WATER RESOURCES IN ANGLIA

A SUSTAINABLE STRATEGY FOR
SECURE WATER SUPPLIES AND A BETTER WATER ENVIRONMENT

NRA
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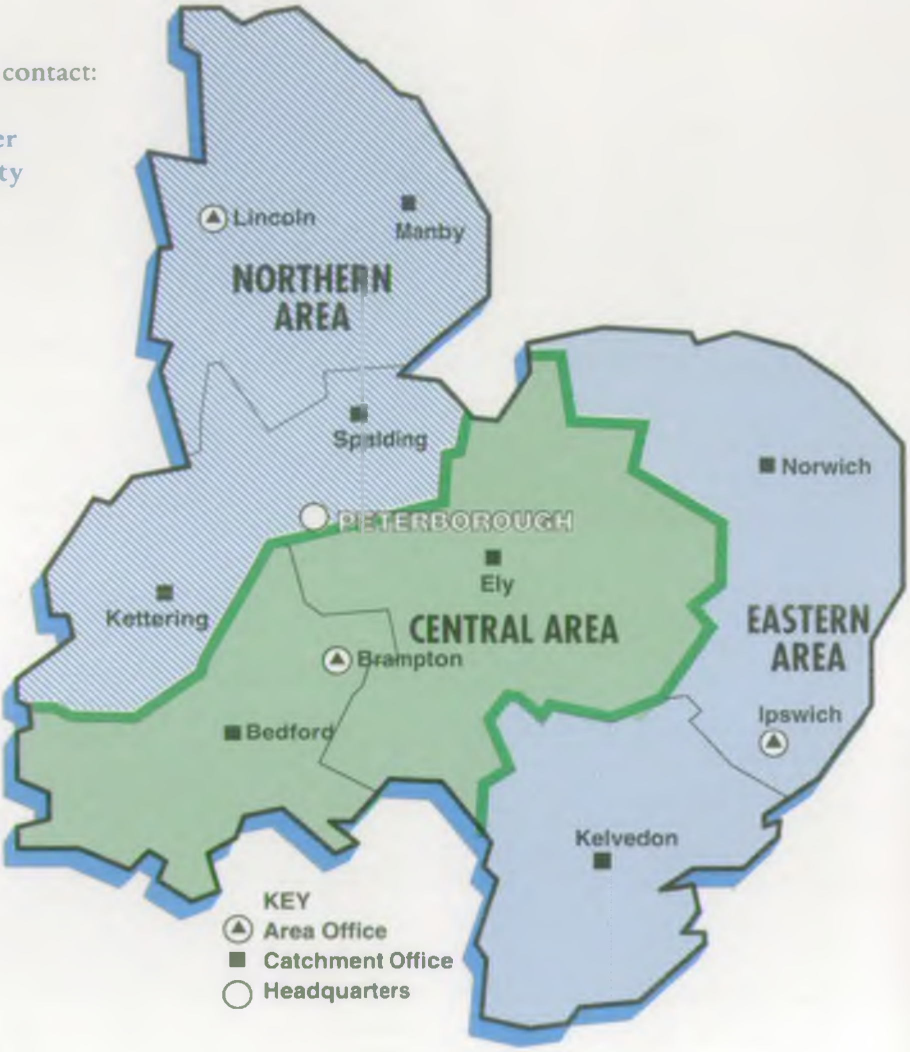

"The National Rivers Authority is committed to the principles of stewardship and sustainability. In addition to pursuing its statutory responsibilities as Guardians of the Water Environment, the NRA will aim to establish and demonstrate wise environmental practice throughout all its functions."

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FOREWORD

Water is vital to life. We are blessed in this country with ample rain - more than enough to sustain a healthy water environment and to meet human needs. But the rain falls unevenly, both in time and place. Our water resources, and the uses we make of them, must be managed sustainably to ensure that water is available, both for people and for rivers and wetlands, in the right quantities at the right times and places, and at the right cost.

This is not a job for the National Rivers Authority (NRA) alone. Water undertakers, industry, farmers, environmental interests, planning authorities and many others have parts to play. What is needed is an overall framework within which all can work to the common good. Our National Water Resources Development Strategy sets out such a framework at the broad national scale. This Regional Strategy deals in detail with the water resources of the Anglian Region.

Our vision of the future

Our rivers and our wetlands are a precious heritage. However, in this Region they are almost totally unnatural because they have been changed by man down the centuries. There is great scope to re-create a better water environment.

However, Anglia has a water problem. In summer evaporation exceeds rainfall. This dries out the soil and depletes water resources. The six million of us who live between the Thames and the Humber rely on a complex water network (part natural, part man-made) to store and distribute winter water both to our rivers and to our taps. A run of dry winters strains that network, as we have recently seen. Such droughts are a feature of our climate, and with a growing population actions are needed to provide security against an uncertain future. Those actions should be planned, not piecemeal; they should give value for money; they should encompass both sustainability and the precautionary principle; they should improve the water environment, not impair it.

The NRA aims to achieve the right balance between the needs of the environment and those of abstractors; or in short:-

Secure water supplies and a better water environment

We see these twin objectives as equally important and we intend to achieve them both.

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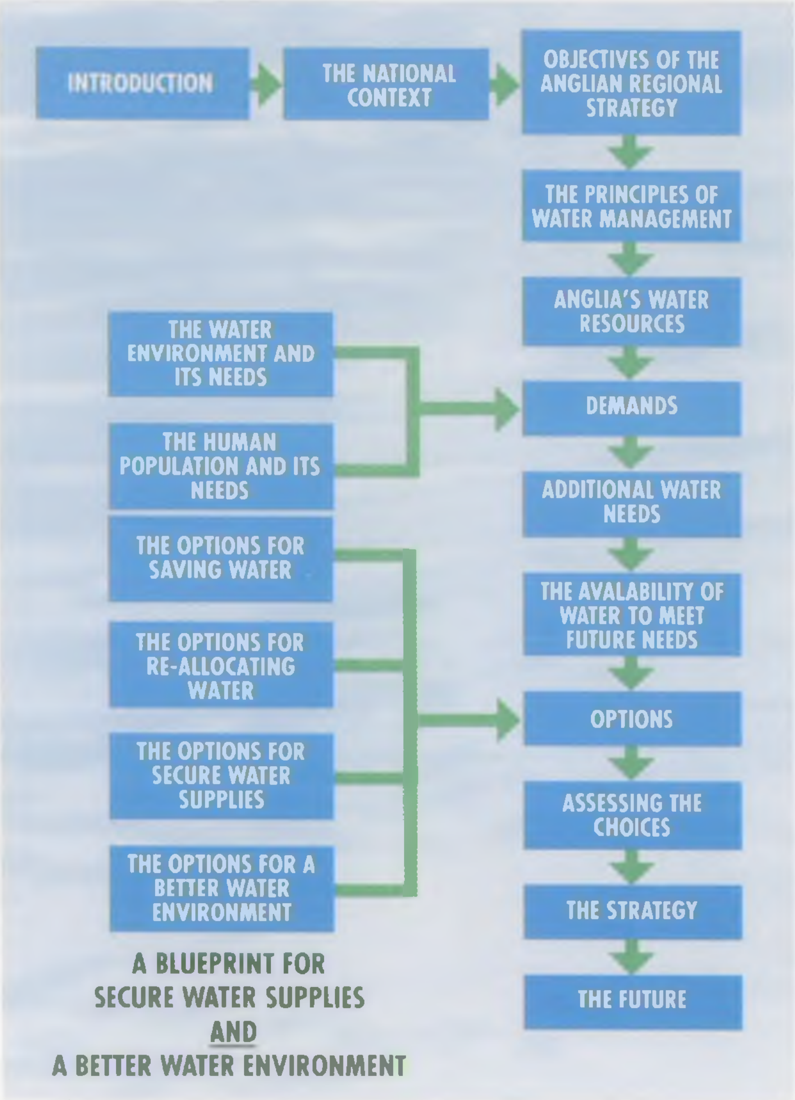

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Chapter 1 - INTRODUCTION

The Anglian Region (Figure 1) is the driest in Britain. It has the fastest growing population and the fastest rising water demands, particularly for public supply and irrigation. Its water environment, though far from natural, is a precious asset.

From 1988 - 1992 Anglia experienced its worst drought in a century of records (Ref 1 and Figure 2). There were hosepipe bans in some areas, more severe restrictions in a few, and local bans on irrigation. Rivers and groundwater levels were low, causing some environmental damage. The fact that almost 6 million people living in the driest part of the country survived such a drought with so little disruption is due to a comprehensive network of water storage and transfers. This network has evolved over the centuries in step with rising water use. It taps into all our major rivers and most of our groundwater resources. It is augmented by transfers from outside the region.

Figure 1 - Major Elements of Regional Water Resource System

Figure 2 - High Rainfall and Dry Periods

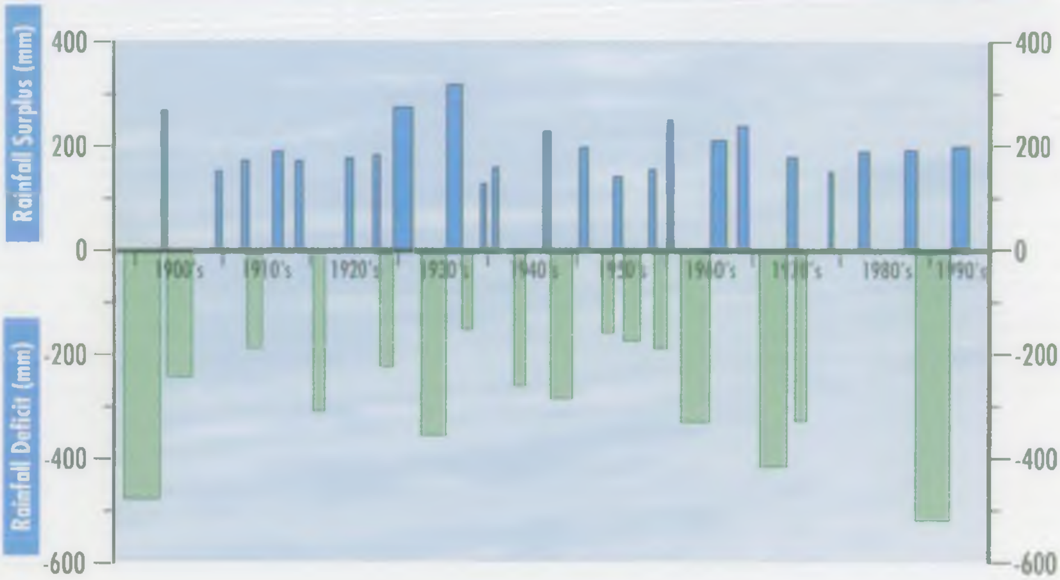


Figure 2 shows that droughts are a regular feature of Anglia's climate. Rising water demands and rising environmental aspirations will not be met during the next drought unless we plan for it now. We must either limit our water use or enhance our water network, or both.

The Anglian Region of the NRA therefore produced, in April 1993, a Consultation Draft of this Strategy (Ref 2). During the four month consultation period 15 meetings were held around the Region, attended by invited audiences totalling over 500. 550 copies of the full Consultation Draft and questionnaire were circulated and 5000 leaflets distributed to raise awareness of the issues and invite comment.

Comments were received at the presentations and at the NRA's consultative committee meetings. Some 72 questionnaires were returned, 43 additional letters and reports were received and 115 organisations and individuals responded. Detailed follow-up meetings were held with major respondents. All respondents are listed in Annexe 1. Annexe 2 provides a glossary of terms.

The full findings of the Consultation Exercise were published in December 1993 (Ref 3.) We are grateful to everyone who contributed. However, the responses were many and varied. Few issues produced a clear consensus view, and in many cases there were diametrically opposite opinions. Clearly it is impossible to act on every individual comment. However, several themes emerged and we have modified this strategy in the light of them.

The NRA's water resources aim is:-
"To manage water resources to achieve the right balance between the needs of the environment and those of the abstractors".

We believe that this strategy now broadly identifies that balance for the Anglian Region, and that it does so in the light of comprehensive public consultation. It is not, however, a tablet of stone. Many of the issues it deals with will always continue to change and we shall review it in a few years time. To that end we will always welcome further views from anyone at any time.

Chapter 2 - THE NATIONAL CONTEXT

THE NRA WATER RESOURCES STRATEGY

In 1993 the NRA published its Water Resources Strategy (Ref. 4). This is not to be confused with the National Water Resource Development Strategy (see below). It is a 'high level' policy document which sets out the legal and institutional frameworks and establishes 66 separate policy statements whereby the NRA will achieve its principal aim to "manage water resources to achieve the right balance between the needs of the environment and those of the abstractors".

This Regional Strategy has been produced in accordance with those policies.

THE NATIONAL WATER RESOURCES DEVELOPMENT STRATEGY

In March 1994 the NRA published its National Water Resources Development Strategy (Ref. 5). This is a broad national overview of current and future water demands, the scope for demand management and the options for water resource development. It is guided by balanced adoption of three fundamental principles; sustainability, precaution and demand management.

The national strategy includes preliminary environmental assessments of major strategic options, and also cost optimisation modelling at national level leading to preferred strategic development programmes for 'high', 'medium', and 'low' demand scenarios. This provides the wider framework within which regional strategies can be developed. For example, it suggests that further export from Anglia to Thames Region may only be nationally economic at high demand forecasts (which are considered unlikely). It puts the date of need for a new strategic resource for East Anglia as between 2006 and 2011 at medium demand forecasts; it identifies the main options for such a resource and recommends early selection of a preferred option.

CHANGING WATER USE

The last year or two have seen a general move towards greater demand management and a downturn, throughout the country, in water companies' forecasts of their future water needs. In some cases, after decades of continuous increase, companies are predicting zero, or even negative, growth. In this region, with its rising population, all companies expect some growth but at much lower rates than before.

This trend is so marked and so widespread as to be a national sea-change in the water supply industry. It has several causes:-

- increase in the public's water consciousness, due partly to the recent drought and partly perhaps to a more general environmental consciousness.
- cost incentives, particularly for industry, to use water more efficiently
- greater enthusiasm for metering domestic use, driven partly by Government's intention to phase out rateable values as the means of charging for water. Metering can save 10% or more of water use.
- increased rates of mains rehabilitation, driven by the water quality requirements of the EC Drinking Water Directive; this has the side effect of reducing leakage when old mains are replaced by new, and
- last but not least, NRA pressure for wise water use.

Some of these causes could be transitory; water consciousness could fade if public perceptions change again, while water companies may not achieve their targets for meters and mains rehabilitation.

Despite these caveats the downturn in demands is likely to have a substantial delaying effect on the need for new water resource developments.

Chapter 3 - OBJECTIVES OF THE ANGLIAN REGIONAL STRATEGY

This strategy is produced by the Anglian Region of the NRA. The NRA does not supply water (that is done by the Water Undertakers), nor control development (that is done by the Planning Authorities). The NRA's role is to manage water resources in such a way as to meet all reasonable needs, both of the environment and of the people.

This Strategy is a framework within which all concerned can operate to achieve that aim - Water Companies, industry, farmers, environmental interests, planning authorities and the NRA itself. We intend it to fulfil the following objectives:-

- To publish best current estimates of the Region's water resources and how they are used.
- To publish best current estimates of future water demands for all purposes.
- To promote appropriate demand management and the wise use of water.
- To define a framework within which water users can plan to meet their needs, as and when they arise.
- To publicise where the NRA will, and will not, allow abstractions of water and on what terms.
- To publicise the scope for improving our water environment, and how this may be achieved (either directly by the NRA, or by others).
- To generate positive attitudes to future change and to ensure that water developments are used as opportunities for environmental improvement.
- To be flexible and robust; the sea-change in demand forecasts is welcome, but we must be able to accommodate any upturn (or further downturn) in demands.
- To be a basis for advice to Planning Authorities as to the implications, costs and timescales of making water available in an environmentally acceptable way; but not a basis for restricting development.
- To achieve a better water environment, as well as secure water supplies.

Chapter 4 - THE PRINCIPLES OF WATER MANAGEMENT

The NRA's vision is of a healthy and diverse water environment, managed in an environmentally sustainable way, balancing the needs of all users. It is our duty to take such action as we consider necessary or expedient to conserve, redistribute and augment water resources, and secure their proper use for the benefit of all users, human and environmental. Specifically, the NRA must, by law (Ref 6.), "have regard" to the reasonable needs of all abstractors and "have particular regard" to those of the water undertakers. It must also "generally promote" and, so far as is consistent with its other duties, "further the conservation" of the water environment.

The duty to secure the proper use of water means achieving the best balance between all the conflicting demands, human and environmental, with due regard to costs and to water quality. In this chapter we set out some of the principles whereby we attempt to do this, and some of the 'ground rules' which underlie the Strategy.

THE NEEDS OF THE WATER ENVIRONMENT

The environment is not an optional extra; a healthy environment is vital to life, and to secure water supplies.

Environmental water needs should be treated as positive demands; not just constraints on other water users but to be met in their own right, and subject to similar considerations of reasonableness and worthwhileness.

SUSTAINABILITY

There is nowadays widespread support, from Government downwards, for the principle of sustainability. There are many definitions of sustainable development, but the prime one is:-

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs". (Ref. 7)

The principle of sustainability is beyond question, but its application can be difficult. For example some natural resources like coal, oil or gravel are not replenished and once used they are gone. However, water resources in this country are intrinsically more sustainable because they are naturally replenished year after year; and because they are often returned after use.

The NRA's main concern is for environmental sustainability. This implies that there should, at the very least, be no long-term systematic deterioration in the water environment due to water resource development and water use. As regards water use this means not allowing long term abstraction to exceed long term replenishment; unlike some other resources water should never be mined. This principle was implicit in the Water Resources Act 1963. It has been fundamental to water resource management in this country for over 30 years, and there is no catchment in the Anglian Region where actual abstraction exceeds replenishment.

However, this merely ensures that things are not getting worse, which some would describe as "weak sustainability".

We believe that sustainability of water resource management should also encompass:-

- That replenishment should always exceed the sum of abstraction *plus 'proper' allowance for the environment.* This too has been widespread (if not quite universal) practice for 30 years. However, it involves value judgements as to what is 'proper', which are discussed in Chapter 6;

- The identification of locations where these 'proper' criteria are not being met, and a programme to put them right. This is discussed in Chapter 8; and

- Due regard to the principle of sustainability in the planning and design of water resource developments. A prime example is reservoir construction, which inevitably destroys some environmental assets, but creates others. We believe that all developments should be viewed as opportunities for net environmental gain, and designed to optimise such gains, while minimising any loss of 'critical environmental capital'.

THE PRECAUTIONARY PRINCIPLE

Where significant environmental damage may occur, but knowledge on the matter is incomplete, decisions made and measures implemented should err on the side of caution. This is the precautionary principle. It applies especially to the often not fully understood effects of water abstraction on rivers, and, particularly, wetlands. We endorse that principle. It is implicit in our licensing guidelines and in the environmental assessments now required of licence applicants.

We also believe that the precautionary principle should apply to the provision of water supply capacity. A margin of available capacity over expected demand not only provides security to water customers, but also to the environment and to other abstractors. This is because spare capacity does not mean more abstractions; but it does mean less need for damaging emergency measures, reservoirs drawn down less, abstraction load spread better across aquifers, and the potential to switch abstractions, or even reallocate water, to counter environmental problems. It is for water companies and OFWAT, (the Office of Water Services), not the NRA, to decide how much money water customers should pay for how much security. However, this is why, in our overall assessment of need, we have allowed in this Region's Strategy a planning margin of 10% as precaution against the range of risks listed in Chapter 7.

MEETING REASONABLE HUMAN NEEDS

The reasonable needs of all abstractors should be met up to appropriate levels of service, which are defined below.

"Reasonable needs" must allow for proper attention to demand management; again, see below.

LEVELS OF SERVICE

Appropriate levels of service are taken as:

For Public Water Supply

We have worked to the reference levels of service set by OFWAT (Ref. 8) which are:-

A hosepipe ban on average not more than once in 10 years.
Need for voluntary savings of water on average not more than once in 20 years.
Risk of rota cuts or use of stand-pipes on average less than once in 100 years.

For Irrigation

Current practice in the Anglian Region is for initial restrictions on average not more than once in 12 years.

DEMAND MANAGEMENT

Demand Management (for example metering and leakage control) and the wise use of water should be practised wherever, and to the extent that, it is economically justified. By this we mean to the point where the costs of saving water match those of making more available, taking full account of all the costs and benefits - financial, social and environmental.

COST

The Strategy aims to meet all legitimate demands in a sustainable manner, and as economically as possible, in overall terms. This includes not only expenditure on water supplies, but also environmental costs and benefits. It also takes account of costs in neighbouring regions.

GENERAL 'GROUND RULES' FOR THE STRATEGY

The Strategy looks to the year 2021 because of the long timescale of major water resource developments.

No specific account is taken of climate change, for reasons given in Chapter 5, save to acknowledge that it would be rash to ignore it. Although OFWAT does not accept climate change as a basis for water company expenditure, we have included it as one of the factors catered for by the planning margin described in Chapter 7.

The Strategy does not address the quality of water resources, except insofar as quality considerations significantly influence the quantities and/or the costs of water.

The Strategy attempts to recommend preferred developments, but does not consider who should pay for what. The NRA will look to the major beneficiaries of water resource schemes to promote, finance and develop them, but may seek operating agreements to make water available to others.

The strategy is not to be confused with the NRA's Catchment Management Plans, which are local plans, integrating all functions, for example flood defence, water quality, fisheries, recreation, conservation and navigation as well as water resources. This strategy is a regional overview of one function; it will be the basis for water resources input into future Catchment Plans, as well as to Local and County Structure Plans.

CONTROL OF ABSTRACTIONS

This strategy is an overview. Security of existing supplies, and the integrity of the environment also have to be preserved in the day to day work of abstractions licensing. To achieve this, in determining all licensing applications, the NRA will:-

- Consider the 'reasonableness' of the need, and possible alternatives such as demand management.
- Consider the overall availability of water; abstraction will not be authorised in excess of renewable resources.
- Consider the potential effects of neighbouring abstractions; abstractions will not be authorised which derogate existing abstractive rights unless suitable arrangements are made in respect of such derogation.
- Consider the potential effect on river flows; abstractions will not be authorised which would unacceptably affect low river flows.
- Consider the potential effect on wetlands; abstractions will not be authorised which would unacceptably affect such sites.
- Issue time limited licences, with appropriate monitoring requirements, in cases where there is any residual doubt.
- Advise the applicant in general terms on the availability of water, the likely consequences and constraints which would have to attach to his abstraction, and how reliable it might therefore be.

It is up to the applicant to meet any such conditions, and to judge for himself what reliability he considers acceptable.

It is also up to the applicant to provide an environmental assessment to the NRA's specification, to assess the potential effects of his proposals upon the water environment and upon existing abstractors.

THE ROLE OF DEVELOPMENT PLANNING

There is a view that development should be restricted on water resources grounds in some areas. However, this region has no overall shortage of sustainable water resources; the problems relate to making water available at the right times, places and costs. We therefore consider:-

- That the NRA should advise the Planning Authorities of the implications, cost and timescale of making water available in an environmentally acceptable way;
- The Planning Authorities should include this with all other factors which influence development planning, and
- That in doing so, planning authorities should regard water resource issues as constraints on the timing and cost of development, but not as an absolute limiting factor. This is in accordance with recent Government guidelines.

In addition the NRA has produced national guidance notes (Ref.9) and regional model policies (Ref.10) for protecting the water environment through Development Plans.

Chapter 5 - **DESCRIPTION**

ANGLIA'S WATER RESOURCES

Anglia lies in the 'rain shadow' of the western hills and its rainfall is about two thirds of the national average. Most of this rain evaporates and only the remaining part, called effective rainfall, is available for use. Figure 3 shows the national pattern of effective rainfall.

Evaporation is roughly the same throughout southern Britain. When it is subtracted from rainfall, the effect is to turn relatively small differences in rainfall into large differences in effective rainfall. For example, Anglia's two thirds share of average rainfall is cut to one third of effective rainfall. In a dry year the effect is greater, and Anglia's effective rainfall can be as low as one eighth of the national figure. It is important to emphasise that this Region is particularly vulnerable to modest fluctuations in either rainfall or evaporation.

Figures 4 to 7 show what happens to this Region's rainfall; how it is shared between human use and river flows; how the picture could change if we respond to rising demands in the way we suggest in this strategy; and that the fundamental problem is how to keep both the rivers and the water supplies going in the summers of dry years.

Anglia's average effective rainfall is far more than current human use (Figure 4), and is about four times the highest forecast of future water need. If it occurred at a steady rate,

Figure 3 - Major Aquifer Outcrops and Average Effective Rainfall

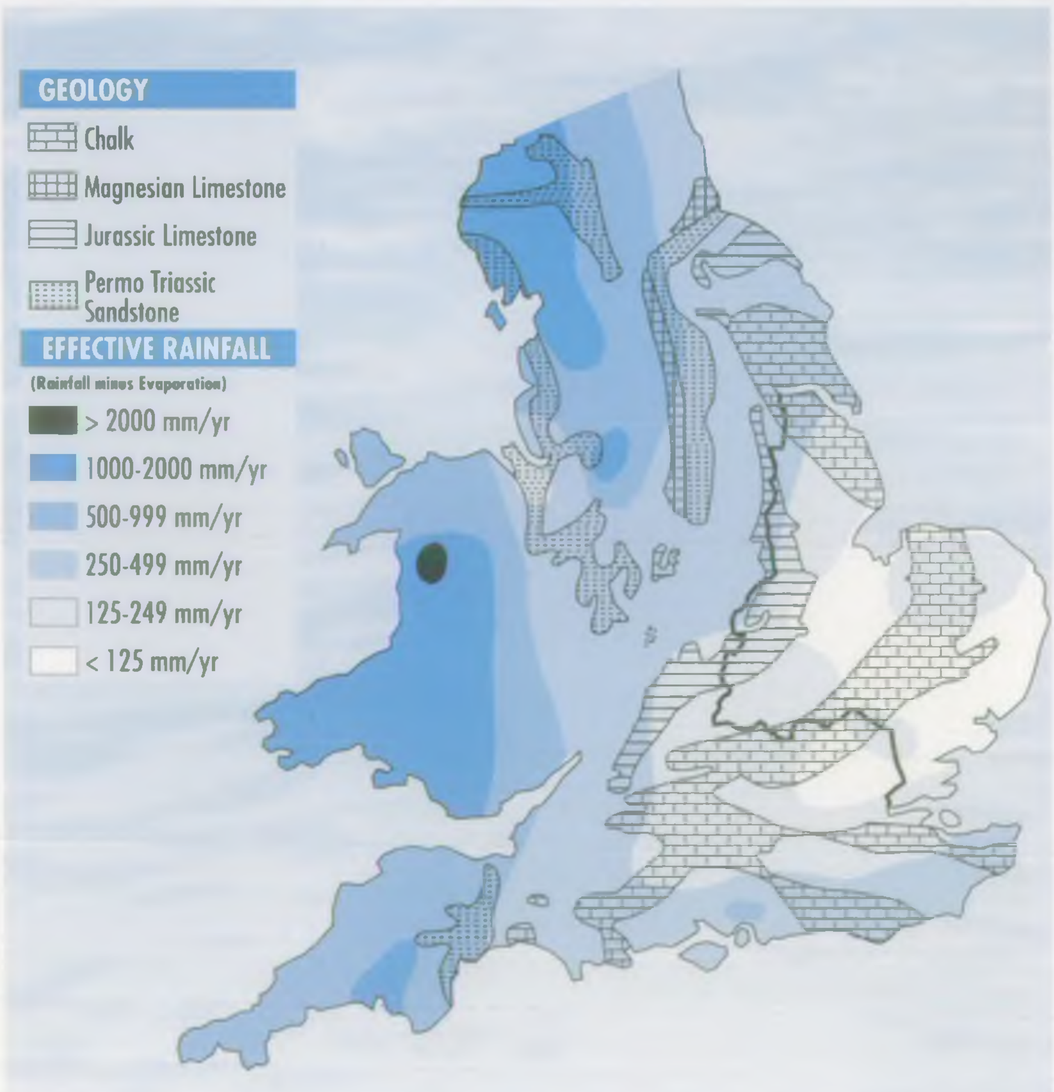


Figure 4 - What Happens to our Rainfall?

AVERAGE YEAR 595 mm		DRY YEAR 505 mm
448 mm	EVAPORATION	435 mm
14 mm	HUMAN USE NOT PUT BACK TO RIVERS	17 mm
16 mm	HUMAN USE PUT BACK TO RIVERS	16 mm
117 mm	RIVER FLOW (EXCLUDING EFFLUENTS)	37 mm

These pictures overstate the effect of abstraction on river flows. This is because some large abstractions are taken at tidal limits (ie. after the water has flowed down the river)

throughout the year and from year to year, there would be no problem. Unfortunately it does not. Figure 5 shows how river flows are sharply reduced in even a moderate (1 in 10) dry year. Within the year there are still sharper variations; even in an average summer, evaporation greatly exceeds rainfall, drying out the soils and causing low river flows. In Anglia all our summer water, in the tap and in the river, has to come from stored winter rainfall.

Nature has provided two sorts of water store, and man has added a third:

Natural Storage

First the soil store. This 'belongs' to the plants and trees. Their roots dry it out through the summer, and it is refilled by winter rains.

Second, the underground store. Suitable rocks, known as aquifers, can store huge amounts of water, usually much deeper than roots can reach. This store can only start to refill when the soil store is full. It helps to even out the year to year variations in rainfall, but its renewable water resource is limited to the average rate at which nature refills it. In nature the underground store 'belongs' to the rivers. Man borrows from it but he must be careful to avoid unacceptable effects on the environment. Figure 1 shows the chalk, limestone and sandstone aquifers which provide the storage which meets about half of the water needs in this region.

Man-made Storage

These are reservoirs, built to store winter river flows in areas where natural storage is inadequate. They range in size from Rutland Water in Leicestershire, one of the largest reservoirs in Europe, to farm reservoirs of a few acres, of which there are several hundred. Anglia's terrain is not very suitable for reservoirs; most have to be built in side valleys, and filled by expensive pumping from the main rivers. All the major reservoirs are recognised as sites of high amenity, recreational and wildlife value.

SURFACE WATER RESOURCES

Roughly 70% of effective rainfall runs to sea as river flow, mainly in winter. This provides no reliable water resource unless there is storage for summer use.

Figure 5 - Where does the Water Go?

Some is consumed by man or put back to tide. The rest all goes to the river (directly or indirectly), like this:

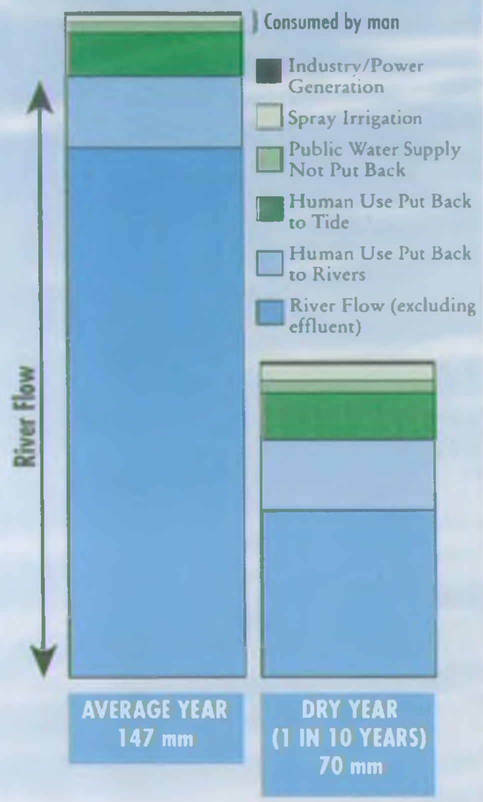


Figure 6 - What Effects will Increasing demands Have?

If all the forecast increase in demand to 2021 is met as suggested in the strategy, the dry year picture will change like this:

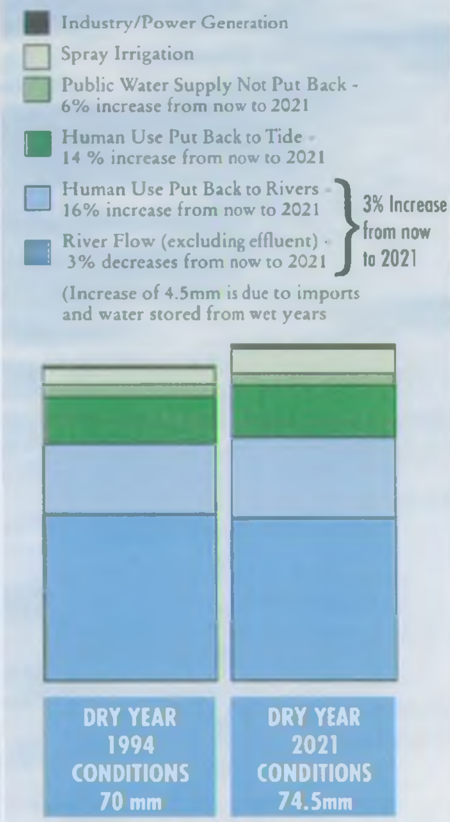
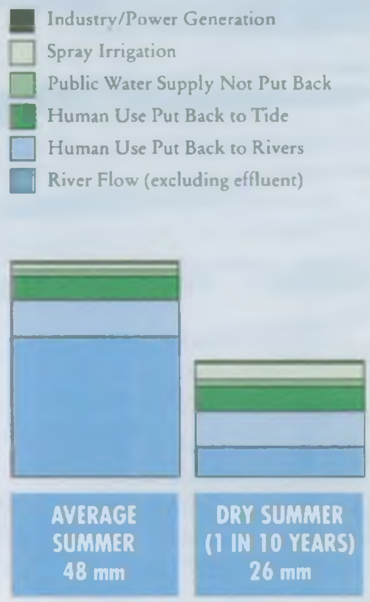


Figure 7 - So What's the Problem?

