report), with the possible exception of the winter months, when high flow rates may cause the River Severn to lose some of its hardwater character because of dilution with softer water from the headwaters. Unfortunately it has proved impossible to investigate this during the study because of the lack of rainfall in the winter of 1996-7. The experimental work carried out during this period did however, show a high release of some metals which cannot be explained from the aqueous solution chemistry, especially manganese, copper, cadmium, & zinc. This is mirrored to a certain extent by a change in some amphoteric metals.

The role of micro-organic species in each river was also considered in this work using information supplied by both Environment Agency regions. Both rivers appear to be relatively free from micro-organic contamination with no potentially toxic compounds recorded in more than a minority of samples. The most commonly found anthropogenic contaminants in the source water (River Severn), such as simazine, atrazine and lindane also tended to be found in the River Thames water. Therefore the injection of high levels of such material, as a result of transfer, appears unlikely on the evidence considered. It is recommended that those compounds at present determined in the River Severn but not in the River Thames should be included in the future monitoring of the River Thames. This will provide useful background information against which to assess future water quality changes.

It was found that sediment collected from the River Severn (Haw Bridge) achieved a constant value for suspended solids (3-4 mg l^{-1}) after about 4-6 hours settlement; most of the remaining material was still in suspension after 5 days and is presumably colloidal material which may be explained by the high clay content of the sediment. Given that the addition of sediment to the River Thames water appears to have little permanent effect on the solution chemistry, the properties required of settlement ponds are likely to be dictated by other factors and any benefit to water chemistry would be accomplished with a relatively short settlement time.

In conclusion, there is a general similarity in chemical composition between the two rivers, as described by parameters such as mineral saturation, pH and dissolved oxygen concentration of the solutions investigated. This infers that interactions with the sediment from the River Severn - whether equilibrium is achieved or a more complex situation exists between sediment and water - should be similar whether the water is from the River Severn or the River Thames. An exception to this may be during conditions which temporarily perturb the solution chemistry away from equilibrium such as occurs in storm episodes or pollution incidents.

6. River Zooplankton

Bass & May (1996)(Appendix IV) conducted a general literature review of river zooplankton. Their report also included proposals to establish the community structure of River Thames zooplankton to complement recent studies on phytoplankton conducted by the Environment Agency.

This study addressed the role of zooplankton in large rivers and included a consideration of the trophic links with phytoplankton, other invertebrates and young fish. The authors also evaluated the potential role and importance of zooplankton in the middle reaches of the River Thames.

Main conclusions of the literature review -

In all studies which have considered rotifers, this group had the greatest potential for influencing the phytoplankton-zooplankton dynamics. However there are few references which assess the role of rotifers in controlling phytoplankton abundance and species composition in large rivers.

The overriding influence of discharge on plankton density is widely reported in the literature, with plankton development inhibited or diluted as retention time decreases with increasing river flows. "Dead zones" or "storage zones" within river channels have been demonstrated to contribute to the delay of downstream displacement of phytoplankton in a range of rivers in Britain.

Recent studies on the habitat utilisation and gut contents of juvenile fish indicated that the size of zooplankton specimens in the diet increases as the fish grow, with rotifers providing the main prey in the first few weeks after fish absorb their yolk sac.

In relation to a Severn-Thames transfer, the discharge of augmentation flows that substantially reduced retention time within the river would inhibit plankton development. The discharge of intermittent augmentation flows may interrupt the sequence of plankton development and act as "re-setting" events, where populations are diluted sufficiently to promote repeated cycles of phytoplankton development followed by zooplankton development.
(Further conclusions on the possible impacts on the River Thames phytoplankton were provided in the subsequent Review of Biological Data, Section 10, page 13-15).

The following zooplankton sampling regime was proposed -

Relatively large sample volumes of river water should be collected from discrete depths with a small battery-powered submersible pump.
Monitor separately the abundance of small abundant taxa (eg rotifers and Protozoa) and large comparatively infrequent taxa (eg cladocerans and juvenile stages of copepods).
Examine contemporary and seasonal differences in zooplankton at 5 river sites.
Examine spatial differences in zooplankton populations at 2 river sites, considered of relevance to grazing pressure on phytoplankton and food resource availability to other dependant fauna.

7. Zooplankton Interactions in the River Thames

Bass, May, Esteban & Collett (1997)(Appendix V) described the zooplankton study undertaken from April until November 1996. The data collected included water temperature, water clarity, suspended chlorophyll$_a$, the microbial community, rotifers, copepods and cladocerans at five sites between Lechlade and Reading. The microbial community was enumerated in a range of size classes and functional categories. The relative scales of abundance within the planktonic microbial food webs present were typical of eutrophic freshwaters.

An overall downstream increase in rotifer abundance occurred in parallel with increases in chlorophyll$_a$ concentration in the river water. This suggested that rotifer abundance was controlled primarily by food availability, as chlorophyll$_a$ levels reflect algal biomass, and most rotifers feed on algal cells. Preliminary calculations of grazing rates indicated River Thames rotifers removed only about 4% of the algal biomass each day in 1996 and would have had little effect on overall phytoplankton abundance. However it is stressed that these extrapolations from laboratory clearance rates remain imprecise.

Analyses of fish guts had previously confirmed that rotifers were an important food sou . for larval fish in the River Thames. A size-selective sieving method was used for quantitative assessment of the larger rotifers and less frequent microcrustaceans ingested by young fish. In May and June the population densities of large rotifers showed varying patterns in relation to depth and location within the river channel at Radley and Wallingford. There were very few copepods and cladocerans recovered from the River Thames zooplankton subsamples at all five sites and on all dates in 1996. This was in contrast with contemporary data on the gut contents of young fish at the Radley site on the River Thames (Mann, *et al.*, 1996)(cited in Section 8, page 10) indicating cladocerans were more numerous in other habitats within the river.

On the basis that a Severn-Thames transfer would reduce reach-retention time downstream from the input point at Buscot it was concluded that the River Thames zooplankton community would be altered in the close vicinity of Buscot. In order to predict changes to the plankton dynamics additional data are required on the growth and loss rates of planktonic organisms and the hydrological characteristics of the river channel at Buscot. The impacts of a Severn-Thames transfer on the plankton further downstream are considered likely to be small owing to the scale of increased channel size and river discharge around Oxford.

Uncertainties remain with respect to the mechanisms controlling the River Thames plankton populations and the precise changes that would result from a Severn-Thames transfer.

It is recommended that future research on this topic should focus on:-

the development of models of the impacts of grazing by zooplankton.
the population growth rates of the rotifer species which are important as algal grazers and food for young fish.

- both taking account of reach-retention time under a range of hydraulic conditions.

Furse *et al.* (1997)(Section 11) included a proposed future monitoring strategy to determine the effects of transfer on plankton, in the event of a Severn-Thames transfer operating. This would be achieved using a fortnightly programme of routine samples of plankton in the River Severn (at the off-take point) and River Thames (above and below the input), they stressed that cell counts with biomass/biovolume conversion would be more appropriate than cell counts and identifications alone.

