HOWARD HUMPHREYS & PARTNERS LIMITED

CONSULTING ENGINEERS

NATIONAL RIVERS AUTHORITY

THAMES REGION

WATER RESOURCES DEVELOPMENT OPTIONS

DRAFT FINAL REPORT

VOLUME 2 TECHNICAL APPENDICES

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WATER RESOURCES DEVELOPMENT OPTIONS STUDY
NATIONAL RIVERS AUTHORITY THAMES REGION
FINAL REPORT

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EXECUTIVE SUMMARY

WATER RESOURCES DEVELOPMENT OPTIONS STUDY
NATIONAL RIVERS AUTHORITY THAMES REGION
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APPENDIX 2

ENGINEERING AND HYDROLOGY DATA

ENGINEERING

APPENDIX 2

ENGINEERING

Engineering Criteria

The following design criteria have been used in drawing up the development options.

1. Storage

Impounding Dams and Bunded Reservoirs	Dams and bunds have been taken as earth fill embankments with crest width of 8m, u/s slopes of 1 on 3.5 and d/s slopes of 1 on 3, freeboard has been taken as 2m.
Bankside Storage	The volume of bankside storage for Severn Thames transfer has been taken as 3 days storage at the maximum transfer rate.
Gravel Pits	It has been assumed that gravel pits will be on average 6m deep, the cut off slurry trench will be 600mm wide and will extend 1m into the clay beneath the gravel. Adjacent pits will utilise a common cut-off and that access roads will be constructed round the perimeter of all pits.

2. Transmission

Pipelines	In sizing pipelines a limiting velocity of between 1.5 and 2.0 m/s has been adopted. The friction coefficient 'C' in the Hazen Williams formula for calculating head loss has been taken as 135. Pipelines have been assumed to be in ductile iron.

3. Pumping

Pumps	Maximum pumping head has been limited to 150m. For heads greater than this multiple inline pumping stations have been adopted.

Engineering Elements

The sizes of engineering elements adopted for the development scenarios are:

Scenario 1

Stage	Item	Size
Drayton	Reservoir	100Mm³
	Tunnel	2.5m dia x 4000m
	Pumps	600 Ml/d 3125 Kw installed
Staines	Storage	10Mm³ increase
	Embankments	Northern reservoir by 3m
	Raised	Southern reservoir by 6m
	Pumps	Addition capacity of approximately 450 kW assumed
Effluent Reuse (Mogden)	Sand Filters	90 Ml/d capacity
	Effluent pumps	90 Ml/d 80 Kw installed
	Ozoniser	90 Ml/d
	Tunnel	2000m dia x 6500m
	Transfer Pumps	90 Ml/d 80 Kw installed
(Deephams)	Sand Filters	50 Ml/d capacity
	Effluent Pumps	50 Ml/d 45 Kw installed
	Ozoniser	50 Ml/d
	Transmission Main	70mm L < 1000m
	Transfer Pumps	50 Mld 130 Kw installed

Scenario 2

Stage	Item	Size
Drayton	As Scenario 1A	
Severn-Trent Transfer	Deerhurst Intake	400 Ml/d
	Low Lift Pumps	400 Ml/d 1040 Kw installed
	Bankside Storage (Severn)	1.2 Mm³
	High Lift Pumps (2 stations)	400 Ml/d 9700 kW installed
	Transmission	2000mm dia 76,000m

Scenario 2A

Stage	Item	Size
Drayton	As Senario 1A	
Severn-Trent Transfer	Deerhurst Intake	400 Ml/d
	Low Lift Pumps	400 Ml/d 1040 Kw installed
	Bankside Storage (Severn)	1.2 Mm^3
	Highlift Pumps (2 stations)	400 Ml/d 9700 Kw installed
	Transmission	2000mm dia L = 53,000m
	Bankside Storage (Thames)	1.2 Mm^3
	Pumps to Drayton	400 Ml/d 2100 Kw installed

Scenario 2B

Stage	Item	Size
Severn-Trent Transfer	Deerhurst Intake	400 Ml/d
	Low Lift Pumps	400 Ml/d 1040 Kw installed
	Bankside Storage (Severn)	1.2 Mm^3
	High Lift Pumps (2 stations)	400 Ml/d 9700 kW installed
	Transmission	2000mm dia L = 53,000mm
	Bankside Storage (Thames)	1.2 Mm^3
	Pumps Thames - Drayton	400 Ml/d 2100 Kw installed
Drayton	As Scenario 1A	

Scenario 3

Stage	Item	Size
Severn-Trent Transfer	Deerhurst Intake	400 Ml/d
	Low Lift Pumps	400 Ml/d 1040 Kw installed
	Bankside Storage (Severn)	1.2 Mm^3
	High Lift Pumps (2 stations)	400 Ml/d 9700 kW installed
	Transmission	2000mm dia L = 53,000m
	Bankside Storage (Thames)	1.2 Mm^3
Anglia-Thame, Stort Trent-Thame	Trent Intake	700 Ml/d
	Trent-Witham Transmission	2400mm dia L = 10,000m
	Witham-Wansford Transmission	2400m dia L = 70,000m
	Witham Pumps	700 Ml/d 13400 Kw installed
	Wansford - Gt Ouse Transmission	2200mm dia L = 40,000m
	Wansford Pumps	600 Ml/d 9400 Kw installed
	Gt Ouse - Waddesdon Res	2000mm dia L = 73,000m
	Gt Ouse Pumps (2 stations)	100 Ml/d 1750 Kw installed
	Waddesdon Dam	17m high 35Mm^3 storage
Denver-Stort	Kennett Pumps	200 Ml/d 3700 Kw installed
	Kennett-Kirting Green Transmission	1400mm dia L = 14,000m
	Stour Improvement	11,000m
	Wixoe Pumps	200 Ml/d 2400 Kw installed
	Wixoe-Gt Sampford (Pant)	1400mm dia L = 10,000m
	Pant (Gt Barfield) - Stort	1400mm dia L = 28,000m
	Gt Barfield Pumps	200 Ml/d 2300 Kw installed

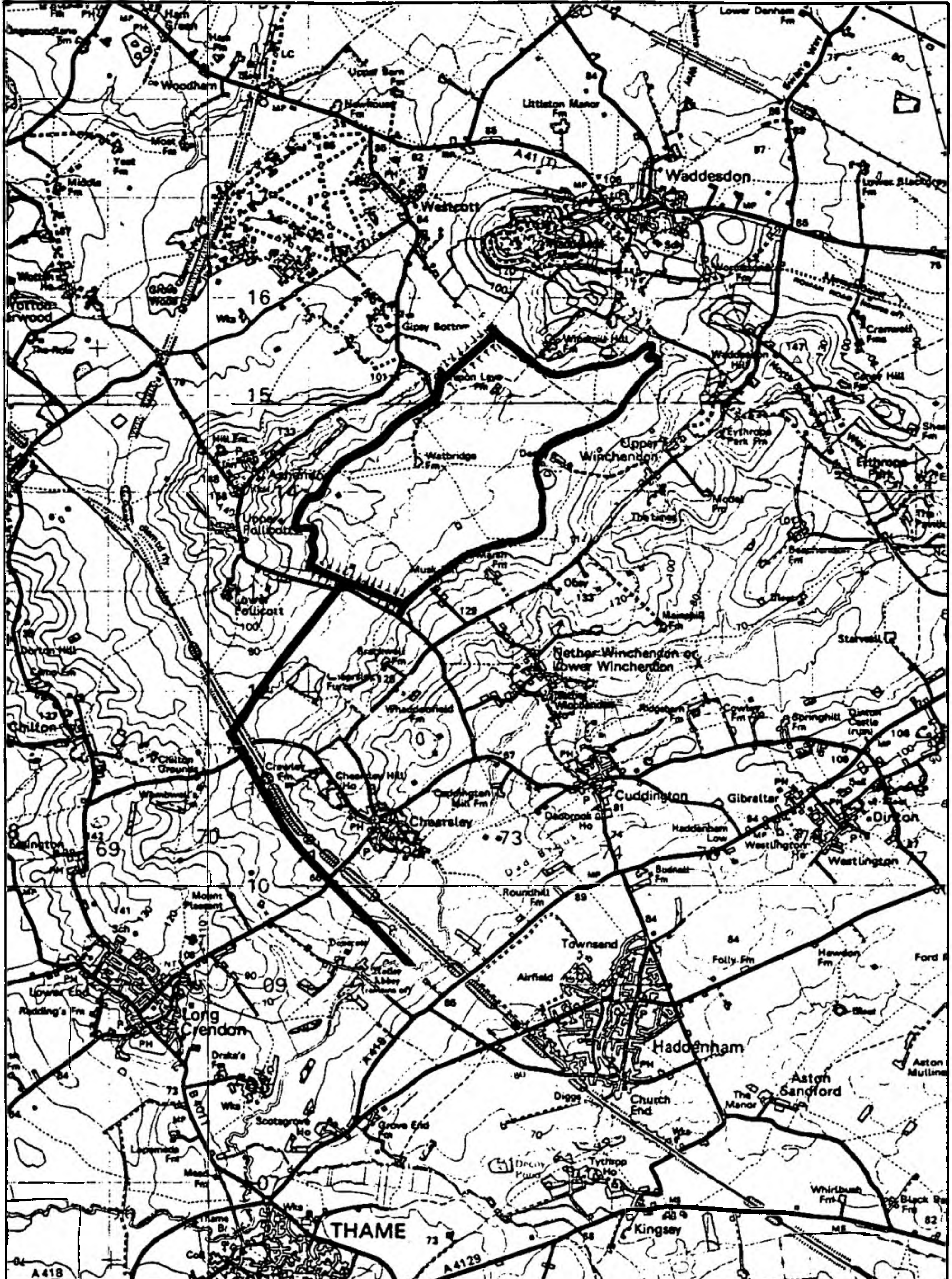
Scenario 3A

Stage	Item	Size
Severn-Trent Transfer	As Scenario 3	
Anglia - Thame, Stort, Grafham	As Scenario 3	
Denver-Stort	Kennett Pumps	200 Ml/d 3700 Kw installed
	Kennett-Kirting Green	1400mm dia L = 14,000m
	Stour Improvement	11,000m
	Wixoe Pumps	200 Ml/d 2400 Kw installed
	Wixoe-Gt Sampford (Pant)	1400mm dia L = 10,000m
	Pant (Gt Barfield) - Stort	1000mm dia L = 28,000m
	Gt Barfjeld Pumps	100 Ml/d 1350 Kw installed
Grafham-Luton	Grafham-Luton	1000m dia L = 45,000m
	Grafham Pumps	100 Ml/d 2000 Kw installed

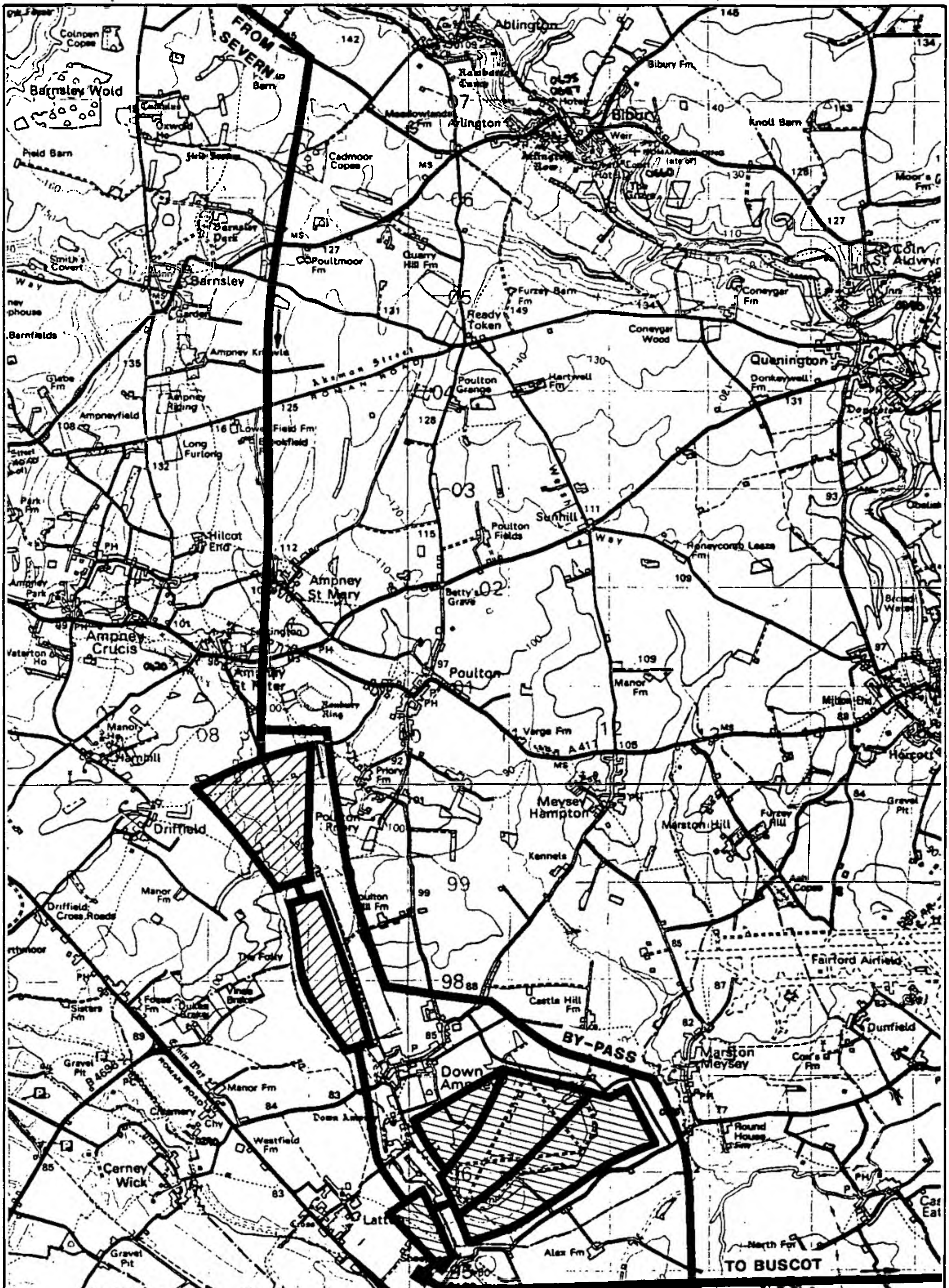
Scenario 3B

Stage	Item	Size
Severn-Trent Transfer	As Scenario 3	
Anglia - Thame, Stort, Roding	As Scenario 3	
Denver-Stort/ Roding	Kennett Pumps	200 Ml/d 3700 Kw installed
	Kennett-Kirting Green	1400mm dia L = 14,000m
	Stour Improvement	11,000m
	Wixoe Pumps	200 Ml/d 2400 Kw installed
	Wixoe-Gt Sampford (Pant)	1400mm dia L = 10,000m
	Gt Barfield - High Roding	1400mm dia L = 15,000m
	Gt Barfield Pumps	200 Ml/d 2300 Kw installed
	High Roding - Sawbridgeworth	1000mm dia L = 13,000m
	High Roding - Longfordbridge (Roding)	1000mm dia L = 17,000m