Most evaporation happens in summer, which means that river flows are very low. In summer the balance of human use and river flows looks like this:

The problem is how to keep both the river and the human supplies going in the summers of dry years.



There are four ways in which major reliable supplies are obtained from our rivers:-

- Abstractions from rivers sustained by natural flows from groundwater storage. (Rivers Wensum, Bure, Waveney, Nar and Wissey)
- Abstractions from rivers sustained artificially by transfers or effluents. (Rivers Ancholme, Nene, Bedford Ouse, Stour, Colne and Blackwater).
- Abstractions to fill reservoirs (Rivers Nene, Welland, Bedford Ouse, Gipping, Bucklesham Mill Stream, Stour, Colne, Blackwater, Chelmer and Louth Canal).
- Abstractions for transfer to other rivers to augment b) and c) (Rivers Great Eau, Witham, Ely Ouse and Trent)

Every river in the Anglian Region which is capable of giving worthwhile supplies is used in one or more of these ways.

Relatively minor supplies, for example for irrigation, are also obtained from all the Region's rivers, often in conjunction with relatively small reservoirs.

Most of the major abstractions are made at or not far above the rivers' tidal limits, and are all subject to hands-off flow constraints for the protection of downstream interests. Pump sizes are generally such that during critical drought periods they can use almost all excess flows.

Table 1 - Summary of Major Surface Water Resources (For details see Annexe 3)

River	Associated Storage Reservoir Name	Volume mcm[1]	Reliable Yield tcmd[2]	Purpose of Use	Comments
Ancholme	Cadney	0.9	85	Public supply	Supported from Witham and Trent.
Ancholme + Witham	-	-	-	Direct users	Supported from Trent
Louth Canal	Covenham	10.9	64	Public supply	Supported from Great Eau
Nene/Welland	Rutland	137		Public supply	
Nene	Pitsford	18	532	Public supply	Yield subject to review
Bedford Ouse	Grafham	56		Public supply	Yield subject to review
Eye Brook	Eye Brook	8	18	Industry	
Nene Tributaries	Ravensthorpe/ Hollowell	4	8	Public supply	
Nar	-	-	8	Public supply	Marham intake. Reliability not certain.
Wissey/Cut Off Channel	-	-	13	Public supply	Stoke Ferry intake supported from groundwater Planned increase to 18 tcmd.
Bedford Ouse	Foxcote	0.5	6.5	Public supply	
Bedford Ouse	-	-	27	Public supply	Clapham intake
Waveney	-	-	21	Public supply	Shipmeadow intake supported from groundwater
Bure	-	-	23	Public supply	Belaugh/Horning intakes
Wensum	-	-	40	Public supply	Costessey intake
Gipping	Alton	9.1	30	Public supply	Includes transfer from Bucklesham Mill River
Colne	Ardleigh	2.4	22	Public supply	Yield subject to review
Stour	Abberton	25.0	327	Public supply	Supported by Ely Ouse - Essex Transfers
Blackwater/Chelmer	Hanningfield	26.1		Public supply	Yield to be reviewed

1. mcm = millions of cubic metres 2. tcmd = thousands of cubic metres per day

The reliable supplies which are obtained in these ways from our rivers are summarised in Table 1, and given in more detail in Annexe 3.

GROUNDWATER RESOURCES

Approximately half of the Region is underlain by chalk, limestone and other water bearing rocks, known as aquifers, which act as natural underground reservoirs. Roughly 30% of effective rainfall infiltrates into these aquifers whose outcrops are shown on Figure 3. In nature, all of this water would reappear at springs, and sustain relatively steady base flows in many of the Region's rivers. However, groundwater offers a widespread source of naturally stored high quality water, and about half of the Region's supplies are taken from it.

Groundwater resources are assessed in terms of safe, or sustainable, yield. The sustainable yield is that rate of groundwater abstraction that can be sustained indefinitely without unacceptable reductions in groundwater level, discharge or water quality.

Groundwater resources are best assessed by 'distributed models'. These are computer simulations which are used to understand and quantify estimates of recharge into the aquifer; the subsequent storage and movements of water within the aquifer; and eventual discharges of water from the aquifer, given various rates of groundwater abstraction. Such models are necessary both for the accurate assessment of aquifer yield and to evaluate possible options for groundwater management.

Distributed models are available for some of the region's groundwater units. However, their development has been somewhat piecemeal. Work is in hand to develop and co-ordinate these models. However for the present purpose a simpler 'accounting' procedure is presented in Annexe 4, with the caveat that it is a first approximation, incorporating precautionary principles, and very much subject to future refinements. This procedure starts with the best assessment of the long term infiltration (which is the basic renewable resource) and evaluates how much of it can be abstracted in a manner which is both sustainable and environmentally satisfactory.

Long term infiltration, or recharge, is assessed by reference to groundwater models (where available) and from records of river flows and abstractions. It is checked against analysis of effective rainfall, catchment areas and geology. As far as possible our estimates are based on the 1961 - 1990 standard period.

Because groundwater contributes to river flows, the amount which can be authorised for abstraction cannot be assessed independently of the needs of the rivers. All borehole abstractions eventually deplete river flows, but the effect is mitigated by the subsequent return of effluents. This double use (by man and then by the river) complicates the assessment of groundwater resources. Annexe 4 gives full details of groundwater balances, including the environmental allocations and how they are assessed. Table 2 summarises, for each groundwater unit, the resource, the environmental allocation, the commitment to abstraction and the remaining 'unallocated' quantity, if any. Figure 8 shows those groundwater units whose resources are fully committed and those where further abstraction may still be considered. It also shows certain units (hatched) where future refinement of the environmental allocation could perhaps lead to the release of some further water for abstraction.

Table 2 shows a small number of catchments where licensed abstraction exceeds recharge, an apparently unsustainable position. However, in every case there are particular circumstances, which are detailed on Table A4.2 in Annexe 4. For example, in some cases the balance is sustained by induced recharge; in others by arrangements to restrict actual abstraction below the licensed entitlement except in wet years. In no case is long term deterioration in groundwater levels occurring.

Table 2 also shows rather more catchments where the "balance nominally available" is negative. This means that the full licensed abstraction plus the full environmental allocation are not always fully met. This situation is sustainable, but may be unsatisfactory. In some cases particular circumstances apply, as discussed above. In almost all cases the full licensed quantity is not taken, and the environmental allocations are precautionary. It is perhaps significant that we have not found evidence of any permanent environmental damage being caused in these catchments by the recent very extreme drought. Nevertheless we will review the resource/demand balance in these catchments and take such actions as are necessary to ensure the proper balance between environmental and abstractive needs.

We also propose to investigate the effects of urbanisation and field drainage on groundwater recharge. However, such published information as is available (Refs. 11, 12 and 13) suggests that the impact is relatively minor. This is because the urban area remains a relatively small proportion of this region and because field drainage is mostly concentrated in areas of heavy soils which allow little recharge in any case.

THE QUALITY OF WATER RESOURCES

It is no use having enough water if its quality is unsatisfactory. The NRA aims to protect the quality of water resources to ensure their fitness for use, using a range of legal powers, including the control of discharges and statutory Water Quality Objectives. Further controls may be required in the future, for example to control diffuse pollution from nitrates and pesticides.

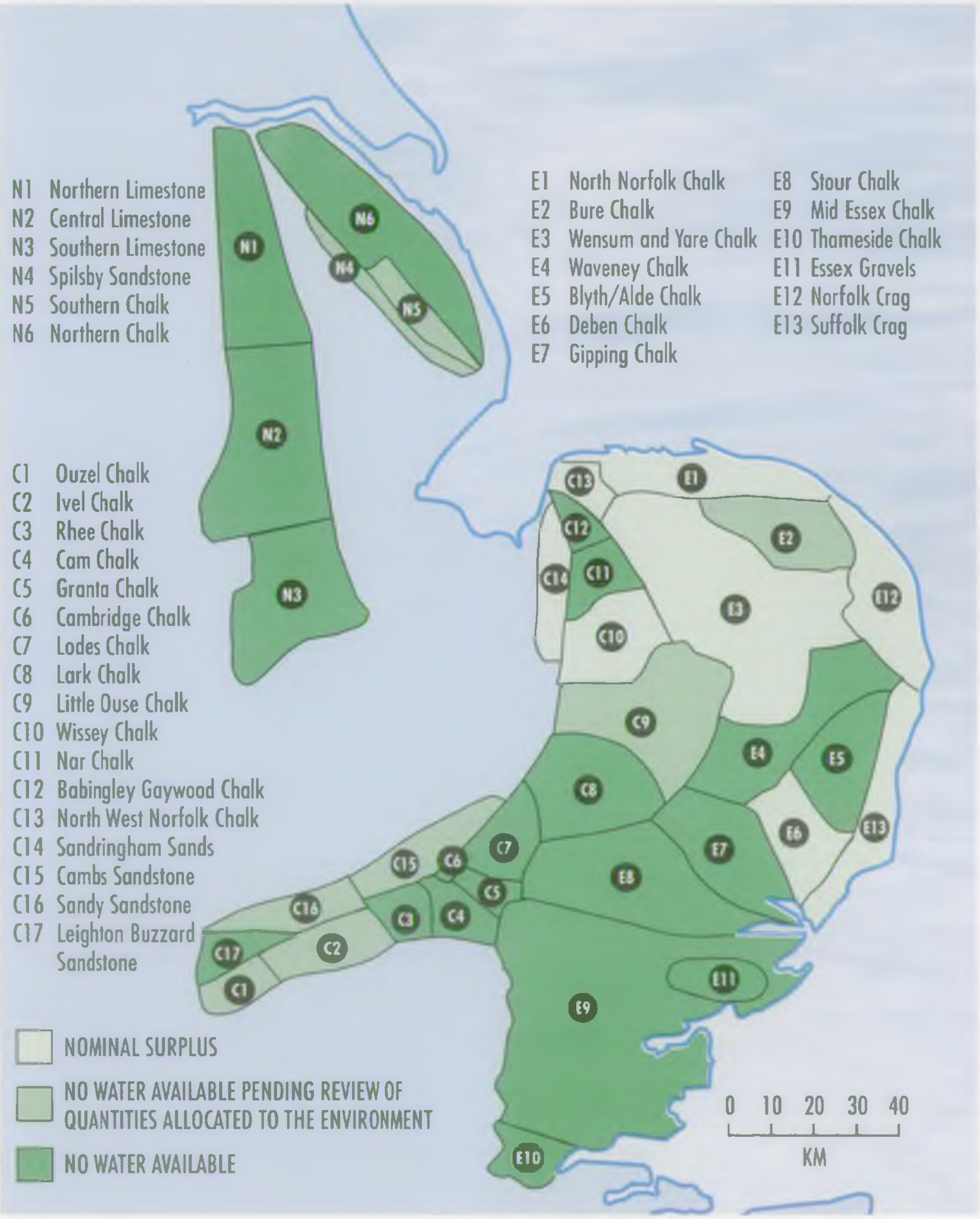
Table 2 - Summary of Groundwater Resources (For details see Annex 4)

Groundwater Unit	Gross Resource	Effective Resource[1] tcmd	Committed to environment[2] tcmd	Committed to abstractions[3] tcmd	Balance Nominally Available[5]	Best estimate of water available[4]
Lincolnshire Chalk						
Northern Chalk[3]	231.0	184.8	21.3	189.1	-25.6	0
Southern Chalk[5]	105.0	28.0	39.3	1.2	-12.5	0
Spilsby Sandstone	47.0	82.0	37.0	36.6	8.5	
Lincolnshire Limestone						
Northern Limestone	92.0	55.2	32.9	33.6	-11.3	-?
Central Limestone	80.0	48.0	19.1	31.8	-2.9	0
Southern Limestone[5]	143.4	86.0	41.2	82.5	-37.6	0
Lincolnshire and Northamptonshire Minor	98.9	79.0	0.0	74.6	4.4	0
Cambridgeshire Chalk						
Ouzel	35.0	28.0	0.0	5.6	22.5	+?
Ivel	118.8	95.0	4.1	38.4	51.9	
Rhee	70.5	56.4	19.5	41.3	-4.4	0
Cam[5]	65.5	52.4	0.0	77.7	-25.3	0
Granta	33.4	26.7	3.3	16.8	5.7	0
Cambridge	2.9	2.3	0.9	0.2	1.2	0
Lodes	84.9	67.9	12.9	57.3	-2.3	0
Lark	159.4	127.5	46.9	83.1	-2.5	0
Little Ouse	263.4	210.8	132.9	81.5	-3.6	0
Wissey	117.7	142.1	75.0	44.9	22.3	22
Nar	87.4	69.9	42.8	28.9	-1.2	0
Babingley/Gaywood	72.5	58.0	32.8	21.9	3.3	0
NW Norfolk Chalk	27.8	22.3	2.1	5.3	14.9	14
Minor Cambs/Beds Oolite/Gravels	15.5	12.4	10.0	9.1	-6.7	0
Sandringham Sandstone	74.4	74.4	29.7	10.7	34.0	34
Camb/Beds Lr Greensand	73.4	73.4	2.8	61.1	9.5	+?
North Norfolk Chalk	135.0	108.0	65.3	27.6	15.1	15
Bure Chalk[5]	207.0	165.7	140.8	37.1	-12.3	0
Wensum/Yare Chalk	374.8	299.9	130.7	99.9	69.2	69
Waveney Chalk	107.7	86.1	24.9	57.1	4.2	4
Blyth/Alde Chalk	30.2	24.2	8.1	13.5	2.6	0
Deben Chalk	32.6	26.1	7.9	12.5	5.7	5
Gipping Chalk[5]	61.9	49.6	13.6	72.9	-37.0	0
Stour Chalk[5]	122.5	122.5	36.4	117.3	-31.3	
Mid Essex Chalk[5]	37.1	37.1	7.0	40.4	-10.2	0
Thameside Chalk[5]	9.3	9.3	0.0	26.0	-16.5	
Norfolk Crag	73.1	58.5	28.4	20.9	9.3	9
Suffolk Crag	126.2	101.0	37.2	26.4	33.2	33
Essex Gravels, Tendring Peninsula	45.6	27.4	0.0	27.8	-4.7	0

FOOTNOTE TO TABLE 2

1. After allowing for limitations of storage.
2. This is primarily the 'dry year' allowance of groundwater to the river. In normal years the river receives substantially more groundwater, as well as variable amounts of surface run-off.
3. Note that much, though not all, of this subsequently returns to the river.
4. See Annexe 4 for derivation of these estimates.
5. See Annexe 4 for comment on nominal deficits.

Figure 8 - The Availability of Groundwater 1994



Particular care must be taken to protect groundwater because it can take decades to recover should pollution occur. The NRA will protect the quality of groundwater resources by use of its own powers under the Water Resources Act 1991 and by encouraging other regulators such as Planning Authorities to use their powers to support the same objective. The criteria which the NRA will adopt and wishes to see adopted are set out in the Policy Document "Policy and Practice for the Protection of Groundwater" (Ref.14)

The purpose of groundwater protection is to preserve quality and quantity for legitimate abstracted uses and to sustain non abstracted use, in particular environmental features and systems dependent upon the presence of groundwater. Since groundwater occurrences and vulnerability to human activities vary depending upon geology, soil and patterns of exploitation a system of source protection and vulnerability zones is used to implement protection policies.

In general, however, if water is there its quality can, and will, be protected or improved. The NRA puts a great deal of effort into ensuring that this is done. This strategy assumes that water quality will continue to be successfully managed. It takes account of water quality issues only in so far as they may affect the availability of water or its cost.

CLIMATE CHANGE

The Water Resource assessments in Tables 1 and 2 make no allowance for the possibility of climate change.

The close balance between rainfall and evaporation makes the water resources of this region particularly sensitive to any change in either rainfall or evaporation, and hence to climate change. However, rainfall is so naturally variable that it would be many years before any underlying trend could be positively detected. Figure 2 shows all the significant drought (and high rainfall) events since 1899. There is no detectable trend. The 1988-1992 drought is within the historical pattern, and the 1899-1903 drought was similar.

Also it is by no means clear whether climate change would increase or decrease water resources. The best predictions (albeit they are very tentative) suggest drier summers but wetter winters. The Institute of Hydrology has concluded (Ref.15) that "average annual run-off in a catchment in Southern UK may be reduced by about 5% by the middle of the next century, but this estimate is very uncertain: run-off may reduce by 30% or increase by 30%"

A research project commissioned by NRA (Ref.16) has corroborated this uncertainty. It shows, for example, that both surface and groundwater resources could either be increased or decreased according to the climate change scenario considered. It goes on to recommend a flexible response, for example ".... maintaining reliable water supplies could entail providing new or enlarged reservoir storage".

Climate change research continues, and it would be rash to ignore it. Tables 1 and 2 still represent the best assessment of future water resources. However our subsequent conclusions are coloured by the "precautionary principle" and we have allowed for climate change within our planning margins.

DEVELOPMENT OF WATER RESOURCES

The natural water resources are extensively used and changed by man. River flows are altered by land use changes, by drainage, by abstractions and by effluent discharges; groundwater is tapped by boreholes both for supply and for river support; river transfer schemes move water into and around the Region; and reservoirs have been built to store winter flows. The resulting network is designed to provide reliable supplies for all purposes. In the process it increases some river flows and reduces others. Figure 1 shows the major components of the network.

Six million people could not live and work in this Region without such a network. It has recently been tested by the most severe extended drought this century. It proved adequate to meet most, but not all, supply needs and to sustain acceptable flows in most, but not all, rivers. The rest of this document essentially examines local shortfalls in the network, how the demands upon it will increase in future years and how it may need to be augmented to keep pace with those demands.

WATER SOURCEWORKS

The water resources described above support a large number of sourceworks operated, under abstraction licences, by water undertakers, by industry and by farmers. Some households take their water from private domestic wells but these are not generally licensable, are unlikely to increase in number and are not addressed in this document. We refer to abstractors of water, other than the water undertakers, as 'direct users'.

The quantity licensed at each sourceworks is not necessarily reliably available under drought conditions, and the term 'Sourceworks Reliable Output' (SRO) is used to define the quantity which the abstractor can rely upon from a sourceworks under design drought conditions. Where possible these are defined by the level of service criteria described in Chapter 4.

Water Undertakers' Sourceworks

The water undertakers' SRO's are summarised on Table 3 and shown in detail in Annexe 5. All figures are given in thousands of cubic metres per day (tcmd). One tcmd is, broadly speaking, sufficient water to supply a town of 4,000 people. These all relate to average outputs; peak abstractions are higher to meet peak demands, but in the great majority of cases these are evened out by storage, either of groundwater or in reservoirs. Provision of peak capacity is of major importance to the undertakers and is provided for in licence conditions; however, as far as water resources are concerned it is the average output that matters.

There are however a few direct river intakes where peak abstraction rates are of water resource significance and these are considered in Chapter 8.

The SRO figures in Annexe 5 have not been adjusted for the possibility of further reductions in cases where excessive abstraction may be having unacceptable environmental consequences. This may be necessary, as discussed in Chapter 7, but reductions are likely to be small in total, and are dealt with in Chapter 8. Neither do they allow for increasing effluents, which are dealt with in Chapter 12.

Direct Users' Sourceworks

The reliable outputs associated with the 10,000 or so licences for direct water use which account for less than 20% of total quantity are not readily available. For strategic planning purposes the broad assumption is made that the total SRO available to direct users is 70% of their total licensed entitlement. This reflects (a) the need to restrict spray irrigation in recent drought summers and (b) the under-utilisation of many industrial licences.

IMPORTS TO THE REGION

There are three substantial imports of water from neighbouring Regions:-

- **Raw water from the Trent.**
  The NRA transfers up to 180 tcmd of water from the Trent at Torksey via the Fossdyke Canal to the rivers Witham and Ancholme, for use by water undertakers, industry and agriculture.

- **Groundwater from the Sherwood sandstone.**
  Anglian Water Services have boreholes in the Sherwood sandstone in Severn-Trent region with an SRO of 65 tcmd. These are included in Annexe 5.

- **Treated Water from the Thames Region.**
  Essex and Suffolk Water Company has a bulk supply agreement with Thames Water Utilities Limited for the supply of 91 tcmd to the Company's works at Chigwell. This is included in Annexe 5.

Table 3 - Summary of PWS Sourceworks reliable Outputs[1] (TCMD)

Water Undertaker	Groundwater	Surface Water	Total[1]
Anglian[3]	785	845	1630
Cambridge	123	-	123
Essex and Suffolk[3] - Essex Area	9	418	427
Essex and Suffolk - Suffolk Area	48	48	96
Tendring Hundred	31	11	42
Total excluding Three Valleys[2]	**997**	**1322**	**2319**
Three Valleys	54	-	54
TOTAL	**1051**	**1322**	**2373**

1. These are totals of sourceworks reliable outputs currently available and those within existing licensed quantities, which the companies will develop in line with demand growth in the appropriate areas.
2. For comparison with Table 8.
3. Including import from adjacent Regions. Figures are subject to review.
4. Relates to sourceworks within NRA Anglian Region only, and excludes the company's entitlements to water from Grafham Water.

Chapter 6 - THE WATER ENVIRONMENT AND ITS NEEDS

For convenience we consider environmental water needs and human water needs in separate chapters. However, man is part of the environment and in reality the two are inextricably linked. Secure water supplies need a healthy water environment, and vice versa.

We regard the needs for water to sustain the water environment as 'demands' in their own right, to be met subject to proper consideration of reasonableness and worthwhileness. However it is important to put these demands into context with all the other factors which combine to determine the state of the water environment.

One such factor is the enormous influence which man has already had upon it. The water environment of this region is totally unnatural. The change from natural forest to man made farm land has increased low flows by reducing evaporation. Channel works and other drainage activities have greatly reduced the areas of marsh and wetland. Abstractions and discharges reduce low flows in some rivers, and increase them in others. Open water has been created by reservoirs, and wet gravel pits have become a major feature of our countryside. Change will continue, and we are determined to do all we can to harness it to the betterment of the water environment.

There are five elements to our fresh water environment:

- Soil water, which sustains plants and trees
- Wetlands
- Lakes (including reservoirs and gravel pits)
- River flows
- Estuary flows

WATER FOR THE SOIL

Soil water is generally (though not always) independent of the deeper water table from which abstractions are made. Soil water is generally in contact with groundwater only along valley bottoms. It is affected by farm practices, especially drainage, but is not generally in conflict with other water uses, and so is not considered further in this strategy.

WATER FOR WETLANDS

Wetlands are areas where the water table is at or near the surface. Developments of all kinds, including farming practice, land drainage and abstraction, have greatly diminished our natural wetlands. Those that remain are rightly seen as valuable heritage. There may be some scope to sustain wetlands artificially and possibly even to enhance them. However, this is limited by the difficulty of artificially reproducing the subtle 'natural' hydrology of wetlands, on which their ecology depends; it is practised in some special cases but in general protection is preferable. Rather, the protection of wetlands is approached by establishing abstraction licensing guidelines. Anglian Region's guidelines include:

- **SSSI's, NNR's and Broads Authority Area**
  Licence applications are refused unless the effect on the ecology of these sites is proven to be insignificant or can be mitigated by works or conditions agreed between the NRA, English Nature and/or the organisation managing the site.

- **Environmentally Sensitive Areas (ESA)**
  Licences are issued only subject to such conditions as are necessary to protect the land use objectives within the ESA.

- **Wildlife Trust Sites recognised in County and District Councils' Structure Plans**
  Licences are issued only subject to such conditions as are necessary to protect valid conservation management objectives.

- **Other Wetland Sites**
  Consideration is given to licence conditions to minimise any adverse effects on wetlands.

These restrictions have the effect of substantially constraining the NRA's ability to allocate nominally 'surplus' groundwater to abstractive uses.

WATER FOR LAKES

We include lakes for completeness, although their water needs are largely covered by those of the wetlands and rivers.

Some lakes are groundwater fed and these are treated as "wetlands". Others, particularly the many wet gravel pits in our river valleys, depend on gravel water tables. These are often linked to river levels, and their water needs are bound up with the management of rivers.

The other main type of lake in this region is artificial reservoirs. These range from small farm reservoirs to Rutland Water, one of the largest lakes in Britain. Their primary purpose is water supply, but they also create valuable water environments. Many are carefully managed to optimise their environmental value (Rutland is a prime example), showing the harmony that can exist between man's needs and nature's.

WATER FOR RIVERS

The NRA's duties to further and promote environmental issues appear incompatible with the fact that every non-returning abstraction reduces river flows. The question is, how much flow reduction is acceptable?

This question is fundamental because the more water is allocated to the rivers, the less there is for the people. But it *cannot* be answered in isolation from all the other factors which combine, with flow, to determine the state of our rivers.

Rivers are naturally changing systems. They have also been greatly changed by man over the centuries. Some river changes happen inadvertently, others are deliberate, and they have combined to make most of the Region's rivers thoroughly unnatural.

Some past changes have been beneficial, some the opposite. Changes will continue and this strategy includes proposals aimed towards managing future change in a way which achieves the best overall balance of interests, not the greatest benefit to any particular one. The ecological health of the river environment is a prime objective, and we seek ways of ensuring it while at the same time meeting reasonable human water needs.

The character of a river depends on its flow, its water quality and the physical characteristics of its bed and banks.

Flows are changed by abstractions, by effluent discharges, by augmentation schemes and by water transfers. The net effect is often to reduce middle range flows but to increase low flows in those reaches which are below major discharge points. (However, low flows sustained by effluents can be vulnerable to any relocation of those effluents).

Quality is changed by effluent discharges, both 'point' and 'diffuse', by land use, by augmentation and transfers, and even by recreational activities.

Physical characteristics are changed by mills, weirs and sluices, by channel works and dredging, by removal (or planting) of trees, by sediment transport due for example to ploughing and by other changes in land use.

The *combined* effect of all these factors determines the state of our rivers. Research aimed at disentangling these complex issues has already shown

- that mills, weirs and sluices, though artificial, are in general beneficial features.

- that the depth of water can be just as important as flow for some aspects of ecology.

- that channel works and dredging are prime influences; there is great scope to restore ecologically degraded channels by such means as re-introducing pools, riffles and gravel beds, encouraging meanders and introducing smaller low-flow channels within wider flood-berms.

Potential river transfer schemes, identified in Chapter 12, offer opportunities for creative channel works of this kind.

- that the excessive, unnatural build up of silt on river beds is very detrimental to their ecology. The creation of buffer zones beside river and tributary channels, coupled with appropriate channel design, could greatly improve river ecology by controlling siltation.

- that eutrophication (the release of excessive nutrients, particularly phosphorous, from sewage works and from farmland) causes undesirable weed and algal growth.

Ways of reducing nutrients include phosphorous removal from sewage effluents, nitrate control in nitrate sensitive areas and, again, the use of buffer zones, perhaps in association with some control over field drains to hold nutrients back in the soil at critical times. Improving agricultural practices may also help to control nutrients.

- that moderate reductions in average flows are not in general ecologically significant.

- that there is a need to sustain acceptable minimum flow regimes; but no objective criteria yet as to what is acceptable. A provisional estimate of acceptable minimum flow is the 'natural 95% flow'. This is the flow which would naturally be equalled or exceeded for 95% of the time. It 'seems to work' (Ref.17), but it is not scientifically based, and it varies greatly as a proportion of average flow in different rivers.

- that autumn/winter flushing is ecologically very important; however in most rivers this is not significantly reduced by abstraction, and usually cannot be significantly increased artificially.

- that the setting of acceptable flow regimes should not normally be constrained by the needs of effluent dilution, as it is almost always more economic to deal with effluents by treatment rather than by dilution.

We conclude that tomorrow's healthier river may need to have not only improved management of its flow, but also improvements to its water quality and its physical characteristics.

Future flow regimes may, perhaps, be somewhat reduced to meet consumptive human water needs, but sustained when necessary at low flows; and, if and where possible, provided with short high flushes for autumn scour.

The Water Resources Act 1963 provided for the setting of minimum acceptable flows (maf's). The Water Resources Act 1991 restates this provision, with minor changes. However no maf's have been set in this (or any other) region. Many hands-off flows (hof's) have been set instead, mostly as control flows, below which specific abstractions must cease. They have a similar effect to maf's but without such legal connotations. They are listed on Tables 4 and 5.

Table 4 - Hands-off Flows - TCMD

River	Location	Existing or Proposed HOF	Comments
Witham	Claypole	35	Provisional figure
Witham	Saltersford	15	Maintained flow, as condition of PWS abstraction
Ancholme & Rase	Bishopbridge	10	Provisional figure
Louth Canal	Louth	10	Provisional figure
Great Eau	Claythorpe	20	Provisional figure
Bain	Fulsby	10	Provisional figure
Slea	Leasingham	5	Provisional figure
Lymn	Partney	10	Provisional figure
Welland	Tinwell	36[i]	Intake to Rutland
Nene	Wansford	136[i]	Intake to Rutland
Nene	Duston	34[i]	Intake to Pitsford
Nene (Brampton Branch)	Merry Tom	11	Intake to Ravensthorpe
Bedford Ouse	Offord	136 + 1/4 of excess[i]	Intake to Grafham
Bedford Ouse	Clapham	9	PWS intake
Wissey	Stoke Ferry	27	Condition of King's Lynn (R. Wissey) Water Order 1967
Nar	Marham	4	Condition of Wisbech Water Order, 1948
Rhee	Burnt Mill	26	Undertaking given at Public Inquiry (smaller flows also sustained at a number of contributory Springs)
Tove	Cappenham	14.6	Licensing Condition
Kym	Meagre Farm, Hailweston	 2.5 13.2	Licensing Condition Summer Winter
Alconbury Brook	Brampton	1.6	As directed by Sec. of State for Environment
Cam	Great Chesterford	12.7	Water Co. required to support flows to maintain MRF
Cam	Dernford	29.3	
Rhee	Wimpole	11.2	
New River	Ness House	7.6	
Swaffham Bulbeck Lode	Swaffham Bulbeck	7.2	As directed by Sec of State for Environment
Soham Lode	Fordham	20.9	
Kennett	Beck Bridge	4.32	Licensing Condition
Sapiston	Euston Rectory Bridge	7.25	As above
Little Ouse	Euston County Bridge	7.30	As above
Thet	Redbridge	12.5	As above
Thet	Bridgham	30.2	As above
Cut-Off Channel	Tollgate Weir	3.4	
Babingley	Castle Rising	29.3	Licensing Condition
Burn	Burnham Overy	6	Proposed in Ref. 22
Glaven	Glandford Mill	7	As above

Continued overleaf

Table 4 - Hands-off Flows - TCMD (continued)

River	Location	Existing or Proposed HOF	Comments
Bure	Ingworth	up to 33	Licensing condition, varying with abstraction
Ant	Honing Lock	9	Proposed in Ref. 22
Wensum	Costessey	44	PWS intake
Tas	Shotesham	11	Licensing Condition
Waveney	Ellingham Mill	up to 34	Licensing Condition, varying with abstraction
Alde	Farmham	2	Proposed in Ref. 22
Ore	Beversham	2	Proposed in Ref. 22
Alde and Ore	Langham Bridge	4	Proposed in Ref. 22
Deben	Nounton Holl	5	Proposed in Ref. 22
Stour	Stratford St Mary	18	Licence condition

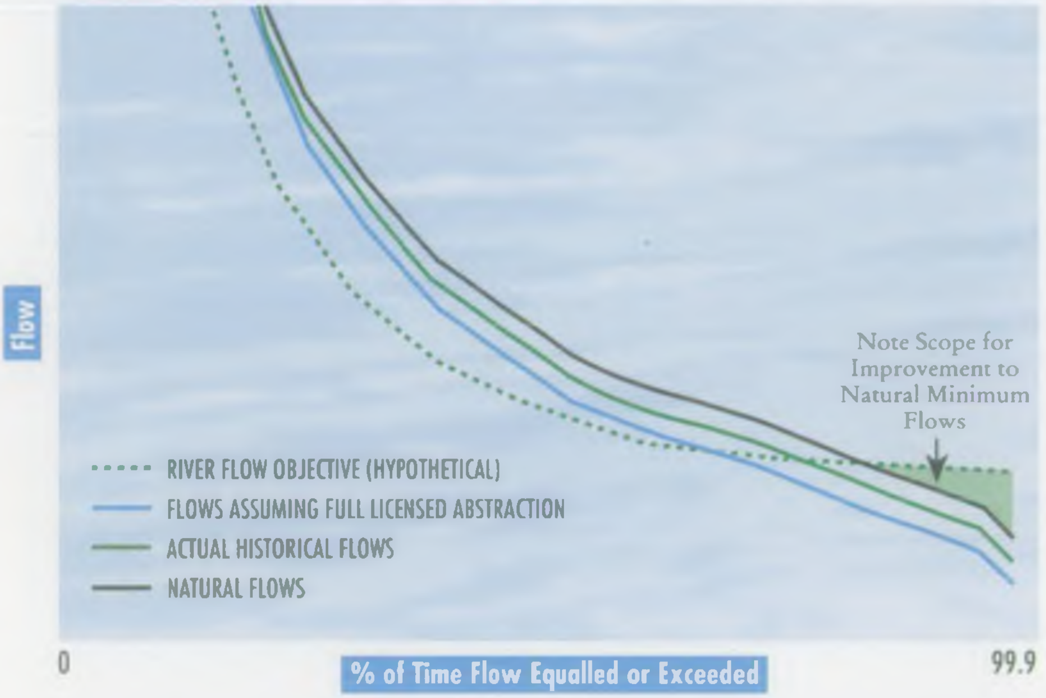
(i) Statutory

Table 5 - Hands-off Flows to Tide

River	Location	Existing or Proposed HOF	Comments
Ancholme	Ferriby Sluice	5	Operational experience during 1988 /92 drought
Witham	Grand Sluice	40	Provisional Fig Ref 23 (plus operational experience)
South Forty Foot	Black Sluice	10	Provisional Fig Ref 23 (plus operational experience)
Louth Canal	Tetney	2.4[i]	Licence condition
Gt Eau	Cloves Bridge	2.4[i]	Licence condition
Vernatts Drain	Surfleet	8	Provisional Fig Ref 23
Bedford Ouse	Brownshill	91	Implied condition of Brownshill intake licence
Ely Ouse	Denver	114 March-Aug[i] 318 Sept-Feb[i]	Ely Ouse- Essex Water Act 1968 (flows under review)
Stour	Cattawade	2[i]	Essex River and South Essex Water Act 1969
Chelmer and Blackwater	Langford	2[i]	Hanningfield Water Order (1950)
Spixworth Beck	Below confluence	2	Proposed in Ref. 22
Bure	Below confluence	30	Proposed in Ref. 22
Wensum	New Mills, Norwich	27	Proposed in Ref. 22
Yare	Below confluence	14	Proposed in Ref. 22
Tas	Below confluence	12	Provisional
Waveney	Burgh St Peter	23	Based on Ref. 22
Deben	Melton	5	Proposed in Ref. 22
Finn and Lark	Martlesham	2	Proposed in Ref. 22
Gipping	Sproughton	9[i]	Intake to Alton Water
Mill River	Bucklesham	1.9[i]	Licence condition

(i) Statutory

Figure 9 - Concept of River Flow Objectives



Against this background we are setting about defining minimum acceptable flow regimes, possibly to be adopted as River Flow Objectives (RFOs). Figure 9 illustrates the possible concept. The NRA is actively researching the principle and how to put numbers to it. For example, four current research projects (Refs. 18, 19, 20 and 21), one national and three on Anglian rivers, are together leading towards a rational way of identifying what flow regimes (not just lowest flow) will support what types of river ecology. Together with the physical improvements listed above, this should lead to the setting of RFOs to control abstraction at sensible levels, while also achieving higher environmental standards. The objective is that our rivers should serve us all better, not only as providers of water supply and carriers of waste, but also as sources of amenity and recreation and as wildlife habitats in their own right.