8. Juvenile fish diet studies

Mann, Collett, Bass & Pinder (1995)(Appendix VI) studied the diets of young-of-the-year (0 group) fish in the River Thames at Abingdon with three main objectives:

assessment of between-species, between-habitats and between-season changes in

fish diets
comparison of the results from the River Thames with those of similar studies by IFE in the River Great Ouse
recommendations for future studies that would increase the robustness of the results of the River Thames studies

In general, the diet of each species changed from small prey (mostly rotifers) to larger items (mostly microcrustacea and insect larvae) as the fish grew in size. However, the larger 0 group perch and gudgeon contained many copepods, whereas the other fish species contained more cladoceran taxa. The most striking difference between species was that, in July, the roach switched from an invertebrate diet to one dominated by the detritus (aufwuchs) that accumulates on the underwater surfaces of plants.

Further studies which would increase the reliability of the results:

examination of more of the fish caught in the 1995 study,
collection of additional samples to determine the extent of year-to-year fluctuations.

For the greatest understanding of fish-prey dynamics, such studies should be accompanied by assessments of prey availability (planktonic and non-planktonic invertebrates).

Juvenile fish diet studies in 1996

Mann, Bass, Pinder, Ibbotson, & Pinder (1996)(Appendix VII) repeated a study of the diets of young-of-the-year (0 group) fish in the River Thames at Radley with the following principal objectives:

Assessment of between-species, between-season and between-year changes in fish diets;
Comparison of fish gut contents with the results of the 1996 zooplankton study at Radley;
Comparison of the results with IFE experience in other rivers;
Recommendation for future sampling strategies that would increase the robustness of the 1995 and 1996 studies on the River Thames.

The Radley results showed no major differences from those from Abingdon (1995); the importance of zooplankton drift to the diet of newly-hatched fish was re-emphasised, as was the value of aquatic plants along the river margins as feeding zones and refuge from the main river current. As in 1995, the roach switched to a detrital diet (aufwuchs) in July.

The correlation between zooplankton densities and fish diets was not clear cut. However, there was some evidence that lower zooplankton densities occurred in the surface waters along the river margins than elsewhere in the river. This may reflect feeding pressure by the 0 group fish and a possible limitation in food resources.

The 1995 and 1996 River Thames studies, together with past and recent studies on the River Great Ouse underline the great importance of aquatic plants as feeding and refuge areas. Any diminution in these areas could have a major impact on the distribution, growth and survival of 0 group fish and a consequent reduction in the numbers surviving to become adult fish.

Conclusions

Further studies of the diets of 0 group fish in the River Thames are only likely to emphasise the conclusions already reached. However, it would be useful to know more about the degree of between-year variation so that any changes resulting from an alteration to the river's hydrology can be placed in context.

9. Habitat Studies in the River Thames

Bass & Collett (1997)(Appendix VIII) investigated three main aspects:

> The historical information provided by the River Thames Soundings Data.
>
> Application of the River Habitat Survey (RHS) methodology.
>
> Mapping of water depth, submerged plants and fine sediment, together with a description of prevailing flow conditions during periods of low discharge.

The extent of the habitats together with their stability over time and their significance for the aquatic fauna and flora were considered. The River Thames Soundings hydrographic survey maps revealed that there had been little movement of the river channel in the general area of Buscot since 1938. The river channel stability has been maintained despite peak annual flood discharges averaging several thousand megalitres day^{-1}. Therefore, in the context of the proposed Severn-Thames transfer (200Ml day^{-1}), it is considered that the River Thames channel and the extent of major habitats would remain stable.

Characteristics of 5 River Habitat Survey sites near Buscot were compared with similar river sites in England and Wales in the RHS database. This established that the mean annual discharge of River Thames at Buscot was at the lower end of the range represented by 86 lowland sites with similar physical attributes.

The within-river habitat survey confirmed that water depth was >2m in about one quarter of the river channel area. Aquatic plants occupied about 20% of the channel area. No species of emergent plant occupied more than 1% of the river channel. A change in the underwater light climate associated with increased water depth or higher turbidity would reduce the area of submerged plants and change the proportions of different habitats available for river fauna. Detailed information is lacking on the settlement of fine sediment in the River Thames at varying river discharges therefore prediction of the impacts of fine sediment transferred from the River Severn, via proposed settlement lagoons, were speculative.

The theoretical mean water velocities in the River Thames at Buscot were predicted for a series of low river discharge values. Addition of 200Ml day^{-1} from the River Severn would more than double the discharge prevailing in late summer in most years. The impoundment of the River Thames between weir structures tends to buffer velocity changes. Operation of the proposed Severn-Thames transfer during May or June, at a time of higher seasonal baseflow, would increase downstream displacement of fish fry and impose sub-optimal feeding conditions.

Recommendations:

Establish precise relationships between the hydrological conditions in the River Thames and velocity changes at low river discharges to assist the prediction of impacts arising from the proposed Severn-Thames transfer.

Investigate the settlement characteristics of transferred sediment to assist the formulation of guidelines on the maximum levels of suspended sediment permitted in any water transferred from the Severn.

Obtain data on the seasonal availability of invertebrates within the aquatic plant stands to provide greater understanding of interactions between submerged plants, invertebrates, plankton and juvenile fish recruitment in the River Thames.

10. A Review of Biological Data

Furse, Welton, Reynolds, Symes & Collett (1997)(Appendix IX)
undertook the construction of a database and the presentation of information on biological data relating to the main channel of the River Thames between St Johns' Lock (near Lechlade) and Caversham Lock (in Reading).

In the case of macro-invertebrates and macrophytes available data were incorporated in a specially devised Microsoft Access 7 relational database and this is provided to the Agency as an output of the collaborative study.

In addition to documenting the fauna and flora recorded, the significance of changes in water chemistry, temperature, flow changes, sediment/turbidity, transfer of biota and transfer of diseases were considered. Suggestions for minimising the potentially deleterious impacts of a Severn-Thames transfer were outlined (mitigation), though this was outside the original scope of the project.

Possible future sampling and monitoring strategies were also outlined.

Chemical changes

It is assumed that the transferred water will be frequently tested and that transfers will suspended if abnormal and potentially harmful concentrations of pollutants are detected.

Transferred water should be well oxygenated during the release process to avoid any possible impacts of low dissolved oxygen levels at the point of release.

Plankton: any dilution or enhancement of the nutrient content is unlikely to much alter the fertility of the mixed water (Severn and Thames).

Macrophytes: no statement

Macroinvertebrates: most taxa have a relatively broad range of tolerance to naturally occurring chemicals and no substantial impacts are expected from the differences in normal baseline chemistry of the River Severn and River Thames.

Fish: the dissolved oxygen (DO) content of the incoming water should be monitored to ensure that there is not a low concentration of DO in released water.

Temperature

The temperature profile of the water is expected to show little change in response to the water transfer and certainly not outside the range of normal annual variation.

Plankton: no statement

Macrophytes: no statement

Macroinvertebrates: no discernable impacts upon macro-invertebrates are expected

Fish: water temperature change is not expected to be a problem.