RESERVOIR LAYOUTS

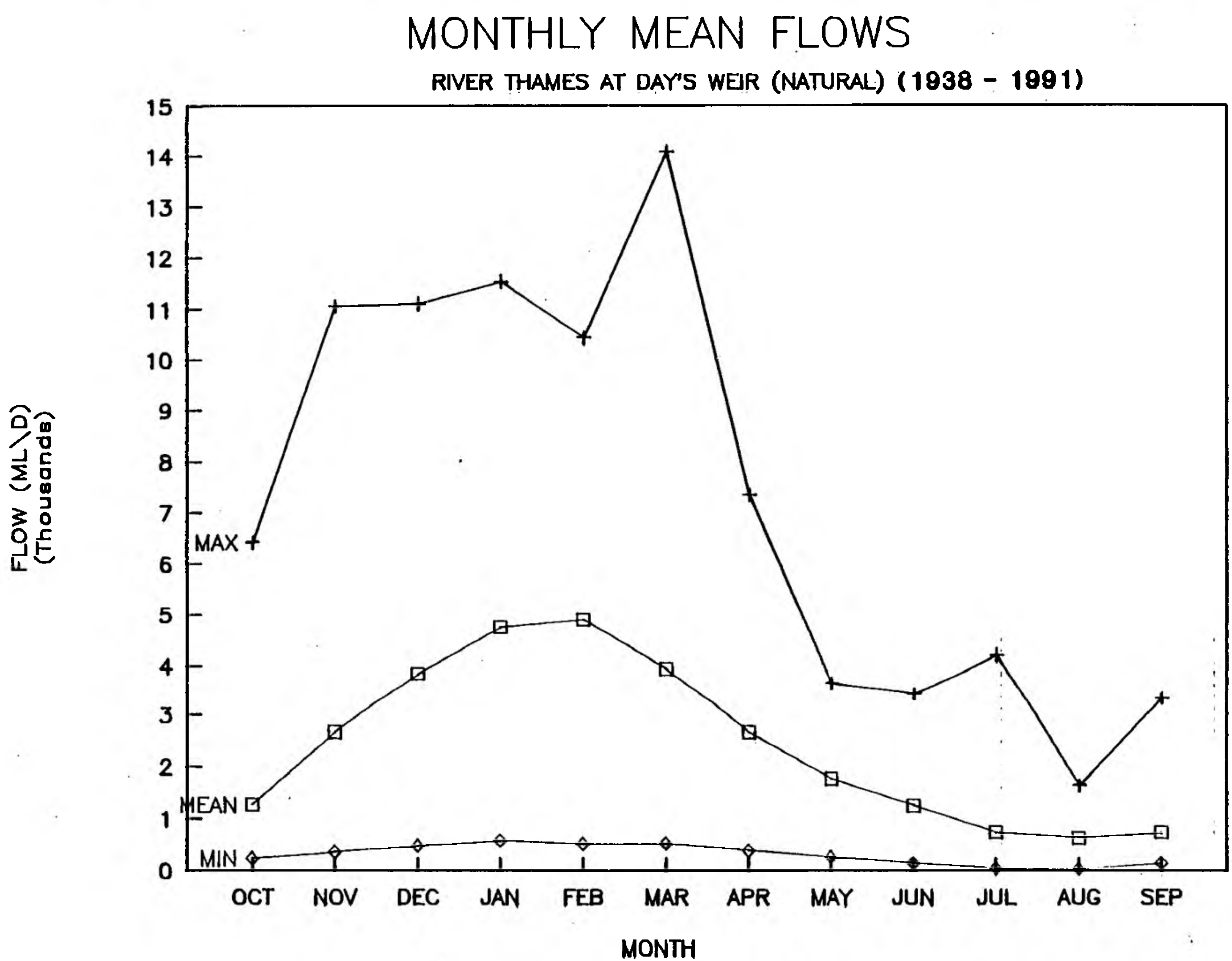


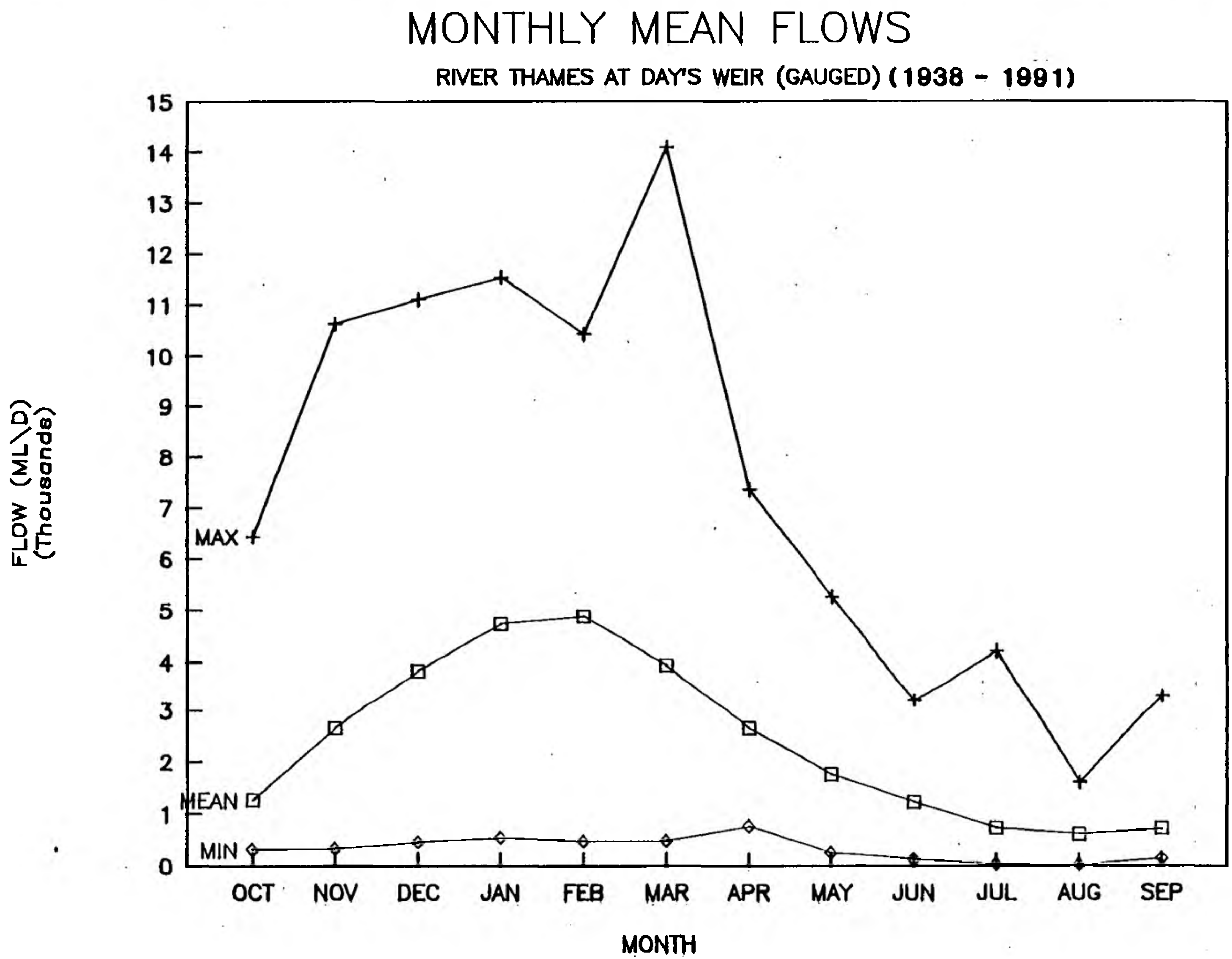
WADDESDON RESERVOIR



DOWN AMPNEY
TENTATIVE GRAVEL PIT LAYOUT

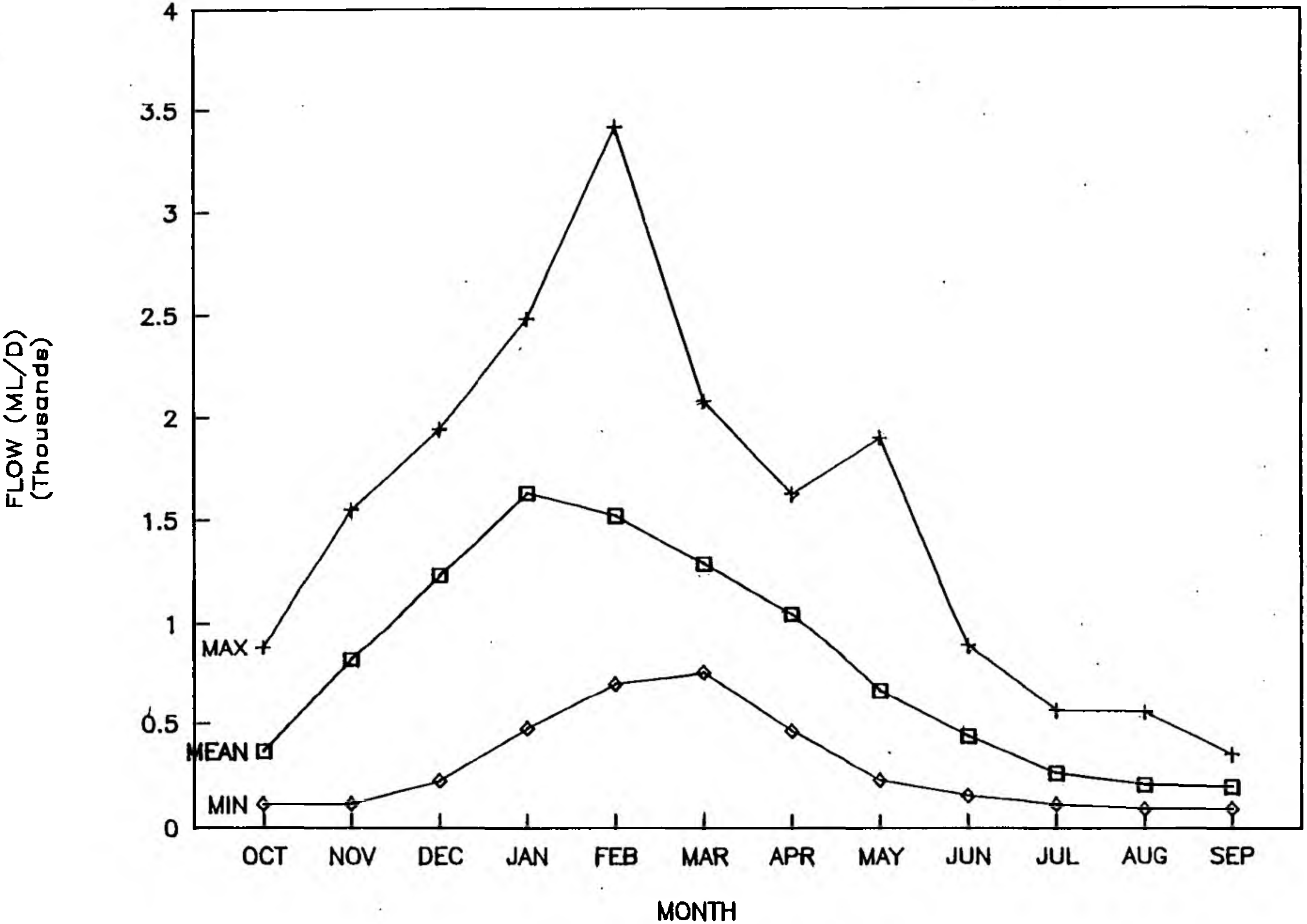
RIVER FLOWS

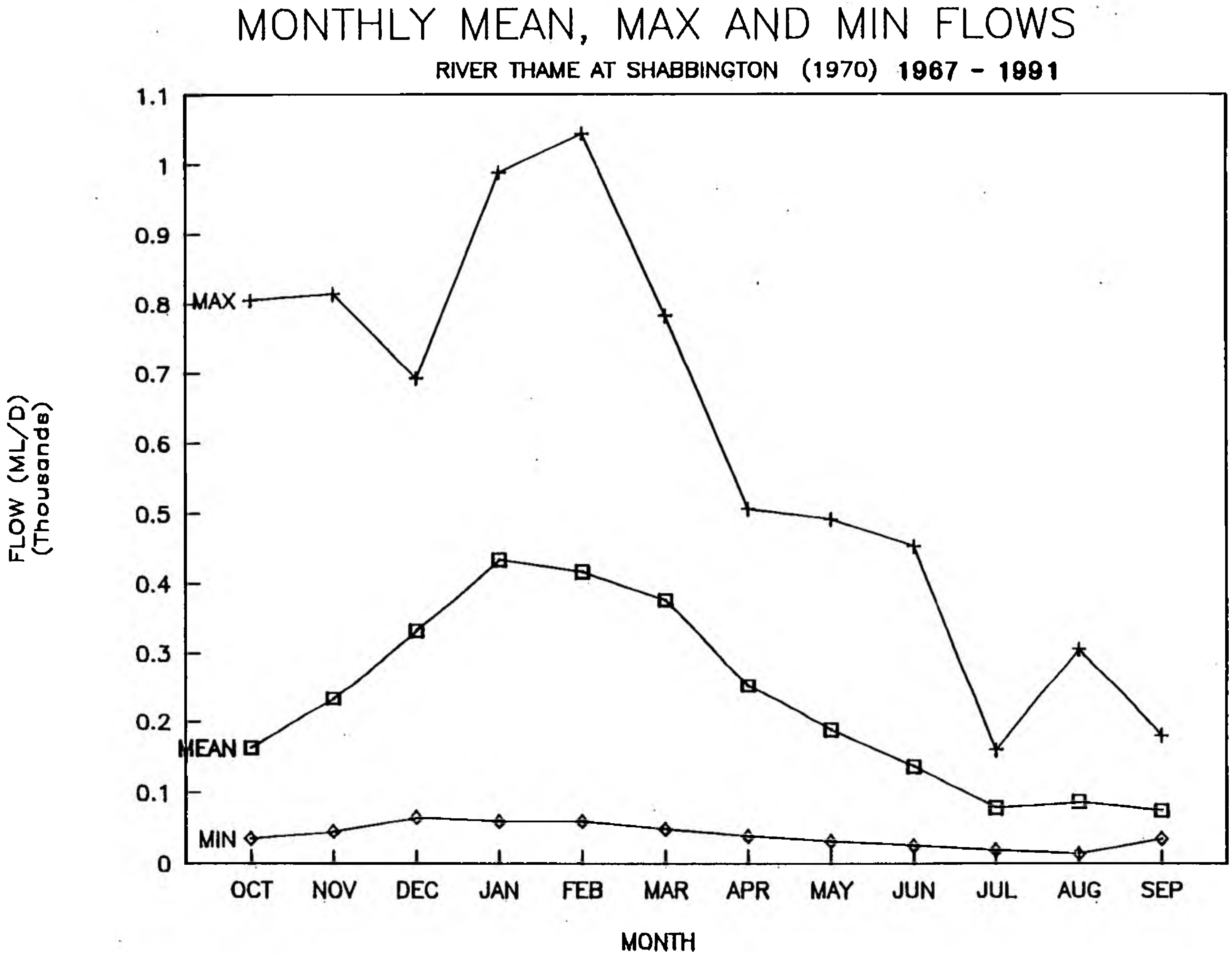

MONTHLY MEAN FLOWS
RIVER THAMES AT DAY'S WEIR (NATURAL) (1938 - 1991)
FLOW (ML\D)
(Thousands)
MAX
MEAN
MIN
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
MONTH


MONTHLY MEAN FLOWS
RIVER THAMES AT DAY'S WEIR (GAUGED) (1938 - 1991)
FLOW (ML\D) (Thousands)
MAX
MEAN
MIN
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
MONTH

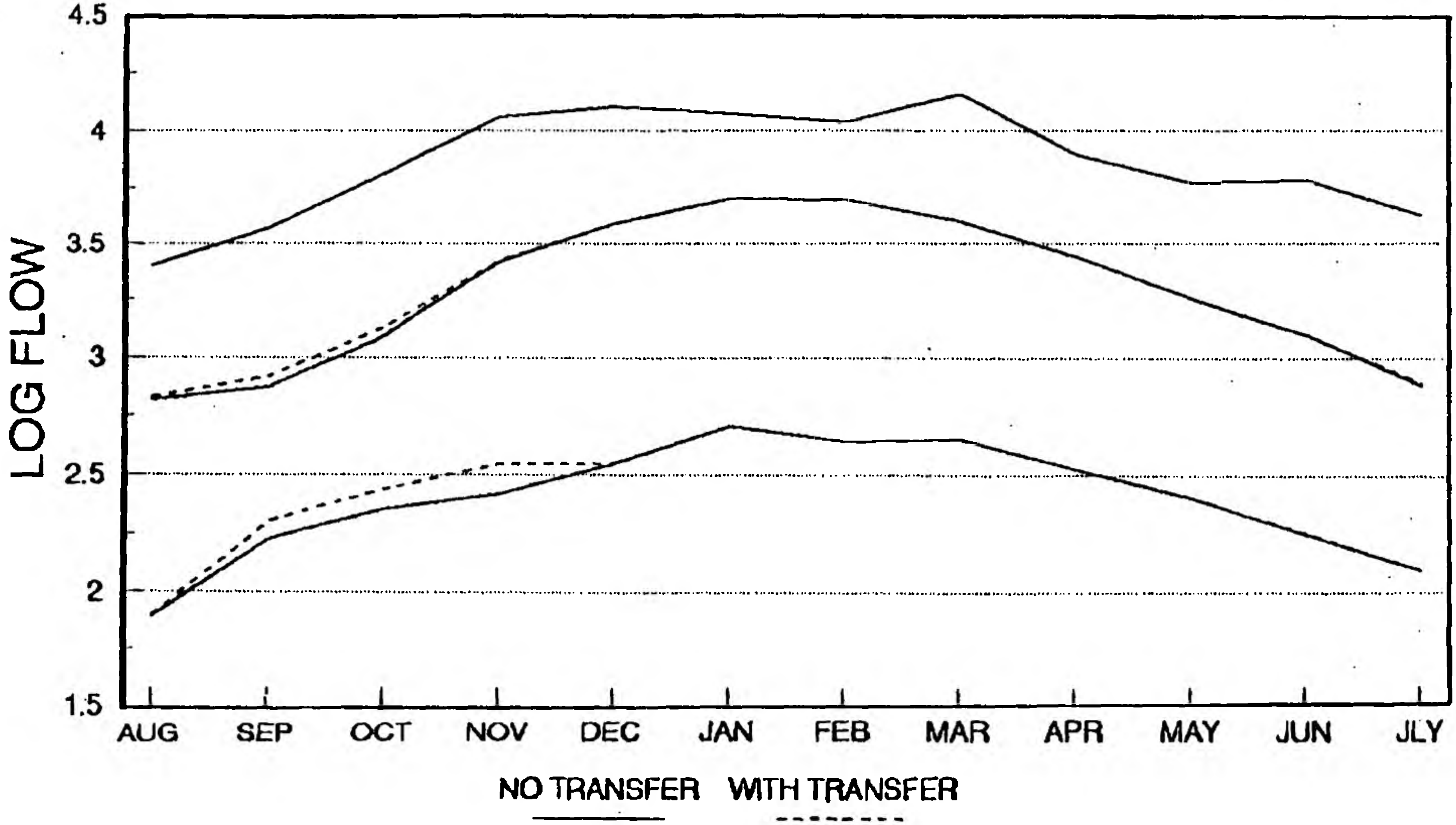
MONTHLY MEAN, MAX AND MIN FLOWS

RIVER THAMES AT BUSCOT (0900) 1979 - 1991




MONTHLY MEAN, MAX AND MIN FLOWS
RIVER THAME AT SHABBINGTON (1970) 1967 - 1991
FLOW (ML/D)
(Thousands)
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
MAX
MEAN
MIN
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
MONTH