WATER FOR ESTUARIES

The criteria for setting 'hands-off' flows (hofs) to estuaries are different to those for inland flows. But the principle of 'the more for the estuary the less for the people' is even more true; environmental flows in rivers can be abstracted at the downstream end, but environmental flows to estuaries are irretrievably 'lost'.

There are major abstractions at or not far from the tidal limits of most of the Region's rivers. Most such abstractions are subject to hofs for the protection of the estuary, which are listed on Table 5.

Every estuary is unique. In this region most have been greatly modified by dredging and in many cases by tidal gates or barrages. They are, nevertheless, of high ecological value, particularly The Wash and The Broads estuaries. Many are also important for navigation and some for commercial fishing.

All these interests can be affected by variations in the regime of freshwater inflows to the estuary. The main impacts are on salt and silt. Lower freshwater flows can cause increased penetration of saline water, with potential consequences to wildlife and to agriculture; and increased siltation, with consequences to navigation and land drainage (though siltation is still mainly controlled by winter flood flows). Other secondary impacts can be on levels, velocities and water quality.

However, the further down the estuary the greater the dominance of tidal flows. This is why very low 'hands-off' flows seem to sustain satisfactory conditions in the estuaries of Lincolnshire and Essex, which are foreshortened by tidal gates, whereas much higher hofs have been set for the longer estuaries particularly the Bedford Ouse and the Ely Ouse.

The 'hands-off' flows listed on Tables 4 and 5 have evolved, independently of each other, over several decades. It would be desirable to re-examine them on a consistent basis. This will be guided by the results of current NRA research. In the meantime, the only changes being contemplated concern the hof's controlling abstractions from the Bedford Ouse to Grafham Reservoir and from the Ely Ouse to Essex. Both of these have been subject to environmental assessments, which are described in Chapter 12.

Chapter 7 - THE HUMAN POPULATION AND ITS NEEDS

The human population is a legitimate part of the environment. As with environmental water needs, the legitimate needs of people should be met subject to proper consideration of reasonableness and worthwhileness.

POPULATION

The Anglian Region has the fastest rising population in the country. Table 6 shows that the 1992 population of 6 million may rise to nearly 6.9 million by the year 2021.

Table 6 - Population By Water Company Areas[1] (thousands)

	1992	2001	2011	2021
Anglian	3905	4202	4412	4594
Cambridge	276	287	306	323
Essex & Suffolk - Essex[2]	1405	1459	1493	1525
Essex & Sugffolk - Suffolk	250	268	280	289
Tendring Hundred	138	145	152	161
TOTAL[3]	5972	6361	6642	6892

1. From Water Companies 1994 Strategic Business Plan submissions to OFWAT
2. Includes population in Thames Region supplied by Essex and Suffolk Water.
3. Excludes populations in Anglian Region supplied by Three Valleys Water and others.

LICENSED WATER USE

Table 7 shows the quantities of water licensed to be abstracted for all purposes. The total quantity, 3927 tcmd (average), is about 35% of average effective rainfall. These figures are not of direct use for planning water resources because, among other things:-

- They make no allowance for water returned after use.
- Licensed entitlements often include margins for flexibility and security of supplies; actual abstractions are therefore less.
- There is a degree of double counting; for example water licensed to fill a reservoir, and then re-licensed for abstraction into supply.

Table 7 - Licensed Abstractions[1] (as at 31 December 1993)

Purpose	From Groundwater tcmd	From Surface Water tcmd	Total tcmd
Public Water Supply	1088	1709	2797
Private Water Supply	40	-	40
Power Generation	0	51	51
Other Industry	367	148	515
Spray Irrigation	171	213	384
Other Agriculture	39	1	40
Fish Farming and Water Cress	5	63	68
Other	19	13	32
TOTAL	1729	2198	3927

1. These are gross licensed entitlements with no allowance for quantities returned to water resources. They exclude abstractions from tidal waters.

PUBLIC WATER SUPPLY

Current Use

Average public water supply (PWS) in the Region (including the whole of Essex and Suffolk Water, but excluding Three Valleys Water whose demands are considered by our Thames Region) is some 1700 tcmd. In addition Anglian Water Services currently provide up to 109 tcmd to Water Companies outside this Region.

PWS demand doubled in the last 30 years. Until recently it was still rising at about 1% per year, due to rising population and to increasing water use per person. However, for reasons given in Chapter 2 the rate of increase has fallen sharply. The indications are that, despite rising populations, lower rates of increase are likely to be sustained.

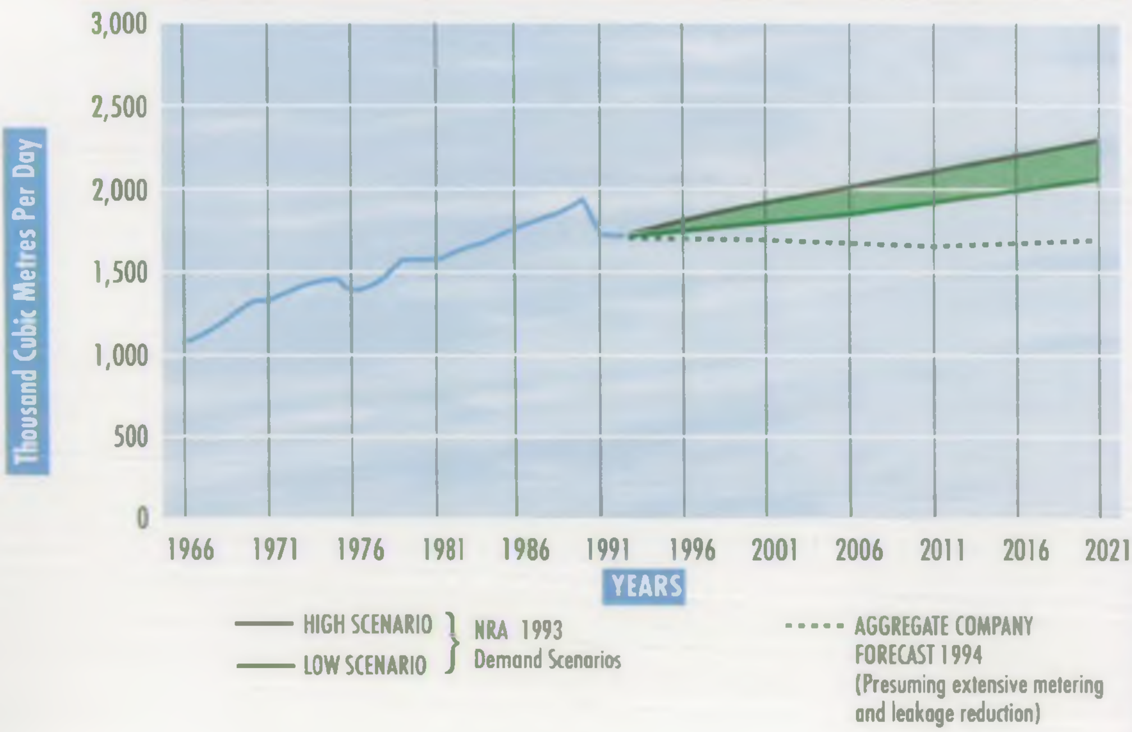
The Companies' Forecasts

All Water Companies submitted demand forecasts to OFWAT in March 1994 as part of their 5 yearly business plans review. Those forecasts depend upon implementation of the Companies' plans for expenditure on metering (which reduces water use) and on mains rehabilitation (which reduces leakage). In particular, Anglian Water's forecasts have fallen, largely because they propose to meter a large proportion of their customers. Other companies' plans are less ambitious, but all have reduced their forecasts. Table 8 and Figure 10 show these water company forecasts. Details are in Annexe 6. However, they remain very dependent on expenditure on metering and leakage reduction.

The NRA's Future Demand Scenarios

As part of its National Strategy (Ref 5), the NRA prepared independent forecasts of future PWS demand, based on alternative 'high' 'medium' and 'low' scenarios. Annexe 6 compares NRA and Company figures and shows that all the Anglian Companies' forecasts lie near, or even below, the NRA's 'low' scenario. Our national strategy states that "the NRA does not consider that a long term strategy should be based upon a specific prediction of a particular future demand, but instead it should be recognised that forecasting is an uncertain process". In this strategy we have not therefore attempted any further scenario forecasting. Should higher demands materialise, they would trigger earlier development proposals by the Companies within the framework proposed in this strategy, which the NRA would compare against demand management options.

Figure 10 - NRA Anglian Region Public Water Supply Demand



Planning Margins

For reasons discussed under "The Precautionary Principle" in Chapter 4 we have added a planning margin of 10% to all the PWS forecasts in Table 8. This is in accordance with the policy statement in our National Strategy (Ref 5) that abstractors should "develop sufficient resources to meet their reasonable needs without frequent drought order applications, which, if granted would adversely impact on the aquatic environment".

It also recognises that a secure water supply requires a greater allocation of resources than the 'most likely' demand forecast in order to cover:

- Impossibility of operating water resource systems 100% efficiently,
- Non transferability of surpluses, especially with groundwater sources,
- Peak demand years (order of 3%),
- Potential loss of sourceworks, due for example to pollution,
- Possibility of unpredicted demand increases, for example a large new factory,
- The possible impact of climate change on water demand,
- The possible additional demand imposed by water quality constraints, e.g. to cope with high nitrate levels.

However, the detailed planning of particular schemes will require margins related to the specific circumstances.

AGRICULTURE

Most of the Region's rainfall is evaporated by plants (Fig. 4). However the demand for abstraction from water resources is more modest, licensed entitlement being some 424 tcmd (average over 365 days). 10% of this is for general agricultural purposes such as washing down and stock watering, which are only partly consumptive and are not significantly increasing. However the rest is for spray irrigation, virtually none of which is returned, and is concentrated in a short summer period when water is scarcest. Authorised spray irrigation in the Anglian Region is over half of the national total; on a peak day it can exceed the demand for public supplies, and in recent years it has been increasing at some 4% per year. This presents a quandary for water resource management; on the one hand spray irrigation is a major demand on water resources, on the other agriculture is a key industry and irrigation is undeniably important both to national food production and to regional employment.

Unlike public water supply, agriculture has no water infrastructure and individual farmers have to obtain water on or adjacent to their farm as best they can. The NRA commissioned research (Ref.24) into prospective future irrigation demands and their importance to the economy. The resulting forecasts are given in Annexe 7 and summarised on Table 8. They suggest an increase of 50% by 2021 (excluding climate change).

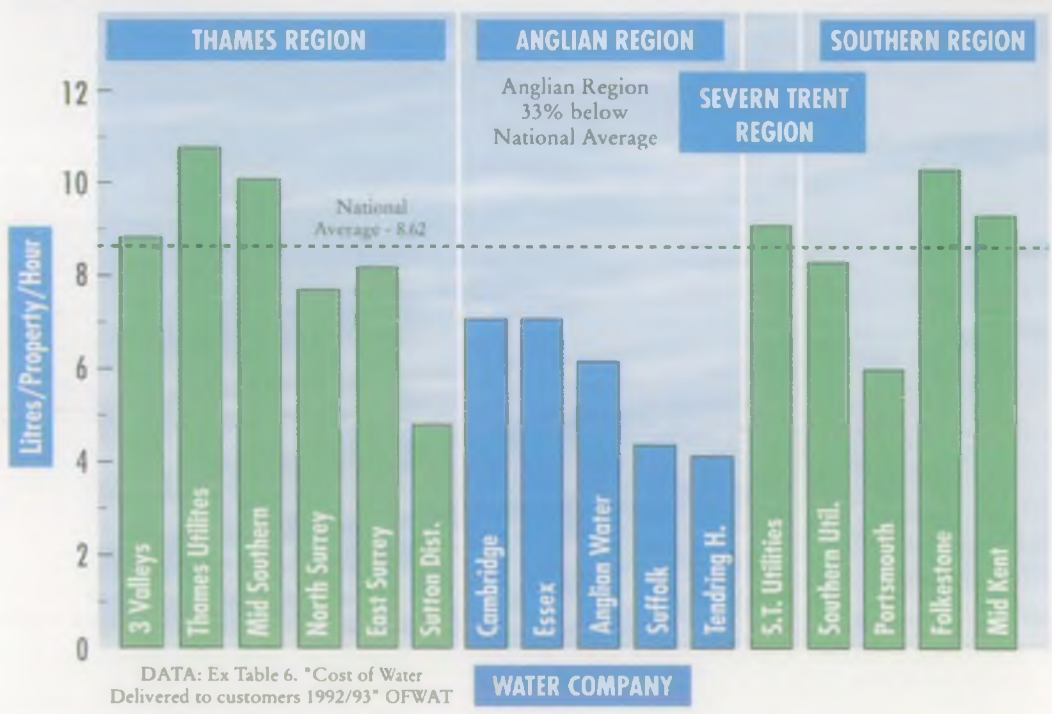
In addition to spray irrigation, water is diverted in dry summers from the main rivers which flow through the Fens into the lower level fen drains. Most of this water is subsequently used by the crops in the form of 'sub-irrigation' (the reverse of normal field drainage). Such transfers and water use are not controllable by licence, but they can account for as much or more water than licensed spray irrigation (Refs. 25 and 26). Resource assessments for other purposes take account of current transfers, but any increase in the practice of sub-irrigation could have profound implications for water resource availability.

* Water Company figures are provisional - see text
1. Forecasts submitted to OFWAT, 1994; dependent on assumptions about expenditure on metering and on leakage control and subject to some very minor discrepancies due to the lengthy submission process.
2. Includes non-potable supplies to Humberside industries.
3. Future PWS figures include the 10% margin described in ch. 7.
4. This is treated water supplied by Anglian WS to Severn Trent WS and to Three Valleys WS. 1993 figure is based on entitlement rather than actual; future entitlements taken as 18 and 91 tcmd respectively, rising to 18 and 136 at 2021.
5. This is an estimate of dry year demand without major restrictions.
6. Assumes entitlement used.
7. Excludes non-consumptive use for fish farming and cress growing.

Table 8 - Summary of Demand Forecasts - tcmd*

	1993	2001	2011	2021
Public Water Supply[1]				
Anglian[2]	1118	1028	1000	990
Cambridge	75	79	87	95
Essex and Suffolk - Essex Area	400	405	434	464
Essex and Suffolk - Suffolk Area	74	82	89	95
Tendring Hundred	31	36	38	40
Total Public Water Supply	1698	1630	1648	1684
Total Public Water Supply + 10%[3]	-	1793	1813	1852
Bulk Exports[4]	109	109	109	154
Direct Water Use				
Power Generation	50[6]	60	70	80
Other Industry	246	246	270	295
Spray Irrigation[5]	265[5]	326	370	390
Other Agriculture[7]	14	16	18	20
Total Direct Water Use	579	648	728	785
Overall Total	2386	2550	2650	2791

Figure 11 - Public Water Supply Total Leakage (1992/93)



DATA: Ex Table 6. "Cost of Water Delivered to customers 1992/93" OFWAT

POWER GENERATION

This is a relatively small demand, as large power stations are on the coast and use sea water for cooling and mains water for other purposes. We have presumed that a major power station previously suggested at Denver is unlikely to be built. However, there is a significant demand for the new generation of smaller gas-fired power stations. In the last year or so, four such stations have been licensed for a total of 51 tcmd, of which about two thirds is returned and one third evaporated. Other enquiries have been received, but no more power station applications are in hand. We believe this is because of the uncertainties in the power generation market. Potential stations have to compete with nuclear, and other large power stations as well as with each other; their economics are very sensitive to location in relation to the power grid and, on the margin, to water availability. Anglia is badly placed in both these respects. It therefore seems that the recent flurry of new licences is untypical, but we nevertheless allow a precautionary 10 tcmd per decade for future growth in this sector. Much of this would be returned after use.

OTHER INDUSTRY

There is a wide range of direct industrial use of water ranging from almost wholly non-consumptive uses such as mineral washing to almost wholly consumptive uses such as top-up cooling. There is some suggestion (Ref.27) that firms could switch from treated to raw water for financial reasons, and some recent indications of increasing water use. However the forecasts given in Annexe 7 and summarised in Table 8 presume only modest growth for this category of use.

NAVIGATION

Navigation requires level, rather than flow. All the Region's navigable rivers are ponded either artificially or by tidal action, and the needs of navigation are limited to making up losses due to lockage and leakage. Flows needed for these purposes are usually much less than those needed for other purposes. A possible exception is in the estuary of the River Ouse where siltation and navigation levels might be affected by abstraction.

FISHERIES AND RECREATION

Fisheries and Recreation are important human uses of water. However, their 'demand' cannot be measured in the same way as abstractive uses. We assume instead that the needs of fisheries and recreation will be met if the rivers are sustained in a healthy state, ecologically and aesthetically. In Chapter 6 we explore the many ways in which this can be achieved, and the implications for water resources.

EFFLUENT DILUTION

River flows are used not only as sources of water but also as diluters of effluent. There can be a conflict of interest between abstractors and dischargers who in effect compete to 'use' the same water for incompatible purposes. The NRA is working towards a flexible policy to strike a balance between abstractors, dischargers and the environment.

However, in this region it has been repeatedly found that it is far more economic to achieve a given river quality by improving effluent treatment rather than by increasing dilution flows. Recent external research (Ref 27) corroborates this.

We therefore assume that dilution needs will be encompassed within the river flow targets set for other purposes and we make no other specific provision for effluent dilution needs.

Chapter 8 -
PUBLIC WATER SUPPLY

ADDITIONAL WATER NEEDS

The demand forecasts in Chapter 7 are combined with the current sourceworks outputs (Chapter 5) to identify future additional needs for public supply. These are summarised in Table 9. By 2021 they total about 92 tcmd. However, this is heavily dependent on expenditure on metering and on leakage control as described in Chapter 7; in reality greater deficits could arise. Table 9 also shows the additional water needs for public supply that would arise under the NRA's 'high', 'medium' and 'low' demand scenarios.

These 'strategic' figures are the measure of how much extra water needs to be found (or saved) in the long term to keep pace with public demand. They can mask local shortfalls. Many such problems will have local solutions in accordance with the principles of water availability and licensing policy in the next chapter. There are, however, some locations which need specific mention:

Norwich

The figures for the Norwich area presume reliability of Anglian Water Services' Costessey intake. However, measures may be necessary to underpin that reliability at times of peak demand in dry summers.

Ipswich

An additional groundwater source may be needed to make time to develop longer term strategic supplies to Ipswich.

Bury St Edmunds

Enhanced demand management or transfers from adjacent zones may be needed to make time to develop longer term strategic supplies to Bury St Edmunds.

Table 9 - Additional Water Needs - tcmd

	2001	2011	2021
Public Water Supply[2]			
Anglian Water[1]	-	-	-
Cambridge Water	-	-	-
Essex and Suffolk Water - Essex Area	17[3]	48[3]	81[3]
Essex and Suffolk Water - Suffolk Area	-	2	9
Tendring Hundred Water	-	-	2
Total Public Water Supply	17	50	92
Direct Water Use			
Power Generation	10	20	30
Other Industry	7	14	30
Spray Irrigation	57	101	139
Other Agriculture	2	4	5
Total Direct Water Use	**76**	**139**	**204**
Allowance for Low Flow Amelioration	30	30	30
Overall Total	**123**	**219**	**324**
Total PWS[2] NRA 'High' scenario	63	209	439
Total PWS[2] NRA 'Medium' scenario	47	87	260
Total PWS[2] NRA 'Low' scenario	33	44	83

1. Figures include for bulk exports to STWS and to Three Valleys WS.
2. Figures include for 10% margin described in chapter 4. They do not allow for re-allocation of surpluses between companies.
3. These figures are subject to review of the yield of the Ely Ouse to Essex system

Sleaford

There is doubt as to whether local resources are sufficient for both abstractive and river needs. The matter is under active investigation.

Lincoln

AWS are investigating ways of using Trent water in Lincoln, and are concerned that minimum flow requirements in the Trent could substantially affect the cost and feasibility of doing so.

Three Valleys WS

It is still not wholly clear how much of Three Valleys' increasing demand should be met from this Region, and how much from Thames Region. For the present purpose, Table 9 includes deficit figures to be met from Anglian resources agreed with the Company on a provisional basis.

AGRICULTURE AND INDUSTRY

Table 9 includes allowance for the future raw water needs of industry and agriculture. These are based on the increases in demand given in Chapter 7, but the assessment is complicated by the fact that any surpluses held by existing water users cannot be set against the future needs of new users. Annexe 8 details the assessment of the amount of 'new' water that would be needed if all the demands for industry and agriculture were to be met.

A particular location of potential deficit is the Middle Level fen, which historically is fed with water transferred from the Lower Nene through Stanground Lock. In dry summers all the available flow is so transferred, and there is not always sufficient for the competing needs of the Middle Level, the North Level, the Nene Washlands SSSI, and the Estuary.

ENVIRONMENTAL DEFICITS - RIVERS

Chapter 6 introduced the concept of River Flow Objectives. If and when such objectives are established, river flow deficits can be assessed as the extent to which the river's flow pattern falls below the objective. In the meantime however river deficits are assessed on a case by case basis.

The NRA nationally has identified, and is addressing, perceived problems of low flows due to abstractions. Several such rivers, and wetlands, are in the Anglian Region. The 1988 - 92 drought led to concern about low flows in other rivers. In order to independently compare rivers across the country the NRA has been testing and refining a new methodology (Ref.28) which produces objective measures of low flow problems. We have applied this method to 50 Anglian rivers which have been suggested as having possible low flow problems.

Table 10 gives an indication of the most affected rivers on the basis of having low flows due to abstraction *and* of suffering ecological effects as a result. Where appropriate it also shows other rivers previously suggested as low flow problems and, in all cases, the current status of investigations or ameliorative works. Figure 12 shows all these locations.

We stress that this methodology still needs further development. We also point out that rivers whose low flows in recent summers were predominantly due to the drought are *not* listed; we do not believe it is a valid objective to sustain flows above their 'natural' values (save in some cases as compensation for loss of higher flows as discussed in Chapter 6).

We are undertaking research into how to put money-values to the benefits of restoring artificially reduced flows. This is likely to take some time. The costs of flow amelioration measures (including licence revocations) tend to be counted in millions of pounds. However they are funded, they must eventually be paid for by the community at large and detailed investigation and assessment of worthwhileness is always necessary before amelioration is undertaken.

An additional problem can occur in rivers used as 'carriers' of water transfers, for example

Table 10 - Possible "Low Flow" Rivers and Wetlands

River/Wetland *	Reach	Ameliorative Measures: Description	Ameliorative Measures: Status
1. Babingley River	u/s Castle Rising		Preliminary study planned for completion in 1994
2. Black Ditch †	Hollesley, Suffolk	Install gauging station to improve enforcement	Completion planned for 1994
3. Caudle Springs	Near Watton, Norfolk	Augmentation, site and water resource management	Completion planned for 1994/5
4. River Deben †	Wickham Market, Suffolk	Augmentation and/or licence revocation	Study for completion in 1994
5. East Ruston Fen †	East Ruston, Norfolk	Relocation, augmentation and/or management	Study for completion in 1995
6. River Freshney Laceby Beck	Laceby to Grimsby	Augmentation from borehole	Further investigation required linked to possible abstraction licence variation.
7. East Glen West Glen †	d/s Wilsthorpe d/s Essendine	Water transfer	Completed in 1990
8. River Granta	-	Augmentation	Completed in 1993
9. Hackthorn Beck and Welton Beck	Hackthorn/ Welton to Barlings Eau		Further investigation required linked to possible abstraction licence variation.
10. Heacham River	Upstream of Heacham		Priority for action to be established by 1995
11. River Hiz †	Hitchin, Hertfordshire	Augmentation	Augmentation complete and improvements being explored
12. Hoffer Brook †	Near Newton, Cambs.	No longer deemed a problem - NRA boreholes support associated SSSI	No action planned
13. River Lark	Upstream Bury St Edmunds & tributaries		Planned to identify solution by 1998
14. River Mun †	Mundesley, Norfolk	Move existing abstraction	Completion planned for 1994
15. Redgrave and Lopham Fen †	Near Diss, Suffolk	Relocation, augmentation and management	Investigations and work planned for completion by 1997
16. River Slea †	Sleaford	Augmentation from borehole	Completion planned for 1994
17. Stringside Beck	Upstream of Whitebridge	Relocation, augmentation or water resource management	Further investigation required
18. Waithe Beck	-		Further investigation required linked to possible abstraction licence variation.

* See Figure 12 for locations

† Included in National "Top 40" List (ref. 29)

the Rivers Stour and Blackwater which carry Ely Ouse water primarily to augment public supply intakes at their tidal limits. Despite the benefits of higher flows, there can also be undesirable effects such as rapid and unnatural fluctuations in depth and velocity, transfer on occasions of algal rich and turbid water and possible transfer of undesirable substances or organisms. We propose research into these effects and to undertake any reasonable ameliorative measures. We also note that any development option which leads to steadier transfer flows would improve the situation.

ENVIRONMENTAL DEFICITS - WETLANDS

In drawing up Table 10 the NRA has recognised that excessive authorised abstractions can cause problems not only to river flows, but also to wetlands. Consequently Table 10 includes three wetlands; Redgrave and Lopham Fens, East Ruston Common and Caudlesprings. At these sites the NRA is currently investigating, with the water companies and conservation bodies, ways of identifying and alleviating problems caused by abstractions, and actions are being taken accordingly.

Figure 12 - Possible "Low Flow" Rivers and Wetlands

The NRA recognises that there may be other candidates for amelioration, but at present there is not enough information available to identify what is required or to justify the possibly considerable expenditure involved. In the wake of the 1988 - 1992 drought much attention has been focused on the effect of reduced water supply to wetlands. Both English Nature (Ref.30) and the Anglian Region Wildlife Trusts (Ref.31) have produced reports that express such concern, and which identify between them 178 wetland sites in Anglian Region which are perceived to have hydrological problems. The reports recognise that these perceptions are based largely on anecdotal evidence, and that it is generally not possible to state categorically whether the problems are caused by the drought, groundwater abstraction, land drainage, dereliction due to under management, or a combination of these factors.

There is however, clearly a concern that many hydrological problems may be due to factors other than drought. In their study for English Nature, Wheeler and Shaw (Ref.32) made a subjective assessment of the causes of floristic changes at 107 spring-fed wetland sites in Norfolk, Suffolk and Cambridgeshire. Their findings, which they state are provisional, suggest that groundwater abstraction probably contributes to problems at 26 sites and that 50 (not necessarily different) sites are probably affected by the deepening of adjoining ditches and watercourses.

The NRA recognises that groundwater abstraction can cause problems for wetlands, and is taking steps to gain better hydrological understanding of wetlands and to improve their protection.
The NRA is taking care to ensure that no such problems are caused by future licences that are issued (see the licensing guidelines quoted in Chapter 6). Within Anglian Region, a project is under way to identify better ways to assess the hydrological impact of proposed (and existing) abstractions upon wetlands, and to improve understanding of the water requirements of wetlands. The aim is that the NRA will have a better framework for protecting wetlands and this will lead to refinements to our licensing policy.

The lack of hydrological data which is often a reason for the current poor hydrological understanding of specific wetlands is also addressed. The NRA Anglian Region is setting up a hydrological monitoring network of wetland sites. This will initially comprise 50 sites within the region which will be chosen with advice from English Nature. The data collected as part of the planned 10 year monitoring programme will provide the basis for an improved understanding of the water regime of specific sites, its controls, and how it might be affected by external factors such as groundwater abstractions.

The NRA will also be taking part in a programme establishing Water Level Management Plans, following guidelines recently issued by MAFF (Ref.33). These plans will provide a means by which the water level requirements for a range of activities in a particular area, including agriculture, flood defence and conservation, can be balanced and integrated. Plans will be prepared for areas which have a conservation interest where the control of water levels is important to the maintenance or rehabilitation of that interest. Where the NRA is the operating authority controlling water levels it will prepare and implement such Plans having consulted with other interests. The NRA will also be taking steps to link the Water Level Management Plans with Catchment Management Plans.

ENVIRONMENTAL DEFICITS - EFFECT ON WATER USERS

Any measures to ameliorate problems of over-abstraction are likely to reduce the amount of water available for human use. It is not yet possible to determine what schemes will prove worthwhile, nor what they would entail. However we have made a provisional allowance of 30 tcmd loss of sourceworks reliable output for this purpose.

This is added to the total deficit figures on Table 9, but not to those of any user category as it cannot be predicted where such losses would fall. The quantity allowed is relatively modest as most of the low flow problems in this Region are relatively local ones, on a lesser scale than, for example, the major problems in streams in the Greater London area.

SUMMARY OF ADDITIONAL NEEDS

Table 9 summarises all the predicted additional water needs in the Anglian Region up to the year 2021.

Note that these figures make no allowance for the needs of other regions, except for specific bulk exports identified in Table 8.

Chapter 9 - THE AVAILABILITY OF WATER TO MEET FUTURE NEEDS

Most of the reliably available water resources of this Region are already allocated, either to abstraction or to the environment. The only exceptions are winter flows (in many rivers), some groundwater (in certain areas only) and some summer flows in rivers augmented by NRA pumping. In allocating such remaining water resources the NRA acknowledges that there is a basic presumption in the relevant legislation that the 'reasonable needs' of would-be abstractors should be met if possible. On the other hand the NRA also has environmental duties; the needs of the environment and of would-be abstractors may conflict, and we will apply the precautionary principle where appropriate.

LICENSING POLICY

Where water is available within the sustainable carrying capacity of a Catchment's water resources, it may be licensed for use, but only with conditions for the protection of the local environment and of neighbouring abstractors as set out in Chapters 4 and 6.

THE CURRENT AVAILABILITY OF RAW WATER

Annexe 9 gives general statements about the current availability of raw water. Annexe 4 adds quantitative information on groundwater availability. The figures within Annexe 4 have been refined by further work since preparation of our Consultation Draft, and the availability tables have been amended accordingly.

In summary,

- Winter surface water is available in most catchments. Where possible the NRA will encourage applicants to use winter water and store it for summer use. However, all abstractions are likely to be subject to a 'hands off flow' condition and 100% reliability of winter filling of reservoirs cannot be taken for granted.

- Summer surface water is rarely available.

- Groundwater is generally available in certain catchments only, as shown on Figure 8 and detailed within Annexe 9. Note that this deals only with the overall availability of water. The term 'Nominal Surplus' does not mean there is water available everywhere in a catchment. Every licence application will always be subject to the usual considerations of derogation and environmental impact.

There are certain exceptions even in 'no water available' areas, which are detailed within our licensing policy. These are all of a minor nature eg for test pumping, for non-consumptive uses and for abstractions which are part of an arrangement which provides overall net benefit to the environment.

THE FUTURE A VAILABILITY OF RAW WATER

In some rivers availability is progressively increasing due to rising effluents, though this may not be fully reliable as effluents may occasionally be relocated.

Chapter 12 enlarges upon specific options for obtaining substantial reliable supplies. In addition, relatively minor supplies may be obtained by individual abstractors, subject to the above criteria.

Further water supplies may be available from neighbouring regions, in particular from the River Trent. This is enlarged upon in Chapter 12.

The assessments of groundwater availability include some precautionary assumptions about the allocation of groundwater to the environment. It may be possible, in the future but not yet, to relax these allocations.

Chapter 10 - THE OPTIONS FOR SAVING WATER

USING WATER WISELY

In this region water resources are heavily committed. 'New' water is expensive and can cause environmental problems. We must therefore look hard at how water is used and how it could be saved. This is generally called 'demand management'. The NRA advocates demand management by all water users to the extent which is economically justified. By this we mean to the point where the costs of saving water match those of making more available, taking account of all the costs, and benefits - financial, social and environmental.

This is endorsed nationally, both by Government (Ref.34) and by our National Strategy (Ref.5) which includes the following specific policies:-

- "requiring Water Companies to achieve economic levels of leakage and metering before new abstraction licences are granted for strategic developments;
- the promotion of water efficiency by industry, commerce, agriculture and the home."

In pursuance of the second point, the NRA strongly encourages water companies and other major abstractors to adopt policies and procedures that result in the efficient use of water, in their operations and by the public, through a balanced approach combining demand management with phased traditional source development. Balanced policies will have regard to both cost to consumers and environmental impact.