Flow changes

Plankton: The phytoplankton supportive capacity downstream would be unlikely to be enhanced while the maintenance of a more sustained flow as a consequence of transfer might contribute to an average diminution.

Macrophytes: marginal and floating macrophytes are susceptible to the impacts of rapid flow changes.

Macroinvertebrates: most macro-invertebrate species are resilient to gradual change because this is the normal seasonal and annual pattern. Sudden changes in discharge are more likely to have a deleterious effect, particularly upon those species living at the waters' edge, including those associated with marginal and floating macrophytes.

Fish: water should be released in stages so that the flow increase is gradual. This is particularly important in the summer when the young-of-the-year are small. Staged releases will allow fry to detect changes and move into sheltered areas to avoid washout.

Sediments and turbidity

Plankton: no statement

Macrophytes: no statement

Macroinvertebrates: impacts of increased sediment load and turbidity will vary according to the extent and quality of the sediment load and the macro-invertebrate taxa involved are liable to lead to a reduction in faunal diversity if their habitat quality and heterogeneity are reduced. In contrast, if increased marginal sedimentation leads to increases in the cover of macrophytes this may act to promote macroinvertebrate diversity. Though any change in community structure may be viewed as detrimental, depending on perception.

Fish: there may be some local redistribution of sediment but this should be no more than is expected following natural increased discharge regimes, ie floods, and fish are able to cope with such changes.

Transfer of biota

Plankton: no substantial risk to the algal quality of either river or abstracted water arises from the proposed transfer.

Macrophytes: the passage of seeds, turions or other propagules leading to the development of novel hybrids is possible. Without detailed knowledge of the fluvial flora of either catchment or a sound grounding in the strains represented therein, it is not possible to predict any particular event dependent on the proposed transfer.

Macroinvertebrates: transfer of taxa is not likely to be a problem with the exception of the zebra mussel, *Dreissena polymorpha* (Pallas), which occurs in the Severn. This taxon occurs in the lower River Thames, certainly as far upstream as Reading (Institute of Freshwater Ecology unpublished records) but does not appear to have colonised the St John's to Caversham section of the river. It is potentially a nuisance species with a propensity to clog the inlets and outlets of power stations and other industrial installations.

Fish: fish can be transferred as eggs or very young larvae and it is unlikely that any practical mesh size can avoid this. Careful positioning of the intake pipe can reduce this probability. The transfer of Zander is considered likely, this predatory species is currently not thought to be present in the River Thames upstream of Oxford.

Disease

Plankton: care must be taken over the possible transfers of diseases, pathogens and parasite propagules associated with zooplankton, suspended benthos or similar sized particles.

Macrophytes: there is the possibility of carriage of plant pathogens from the River Severn to the River Thames.

Macroinvertebrates: this is not considered to be an important issue.

Fish: most common fish diseases are already present in the River Thames and the probability of transfer of a major problem is low. A check should be kept on the incidence of disease in the River Severn.

11. Recommendations on a future monitoring strategy (fauna and flora)

Furse, Welton, Reynolds, Symes & Collett (1997)(Appendix IX)

Plankton

The implications for the proposed transfer are that potentially high concentrations of fluvial algae will be transferred to the River Thames, at a point where, under present circumstances, high algal populations would be usually low. The species added would be similar to (though not necessarily identical with) the species either already present or potentially so downstream, and the growth requirements would remain unchanged. An adequate basis for determining the effects of transfers of River Severn water on the plankton of the River Thames could reasonably be established with a fortnightly programme of routine samples. Such a programme to include: (1) the biomass of River Severn plankton transferred, sampled at or just above abstraction point and in the aqueduct at the point of discharge (2) the biomass of River Thames plankton at one point above the point of discharge (3) the biomass of River Thames plankton 1-2 km below the point of discharge, after good integration has been allowed to take place, and (4) the biomass at one or two stations (say 10 to 20 km) further downstream. Determinands should include cell counts (with biomass/bio-volume conversion). This is far superior to qualitative identification of the species making up the measured chlorophyll contents.

Macrophytes

Monitoring should be undertaken at selected or randomly chosen sites on the River Thames. Repeated at 5-year intervals for ongoing comparison of species status, plant health, etc. All data should be stored in a relational database.

Macroinvertebrates

To demonstrate that the ecological quality of the study section of the River Thames remains within the normal temporal range, routine monitoring, using established sampling techniques, should be maintained at all current sites (i.e those sampled in 1994 and/or 1995) with an existing time series of data of at least five years. Routine monitoring needs to be instigated in the Buscot reach as matter of urgency. No sampling has been undertaken in this reach since 1977 when there were indications of environmental stress and it is imperative that new baseline conditions are established.

Fish

As abundance and year class strength is largely determined from factors impinging on the fry, factors affecting fry survival should be examined. Surveys of larval and juvenile habitat should be carried out to ensure that these areas are conserved. In addition, studies on the food availability, feeding and growth of fry should be maintained.

Monitoring macroinvertebrate diversity

In order to demonstrate that faunal diversity is maintained during years of augmentation it is recommended that a regular habitat-specific sampling programme is established at selected sites upstream and downstream of the augmentation point at Buscot, with faunal identification at species level.

Monitoring macroinvertebrate taxa of conservation importance

Regular sampling programmes to monitor the presence of taxa with national conservation status is not recommended because the process itself may impact upon the taxa being monitored. Instead it is recommended that sub-sets of routine monitoring samples be identified to species level either internally or by contracting out to specialist organisations.

12. Appendix I

Literature review of the Severn-Thames Transfer.
Mann, R.H.K. & Bass, J.A.B. (1995)

EXECUTIVE SUMMARY

This project on the proposed Severn-Thames water transfer had two initial objectives:

to review literature on the ecological impacts of water transfer schemes,
to identify Key issues relating specifically to the Severn-Thames scheme and to scope appropriate studies to investigate these issues.

The literature review revealed an abundance of general papers on potential ecological effects of water transfers, both on the donor and the recipient river. However, there were few documented case studies in which causal effects were clear. Many schemes involved the transference of water volumes far greater than those envisaged in the Severn-Thames scheme. Some useful information was obtained from accounts of water resource schemes other than those involving inter-basin transfers.
The transference of plant and animal species not already present in the recipient river was described in some papers from North America and South Africa. Other papers emphasised the changes in physical habitat associated with a modified flow regime, together with some observations on floral and faunal changes. No papers described the ecological consequences of mixing waters with different chemical constituents.
The key issues relating to the Severn-Thames transfer are based on information gleaned from the scientific literature plus ideas developed in consultation with IFE colleagues.

The Key Issues are:

Changes in the water chemistry.
Changes in the flow regime and temperature.
Movement of sediments.
Transfer of algae and invertebrates.
Development of lentic populations of algae and nutrients in the Thames-side reservoir and their transference to the river.
Changes in micro-habitat distribution, growth and survival of newly-hatched fish.

The sub-projects within the overall scoping exercise are being developed separately and remain to be integrated into a future research strategy.