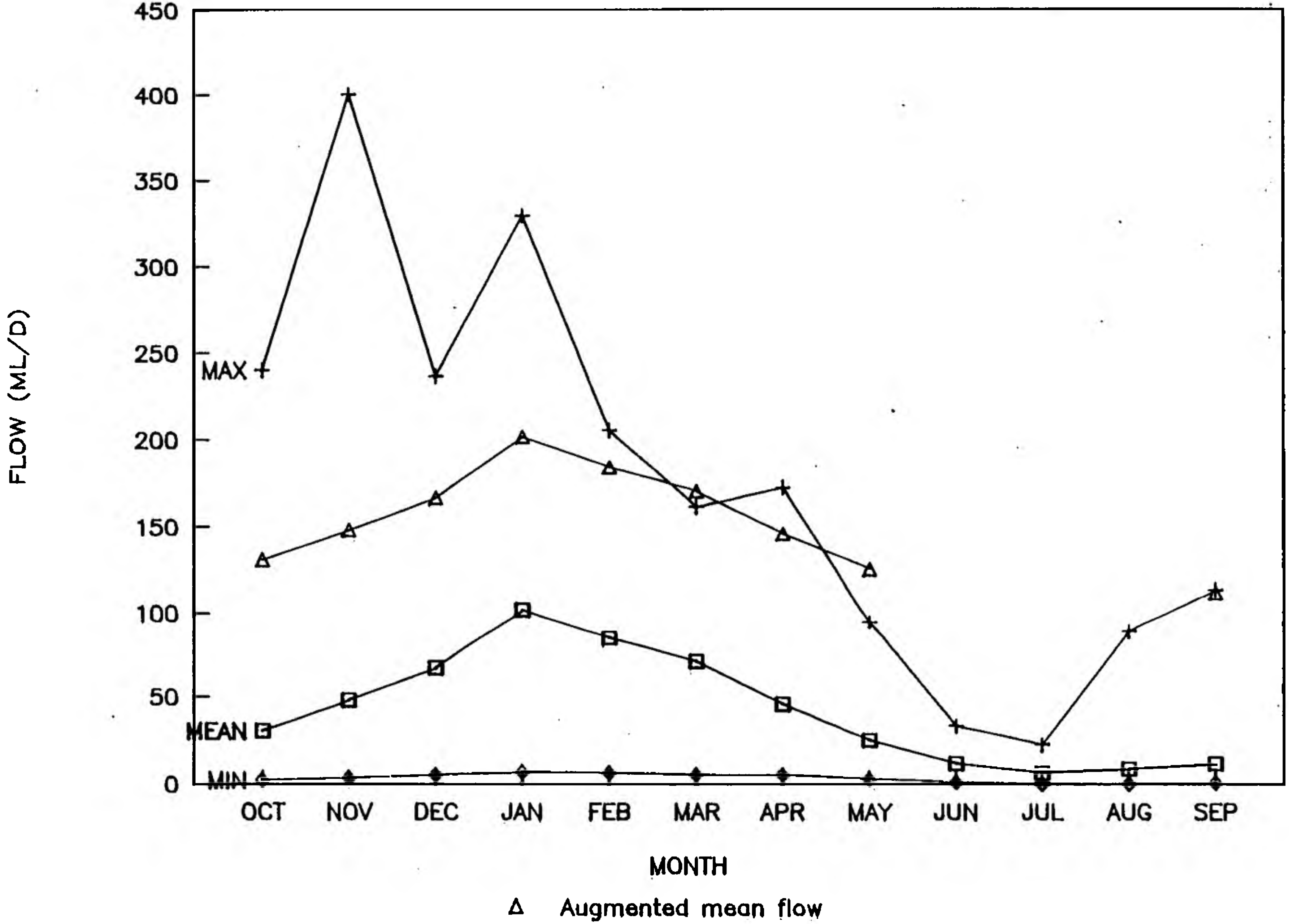
RIVER FLOW AT DAYS WEIR

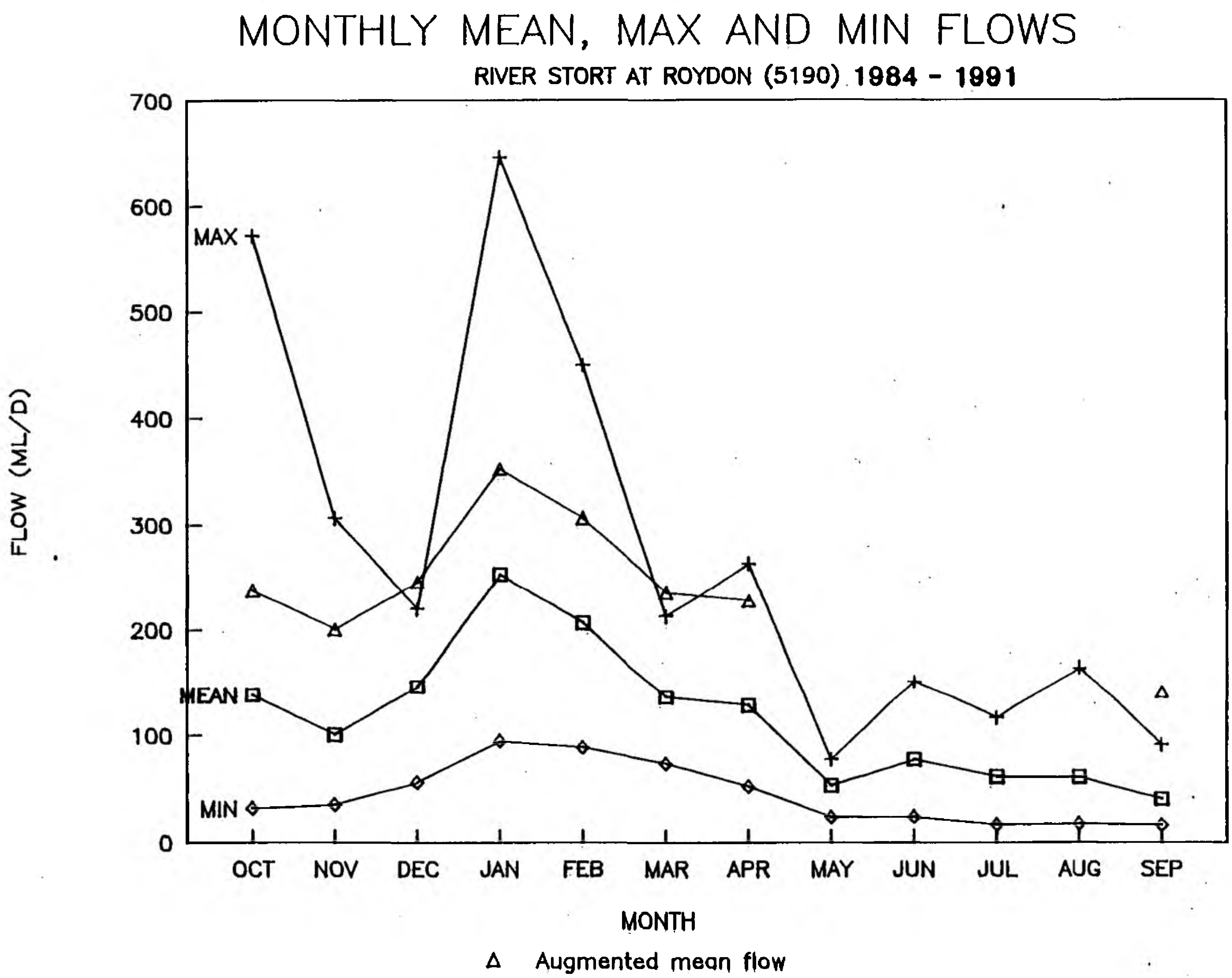


SEVERN TRANSFER AT 400 ML/D
NO STORAGE LONDON DEMANDS @ 2545 ML/D

MONTHLY MEAN, MAX AND MIN FLOWS

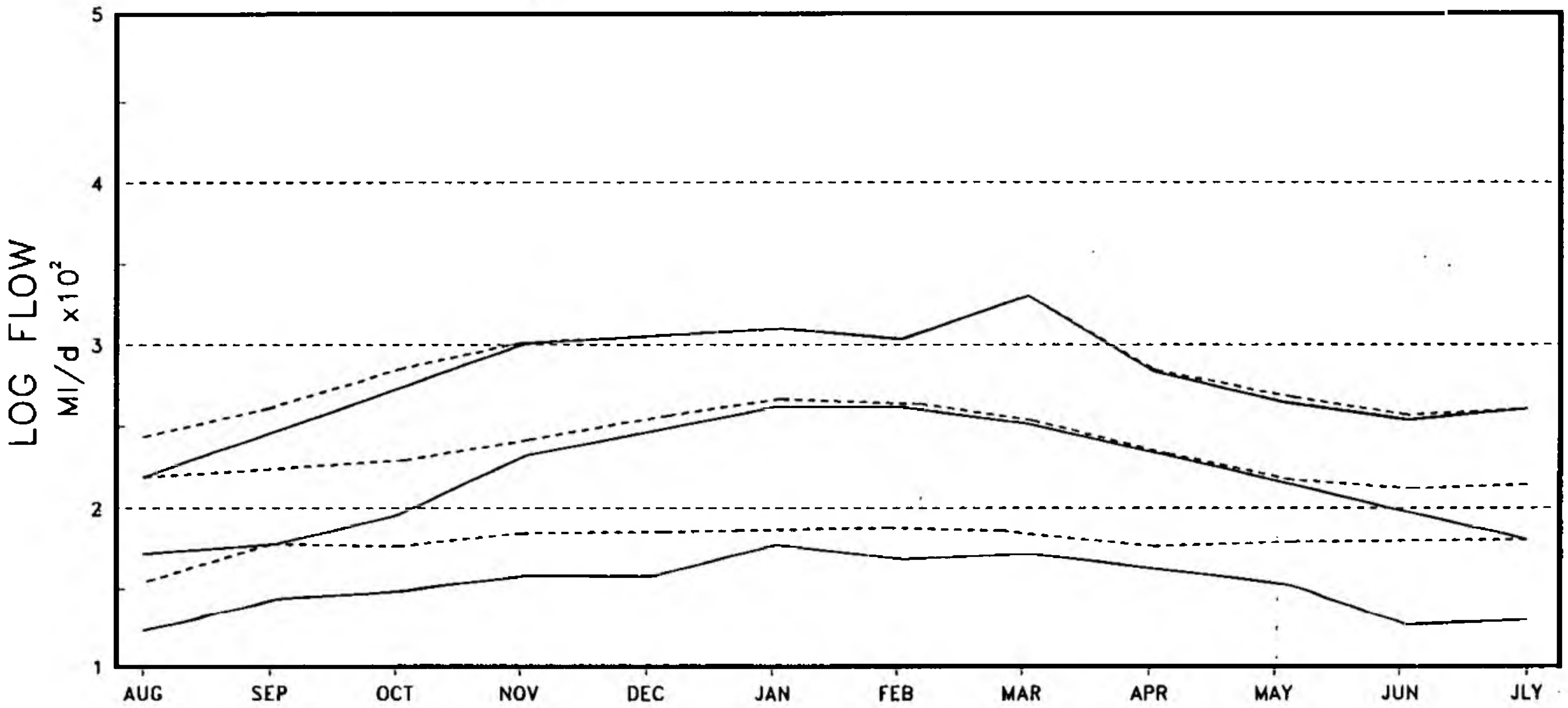
RIVER RODING AT HIGH ONGAR (5420) **1963 - 1991**




MONTHLY MEAN, MAX AND MIN FLOWS
RIVER STORT AT ROYDON (5190) 1984 - 1991
FLOW (ML/D)
700
600
500
400
300
200
100
0
MAX
MEAN
MIN
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
MONTH
Δ Augmented mean flow

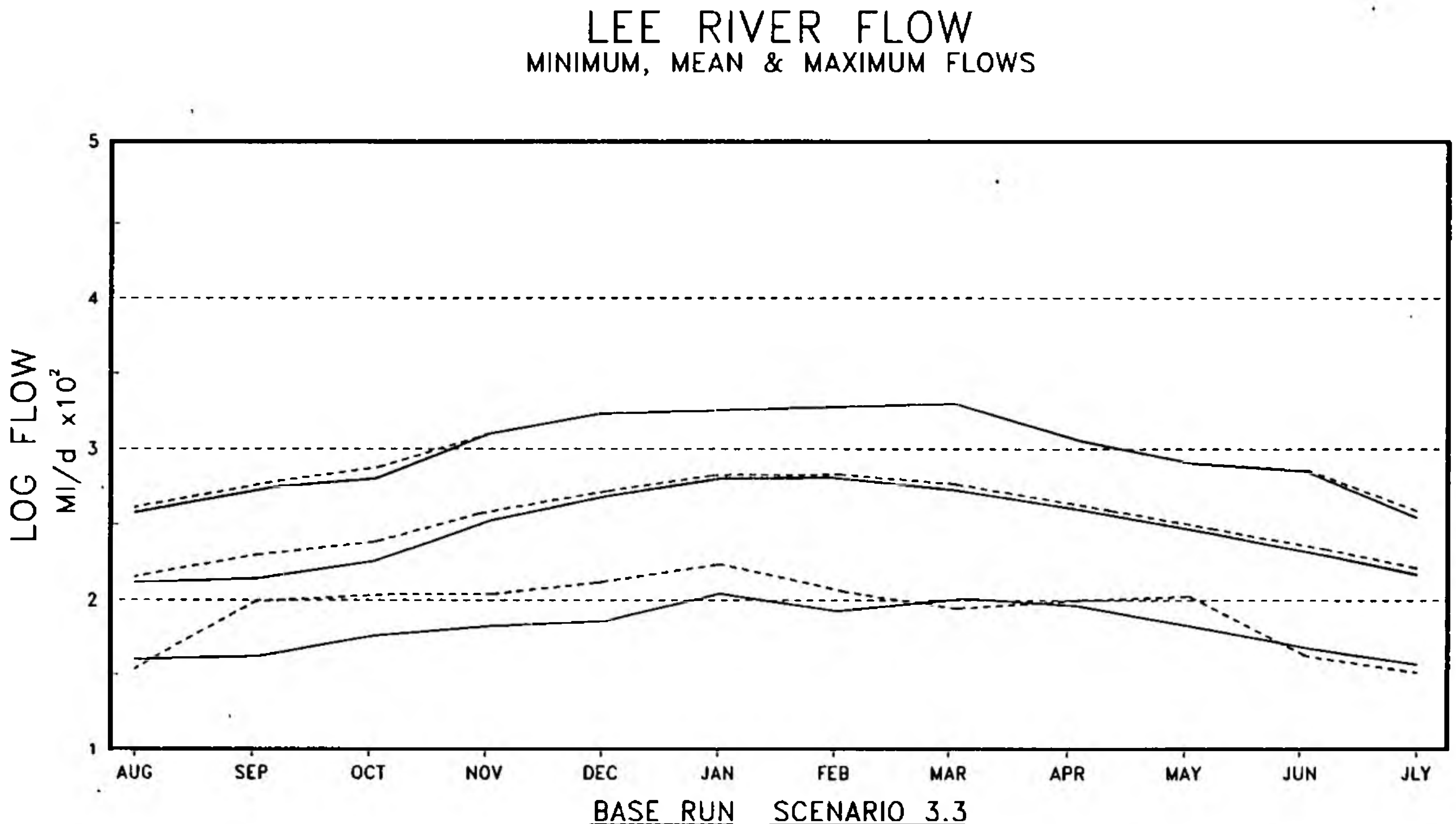
THAME RIVER FLOW

MINIMUM, MEAN & MAXIMUM FLOWS



BASE RUN SCENARIO 1.2

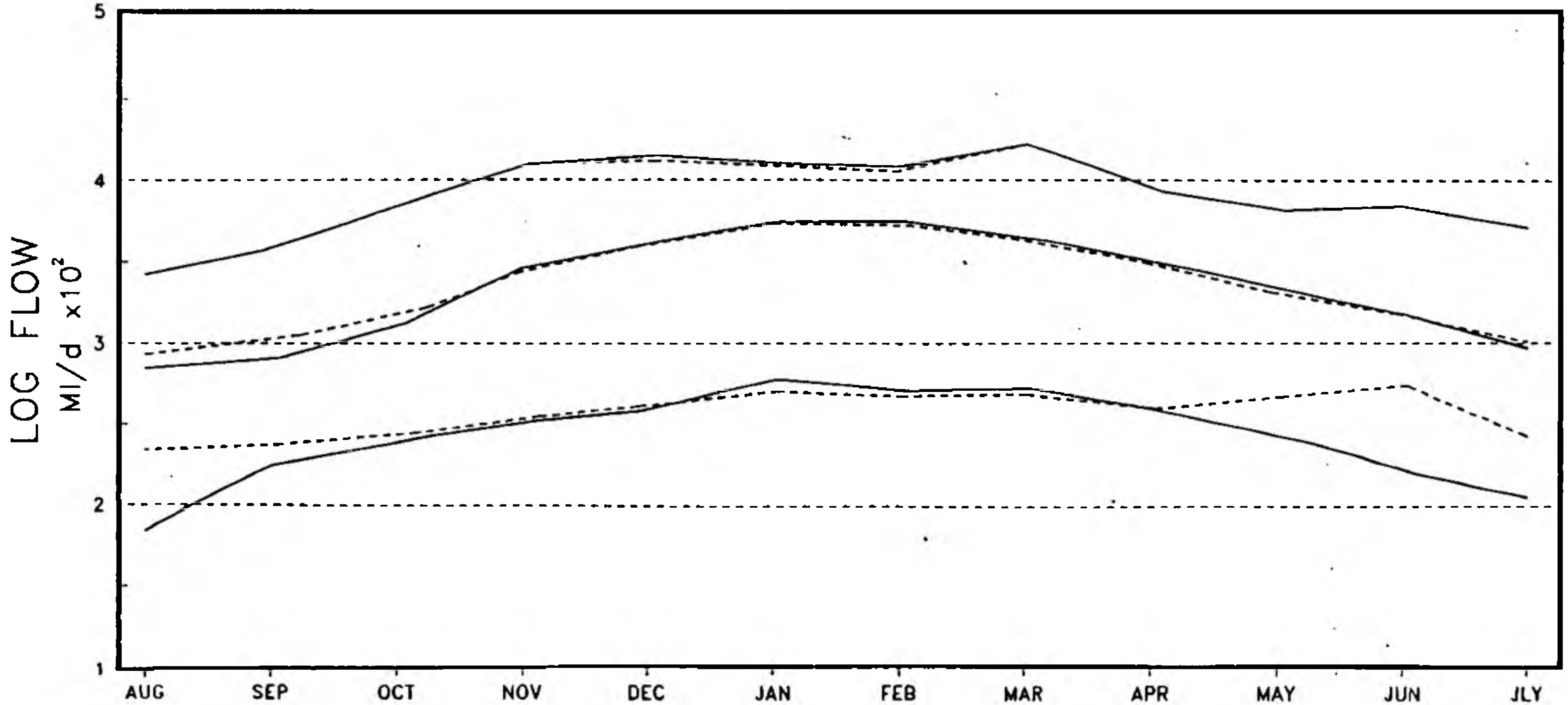
SCENARIO 3.3 – SEVERN TRANSFER TO BUSCOT GRAVEL PIT PLUS TRENT TRANSFER TO THAME/STORT