Our regional consultation exercise showed strong public support for using water wisely. Our consultees generally thought that the NRA should actively promote:-

- selective metering, with appropriate tariffs which combine care for the environment with care for those who have to pay.
- leakage control
- public education
- more efficient appliances
- incentive charging for water, and
- "more efficient" irrigation

CURRENT DEMAND MANAGEMENT IN ANGLIA

Demand management in this dry region is not new and we acknowledge the responsible attitude which is being taken by Water Companies and other users, in this Region. This was encouraged by the recent drought, but Anglia's dry climate has long forced water economy on the water industry, if not always on the general public.

More recently all the Water Companies have reviewed their demand management policies as part of their five yearly "AMP" submissions to OFWAT (see Chapter 7). This is expected to lead to reduced leakage, due to enhanced mains rehabilitation, and to reduced domestic water use, due to increased metering. Anglian Water plan to meter a significant proportion of their customers and believe this may achieve 15% savings in domestic use. They take the view that these measures, together with the associated tariffs, will lead to static, or even decreasing demand.

Demand management in this region is therefore as advanced as anywhere in the country. It is playing an increasing part in sustaining the balance between supply and demand. However, with rising population, we still need to be prepared to respond to some increase in demands, at least in some areas.

THE MEANS OF DEMAND MANAGEMENT

The principal means whereby water demand can be restricted are:-

Drought Measures (e.g. Hosepipe Bans)

OFWAT's target levels of service for drought measures are built in to the estimation of yields. These include having hosepipe bans not more often than once in 10 years and standpipes once in 100 years. More frequent restrictions would defer the need for new water resource developments. For example, if hosepipe bans were accepted as a 'normal' event once in 5 years, and standpipes once in 50 years, then the measures put forward in this strategy might be delayed by 7 years or more.

Pressure Reduction

This technique, which can reduce leakage and water use, is increasingly practised by water companies and we look to them to extend pressure reduction wherever possible in stressed areas. However, the scope is limited because pressures are generally low in this flat region, and also due to the companies' need to meet levels of service targets for water pressure.

Leakage Reduction

In some areas of the country distribution losses account for 30% or more of water put into supply. However such losses in Anglia are less than half the national average (Figure 11).

The NRA expects companies to minimise leakage, particularly in stressed areas. The progressive mains improvements which all the companies carry out for other purposes (for example to improve water quality) will help to facilitate this, and the demand forecasts accord with it. There may be local circumstances where tighter leakage control is justified, but we acknowledge that there is a strong law of diminishing returns (it will never be economic to find every leak) and that constant effort is necessary to hold leakage down. Also a significant proportion of leakage is from customers' supply pipes, over which the companies have no direct control. Metering, however, will increasingly impose financial incentives on customers to reduce their leakage.

Better Design of Water-Using Appliances

Water can be saved by improving the design of washing machines, dishwashers and other appliances, and by reducing the flush-volumes of wc's. We welcome and endorse national moves in this direction, for example the initiatives in 'Using Water Wisely' (Ref. 34). Water byelaws have been imposed for some water saving devices. For example recently imposed byelaws require all new cisterns to have a capacity of 7.5 litres as opposed to the previous 9.0 litres. Eco-labelling of water saving devices such as washing machines and dishwashers, which would require that certain efficiency standards have been met, should also be promoted. Some water companies have taken steps in this direction; a concerted approach will be needed to achieve serious results.

On the other hand we note that it may take price incentives (see 'metering' below) to achieve a real impact on appliance design, and that there are social and public health limitations - we are not advocating poorly washed clothes or inadequately flushed toilets. We will continue to press for acceptable savings, but we also note trends, such as power showers, which may legitimately increase water use.

Consumer Education

Again we endorse all moves to educate the public to use water wisely, and we have taken a lead in this direction ever since our formation. But again it takes constant effort to sustain public awareness, while the major savings that individuals can make, other than in drought emergencies, are in outdoor uses such as garden watering. These are more related to saving peak distribution costs than to saving water resources.

Metering of Household Water Use

Metering of household use, with appropriate tariffs, is probably the most effective way of reducing water use. It is favoured by many customers as being fairer and 'greener'; but it is expensive. National metering trials, notably on the Isle of Wight, indicate savings of the order of 8 - 15% of domestic use (Ref.35). If 10% reduction were achieved throughout the region it would save some 80 tcmd. However there is a law of diminishing returns with metering, too, and there are practical, social and economic factors which may influence the rate and extent to which meters are introduced.

All the water companies in this region have programmes of meter installation (see Chapter 7) and their demand forecasts allow for 10% savings in those households which they expect to meter. Where water resources are under stress we will expect the companies to look to additional metering as an alternative to developing 'new' water, to be compared on the criteria of cost, environmental impact and social acceptability.

Industry

There may be scope for industry to save water by more water effective processes and/or by re-cycling water within the factory. Again the scarcity of water in this region has forced such measures on many industrial users. For example, major power stations are all sited on the coast, to use sea water for cooling; some smaller ones inland use air-cooling because fresh water is not available; Thameside industries practice re-cycling within and between factories, and Humberside industries have responded well to NRA pressure to reduce raw water use to avoid saline intrusion.

The value of re-use has already been realised in many sectors of industry and commerce. Many large water users/dischargers have recognised the cost savings from recycling water, not necessarily from reducing the costs of treated water, but from the savings of reduced trade effluent disposal. In Yorkshire, the NRA has played a major part in fostering such savings through the "Aire and Calder" project (Ref.36) which produced water savings of about 10%. We intend to apply the same techniques to a pilot catchment in this region, and if successful to extend them to other catchments. In the meantime we look to industry to continue good water husbandry and our forecasts make due allowance for it.

Irrigation

The need for water economy was forcibly brought home to farmers by the recent drought. The NRA, in conjunction with MAFF, produced guidelines on Good Irrigation Practice (Ref.37) designed to minimise any wasteful irrigation. We will continue to press farmers to ensure these guidelines are followed. There is, however, an irony that greater attention to good practice could actually increase irrigation use, as many farmers currently apply less than the optimum amount of water to their crops (Ref.24). "More efficient" could mean more water.

THE EFFECTS OF DEMAND MANAGEMENT ON THE ENVIRONMENT

In this region the practical effect of reducing water use is less than in some others. This is because about 60% of Anglia's population returns its water, after use, to the rivers; while most of the 40% around the coast are supplied with water taken from rivers at or near their tidal limits anyway.

Neither leakage nor profligate use destroy water; they only result in moving it from one place or time to another. The environmental effects of such movements are sometimes bad, sometimes neutral and sometimes good. Where they are neutral or good there is no environmental case for demand management. Where they are bad there is such a case and these are the areas where we advocate *selective* demand management.

Areas where 'wasting' water can actually do some environmental good are those inland, where the effect is to boost low river flows, giving increased dilution capacity. Neutral areas include those where demand is met from the tidal limit of a river; in such areas the effect of 'waste' is just to move water from one point of entry to the sea to another. Areas where wasting water can be environmentally harmful are particularly:-

- those where demands are met from groundwater, and
- those where saving water can defer or eliminate the need for a new development which is considered environmentally damaging.

We are working to better define these distinctions, and to refine our "use water wisely" policy accordingly.

Chapter 11 - THE OPTIONS FOR RE-ALLOCATING WATER

The system of licences introduced by the Water Resources Act 1963 allocates water to the first person or organisation to show reasonable need for it. The system is a rigid one of first come first served, and once issued a licence confers a valuable right upon its holder. Recently it has become more common to make licences time limited, but generally only for reasons of uncertainty over water availability. Most licences are valid "until revoked". The only way to re-allocate water is for the NRA to revoke an existing user's licence, then re-issue to a new user. This makes sense if the value of water to the new user is greater than the value to the old user. However, the NRA has to pay full compensation to the old user, and gains no increase in licence income. The compensation has to be paid for by increased charges to all licence holders.

Many of the 10,000 or so licences in this region are approaching 30 years old, may not have been efficiently issued (in the economic sense) in the first place, and could now be inappropriate. Against this background we review the options for re-allocating water to where it would be best used:-

UNDER-USED AND 'INEFFICIENTLY' USED LICENCES

We use the term 'inefficiently' in its economic sense, meaning water allocated by licence to a relatively low-value use when there is an alternative relatively high-value use needing water. We commissioned economic research by Hull University (Ref.27) to advise, among other things, on how best to deal with this situation, bearing in mind the incentives on licence holders not to give up their rights and the penalties on the NRA of revocation. They concluded that the economic answer would be to introduce 'tradeable permits' - that is to allow a free market in licensed abstraction rights (with a regulatory role by the NRA). In theory this could in the long term lead to the allocation of water to the highest value uses. However, it would need new legislation. Reference 27 identifies various practical problems and recommends a pilot exercise.

It is to be noted that tradeable permits may carry some environmental risk. Many licences are not fully used, and the water remains in the environment. If unused rights are sold they are likely to become used. Economic efficiency could therefore be increased at the expense of the environment.

'SURPLUS' ENTITLEMENTS HELD BY WATER COMPANIES

The recent fall in PWS demand forecasts (Chapter 7) has left some companies, notably Anglian Water, with a surplus of reliable supplies over predicted demand. The reality of this nominal surplus may be questionable - it would be eliminated before 2021 even at the NRA's 'medium' scenario. There would also be considerable costs, as well as organisational and operational problems, in reallocating any such surplus from where it may occur (say Rutland) to where it might be useful (say Essex).

Some investigation has already taken place on this issue, and the conclusions were unfavourable. However, demand forecasts were at that time higher than they are now. We believe that the possibility of regional-scale reallocation of water should be reconsidered when companies' demand forecasts are firmed up in the light of realistic expectations of expenditure on metering and leakage control (see Chapter 10).

ENVIRONMENTAL ALLOCATIONS

Some perceived environmental deficits have been described in Chapter 8. More positively, water is allocated to the environment in the form of the 'hands off' flows (particularly those to the estuaries) listed in Tables 4 and 5, and by the allocations of groundwater to the rivers listed in Table 2.

In all these cases it is right to review whether the environmental allocation may be too high or too low.

Low Flow Rivers

In the case of the perceived low flow rivers and wetlands the implication is that the environmental allocation may be too low. We have allowed a nominal 30 tcmd reallocation to the environment for this purpose.

Allocation of groundwater to spring/river flows

Our procedure for allocating groundwater includes an allowance to the river linked to the natural 95%-flow (Annexe 4). This is based on experience; being a frequently experienced flow it is likely to reflect the physical, chemical and aesthetic requirements of current river users and it 'seems to work' (Ref.17). It is not, however, a proper objective approach, and it gives proportionately much more to groundwater-fed rivers than to surface-fed rivers. In the extreme it would allow no groundwater abstraction at all from a catchment where spring flows were fully evened out by groundwater storage. In Annexe 4 we explore the possibility of limiting the river allocation to 50% of the gross resource. (This would mean that the river would get in total the 'reliable' 50% plus the 'unreliable' 20%, leaving a maximum of 30% for abstraction). We propose to refine the river allocation by reference to the actual needs of the rivers' ecology. Research on this is in progress and should lead to better environmental allocations in the form of river flow objectives. (Refs. 18, 30, 31 and 32).

INCENTIVE CHARGING

Our charges for water abstraction must, by law, be set to balance the costs we incur in managing water resources. They are therefore relatively low, and are in no way related to the value-in-use of water, nor to the cost of making 'new' water available. We are therefore looking into whether economic principles, particularly incentive charges, could be used to improve the management and allocation of water resources. Initial research (Ref.27) suggests there is scope for improvement, but also identifies many problems and confirms the need for legislation before the current system could be significantly changed. The NRA is therefore investigating the matter of incentive charging for the future, but it is too soon to build any assumptions about it into this strategy.

CONSULTATION

It is worth recording that our consultation exercise revealed a widespread view that licences of right should be revocable without compensation, and/or the that NRA should revoke 'offending' licences even if compensation is payable.

There is also considerable support for proposals for tradeable permits, incentive charges and for bringing 'slacker' abstractions within licensing control. (These are summer transfers of river water 'backwards' into fen drain systems).

Chapter 12 - THE OPTIONS FOR SECURE WATER SUPPLIES

There are various ways in which more water could be made reliably available. However, most of them involve significant cost or significant environmental impact, or both. No major option is both cheap *and* without impact.

It is not the NRA's role to develop these options, but rather to act as facilitator so that others may develop them in an optimum, co-ordinated manner.

The options are summarised in Table 11. In brief the options are as follows:

MINOR LOCAL SOURCES

Winter water is relatively plentiful and can be stored for summer use. There are already over 600 **farm reservoirs** in the Region and it is NRA policy to encourage this way of meeting irrigation demands. Low winter abstraction charges are offered as an incentive. In appropriate circumstances the cost of farm storage compares well with larger water resource schemes, but we acknowledge that this may not be so where land is particularly valuable or where soil conditions demand reservoir lining.

There are widespread **gravel** deposits, **and other minor aquifers** which can sustain small local supplies; there are also opportunities for **local transfers** such as the existing arrangements to feed the East and West fens in Lincolnshire with Trent derived water transferred from the Witham.

A particular local resource exists at **Eye Brook reservoir** on a tributary of the River Welland. Eye Brook is an 8 million cubic metres (mcm) reservoir built in the 1930's for industrial supply and now owned by the Corby and District Water Co, a subsidiary of British Steel. It has an estimated yield of some 18 tcmd, but after a history of changes, is currently licensed for only 6.8 tcmd. Eye Brook could offer a significant local supply, perhaps to augment the Welland, and in the interest of securing the proper use of water we draw attention to its existence.

Progressive allocation of **local water to local use,** like irrigation, raises questions about derogation to existing abstraction rights - in a sense it is robbing Peter to pay Paul. We take the view that, where 'Paul' is a local user with no other option, and 'Peter' is a major user whose loss can be made good from strategic sources, then such reallocation is a proper use of water resources, provided that strategic sources are planned in good time and that any appropriate financial arrangements are made.

This strategy assumes, arbitrarily for the present purpose, that half of the forecast deficiencies for industry and agriculture can be met from relatively local sources, *but* that 40% of this will be at the expense of existing users and/or of strategic sources. (This has the effect of reducing the total deficiency by only 30% of its industrial and agricultural component).

GROUNDWATER

Conventional Use

Table 2 has shown that 'surplus' groundwater totalling over 200 tcmd may be available for abstraction from parts of the chalk, sandstone and crag aquifers of Norfolk and Suffolk, after allowing river allocations related to the 'natural' 95%ile flow.

The NRA could not allow the full amount to be developed for abstraction because of the need to protect wetlands, springs and headwaters and to avoid local derogation. Every proposed new abstraction has to be judged on its merits, and any substantial groundwater development will be subject to full environmental assessment. However, for strategic planning purposes we assume on a precautionary basis that perhaps 100 tcmd can be sustainably used in an environmentally acceptable way, provided appropriate abstraction locations can be found.

Name of Option	Description	Potential Beneficiaries	Source of Water	Storage	
				Location	Capacity $m^3 \times 10^6$
Minor Local Options Farm Reservoirs Gravels and Minor Aquifers Local Transfers of water from strategic sources		Individual Direct abstractors	Winter River Flows plus minor aquifers	Various	-
Groundwater	See text	All, including environ-mental needs	Natural ground-water recharge	Natural ground-water storage	Very large
Surface Water Offord hof eg 109 tcmd	Reduce hands off flow constraint on filling Grafham	AWS	Bedford Ouse	Grafham	Existing
Brownshill Tunnel	Additional intake to Grafham	AWS	Bedford Ouse	Grafham	Existing
Denver hof - 114 tcmd all year - 50 tcmd all year	Reduce hof constraint on NRA's abstractions at Denver to augment Essex Rivers	Essex & Suffolk Water plus other abstractors from Essex Rivers	Ely Ouse	Essex Reservoirs	Existing

1. All costs are at 3rd quarter 1992 prices.

Intake		Estimated Yield		Estimated Capital Costs[1]		Comments
Location	Pump Capacity tcmd	Basis	Amount tcmd	Total Cost £m	Unit Cost £m per tcmd	
-	-				Typically 0.1 - 0.5	Not identified in detail.
- -	- -	See Table 2 for best estimates of water available			0.1 - 0.5	Unit cost varies but typically 0.1-0.5 £m/tcmd (Ref.38)
Offord	Existing	AWS Estimate	50-60	2?	Low	Subject to EA and mitigation measures
Brownshill		AWS Estimate	100?	35?	0.35?	Powers already exist but EA will be required
Existing Blackdyke/ Kennett	Existing	NRA simulation (worst recorded Drought)	19 34	Low	Low	Subject to EA and mitigation measures *Continued overleaf*

Table 11 - Potential Water Resources Development Options

Name of Option	Description	Potential Beneficiaries	Source of Water	Storage	
				Location	Capacity $m^3 \times 10^6$
Great Bradley	Reservoir on Upper Stour	E & SW AWS THW CW Co ? Thames Region Direct water users in Essex	Ely Ouse	Great Bradley	100 80 60 40 20
Great Bradley + increased Ely Ouse - Essex Pumps - 455 tcmd 568 681 796	Reservoir on Upper Stour	E & SW AWS THW CW Co ? Thames Region Direct water users in Essex	Ely Ouse	Great Bradley	40
Fenland Reservoir	Bunded Reservoir on Fens near Feltwell	Essex & Suffolk Water plus others?	Ely Ouse	Fens Reservoir	100 60 40 20
Fenland Reservoir + increased Ely Ouse - Essex Pumps	Bunded Reservoir on Fens near Feltwell	Essex & Suffolk Water plus others	Ely Ouse	Fens Reservoir	100 60 40 20
Wash Storage	Bunded Reservoir(s) in the Wash?	As above	Ely Ouse + Nene	The Wash	65

Table 11 - Potential Water Resources Development Options (Continued)

Intake		Estimated Yield		Estimated Capital Costs[1]		Comments
Location	Pump Capacity tcmd	Basis	Amount tcmd	Total Cost £m	Unit Cost £m per tcmd	
Existing Blackdyke/ Kennet	Existing	Simulation of worst recorded drought	146 128 109 80 49	122 88 55 46	0.84 0.81 0.69 0.94	See Note 2.
Blackdyke/ Kennett	455 568 681 796	Simulation of worst recorded drought	106 123 135 142	55 plus: 2.6 12.0 13.3 34.5	0.54 0.54 0.51 0.63	See Note 2. 40 mcm is the largest costed size considered environmentally acceptable
Denver	400	Simulation of worst recorded drought	148 146 126 83	153 119 94 69	1.03 0.82 0.75 0.83	See Note 2. Yield at larger size is restricted by pump sizes
Denver + Kennett	400 681	Simulation of worst recorded drought	224 166 131 86	167 132 107 83	0.75 0.80 0.82 0.97	See Note 2. 100 mcm is the size needed for maximum demands. 681 tcmd is the pump capacity which optimises yield
?	?	CWPU estimate	180	175	0.97	

Name of Option	Description	Potential Beneficiaries	Source of Water	Storage		Intake
				Location	Capacity $m^3 \times 10^6$	Location
Eye Brook	Under-used existing reservoir	Local direct water users	Eye Brook	Eye Brook	8	-
Chelmsford Effluent - all - up to 40 tcmd	Diversion from estuary to river Chelmer	Essex & Suffolk Water	Chelmsford Effluents	Hanning-field - Existing	-	Langford
Trent	200 tcmd to Denver	Essex and Suffolk Water and others	River Trent	Essex Reservoirs existing		Existing
Trent	400 tcmd to Denver	As above	As above	As above		As above
Trent + increased Kennett Pumps	200 tcmd to Denver 400 tcmd to Denver	As above As above	As above As above	As above As above		Kennett Kennet
Trent + increased Kennett Pumps + Grt Bradley Reservoir	200 tcmd to Denver 400 tcmd to Denver	As above As above	As above As above	plus Bradley As above	100 100	Kennet Kennet
Desalination						

1. All costs are at 3rd quarter 1992 prices.

Table 11 - Potential Water Resources Development Options (Continued)

	Estimated Yield		Estimated Capital Costs[1]		Comments
Pump Capacity tcmd	Basis	Amount tcmd	Total Cost £m	Unit Cost £m per tcmd	
-	Yield (18) minus current licence (6.8)	11	?	?	Owned by Corby and District Water Company
Existing	Simulation Model	Approx 30	Up to 13.5	Approx 0.45	Cost estimates provisional (Ref.39)
	Simulation model	65	93	1.43	Costs are approx due to assumptions on 'sharing' common costs with other areas
681	As above	83	152	1.83	
681	As above	73	106	1.45	Would need increased intake capacity
681	As above	107	165	1.54	
681	As above	321	179	0.56	As above
681	As above	386	238	0.62	
				4-6	Reference 38

The use of groundwater for any non returning purpose affects river flows. As groundwater use progressively increases it is necessary to monitor the effect on river flows. If the reduction of base flow becomes unacceptable, further groundwater development may be allowed only if seasonal low flows can be supplemented (see Chapter 6 and Figure 9).

A particular opportunity for groundwater redevelopment exists in the Romford area (in Thames NRA Region) where Essex and Suffolk Water hold licences but have taken the associated boreholes out of service for water quality reasons. We believe that, with appropriate treatment, perhaps 4 tcmd or so could be economically redeveloped from this source.

River Support for Downstream Abstraction

Groundwater used locally for public supply mostly returns to the river and can be used downstream. Alternatively, river abstractions may be supplemented during low flow conditions by seasonal pumping of groundwater to sustain river flow. This may be used either to guarantee the reliability of river intakes in time of drought or to increase their yield. This already happens in the Waveney, Thet and Little Ouse catchments and could well be extended to the Bure, Wensum, Wissey and Nar to secure current or increased public supply abstractions which supply much of Norfolk. Care is needed with such schemes to ensure environmental acceptability (for example water temperatures) but they are probably the most economic and environmentally acceptable way of meeting much of Norfolk's future needs.

More problematic is the question of further artificially augmenting the Ely Ouse tributaries to enhance the Ely Ouse to Essex system yield. This is the principle of the Great Ouse Groundwater (GOGW) scheme. It was established in the 1970's that the GOGW scheme could be used to regulate flows at Denver and hence significantly increase resources in Essex. This remains true, but there are three reasons why this option is now seen as less advantageous.

- Part of the then-proposed GOGW scheme is now operational; the 'easy' water has already been developed.

- The unit cost of additional GOGW development, per additional unit of yield in Essex, is high.

- The scale of development envisaged in the 1970's would involve widespread lowering of the groundwater table in Norfolk and Suffolk. Such lowering would not be tolerable to the NRA or to many local interests. The need to safeguard wetlands increases the unit cost still further, and reduces the potential yield of this option.

For these reasons we make no allowance for further development specifically for Essex.

Groundwater Storage

There are local areas, where groundwater is confined by clay strata, where natural recharge is limited but groundwater storage can be used in time of extreme drought, then allowed to fill slowly in subsequent years. The Stour Augmentation Groundwater Scheme uses this conjunctive use principle to enhance the yield of the Ely Ouse-Essex system. However, this requires unusual geological conditions; preliminary investigations suggest no other feasible locations for such development, unless accompanied by artificial recharge.

Artificial Recharge

This means using the natural underground storage as a reservoir filled artificially by injecting water from the surface.

A successful artificial recharge scheme requires:

- An adequate volume of deep groundwater 'reservoir' whose level can be manipulated without unacceptable effects on spring flows or wetlands.

- An adequate supply of water to recharge with. Generally this means reasonable proximity to a river with surplus winter flows.

- Recharge water of acceptable quality. It is very easy to put polluted water into an aquifer, but very hard to remove it. Generally this means pre-treating recharge water to near potable standard.

- Appropriate facilities to recharge at a rate capable of capturing high river flows as and when they are available. Generally this means a network of boreholes and/or of recharge basins.

- Appropriate means of re-abstracting the water and getting it into supply.

These conditions limit the scope for artificial recharge and make it relatively expensive. Artificial recharge is already practised in the Thames Region near to the Anglian boundary, but this is a special circumstance where surplus treated water is available in wet years and where appropriate geological conditions exist to store it for use in dry years. Comparable geological conditions exist in the upper Chelmer and Pant areas.

However, there is no comparable source of recharge water or of recharge facilities. There could be excess treated water in wet years from sources such as Alton, Abberton and Hanningfield, but the geological conditions for recharging and storing water in these areas are untested. We propose to investigate the feasibility and cost of using the Chalk to store surplus winter water in much the same way as a surface reservoir might. However, the initial indications are that this would be very costly.

Another location where artificial recharge could be feasible is in the Bunter sandstone in the Severn Trent Region, which could be recharged with surplus Trent flows. This was investigated in the 1970's (Ref.40). However Trent water is available to this region, if required, in all but a few months in the driest of summers; there is sufficient storage to cover for such periods and therefore we see recharge of the Bunter sandstone only as a very long term possibility.

SURFACE WATER

Reliable supplies of surface water can only be provided by storing winter flows for summer use. Surface water options therefore fall into two categories - relaxing the constraints on filling existing reservoirs; and building new reservoirs. There are only two practical opportunities for the former and a limited number of realistic sites for the latter.

Many possible reservoir sites have been considered over the years, and rejected for a variety of reasons. In 1992 a systematic search for reservoir sites in the south-eastern part of Anglia was commissioned by the then Essex Water Company. That search revealed some relatively small potential sites, but only one feasible site of adequate size to compare with a prime site already under investigation by NRA. Both are described below. We also describe the Wash barrage proposals which were studied in depth in the 1970's. To avoid any question of unnecessary planning blight, we do not list the minor Essex Company sites nor the various other sites throughout the region which have been considered and rejected for good geological, economic or social reasons.

We have also excluded the ideas of using old clay workings or gravel pits as significant reservoirs. The clay workings in the Bedford and Peterborough areas have been considered in the past, (Ref.41) but found unsuitable for a variety of reasons. These included water quality (sulphates), engineering stability (emptying in a drought could cause collapse of adjacent features such as roads or railways), size (the pits are much smaller than major reservoirs) and availability (most pits are earmarked for other uses).

Wet gravel pits are essentially open areas of groundwater, often hydraulically linked to adjacent rivers. Therefore although they are sometimes useful as relatively small scale bankside storage for emergency and water quality purposes, they offer little additional water resources over and above those of the rivers and groundwaters already accounted for.

The realistic options for developing additional surface water supplies within the Anglian Region are thus:-

Filling Grafham Water; Offord Hands Off Flow

Grafham Water is filled by pumping from the Bedford Ouse at Offord. The abstraction has to leave in the river a 'hands-off' flow (hof) of at least 136 tcmd plus 25% of the 'natural' flow above 136.

Anglian Water Services have the necessary powers to construct an additional intake, with a 'hands-off' flow of only 91 tcmd, further downstream at Brownshill, near Earith. However, this would involve major works, and as a possible alternative they are considering a reduction in the Offord hof instead. This would reduce low flows in the reach between Offord and Brownshill, and could have environmental consequences, for example in the back channels which are of high environmental and recreational value, and possibly further downstream.

AWS have undertaken an Environmental Assessment into both proposals. The company believes that a reduction of the Offord hof to 109 tcmd, together with ameliorative measures, would have less environmental impact than the Brownshill option.

The Brownshill option might increase Grafham yield by up to 100 tcmd. The Offord option might yield 50-60 tcmd, depending on the company's intake pump capacity. Alternatively, more sophisticated control rules could be devised to increase Grafham yield by somewhat less, but at lower environmental cost.

This option cannot be considered in isolation from the next, as both would affect flows into the Ouse Estuary and the Wash.

Filling the Essex Reservoirs; Denver Hands Off Flow

The NRA's transfer of water from the Ely Ouse to the Essex rivers and hence to the Essex reservoirs is constrained by hof's required to be passed from the Ely Ouse to the tidal estuary at Denver of

114 tcmd March to August
318 tcmd September to February (the sugar beet processing period)

These hof's appear to have been fixed primarily to maintain acceptable oxygen conditions in the estuary. However, they also serve other purposes, principally:-

- to help reduce siltation in the tidal reaches, and so help maintain navigation channels
- to help dilute discharges in the King's Lynn area, notably from King's Lynn Sewage Treatment Works, and from a sugar beet factory;
- to limit incursion of saline water; and
- to preserve fresh water flow to the Wash

The NRA therefore commissioned an Environmental Assessment into potential reductions in the Ely Ouse hof. The 'issues and options' stage of that assessment is complete (Ref.42) . It concludes that the main effects of a reduction in Denver hof could be :-

- Slight adverse effect on water quality in the tidal river and the Wash, but this is "unlikely to be significant".

- Slight lengthening of the time in drought years that navigation problems are experienced due to siltation at King's Lynn. (This could probably be compensated by additional dredging).
- Slightly increased risk of summer flooding in the Ouse Washes, and
- More frequent saline intrusion at Salters Lode and Welney.

The report suggests that it should be possible to compensate these issues. Nevertheless they are real and would need more detailed evaluation leading to satisfactory mitigating measures by any party seeking to promote a reduction in Denver hof.

Reduction of the hof constraint to 114 tcmd, or to 50 tcmd, all year round would increase the Essex yield by 19 tcmd and 34 tcmd respectively. Engineering costs are likely to be relatively modest.

Great Bradley Reservoir Site

The feasibility of building a reservoir, perhaps comparable to Grafham or Rutland, at Great Bradley on the headwaters of the River Stour, was studied in the 1970's (Ref.43). It was not promoted, because further groundwater resources were then still available. However, the site is ideally placed to be filled with winter water from the Ely Ouse via the existing Ely Ouse to Essex transfer system; and to release water to the Stour and the Essex rivers to augment supplies in an area from Ipswich to London. In 1991 an updated study (Ref.44) confirmed the geological suitability of the site; recommended an updated design to minimise the impact and maximise the environmental benefits; identified the environmental and social consequences; and reassessed the costs.

The maximum possible size would be 106 million cubic metres (mcm), with a water area of about 1200 hectares . However, lower demand forecasts suggest that this is unlikely to be necessary. The actual size which might eventually be chosen would depend on many factors, within and beyond this region. However, a realistic size might be of the order of 40 - 60 mcm, yielding perhaps 80 to 150 tcmd, depending on pump sizes and on system operation.

The inflows would probably have to be treated to avoid algal blooms within the reservoir. It would then greatly improve the quality of water subsequently transferred through the Essex rivers by reducing nitrate and phosphate levels and other pollutants. The reservoir would act effectively as a 'header tank' allowing much better control of transfers through the Essex rivers, which would ease recent difficulties due to rapidly fluctuating transfers.

In common with comparable reservoirs such as Rutland, a reservoir at Great Bradley could provide a range of amenity, recreation and nature conservation facilities.

On the 'down' side, such a reservoir would cause upheaval to local residents. It would also necessitate realignment of several roads, flood farmland and affect up to four Sites of Special Scientific Interest, including some ancient woodlands. The extent of these effects would depend very much on the required size of reservoir. The study makes recommendations for mitigating them, and the cost estimates include for proper financial compensation.

The reservoir would be filled with surplus flows from the Ely Ouse at Denver, and low estuary flows would continue to be protected by the hands-off flow constraints. However, the total freshwater flow to the estuary would be reduced (though by less than the extra drought year yield as in normal years much of the extra water would come from the Essex rivers). Reference 30 describes the potential environmental effects and discusses mitigating measures. Further environmental assessment would be required.

'Fenland' Reservoir Site

An alternative reservoir site (Ref.45) is on the South Level Fen between Feltwell and Ely.

It would be a 'bunded' reservoir, that is it would be entirely surrounded by earth banks. It would be pump filled from the Ely Ouse (possibly augmented from the Trent at a later stage). Like Great Bradley it would be used to augment the Stour and Essex rivers. It could also augment summer supplies for agriculture in the South Level (though this would reduce its yield to Essex).

There is more or less no limit to the size of bunded reservoir that could be created on the Fens. For example a reservoir of 100 mcm capacity could be created by banks 8 metres high covering an area of 1500 hectares.

Exactly the same considerations would apply as for Great Bradley to the filling of a Fenland reservoir from the Ely Ouse; to the consequences to the estuary; and to the benefits of more even flows and better quality of water transferred through the Stour and Essex rivers.

A Fenland site could also offer benefits to amenity, recreation and nature conservation, but disbenefits in terms of the effects on local residents and the flooding of high grade farmland.

Site investigations and preliminary environmental studies have been carried out, (Refs. 45 to 47). These have proven the engineering feasibility, provided cost estimates, and given some idea of the environmental and social costs and benefits.

Comparison of Potential Reservoir Sites

In May 1994 the NRA commissioned a 'level playing field' comparison of the potential reservoir sites, including Great Bradley and Fenland and various supporting investigations carried out by Essex and Suffolk Water. The terms of reference emphasised the need for independence, comprehensiveness and transparency in the comparison. This work was completed in August 1994 (Ref.48) and its principal findings are :-

- Both sites are technically feasible.
- Fenland is the most expensive, though proportionally less so at the larger sizes.
- Both would flood valuable farm land (Grade 1 at Fenland; Grade 2 at Great Bradley).
- Great Bradley would flood properties, though the number affected would reduce significantly at smaller sizes.
- Fenland would flood a small number of properties.
- Great Bradley would flood an area of ancient woodland SSSI, though the area affected would reduce at smaller sizes.
- Fenland would have no severe environmental disbenefits.
- Great Bradley at smaller sizes, up to 40 - 50 mcm capacity, would complement the landscape, provide valuable shallow water habitats and become a focus of attraction for water related activities including fishing, bird watching, sailing and walking.
- Fenland would offer fewer environmental, social or recreational benefits.

Reference 48 makes the following firm conclusions:-

- That for a reservoir of up to 40 - 50 mcm Great Bradley should be the preferred site on both cost and environmental grounds.
- That for a reservoir of 60 mcm or above, Fenland is the only environmentally acceptable site.

Storage in the Wash

We include this option for completeness, as it was studied in detail and much publicised in the 1970's (Ref.49). Those studies showed that it would be feasible to build bunded storage reservoirs on the inter-tidal fringes of the Wash. Hydrologically this would be much the same as Essex and Suffolk Water's Fenland Reservoir proposal, but would avoid taking valuable farmland. On the other hand bank construction in tidal conditions would be more expensive than on land, the reservoir would be remote from the point of need and there would be major environmental implications. Reference 49 put the cost of a scheme to yield 180 tcmd at £62.5m in 1975 prices, equivalent to £175m in 1992. We do not advocate further consideration of this proposal.