13. Appendix II

The NRA Severn-Thames Transfer Project: Phase 1 - An Assessment of the Effect of Mixing of Source Waters on the Chemical Composition.

House, W.A., Talbot, J.D.R., Smith, J.T., Sadak, R. & Lawlor, A.J. (1996).

CONCLUSIONS

Changes in the chemistry of these waters during mixing are generally small for the major ions and this is predicted from theoretical calculations from WATEQ*. For the trace metals the effects appear to be greater for certain elements, noticeable for amphoteric metals aluminium/zinc and for the transition metals copper/nickel/vanadium. It must be emphasised that these results only pertain to one set of mixing. The theoretical calculations during mixing experiments revealed a shortcoming of WATEQ - pH must be entered as a separate determinand - in other cases it can be measured and a compromise value was used for these calculations. It is possible however to develop from first principles (mass balance, charge balance and equilibrium constants) a mixed sample - neither of which appear to vary significantly with mixing - and this may improve further the utility of WATEQ in modelling such a system.

To summarise, the chemical changes which occur are either predicted by WATEQ to a fairly good degree or - for some of the metals - they can be rationalised from a knowledge of their inorganic chemistry. This work has looked at mixing waters direct from the river and so the effect of storage of incoming waters before addition to the River Thames - a postulated part of the Severn-Thames transfer project remains an unknown quantity.

* WATEQ - a chemical speciation program used to calculate ion balances and all major thermodynamic equilibria both in solution and mineral phases. The program version used determines the potential stability of over one hundred chemical entities in water. Data on total calcium, magnesium, sodium, potassium, alkalinity (as bicarbonate), sulphate, chloride, nitrate, dissolved oxygen, silica, phosphate and ammonia were used. In some cases measurements of iron, fluoride, manganese, borate and aluminium were also available.

14. Appendix III

The Severn-Thames Transfer Project: Phase II - Chemical Interactions of Transferred Sediment with the Host Water.

Talbot, J.D.R., House, W.A., Irons, G.P.,Lawlor, A.J. & Clarke, K.J. (1997).

EXECUTIVE SUMMARY

The primary purpose of the work carried out at the IFE River Laboratory on behalf of the Environment Agency (formally the NRA) Thames Region was to investigate the potential effects of sediment involved during the transfer by pipeline of water from the lower reaches of the River Severn into the upper River Thames. As part of this project samples and *in situ* measurements were taken at sites from either end of the proposed pipeline, namely at Haw Bridge on the River Severn (the extraction site) and at Buscot on the River Thames (the host site for the transfer). This was done for each of four seasons in the year 1996-7 and experiments were carried out to determine the potential effect of sediment influx during transfer on aqueous chemistry of the host water. This comprised adding sediment extracted from River Severn water to unfiltered River Thames water and monitoring changes in chemical composition over a period of 24 hours. The relative volumes of water from which the sediment to host water was 50:1 to magnify changes in solution composition.

Parameters considered in this work include 10 major ions, 13 metals, the particle size, mineral components and biological composition of the sediment and the organic content of the solution. From this, together with the previous work carried out on the mixing of River Severn and River Thames water (IFE Report No.T04073o7/1), it has been possible to predict potential changes in the concentrations of chemical species which may occur once water is transferred and this is summarised in Table 1 on page 13. This predicts that, if complete mixing of incoming water occurs and adequate dispersal of transferred sediment is achieved, the concentrations of most species should be similar to that in the unmixed River Thames assuming the defining chemical equilibria are relatively unaffected. Exceptions to this may be barium which could be expected to increase on transfer and certain other trace metals e.g. copper, nickel, manganese and zinc which may exhibit unpredictable behaviour.

The complexity of the chemistry involved in these solutions, comprising many different species, combined with the lack of information regarding previous inter-riverine transfer projects, has also required that predictions have been primarily based on an interpretation of the underlying aqueous chemistry - specifically concerning the equilibrium speciation of solutions with respect to pH and oxygenation (strictly redox potential) - rather than on direct comparisons with other schemes. Prediction of the rate at which solutions approach

equilibrium is more difficult. This is because information on the mechanisms involved in many important chemical reactions in natural waters - for example on iron(II) oxidation by atmospheric oxygen - is limited and extrapolation of rate orders derived from experiments on pure laboratory solutions may not be justified. This therefore precludes accurate prediction of chemical kinetics including estimations for the time for equilibrium to be achieved.

Changes in solution concentrations immediately after mixing depend on the pH and degree of oxygenation of the water - both of which decrease presumably as a result of respiration due to the organic content in the sediment; however in the experiments pH and oxygen concentration appeared to re-establish a more equilibrium value within 24 hours. Considering that in the real situation of water mixing after pipeline transfer the sediment content of the water will be of the order of 1/50 of that of these experiments, changes in pH and oxygenation after mixing would be considerably smaller and the time for re-equilibrium correspondingly less.

The role of micro-organic species in each river was also considered in this work using information supplied by both Environment Agency regions. Both rivers appear to be relatively free from micro-organic contamination with no species recorded in more than a minority of samples. The most commonly found anthropogenic contaminants in the source water (River Severn), such as simazine, atrazine and lindane also tended to be found in the host Thames water. Therefore the injection of high levels of such material as a result of transfer appears unlikely on the evidence considered. It is recommended however that those compounds at present determined in the River Severn but not in the River Thames should be included in the future monitoring of the River Thames. This will provide useful background information to assess future water quality changes.

The chemical nature of the two waters appear largely similar (as discussed in the previous report - T04073o7/1), with a possible exception during winter months, when high flow rates may cause the River Severn to lose some of its hardwater character because of dilution with softer water from the headwaters - unfortunately it has proved impossible to investigate this during the study because of the lack of rainfall in the winter of 1996-7. The experimental work carried out during this period did however show a high release of some metals which cannot be explained from the aqueous solution chemistry, especially manganese, copper, cadmium, & zinc. This is mirrored to a certain extent by a change in some amphoteric metals - compare aluminium & titanium - but not for 'conservative' metals (e.g. strontium and lithium) or the major ions, and the strange behaviour of this sample may be due to accumulated particulate debris of anthropogenic nature washed in by heavy rains after a long dry spell and which may also explain the high biodiversity (see electron micrographs) in the sediment. Therefore the observed changes in the chemistry of these metals in this sample may be anomalous and have not been included in the discussion.

It was found that sediment collected from Haw Bridge achieved a constant value for suspended solids (3-4 mg/l) after about 4-6 hours; most of the remaining material was still in suspension after 5 days and is presumably colloidal material which may be explained by the high clay content of the sediment. Given that the addition of sediment to the host water appears to have little permanent effect on the solution chemistry, the question of provision of settlement ponds is likely to be dictated by other factors and any benefit to water chemistry would be accomplished with a relatively small settlement time.