SCENARIO 3.3 – SEVERN TRANSFER TO
BUSCOT GRAVEL PIT PLUS TRENT TRANSFER
TO THAME/STORT

RIVER FLOW AT DAYS

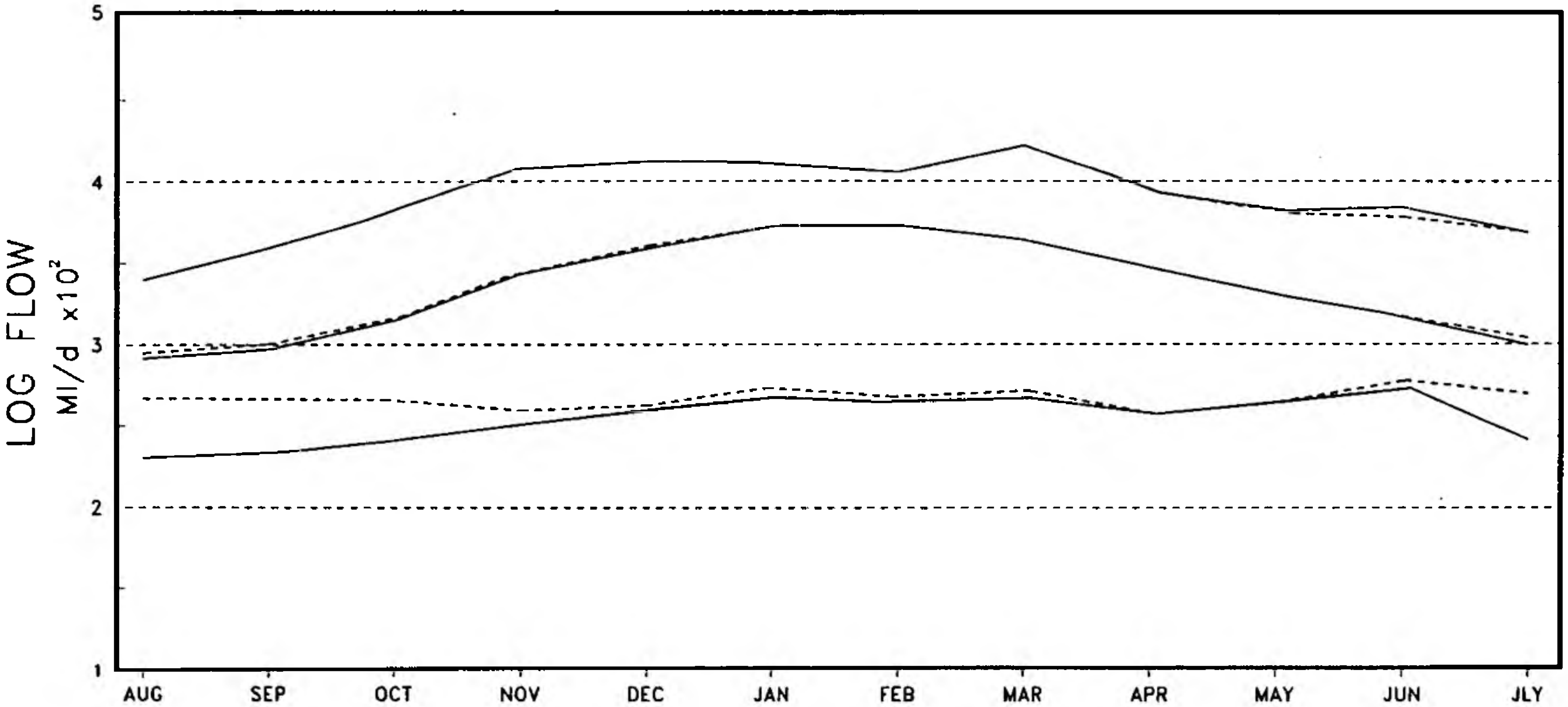
MINIMUM, MEAN & MAXIMUM FLOWS



BASE RUN SCENARIO 1.2

SCENARIO 1.2 – RISING GROUNDWATER, LICENCE REVISION, THAMES SIDE, FULL ARTIFICIAL RECHARGE & DRAYTON RESERVOIR

RIVER FLOW AT DAYS
MINIMUM, MEAN & MAXIMUM FLOWS

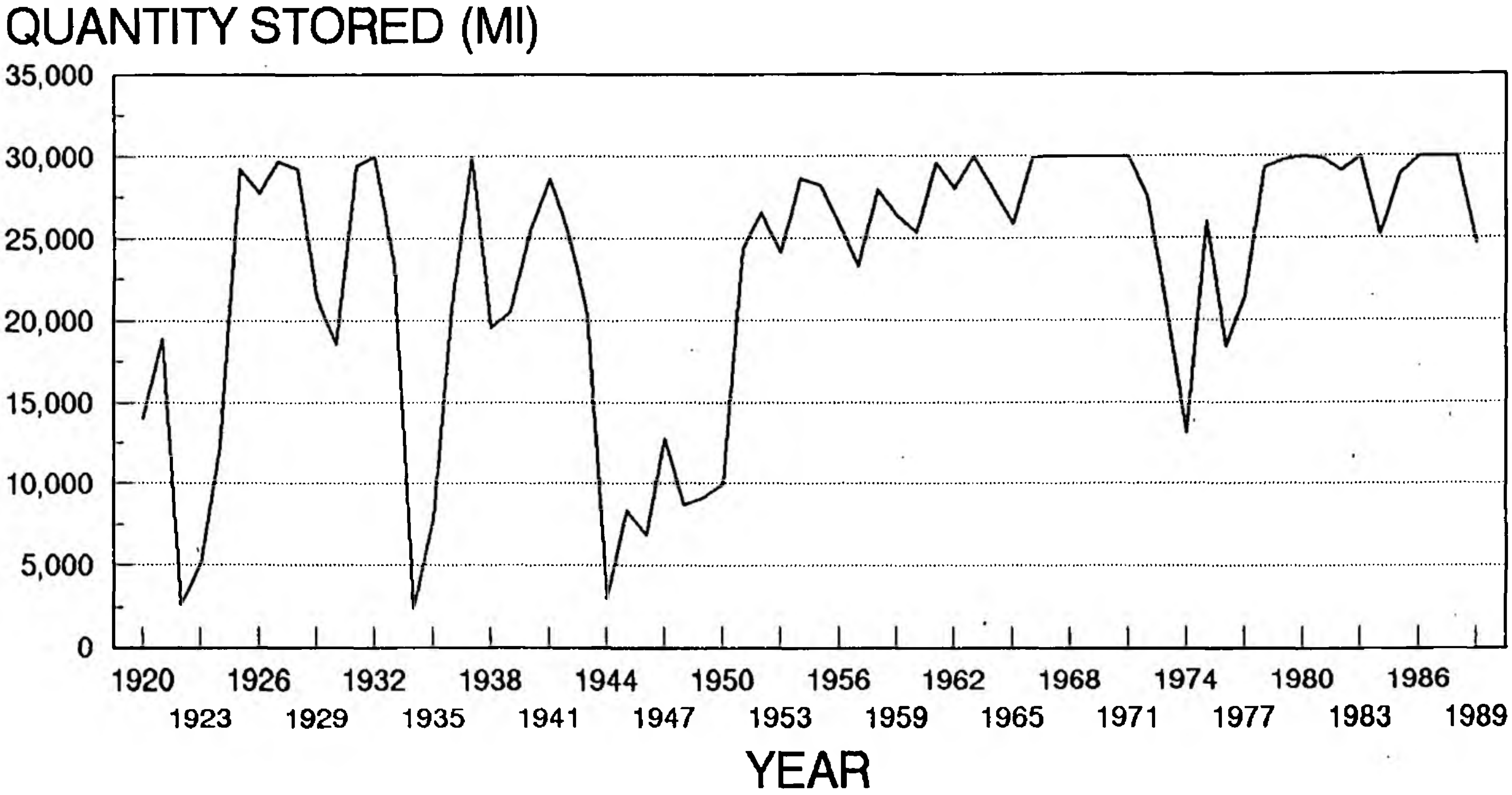


BASE RUN SCENARIO 1.2

SCENARIO 2.3 – AS FOR SCENARIO 1.2
WITH ADDITIONAL OF A TRANSFER
FROM SEVERN TO DRAYTON

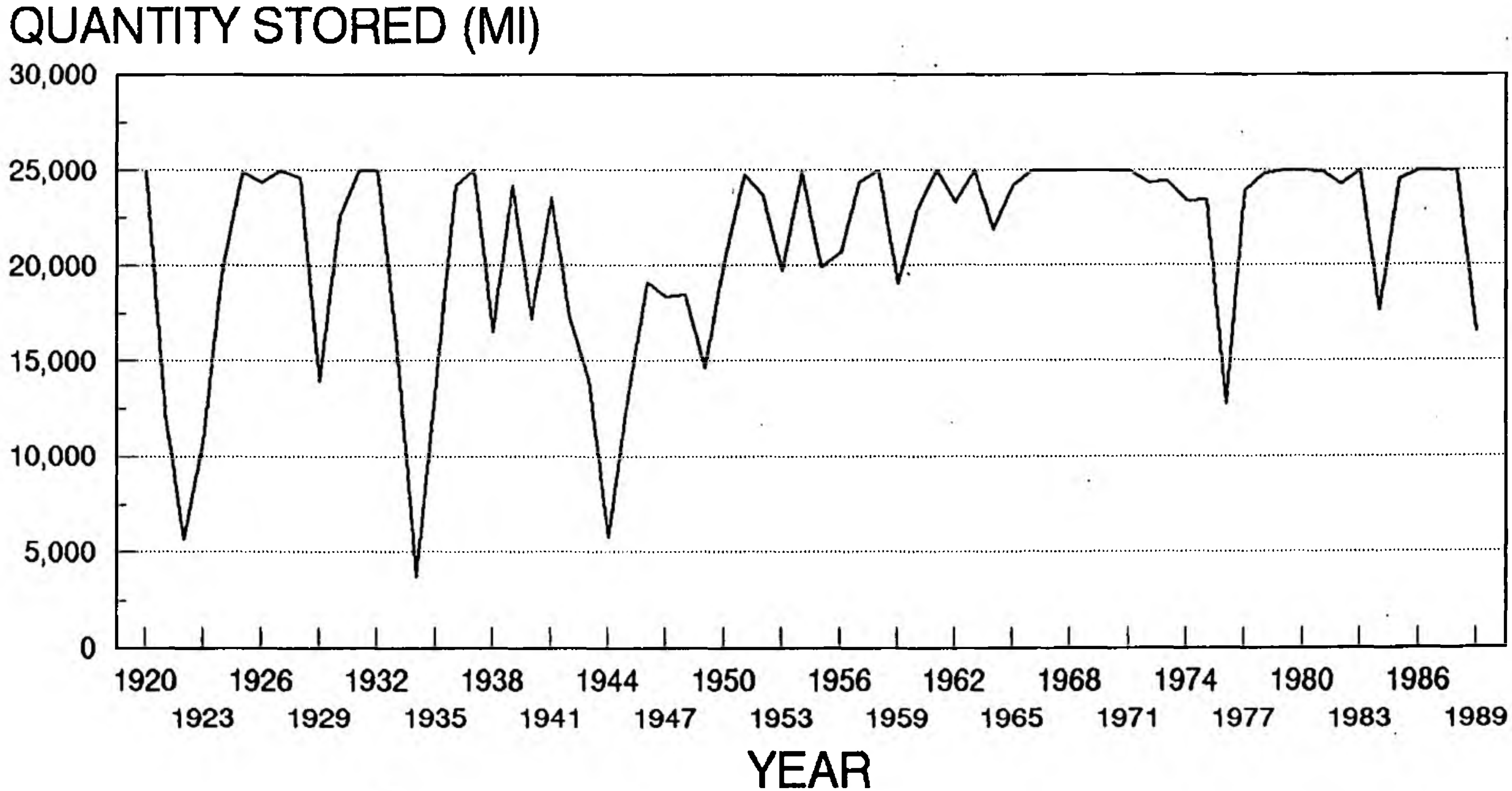
RESERVOIR STORAGE LEVELS

QUANTITY STORED IN WADDESDON RESERVOIR



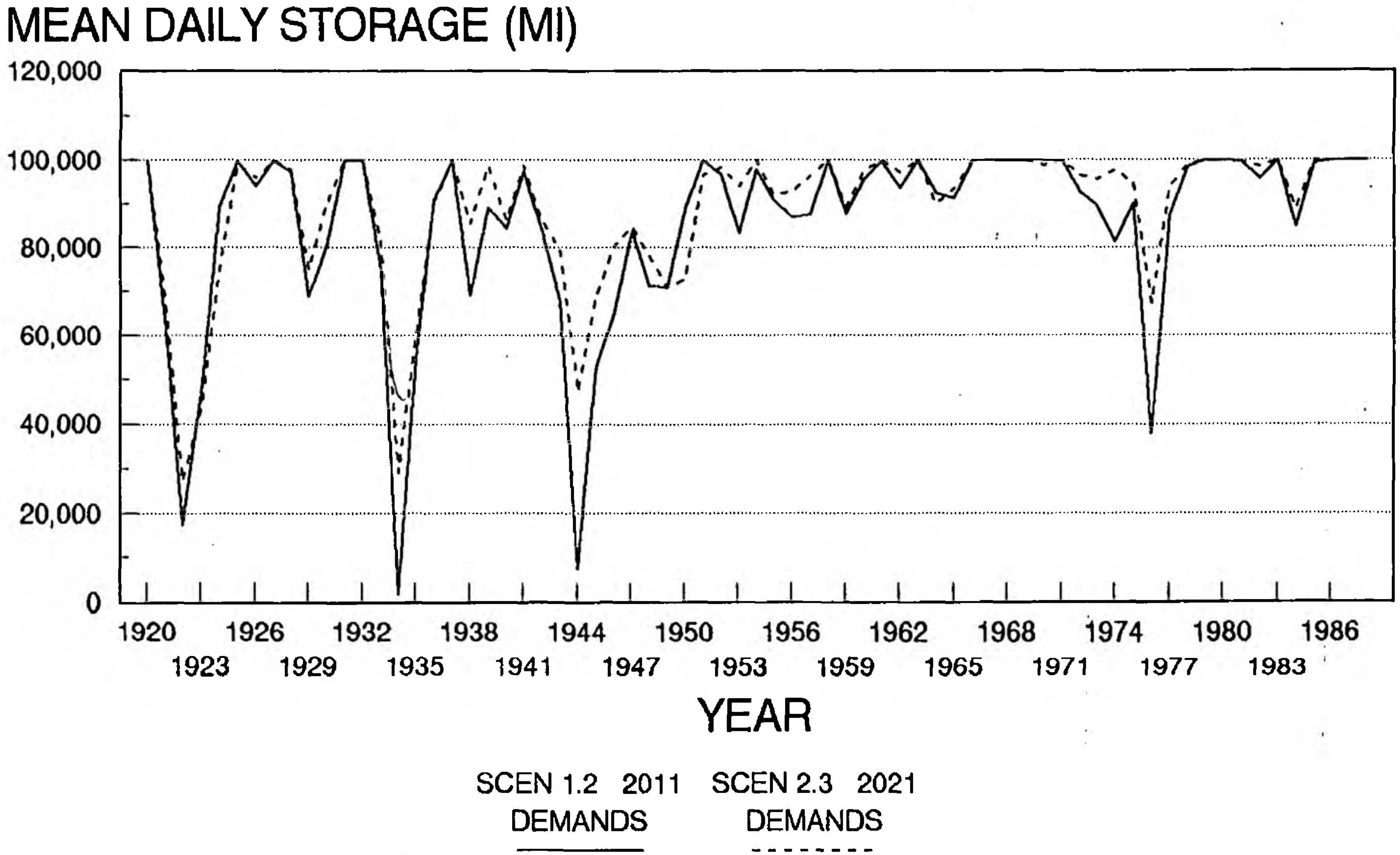
SCEN 3.3 2020
DEMANDS

QUANTITY STORED IN DOWN AMPNEY RESERVOIR



SCEN 3.3 2020
DEMANDS

STORAGE IN DRAYTON RESERVOIR



APPENDIX 3

ENGINEERING COSTS

APPENDIX 3

Engineering Costs

Engineering costs have been based on data derived from the following sources:-

- Water Research Centre - Technical Report TR61
- Water Research Centre - External Report 72E
- Central Water Planning Unit - Severn to Thames water Transfers
- Thames Water - Water Resources Strategy
- Wessex Database Civil Engineering
- Howard Humphreys - Internal cost data

Costs have been presented at late 1991 rates and in order to arrive at these rates escalation has been based on the published public works and construction materials indices.

The following tables give the cost parameters used for capital and annual operating expenditure.

The costs given in the tables of capital costs do not include engineering costs or contingencies.

Because of the very outline nature of the designs included in the options a contingency allowance of 25% has been made in the costing of options.

Engineering costs have been taken as 4% of its capital cost for design and head office supervision of construction and 4% of capital cost for site supervision of construction. These costs have been spread over estimated design and construction periods.

CAPITAL COSTS

Item	Works	Cost/Unit Cost	Remarks
Storage	Impounding Dams (earth fill)	$17.4 * Fill^{0.8}$	Cost in £ million Fill : Volume of embankment in Mm^3
	Bunded Reservoirs	$5.15 \times Vol^{0.68}$	Cost in £ million Vol : Storage in Mm^3
	Bankside storage on Severn/Thames transfer	£0.024M per Ml/d transfer	From CWPU 1977 costing for 3 days storage at 225 Ml/d transfer
	Gravel Pit	£30 per m^2 of Cut-off trench	Assumes 600mm wide slurry trench to maximum depth of 10m along perimeter of gravel pit. Winning of gravel assumed to cover cost of excavating any minor bunding and landscaping
Transmission	Pipelines	$12.45 \times 10^{-3} \times D^{1.848}$	Cost in £ per metre D: diameter in mm Based on ductile iron pipes
	Tunnels	2.0m dia £200/m £2000/h 2.5m dia £300/m £3000/m	

CAPITAL COSTS

Item	Works	Cost/Unit Cost	Remarks
Pumping	Pumping Plant	$11.3 \times Kw^{0.6}$	Cost in £ thousands Kw = Installed water power including standby plant Based on HH recent tenders and Halcrow example in national strategic options
	Pump House	$16 \times Q^{0.79}$	Cost in £ thousands Q = Throughput in Ml/d Based on TR61 with constant revised and adjusted for HH and Halcrow examples
Tertiary Treatment of Effluent	Filters	$0.628\ Q^{0.655}$	Cost in £ million Q = Throughput in Ml/d Formula derived from TR61 escalated and upper confidence limit applied
	Ozoniser	£1300 per Ml/d throughput	Based on manufacturer's budget quotation
Miscellaneous	Drayton Reservoir	£225m	From estimate provided by NRA - TR
	Land	£4900 per hectare	Agricultural Land

ANNUAL OPERATING COSTS

Item	Annual Cost	Remarks
Electricity	4.25p per unit (Kwhr)	Assumed overall efficiency of pumping plant of 80% and pumping over 24 hours
Tertiary Treatment Filtration	$0.025\ Q^{0.617}$	Cost : £M per annum Q = Throughput in Ml/d Based on TR61 (filtration only) escalated
Ozonation	Oxygen : £1800 per Ml/d Power ; £880 per Ml/d	Based on equipment supplier's budget quotation and assuming oxygen used as base gas
Maintenance	Dams/Reservoirs 0.1% Civil Structures 0.2% Pipeline 0.5% Pumps 5% Ozonation 10%	Annual maintenance taken as a percentage of capital cost

APPENDIX 4

WATER QUALITY DATA

APPENDIX 4

TABLE A4.1a - RIVER WATER QUALITY

Parameter	RIVER THAMES AT BUSCOT			RIVER SEVERN AT HAW BRIDGE		
	MAX	MIN	MEAN	MAX	MIN	MEAN
Temperature°C	24	3.3	11.12	22	0	10.6
BOD_5	4.4	<1	2.01	-	-	-
Chlorides	118	23	38.6	117	20	57.3
pH	8.2	7.0	7.78	89	7.2	7.86
$NH_3(N)$	0.023	<0.001	0.0027	0.033	<0.001	0.004
SS	181	1.2	14.3	320	2	32.9
$KMmO_4$						
$Alk(CaCO_3)$			190			143#
Diss O_2	13.2	7.1	10.2	14.4	6.4	10.3
THard $(CaCO_3)$	354	177	278*	383	98	232
Cadmium						
Chromium	0.25+					
Copper	0.028+					
Nickel	0.2+					
Zinc	0.5+					
Lead	0.25+					
Manganese*	0.0460	<0.005	0.01			
TDS						
TON(as N)						
NH_3(un-ion)*	0.025			1.3	<0.01	10.004
Silica						
Colour*			16		-	-
Turbidity*			17	60	2	10.7
	Taken from results for BUSCOT 1986 - 1990			Taken from results for Haw Bridge 1986-1990		

Results in mg/l except where stated

+ Statutory Limit   * Measured at Farmoor   # Projected

APPENDIX 4

TABLE A4.1b - RIVER WATER QUALITY

Parameter	RIVER THAMES AT BUSCOT			RIVER SEVERN AT HAW BRIDGE		
	MAX	MIN	MEAN	MAX	MIN	MEAN
Temperature°C	24	3.3	11.12	22	4	11.7
BOD_5	4.4	<1	2.01	63	1.4	3.0
Chlorides	118	23	38.6	110	32	50
pH	8.2	7.0	7.78	84	7.2	7.7
$NH_3(N)$	0.023	<0.001	0.0027	0.8	0	0.3
SS	181	1.2	14.3	140	12	32
$KMmO_4$				7.8	1.4	3.8
$Alk(CaCO_3)$			190	270	92	143
Diss O_2	13.2	7.1	10.2	14	7.2	13
THard $(CaCO_3)$	354	177	278*	304	166	235
Cadmium				0.03*	0	0.01
Chromium	0.25+			0.01*	0	0.01
Copper	0.028+			0.02*	0	0.01
Nickel	0.2+			0.02	0	0.01
Zinc	0.5+			0.07*	0.01	0.03
Lead	0.25+			0.05*	0	0.02
Manganese*	0.0460	<0.005	0.01	0.08*	0.01	0.04
TDS				538	299	401
TON(as N)						5.6
NH_3(un-ion)*	0.025					0.005
Silica						-
Colour*			16		-	10.7
Turbidity*			17		2	
Taken from results for BUSCOT 1986 - 1990				Taken from results for Haw Bridge 1986-1990		

Results in mg/l except where stated

\+ Statutory Limit   * Measured at Farmoor   # Projected

TABLE A4.2 - RIVER THAMES QUALITY AT BUSCOT

STATION: BUSCOT Flow 1.44m^3/sec (95% ile)
(124 ml/d)

RIVER QUALITY: CATEGORY 2A

River Quality Objectives

2A Fair Quality Waters:

a) Suitable for potable supply after "advanced treatment"

b) Suitable for agricultural use
c) Capable of supporting good coarse fisheries
d) Moderate amenity value.