USE OF EFFLUENTS

Over 60% of returning effluents are discharged into inland waters and so are largley re-used, whether by reabstraction downstream or as contributions to river flows. These effluent flows are accounted for in our resource calculations.

The remaining 40% or so are discharged to tidal estuaries or to the sea and are wholly lost to water resources. Clearly these effluents could be diverted and re-used. However the direct re-use of effluent in the locality of its origin, though perhaps technically feasible with sophisticated treatment, may be undesirable on grounds of public acceptability. Furthermore, case studies have shown that the costs of piping effluent a long way up river, plus additional treatment costs to the higher standard necessary, generally far outweigh the costs of other means of providing water resources.

The options for re-using effluents are therefore limited to (a) any 'automatic' increase in inland effluents and (b) any specific locations where diversion of effluents discharged to the sea proves worthwhile.

The discharge of effluent to rivers, and its consequent reuse, are accepted practise throughout the country, and are fundamental to our management both of our water supplies and of our wastes. However, we believe there should be continuing research into the issues of effluent quality, treatment requirements and public health.

An alternative way of re-using effluents is to supply 'grey water' - well treated effluent - for low grade uses such as toilet flushing or outside uses (car washes, parks, sports grounds and horticultural irrigation), or for industry. The potential for this depends not only upon engineering feasibility and environmental impact but more particularly upon safeguarding public health. In much of the region, fitting a dual supply system into existing infrastructure (one for potable, the other for 'grey water') is likely to be too expensive to undertake. Installing dual systems into new housing and commercial developments, however, might be contemplated in major new developments such as the East Thames Corridor.

This location is relatively close to a number of major sewage treatment works, and given the scarcity of resources in the area, this could be a cost-effective method of providing some of the water needs. However, the development of dual supply systems carries with it a number of public health risks, particularly arising from DIY activities and the risk of interconnection and cross-contamination between two systems. It would also be far from cheap, and we do not therefore advocate it in this strategy.

Increasing Inland Effluents

The resources of rivers receiving effluents from inland towns progressively increase with water use, and hence effluent discharged from those towns, increase. This may be seen as a windfall gain to, for example, reservoirs filled from such rivers; or it may be regarded as an increasing resource available to be allocated according to the usual criteria.

We take the latter view and are prepared, where appropriate, to consider applications for the use of such resources as they build up. However, because of the downturn in PWS demand forecasts, no such increase in yield can be relied upon.

Chelmsford and Witham Effluents

This is an unusual historical circumstance where effluents from these two towns are piped many miles to the sea instead of being discharged to the local river, specifically to avoid reabstraction at Essex and Suffolk Water's intakes about eight miles downstream. The practice has a long history but is anomalous nowadays with modern treatment capability and because those intakes already take a proportion of effluent from other works. A study by Essex and Suffolk Water (Ref.39) concludes that it is feasible to divert all or part of Chelmsford's effluent to the River Chelmer, with suitably improved treatment. As a result the yield of the Company's Hanningfield source could be increased in the order of 30 tcmd at a cost of the order of £13.5 million. The scheme has become known as ROSES (Reuse Of Sewage Effluent Scheme).

Its feasibility depends upon negotiations with Anglian Water Services (AWS), who own the sewage works, and on public acceptability, though the proposal is no different from what is practised in most of the South and East of England. The principle could, at a later date, be extended to Witham, although the quantities are much less and the benefits more marginal.

The company is currently working with AWS on technical details, and with the NRA on environmental aspects, with a view to seeking the necessary powers.

Whitlingham Effluent

Whitlingham Sewage Works, which serves Norwich, discharges some 44 tcmd to the Yare estuary. Anglian Water Services' ability to abstract from the Wensum at Costessey upstream of Norwich is constrained by the requirement for a 'hands-off' flow through the city. It has been suggested that Whitlingham effluent could be piped back, not to be used directly, but to compensate the river for increased abstractions at Costessey. There would be increased treatment costs, plus pipeline costs plus concern over river water quality in Norwich. This therefore seems less feasible than other options but it could warrant further investigation if necessary.

Tiptree and Hatfield Peverel Effluents

These are two special cases, where relatively small quantities of effluent either have, or are likely to be diverted for cost reasons to different receiving waters. In one case this deprives Essex and Suffolk Water of a water resource; in the other case, the reverse. We have therefore allowed for no net change, but the example illustrates the vulnerability of the effluent component of water resources to other economic forces.

Other Effluents

Anglian Water Services plan to investigate the re-use of effluent at selected locations as part of a research and development project. Apart from this we are not aware of other circumstances where effluents could be diverted to enhance water resources on any significant scale.

IMPORTS

The only neighbouring region with any possibility of spare water resources to transfer to Anglia is Severn Trent. The River Trent is a major potential source, and there could be other sources further west which might be transported via the canal system.

Imports from the River Trent

The NRA already transfers Trent water through the Rivers Witham and Ancholme for use in Lincolnshire and South Humberside. Trent flows are far higher than those in Anglian rivers. Subject to needs in the lower Trent there is no physical reason not to increase Trent transfers and extend them as far as it is economically worthwhile to do so.

The quality of the Trent has been improved greatly in the last decade or two and, with suitable treatment, it is already being used indirectly for public supply. However, the acceptability of its widespread use needs to be considered; and so do the costs and the environmental effects of transferring large flows of Trent water through the Anglian river system.

NRA Anglian therefore commissioned a study (Ref.50) into the feasibility, environmental impact and costs of transferring various quantities of Trent water through various Anglian and Thames Region rivers. NRA, Severn Trent commissioned two studies (Refs. 51 and 52) into the effects of possible abstractions on the Trent.

The Severn Trent studies suggest that considerations of salinity, siltation and water temperature in the lower Trent may necessitate the imposition of a hof constraint on future new abstractions. The implication of this is that continuously reliable supplies may not be available to Anglia, and that storage would be necessary to tide over periods of non-availability. Clearly this either increases the costs and/or reduces the yield of Trent options for Anglia.

The Anglian study looked at the feasibility, costs and environmental implications of transferring Trent water to the Rivers Witham, Ancholme, Ely Ouse, Nene and Bedford Ouse (for Rutland or Grafham), Wensum (for Norwich), Stour, Colne, Blackwater and Chelmer (for Essex Water Company and others) and Roding and Stort (for Thames Region).

In each case alternative routes and means of transmission were considered; for example canals, river channels, tunnels and/or pipelines. Reference 50 gives the results in detail; Table 12 summarises for each potential transfer the preferred route, the costs and the major implications. Figure 11 shows these routes in outline.

The water quality implications of transferring Trent water through the Anglian river system include:

- The EC Nitrates Directive requires all rivers used as public supply rivers (ie, having Public Water Supply intakes on them) and which exceed 50 mg/l nitrate to be designated as nitrate sensitive zones (NSZs)

  If the Trent were so designated (currently it isn't) there could be significant implications for agriculture. The first round of NVZ proposals has excluded inter-river transfers, but it is unclear whether a major Trent transfer to supply PWS via intakes on Anglian rivers would trigger designation under future rules.

- The fact that Trent water is nutrient-rich is undesirable; however Anglian rivers already have excess phosphates and we have not therefore allowed for phosphate stripping of Trent water.

- Trace organics and pesticides need to be considered, but specific problems seem to be no more likely than with Anglian rivers.

- Proposed flue gas desulphurisation at some Trent power stations could significantly increase sulphate and metal concentrations in the Trent, and hence Anglian rivers.

- NRA's policy of no deterioration in river quality classification would preclude the transfer of Trent water into grade A Anglian rivers. This has influenced the recommendations to avoid the Wensum, the Upper Witham and the Upper Chelmer.

Imports via Canals

Water from Severn Trent region (perhaps originating from beyond it) could be transferred to the upper reaches of the Nene and/or the Ouse via British Waterways' canal system. British Waterways have undertaken feasibility and cost studies of such transfers on a national scale. Anglian Water Services have expressed interest in the possibility of enhancing their Rutland and Grafham reservoir yields in this way.

Table 12 - Trent Transfer Options - Summary of Preferred Routes and Capital Costs

Component No. (Ref 51) and Description	Preferred Route	Transfer Capacity tcmd	Capital Cost £m (1992)	Comments
1. Trent-Witham - Ancholme	Fossdyke Navigation, River Witham	50 100 200 300 400 600	3 5 8 13 18 21	No significant public water supply quality problems Bank protection, lock and dredging works needed Availability of Trent Water at low flows to be reviewed
As above	Pipeline from Short Ferry (R Witham) to Toft Newton (R Ancholme)	50 100 150	9 18 28	Includes additional storage at Toft Newton needed for security against R Trent pollution Opportunities for Ancholme channel improvements for fisheries
2. R Witham to R Ely Ouse at Denver	Direct Pipeline or Pipeline to Ouse at Offord via Nene at Wansford	100 200 400 100 200 400	62 85 134 51 74 145	Avoids control and environmental problems across Fens Would enable controlled feed to Middle and South Level Enables transfers to Rutland and Grafham if required (but not) sized for additional quantities)
As above plus to Ouse and Nene	As above	100 200 400	78 107 171	As above to Denver *plus* 50 tcmd to Rutland and 100 tcmd to Grafham
3. Denver to Costessey	Direct Pipeline to Costessey wtw	50 100	14 26	Ensures no environmental or quality problems in R Wensum
4. R Pant (Blackwater) to R Chelmer	Pipeline Gt Sampford to Gt Dunmow	50 100 200 400	6 13 21 37	Less impact and cheaper than routing along R Pant (Blackwater) or discharging to upstream reaches
5. R Chelmer to R Roding	Pipeline Gt Dunmow to Gt Canfield (R Roding)	50 100	6 11	Opportunities for environmental improvements to R Roding
6. R Roding to R Stort	Pipeline Gt Canfield to Sawbridgeworth (R Stort)	50 100	6 11	Less impact than Pincey Brook or direct pipeline alternatives
River Ely Ouse to R Stour	Existing route	455 568 681 796	2.6 12.0 13.3 34.5	Increased transfer capacities Ref. 53
R Stour to R Pant	Existing route	341 455 568	1.6 3.1 3.2	Increased transfer capacities Ref. 53

Our National Strategy (Ref 5) identifies that a transfer capacity of 100 tcmd from the River Severn to the Oxford area would cost approximately £49m and would involve various engineering and environmental issues. In addition there would be substantial costs in bringing reliable water resources to the canals, and Ref 5 concludes that "large scale transfers via the existing canal network are not favoured ....".

'ESOTERIC' OPTIONS

The options list would be incomplete without at least recognising that water need not necessarily come from a relatively local river or borehole. An exhaustive list of alternative sources has been examined on behalf of NRA nationally (Refs. 5 and 38) including:

Figure 13 - Strategic Transfer Links - Existing and Potential

- barrages
- undersea pipelines
- national grid (comparable to the gas or electricity grids)
- desalination
- transfers from Europe
- transfer by ship or by 'drogue'

These all proved either impractical or far more expensive than conventional schemes, or both. The only possible exception could be desalination, if technological progress were to allow a substantial reduction in the cost and energy consumption. We have discounted all of these 'esoteric' options from the present analysis.

Chapter 13 – THE OPTIONS FOR A BETTER WATER ENVIRONMENT

INTRODUCTION

Our Consultation Exercise showed universal support for "a better environment", though only a minority said "at any price". The consensus view was that "the environment should be protected at the highest sustainable level, within reasonable costs". This chapter sets out ways to achieve that objective.

Our water environment is degraded in many different ways (though perhaps improved in some others). Improvements must therefore take many different forms. The Secretary of State for the Environment said in March 1994 (Ref.54) "We are learning that you have to understand how the natural processes work, and recognise that there is no single answer to the real problems of working with nature and building again an environment to be proud of".

This chapter therefore steps beyond water resources issues and puts forward an integrated approach towards achieving a better environment.

IMPROVING OUR WETLANDS

The NRA, and others, are concerned that wetlands should be protected and in some cases restored or improved. The ways in which this can be achieved include:-

- **Precautionary Licensing**
  Our licensing procedures have been further strengthened to avoid any risk of 'new' damage by abstraction to important wetlands.

- **Understanding Wetland Requirements**
  We are involved in two collaborative projects to understand better the hydrology of wetlands, the water requirements of different wetland communities, and the potential impact of abstraction upon them (see Chapter 8). We will share the results with all concerned, and we hope to benefit from comparable research by others. The aim is to protect all important wetlands as far as possible, and particularly those which are still in good condition.

- **Licence Revocation or Re-location**
  Where wetlands are identified as being unacceptably affected by abstraction, revocation and/or relocation of the relevant licences will be considered, along with alternative measures (See below). Three examples are already on the 'low flows' list (Table 10), and plans for relocation are at an advanced stage for one of these, Redgrave and Lopham Fen.

- **Wetland Support**
  There is some scope to sustain wetlands artificially and possibly even to enhance them. This is limited by the difficulty of artificially reproducing the subtle natural hydrology of wetlands, on which their ecology depends, but it is practised in some special cases. An example is Chippenham Fen in Cambridgeshire, where wetland support, from a nearby borehole has been practised for over three years. The scheme was financed by the NRA, but devised in consultation with other agencies, including English Nature. It is operated and monitored in conjunction with them. So far it appears to be successful, and similar schemes may be applicable elsewhere.

- **Other Improvements**
  By no means all the problems of wetlands are caused by abstraction. Reference 32, for example, showed that twice as many are affected by adjacent drainage works, and others by inappropriate site management. We look forward to working with others to identify and where possible put right whatever may by affecting precious wetlands.

- **Levels of Service**
  In the course of our consultation exercise the setting of environmental levels of service was suggested. We develop the idea in connection with river flows in the next section.

We hope to be able to work with others towards a realistic concept of levels of service for wetlands.

IMPROVING OUR RIVERS

Where does the problem lie?

A river's environment is governed by its flows, by its water quality and by the physical characteristics of its channel. Just like a chain, all three must be strong if the river's biological value is to be preserved. Just like a suspect chain, we must examine every link and then focus attention first on the weakest. Different rivers will have different 'weak links' and no one approach is appropriate to all rivers.

An example of this approach is work carried out for the NRA by the University of East Anglia on the Rivers Nar, Bure and Wensum (Ref.55). The brief was essentially to identify past changes to the character and ecology of those rivers and establish the causes and the opportunities for improvement. In these particular rivers the main causes of change are physical (mills, dredging, siltation and related factors); quality issues are secondary and only in the Nar are the effects of abstraction significant. In other rivers the balance may well be different.

River flows

Rivers do not have a single flow, but a constantly changing 'regime' of different flows. As a generalisation the flows which are most important ecologically are the lowest flows (for obvious reasons) and the highest (which cleanse the river of damaging build-ups of silt).

The ecology of a natural river is adapted to its natural flow regime. However, every abstraction reduces that regime, and every discharge increases it; in some rivers flows are greatly increased by inter-basin transfers. Every change may have good effects and bad, and we have to manage continuing changes to our rivers' flow regimes. To help to do this, two concepts are being developed:-

- **Minimum Acceptable Flows (MAFs)**
  The NRA has a legal duty to consider setting MAFs. Such duty has existed for over 30 years, but no MAFs have been set, anywhere in the Country. There are valid reasons for this, mostly because the concept is too simplistic for practical application. Tables 4 and 5 show the many locations in Anglia where 'hands-off' flows (hofs) have been set instead. However, these serve just to control particular surface water abstractions, and are only a partial measure. The NRA is now actively researching how to use the MAF legislation to best effect (Refs. 18 and 56). This could well lead to the second concept;

- **River Flow Objectives (RFOs)**
  RFOs were introduced in Chapter 6. They would define a target flow regime (not just the lowest flows) to which water resource management would aim, in order to meet defined environmental objectives. Abstractions, discharges and river support pumping would be tailored to try to achieve a suitable minimum regime. This would in turn provide the flow input to determining discharge consent conditions, and so help to get water quality right too.

The target flow regime would be a form of level of service for river flows. We are not yet in a position to rationally set such targets, but work towards that aim is under way (Refs. 18, 19, 20, 21 and 56).

'Low Flow' Rivers

In Chapter 8 we identified a number of rivers whose flow regimes are either known or suspected to have been unacceptably reduced. In each case ameliorative measures either have been taken already, are planned to be taken or are under investigation. Such measures include licence revocation and/or relocation, river support for low flows or possibly channel or water quality improvements to compensate for reduced flows. In every case we believe that the best solution should be identified and tested for worthwhileness; and that every one that is shown to be worthwhile should be vigorously promoted.

We have supported Water Companies in earmarking funds in appropriate cases, and OFWAT have endorsed the inclusion of low flow amelioration at some sites in the companies' Strategic Business Plans. An alternative is for the NRA to promote ameliorative measures itself, subject to Government control on our budget. In addition, we seek routinely to identify opportunities where conditions on new abstraction licences may be used, where appropriate, to secure compensating flow or channel improvements to affected rivers.

'Carrier Rivers'

Certain rivers are used to transfer water around the country. Such carrier rivers include the Witham, Ancholme, Stour and Pant/Blackwater. Their natural flow regimes are distorted by such transfers, particularly in the upper reaches. Despite the benefits of higher flows, there can also be undesirable effects such as rapid and unnatural fluctuations in depth and velocity, occasional transfer of algal rich and turbid water and possible transfer of undesirable substances. Some effects can be ambiguous. For example, during the recent drought, sustained operation of the Ely Ouse to Essex transfers contributed to the development of the best level of fish stocks ever recorded in the Upper Pant; however, those same flows were widely condemned by anglers as making pursuit of their sport effectively impossible!.

We propose research into all these effects. We also note that a major reservoir, either at Great Bradley or on the Fens, would give significant benefits in terms of the control it would allow over the scale, timing and quality of augmentation flows in the Upper Stour and Blackwater.

River Water Quality

River water quality is an extensive topic, which we do not attempt to cover in this document. It is however vital to ensure integrated management of river flows, quality and physical characteristics. Our Catchment Management Plans are progressively developing this integrated approach.

Physical Characteristics

We described the importance of the physical characteristics of a river's bed and banks at some length in Chapter 6. Recent projects (Refs. 19, 20 and 55) have shown physical changes to be dominant in some rivers. The options for what could be major ecological improvements, in this region of heavily engineered river channels, include:-

- Encouraging channels to develop natural meanders and other physical features

- Reconstructing pools and riffles.

- Faster flows in a narrow normal channel, with wider berms to carry flood flows.

- Buffer strips, maybe 10 - 20 metres wide along both banks, of wild land, willows etc.

- Controlled field drainage outfalls, to reduce nutrient input and so reduce eutrophication.

- Some management of the river bed, for example artificially introduced gravel runs.

This topic is enlarged upon in our recent publication, The New Rivers and Wildlife Handbook (Ref.57)

OTHER ENVIRONMENTAL IMPROVEMENTS

Artificial waters, such as reservoirs and wet gravel pits, are also part of the water environment. Gravel pits are not affected by water resource management, but reservoirs are; properly designed and managed they can be a major environmental asset. They have negative aspects too which must be taken into account, but any positive net benefits of potential reservoirs, large or small, are options for a better water environment.

Chapter 14 - ASSESSING THE CHOICES

INTRODUCTION

So far we have described the Region's water resources and the demands upon them; and we have identified the options for ensuring secure water supplies and those for a better water environment.

Figure 4 showed that consumptive human use is a perhaps surprisingly small proportion of our average water resource. In normal years there is no real problem, given the water network which has been built up to meet the needs of a large population in a dry region. However, that population, its need for water, and its environmental expectations are all rising, and plans must be prepared for future droughts. This means

- Defining policies for the wise use and management of water.
- Addressing a number of relatively local environmental problems,
- Addressing a number of relatively local problem areas for water supply.
- Developing integrated plans to improve the water environment, and the contribution of water resource management to that end; and
- Identifying the 'what' and the 'when' of the next extensions to the region's water network.

SUMMARY OF ENVIRONMENTAL NEEDS

Wetlands

Table 10 identifies three specific wetlands suggested to be suffering from over-abstraction. On-going studies could add to this list.

There are also needs to better understand the hydrology and the ecology of wetlands.

Rivers

Table 10 identifies 18 rivers suggested to be suffering from over-abstraction. Some have already been tackled, some are still subject to investigation.

There are also needs to define river flow targets, whether as MAFs, RFOs or whatever; for a better way to assess the benefits of low flow alleviation; and for better ways to integrate improvements to rivers' flow, quality and physical characteristics. A few particular rivers (mainly the Stour and Blackwater) suffer problems associated with interbasin transfers.

Estuaries

There is a need to review the adequacy of the hofs which control major abstractions at or near tidal limits.

General

We have identified certain catchments where abstraction rights plus our provisional environmental allocation are not fully met.

SUMMARY OF ADDITIONAL HUMAN NEEDS

The additional 'strategic' needs of this Region are given in Table 13:-

These are indicative figures, not precise ones. They presume that all future demands should be met; but they also presume substantial success with demand management. The conclusion is that this Region may need to find (or reallocate) between two hundred and over four hundred tcmd over the next thirty years. This is very roughly the equivalent of one to two Grafham Waters.

The figures in Table 13 neglect the possibility of reallocating any surplus held by one company for the benefit of another. Chapter 11 briefly explores this possibility. We have

Table13 - Predicted 'Strategic' Needs

	2001 tcmd	2011 tcmd	2021 tcmd
Public Supply[1]	17	50	92
Direct Users[2]	53	97	142
Reallocation to the Environment	30	30	30
Total	100	177	264
High Estimate[3]	143	233	460
Low Estimate (-20%)	80	140	210

Notes:

1. Includes 10% margin against the range of hazards given in Chapter 7.
2. From Table 9, less 30% for local sources (see page 50).
3. Taken as NRA's 'medium' scenario for PWS and +20% for direct users.

not included it in the subsequent analysis, but we believe it should be kept under review, and seriously considered before any major new development is promoted.

In addition, some of Thames Region's needs might be met, directly or indirectly, from Anglian resources, or by inter-region transfers routed through Anglia. For example Anglian resources could substitute for Essex and Suffolk Water's bulk supplies from Thames Water; Three Valleys Water's needs might be met by greater supplies through Grafham; Three Valleys and Thames Water might both be supplied directly via the rivers Roding or Stort. Our Thames Region's strategy (Ref.58) examines options for 100 tcmd transfer from Anglia to Thames, and recommends study of their costs, practicalities and environmental implications.
The provision of adequate resources from developments in this region could potentially reduce the need for large scale resource development within Thames. For the present purpose we therefore allow provisionally for a potential 100 tcmd for Thames Region.

THE SCOPE FOR IMPROVING THE WATER ENVIRONMENT

Chapter 13 identifies many ways to improve the water environment. Some involve water resource management or development; others are matters of water quality or physical management. An integrated approach is necessary.

THE SCOPE FOR DEMAND MANAGEMENT

Chapter 10 looked at the options for restricting water use, rather than providing more water. It concluded that the scope is limited, largely because in this dry region, a great deal is already being done to limit water use. In particular

- leakage is less than half the national average; the forecasts include for some further reduction, which may result from mains improvements done for other reasons but any more would only be economic in exceptional circumstances.

- better design of water appliances, coupled with customer education. The Water Companies have held down their forecasts in the expectation of some success in this field.

- metering proposals are allowed for in the forecasts.

- doubling the frequency of restrictions on water use might save some years of demand growth, but only at the expense of much less reliable water supplies than are currently required by OFWAT.

Chapter 10 also showed that demand management does not necessarily improve the environment, except in areas:-

- Where demands are met from groundwater, or

- Where saving water can defer or eliminate the need for a new development which is considered environmentally damaging.

THE SCOPE FOR REALLOCATING WATER

The scope for reallocating 'spare' water entitlements to users with greater need is also limited, subject to the above section on 'Surplus' entitlements.

We propose to investigate the scope for tradeable permits, and for incentive charging, as means of releasing any 'hoarded' entitlements. However both are long term prospects, and probably of limited application. We have already allowed for some reallocation from human use back to the environment; and we consider below certain circumstances where the reverse might be appropriate.

THE NEED FOR ADDITIONAL WATER

If all the predicted demands are to be met up to accepted levels of service, the total additional secure supplies which need to be developed by 2021 are in the order of 260 tcmd, with 'high' and 'low' scenarios of perhaps 320 and 210 tcmd.

Within these overall figures there are some particular local problem areas, given in Chapter 8.

THE DEVELOPMENT OPTIONS

Chapter 12 has identified the practical options for developing additional secure water resources, from within and beyond this Region. They comprise

- Minor 'local' sources; already allowed for in the above figures.
- Further abstraction of groundwater; limited to the Norfolk and Suffolk areas, and subject to environmental constraints.
- Artificial recharge of groundwater; a long term prospect.
- Reallocating certain estuary flows to human use; low cost options, subject to environmental assessment.
- A new reservoir; two alternatives are described.
- Re-use of effluents; only one practical and economic option has been identified (other than the automatic re-use of inland effluents which is already allowed for).
- Imports from neighbouring regions; the cost and implications of using Trent Water widely through Anglia are described.
- Esoteric options; various possibilities, for example desalination, are rejected on grounds of cost and practicality.

THE RESULTS OF PUBLIC CONSULTATION

Our Consultation Exercise showed that people accept that meeting reasonable human needs at reasonable cost is a valid objective. However, many add caveats such as "only if ..... no detrimental ecological effects". The general views on particular forms of water resource development were:-

Groundwater Development

People view groundwater development with suspicion. Only two respondents opposed it outright, but many others voiced concern, particularly over the potential effects on wetlands. On the other hand several water users pointed out that groundwater is a valuable resource, whose use should not be unnecessarily constrained. We believe that groundwater can be used, but must not be abused.

Reservoirs

There is general support for a new reservoir, as and when it is shown to be needed. People clearly recognise both the environmental gains and losses that a reservoir entails and there is a general view that the gains can outweigh the losses. There were several voices in opposition to a reservoir, very understandably, from people who might be adversely affected.

Only one respondent explicitly favoured reservoirs as opposed to groundwater development, but that preference was implicit in many more responses.

There was widespread support for farm reservoirs to store winter water for summer irrigation, and recognition of their environmental value. Several agricultural respondents called for financial incentives to build farm reservoirs.

Inter Basin Transfers

Our proposals played down any need for substantial further imports from the Trent, but advocated increased Ely Ouse - Essex transfers. Respondents expressed concern over the effects on water quality, recreation and navigation in receiving rivers. There was particular opposition to any transfers which could cause deterioration in river quality classification.

Possible Reductions in Flows to Estuaries

Several respondents were concerned about potential adverse effects in the Ouse estuary. We share this concern and the issues are already under investigation.

DISENTANGLING THE CHOICES

No one option would meet all the needs; geography and economics dictate some combination of options. Also there are no 'magic' solutions - every option involves disadvantages to somebody. What is needed is an overall package which, as far as possible, maximises the benefits (including environmental improvements) and minimises the disadvantages. It must also be fully sustainable, precautionary where necessary and adaptable to changing circumstances. In short, it should provide for secure water supplies *and* a better water environment at reasonable cost.

We have already identified many policies and approaches which are applicable everywhere. In the rest of this chapter we examine the particular needs of particular areas.

The areas we use (Fig. 14) are defined by their water resource characteristics, not by County or even catchment boundaries. There is some degree of overlap. Some areas lend themselves to relatively clear cut solutions, at least in the short term. Others may need larger strategic measures, in line with the national strategy. We consider each area in turn, leading to recommendations as to how future needs in each area might best be met, if and when they may arise.

Lincolnshire and South Humberside

Local water is virtually fully committed and the area already depends on imported Trent water. The only alternatives to more Trent water would be

- To transfer water from Rutland via the Witham, which would be expensive and would exacerbate problems further south, or

- To create additional reservoirs, which would be even more expensive as the geography and geology are unsuitable.

The NRA provides Trent-Witham-Ancholme transfers to meet demands of all kinds in this area. Anglian Water Services is investigating the use of Trent water in its Lincoln zone. We hope that additional Trent water will enable some pressure to be taken off groundwater, both the Lincolnshire chalk and the Sherwood sandstone, and hence improve dependent streams. We are actively addressing local problems in the Sleaford area.

We see the Trent as the prime source of additional water for Lincolnshire and South Humberside, perhaps used conjunctively with local resources.

'West Anglia'

By this we mean the area, mostly west of the A1, where public supplies come largely from Anglian Water's Rutland, Grafham and Pitsford Reservoirs (the 'Ruthamford System'). It includes parts of Three Valleys Water's area (Luton and further South) which are supplied

Figure 14 - 'Water Resource Areas'

from Grafham. This is an area of relatively low agricultural use, and where river flows are mostly increased by effluents rather than reduced by abstractions. The issues are therefore those of public water supply. Even at our higher estimate of need (Table 13), the Ruthamford System is likely to remain in surplus until well into the next century. The choices for its subsequent augmentation are:

- To augment it from the Trent, which is expensive and could have environmental consequences on carrier water courses, as well as implications in the Trent catchment.
- To augment Grafham inflows by constructing Brownshill Tunnel, for which powers and abstraction entitlements already exist.
- To relax the flow constraints on filling Grafham, subject to environmental assessment.
- To transfer water to the Ouse and the Nene via the canal system, which is under investigation, but is unlikely to be cheap.

Because of the timescale it is premature to offer a judgement between these options.

The Fens

The fens are an area of high agricultural water use and relatively low public supply and industrial use. We have included public supply needs within the other areas, but we consider the agricultural and river flow needs of the fens and their estuaries in their own rights. We include in this the ecological water needs of the Ouse and Nene Washes.

Much of the agricultural use is by 'sub-irrigation'. In summer, the fens literally soak up large amounts of water transferred into them from the Rivers Ouse, Nene, Welland and Witham. These 'slacker' transfers are not subject to control by licence. In addition spray irrigation is rapidly increasing. These agricultural demands compete with the estuaries for summer river flows. Being non-licensable, the slackers have first call, and the NRA believes that legislation should be amended so that water can be more rationally allocated. We also believe that positive means of meeting these legitimate water needs should be considered. For example:-

- The Witham, and its associated fens, are already augmented from the Trent, and this could be extended.

- The Welland and its associated fens could conceivably be augmented from Eye Brook, if the demand and the economics were proven.

- The Nene and its associated fens depend in summer on the 'hands-off' flow which constrains pumping into Rutland. We are exploring the possibility of amending this constraint, to allow more water to the fens in high summer, perhaps compensated by reducing it in other months when the fens' need is less and more water could go to Rutland.

- The Ouse and its associated fens remain a problem. Their needs could be met by storing winter water locally, either by a farmers' consortium, which has been suggested, or from the possible Fenland reservoir, or even by back-pumping from the possible Bradley reservoir. The NRA would, in principle, encourage any such proposals, subject to the usual licensing criteria.

The Cambridge Area

By this we mean the Cambridge Water Company, whose needs until recently were met almost entirely from the Cambridgeshire chalk. The Company also has licences (which are partially conditional) from the Little Ouse chalk near Thetford. It seeks to make those licences unconditional and perhaps eventually to increase the quantity, though probably not within the planning horizon. The overall availability of water at least to consolidate the current licensed quantities is not in doubt, particularly in the area downstream of Thetford. There are however, competing demands both for other water undertakers, for agriculture and not least for the rivers and wetlands. The wetlands will be protected by restricting abstraction to appropriate areas, and river flows by establishing appropriate flow targets.

'East Anglia'

By this we mean most of Norfolk and Suffolk (other than Ipswich). This area has rising demands, both for public supply and for irrigation, coupled with a water environment of high amenity, recreational and ecological value. Unlike the rest of the region, the groundwater resources of most (though not all) of its catchments are not fully used (Fig. 15 and Table 2). The remaining groundwater resources offer by far the most economic source to meet the area's needs. There has, however, been some public anxiety over possible over-exploitation of these resources. We believe that this is justified in certain local areas such as Redgrave and East Ruston Fens, which we are addressing, but not so in general - See Figure 15.

Chapter 12 suggests that perhaps 100 tcmd further groundwater development could be allowed in this area in an environmentally acceptable way. This would be enough to meet even the 'high' forecast demands well beyond 2021.

We believe that the needs of this area are best met by

- Conventional use of groundwater for non consumptive uses, such as public supplies in inland areas, where the resulting effluent is returned to the river.

- River support boreholes to sustain river flows for abstraction at or near the tidal limit, to supply towns such as Norwich, Yarmouth and Lowestoft, whose effluents are lost to sea; such support pumping is only needed for short periods during drought years.

- Limited groundwater abstraction for consumptive purposes such as irrigation, subject to establishing, and where appropriate maintaining, satisfactory river flow targets.

Boreholes for all these purposes will require careful siting to avoid unacceptable effects on wetlands and existing users and will also be subject to establishing, and where appropriate sustaining, acceptable river flow targets.

There may remain local problem areas, where groundwater resources are particularly stretched, in which alternative supplies and/or enhanced demand management could be needed.