In conclusion, there is a general similarity in chemical composition of the two rivers, as described by parameters such as mineral saturation, pH and dissolved oxygen concentration of the solutions investigated. This infers that interactions with the sediment from the River Severn - whether equilibrium is achieved or a more complex situation exists between sediment and water - should also be similar whether the bulk water is River Severn or River Thames water. Therefore permanent changes in the inorganic chemistry as a result of water transfer should be expected to be relatively small except for the few species outlined in Table 1; the reasons for these changes are explained more elsewhere in this text. An exception to this may be during conditions which temporarily perturb the solution chemistry away from equilibrium such as occurs in storm episodes or pollution incidents.

15. Appendix IV

Zooplankton Interactions in the River Thames (Literature Review and Sampling Proposals).

Bass, J.A.B & May, L. (1996)

EXECUTIVE SUMMARY

This study addresses the role of zooplankton in large rivers, considering the trophic links with phytoplankton, other invertebrates and young fish. It also evaluates the potential role and importance of zooplankton in the middle reaches of the River Thames.
A zooplankton sampling programme was presented in the Interim Report (Bass & May, 1996).

Main conclusions of the literature review -

Rotifers are often mentioned in studies on the zooplankton of running waters, however, in most cases, the sampling strategies used have been designed, primarily, for the study of the larger crustacean zooplankton. In all studies which have considered rotifers, this group had the greatest potential for influencing the phytoplankton-zooplankton dynamics. However, there are few references which assess the role of rotifers in controlling phytoplankton abundance and species composition in large rivers.

Planktonic copepods, within riverine situations, are represented predominantly by the juvenile stages (copepodites and nauplii). With a few notable exceptions, planktonic cladocerans appear disfavoured by riverine conditions and frequently occur in comparatively very low population densities for much of the year.

Waterbodies connected to rivers, with similar water chemistry and nutrient status, frequently maintain higher phytoplankton and zooplankton populations through the summer, indicating the potential for greater plankton development in rivers should water retention time increase.

The overriding influence of discharge on plankton density is widely reported in the literature, with plankton development inhibited or diluted as retention time decreases with increasing river flows. The role of "dead zones" or "storage zones", with respect to phytoplankton within river channels, contributing to the delay of downstream displacement, has been demonstrated in a range of rivers in Britain.

Recent studies on the habitat utilisation and gut contents of juvenile fish indicated that zooplankton contribute a sequence of prey increasing in size, as the fish grow, with rotifers providing the main prey in the first few weeks after fish absorb their yolk sack.

Future river regulation:
implications for zooplankton trophic interactions in the River Thames -

Several scenarios were considered on the basis that river regulation and augmentation flows to the River Thames may change in the future.

1) We conclude that river regulation or augmentation of river flows in autumn will have no appreciable impact on river zooplankton, as it is universally reported to occur at low population densities at this time.

2) During autumn and winter months with, typically, high river flows and low temperatures, augmentation flows containing a significant algal component are not considered likely to promote the development of river zooplankton.

3) Spring diatoms, released from a reservoir, would be readily utilised and transferred to other trophic levels including zooplankton in the River Thames, however, releases of the larger algae, such as filamentous blue-greens in the summer may have consequences for other trophic levels, such as filter feeding macroinvertebrates, rather than the river zooplankton.

4) Reductions in summer discharge within the middle reaches of the River Thames may result in an upstream extension of the plankton community characteristic of the lower reaches, where retention time is greatly increased. Based on studies in other rivers, changes to the zooplankton would include an increase in the crustacean component.

5) During spring and early summer the discharge of augmentation flows that substantially reduce retention time within the river will inhibit plankton development, whilst the discharge of intermittent augmentation flows may interrupt the sequence of plankton development and act as "re-setting" events, where populations are diluted sufficiently to promote repeated cycles of phytoplankton development followed by zooplankton development.

.In order to establish the current situation with regard to River Thames zooplankton, the following sampling regime was proposed in the Interim Report (Bass & May, 1996) -

> Relatively large sample volumes of river water should be collected from discreet depths with a small battery-powered submersible pump.
>
> Monitor separately the abundance of small abundant taxa (eg rotifers and Protozoa) and large comparatively infrequent taxa (eg cladocerans and the young stages of copepods).
>
> Examine contemporary and seasonal differences in zooplankton at 5 river sites.
>
> Examine spatial differences in zooplankton populations at 2 river sites, considered of relevance to grazing pressure on phytoplankton and food resource availability to other dependant fauna.

16. Appendix V

Zooplankton Interactions in the River Thames (results and conclusions from sampling in 1996).
Bass, J.A.B., May, L., Esteban G.F. & Collett, G.D.(1997)

EXECUTIVE SUMMARY

This report describes a study undertaken by the Institute of Freshwater Ecology on the zooplankton of the middle reaches of the River Thames from April-November in 1996. Seasonal changes in the abundance of individual taxa and the plankton community composition are described. The five sampling sites on the middle River Thames were at Inglesham (NGR SU20409840), Radley College Boathouse (NGR SU53809880), Abingdon Lock (NGR SU50609700), Wallingford Bridge (NGR SU61008950) and Caversham Lock, Reading (NGR SU72107420).

Parallel work on the available biological data in the middle reaches of the River Thames, descriptions of within-river habitats, diet studies on young fish and water chemistry characteristics relating to a possible Severn-Thames transfer are reported elsewhere and an overview of the conclusions from these studies will be the subject of a separate report. The zooplankton study included collection of data on water temperature, water clarity, suspended chlorophyll$_a$, the microbial community, rotifers, copepods and cladocerans. The microbial community was enumerated in a range of size classes and functional categories. The relative scales of abundance within the planktonic microbial food webs present were typical of eutrophic freshwaters. Although 40 species of ciliates were recorded they were always the least abundant component of the microbial community at the five sites. An overall downstream increase in rotifer abundance occurred in parallel with increases in

chlorophyll$_a$ concentration in the river water. This suggested that rotifer abundance was controlled primarily by food availability, as chlorophyll$_a$ levels reflect algal biomass, and most rotifers feed on algal cells. Preliminary calculations of grazing rates (section 5.8.1) indicate River Thames rotifers removed only about 4% of the algal biomass each day in 1996 and would have had little effect on overall phytoplankton abundance. However it is stressed that these extrapolations from laboratory clearance rates remain imprecise.

Earlier analyses of fish guts (Mann, *et al*, 1995) confirmed that rotifers were an important food source for larval fish in the River Thames, therefore two rotifer sampling methods were compared. These were (1) a settlement method using 500ml water samples which recovered all rotifers of significance as phytoplankton grazers; (2) a size-selective sieving method utilising 20 litres or 5 litres of water which was suitable for quantitative assessment of the larger rotifers and less frequent micro-crustaceans ingested by young fish. In May and June the cross-channel population densities of large rotifers showed varying patterns in relation to depth and location within the river channel at Radley and Wallingford. There were very few copepods and cladocerans recovered from the River Thames zooplankton subsamples at all five sites and on all dates in 1996. Contemporary data on the gut contents of young fish at the Radley site (Mann, *et al.*, 1997) indicated cladocerans were more numerous in other habitats within the river.

Taking account of previous studies on other rivers and the results from this seven month study of the River Thames zooplankton, it was established that a seasonal and downstream sequence of rotifer population development occurred which reflected changes in phytoplankton biomass but not algal cell numbers.