River Quality Standards - in mg/l

	95% ile	50% ile
Dissolved O_2 (min)	40%	7 mg/l
BOD	9	
NH_4^+	3	
NH_3 (unionised) as	0.025	
SS	25	
pH	6 - 9	
Nitrite as NO_2	0.5	

if hardness	< 250 mg/l	> 250 mg/l
Cr	0.2 mg/l	0.25 mg/l
Cu	0.01 mg/l	0.028 mg/l
Pb	0.25 mg/l	0.25 mg/l
Ni	0.2 mg/l	0.2 mg/l
Zn	0.25 mg/l	0.5 mg/l

TABLE A4.3 - CHEMISTRY OF MIXED RIVER SEVERN (HAW BRIDGE) AND RIVER THAMES (BUSCOT) WATERS

Thames Flow Ml/d	Severn Transfer Ml/d	Total Flow Ml/d	Analysis No.
124	0	124	(1)
124	100	224	(2)
124	200	324	(3)
124	300	424	(4)
124	400	524	(5)
124	500	624	(6)
124	600	724	(7)
124	700	824	(8)

TABLE A4.4 - PROVISIONAL CHEMISTRY OF SEVERN WATER AND THAMES (BUSCOT) WATER, MIXED

ANALYSIS No.	BICARBONATE ALKALINITY	CHLORIDE	AMMONIA	SUSPENDED SOLIDS *	pH	SILICA	TOTAL HARDNESS	BOD_5	T° C	DISSOLVED OXYGEN
1	190	386	0.0027	14.3	7.78	10.5	278	2	11.6	10.2
2	169	47	0.0033	227			257		10.9	
3	161	50		25.8			250			
4	157	52		27.5			245			
5	154	53		28.4			243			
6	152	53.5		29.2			241			
7	151	54		29.7			240			
8	150	54.5		30.1			239			
9	149	55		30.4			238			
10										
11	148	55	0.0038	30.8	7.8		237		10.7	103

* NO STORAGE

Composite analysis of water abstracted from Haw Bridge on the River Severn and mixed directly with Thames Water at Buscot. Based on NRA analyses figures of 1986-90 except for Alkalinity which for River Severn Water has been taken as previous 5 year mean. ALL RESULTS BASED ON MEAN VALUES.

TABLE A4.5 - EFFLUENT QUALITY

Parameter (all mean values)	Hogsmill STW	Deephams STW	Beckton STW	Mogden STW	Kew STW	Crossness STW
pH	7.06	7.198	7.49	7.437	7.29	7.68
SS	8.60	9.02	19.318	14.482	9.73	17.00
BOD_5	6.21	5.12	9.14	10.57	5.03	10.06
DO	5.90	-	-	3.07	-	-
$N(NH_3)$	4.3	0.82	1.474	1.122	0.534	8.55
Chlorides	106.3	177.1	148.197	114.212	113	181.3
Hardness	305.83	-	267.33	312.0	316.0	303.5
Zinc	0.063	0.144	0.058	0.063	0.034	0.051
Flow	77.7	-	-	508	-	836.4

Results in mg/l except for pH

APPENDIX 5

ENVIRONMENTAL APPRAISAL OF OPTIONS

CONTENTS

Environmental Assessment of Strategic Options

THAMES-SIDE GROUNDWATER

PROJECT DESCRIPTION

Works required at the groundwater development sites will include:

- construction of abstraction and monitoring wells;
- headworks to wells;
- pumping stations and distribution pipelines;
- disinfection plant, probably using chlorination.

PLANNING AND DEVELOPMENT

It is not anticipated that any of the groundwater development sites will have any effect on planning issues in the vicinity. It is useful to note however, that the site at West Marlow lies within an Area of Attractive Landscape as identified in the Buckinghamshire Structure Plan. The site at Remenham lies within an Area of Great Landscape Value (AGLV) identified in the Berkshire Structure Plan, and Harpsden also lies within an AGLV, as identified in the Oxfordshire Structure Plan.

It is not considered that development of the type and scale proposed will conflict with these county level landscape protection policies.

LANDSCAPE AND VISUAL

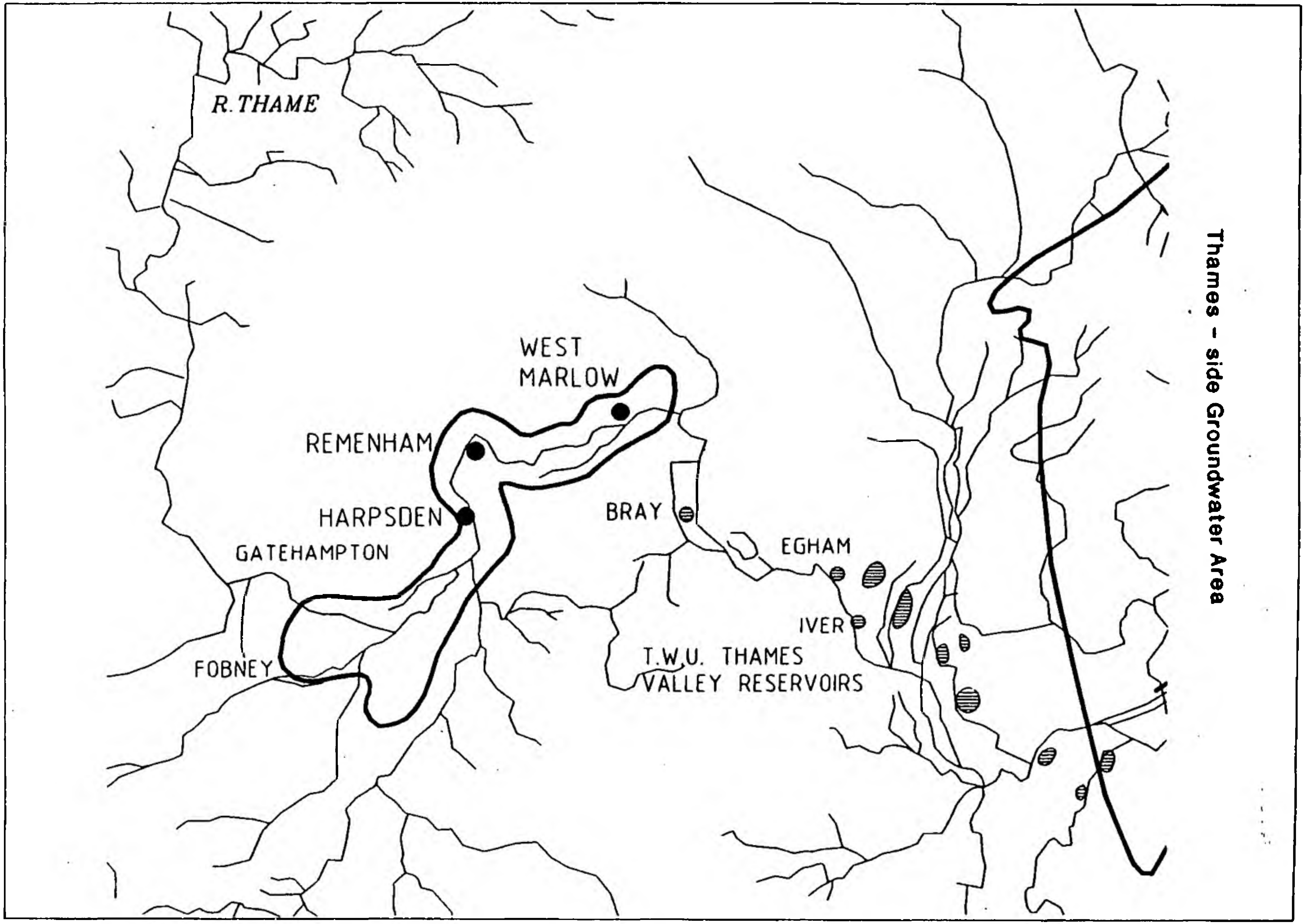
Any effects resulting from the development of these sites are likely to be primarily related to the construction stage. This will probably involve the creation of improved access at Remenham and West Marlow as both sites lie away from the road (Harpsden is already licensed and lies adjacent to the A4155). In addition there will be disturbance during the construction of pump housing and possible chlorination facilities. Finally pipeline laying will create disturbance along the route which is expected to run to the nearest highway.

Specifically, these impacts will involve temporary visual effects through excavation and building works and trenching for pipeline laying. There will be some residual effects through the existence of any necessary pumping or treatment buildings. These installations are likely to be small in size however, and any views of them are likely to be very localised.

Provided pipeline trenches are restored and construction materials are removed on completion the duration of significant visual effects is likely to be limited to 1-2 months at each site.

RECREATION AND AMENITY

Impacts on recreational uses in the vicinity will be restricted to effects on users of the popular riverside footpaths which pass close to the Remenham and West Marlow sites.



Thames - side Groundwater Area

Such impacts may be significant during construction, but will be limited to disturbance of views and the peaceful character of the riverside areas. There will not be any requirement for closure or diversion of footpaths.

Longer term residual impacts will depend on the scale of any structures required which may be visible from footpaths. As stated earlier, these are not anticipated to result in significant impacts.

It is useful to note that the villages of Remenham and Aston are identified as 'main informal recreation sites' in the Berkshire Countryside Recreation Strategy. Construction traffic may pass through Remenham but there will not be any operational impacts on either villages. The two centres do however attract a significant number of users of the footpath which passes 150-200m north of the Remenham abstraction site.

ARCHAEOLOGY AND HISTORY

As with most other resource options under consideration, potential for impact on archaeology is a significant factor. However, the groundwater abstraction in these Thame-side locations is likely to involve limited infrastructure and therefore any potential impacts remain a matter for detailed evaluation in the field as appropriate.

It should be noted that the Thames valley as a whole is extremely rich in archaeology and any infrastructure works in close proximity to the river have particularly strong potential for disturbing sub-surface remains.

TERRESTRIAL ECOLOGY

There are no SSSI's in the vicinity of proposed pumping sites, however there may be sites of local or county importance and information on these sites should be obtained from the local naturalist trust.

It is not anticipated that these groundwater developments will have an effect on any wetland sites within the area, however this should be clarified through discussions with conservation organisations.

AQUATIC ECOLOGY

It is important that these groundwater abstractions do not adversely affect groundwater fed surface water courses.

LONDON BASIN GROUNDWATER

PROJECT DESCRIPTION

- Construction of 14 new boreholes at sites adjacent to the New River and linkage to the distribution system;
- construction of 20 new boreholes in south London and linkage into the distribution system;
- construction of boreholes at 15 sites in London to control rising groundwater levels and linkage to the distribution system;
- possible replacement or refurbishment of existing boreholes, and pump replacement.

PLANNING AND DEVELOPMENT

Impacts under this heading are considered to be very limited and will depend largely on the form and location of borehole and pumping infrastructure. It is assumed that much of this can be accommodated within existing built development, and therefore negative impacts are unlikely to accrue.

There will be a significant positive impact arising from the lowering and stabilisation of groundwater levels in London. These have risen significantly during the past 40 years to the point where they threaten underground services and basements. Proposed abstraction will greatly improve this situation.

LANDSCAPE

It is not anticipated that any landscape impacts will accrue from this option.

RECREATION AND AMENITY

No direct impacts are expected to result, but there will be an indirect positive impact through the ability to maintain flows in the Thames while abstracting more water.

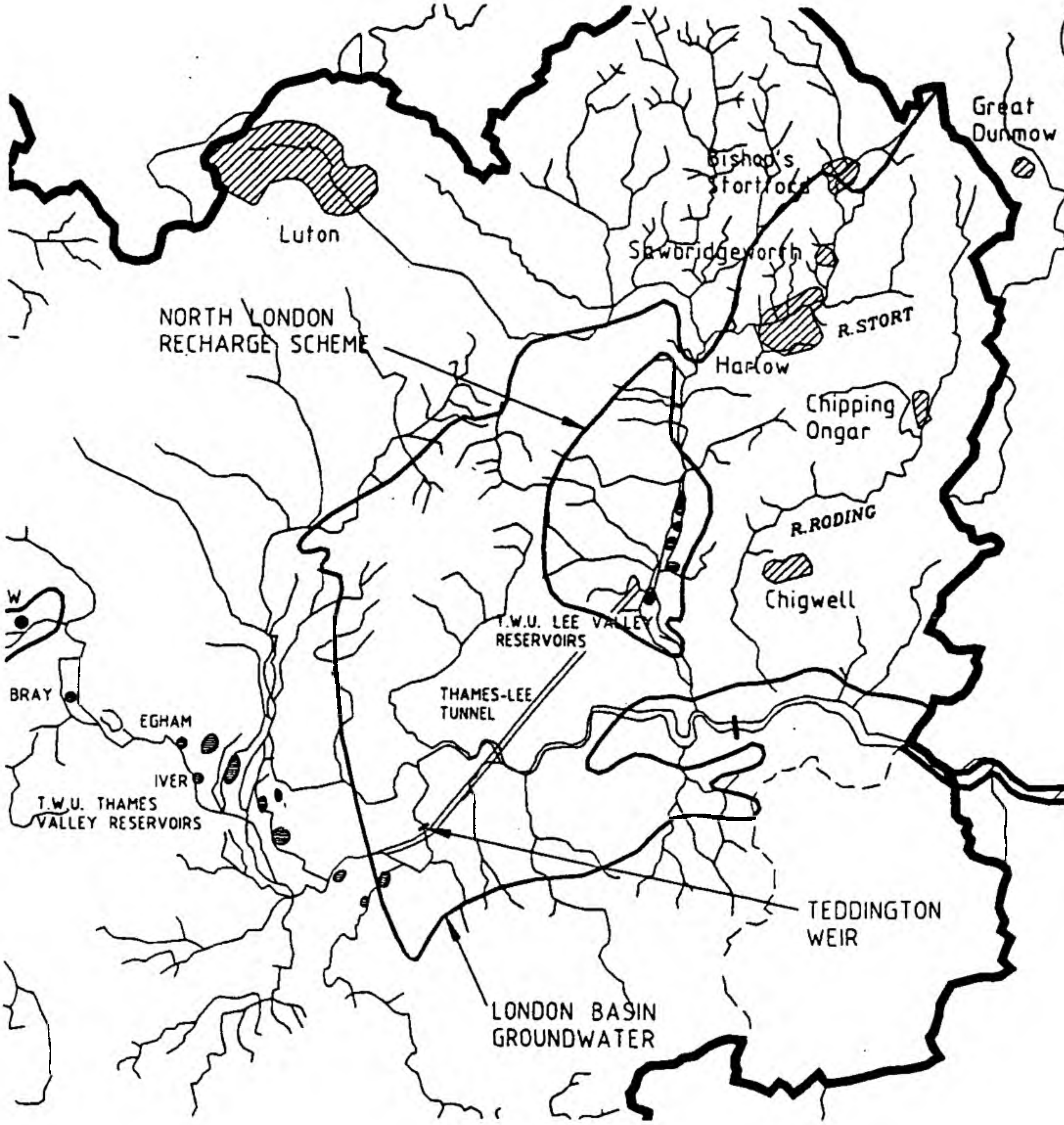
ARCHAEOLOGY AND HISTORY

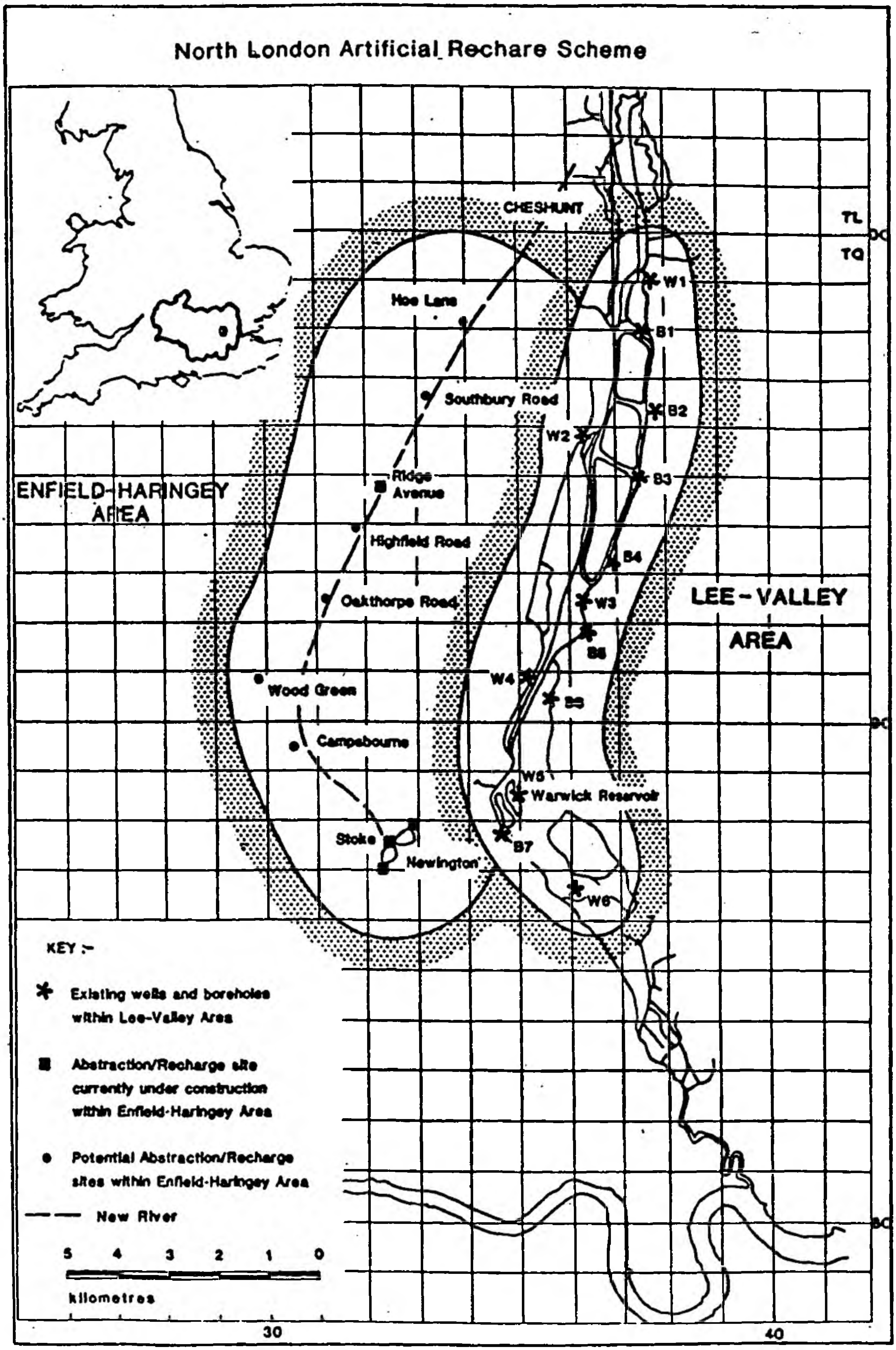
Provided installation of borehole and pumping facilities can be within existing built development then no impacts are anticipated. If disturbance to previously undisturbed land (unlikely in London) is involved, then some consideration of possible archaeological impacts may be necessary.