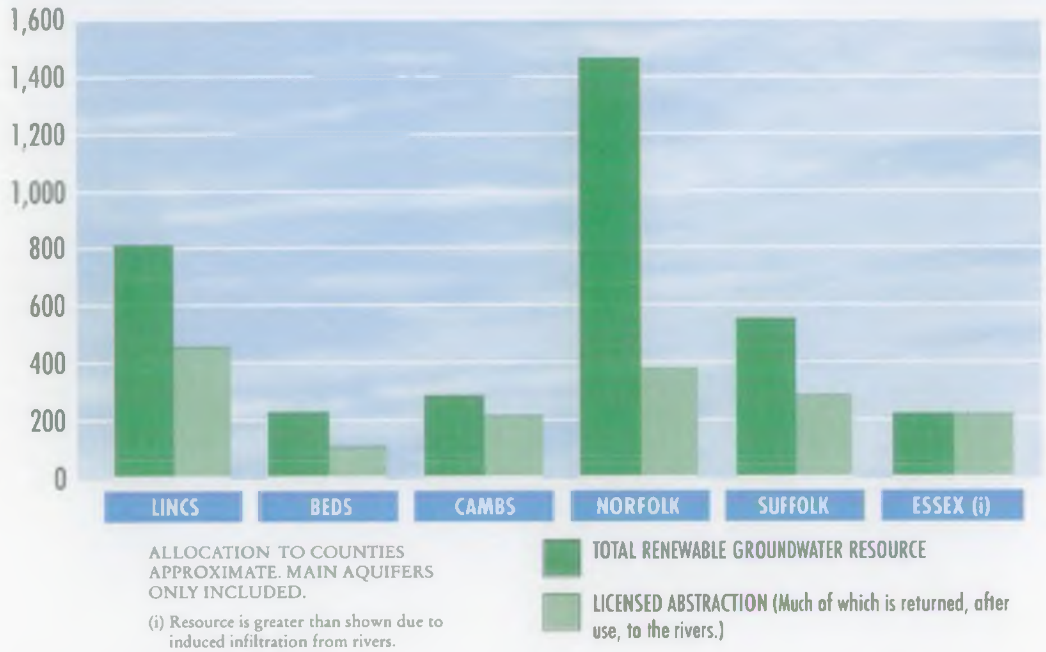
If groundwater development should not prove acceptable, there are no other practical water resources within this area, and we therefore explored the alternatives of transferring water from the Trent or from the possible new reservoir discussed below under 'South Essex'. We estimate that either of these would cost two to three times more than groundwater. We therefore regard both Trent and reservoir options only as fall-backs if continuing groundwater development were to prove unacceptable.

'North Essex'
By this we mean the areas of Colchester, the Tendring peninsula and Ipswich (in Suffolk). Local groundwater is largely committed and local river flows are committed to filling existing reservoirs. The Colchester and Tendring areas should remain in surplus into the next decade. Tendring's need could be the more urgent, especially at higher demand scenarios, and we are discussing possible contingency arrangements with the company. Some minor groundwater sources might be available. However, local resources will then be fully committed. Thereafter this area would join south Essex in being dependent on Ely Ouse to Essex transfers.

'South Essex'
By this we mean the Essex area of Essex and Suffolk Water Company, and (perhaps) parts of Thames region, where the dominant demand is for public supply. Local water resources have been fully committed for many years. Since 1971 the area has depended on the Ely Ouse to Essex Transfers, without which the recent drought would have necessitated widespread use of standpipes for months if not years. The transfer scheme operated to full capacity during the drought, but even so hosepipe bans were necessary in the last three years. Demands continue to grow and the area needs action. *All* of the possible actions are problematic, or expensive, or both, and the decisions are not clear cut. This is the major single issue addressed in this strategy and we therefore explore it in some detail:-

The need for extra water
Essex and Suffolk Water's additional need in this area is predicted to be 81 tcmd at 2021, or 109 tcmd at NRA's 'medium' demand scenario.

Figure 15 - Groundwater Resources and Licensed Abstractions by Counties



ALLOCATION TO COUNTIES APPROXIMATE. MAIN AQUIFERS ONLY INCLUDED.

(i) Resource is greater than shown due to induced infiltration from rivers.

Tendring Hundred Services may need in the order of 5 tcmd, or 9 tcmd at NRA's 'medium' demand scenario.

Anglian Water Services potential need in north and south Essex is heavily dependent on success with their proposed metering and leakage programme. It could range between 0 and 50 tcmd at 2021.

Thames Region could provisionally need 100 tcmd.

Direct Water Users who could share in strategic developments in this area have a predicted total need of the order of 70 tcmd. If we assume that say half of this may be best met, directly or indirectly, from such development, then the direct users' need is say 35 tcmd.

There are no **environmental needs** to be directly met, but:-

- Any development which gives the area secure resources could take the pressure off local environmental problems and

- Any development which provides for regulated flows of stored water down the Stour and Blackwater would mitigate the environmental problems of the current irregular transfers down those rivers, as well as greatly improving their quality.

In **total** therefore the *quantifiable* need is in the range of 100 to 300 tcmd at 2021.

The need for security

The simple demand/resource comparisons above hide a host of uncertainties; climatic, hydrological and human. They are the differences between very uncertain demand forecasts and even more uncertain yield estimates and are vulnerable to a whole range of uncertainties eg:-

- Success in leakage control to perpetuity.

- Achievement of metering proposals and sustained water savings resulting from metering.

- Other uncertainties in demand forecasts, particularly in the longer term if warmer climate causes increased water use, and

- Even greater uncertainties in yield estimates. The fine balance between rainfall and evaporation makes this region very vulnerable both to long term climate change and to even small run-of-the mill fluctuations.

Secure water supplies need strategic storage to keep wet winter rain for dry summer use. A margin of capacity is necessary to give security not only to the public, but also to other water users and to the environment. Furthermore, demands may well increase beyond our planning horizon of 2021. We do not advocate grandiose schemes for their own sake, but equally we must avoid short-termism or unnecessarily piecemeal development.

These issues are somewhat intangible, and security does not show in company accounts. However, we believe that decisions as to how to meet the tangible needs identified above, should also take account of the need for long term security in Britain's driest region.

The Options

The options for action are as follows:-

- **Major Additional Demand Management**
  Essex and Suffolk Water have carried out detailed analysis, through London Economics (Ref.59), of the relative economics of metering, enhanced leakage reduction and new water resource development. It concludes that even the most expensive development option would be less costly than metering. However, meters have other advantages, which should also be considered. We endorse the company's plans to install meters and reduce leakage. These assumptions are already built into the deficit forecasts.

- **Minor Groundwater Sources**
  Essex and Suffolk Water are reviewing the potential to redevelop perhaps 4 tcmd of groundwater in the Romford area.

- **Supply from Anglian Water Services (AWS)**
  Chapter 11 refers to the current surplus held, in total, by AWS. Subject to future demands, such surplus may, or may not, continue to be available in the future. If it is, there are various ways in which it could physically be transmitted to South Essex; for example by release from Grafham Water and transfer, via the Old West River, to the Ely Ouse and hence to the Ely Ouse-Essex system. There would be substantial costs, direct and indirect, and organisational and operational problems, but the option should be considered at the appropriate time.

- **Diversion of Chelmsford effluent to the Chelmer**
  This is economically attractive and environmentally acceptable. The company should continue to pursue it. Subject to public acceptability, it should reduce the deficit figure by some 30 tcmd.

- **Reduction of Denver Hands-off Flow**
  This is economically very attractive, but raises some environmental problems. It could reduce the deficit by about 20 tcmd. We will investigate it further for possible use at least on a temporary basis to buy time for major development and that its long term acceptability should be reviewed in the light of experience.

- **Trent Transfer**
  Our earlier analysis showed this to be more expensive, and environmentally more dubious than a reservoir. It would only be appropriate to reconsider it if reservoir costs and implications proved much less favourable than those identified in Reference 44. If that were so, then it might be necessary to carry out more analysis to determine

Figure 16 - Potential Area of Benefit from Gt. Bradley/ Feltwell Reservoirs

the relative merits of reservoir and transfer alternatives on financial, economic and environmental grounds. However, for the present purpose we discount this option.

- **Additional Reservoir Storage**
  A reservoir, either on the fens or at Great Bradley, could provide strategic storage to serve the following purposes.

  - To meet PWS shortfalls in much of south and east Anglia and potentially in parts of London as shown in Figure 16.
  - To meet direct demand shortfalls in a similar area.
  - To provide *security* of supplies for all purposes.
  - To improve raw water quality, particularly in the Essex rivers.
  - To allow much steadier transfers through the Essex rivers.
  - To avoid the need for other more piecemeal and perhaps less certain developments.
  - As 'by products', to provide environmental, recreational and social benefits, as well as associated disbenefits.

A decision between these two competing sites will be a matter of cost against a complex balance of benefits and disbenefits, both environmental and social. For the reasons explored in Chapter 12 we believe that regional needs would best be served by a reservoir of the order of 40 - 50 mcm capacity. Our Consultants' advice (Ref. 48) is that, for both environmental and cost reasons, such a reservoir would best be sited at Great

Bradley; however, if or when demands should rise to the point where storage of 60 mcm or more were required, then the only environmentally acceptable site would be a bunded reservoir on the Fens. This could follow, perhaps a decade a more later, with no significant cost penalty.

Our Consultant's report (Ref.48) notes the possibility of Essex & Suffolk Water looking to alternative more 'parochial' storage in the south of the region, which might meet their needs alone. However, this could raise environmental and other problems of its own, would probably suffer diseconomies of scale and would fail to meet the strategic needs listed above.

The NRA will not be the promoter of a reservoir. It will, however, take account of these findings in responding to any application for a licence to impound, or to abstract water to fill, any such reservoir. On the basis of these findings, it would be likely to object on environmental grounds to any reservoir at Great Bradley in excess of say 50 mcm. It would be unlikely to object to a reservoir of 50 mcm or less, provided it was satisfied with proposals to mitigate the ill effects and to maximise the good effects. Neither would it be likely to object to any proposal for a Fenland reservoir, although it would point out the cost and environmental implications.

The Way Forward

We have set out the background to what are still not clear cut decisions on the siting, sizing and timing of developments to meet the future needs of the south and east of this region. However, we recognise the need for as clear a course of action as possible and we therefore recommend:-

- That Essex and Suffolk Water should proceed with metering and leakage control in its Essex area to the economic limit.

- That their demands should be closely monitored, and the timing of the following measures adjusted accordingly.

- That Essex and Suffolk Water should seek to redevelop minor groundwater resources, of the order of 4 tcmd, in the Romford area.

- That Essex and Suffolk Water with the co-operation of Anglian Water Services should promote the diversion of Chelmsford effluent to the Chelmer.

- That an environmentally acceptable reduction in Denver hof, perhaps on a time limited basis, should be investigated with appropriate ameliorative measures.

- That any possibility of reallocation of `surplus' entitlements held by others should be kept under review.

- That a decision in principle should now be taken, by the relevant water companies acting together with the NRA on behalf of other water users, human and environmental, to move towards the construction of a strategic reservoir. Based on the information currently available, the NRA believes that such a reservoir may be best located at Great Bradley and that it should be of the order of 40 - 50 mcm capacity.

- The timing of moves towards a reservoir is not a matter for the NRA. However, assuming success with items 3, 4 and 5 above it would need to be in service between 2006 and 2011 as identified for the medium demand scenario in our National Water Resources Development Strategy (Ref 5). With the Company's demand forecast, and neglecting the planning margin, the date of need might be delayed.

Chapter 15 - THE STRATEGY

Our strategy for achieving a better water environment ***and*** secure water supplies is as follows.

GENERAL POLICIES FOR MANAGING WATER RESOURCES

1. We aim to manage water resources to achieve the right balance between the needs of the environment and those of the abstractors.

2. Our vision is of a healthy and diverse water environment, managed in an environmentally sustainable way, balancing the needs of all users.

3. We are guided by the balanced adoption of three fundamental principles; sustainability, precaution and demand management.

4. We aim to allow the reasonable needs of all abstractors (public supply, industry and agriculture) to be met at reasonable cost up to appropriate levels of service.

5. "Reasonable needs" must allow for proper attention to demand management; for example leakage control and consideration of water metering.

6. We aim to meet all reasonable environmental water needs, ie those of rivers, wetlands and estuaries, including the needs of nature conservation, navigation, fisheries and recreation.

7. We intend this strategy to be a basis for advice to Planning Authorities as to the implications, costs and timescales of making water available in an environmentally acceptable way; but *not* a basis for restricting development.

8. We also intend it to provide water resources input to our Catchment Management Plans.

POLICIES FOR CONTROLLING THE DEMAND FOR WATER

9. The NRA strongly encourages Water Companies and other major abstractors to adopt policies and procedures that result in the efficient use of water, in their operations and by the public, through a balanced approach combining demand management with phased traditional source development. Balanced policies will have regard to both cost to consumers and environmental impact.

10. We advocate demand management by all water users to the extent which is economically justified. By this we mean to the point where the costs of saving water match those of making more water available, taking account of *all* the costs and benefits - financial, social and environmental.

11. Before any new sources are developed, it is essential that Water Companies make sure they are doing all they can to reduce leakage and to carry out effective demand management. We support selective domestic metering, with an appropriate tariff, in areas where water resources are stressed.

12. We will require Water Companies to achieve economic levels of leakage and metering before new abstraction licences are granted.

13. We will promote water efficiency by industry, commerce and agriculture.

14. We will work to better define the environmental benefits (or in some circumstances, disbenefits) resulting from 'saving' water, in order to better target demand management efforts.

POLICIES FOR ALLOCATING (OR REALLOCATING) WATER

15. When determining applications for new water abstractions we will:-

- Consider the overall availability of water: abstraction will not be authorised in excess of renewable resources,
- Consider the potential effects on neighbouring abstractors: abstractions will not be authorised which derogate existing rights unless suitable arrangements are made.
- Consider the potential effects on river flows: abstractions will not be authorised which would unacceptably affect low river flows.
- Consider the potential effects on wetlands: abstractions will not be authorised which would unacceptably affect them.
- Set time limits and monitoring conditions on new licences where appropriate in accordance with the precautionary principle.

16. Where appropriate we will consider the revocation or relocation of existing licences which are shown to be unacceptably breaching these criteria.

17. Where appropriate we will allocate minor local sources to minor local needs such as industry and agriculture, provided that any loss to downstream entitlements can be made good and that any appropriate financial arrangements are made. New abstractions for predominantly non-consumptive uses such as cooling and gravel washing will generally be allowed, subject to consideration of local effects.

18. We will investigate the scope for tradeable permits, and for incentive charging, as means of releasing entitlements to abstract water for relatively low value uses.

19. We will press for legislation to make significant, but uncontrolled, abstractions or water transfers licensable.

20. We will not, usually, allocate water specifically to the dilution of effluents; but rather we will set effluent consent conditions according to the anticipated regime of dilution flows.

21. Before licensing water for major new developments we will consider the possibility of reallocation of any surplus entitlements held by others.

ACTIONS TO REDISTRIBUTE AND AUGMENT WATER RESOURCES

22. We will continue to operate raw water transfer works and river support schemes under our control to sustain river flows, for all purposes, during dry conditions.

23. We will continue to work with Water Companies, and others, to ensure that where appropriate such transfers are continued, and extended as necessary in the future.

ACTIONS TO ACHIEVE A BETTER WATER ENVIRONMENT

24. Where wetlands or rivers are shown to be unacceptably affected by abstraction we will ensure that the optimum solution is identified, tested for worthwhileness, and where shown worthwhile, vigorously promoted.

25. We will develop and apply a methodology for defining acceptable targets for river flow regimes; then attempt to sustain those regimes through the control of abstractions and discharges and as appropriate by river support or water transfers.

26. In setting flow targets we will ensure that river water quality and physical characteristics are taken into account. We will press for water quality and physical measures which, combined with good flow regimes, will maximise the ecological value of our rivers.

ACTIONS TO ACHIEVE SECURE WATER SUPPLIES

27. We will investigate the problems of unnatural fluctuations of flows in 'carrier' rivers, and take action as appropriate.

28. We will ensure that all new water developments pay full attention to the needs of the water environment and as far as possible give a net benefit to it.

29. We will develop the water resources input to our Catchment Management Plans to ensure optimum, integrated environmental improvements.

30. We will continue to allocate water to meet reasonable human needs in accordance with its sustainable availability (see Chapter 9), and in accordance with the allocation principles above.

31. We will encourage the use of local water to meet local needs, as above.

32. We will continue to encourage the development of farm reservoirs to store winter water for irrigation.

33. We believe that the best means of meeting future water needs as and when they arise are as set out below. We will encourage, and where necessary use licensing powers to control, developments accordingly. We will also seek to ensure that any major development proposals take account of the needs of other potential beneficiaries.

34. **Lincolnshire and South Humberside**

    1. Capacity of Trent-Witham-Ancholme (TWA) transfer to be enhanced as necessary.
    2. Trent water, either direct or via TWA transfers, to meet all major future needs.
    3. Investigations to continue into water quality and water quantity aspects of increasing abstractions from the Trent.

35. **'West Anglia'**

    The prime need in this area is public water supply, which should remain in surplus well into the next decade.

    Investigations to continue into subsequent options of:

    1. Additional intake to Grafham, at Brownshill.
    2. Relaxing flow constraints on filling Grafham.
    3. Transfer to Ouse and Nene from the canal system.

36. **The Fens**

    1. Better control of water in the fens by legislation to bring 'slacker' transfers within the licensing system.
    2. Consider further augmenting Lincolnshire fens from the Trent.
    3. Consider augmenting Middle Level fens by modifications to upstream abstraction conditions.
    4. Consider augmenting South Level fens from strategic storage, and/or by storage installed by a consortium of farmers.

37. **The Cambridge Area**

1. Seek appropriate sites to consolidate Cambridge Water Company's current licensed entitlement from the Little Ouse Chalk.

2. Continue investigations into Little Ouse Chalk resources and the need to allocate water to the river, to establish further availability of chalk water, if any.

38. **'East Anglia' (Norfolk and Suffolk, excluding Ipswich)**

1. Conventional use of groundwater (subject to environmental constraints) for non-consumptive uses, such as public supplies in inland areas, where the resulting effluent is returned to the river.

2. River support boreholes to sustain river flows for abstraction at or near tidal limits, to supply towns such as Norwich, Yarmouth and Lowestoft, whose effluents are lost to sea.

3. Limited groundwater abstraction for consumptive purposes such as irrigation, subject to establishing, and where appropriate maintaining, satisfactory river flow targets, and other environmental protection measures.

4. Consider alternative supplies and/or enhanced demand management in local areas where groundwater is fully used.

39. **'North Essex' (Colchester, Tendring and Ipswich)**

1. Develop small remaining groundwater resources, subject to environmental constraints.

2. Augment from Ely Ouse to Essex scheme, backed by developments described for 'South Essex'.

40. **'South Essex' (Essex part of Essex and Suffolk Water plus perhaps parts of Thames Region)**

1. Redevelop minor groundwater sources in the Romford area.

2. Promote the diversion of Chelmsford effluents to the Chelmer.

3. Investigate environmentally acceptable reduction in the Denver hands-off flow, perhaps on a time limited basis.

4. Keep under review the possibility of reallocation of 'surplus' entitlements held by others.

5. Decision in principle to move towards the construction of a strategic reservoir of the order of 40 - 50 mcm capacity. On both cost and environmental grounds, the best site for a such a reservoir appears to be at Great Bradley, 20 kilometres east of Cambridge. Its promotion and timing are not matters for the NRA, but provisionally it might need to be in service between 2006 and 2011.

INVESTIGATIONS

In addition to the specific investigations already identified above, we will ensure that a programme of investigations is carried out, by ourselves and by others, to underpin the maintenance of secure water supplies and continuing improvement to our water environment. These investigations will include:-

41. **Water Demands**

Continue to improve demand forecasts for all purposes.

Foster wise water use; in particular encourage catchment based waste minimisation projects.

Define environmental benefits/disbenefits of 'saving' water, in order to better target demand management.

42. **Water Resources**
Undertake detailed Water Resource Management Plans for specific catchments/aquifer units, to refine and apply the principles of this strategy at local scale and provide input to Catchment Management Plans

43. **River Needs**
Continue work to identify in-river flow needs and where appropriate define minimum acceptable flows and/or river flow objectives.

Review the needs for freshwater flows to estuaries.

Establish techniques to evaluate the benefits of flow enhancement.

Study the effects of water transfers on 'carrier' rivers and undertake any reasonable environmental measures.

44. **Groundwater**
Continue to review estimates of groundwater available for abstraction.

Refine the environmental allowances in the groundwater balances.

Review those catchments which show a 'negative' balance.

Continue to develop groundwater models, and to refine groundwater resource assessments.

Investigate options for artificial recharge of groundwater.

Investigate the effects of field drainage and urbanisation on groundwater recharge

Investigate areas of rising groundwater levels.

45. **Wetlands**
Monitor 50 key wetland sites.

Continue investigations into the hydrology and ecology of wetlands.

Consider the feasibility of defining levels of service for wetlands.

46. **Economic Instruments**
Explore incentive charging.

Explore tradeable permits.

Review and revoke unused licences where appropriate.

47. **Long Term Issues**
Undertake research and maintain a 'watching brief' on climate change.

Maintain a 'watching brief' on esoteric options such as desalination.

Chapter 16 - THE FUTURE

This strategy is a framework within which all concerned can work towards the objectives of:-

- Improving the water environment
- Meeting reasonable water needs to accepted levels of service at reasonable costs (in most cases not unduly greater than current costs)
- Minimising the adverse effects of change
- Maximising the beneficial effects of change

We believe that, broadly, all these objectives can be achieved. But we do not pretend that it will ever be possible to fully satisfy everybody's aspirations at all times. The strategy involves a series of measures, all of which are likely to have disadvantages as well as benefits; and all of which are likely to be objected to by somebody! We have put forward what we believe at this stage to be the best overall 'package' in the interests of both the community and the water environment.

However, planning for the future is a continuous process; demands change, peoples' perceptions change, even the climate changes. This strategy is the NRA Anglian Region's view as at 1994, but it is not a tablet of stone. We will continue to modify it in the light of changing circumstances. To help us to do so, we will always welcome new information and positive suggestions, or criticisms, from anybody.

In the meantime we will work to ensure the continued, sustainable provision of water supplies and continuing sustained improvements to the environment of Britain's driest region.

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ANNEXE 1

CONSULTEES

We list below all those who responded to our Consultation Draft. We gratefully acknowledge their contributions, and those of all others who have helped in the preparation of this strategy.

Key:- * Questionnaire style reply. † Questionnaire and/or letter received. ‡ Roadshow comment.

† Agricultural Development Advisory Services
‡ ARC
† Anglian Water Services
† Babergh District Council
† Bedford Borough Council
‡ Bedfordshire Group of Drainage Boards
* Braintree District Council
† Breckland District Council
* Broadland District Council
† Broads Authority
‡ Broads Society
* Buckinghamshire County Council
‡ Burn Action Group
† Cambridge Water Company
* Cambridge City Council
* Cambridgeshire Federation of Womens Institutes
* Cambridgeshire County Council
* Carlton Parish Council
* Carlton Residents
† Castle Point Borough Council
† Chelmsford Borough Council
‡ CIBA Composites
* Clean Rivers Trust
* Consultant Hydrogeologist
* Country Landowners Association
† Council for the Protection of Rural England
† Department of the Environment
* Eastern Council for Sport & Recreation
† East Midlands Regional Planning
* East Cambridgeshire District Council
* Ely Group of Drainage Boards
* English Nature
* Environmental Consultants
† Essex County Council
† Essex Water Company
* Essex Wildlife Trust
‡ F Hiam Ltd
‡ Farmer
‡ J Garrett (MP)
† Great Bradley Residents
* Great Ouse Boating Association
‡ Great Ouse Flood Defence Committee
* Greens of Soham Ltd
* Great Bradley Parish Council
† Humberside County Council
† Huntingdon District Council
* Individual/Parish Council
* Inland Waterways Association
† Institution of Directors
* Ipswich Borough Council
* John R Keeble & Son
‡ Joint Anglers Federation
* King's Lynn Conservancy Board
† King's Lynn/ West Norfolk Borough Council
† King's Lynn Internal Drainage Boards
‡ Kirtling Residents
‡ Lakenheath Internal Drainage Board
‡ Local Flood Defence Committees
† Lincolnshire Trust
‡ Lincolnshire & District Angling
† Lincolnshire County Council
* Lord de Ramsey
* Meteorological Office
‡ Mid Bedfordshire Councillor (RAC)
* Mid Bedfordshire District Council
‡ Middle Level Commissioners
* Milton Keynes Borough Council
* Mott Macdonald
‡ North Norfolk District Council
* National Trust
* National Farmers Union
† National Farmers Union (East Anglia)
* National Farmers Union (East Midlands)
* Norfolk County Council
* Norfolk Friends of the Earth
‡ Norfolk Fisheries and Wildlife Advisory Group
* Norfolk Naturalists Trust
‡ Norfolk Rivers Groundwater Group
† Norfolk Society
* Northamptonshire County Council
* Norwich City Council
† Notcutts Nurseries
† Nottinghamshire County Council
‡ OFWAT
* OFWAT Eastern Customer Services Committee
† Powergen
* Ramblers Association Essex
* Rochford Council
† Regional Rivers Advisory Committee
† Royal Society for the Protection of Birds
‡ RST Irrigation Ltd
* Residents for Stour Valley Preservation
† South Cambridgeshire District Council
* South Holland District Council
* South Norfolk District Council
* Salmon & Trout Association
† Standing Conference of East Anglian Local Authorities
† Southend Borough Council
† Suffolk County Council
† Suffolk Wildlife Trust
† Tendring District Council
* Tendring Hundred Water Services
* Thetford Society
* Three Valleys Water Services
* United Kingdom Irrigaton Association (Silsoe)
† Uttlesford District Council
* West Wickham Parish Council
* Waterman Agricultural Engineers
‡ Wensum Internal Drainage Board
* Wensum Valley Project
* West Wratting Parish Council
* Westley Residents
‡ Willingham Green Residents
* Woodditton Parish Council

Questionnaires and/or letters were also received from other members of the public.

ANNEXE 2

GLOSSARY OF TERMS

mcm
millions of cubic metres

tcmd
thousands of cubic metres per day (same thing as Ml/d, or Megalitres per day)

Alleviation of Low Flows
(ALF) The strategy for resolving environmental problems caused by over-abstraction in certain catchments.

Asset Management Plan
Water Companies' Strategic Business Plans - initiated (e.g. AMP 2) by OFWAT as part of the periodic review of water company charges.

Abstraction
The removal of water from any source, either permanently or temporarily.

Abstraction Licence
Authorisation granted by the NRA to allow the abstraction of water from a source of supply.

Aquifer
A porous underground formation of permeable rock, sand or gravel capable of holding or transmitting significant quantities of water.

> **Confined Aquifer:** an aquifer which is overlain by rocks of low permeability so that the movement of water is restricted and the groundwater within the aquifer is confined under pressure. A confined aquifer is termed artesian when boreholes drilled into it overflow without being pumped.
>
> **Unconfined Aquifer:** an aquifer in which the groundwater forms a free water table within the porous rock.

Artificial Recharge
The filling or recharging of an aquifer by means other than natural infiltration of precipitation and runoff (e.g. by use of treated river water.)

(River) Augmentation
To increase, support or regulate river flows by releasing or pumping water from stored resources e.g. reservoir or groundwater scheme.

Biodiversity
Having a range/variety of species.

BMWP
Biological Monitoring Working Party.

BW
British Waterways.

Brundtland Report
Report of the 1987 World Commission on Environment and Development.

Bulk Supply
Legal arrangements between supply companies for the transfer of (sometimes large) quantities of raw or treated water.

CBI
Confederation of British Industry.

(Environmental)Carrying Capacity
The capacity required to safeguard the natural environment.

Catchment
The area from which precipitation and groundwater will collect and contribute to the flow of a specific river.

Catchment Management Plan
The planning process being used by the NRA with the aim of integrated sustainable river basin development at the catchment scale.

Channel Morphology
The physical shape or form of river channels arising from hydrological processes, and from artificial modifications.

Compensation Flow (CF)
The flow maintained below dams to compensate for impounding.

Confined Aquifer
see Aquifer.

Conjunctive Use
Combined use of different sources of water (usually surface water and groundwater)

DoE
Department of Environment.

Demand
The requirements for water for human use.

> **Average Demand:** usually refers to the average daily demand (averaged over the year)
>
> **Peak Demand:** may refer to the seasonal peak use, peak week, or peak daily demand.
>
> **per Capita Demand:** Demand expressed as per head of population - litres/person/day.

Demand Centre
A generally discrete area of public water supply demand in which specific sources of supply can be used to meet demand throughout that area.

Demand Management
Activities to manage the amount of water required from a source of supply; includes measures to control waste and/or to discourage use.

Derogation
A legal term that describes a diminution of the water rights of existing water users due to a new abstraction.

Direct re-use
Use of treated effluent from a sewage treatment plant directly as a source of water for another use, usually with further treatment.

Discharge Consent
Authorisation granted by the NRA to discharge effluent of specified quality and volume at a specific point.

Drought
A general term covering prolonged periods of below average rainfall resulting in low river flows and/or low recharge to groundwater, imposing significant strain on water resources.

> **1 in 50 year Drought:** A drought of a severity which is likely to be equalled or exceeded on average approximately once every 50 years.

EA
Environmental Assessment

Ecology
The relationship between living systems and their environment.

Ecosystem
Referring to a biological community and its functioning as a self-sustaining ecological unit.

Effluent
Liquid waste from industrial, agricultural or sewage plants.

Effluent Re-use
The use of effluent treated to appropriate standards for various uses from low grade (grey water) uses to potable supply. The term generally refers to indirect use of treated effluent - effluent mixed to a large degree with other raw water (c.f. Direct Re-use).

Effective Rainfall
That rainfall available for recharge of aquifers or to support river flows after `losses' due to evaporation and take up by plants.

Global Warming
The generic term used to describe the climate changes which may occur for example, as a result of depletion of the ozone layer or through the emission of `greenhouse' gases.

ha
Hectare

Habitat
The customary and characteristic dwelling place of a species or community.

Hands Off Flow
The flow below which abstractions must be reduced or supported in order to preserve natural low flows below the intake.

Hydrology
The study of water on and below the earth's surface.

Incentive Charging
Charging policy (for water) designed to encourage optimum use.

Groundwater
Water held in aquifers.

l/h/d
Litres per head per day. (This is a way of expressing per capita consumption.)

l/prop/day
Litres per property per day.

MAF
Minimum Acceptable Flow. See also Hands-off Flow and River Flow Objectives.

MAFF
Ministry of Agriculture, Fisheries and Food.

mAOD
Meters above ordnance datum.

Macroinvertebrate
Organism having no backbone often used as indicator species because of tolerance or vulnerability to water quality changes and pollutants.

Minimum Maintained Flow (MMF)
The flow at a control point downstream of an intake on a regulated river that must be maintained at all times.

Mitigation
Refers to the environmental impact of scheme development or operation and the actions which may be taken to reduce or ameliorate such impacts.

NRA
National Rivers Authority.

NPC
Net Present Cost - the total cost of future expenditure discounted to present values.

OFWAT
Office of Water Services. OFWAT controls how much Water Companies can charge for their services.

Outage
A term used by the Water Companies to describe the loss of public water supply source yields due to planned or un-planned maintenance and the temporary loss of supply due to pollution.

PCC
Per Capita Consumption, or the quantity of water used for household domestic purposes expressed as a volume per person.

Planning Margin
Margin of supply capacity over demand (encompasses "outage" and other factors) to ensure secure water supplies.

Prescribed Flow
A generic term for any flow 'prescribed' in a statute which must not be diminished by abstraction. It encompasses Compensation Flow, Hands-off Flow and Minimum Maintained Flow.

Public Water Supply (PWS)
Water treated to potable standards, supplied to domestic and commercial users.

Precautionary Principle
General principle of "if in doubt, play safe".

Q95
The mean daily flow of a river which is equalled or exceeded on average for 95% of the time.

RFO
River flow objective.

RQO
River quality objective.

Ramsar
Town in Iran where an international convention originally agreed in 1975 to stem the progressive encroachment on, and loss of, wetlands.

(Flow) Regime
The statistical pattern of a river's constantly varying (daily) flow rates.

Rising Groundwater
Resulting in some locations from the natural recovery of an aquifer following a reduction in groundwater abstraction.

Raw Water
Water in its natural state; i.e. before treatment

Recharge
The amount of effective rainfall that percolates into the ground and replenishes groundwater storage.

RIVPACS
River Invertebrate Prediction and Classification System.

Regulated River
A river whose flow is augmented through the addition of water from another source.

SEA
Strategic Environmental Assessment.

SPA
Special Protection Area.

SPL
Supply Pipe Leakage.

SSSI
Site of Special Scientific Interest designated by English Nature under the Wildlife and Countryside Act 1991.

Sewage
Liquid waste from cities, towns and villages which is normally collected and conveyed in sewers for treatment and/or discharge to the environment.

Sourceworks
Works whereby water may be withdrawn from a water resource.

(River) Support
see Augmentation.

Surface Water
Water which flows or is held on the ground surface; streams, rivers, lakes and ponds.

Sustainable Development
Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The term encompasses the concepts of (environmental) carrying capacity, critical natural capital thresholds and inter-generational equity. Arises from the Rio Summit meeting and is described by Brundtland (1987).

Sustainable Management
The interpretation of the principles of sustainable development at a local/regional level within the boundaries of national and international political, economic and environmental decisions.

Total Capital Costs
All costs of constructing a new water resource scheme.

Total Treated Water Losses
The sum total of the loss of water from company distribution systems (trunk mains and distribution losses), customer supply pipes and general domestic leakage.

Water Delivered
The quantity of water at the point of delivery to customers, including measured/unmeasured commercial and household uses. Water delivered to households includes losses on the customers' premises (e.g. supply pipe losses, leaking valves etc).

Water Into Supply
Or Distribution Input. The total quantity of treated water pumped into the distribution system. Includes water delivered, distribution losses and water used by the supply company (Water Not Delivered) and for fire-fighting.

Water Resource
The naturally replenished flow or recharge of water in rivers or aquifers.

Water Table
The level in an aquifer below which the ground is wholly saturated with water.

Wetland
An area of low lying land where the water table is at or near the surface for most of the time leading to characteristic habitats.

Yield
The reliable rate at which water can be drawn from a water resource.

ANNEXE 3

MAJOR SURFACE WATER RESOURCES

There are five ways in which major reliable supplies are obtained from our rivers:

- Abstractions from rivers sustained naturally by groundwater storage. (Rivers Wensum, Bure, Waveney, Nar and Wissey)
- Abstractions from rivers sustained artificially by transfers or effluents. (Rivers Ancholme, Bedford Ouse, Stour, Colne, Chelmer and Blackwater)
- Abstractions to fill reservoirs. (Rivers Nene, Welland, Bedford Ouse, Gipping, Bucklesham Mill Stream, Stour, Colne, Blackwater, Chelmer and Louth Canal)
- Abstractions for transfer to other rivers to augment b) and c) (Rivers Great Eau, Witham, Ely Ouse and Trent).
- Abstractions from onstream reservoirs.