In the context of a possible Severn-Thames transfer, studies on water mixing (House *et al.*, 1996) and the potential transfer of suspended sediment from the Severn (Talbot, *et al.*, 1997) concluded there would be no major changes in plant nutrients or elevated concentrations of pollutants but uncertainties remain with respect to the intermittent transfer of trace pollutants. On the basis that a Severn-Thames transfer would reduce reach-retention time downstream from the input point at Buscot it is concluded that the River Thames plankton community would be altered in the close vicinity of Buscot. In order to predict changes to the plankton dynamics additional data are required on the growth and loss rates of planktonic organisms and the hydrological characteristics of the river channel at Buscot. The impacts of a Severn-Thames transfer on the plankton further downstream would be small owing to the scale of increased channel size and river discharge around Oxford.

It is recommended that future research (which might include collaboration between the Institute of Freshwater Ecology, the Institute of Hydrology and the Environment Agency) should focus on further elucidation of the phytoplankton loss-processes in the middle reaches of the River Thames. The primary aim being to optimise summer discharge management in relation to water quality, whilst safeguarding components of the River Thames food web regarded as beneficial to conservation and fisheries.

The main areas identified as requiring further research are :

reach-retention time within the middle reaches of the River Thames (particularly between Buscot and Oxford) under a range of hydraulic conditions relevant to operation of a Seven-Thames transfer.

characteristics and population densities of zooplankton which would be transferred from the River Severn to the River Thames, during operation of a Severn-Thames transfer.

model the impacts of grazing on dominant phytoplankton taxa by planktonic rotifers in the middle reaches of the River Thames.

calculate population growth rates of the planktonic rotifer species which are important as algal grazers and food for young fish in the middle reaches of the River Thames.

17. Appendix VI

River Thames 0 Group Fish Gut Contents Study, 1995.
Mann, R.H.K., Collett, G.D., Bass J.A.B. & Pinder, L.C.V. (1995)

EXECUTIVE SUMMARY

This project on the diets of 0 group fish in the River Thames at Abingdon had three main objectives:

a) Assessment of between-species, between-habitats and between-season changes in fish diets,
b) Comparison of the results from the River Thames with those of similar studies by IFE in the River Great Ouse,
c) Recommendations for future studies that would increase the robustness of the results of the River Thames studies.

The diets were analysed for five fish species: roach, gudgeon, chub, silver bream, perch. Although differences were observed in the diets of single species caught in different plant habitats, these were small compared with those observed between species. In general, the diet of each species changed from small prey (mostly rotifers) to larger items (mostly microcrustacea and insect larvae) as the fish grew in size. However, the larger 0 group perch and gudgeon contained many copepods, whereas the other fish species contained more cladoceran taxa. The most striking difference between species was that, in July, the roach switched from an invertebrate diet to one dominated by the detritus (aufwuchs) that accumulates on the underwater surfaces of plants.

The results from the River Thames show a close parallel with those of the same fish species in the River Great Ouse. This similarity adds weight to the reliability of the Thames results, even though they are based on a small number of fish per sample. However, the Great Ouse data show marked differences in the numbers and types of prey eaten in different years, which presumably reflects changes in the availability of different taxa.

Further studies to increase the reliability of the results are: a) examination of more of the fish caught in the 1995 study, b) collection of additional samples to determine the extent of year-to-year fluctuations. For the greatest understanding of fish-prey dynamics, such studies should be accompanied by assessments of prey availability (planktonic and non-planktonic invertebrates).

18. Appendix VII

River Thames 0 Group Fish Gut Contents Study, 1996. Mann, R.H.K., Bass J.A.B., Pinder, A.C., Ibbotson, A. & Pinder, L.C.V. (1996)

EXECUTIVE SUMMARY

This study of the diets of 0 group fish in the River Thames at Radley had the following principal objectives:

a) Assessment of between-species, between-season and between-year changes in fish diets;
b) Comparison of fish gut contents with the results of the 1996 zooplankton study at Radley;
c) Comparison of the results with IFE experience in other rivers;
d) Recommendation for future sampling strategies that would increase the robustness of the 1995 and 1996 studies on the River Thames.

The diets were analyzed for four fish species: roach, gudgeon, dace and bleak. The first two species were included in the 1995 study at Abingdon, but not the last two species. The Radley results showed no major differences from those from Abingdon; the importance of zooplankton drift to the diet of newly-hatched fish was re-emphasised, as

was the value of aquatic plants along the river margins as feeding zones and refuge from the main river current. As in 1995, the roach switched to a detrital diet (aufwuchs) in July. The bleak was the only other species that utilized this food source, but it did not do so to the same extent as the roach.

The growth rates of roach and gudgeon were slower in 1996 than in 1995 and, as fish size can affect diet composition, this made some differences to the seasonal changes in diet composition. However, although minor differences were observed, the overall pattern of feeding for both species in the two years was much the same.

The correlation between zooplankton densities and fish diets was not clear cut. However, there was some evidence that lower zooplankton densities occurred in the surface waters along the river margins than elsewhere in the river. This may reflect feeding pressure by the 0 group fish and a possible limitation in food resources. The switch by roach to a detritus diet, and the disappearance of gudgeon from the late summer samples may also reflect a change in feeding pattern caused by food supplies becoming limited (the last sample of gudgeon obtained contained many fish with empty guts).

The 1995 and 1996 River Thames studies, together with past and recent studies on the River Great Ouse underline the great importance of aquatic plants as feeding and refuge areas. Any diminution in these areas could have a major impact on the distribution, growth and survival of 0 group fish and a consequent reduction in the numbers surviving to become adult fish.

Further studies of the diets of 0 group fish in the River Thames are only likely to emphasise the conclusions already reached. However, it would be useful to know more about the degree of between-year variation so that any changes resulting from an alteration to the river's hydrology can be placed in context.

19. Appendix VIII

Habitat Studies in the River Thames: in Relation to a Severn-Thames Transfer.
Bass, J.A.B. & Collett, G.D. (1997)

EXECUTIVE SUMMARY

On the assumption that a possible Severn-Thames transfer would involve discharge of water from the River Severn into the River Thames near Buscot the present study consisted of an investigation of the habitat structure within the River Thames from St John's Lock (NGR SU222991) to below Grafton Lock (NGR SU278989). Preliminary modelling results by the Environment Agency indicate the transfer would be needed about

one year in six for an average of five months, most commonly in July-November. In major drought years the transfer would be required earlier (May or June) and in some years it might be required after November.
In the present study the extent of major physical habitats, together with their stability over time and their significance for the aquatic fauna and flora were considered.

Three main aspects were investigated:

The historical information provided by the River Thames Soundings Data.

Application of the River Habitat Survey (RHS) methodology.

Mapping of water depth, submerged plants and fine sediment, together with a description of prevailing flow conditions during periods of low discharge.