TERRESTRIAL ECOLOGY

There do not appear to be any significant environmental issues relating to this option. Historically, pumping has lowered groundwater levels in the London Basin to such an extent that there is now only one site of nature conservation value which is still spring fed and this is located in Sutton. The site however has

London Basin Groundwater Area




North London Artificial Rechare Scheme
CHESHUNT
TL
TQ
Hoe Lane
Southbury Road
Ridge Avenue
Highfield Road
Oakthorpe Road
Wood Green
Campsbourne
Stoke
Newington
ENFIELD-HARINGEY AREA
LEE - VALLEY AREA
W1
B1
B2
W2
B3
B4
W3
B5
W4
B6
W5
Warwick Reservoir
B7
W6
KEY :-
Existing wells and boreholes within Lee-Valley Area
Abstraction/Recharge site currently under construction within Enfield-Haringey Area
Potential Abstraction/Recharge sites within Enfield-Haringey Area
New River
5 4 3 2 1 0
kilometres
30
40

been heavily degraded due to dropping water levels such that it is more a nature reserve in name rather than in nature conservation interest.

Abstraction therefore will not affect wetland sites in the London area, and as the aquifer is confined, abstraction is unlikely to affect peripheral spring fed sites outside the London basin.

RESERVOIR AT ABINGDON/DRAYTON

PROJECT DESCRIPTION

- River intake/outlet in Culham reach with an additional or alternative inlet/outlet just downstream of the Thame confluence, with low lift pump station;
- transmission tunnel to reservoir (about 2.5 m diameter);
- bunded reservoir, of unknown shape and size, but nominally with 20 m high hunds and a storage of 100,000 Ml;
- reservoir off-take, pump station and water treatment plant to provide up to 100 Ml/d of potable water, with forwarding pumps and pipeline to take water to Swindon and the Cotswolds;
- possible reservoir oxygenation/bubbler system to turn over storage and prevent stratification/eutrophication.

PLANNING AND DEVELOPMENT

The proposed site of the reservoir has no planning designations applying to it, of national, county or district origin.

Key planning concerns will consist of impacts on nearby residential areas including construction impacts, the creation of new access routes and closure/diversion of an existing road, and pressure for recreational use on completion. The River Information and Control Manager of NRA-TR has also raised the issue of emergency planning considerations for the proposal.

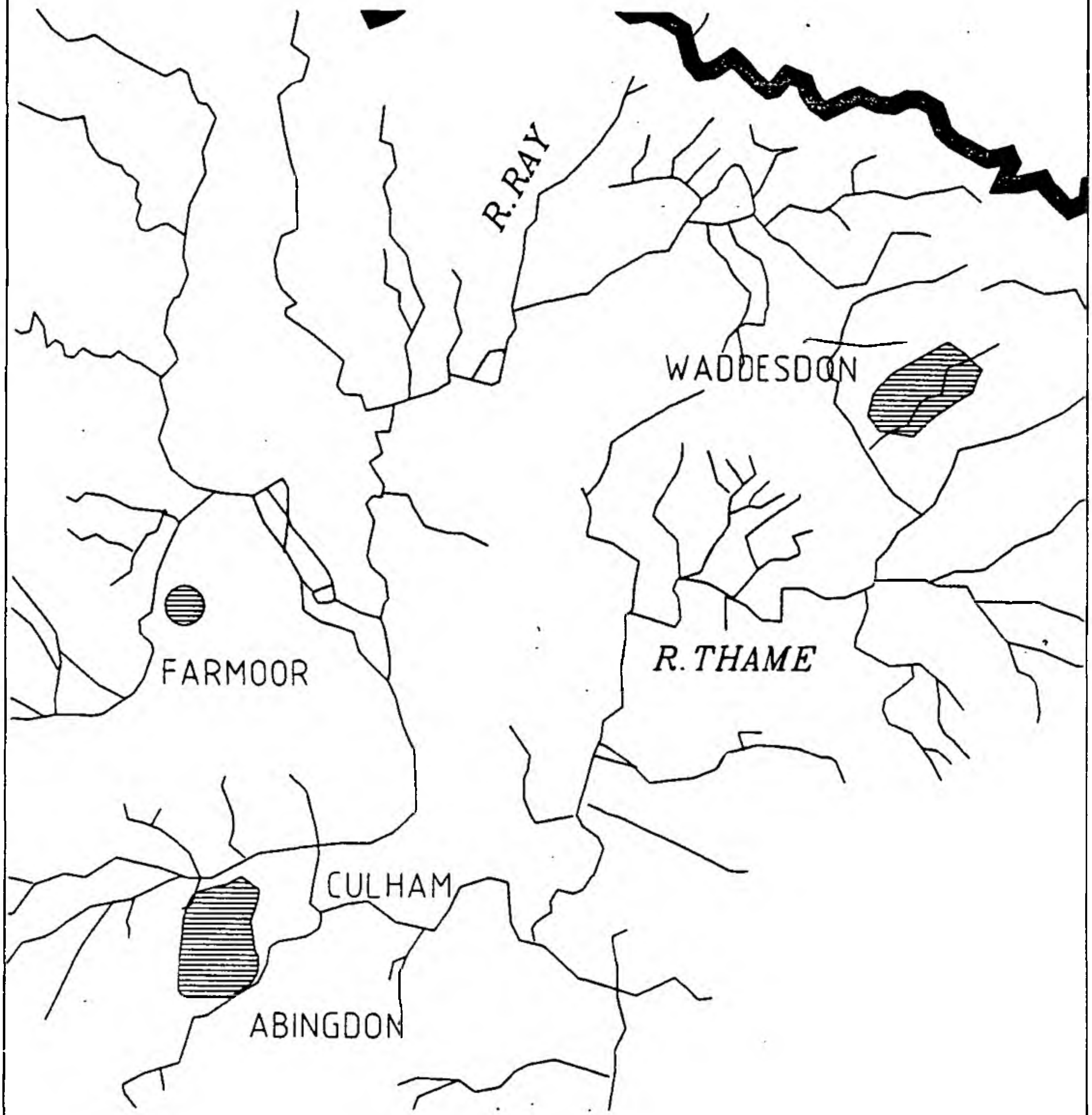
Construction impacts arising from the scheme will be considerable. Although not involving the loss of a significant number of dwellings within the reservoir area, the site will be in comparatively close proximity to Steventon and Drayton with consequent potential for disturbance through noise, dust, vibration and traffic movements.

The construction phase will be extensive in duration and is likely to require the creation of a new access to the site, the route of which is not known at present. Traffic levels during this phase will be considerable, although it is proposed that a significant amount of required aggregates can be extracted on-site, thus reducing the importation of materials.

The emergency planning issue raised relates to the two scenarios of: Actual failure of an impoundment bund, and: Emergency drawdown of reservoir water levels due to impending failure of a bund. The first of these requires an appraisal of the path of escaping water, and the need for any structures or works to facilitate safe discharge. The proximity and location of Steventon, Drayton and, in particular, Abingdon may require detailed consideration of this issue.

The second scenario is that of emergency drawdown of levels within the reservoir. This requires the consideration of the impacts of rapid discharge into the Thames. These may include flow/flood capacity, the effect on river control and other structures and the effect on recreational and residential craft downstream. As part of any assessment which may be undertaken will be the

Reservoir at Abingdon/Drayton



need to consider effective communications and warning facilities for use in such an emergency event.

On completion of the project there may be pressures for recreation related development arising from what may become an attraction of regional significance.

AGRICULTURE AND DRAINAGE

Land-take for a reservoir of the size proposed will clearly be extensive. This is tempered by the fact that the land in question is a mixture of Grades 3 and 4 of the Agricultural Land Classification. These are classified as moderate and poor quality respectively. In the light of trends in Structure Plan planning policy towards a more general protection of the better grades of land it is not felt that the issue of agricultural land-take remains as significant as it would have been 5-10 years ago.

Local drainage will inevitably be disrupted, however, it is considered that appropriate mitigation measures can be engineered satisfactorily.

LANDSCAPE AND VISUAL EFFECTS

Limited information is available about the details of size, layout and approach to construction of a reservoir at Abingdon. It is however possible to make a range of assumptions about potential impacts, based on available information and experience of other developments. It is important to realise that the scale of the proposed development, the complexity of works involved and also the likely duration of the construction period will have a major impact, one element of which will be landscape and visual effects. As stated however, there are no designated landscapes involved and therefore impacts are likely to be assessed largely for their visual effects on residents and other receptors.

The site benefits in some respects from its flat and low-lying character which means that long distance views will be limited to some extent. The construction stage will nevertheless involve significant effects arising from site preparation and the construction of bunds.

Significant views to the site from the A34 trunk road will result as it runs on embankment approximately 0.5 km to the east of the proposed site. Other views will be more intermittent due to the flatness of the surrounding countryside and the opportunity therefore for screening vegetation. It is anticipated that retaining bunds will be up to 20m in height, and the initial construction of these will result in moving vehicles in an elevated position in the landscape. After initial placement the bunding will also appear raw and prominent until remedial landscape works can take effect.

No details of pipeline or tunnel routes between the reservoir and the Thames are yet available, but construction of these will create a temporary but potentially severe impact. In addition the construction of discharge/abstraction infrastructure on the river itself may create significant impacts during this period.

As stated, views of the bunds will be lessened to a degree by the flatness of surrounding land. However, on completion effective offsite screen planting, together with landscape works to the bunds themselves (including variation of slope, line etc) will be essential to mitigate visual impacts resulting from 20m high structures. Any proposals to undertake offsite screen planting and vegetation management would need to be supported by evidence that they can be undertaken without any problems of land ownership arising.

With appropriate landscape works to the reservoir itself and to the associated infrastructure it should be possible to mitigate most detrimental visual impacts, despite the scale of the development. There will be an inevitable effect on the local landscape, but this will not in itself necessarily constitute a negative impact.

RECREATION AND AMENITY

Recreational impacts of the reservoir proposal will involve negative impacts due to the loss of the network of public footpaths and bridleways which cross the site, and positive impacts arising from the recreational resource created by the new water body. There may also be effects on footpath users on the Thames during construction of infrastructure.

Up to 6 separate footpaths/bridleways cross the site at present and these will either be lost or diverted to run round the periphery of the reservoir. None are long distance paths and none form part of the Oxfordshire Circular Walks network.

It is not considered that loss of these paths will be a significant impact, particularly when considered with new footpath routes likely to be created on and around the reservoir bunding.

An additional potential impact which should be considered is the effect on recreational craft using the Thames. This use may be affected in the event of sudden fluctuations of flow and therefore the regulation of flow suggested for other potential impacts will be important in this context. The ability of the reservoir to improve flow regulation would be a benefit to such users.

Creation of sailing, canoeing, bird-watching and other water based recreations will be a very significant positive impact arising from the development. The details of what activities will be permissible are not yet available, but the reservoir will form a major recreational resource, probably of regional significance.

Amenity impacts will result for local residents and are likely to be perceived as negative in the main. These would result from construction, the presence of a major development in close proximity to residential areas, traffic and disturbance arising from recreational use. There will be a significant impact for those few residents who will need re-housing as part of the development.

Some micro climatic effects may arise from the scale of water body and bund height, and further research may be necessary to quantify these.

ARCHAEOLOGY AND HERITAGE

There is little, known, evidence of archaeological interest on the site at present. No listed buildings would be lost, although the setting of Venn Mill on the A338 to the north west may be affected.

It is highly likely that a site of the size involved will yield features of archaeological interest. It is therefore essential that a comprehensive desk study supported by field evaluation and/or geophysical survey be undertaken to identify the presence or absence of such features. Any features will need full recording prior to removal, and any historic buildings, even though not listed should be photographed prior to demolition.

TERRESTRIAL ECOLOGY

Direct Effects

The proposed site is under intensive agricultural production and therefore is of limited value in nature conservation terms. Wildlife interest is concentrated in small areas of more semi-natural habitat, such as some of the water courses associated with the River Ock, water bodies and damp grassland along the Didcot railway and small woodlands. None of these have been designated for their conservation value and the reservoir would therefore not have a direct impact on a protected site. There is however a Site of Special Scientific Interest (SSSI) Barrow Farm Fen located approximately 2-3km upstream of the site on the Sandford Brook. Any changes to the hydrological regime in the area as a result of construction should be considered in light of the above.

Indirect Effects

The operation of Abingdon Reservoir will reduce winter flooding. Depending on the extent of reduction, this may have significant adverse effects on downstream sites of nature conservation interest, whose value relies on periodic winter flooding or water levels in general. Flooding enriches and softens soil and is beneficial to both invertebrates and wading birds in particular. It also maintains botanic diversity by improving the competitive ability of less aggressive species.

There are numerous wetland sites located downstream of Abingdon although they are largely of county rather than national importance. A nationally important site however is located directly upstream of the Culham Reach in a seasonally flooded backwater, it is called Culham Brake SSSI, GR SU 508 964. This is a small area of willow carr by the Thames containing one of the largest populations of a Red Data book species summer snowflake *Leucojum aestivum*. (Red Data book species are those species that are rare or threatened in Great Britain). In addition the site supports lush carr flora. The area is directly watered from the river Thames.

According to a study carried out by BBONT Berkshire Buckinghamshire and Oxfordshire Naturalist Trust in 1984, there are at least 53 wetland, carr or open water sites in the middle and lower Thames which are periodically inundated with water from the Thames. These sites range from areas of local and county importance to sites which have not been classified as further survey is required. Below Abingdon in the middle Thames there are 16 sites which have not been classified due to lack of data, 3 have been classified as being of local importance, 5 sites were of county importance and 4 were defined as being of regional importance. In the lower Thames there are 10 sites which have not been classified due to lack of data, 5 classified as being of local importance, 8 of county importance, 1 of regional importance and 1 SSSI.

Sites which are of county importance and occur downstream of Abingdon include Clifton Hampden Meadows (SU 556 957) which are a series of unimproved meadows with some open water; South Stoke Marsh (SU 594 844) which includes a number of wetland habitats adjacent to the river Thames; Cholsey marsh which is a (BBONT) Nature Reserve; Shillingford Meadows (SU 594 923) comprising a number of wet meadows and Hayward Eyot (SU 543

938) which comprises tall fen vegetation and other wetland habitats subject to periodic flooding.

A full study of other sites of ecological value both designated and otherwise and consultation with English Nature and the local naturalist trusts should be undertaken. This will determine where the sites are located and what levels of flooding they are currently experiencing and what level of flooding they require to sustain their conservation interest. The type of licence abstraction could aim to take into account the need for these sites to experience low level flooding. It is thought however that the Oxfordshire flood meadows above Abingdon are more important in nature conservation terms than those present downstream.

There are a number of other wetland sites located on the Thames tributaries which are periodically inundated, however it is difficult at this stage to determine to what extent these would be affected by reduced winter flows in the Thames.

CONSERVATION GAIN

With careful design and management, reservoirs can be of considerable benefit to wildlife. A number of existing reservoirs have been designated SSSIs usually for their wildfowl interest. The Abingdon Reservoir has the potential of becoming an important wetland area in the South East of Britain, particularly as many wetland habitats have been drained and ploughed to increase agricultural production. Examples of reservoirs which have received SSSI status include Rutland Water in east Leicestershire, Grafham water, Staines and Walthamstow. Wildlife considerations could be incorporated in the planning stage, which identify the need for areas of water and land to be specifically managed for wildlife conservation, and certain parts to be protected from disturbance by recreational activity. Aside from obvious benefits to wildfowl, terrestrial wildlife can also benefit, with grassland being managed as traditional hay meadows. During draw-down there will be loss of habitat, but with careful design this can be minimised, ie with the creation of a wide range of profiles down the slope and a crenellated perimeter.

The conservation division of NRA-Thames commented that this option would have additional benefits if it resulted in a reduction in ground water abstraction in the Cotswold region. This could help alleviate low flow conditions in a number of chalk streams and rivers such as the Coln and Churn.

Prior to Rutland water being commissioned in 1977, the Southern Lincolnshire Limestone aquifer had been over abstracted to the extent that spring flows to the River Glen were reaching critical levels and had been reduced to zero in 1976. Groundwater abstraction was reduced once Rutland Water came into supply and the River Glen has benefited from increased summer flows (Moore and Driver 1989).

AQUATIC BIOLOGY

Considerable research has been carried out on the effects of impoundment reservoirs on instream ecology, fisheries and sedimentation, by authors such as Petts and Armitage. However comparatively little research has been carried out on the effects of pumped storage reservoirs on river ecology, although limited research has been undertaken on the Gwash downstream of Rutland water. These two types of reservoir do differ in fundamental ways and therefore only limited comparisons can be made.

The scheme may impact upon ecology and fisheries due to changes in the downstream water quality and flow regime of the Thames and detailed consideration will need to be given to these aspects to determine whether these impacts will be significant and what mitigation measures, if any, are needed to ameliorate these impacts.

The following section is divided into physical, chemical and biological impacts, preceded by a review of potential construction impacts.

CONSTRUCTION IMPACTS

Construction impacts may include construction landtake such as temporary spoil heaps, access and roads; contsruction disturbance such as light, noise, dust emissions; construction effluents such as oil, inputs of particulates and suspended solids in site run-off. Other impacts include littering and fouling by construction workers, increased disturbance to local vegetation communities and increases in ruderal communities. However some of these impacts such as elevated suspended solids are temporary and after autumn floods faunal and floral communities which may have been adversely affected should have recovered. Increased turbidity reduces photosynthetic activity by submerged aquatic macrophytes and may affect the nutrition of filter-feeding macroinvertebrates. Construction activities will necessitate the diversion of a number of streams and impacts on downstream water courses will need to be addressed.

Physical Impacts

Flows will be considerably affected by the operation of the reservoir. Water will be abstracted during the winter months up to a maximum of 600 Ml/d, and residual flow requirements are set at approximately 450 Ml/d. The result will be reduced winter flooding, and slightly increased flow during the summer months. Physical impacts include altered flow regime, temperature effects and sedimentation.

Flow Regime
Invertebrates are adapted to their environment and any alterations as a result of abstraction, changes in temperature, flow, substrate, vegetation, flood supply and water quality will alter the composition and abundance of stream benthos. With so many interacting factors it has been hard to establish causal relationships. Several authors such as Ward and Stanford (1979) identified temperature, flow and substrate as being the three dominant variables controlling invertebrate distribution and experience in the field has indicated that substratum and velocity are more important determinads of invertebrate's distribution than depth (Armitage and Ladle 1991).