The major such developments are listed at Table A3:1. The sourceworks reliable outputs of specific developments in Table A3:1 do not include allowance for future increases due to increasing river regulation by returning effluents, as there is no reason why such increase should automatically accrue to any particular abstractor.

Table A3.1 - Surface Water Resources

River	Augmented From	Abstraction Point	Purpose	Type of Use	Min Resid Flow tcmd	Associated Storage		Reliable Yield tcmd	Comments
						Description	Gross Volume mcm		
Witham	R. Trent at Torksey	Short Ferry	River Transfer	d	-	Toft Newton	0.8	-	Supports abstractions from Ancholme
Witham	R. Trent at Torksey	Antons Gowt	Agriculture	b	-	-	-	-	Operated by Water Transfer Limited
Witham	(Rutland Water)	Saltersford	PWS-AWS	b	-	Rutland	-	4(20)	4 from Witham; up to 16 from Rutland
Ancholme	River Witham + River Trent	Cadney	PWS-AWS	b	-	Cadney	0.9	85	Treated at Elsham
Louth Canal	River Gt Eau at Cloves Bridge	Covenham	PWS-AWS	b/c	2.5	Covenham Reservolr	10.9	64	
River Nene		Wansford	PWS-AWS	c	136	Rutland Water	137		Increase is due to rising effluents and depends on actual growth of water use. Yields *exclude* any potential drought order reductions in mrf
River Welland		Tinwell	PWS-AWS	c	36	Pitsford	18	532 rising to 604	As above
Nene	-	Duston Mill	PWS-AWS	c/e					As above
Bedford Ouse	-	Offord	PWS-AWS	c	136+ 1/4 remaining flow	Grafham Water	56		As above
Eyebrook	-	Eyebrook Reservoir	Industry	e	-	Eyebrook Reservoir	8	17.7	Only 9.5 tcmd licensed
Nene Tributaries	-	Ravensthorpe + Hollowell	PWS-AWS	e	-	Ravensthorpe + Hollowell	4	8	Hydrological yield
Gaywood	-	Loke Road Kings Lynn	PWS-AWS	a	-	-	-	0	Emergency source only

Table A3.1 - Surface Water Resources (Continued)

River	Augmented From	Abstraction Point	Purpose	Type of Use	Min Resid Flow tcmd	Associated Storage: Description	Associated Storage: Gross Volume mcm	Reliable Yield tcmd	Comments
Nar	-	Marham	PWS-AWS	a	-	-	-	7	Operates in conjunction with Marham and Beachamwell groundwater sources
Wissey	Cut OffChannel/ GOGW S boreholes	Stoke Ferry	PWS-AWS	a/b	27	-	-	13	Planned increase to 18 tcmd.
Ely Ouse	GOGWS borcholes	Denver Transfer	River	d	114/318	-	-	-	Augments Essex Rivers
Bedford Ouse	-	Foxcote	PWS-AWS	b/c	-	Foxcote Reservoir	0.5	6.5	
Bedford Ouse	-	Clapham	PWS-AWS	b	-	-	-	22	
Waveney	Waveney Groundwater Scheme	Shipmeadow	PWS-E & S W Co	a	34 (Varies with abstraction)	-	-	21	
Bure	-	Belaugh + Horning	PWS-E & S W Co	a	33(Varies with abstraction)	-		23	Includes Ormesby Broad
Fritton Lake	-	Lound	PWS -E & S W Co	a	-	-		5	
Wensum	-	Costessey/ Heigham	PWS-AWS	a	44	Bankside storage only		40	Potentially unreliable in extreme droughts
Gipping	-	Sproughton	PWS-AWS	c	9	Alton	9.1	}	
Bucklesham Mill River	-	Bucklesham	PWS-AWS	c	2	Alton	-	30	
Newbourn Stream	-	Newbourn	PWS-AWS	c	0.2	Alton	-	}	
Colne	Ely Ouse	Colchester	PWS-AWS + THWS	b/c	0	Ardleigh	2.4	22	Yield under review
Stour	Ely Ouse	Langham and Cattawade	PWS-E & S W Co	b/c	-	Abberton	25.0	327	Yield subject to review; includes for Hanningfield improvements, and increase in input capacity to Abberton (both to be installed within 2 to 3 years)
Roman River	-	Abberton	PWS-E & S W Co	c	-	Abberton	-	}	
Chelmer/ Blackwater	Ely Ouse	Langford	PWS-E & S W Co	b/c	2	Hanningfield	26.1		

ANNEXE 4

DETAIL OF GROUNDWATER RESOURCES

Figure A4:1 shows schematically how the Region's groundwater resources are assessed and 'balanced out' between the needs for abstraction and the needs of the rivers. Note that this is a grossly simplified 'water accountancy' procedure. The availability of water at any one spot or from any one groundwater unit will always be subject to local evaluation.

The procedure shown in Figures A4:1 (and A4.2) works as follows:-

1. Long average recharge (1) is assessed by reference to groundwater models (where available), records of river flows and abstractions. It is checked against analysis of effective rainfall, catchment areas and geology. The long average recharge is referred to as the 'gross resource'. As far as possible recharge estimates have been based on 1961 - 1990 standard period.

2. The gross resource is reduced to reflect the inadequacy of aquifer storage to fully even out the year to year variations in recharge. Typical reductions are 20% for chalk catchments, 40% for limestone. These are empirical factors, based on experience, and may be subject to review. The reduced quantity is referred to as 'effective resource'; it is this which is reliably available for allocation either to abstraction (2) or to the environment (4).

3. The environmental requirement for groundwater (4) is assessed. This is primarily the minimum required river flow. Ideally this might involve detailed ecological studies, but no satisfactory objective method is yet available. In its absence current practice is to use the natural 95% flow (ie the flow which, in the absence of any abstractions or discharges, would be equalled or exceeded 95% of the time).

   As an interim suggestion we also show the effect of limiting the 'reliable' river allocation to 50% of the gross resource. (This would mean that the river would get in total the 'reliable' 50% plus the 'unreliable' 20%, leaving a maximum of 30% of gross resource for abstraction).

   In some cases an additional environmental allocation is made to prevent saline intrusion. This is presently based on the surface area of the unit, and requires refinement.

4. In practice, river flows are sustained by treated sewage effluents(6), and reduced by abstractions (5). These are quantified and the allocation to the river from groundwater(3) is adjusted accordingly. Abstractions are taken as the annual average licensed quantity; and reliable effluents are taken as 75% of their normal dry weather flow, to account for reduced water usage in drought conditions.

5. The quantity allowable for abstraction(2) is the effective resource minus this allocation of groundwater to the river(3).

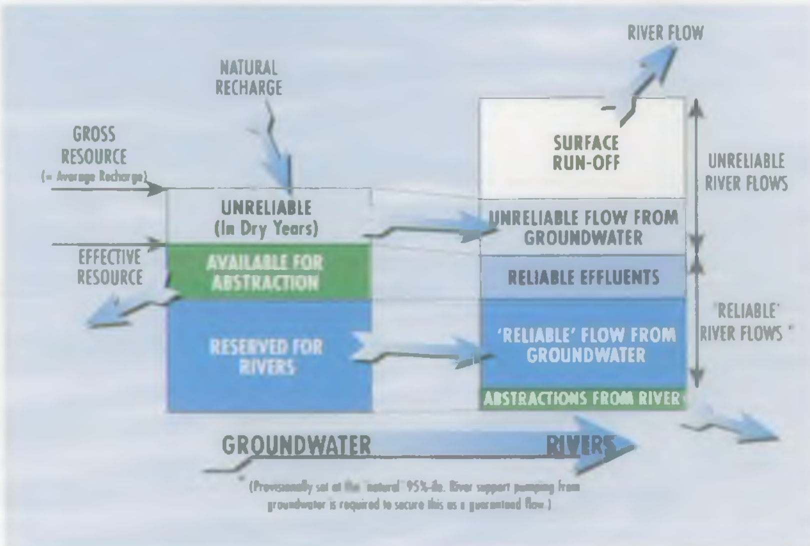
6. The quantities thus allocated to the river are the natural 95% flow plus the remaining 20% (or 40%) of 'unreliable' recharge, plus all surface runoff. (Note that this leaves a river with naturally - varying flow characteristics. If a sustained minimum flow is required, river support pumping is necessary to achieve it. The method of allocating the resource leaves sufficient for this purpose up to the natural 95 percentile flow).

Fig A4.2 shows how the method allocates the groundwater resource between abstractions and the river, and the resulting components of river flow.

The results of the assessments are shown on Table A4:1 leading to a tabulation of the balance of nominal over- or under-abstraction in each unit. However, these nominal figures must be interpreted in the light of the comments which follow Table A4.1. We have carried such interpretation through to Table A4.2 which gives our best assessment of the actual state of over- or under-licensing in each unit.

Figure A4.1 - Groundwater Balance Methodology

Figure A4.2 - The Allocation of Groundwater to Rivers



RESOURCES				RIVER NEED		
Groundwater Unit and Catchment		Gross Resource	Effective Resource	Gross Environ. Allocation		Net Reliable Effluent minus Unconstrained Abstractions
				Full Allocation	Limited to 50% Gross Resource (changes)	
		tcmd	tcmd	tcmd		tcmd
(1)		(2)	(3)	(4)	(5)	(6)
Lincs Chalk and Sandstone						
Spilsby Sandstone	-	47.0	82.0	39.0	23.5	2.0
Southern Chalk	-	105.0	28.0	39.4		.1
Northern ChaLk	-	231.0	184.8	26.6		5.3
Lincs Limestone						
N. Limestone	12 to 14	92.0	55.2	38.4		5.5
C. Limestone	15a & b	80.0	48.0	24.3		5.2
S. Limestone	16 to 19	143.4	86.0	47.6		6.4
Lincs and Northants Minor						
Lincs & Northants Minor		98.9	79.0	.0		.0
Cambs. Chalk						
Ouzel	Unit 1	35.0	28.0	8.8		13.8
Ivel	Unit 2	118.8	95.0	25.9		21.8
Rhee	Unit 3	70.5	56.4	28.0		8.5
Cam	Unit 4	65.5	52.4	21.3		50.6
Granta	Unit 5	33.4	26.7	5.5		2.2
Cambridge	Unit 6	2.9	2.3	.8		-.1
Lodes	Unit 7	84.9	67.9	21.5		8.6
Lark	Unit 8	159.4	127.5	62.2		15.3
Little Ouse	Unit 9	263.4	210.8	144.7	131.7	11.8
Wissey	Unit 10	177.7	142.1	78.8		3.9
Nar	Unit 11	87.4	69.9	42.8		6
Babingley/Gwood	Unit 12	72.5	58.0	33.2		3
NW Norfolk Chk	Unit 13	27.8	22.3	2.1		0
Lower Greensand						
L Buzzard	GS 1	11.0	11.0	4.3		7.5
Sandy	GS 2	43.3	43.3	11.1		17.5
Cambridge	GS 3	19.1	19.1	4.4		1.6
Sandringham	GS 4	74.4	74.4	31.5		1.7

Table A4.1 - Groundwater Resource Balances

Groundwater Allocation to River	ABSTRACTIONS AND NOMINAL SURPLUS				
	Allocation with 50% of Gross Resource (changes)	Licensed Abstraction	Balance Nominally Available	Balance Nominally Available with Env. Limited to 50% Gross Resource (changes only)	
tcmd 7 = (4-6)	tcmd 8 = (5-6)	tcmd (9)	tcmd 3 - (7+9)	tcmd 3 - (8+9)	
37.0	21.5	36.6	8.5	23.9	*2
39.3		1.2	-12.5		*1
21.3		189.1	-25.6		*1
32.9		33.6	-11.3		
19.1		31.8	-2.9		
41.2		82.5	-37.6		*3
.0		74.6	4.4		
.0		5.6	22.5		*4
4.1		38.4	51.9		*4
19.5		41.3	-4.4		
.0		77.7	-25.3		*5
3.3		16.8	5.7		
.9		.2	1.2		
12.9		57.3	-2.3		
46.9		83.1	-2.5		
132.9	119.9	81.5	-3.6	9.4	*6
75.0		44.9	22.3		
42.2		28.9	-1.2		
32.8		21.9	3.3		
2.1		5.3	14.9		
.0		25.5	-14.4		* 12
.0		25.1	18.2		* 12
2.8		10.5	5.7		* 12
29.7		10.7	34.0		* 12

RESOURCES				RIVER NEED	
Groundwater Unit and Catchment		Gross Resource	Effective Resource	Gross Environ. Allocation	
				Full Allocation	Limited to 50% Gross Resource (changes)
		tcmd	tcmd	tcmd	
(1)		(2)	(3)	(4)	(5)
Central Minor Oolite/Gravels	-	15.5	12.4	10.0	7.8
North Norfolk Chalk					
Hun	34/01	16.7	13.4	5.6	
Burn	34/02	24.6	19.7	11.3	
Stiffkey	34/03	34.8	27.8	14.7	
Glaven	34/04	37.8	30.2	24.4	18.9
Mun	34/05	21.1	16.9	10.0	
Bure Chalk					
Bure	34/06	135.6	108.5	101.2	67.8
Spixwarth	34/07	16.7	13.4	9.3	8.4
Ant	34/08	21.0	16.8	14.7	10.5
Bure/Ant	34/09	33.7	27.0	22.3	16.9
Wensum Chalk					
Wensum	34/11	219.6	175.7	90.7	
Tud	34/12	15.7	12.6	5.2	
Yare	34/13	63.4	50.7	17.7	
Tas	34/14	37.7	30.2	13.8	
Tidal Yare	34/15a	38.4	30.7	24.8	19.2
Waveney Chalk					
Waveney	34/16	21.9	17.5	5.7	
Dove	34/17	29.9	23.9	8.0	
Waveney	34/18	51.0	40.8	20.0	
Tidal Waveney	34/19a	4.9	3.9	5.5	2.5
Blyth/Alde Chalk					
Blyth	35102a	9.1	7.3	4.3	
Alde	35/04a	21.1	16.9	6.5	

Table A4.1 - Groundwater Resource Balances (Continued)

		ABSTRACTIONS AND NOMINAL SURPLUS				
Net Reliable Effluent minus Unconstrained Abstractions	Groundwater Allocation to River	Allocation with 50% of Gross Resource (changes)	Licensed Abstraction	Balance Nominally Available	Balance Nominally Available with Env. Limited to 50% Gross Resource (changes only)	
tcmd (6)	tcmd 7 = (4-6)	tcmd 8 = (5-6)	tcmd (9)	tcmd 3 - (7+9)	tcmd 3 - (8+9)	
.0	10.0	7.8	9.1	-6.7	-4.5	
-.2	5.8		.2	7.3		
.7	10.6		2.4	6.7		
-.2	14.9		10.8	2.1		
.3	24.0	18.6	7.4	-1 1	4.2	
.0	10.0		6.8	.1		
1.7	99.5	66.1	14.9	-5.9	27.5	*7
.4	8.9	8.0	3.5	1.0	2.0	*7
.7	14.0	9.8	4.3	-1.5	2.7	*7
3.9	18.4	13.0	14.4	-5.9	-.4	*7
14.4	76.3		38.3	61 . 1		*8
1.2	4.0		1.5	7.0		*8
4.6	13.1		23.7	13.9		*8
2.7	11.1		11.2	7.9		*8
-1.3	26.2	20.5	25.2	-20.7	- 15.0	*8
3.4	2.3		9.9	5.3		
3.2	4.8		15.6	3.5		*9
7.9	12.2		10.9	17.7		*9
-.1	5.6	2.6	20.7	-22.3	-19.4	*9
1.9	2.4		7.0	-2.1		
.7	5.7		6.5	4.7		

RESOURCES				RIVER NEED	
Groundwater Unit and Catchment		Gross Resource	Effective Resource	Gross Environ. Allocation	
				Full Allocation	Limited to 50% Gross Resource (changes)
		tcmd	tcmd	tcmd	
(1)		(2)	(3)	(4)	(5)
Deben Chalk					
Deben	35/06	25.5	20.4	8.2	
Fynn/Lark	35/07	7.1	5.7	1.1	
Gipping Chalk					
Gipping	35/08	57.7	46.2	16.9	
Belstead Brook	35/09	4.2	3.4	1.0	
Felixstowe Pen	35/10a	.0	.0	8.6	.0
Stour Chalk					
Upper Stour	36/11	47.9	47.9	17.9	
Glem	36/12	17.5	17.5	6.4	
Chad Brook	36/13	10.4	10.4	3.5	
Belchamp Brook	36/14	9.5	9.5	3.7	
Lower Stour	36/15	3.4	3.4	.7	
Box	36/16	3.0	3.0	1.4	
Brett	36/17	30.8	30.8	8.9	
Stratford/Fltfrd	36/18	.0	.0	.0	
Stour Estuary	36/19	.0	.0	6.9	.0
Mid Essex Chalk					
Colne	37/21	14.1	14.1	3.3	
Colne	37/22	1.2	1.2	.0	
Colne	37/23	.0	.0	.0	
Colne	37/24	.0	.0	.0	
Colne	37/25	.0	.0	.0	
Colne	37/26	.0	.0	.0	
Blackwater/Chelmer	37/31	16.0	16.0	7.2	
Blackwater/Chelmer	37/32	.0	.0	.0	
Blackwater/Chelmer	37/35	5.8	5.8	.8	
Blackwater/Chelmer	37/39	.0	.0	.0	

Table A4.1 - Groundwater Resource Balances (Continued)

Net Reliable Effluent minus Unconstrained Abstractions	Groundwater Allocation to River	ABSTRACTIONS AND NOMINAL SURPLUS Allocation with 50% of Gross Resource (changes)	Licensed Abstraction	Balance Nominally Available	Balance Nominally Available with Env. Limited to 50% Gross Resource (changes only)
tcmd (6)	tcmd 7 = (4-6)	tcmd 8 = (5-6)	tcmd (9)	tcmd 3 - (7+9)	tcmd 3 - (8+9)
1.0	7.2		9.6	3.5	
.4	.7		2.9	2.2	
12.2	4.7		45.9	-4.4	
.8	.3		6.4	-3.4	
.0	8.6	.0	20.6	-29.2	*10
8.9	9.0		12.5	26.4	*11
.7	5.7		.2	11.6	*11
.3	3.2		.1	7.1	*11
.1	3.6		.1	5.8	*11
2.9	.0		57.6	-54.2	*11
.9	.5		.7	1.7	*11
1.4	7.5		21.3	2.0	*11
.7	.0		9.9	-9.9	*11
.0	6.9	.0	14.9	-21.8	*11
3.4	.0		7.9	6.2	*11
-.4	.3		.0	.8	*11
.0	.0		5.0	-5.0	*11
.0	.0		.3	-.3	*11
.0	.0		.0	.0	*11
.0	.0		.2	-.2	*11
.9	6.3		22.1	-12.3	*11
.0	.0		.0	.0	*11
.4	.4		4.8	.7	*11
.0	.0		.1	-.1	*11

Table A4.1 - Groundwater Resource Balances (Continued)

RESOURCES				RIVER NEED				ABSTRACTIONS AND NOMINAL SURPLUS			
Groundwater Unit and Catchment		Gross Resource	Effective Resource	Gross Environ. Allocation: Full Allocation	Gross Environ. Allocation: Limited to 50% Gross Resource (changes)	Net Reliable Effluent minus Unconstrained Abstractions	Groundwater Allocation to River	Allocation with 50% of Gross Resource (changes)	Licensed Abstraction	Balance Nominally Available	Balance Nominally Available with Env. Limited to 50% Gross Resource (changes only)
		tcmd	tcmd	tcmd		tcmd	tcmd	tcmd	tcmd	tcmd	tcmd
(1)		(2)	(3)	(4)	(5)	(6)	7 = (4-6)	8 = (5-6)	(9)	3 - (7+9)	3 - (8+9)
Thameside Chalk											
Crouch/Thames	37/43	.0	.0	.0		.0	.0		.1	-.1	*11
Crouch/Thames	37/44	.0	.0	.0		.0	.0		.4	-.4	*11
Crouch/Thames	37/56	9.3	9.3	8.0	4.7	12.1	.0	.0	25.5	-16.0	*11
Norfolk Crag											
Thurne	34/10a	14.8	11.8	6.6		.8	5.8		1.1	5.0	
Ormesby/Filsby	34/10b	13.7	11.0	5.9		-.3	6.2		6.0	-1.3	
Bure	34/10c	9.0	7.2	3.1		.6	2.6		2.0	2.6	
Tidal Yare	34/15b	3.3	2.6	3.3	1.7	.1	3.2	1.6	.1	-.6	1.0
Tidal Waveney	34/19b	32.3	25.9	13.6		3.0	10.6		11.7	3.6	
Suffolk Crag											
Lothinglnd 100	35/01	16.7	13.4	7.8		-1.1	8.9		1.9	2.6	
Tidal Blyth	35/02b	19.4	15.5	5.1		1.6	3.5		3.7	8.3	
Yox & Minsmere	35/03	13.6	10.9	4.6		1.0	3.7		7.2	.1	
Ore	35/04b	8.5	6.8	2.3		.5	1.9		0.5	4.4	
Tidal Alde and Ore	35/05	31.0	24.8	6.3		-4.1	6.3		9.4	4.9	
Felixstowe Penin	35/10b	37.0	29.6	14.2		1.2	12.9		3.7	12.9	
Tendring Gravels											
Tendring Penin	37/25	45.6	27.4	11.5		17.3	.0		27.8	-4.7	-.4

TABLES A4.1 COMMENTS

General : Some minor discrepancies are due to rounding errors.

1. **Lincs Northern Chalk**
   This aquifer is over-licensed by licences of right, but which are retained to allow advantage to be taken of wet years. *Actual* abstractions are managed and reduced as necessary using the Northern Chalk model, to ensure that actual abstraction does not exceed the resource. 'Total abstraction' figure is reduced accordingly.

2. **Lincs Southern Chalk and Spilsby Sandstone**
   It is thought that abstractions from the Spilsby Sandstone are largely met by induced recharge from the overlying Southern Chalk aquifer and that recharge to the Spilsby Sandstone outcrop largely emerges as spring flows. See Mott MacDonald Spilsby Sandstone model 1989. The net resource figures for these two units have been adjusted to match this, by subtracting 35 tcmd from the S. Chalk net resource and adding it to the Spilsby Sandstone resource.

3. **Lincs Southern Limestone**
   Licences of right of 124 tcmd have been reduced to 82 tcmd, but a large proportion of the effective resource is still licensed for PWS abstraction. The 'standard' environmental allocation, assessed as part of this review, suggests that in drought years river flows may suffer at the expense of abstraction. However this standard allocation may be unnecessarily high as low, sometimes zero, flows probably occurred naturally in the rivers fed from this aquifer. Also low flows in the West Glen are supported from Rutland Water. The resource balance is under review by Birmingham University.

4. **Cambs Chalk, Ouzel and Ivel Units**
   The apparent large surpluses in these units are viewed with caution for two reasons:-

   Firstly, net river needs are very low because of a high volume of effluent support. It may not be wise to plan to rely on such high effluent flows in future.

   Secondly, the groundwater boundary has considerable overlap with Thames Region, and a joint policy overview is needed.

   Work is in progress to further investigate the groundwater resource status of the Ivel Chalk.

5. **Cambs Chalk, Cam Unit**
   A large proportion of the groundwater abstracted is returned within the catchment to the River Cam. The main river therefore receives ample artificial support from effluent return, but springs and streamflow in the upper parts of the catchment may suffer. These issues are discussed in the NRA Cam Catchment Management Plan (1992).

6. **Cambs Chalk, Little Ouse Unit**
   This unit has a large groundwater resource which is relatively lightly exploited (30% of gross resource licensed). However, the provisional river flow need (based on estimated natural 95%ile flow) suggests that over half the resource should be reserved for the river, and that virtually no further abstraction should be licensed. Even with the river allocation limited to 50% of gross resource, only a further 9 tcmd could be considered for abstraction. Further investigation of river flow needs is required.

7. **Bure Chalk, Norfolk**
   The river flow characteristics of the Bure are naturally very well regulated, leading to a very high river flow allocation (two thirds of the average annual recharge). This means that the aquifer appears fully developed, even though less than 20% of the resource is licensed. Limiting the river allocation to 50% of gross resource would 'release' about 30 tcmd for abstraction.

   Further investigation is planned to review the balance of allocation of water between abstractors and the river. The extent to which water can reliably be abstracted from the chalk aquifer as opposed to the overlying sands and crag also needs investigation.

8. **Wensum/Yare Chalk, Norfolk**
   This unit shows a nominal large surplus (nearly 70 tcmd). However, further use for abstraction will require careful development, to ensure local environmental needs are considered, and that the SSSI status of the river is preserved.

9. **Waveney Chalk Norfolk and Suffolk**
   The apparent large deficit in the tidal Waveney Chalk (34/19a) is met by the surplus resource in the Lower Waveney (34/18) plus induced recharge from the river valley sands and gravels.

   The 'environmental allocation' for the Dove catchment *includes* 8.3 tcmd of river support, in addition to the normal in river need, to support downstream abstraction.

   The possible limitation of the environmental allocation to 50% of gross resource is not applicable to this catchment because of the extent to which the groundwater is committed to augmenting low river flows to support downstream abstraction.

10. **Gipping Chalk/Felixstowe Peninsula, Suffolk**
    The chalk aquifer of the Felixstowe Peninsula is continued beneath impermeable London Clay. Abstractions are met from recharge to the Gipping and Deben Chalk.

    The apparent large deficit in this groundwater unit is much less severe in reality for two main reasons:-

    - Firstly, actual abstractions are much lower than licensed, particularly for industrial abstraction in Ipswich.

    - Secondly, major industrial abstractions on the Felixstowe Peninsula take partially saline water, so that the net drain on the freshwater groundwater resource is less.

11. **South Suffolk/Essex Chalk (Stour, Mid Essex and Thameside)**
    A large part of the chalk aquifer in this area is confined

beneath the impermeable London Clay, so surpluses and deficits in individual sub-catchments cannot be considered in isolation. The apparent deficits overall are met at least partly by induced infiltration from the rivers, through overlying shallow sands and gravels in the river valleys. The amount of water supplied by this means is not readily quantified, and so is not included in the balance presented here.

12. Lower Greensand

Resource availability is uncertain. Units 1 and 2 may be in continuity with each other. Study is in progress into both hydrogeology and environmental needs.

Table A4.2 - The Availability of Groundwater

Groundwater Unit	Balance Nominally Available		Comments	Best Estimate of Water Available tcmd	
	Full 95% allocation to environrnent	Environmental allocation limited 50% of gross resource		Full 95%ile allocation to environrnent	Environmental allocation limited to to 50% of gross resources
Lincolnshire Chalk					
Northern Chalk	-25.6		Actual abstraction restricted Rivers allocation to be reviewed	-?	-?
Southern Chalk	-12.5	} 23.9	Inter-related	} -4	} 11
Spilsby Sandstone	8.5		Inter-related		
Lincolnshire Limestone					
Northern Limestone	-11.3		River allocation to be reviewed	-?	-?
Central Limestone	- 2.9			0	0
Southern Limestone	- 37.6		Detailed modelling is in progress. River supported from external source.	0	0
Lincolnshire Minor	4.4		Surplus within error term of essessment	0	0
Cambridgeshire Chalk					
Ouzel	22.5		Ivel resource investigation in progress. Availability expected to be much less than nominal balance.	+?	+?
Ivel (Hiz)	51.9		As above		
Rhee	-4.4		Deficit within error term of assessment.	0	0
Cam	-25.3		River sustained by effluents. Need to review unused licences.	0	0
Granta	5.7		Rivers allocation subject to (probably upward) review.	0	0
Cambridge	1.2		As above		
Lodes	-2.3		Deficits within error terms of assessment.	0	0
Lark	-2.5		As above	0	0
Little Ouse	-3.6	9.4		0	9
Wissey	22.3			22	22
Nar	-1.2		Detailed study in progress	0	0
Babingley/Gaywood	3.3		Surplus within error term of assessment	0	0
NW Norfolk Chalk	14.9			14	14
Minor CamblBeds Oolite/Gravels	-6.7	-4.5	Deficit within error term of assessment	0	0
Sandringham Sands	34.0			34	34
Cambs/Beds Lr Greensands	9.5		River allocation to be reviewed Unused licences to be reviewed	+?	+?

Table A4.2 - The Availability of Groundwater (Continued)

Groundwater Unit	Balance Nominally Available		Comments	Best Estimate of Water Available tcmd	
	Full 95% allocation to environment	Environmental allocation limited 50% of gross resource		Full 95%ile allocation to environment	Environmental allocation limited to to 50% of gross resources
North Norfolk Chalk	15.1	20.4		15	20
Bure Chalk	-12.3	31.8	River allocation to be reviewed	-12	31
Wensum/Yare Chalk	69.2	74.9	Particular care needed in developing nominally 'spare' water	69	75
Waveney Chalk	4.2	7.1		4	7
Blyth/Alde Chalk	2.6		Surplus within error term of assessment	0	0
Deben Chalk	5.7			5	5
Gipping Chalk	-37.0		Apparent deficit mostly due to unused licences plus use of saline water	0	0
Stour Chalk	-31.3		Apparent deficits are met by induced infiltration		
Mid Essex Chalk	-10.2		As above	0	0
Thameside Chalk	-16.5		As above		
Norfolk Crag	9.3	10.9		9	11
Suffolk Crag	33.2			33	33
Essex Gravels, Tendring Peninsula	-4.7		Deficits within error term of assessment	0	0

ANNEXE 5

PUBLIC WATER SUPPLY SOURCEWORKS RELIABLE OUTPUTS (SRO'S)

This annexe identifies how much water is reliably available to the water undertakers, grouped where relevant into their appropriate supply zones. It draws upon the resources figures in Annexes 3 and 4, and upon estimates of their sourceworks reliable outputs (down to individual boreholes) provided by each undertaker. The 'SRO for planning purposes' is determined by adding current SRO figures to quantities anticipated to be developed, within current licence conditions, in the future. These are summarised in Table A5:1 which identifies where the water is supplied to. The same information is re-ordered in Table A5:2 in terms of where the water comes from.

Table A5.1 also summarises information on remaining excess entitlements (ie. the difference between licensed quantity and SRO for planning purposes), and specifies intentions as to its future use or otherwise.