The River Thames Soundings hydrographic survey maps revealed that there had been little movement of the river channel in the general area of Buscot since 1938. At a few locations bank erosion and deposition had resulted in the channel moving from a few metres to the full channel width. In most areas the patterns of water depth along the river channel have remained very similar over several decades. The river channel stability has been maintained despite peak annual flood discharges averaging several thousand megalitres day^{-1}. Therefore in the context of the proposed Severn-Thames transfer it is considered that the River Thames channel and the extent of major physical habitats would remain stable.

Characteristics of five River Habitat Survey sites near Buscot were compared with similar river sites in England and Wales in the RHS database. This established that the mean annual discharge of River Thames at Buscot was at the lower end of the range represented by 86 lowland sites with similar physical attributes.

The within-river habitat survey confirmed that water depth was >2m in about one quarter of the river channel area and aquatic plants were absent from 90% of this deep zone but overall they occupied about 20% of the channel area. No species of emergent plant occupied more than 1% of the river channel. A deterioration in the underwater 'light climate', associated with increased water depth or higher turbidity, would reduce the area of submerged plants and change the proportions of different habitats available for river fauna. However detailed information is lacking on the settlement of fine sediment in the River Thames at varying river discharges therefore conclusions on the impacts of fine sediment transferred from the River Severn, via proposed settlement lagoons, were speculative.

The theoretical mean water velocities in the River Thames at Buscot were predicted for a series of low river discharge values using the average volume of water present within the river channel. Addition of 200Ml per day from the River Severn would more than double the discharge prevailing in late summer however the impoundment of the River Thames between weir structures tends to buffer velocity changes. At higher baseflow discharges, when velocities restrict the spatial distribution of young fish in the River Thames, operation of the proposed Severn-Thames transfer during May or June would increase downstream displacement of fish fry and impose sub-optimal feeding conditions.

In conjunction with the parallel review of biological data (Furse, *et al.*, 1997), it was concluded that significant gaps in information remain. It is recommended these are addressed prior to the formulation of conditions under which the proposed Severn-Thames transfer would operate.

Recommendations:

Establish precise relationships between the hydrological conditions in the River Thames and velocity changes at low river discharges to assist the prediction of impacts arising from the proposed Severn-Thames transfer.

Investigate the settlement characteristics of transferred sediment to assist the formulation of guidelines on the maximum levels of suspended sediment permitted in any water transferred from the Severn.

Obtain data on the seasonal availability of invertebrates within the aquatic plant stands to provide greater understanding of interactions between submerged plants, invertebrates, plankton and juvenile fish recruitment in the River Thames.

20. Appendix IX

Severn-Thames Transfer: A Review of Biological Data
Furse, M.T., Welton, J.S., Reynolds, C.S., Symes, K.L. & Collett, G.D. (1997)

EXECUTIVE SUMMARY

General

The overall aim of the study was to assemble existing data on the fish, macro-invertebrate, macrophyte and algal assemblages of the River Thames for assessing the possible impacts of any Severn-Thames transfer schemes. The principal impacts of the transfer scheme are considered briefly for each group and future sampling schemes are recommended which should allow the impacts of any release of augmentation water to be evaluated.

The data were held in a variety of different formats and different approaches were adopted for each of four major taxonomic groupings. In the case of macro-invertebrates and macrophytes, available data were incorporated in a Microsoft Access 7 relational data-base supplied to the Agency. Key features of the data are provided in the text of chapters 3 (macro-invertebrates) and 4 (macrophytes). The fish and plankton data and comments on their significance are presented in text form in chapters 2 (fish) and 5 (plankton).

Fish

The fish chapter contains, a summary and interpretation of the main findings of all known surveys of fish stocks. This is supported by a set of summary information from each significant report produced on the section of river of interest and by key tables and figures from these reports. The latter is held in Volume 2 - Appendices.

There is a considerable variation in the times and temperatures associated with the spawning of the main fish species. Adult fish have a greater range of habitat tolerance than juvenile fish and studies have shown that spawning habitat is more precise and thus of greater importance than feeding and refuge habitats. Variations in spawning characteristics arise due to local conditions, to repeat spawning (eg gudgeon and ruffe), to older fish spawning earlier than smaller fish (eg roach) and to intra-specific variation between years due to environmental factors.

Water velocity is an important factor in determining the effect of the transfer on the fish populations. Flows at and immediately after spawning could determine the year class strength of many species in the Thames. Critical velocities are related to fish size and water temperature. These critical values are velocities which displace at least 50% of the larvae in three minutes. Preferred velocities are much lower. Velocities >2 cm s^{-1} can lead to displacement of newly hatched fry. Only 3% of the area of the Thames has flows of less than 2 cm s^{-1} during the time when small fry are present and these areas may be vital to the success of certain species.

Good marginal habitats for fry are shallow and gently sloping with macrophyte cover and marginal vegetation. An increase in water level is likely to cause flooding of the marginal vegetation where fry can take refuge. The augmentation of flow is likely to occur during mid to late summer which means that late spawners are more likely to be affected. Even though the areas of refuge may not be affected, it is likely that there will be some impact on distribution because fry venturing into stronger currents will be carried further downstream.

The importance of aquatic vegetation as feeding and refuge areas for fry is emphasised. Macrophytes in general, and *Nuphar* in particular, can be damaged by high flows. Thus any changes in the hydrological regime of the Thames that damage marginal plants would be detrimental to the feeding, growth and survival of young-of-the-year (0 group) fish. The abundance of food may be affected by increased turbidity resulting from increased flows. Phytoplankton production may be reduced due to the lower light levels. This in turn would reduce the biomass of the zooplankton on which the 0 group fish are feeding and possibly make food more difficult to find.

The principal impact of sedimentation on fish occurs during the egg and early larval stage. For early spawners, there is unlikely to be any effect of water transfer as the fry will have passed the early larval stage. For late spawners, the increased velocity may redistribute fine sediment and this may settle on fish eggs in low flow areas reducing hatching success.

The water that is transferred from the Severn will undergo a period of settlement before being introduced into the Thames. Therefore, the augmentation process is unlikely to increase the sediment load in the Thames. There may be local redistribution of the natural Thames sediments over a very short time period and this may affect the feeding rates of some fish species. However, routine maintenance dredging is likely to have a more substantial impact on the fish populations.

Marked decreases in dissolved oxygen (DO) concentrations could cause fish kills. If the transferred water is well aerated then any problems resulting from inadequate DO concentrations will be eliminated in the transferred water.

The temperature of water from the Severn is expected to be similar to that of the Thames when it is released into the river and thus should not have any implications to spawning, recruitment or growth of fish.

Although not known categorically, the probability of fish parasites or pathogens being transferred is high but the probability of there being effects on the fish communities of the Thames is considered to be low.

The species compositions of the Severn and the Thames are very similar. There is some concern over the potential introduction of zander which occur in the Severn at the abstraction point. It is reported that some stocking of elvers from the Severn has already taken place in the upper Thames so the transfer of this species is unlikely to be a problem.