The Thames supports diverse macroinvertebrate communities which are certainly of local but possibly of county importance particularly those occurring in the upper reaches. As with many rivers the biological quality of the river varies along its length depending on a number of factors. The biotic classes of communities sampled at 4 points on the Thames in 1991 have been classified as either A or B. Results from the RIVPACS model indicated that the actual Biological Monitoring Party (BMWP) scores were close and sometimes exceeded those predicted for the sites. The biotic classes of a number of the tributaries ranged from A-D, although they were generally classified A or B.

It is difficult to predict at this stage the likely impacts that may result from changes in the flow regime, however adverse impacts on the macroinvertebrate community are more likely to occur through indirect effects of changes in the sedimentation regime than in the changes in flow per se. The biological quality of the Gwash downstream of Rutland water appears to have improved, with slightly higher BMWP scores (Barham NRA pers. comm.).

Sedimentation
Research by Ward (1976), Brooker (1981), and Armitage (1984) has shown that regulated flows can affect river biota in a variety of ways, depending on the extent and type of regulation. Studies suggest that flood regulation, specifically the reduction in the magnitude of flood events, often leads to increased sedimentation and infiltration of fine particles into and a concentration of these sediments within, open framework gravels. The time a particle may stay in suspension until its concentration has been reduced to half the original value by deposition in gravel beds, is a function of water depth and settling velocity (Einstien 1960, Reynolds *et al.* 1990). Flow velocity has only a minor effect. However the distance over which deposition is distributed and hence the area of deposition is directly proportional to average flow velocity (Carling 1984).

Build up of sediments caused by flow stabilisation has had adverse effects on invertebrates in the River Tees Channel. Sedimentation from impoundments has occurred as a consequence of the elimination or reduction in magnitude and frequency of floods which act as natural 'flushing flows' to transport sediment (Petts 1979, Petts and Thoms 1986, Petts 1988)

It is likely therefore that changes in the hydrograph will increase sedimentation patterns in the river downstream of the reservoir which is likely to effect the macroinvertebrate fauna, particularly as a feature of major importance to benthos is the distribution and settlement of fine particulate material (Armitage and Ladle 1991). However research carried out by Petts and others (unpublished) has indicated the impact of siltation tends to be localized and that the slow rate of advance of sedimentation is unlikely to have significant effects on the ecology of UK rivers. Often it can be the chemistry of the fines (ie in industrial areas) that will have a greater impact than quantity.

Therefore increased sedimentation is more likely to result in subtle changes in species composition rather than gross changes. There has been an increase in siltation and macrophyte abundance in the Gwash as a result of the construction of Rutland Water, (Barham NRA-Anglian per comm). However as has been noted previously it does not appear to have resulted in significant changes in macroinvertebrate or brown trout populations.

Increased siltation may have adverse effects on fisheries. The Thames is species rich and NRA are hoping to encourage salmon into the Abingdon area. Siltation of gravels has been partially detrimental to salmonids (Petts 1984) by entombing alevine and fry, and modification to the rate of sediment deposition can modify the risk of redds being choked by silt. The infilling of gravel interstices may also reduce the amount of cover available for young trout and for their invertebrate prey. The survival of embryos of some salmonids may be adversely affected when the proportion of substrate finer than 2 mm exceeds 20-26% (Petts 1988 cites Platts and Megahan 1975; and Tappel and Bjornn 1983). Reduced flows tend to result in smaller wetted area, lower velocity, reduced scour and increased deposition.

Appropriate structures will need to be incorporated into the intake structures to prevent salmonids from entering the reservoir. Other important considerations include discharge velocity which may cause localised impact upon fish fry.

Faunal changes again are likely to be subtle involving shifts in dominance of species and increases and decreases in overall abundance. In order to predict these changes with accuracy in relation to physical habitat more basic work is needed on the factors controlling the distribution of individual species.

Set against these potentially adverse influences are possible ecological benefits to be gained, not least of which is the general prescription of maintaining river flows above normal, and avoiding stress in the summer period.

Temperature
Storage tends to reduce the amplitude of daily and annual temperature fluctuations. Depression of summer temperature and elevated winter temperature may result in adverse effects such as retarded growth and reduction in primary and secondary productivity. However, it is also possible to experience undesirably warm waters resulting from storage due to thermoclines - with sun-warmity of waters at the surface. The magnitude of effects will vary from site to site and will be influenced by location, size and depth of reservoir and by any measures introduced to circulate mix waters within the reservoir.

The ecological implications of modifying downstream thermal conditions have been reviewed by several workers Pett (1984), Edwards (1984), Brooker (1981) and Ward (1976). Thermal changes have impacted on the life cycles and growth rates of instream fauna, although beneficial effects may arise from reduction of maximum summer temperatures. Cowx *et al* (1987) revealed from studies on two regulated rivers in mid Wales that seasonal and daily temperatures were markedly influenced by the release discharge and depth of withdrawal from the reservoir. However, downstream influence appeared to be confined to a relatively short reach. The effects of pumped storage reservoirs are unlikely to be as extreme as those of resulting from instream impoundment reservoirs.

Shore Erosion
Reduction in winter flooding and fluctuating water levels, and the wetting of bank in summer could lead to bankside erosion over time.

Chemical

Off-river storage accepts water from adjacent rivers when flows are high and returns water to the stream when flows are lower. Within the storage chemical exchanges and cycling processes occur in conjunction with biological degradation and uptake, such that water leaving the storage is likely to have different characteristics from that entering, in terms of water chemistry and sediment load. The storage may act as either a sink for contaminants carried by the main river or a source of contaminants to the main river. The behaviour involves complex interactions between a large number of variables.

Reduced winter flooding is unlikely to have significant effects on effluent water quality, however the other key issues pertaining to water quality is reservoir water quality. As discussed above the chemical properties of stored water often differ from those encountered in a river. For example the hypolimnion is often poorly oxygenated with higher concentrations of dissolved iron and manganese than river water and in addition the reservoir may concentrate Group 1 and Group 2 subtances. Nutrient levels are often reduced when stored. Oxygen levels are usually increased on discharge, especially where there is turbulence. Management solutions include multiple draw-off facilities or forced circulation within the reservoir.

Biological

The river Thames is a relatively nutrient-rich river and it is likely therefore that the reservoir water will become eutrophic and result in the outbreak of algal blooms. This will be particularly important after a number of years when conditions stabilise and the concentration of phosphate in the reservoir is over 80% of the input level. In the first few years phosphate concentration in reservoirs tends to be much lower due to absorption and deposition.

Eutrophication is not just the supply of nutrients but also a set of linked biological consequences. The input of excessive plant nutrients result in changes in algae, both phytoplankton and periphyton. Species composition alter, the latter often greatly elevated, and blooms of species breakout. The water becomes turbid, supersaturated with oxygen in the daytime, perhaps anoxic at night and during decay of blooms. When populations crash, some species notably blue-green algae produce toxins and become increasingly dominant as eutrophication proceeds.

Recreational uses of eutrophic waters are widespread. To a certain extent these conditions are tolerated by anglers, and by those who undertake recreations such as sailing and informal shoreline recreation on water bodies experiencing planktonic or littoral algal growth. However severe if localised economic consequences result if the facility has to be closed, as happened at Rutland Water during the summer of 1989. Recreation can become hazardous as some algal toxins affect humans who swallow water whilst swimming and in 1990 the NRA identified more than 50 water bodies as containing potentially toxic algae.

One of the most serious effects of eutrophication is that the decay process acting upon debris from the production of the epilimnion, cause partial or complete dioxygenation in the hypolimnion. The reducing conditions which then occur in the hypolimnion lead to the re-solution of iron and manganese, the production of ammonia and sulphides, and the release of phosphates and silicates.

As reservoir water will become an increasingly large component of the river Thames, the introduction of algal rich water to the river must be considered and controls placed on those discharges.

Management
The main factors affecting the potential for Abingdon reservoir to become eutrophic will be the winter level of phosphate in the source water, the rate of nutrient loss in the reserevoir, the turbidity and clarity of water in the reservoir and depth of mixing zone. In the UK, reservoirs with average depths of more than 15 m which are either naturally or artificially well mixed, have less problems than those with mixing zones less than 15 m.

Mitigation measures include phosphate stripping and timing of water draw-off. However it is often impossible to control the timing of abstraction and there may be long periods when water quality is not satisfactory. Artificial destratification to maintain the water body in an isothermal condition or artificial aeration of the hypolimnion are also important in maintaining good water quality. Management problems, other than water treatment, revolve around excessive weed growth and fisheries.

COMPENSATION OR RESIDUAL FLOWS

Prescribed flows are likely to be set around 450Ml/d. Water management in the UK has historically adhered to discharge-based methods in the setting of prescribed flows, being set according to the Dry Weather Flow. The Dry Weather Flow is indexed by a low flow discharge, typically either the 95 percentile flow duration statistic, or the mean annual minimum seven day flow frequency statistic.

In recent years there has been increasing interest in the concept of environmentally acceptable flowsrates (EAFR) This involves establishing flows that will maintain the biological and general environmental integrity of the river under other than the natural discharge regime. The concept entails determining the minimum flow requirements of the fauna, flora and to maintain amenity and water quality.

Although the theory behind the concept is sound, it is very difficult to define exactly what an EAFR should be in any particular stretch of river. The flow requirements of selected species of fish have now been largely defined, but comparatively little conclusive research has been carried out on the instream flow requirements of macroinvertebrates.

At present the NRA has commissioned an R & D project in Ecologically Acceptable Flows using models such as PHABSIM-Physical HABitat SIMulation . The results of their project will no doubt shed more light on the matter. However accurate assessments of habitat preferences require detailed analysis of microdistribution patterns in relation to flow velocity and substrate.

Compensation flows should in the meantime provide for the conflicting and varied demands. In ecological terms there should be sufficient flow in the river downstream of the abstraction to ensure that fish can breed and migrate successfully, to ensure adequate dilution to maintain water quality and to ensure water temperatures do not become excessively high and to maintain water levels such that ecological sites downstream of the reservoir retain their conservation interest.

Recommendations from a review of compensation flows below impounding reservoirs in the UK (Gustard *et al.* 1987) suggest that a re-evaluation of awards is warranted but that any negotiation of new awards should move away from simply setting prescribed flows as a fixed percentage of the mean flow. There is a recognition that aquatic ecosystems have specific flow requirements, which can bear little relation to existing compensation.

Progress in the development of methods for determining instream flow requirements for fish and invertebrates is such that river management policies and reservoir operational rules may soon be formulated to optimize both water and ecological resources.

FURTHER RESEARCH REQUIREMENTS

It is important to know more of the mechanisms which relate flow regime quantitatively to movements of bed material and to the infilling of gravels by sediment. This situation is complicated by the fact that managed flow changes may not be sufficiently great to alter the basic substrate type but may allow the deposition of a thin layer of fines.

REDEVELOPMENT OF STAINES RESERVOIR

PROJECT DESCRIPTION

- draindown of the reservoirs;
- rehabilitation and increase of bund heights;
- removal of bund separating the two reservoirs;
- possible alteration of draw off/fill arrangements;
- possible forced airation/circulation systems;
- possible additional pumping capacity.

PLANNING AND DEVELOPMENT

The reservoir is set within a built-up residential area and construction activities are likely to have an impact on this, particularly as deepening of the reservoir will involve large scale extraction of sand and gravel.

In addition, and as for other reservoir schemes, there will be an emergency planning issue to be considered in terms of the higher bunds and greater capacity and existing emergency scenarios will require updating and modification.

LANDSCAPE AND VISUAL

Impacts will be limited during much of the construction phase due to the screening effect of the existing bunds. However, works on the bunds themselves will result in a significant visual impact due to their extreme prominence.

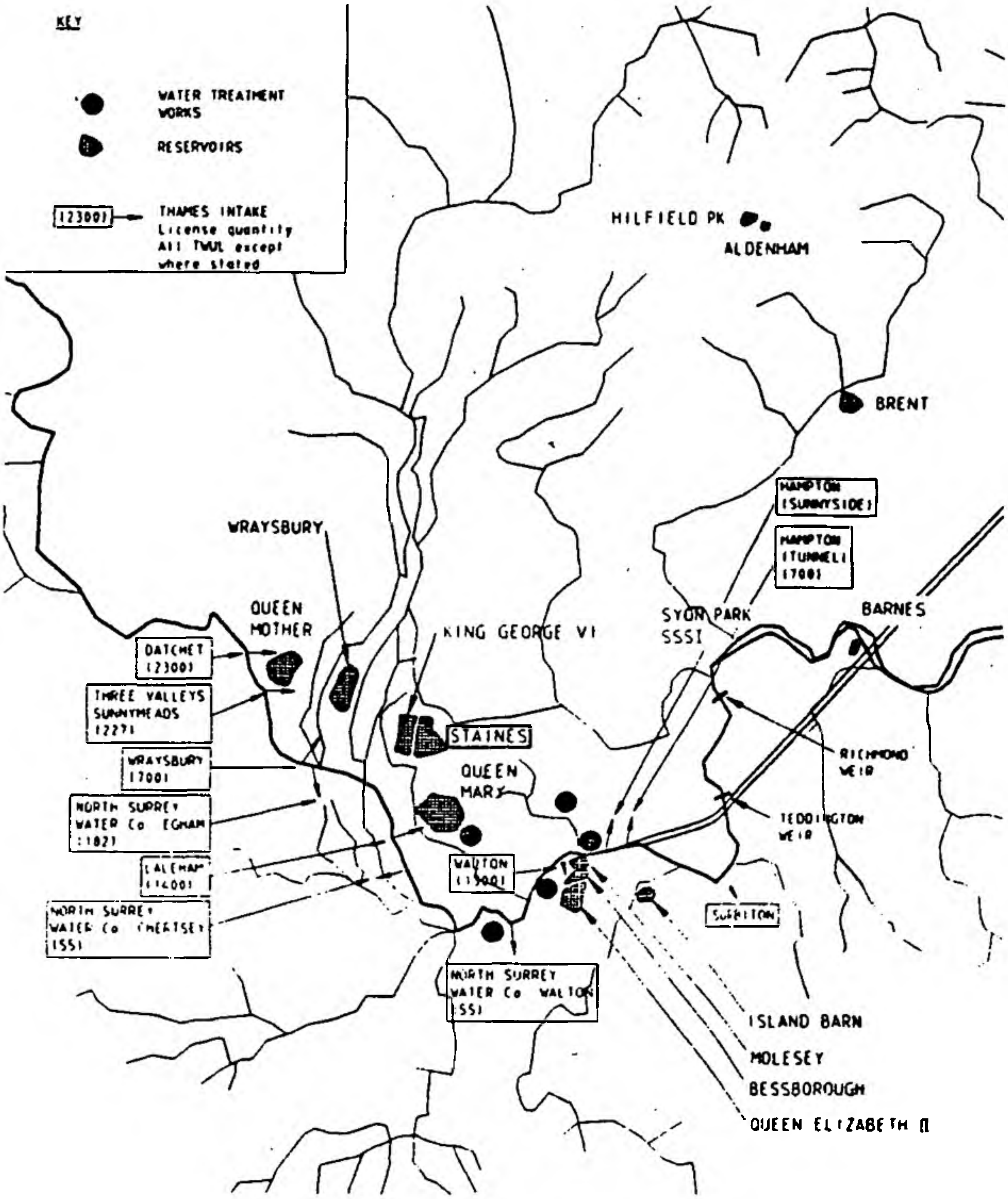
This prominence means that impacts once operational will also be significant as the bunds are already extremely intrusive within the built up area. They are straight sided and have a minimum of tree planting, with further screening opportunities severely restricted due to constraints on available land. Additional height of these bunds will be a significant impact.

RECREATION AND AMENITY

There will be significant impacts during construction when the reservoir will be completely drained thus eliminating any recreational use for the construction period. This loss is partially offset by the large numbers of water bodies in the vicinity, many of which offer recreational use. On operation it is assumed that recreational uses will be able to resume.

There are likely to be major detrimental impacts on the amenity of residential areas in the vicinity of the reservoir during construction, primarily due to the traffic flows anticipated. Construction will certainly involve large quantities of sand and gravel being exported from the site, for commercial use, and will probably involve significant quantities of imported material for bund construction. All of this is likely to require road transport with consequent severe impacts. On operation, impacts will be confined to additional loss of visual amenity as already referred to, due to increased bund heights.

RE-DEVELOPMENT OF STAINES RESERVOIR



ECOLOGY

Staines reservoir is a Site of Special Scientific Interest and is part of the network of reservoirs and water filled gravel pits in the Colne Valley which form an important habitat for wildfowl. Loss of Staines reservoir during construction will be a severe impact, but as with recreational impacts, will be offset by the presence of other water bodies in the area. Again it is assumed that impacts will largely be temporary and that on filling, a similar ecological resource will be created.

Other impacts, for example on water quality and expected to be minimal, although it will be important to ensure good site practice during construction, to avoid any pollution of adjacent water courses with suspended solids etc. Due to the increased depth and capacity of the reservoir it may be necessary to install additional operational measures such as bubblers to achieve water turnover and thus prevent stratification and eutrophication.

REUSE OF EFFLUENT DISCHARGED TO THE TIDAL THAMES

The Mogden effluent re-use scheme will comprise:

- filtration plant,
- ozonation plant,
- pumping stations to circulate and to transfer treated effluent to the river;
- 2.0 m diameter tunnel, about 7.0 km long, from Modgden STW to the river Thames at Sunbury;
- discharge works to the river, incorporating aeration.

At Deephams STW, the scheme will consist of:

- filtration and ozonation plant
- 700 mm diameter, pipeline from the STW to William Girling reservoir,
- discharge works to the reservoir, incorporating aeration;
- pumping stations to circulate effluent through tertiary treatment and transfer treated effluent to its reservoir.

PLANNING AND DEVELOPMENT

Environmental impacts associated with this option are likely to be limited and are difficult to quantify without going to the stage of detailed design of infrastructure.

Broadly, impacts out of the river are most likely in relation to the construction of a tunnel to convey treated effluent from Mogden STW for discharge into the river Thames at Sunbury upstream of Teddington weir.