Table A5.1: Summary of PWS Sourceworks Reliable Outputs (tcmd) by Water Co/ Zone Supply Area

Company/Zone	Licensed Quantity	Sourceworks Reliable Output			Excess Entitlements		
		Current	To be Developed	Total SRO for Planning Purposes	Required for Conjunctive Use Emergencies etc	To be reviewed after resource assessment	Excess Licensed Quantities
AWS WRZ 1	146.60	134.03	3.90	137.93			
AWS WRZ 2	171.40	130.60	.00	130.60			
AWS WRZ 3	94.48	75.27	1.55	76.82			
AWS WRZ 4	46.39	38.88	4.69	43.57			
AWS WRZ 5	36.15	36.40	.00	36.40			
AWS WRZ 6	80.08	76.48	3.60	80.08			
AWS WRZ 7	817.85	600.71	5.14	605.85			
AWS WRZ 8	8.36	8.22	.00	8.22			
AWS WRZ 9	20.53	18.97	1.56	20.53			
AWS WRZ 10	77.37	67.46	7.64	75.10			
AWSWRZ 11 & 12	100.71	89.23	5.11	94.34			
AWSWRZ 13	11.80	11.22	.00	11.22			
AWS WRZ 14	7.42	6.98	.00	6.98			
AWS WRZ 15	5.48	5.00	.48	5.48			
AWS WRZ 16	34.13	29.07	5.06	34.13			
AWSWRZ 17	11.20	11.16	.00	11.16			
AWS WRZ 18	14.28	12.92	1.31	14.23			
AWS WRZ 19	15.44	7.15	8.29	15.44			
AWS WRZ 20	19.18	16.26	2.92	19.18			
AWS WRZ 21	30.01	27.32	2.69	30.01			
AWS WRZ 22	11.23	10.96	.00	10.96			
AWS WRZ 23	11.37	11.37	.00	11.37			
AWS WRZ 24	8.80	8.80	.00	8.80			
AWS WRZ 25	71.84	71.80	.00	71.80			
AWS WRZ 26	9.30	9.30	.00	9.30			
AWS WRZ 27 & 28	62.66	60.68	.00	60.68			
AWS COMPANY TOTAL	1924.06	1576.24	53.94	1630.18	186.01	83.67	5.94
TVWS COMPANY AREA	73.72	50.20	3.87	54.07	5.80	2.74	11.11
E & SW - SW Co Area	100.47	93.22	3.14	96.36	1.21	2.90	
L & SW - EWCo Area	474.94	427.06†	.00	427.06†		47.75	0.13
THWS COMPANY AREA	44.18	42.20	.00	42.20			
CWCo COMPANY AREA	130.50	111.90	11.48	123.38	5.90		1.22
PWS SRO GRAND TOTALS	2747.87	2300.82	72.43	2373.25	198.92	139.04	18.4

† Under Review

Table A5.2: Public Water Supply SRO's. By Resource/Unit

Company	Resource/Unit	Current Licensed Entitlement tcmd (average)	SRO tcmd (average)	Comment
Anglian Water Services Ltd.	GROUNDWATER			
	Lincs Chalk and Sandstone			
	Northern Chalk	158. 17	110.60	
	Southern Chalk	7.94	7.94	
	Spilsby Sandstone	31.03	31.03	
	Lincs Limestone			
	Northern Limestone	21.57	19.61	
	Central Limestone	28.18	18.40	
	Southern Limestone	80.08	80.08	
	Lincs Minor			
	Lincs Minor	0.90	0.00	
	Cambridgeshire Chalk			
	Granta - Unit 5 } Cambridge - Unit 6	0.27	0.00	
	Lodes - Unit 7	12.90	12.83	
	Lark - Unit 8	60.12	53.08	
	Little Ouse - Unit 9	27.74	26.16	
	Wissey - Unit 10	37.84	29.76	Sources are linked by aggregate condition.
	Nar - Unit 11	10.87	13.27	As above
	Babingley/Gaywood - Unit 12	20.20	20.71	
	NW Norfolk Chalk - Unit 13 & 14	3.92	3.78	
	Lower Greensand			
	Leighton Buzzard - Unit GSi	9.34	9.34	
	Sandy - Unit GS2	22.89	21.96	
	Cambridge - Unit GS3	4.55	4.55	
	Sandringham - Unit GS4	6.76	8.00	
	Central Minor			
	Oolites/Gravels	8.63	1.50	
	North Norfolk Chalk			
	Stiffkey - 34/03	6.99	6.99	
	Glaven-34/04	4.11	4.11	
	Mun - 34/05	5.20	5.20	
	Bure Chalk			
	Bure - 34/06	10.63	10.11	Development of Aylsham not included
	Ant - 34/08 } Bure/Ant - 34/09	5.48	5.48	Includes Crag Source at Ludham in hydraulic continuity with the Chalk
	Wensum Chalk			
	Wensum - 34/11	10.31	10.31	
	Yare - 34/13	17.72	17.72	
	Tas - 34/14	9.63	9.63	
	Tidal Yare - 34/15a	19.18	19.18	Includes Sand and Gravel Source at Kirby Cane - in hydraulic continuity with the Chalk
	Waveney Chalk			
	Waveney - 34/16	9.84	9.84	
	Waveney - 34/18	2.27	2.00	
	Stour Chalk			
	Upper Stour - 36/11	10.96	10.96	
	Lower Stour - 36/15	34.37	34.37	
	Brett - 36/17	8 80	8.80	

Table A5.2: Public Water Supply SRO's. By Resource/Unit

Company	Resource/Unit	Current Licensed Entitlement tcmd (average)	SRO tcmd (average)	Comment
	Deben Chalk			
	Deben - 35/06			
	Fynn/Lark - 35/07			
	Gipping Chalk	41.80	41.80	Sources within 35/6 to 35/10 are linked by aggregate
	Gipping - 35/08			
	Belstead Brook - 35/09			As above
	Felixstowe Peninsular- 35/10a			As above
	Mid Essex Chalk			
	Colne - 37/21	9.30	9.30	
	Colne - 37/23	4.11	4.11	
	Blackwater/Chelmer - 37/31	19.47	19.47	
Anglian Water Services Contd.	SURFACE WATER			
	Saltersford	20.00	22.00	
	Cadney	85.00	85.00	
	Covenham	63.60	63.60	
	Rutland	328.77	245.00	
	Pitsford	54.60	40.00	
	Ravensthorpe/Hollowell	16.20	8.00	
	Gaywood	2.27	0.00	
	Marham	11.86	6.82	
	Stoke Ferry	18.00	18.00	
	Foxcote	9.12	6.50	
	Clapham	27.35	22.00	
	Grafham	336.40	247.00	
	Costessey/Heigham	46.60	46.60	
	Alton	30.04	30.00	Potential Increase to Alton Yield from Bucklesham (unproven but could equal 36 tcmd in wet years)
	Ardleigh	13.08	11.00	SRO restricted for precautionary reasons
	Import from EWCo.	3.00	3.00	
Cambridge Water Company	GROUNDWATER			
	Cambridgeshire Chalk			
	Rhee - Unit 3	25.00	24.13	
	Cam - Unit 4	15.23	13.74	
	Granta - Unit 5	16.52	16.23	
	Cambridge - Unit 6			
	Lodes - Unit 7	43.06	41.35	
	Little Ouse - Unit 9	23.34	23.34	
	Lower Greensand			
	Cambridge - Unit GS3	3.86	3.49	
	Central Minor			
	Oolites/Gravels	3.49	0.00	
Three Valleys Water Services plc.	GROUNDWATER			
	Cambridgeshire Chalk			
	Ouzel - Unit 1	0.00	0.00	Excludes sourceworks in Thames NRA Region which may draw on recharge within the Anglian Region.
	Ivel - Unit 2	33.87	28.92	As above
	Rhee - Unit 3	8.42	5.22	As above
	Cam - Unit 4	25.27	14.74	

Table A5.2: Public Water Supply SRO's. By Resource/Unit

Company	Resource/Unit	Current Licensed Entitlement tcmd (average)	SRO tcmd (average)	Comment
	Mid Essex Chalk Blackwater/Chelmer - 37/31 Blackwater/Chelmer - 37/35	 2.27 3.90	 1.69 3 50	
Essex & Suffolk Water Company (Essex area)	GROUNDWATER Thameside Chalk Crouch/Thames - 37/44 Crouch/Thames - 37/56	 0.13 10.21	 0.00 9.06	
	SURFACE WATER Abberton,Hanningfield and Associated Sources	373.60	327.00	Excludes groundwater emergency use from Langham boreholes
	Imports - Thames Water/Chigwell	91.00	91.00	
Essex & Suffolk Water Company (Suffolk area)	GROUNDWATER Cambridgeshire Chalk Little Ouse - Unit 9	 3.61	 3.44	
	Bure Chalk Bure/Ant - 34/09	 4.83	 4.83	
	Waveney Chalk Dove 34/17 } Waveney - 34/18 } Tidal Waveney 34/19a	 4.49 20.43	 4.49 20.43	Sources within Dove and Waveney catchments are limited by aggregate.
	Blyth/Alde Chalk Blyth - 35/02a Alde - 35/04a	 5.71 4.23	 5.71 4.23	
	Suffolk Crag Lothingland - 35/01 Yox & Minsmere - 35/03 Tidal Alde & Ore - 35/05	 1.23 4.47 0.25	 1.23 4.47 0.25	
SURFACE WATER	Shipmeadow Belaugh & Horning Lound	20.55 22.57 8.10	20.55 22.57 5.20	
Tendring Hundred Water Services	GROUNDWATER Stour Chalk Brett - 36/17 } Stratford/Flatford } Stour Estuary - 36/19 }	28.50	28.50	Sources within Brett, Stratford/Flatford and Stour estuary catchments are linked by aggregate. As above As above
	Tendring Gravels Tendring Peninsular	 2.60	 2.60	Used as emergency source only, due to water quality
	SURFACE WATER Ardleigh	 13.08	 11.00	SRO restricted for precautionary reasons

ANNEXE 6

PUBLIC WATER SUPPLY DEMAND FORECASTS

Basis of the Forecasts:-
The Regional forecast is based on the individual Water Company demand forecasts as prepared for their 'AMP2' submissions to OFWAT in October 1993 and amendments thereto up to January 1994. These forecasts have been scrutinised against independent demand scenarios compiled on a water company area basis by the NRA in its preparation of the National Water Resources Development Strategy (Ref 5). The NRA future demand scenarios use a base year assumption of recorded 'Actual Consumption' by the water companies for the year ending December 1992 and forecast growth thereafter according to prescribed 'High', Medium' and 'Low' scenarios.

All of the Water Company forecasts in the Anglian Region fall below the NRA 'Low' growth-line due mainly to the Companies' immediate plans for either direct or indirect demand management. This feature broadly endorses the company forecasts and is confirmed by scrutiny of the various components against assessed target values for the Region.

We are further encouraged to note greater consistency between the components of demand adopted by each Company both in terms of base-year and forecast values and by the fact that they are all adopting selective demand management.

Populations
Independent water company area population forecasts have been derived as far as possible from County and District Council information and the balance obtained from OPCS. The population data agree with Water Company assessments to within 3 - 5%.

The population forecasts remain provisional, as Counties are continually updating their forecasts in the light of the 1991 census. The current figures appear at Table 6 in the main text.

Household Water Use

a) Unmeasured

The variations in per capita household water use are shown in Figure A6.1. There is general uniformity between companies both in past and forecast use, with two exceptions, Tendring Hundred Water and the Suffolk area of Essex and Suffolk Water.
Tendring has up to now declared a low value for this component but an increase is shown over the period to 1995/96 as a result of an assessed "bounce-back" in consumption following the 1988/91 drought as well as a subsequent rebalance between household and non-household consumption in the overall "unmeasured" category of consumption. The Suffolk area forecasts a lower use profile than the other companies.

This reflects the rural nature of the area, a high incidence of 'less affluent' domestic properties; higher than average proportion of retired persons within the population and finally the remoteness of the area from the "Commuter Belt" of London which would otherwise influence higher housing classification and the associated higher per capita water use.

The future increase in per capita consumption as assessed by the Water Companies ranges between 1.1 and 1.4% per year. The weighted Regional average is about 1.1%. However, this component has a decreasing significance through the forecast period due to the planned household metering programme.

b) Measured

All the Water Companies plan to introduce a compulsory household metering programme with

Figure A6.1 - Public Water Supply - Unmeasured Water Delivered

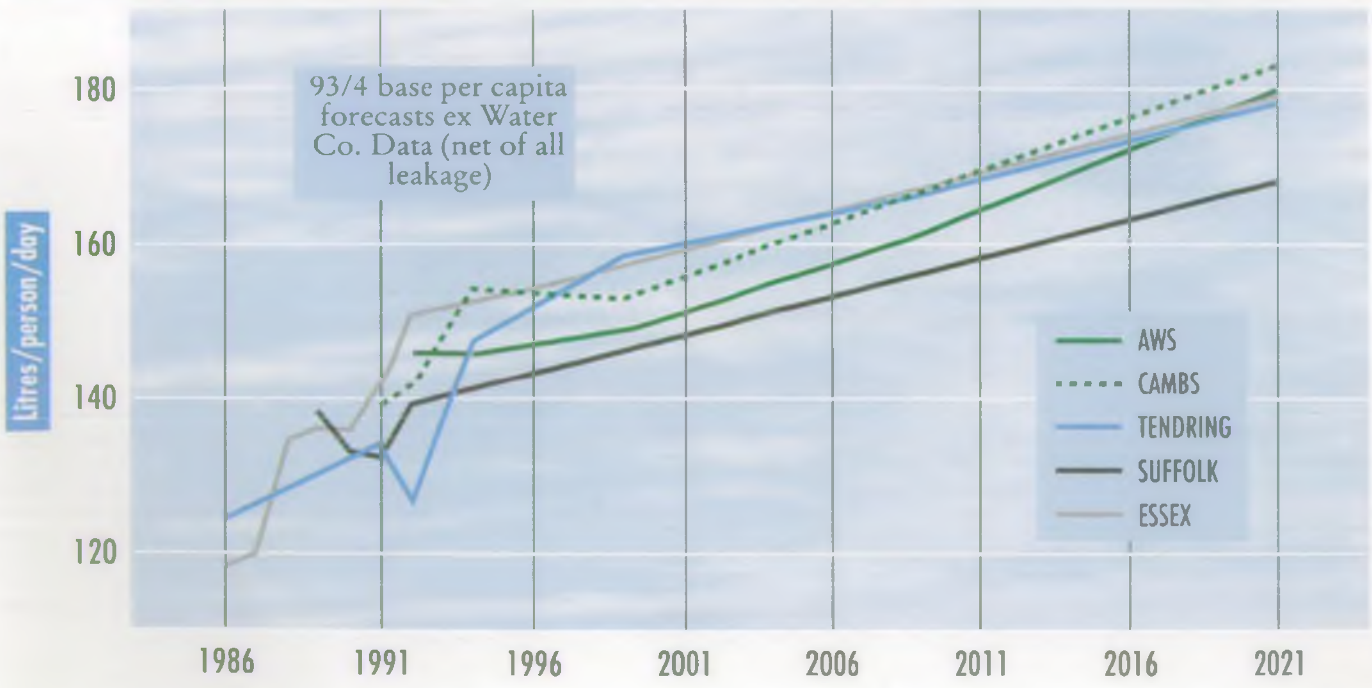
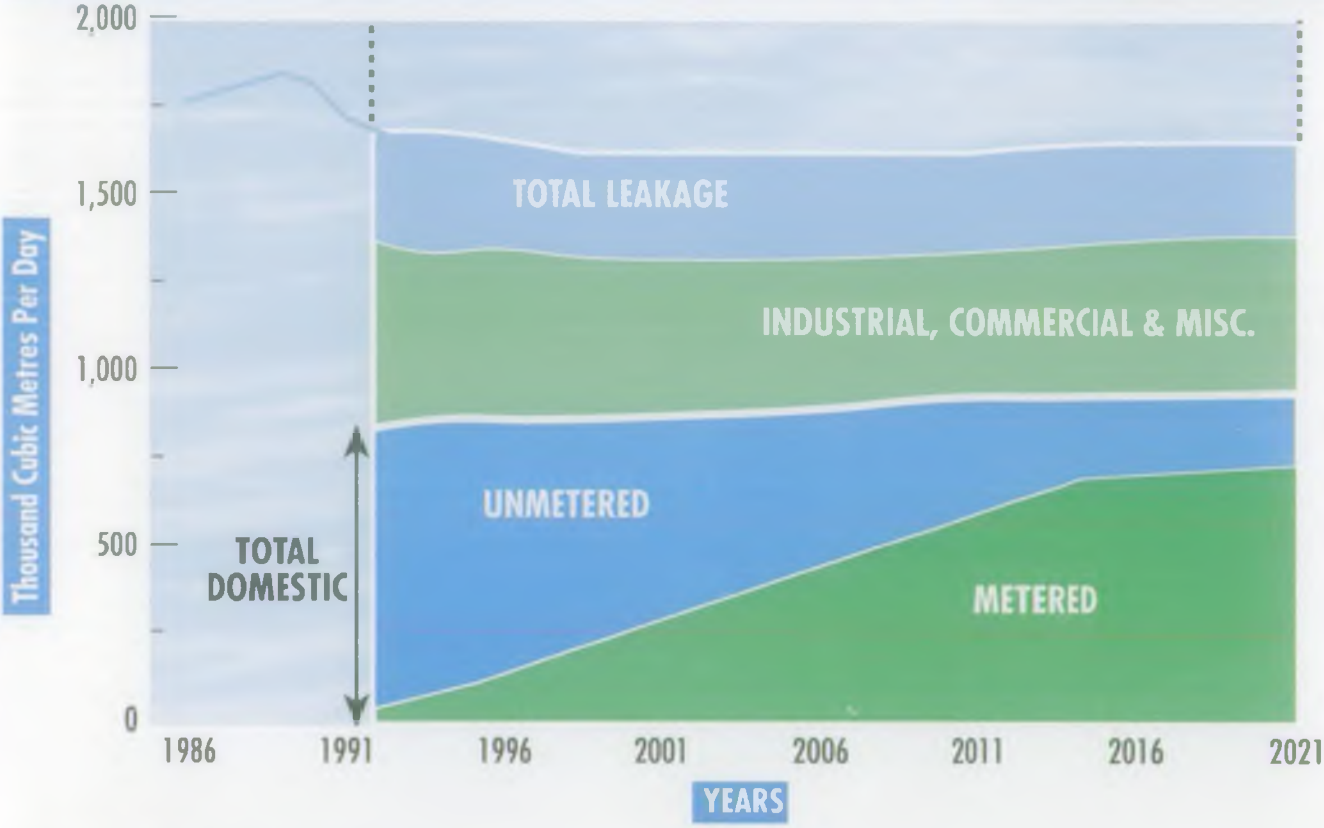


Figure A6.2 - Components of Public Water Supply Demand Anglian Region



various rates of meter penetration as follows:-

Anglian Water	96% by year 2014/2015
Cambridge Water	43% by year 2014/2015
Essex and Suffolk Water	44% by year 2014/2015
Tendring Hundred Water	77% by year 2014/2015

The corresponding target figure assumed in the NRA National Strategy is 30% meter penetration by the year 2021.

The assumed reduction due to metering is taken as 10%, in line with the results of the National Metering Trials (Ref 35). The resulting forecast of total household water use is given in Figure A6.2.

Non-Household Use

This component of the forecast is difficult to assess due to the uncertain factors of the national economy and the market forces of the various sectors of industries using potable water supplies for either service or production purposes.

The Water Companies are collectively forecasting a regional 19% reduction in this category of water use by the year 2014/2015. This continues a downward trend which has existed since 1988. The reasons for this are various though the downturn in the economy and plant closures are thought to feature strongly along with increasing efficiency in water-use by the more prolific consumers as part of their anti-recessional strategy.

The resulting forecast for Non-Household use is included in Figure A6.2

Leakage

(i) Water Company Mains Leakage

When compared against the National range of Public Water Supply leakage, the Water Companies in Anglian Region continue to perform well. To a large extent the Companies are regulating themselves in recognition of the sensitivity of regional resources and of the need to regulate leakage for reasons of operational efficiency.

The present total leakage within the Region arising from the total distribution network amounts to 19% of the total distribution input for PWS. This is presently forecast to reduce to 17% by year 2015. This range of leakage levels for the Region falls well within that expected of the Water Companies from the range of NRA National Demand Scenarios.

The forecast reduction in leakage as a percent of "water delivered" is seen as an ambitious target and is regarded as provisional in the light of the extensive Mains rehabilitation required to achieve such a target over a relatively short period of time. It is currently proposed that rehabilitation of water mains planned for much of the region's area would be undertaken for potable water quality reasons with water resources as an incidental beneficiary.

(ii) Customer Service Pipe Leakage

Water Companies commonly ascribe one-third of total leakage to the householders section of the supply service pipe and therefore regarded as the consumers responsibility and part of the chargeable supply. This aspect of leakage is currently masked by the dominant percentage of household supply being in the "Unmeasured" category. As properties become metered this aspect of leakage will become apparent and gradually reduced by the customer effecting repairs in order to avoid inflated charges. This is seen by the NRA as a major advantage of household water metering and a significant factor in future potential for reduced household water consumption.

Total Water put into Supply

The latest forecasts for Total water into supply predict a slight (0.8%) decline over the next 30 years. This is due to a combination of the high penetration of household meters, leakage reduction arising from mains rehabilitation and the downturn in the Non-Household use of water. Should this forecast be sustained, it will form a watershed in Water Resource Planning in the Region by forecasting negative growth in PWS demand for the Region of highest population growth rate in England and Wales. This is perhaps a high expectation; it is based on the Water Companies' forecasts and it assumes substantial expenditure on metering and on mains rehabilitation.

Table A6.1 shows the current forecasts of total demand for each Water Company. Figure 9 in the main text shows the regional forecast compared with the range of national forecast scenarios prepared by the NRA.

Figure A6.2 shows the Regional forecast broken down between household use, the diminishing demands of Non-Household use and the predicted decrease in leakage. The component of Total Household use is displayed in the form of the predicted growth in "Measured Household" and the corresponding decline in "Unmeasured Household".

Table A6.1 Water Companies' Demand Forecasts

WATER COMPANY	1992	1996	2001	2011	2021
Anglian Water Services	1118	1053	1028	1000	990*
Cambridge Water	75	78	79	87	95*
Essex and Suffolk Water - Essex Area	400	394	405	434	464
Essex and Suffolk Water - Suffolk Area	74	79	82	89	95
Tendring Hundred Water	31	34	36	38	40*
REGION	1698	1638	1630	1648	1684

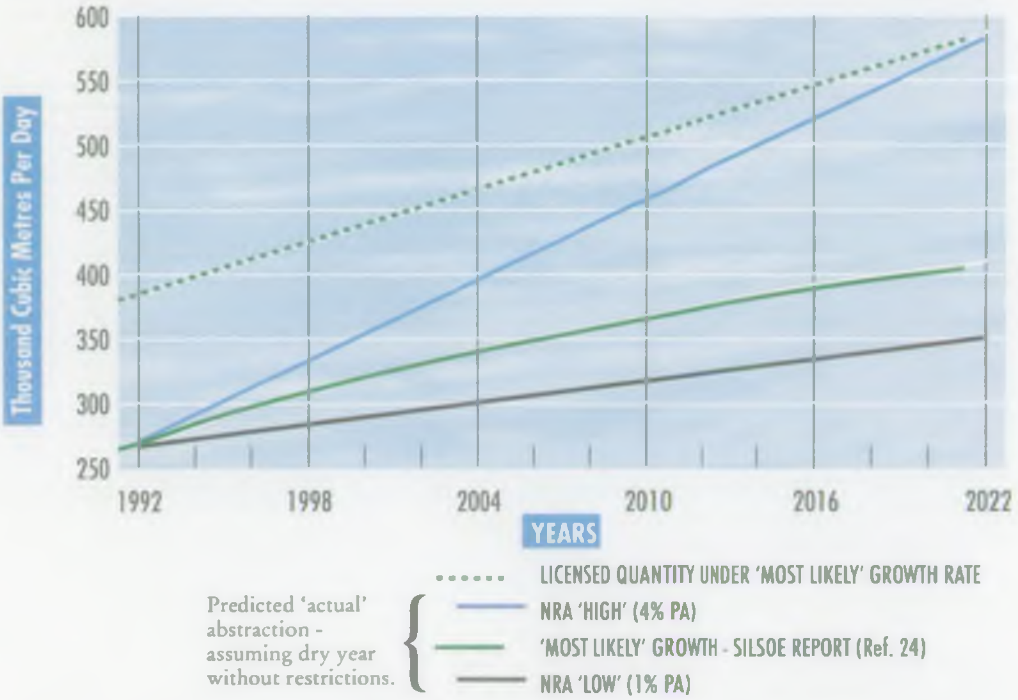
* Year 2021 extrapolated by NRA.

These forecasts assume substantial demand reductions due to the companies' planned metering and mains rehabilitation programmes.

ANNEXE 7

DIRECT ABSTRACTION DEMAND FORECASTS

Figure A7.1 - Demand Forecast Spray Irrigation *(Anglian Region)



SPRAY IRRIGATION

Current Demand

There are 4220 irrigation licences, totalling 140 mcm/year, or 384 tcmd (average over 365 days). Peak abstraction rates are very much higher.

In the last decade or so the average growth in licensed demand has been 4% per year (simple). This growth rate reflects both the long term expansion of irrigation for both quality and quantity of agricultural produce and accelerated demand during and following the dry years of 1988 to 1992 (as also seen during and after the 1975/76 drought). 4% is therefore unlikely to be representative of future growth, which is likely to be lower.

Future Demand

NRA commissioned research by Silsoe College (Ref 24) which predicts future growth in the demand for water for agricultural irrigation in England and Wales and advises as to how the NRA should respond. The predictions exclude the possible effects of climate change.

The 'most likely' National prediction for growth in volumetric demand is 1.7% per year from 1996 to 2001 and 1% per year from 2001 to 2021 for the 'dry' year. Within these figures there would be a growth in irrigation of potatoes, vegetables and soft fruit and a decline in the irrigation of grass and cereals. The economic case for irrigating sugar beet will remain marginal.

The analysis predicts a large possible range around these 'most likely' values. Growth under the high prediction is two to three times higher. It remains positive but very slow under the low predictions.

The report describes the benefits of irrigation to the nation and to the consumer, and concludes that it is in the national interest to meet future irrigation demands where possible, but subject to adequate protection of the environment and any costs incurred being charged to the beneficiaries.

We have adjusted the predictions of Reference 10 by applying their forecast growth rates to a base year assumption of 70% of total current licensed spray irrigation. The resulting figures are given in Table A7.1 and shown in Figure A7.1, together with 'high' and 'low' alternatives

Table A7.1 Spray Irrigation

1993 Regional Licensed Quantity tcmd	Future Demand Scenario	Gross Demand assuming dry year - tcmd (average over 365 days)						
		1993	1996	2001	2006	2011	2016	2021
384	LICENCE	384	399	419	438	457	476	495
	Low Growth: 1% pa							
	GROSS ACTUAL	269	279	293	307	320	333	347
384	LICENCE	384	445	522	599	676	753	829
	High Growth: 4% pa							
	GROSS ACTUAL	269	311	365	419	473	527	580
384	'Most likely' prediction Demand'	269	297	326	349	370	390	408

1 From Ref 24

GENERAL INDUSTRY

Current Demand

There are 880 general industrial licences totalling 188 mcm/year, or 515 tcmd (average). Typically, less than half of this is actually abstracted and about half of the abstracted amount is returned after use to the rivers.

There has been a pronounced decline in demand for industrial raw water for a number of years in this Region, typified by a 28% reduction in licensed quantity over the past four years. This is accountable to a changing face of industry within the Region as the traditional general manufacturing processes are replaced by modern technological and service industries with little requirement for raw water supplies. The national economic recession was another major influence in this respect.

Future Demand

The 1% per year (simple) growth rate used in earlier forecasts now appears high. It is considered that any future industrial growth in the region will entail only a minority of 'raw-water' demanding industry.

However there may be an underlying trend for some industries to substitute raw water supplies for treated water in order to save money.

A low forecast is assumed to entail a continued recession in demand of 1% per year to 2001 and only then returning to 1% growth. The most likely forecast is taken as the mean value between this and the continuous 1% growth scenario.

Note however, that a single new large water using industry could grossly distort this forecast.

Table A7.2 General Industry

	1993		1996		2001		2006		2011		2016		2021	
Abstraction/Net Consumption tcmd	Abs	Cons	Abs	Cons	Abs	Cons	Abs	Cons	Abs	Cons	Abs	Cons	Abs	Cons
(i) High Growth Rate @ 1% pa	246	130	253	134	266	141	278	147	290	154	303	161	315	167
(ii) Low Growth @ (-) 1% to 2001, (+) 1% thereafter	246	130	239	127	226	120	239	127	251	133	263	139	275	146
Mean Values of (i) and (ii)	246	130	246	130	246	130	258	137	270	143	283	150	295	156

Abs = Quantity abstracted Cons = Quantity consumed, ie. not returned to the river.

GENERAL AGRICULTURE

Current Use

There are approximately 4400 licences for general agricultural use, totalling about 15 mcm per year or 40 tcmd (average). Actual abstraction appears to be only about one third of this, and most such water is returned after use to the rivers. These figures exclude fish farming and water cress growing, which are non-consumptive.

Abstractions in this category mainly relate to groundwater sources and are concentrated in the Eastern area of the region.

Future Demand

In general, annual quantities are small with no defined trends. In recognition of the relatively low profile of this demand category, the previous (1990) forecast growth is adopted to a revised base year quantity

Table A7.3 General Agricultural Demand

Gross Demand (tcmd average)						
1993	1996	2001	2006	2011	2016	2021
14	15	16	17	18	19	20

POWER GENERATION

Current Demand

The major power stations in this region are located on and around the coastline using sea water for cooling purposes. It is understood that any future development of such stations would be similarly located.

However, in the last few years several smaller gas fired power stations have been built at inland locations. Some have had to use expensive air cooling because of lack of reliably available water resources. However, four others have been licensed in the last two years, for a total of 51 tcmd (average), of which some 17 tcmd is expected to be evaporated and the rest returned to the relevant rivers.

We assume a base year 'actual' demand of 50 tcmd (gross).

Future Demand

The recent 'flurry' of new stations is unlikely to continue because:

1. There remains uncertainty in the Industry as to the future level of input by Nuclear power generation into the National Grid and hence the extent of the long term development of conventional inland power stations. (Nuclear stations feature in coastal locations and depend on sea water for cooling purposes).
2. The strategy for inland power station development is influenced by the alternative option of National Grid reinforcement remote from the centre of demand. Which of the options is selected depends on the local

circumstances dictating the market forces and the level of premium payable to private companies for the design, construction and management of strategically located power stations, the cost of which may run into many millions of pounds. There is presently only modest commercial incentive for power station development in the Anglian region as opposed to the Regions at the 'end' of the power distribution system.

3. The availability of raw water for direct abstraction is not necessarily a prerequisite for the siting of a modern Gas Turbine generation station. Apart from the alternative options described above, there is a further option of air-cooled turbine stations which require only modest quantities of potable mains water for minor industrial use and domestic needs. The latter type of stations are, however, significantly more expensive.

In the light of this very uncertain situation, we have made a precautionary allowance of a further 10 tcmd (gross) per decade for additional power generation.

Table A7.4 Power Generation

	1993		1996		2001		2006		2011		2016		2021	
	Abs	Cons	Abs	Cons	Abs	Cons	Abs	Cons	Abs	Cons	Abs	Cons	Abs	Cons
Assumed Abstraction/Net Consumption tcmd	50 [1]	17	50	17	60	20	65	22	70	23	75	25	80	26

1 Presumes licences fully used, although they relate to new stations which were not quite commissioned in 1993.

Abs = Quantity abstracted Cons = Quantity consumed, ie. not returned to the river.

ANNEXE 8 - Derivation of Deficit Forecasts for Direct Water Use

Regional Totals: all tcmd (average)

		1993	2001	2011	2021
INDUSTRY					
1. Current and forecast demand	Table 8	246	246	270	295
2. % assumed due to new users[2]	x%	0	3	5	10
3. ∴ demand of new users	Line 1 x x %	0	7	14	30
4. Demand of existing users	1 minus 3	246	239	256	265
5. Current entitlement	Lic'd qty (Table 9)	515	515	515	515
6. Current SRO (see ch.7)	70% x 5	360	360	360	360
7. ∴ surplus or deficit, existing users	6 minus 4	+ 114	+ 121	+ 104	+ 95
8. Total deficit[1]	3 plus any negative at 7	0	- 7	- 14	- 30
SPRAY IRRIGATION					
1. Current and forecast demand	Table 8	269	326	370	408
2. % assumed due to new users	x%	0	15	20	25
3. ∴ Demand of new users	Line 1 x x%	0	49	74	102
4. Demand of existing users	1 minus 3	269	277	296	306
5. Current entitlement	Lic'd qty (Table 9)	384	384	384	384
6. Current SRO (see ch.7)	70% x 5	269	269	269	269
7. ∴ surplus or deficit, existing users	4 minus 6	0	-8	-21	-37
8. Total deficit[1]	3 plus any negative at 7	0	-57	-101	-139
OTHER AGRICULTURE3					
1. Current and forecast demand	Table 8	14	16	18	20
2. % assumed due to new users	x%	0	15	20	25
3. ∴ Demand of new users	Line 1 x x%	0	2	4	5
4. Demand of existing users	1 minus 3	14	14	14	15
5. Current entitlement	Lic'd qty (Table 9)	40	40	40	40
6. Current SRO (See ch.7)	70% x 5	28	28	28	28
7 ∴ surplus or deficit, existing users	6 minus 4	+ 14	+ 14	+ 14	+ 13
8. Total deficit[1]	3 plus and negative at 7	0	- 2	- 4	- 5
POWER GENERATION					
1. Current and forecast demand	Table 10	50	60	70	80
2. % assumed due to new users					
3 ∴ demand of new users		0	10	20	30
4. Demand of existing users		50	50	50	50
5. Current entitlement	Lic'd qty (Table 9)	51	51	51	51
6. Current SRO		50	50	50	50
7 ∴ surplus or deficit, existing users	4 minus 6	0	0	0	0
8. Total deficit[1]	3 plus any negative at 7	0	10	20	30

1: These are gross deficits: Net use will be appreciably less.

2: These are low assumptions, to allow for some degree of substitution of resources unused, or given up, by current industrial licence holders to meet the needs of new ones.

3: Excludes fish farming.

ANNEXE 9

THE AVAILABILITY OF WATER

WATER AVAILABILITY - NORTHERN AREA

The following is a general statement of the current availability of additional raw water for abstraction in the Northern area of the Anglian region.

Surface Waters

Some winter water in all catchments.

Summer water only from rivers or drains augmented by NRA's Trent-Witham-Ancholme transfers or by returning effluents. Currently this means the following rivers and fen drains fed from them:-

Fossdyke (via British Waterways Board

Lower Witham

Ancholme

East and West Fens Welland Nene	Subject to arrangements for transfers from River Witham, but limited by derogation considerations

Groundwaters (See Figure 8)

Northern Chalk:	None
Southern Chalk: Spilsby Sandstone and Associated Strata	None, pending review of quantities allocated to the environment
Northern Limestone	None
Central Limestone	None
Southern Limestone	None
Gravels, Northampton Ironstone and other minor aquifers	Minor local abstractions for minor local needs

WATER AVAILABILITY - CENTRAL AREA

The following is a general statement of the current availability of additional raw water for abstraction in the Central area of the Anglian region.

Surface Waters

Some winter water in all catchments. Summer water only in limited quantities from rivers or drains augmented by NRA's Great Ouse Groundwater Scheme, or by returning effluents. Currently this means the following rivers and fen drains fed from them:-

Ely Ouse	Subject to cessation conditions, derogation considerations and the acceptability of NRA support costs
Bedford Ouse	As above
Ivel	As above

Groundwaters (Figure 8)

Chalk; Ouzel and Ivel Catchments	Availability under review
Chalk; Cam Catchment	None
Chalk; Rhee Catchment	None
Chalk; Lodes/	None
Granta Catchment	None
Chalk; Lark Catchment	None
Chalk; Nar Catchment	None
Chalk; Babingley and Gaywood	None
Chalk; Wissey Catchment	Water available subject to local investigations, protection of environmental waters and possible need to augment river flows
Chalk; N W Norfolk	As above
Chalk; Little Ouse and Thet	None, pending review of quantities allocated to the environment
Greensand; Leighton Buzzard	None
Greensand; Sandy and Cambridge	None pending review of quantities allocated to the environment
Greensand; Sandringham	Water available subject to local area investigations, protection of environmental waters and possible need to augment river flows.
Oolites	Minor local abstractions for minor local needs
Gravels	As above

WATER AVAILABILITY - EASTERN AREA

The following is a general statement of the current availability of additional raw water for abstraction in the Eastern area of the Anglian region.

Surface Waters

Some winter water in most catchments.

Summer water only from rivers augmented by NRA's Ely Ouse-Essex transfers or by river support boreholes. Currently this means:

R Stour	Subject to cessation conditions, derogation considerations and the acceptability of support costs
R Pant/Blackwater	As above
R Waveney	As above

Groundwaters (See Figure 8)

Chalk and Crag; Yare, Waveney, Wensum, North Norfolk, (other than Broads Executive Area)	Some water available subject to local investigations, protection of environmental waters and possible need to augment river flows
Chalk Deben	As above
Chalk and Crag; Broads Executive Area	None
Chalk; Bure	None, pending review of quantities allocated to the environment
Chalk; Blythe, Alde, Felixstowe Peninsula and Gipping; Chalk; Essex Area	None
Crag; Suffolk Coast and Felixstowe Peninsula; Gravels	Minor local abstractions for minor local needs

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