The normal expectation is that any changes in fish population structure will become evident at the fry stage first. For this reason, the surveys of fry and juvenile fish already being carried out annually for South West Oxfordshire Reservoir Proposal should be continued. In addition, factors affecting fry survival should be examined. Surveys of larval and juvenile habitat should be carried out to ensure that these areas are conserved. Studies on the food availability, feeding and growth of fry should be maintained. In order to more closely monitor the immediate impacts of Severn-Thames transfer, similar fry and juvenile fish surveys should be initiated in the reaches most likely to be affected, including a control reach.

Macro-invertebrates

The macro-invertebrate data-base holds information on 379 individual samples containing, between them, information on 487 distinct taxa. The specific habitat requirements of most of these taxa were analyzed. The 487 taxa included 14 with national conservation status.. Brief details of the national and local distribution, habitat preferences and ecology of these 14 and two other rare taxa are given. Detailed macro-invertebrate data are presented in Volume 2. The ecological quality of the study reach was generally good, as assessed by applying RIVPACS procedures to the water industry macro-invertebrate samples collected between 1977 and 1995. However, available data suggested that the section of river immediately downstream of the probable water release point near Buscot is taxon-poor.

This section of river was last sampled in 1977 following dredging, severe drought and flooding.

Habitat preferences and zonation patterns of macro-invertebrate taxa were examined. More taxa had apparent preferences for the section of river downstream of Oxford than upstream, macrophyte habitats rather than in non-vegetated marginal and midstream zones, and floating vegetation rather than either emergent plants or gravel substrata.

Most macro-invertebrate species are resilient to gradual change because this is the normal seasonal and annual pattern. Sudden changes in discharge are more likely to have a deleterious effect, particularly upon those species living at the waters' edge, including those associated with marginal and floating macrophytes.

Increased sediment loads and turbidity could have a range of direct and indirect impacts on aquatic macro-invertebrates. The accumulation of fines may impact habitat diversity and quality directly on river bed or indirectly through its impact on plants. Whereas most macro-invertebrate species are more likely to be disadvantaged than favoured by increased siltation and turbidity, some filter-feeding species are likely to benefit.

No discernable impacts upon macro-invertebrates are expected resulting from temperature differences in the Thames and the released water, which are anticipated to be small. Furthermore, most macro-invertebrate taxa have a relatively broad range of tolerance to naturally occurring chemicals and no substantial impacts are expected from the differences in normal baseline chemistry of the Severn and Thames. Studies have also showed that both rivers appeared to be relatively free of micro-organic contamination.

It is feasible that specimens of macro-invertebrates may be transferred from the Severn to the Thames but this is not likely to be a problem. The zebra mussel, *Dreissena polymorpha* (Pallas), which occurs in the Severn, is a potential nuisance species but it also occurs in the lower Thames and does not appear to have colonised the St John's to Caversham section of the river. Transfer of disease is not considered to be an important issue.

To demonstrate that the ecological quality of the study section of the river remains within the normal temporal range, routine monitoring should be maintained at all current Agency sites with an existing time series of data of at least five years. In addition, as a matter of urgency, routine monitoring needs to be instigated in the section of river between Buscot and Grafton Locks, immediately downstream of the probable water release point. New monitoring sites are also recommended between Grafton and Radcot Locks and between Shifford and Northmoor Locks.

To demonstrate that faunal diversity is maintained during years of augmentation, it is recommended that a regular habitat specific sampling programme is established with faunal identification at species level. Ideally this should be co-ordinated with the recommended macrophyte sampling programme.

Macrophytes

Few macrophyte surveys have been undertaken on the Thames. The only available information comprises a longitudinal survey from St John's to Benson's Lock, undertaken by the Freshwater Biological Association (FBA) in 1978, and two River Corridor surveys conducted by Ecosurveys Ltd in 1992. The FBA data are presented in the main report. The key sections of the River Corridor Surveys are presented in Volume 2.

Twenty-three macrophyte taxa were recorded in the FBA Survey. Some were distributed over the study section of the river. However, others showed evidence of longitudinal zonation. The break point in the zonation of many taxa was at, or about, Godstow Lock, near Oxford.

The main concerns arising from the proposed transfer are the passage of seeds, turions or other propagules, the opportunity for spawning vigourous novel hybrids and for the carriage of pathogenic organisms. There is a small risk of a virulent, invasive spread of a new hybrid, or of a die-back of existing flora through the introduction of a new strain of pathogen.

Macrophyte assemblages should be monitored in four reaches; St John's, Buscot (two sites), Grafton and Shifford. Sampling sites should be at or near the existing or recommended routine macro-invertebrate sampling sites in order that results can be cross-referenced. The recommended sampling methodology is the Mean Trophic Rank (MTR) method. It is recommended that the FBA's 1977 survey is repeated before the first release of augmentation water and thereafter at five-yearly intervals to co-incide with the habitat specific macro-invertebrate sampling.

Plankton

The appraisal of the impact of water transfer upon the planktonic communities of the Thames was supported by a series of Microsoft Access files whose current names and contents are listed within the chapter.

A brief review of the ecology of phytoplankton populations in large rivers indicated that no substantial risk to the algal quality of either river or abstracted water arises from the proposed transfer. Whatever may be the objections to such a transfer, the likely impact on the phytoplankton of the Thames is not one of them.

The impact on zooplankton is not considered a major issue, although knowledge of what species are present, or likely to be present, in British rivers is less well-developed than that of the phytoplankton.

An adequate basis for determining the effects of transfers of Severn water on the phytoplankton of the Thames could reasonably be established with a fortnightly programme of samples, which should be instigated before any engineering work is implemented.

The principal variables that should be monitored are the biomass of Severn phytoplankton transferred, sampled at or just above abstraction point and in the aqueduct at the point of discharge into the Thames, and the biomass of Thames phytoplankton above the point of discharge, 1-2 km below the point of discharge and at stations approximately 5km, 10km, 25km and 50km further downstream. Zooplankton should be enumerated from larger volumes of the same water.The overall aim of the study was to assemble existing data on the fish, macro-invertebrate, macrophyte and algal assemblages of the River Thames for use in assessing the possible impacts of any Severn-Thames transfer schemes.

The data were held in a variety of different formats and different approaches were adopted for each of four major taxonomic groupings.

In the case of macro-invertebrates and macrophytes available data were incorporated in a specially devised Microsoft Access 7 relational data-base and this is provided to the Agency as an output of the R&D study. Key features of the data are provided in the text of chapters 3 (macro-invertebrates) and 4 (macrophytes).

The macro-invertebrate data-base holds information on 379 individual samples containing, between them, information on 487 distinct taxa. The specific habitat requirements of most of these taxa were analyzed. Fourteen taxa with national conservation status were recorded in one or more samples. Detailed macro-invertebrate data are presented in Volume 2 - Appendices.

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The fish and plankton data and comments on their significance are presented in text forms in chapters 2 (fish) and 5 (plankton).

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The appraisal of the impact of water transfer upon the planktonic communities of the Thames is supported by a series of Microsoft Access files whose current names and contents are listed within the chapter.

The principal impacts of the transfer scheme are considered briefly for each group and mitigation measures are recommended together with future sampling schemes for monitoring the impacts of any of the release of augmentation water.

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