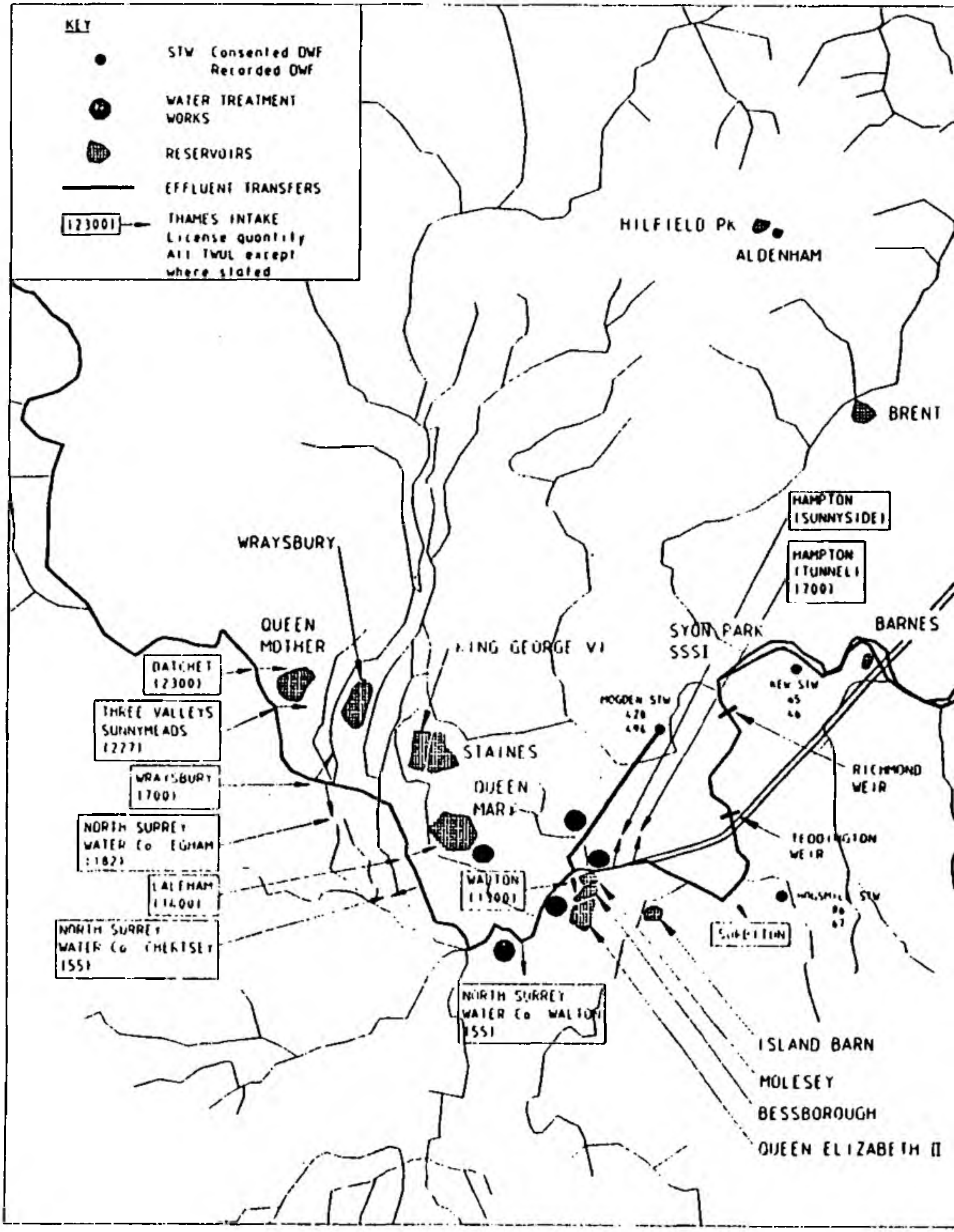
Re-use of effluent from Deephams STW would involve little or no disturbance arising from new infrastructure development as this could probably be accommodated within the existing works site. In addition, treated effluent would be discharged via a short pipeline into the William Girling reservoir adjacent to the treatment works, obviating longer distance pipeline routes.

LANDSCAPE AND VISUAL

There will be temporary visual impacts during construction, but these are not expected to be significant.

RECREATION AND AMENITY

Similar issues would arise at Deephams as for the Mogden works, except that there is a greater potential for perceived human and nature conservation impacts. The reservoir is identified in the Waltham Forest Unitary Development Plan (1990) as a principal Site of Nature Conservation Importance, as is the King George V Reservoir immediately to the north. Both reservoirs lie within the Lea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KING GEORGE VI
WRAYSBURY
QUEEN MOTHER
DATCHET (2300)
THREE VALLEYS SUNNYMEADS (227)
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NORTH SURREY WATER Co EGHAM
STAINES
QUEEN MARY
WALTON (11300)
NORTH SURREY WATER Co CHERTSEY (55)
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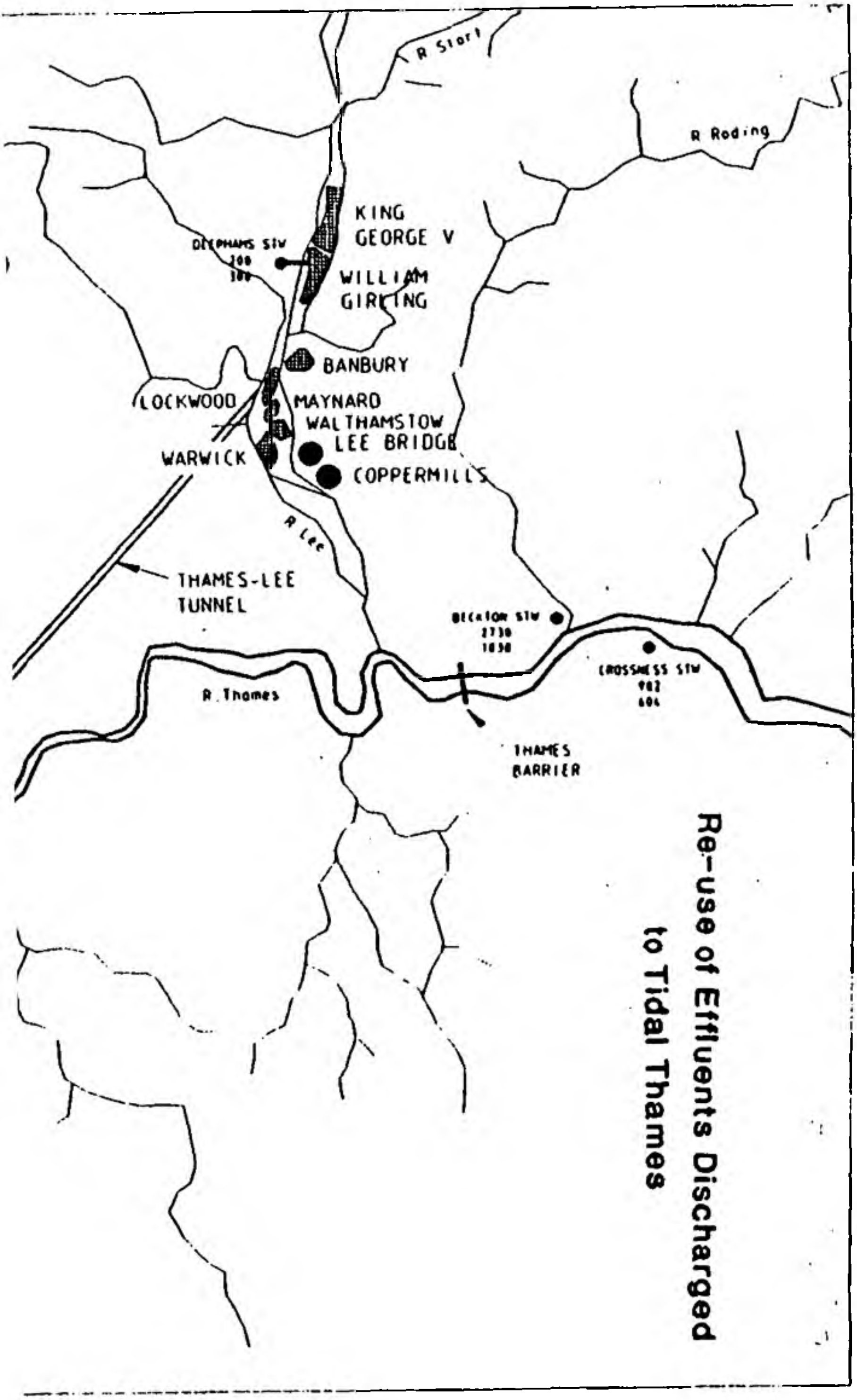
BESSBOROUGH
QUEEN ELIZABETH II



Re-use of Effluents Discharged to Tidal Thames

Valley Park and have a number of recreational uses including canoeing and sailing.

ARCHAEOLOGY AND HISTORY

There may be some potential for archaeological disturbance of land at the riverside but this is likely to be slight. In order to properly mitigate archaeological impacts, desk research supported by field evaluation should be undertaken where necessary.

AQUATIC ECOLOGY

The main in-river issues relating to this option are those of water quality and public acceptability. As flows between Sunbury and Teddington reach will largely comprise effluent, major problems could result from a failure in the STW. Variability of effluent quality could also be a problem together with ongoing management of the stream.

A failure in the STW followed by a closure would result in little or no flow over Teddington unless accompanied by a reduction in river abstraction. If the treatment works were not closed, there would be the risk of significantly lower water quality. The modular form of treatment processes would ensure that total failure of the STW would be most unlikely. In the event of closure of the STW, discharge of effluent would be switched to the tideway outfall.

There will not be any significant benefit in flows over Teddington weir as the volume of effluent discharged to the river will equate to the additional volume of water that will be abstracted upstream.

As stated, William Girling and King George V Reservoirs are SNCIs. This is understood to relate primarily to their ornithological interest however, and is unlikely to be affected by discharge of treated effluent from Deephams STW. The public perception of this issue may require addressing however.

While impacts are in reality unlikely to be significant the effects on promotability and public perception of this option require careful evaluation.

(SEVERN-THAMES TRANSFER AND) GRAVEL PIT STORAGE

PROJECT DESCRIPTION

Typical works required for this option are:

- introduction of slurry trenches around the perimeter of each trench to prevent seepage from, or groundwater seepage into, the gravel pits;

- inter-connecting and by-pass pipework to each pit;

- low lift pumping station for transfer to the river Thames at Buscot.

PLANNING AND DEVELOPMENT

The main planning issue involved is the identification and designation of appropriate locations for the storage element of development. At present, there are four main locations which appear suitable in principle:

- Down Ampney, south of Cirencester;
- Stanton Harcourt, south east of Witney;
- Bampton, south of Witney;
- Cassington-Yarnton near Kidlington.

All are either formally identified for gravel extraction or are subject to existing consents/working with the exception of Bampton which is at present only informally identified for future extraction in the longer term.

In order to establish whether water storage is a viable and acceptable restoration use it will be necessary to reach agreement with both the planning authority and landowner. The planning authority may prefer restoration to agriculture for some areas, and this is certainly the case at Down Ampney.

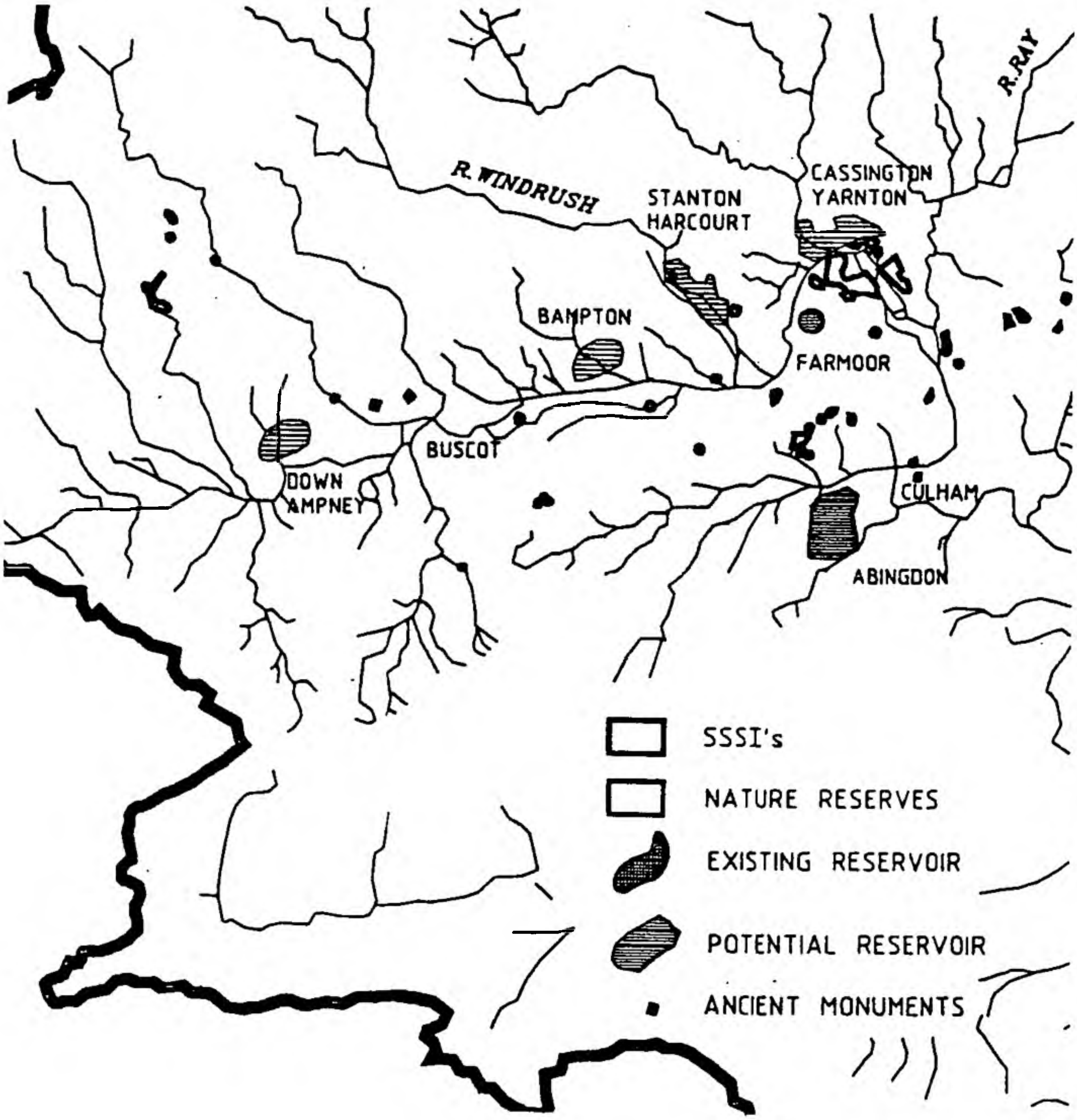
Landowners will often wish to restore voids by landfill wherever possible for commercial reasons, and significant levels of compensation might arise in the event that water storage were forced upon them. It is however, important to note that most of the gravel pit storage areas lie within or close to the flood plain which will significantly restrict potential for landfill.

AGRICULTURE AND DRAINAGE

The issue of loss of agricultural land will normally have been addressed at the mineral extraction proposal stage. Therefore for those areas where the accepted restoration strategy is to water, the issue will not arise in connection with reservoir proposals.

The notable exception to this scenario is at Down Ampney where the Ministry of Agriculture Fisheries and Food (MAFF), and the planning authority strongly favour restoration to agriculture. A proposal for water storage will need to address this conflict, but it will be necessary to identify just how feasible restoration to agriculture would be. Soil spreading at gravel pit base levels is likely to be a problem due to the water table, and it is not clear whether sufficient inert landfill materials will be available to restore levels.

Gravel Pit Storage in Upper Thames



Drainage may be a more critical factor, as the NRA-TR Drainage and River Management departments have raised the issue of loss of flood capacity as a potential constraint to this option.

All of the gravel extraction areas identified lie at least partly within the flood plain of the Thames with the exception of Down Ampney which is affected by flood areas associated with Ampney Brook. While use of gravel pits as they exist at the end of working for water storage would raise no problems, if bunding above ground level were required then very significant areas of flood storage capacity may be lost. This would be an unacceptable impact on flood control and would be strongly resisted.

The issue of groundwater movement through gravels and interruption/diversion around lined gravel pits is not considered to create significant environmental impacts.

LANDSCAPE AND VISUAL

Impacts which need to be taken into account are those arising from the creation of the water bodies - rather than the principle of development through mineral extraction. In other words, use for water storage follows a much more disruptive land use which would have taken place regardless of the reservoir function. In general terms, construction impacts will be less significant than for other reservoir development as works will take place within existing void areas.

Restoration to water is often looked upon as a significant positive impact of mineral extraction. However, at Down Ampney, which already lies between two areas of water park, this would almost certainly be regarded as an undesirable impact. In all cases, the creation of large bodies of water within what is a predominantly agricultural landscape must be regarded as a significant landscape impact, although not always either detrimental or beneficial.

If bunding above ground level is required for greater capacity, then similar visual and landscape effects will arise as for reservoir development such as the Abingdon/Drayton proposal already reviewed. These effects will however be much smaller in scale as the bunds are likely to be smaller, while still lying in a flat landscape, with limited long distance view points. The same careful treatment of bunds through variation of line and slope will be required together with planting schemes in order to minimise the impacts of any purpose-engineered structures.

Impacts arising from infrastructure associated with gravel pit storage will be similar to those discussed in relation to a reservoir at Abingdon/Drayton. Again however, it will be necessary to minimise any impacts arising from the abstraction/discharge elements where they are proposed for riverside or other prominent locations.

RECREATION AND AMENITY

Significant recreational benefits would accrue from use of gravel pits for water storage although planning policies are more likely to control uses then perhaps has been the case in the past, due to the extent of water based recreation already available in, for example the Cotswold Water Park. The potential for such use will depend therefore to an extent on the location of the pit, should this option be pursued.

Negative effects on recreation or amenity aspects are considered unlikely to arise.

ARCHAEOLOGY AND HISTORY

Due to the fact that this option utilises areas of worked out gravel pits, it is not considered that significant archaeological impacts will result.

TERRESTRIAL ECOLOGY

Stanton Harcourt

There are two sites of nature conservation importance within the defined area, Vicarage Pit Local Nature Reserve (LNR) which is a Local Authority designation, and Ducklington Mead which is a water meadow SSSI. Construction of gravel pits should avoid these sites.

Cassington-Yarton

Within the defined area lies the Pixy and Yarnton Meads SSSI; this site falls within the area of greatest objection to gravel extraction. Just south of the Thames is another wetland SSSI, the Wytham Ditches and Flushes.

Down Ampney

There are no SSSIs or LNRs within the defined area, although there are a number of important wetland SSSIs just outside the area, Whetford Meadow and the North Meadow Cricklade Natural Nature Reserve (NNR).

CONSERVATION GAIN

Like the Abingdon reservoir, gravel pits could provide nature conservation opportunities. Many gravel pits have been designated as SSSIs. There is however greater opportunity with Gravel Pit storage that abstractions will occasionally conflict with nature conservation. Careful design and management can often help eliminate this.

NRA Conservation Division did express concern over any possible disruptions to ground water flow. Gravel workings and other developments have reduced ground water flow into the Staines Moor area and thus dried part of it out. If the pits are sealed and do not draw in water from neighbouring streams no significant environmental impacts are foreseen.

The Upper Thames and its tributaries have just been proposed an 'Environmentally Sensitive Area' commencing 1993. This would mean that Farmers/landowners would be allocated grants to maintain or restore habitats of conservation interest, reducing intensive farming inputs.

This may mean that there would not be a presumption to allow the after use of gravel pits to be open water, rather, there would be encouragement to restore them to woodland and flood meadows. It is likely however that designation of an ESA will not make a significant difference to the policy context for this option.

AQUATIC BIOLOGY

As with the Abingdon Reservoir, eutrophication is likely to be a problem as is the potential for discharging algae rich water, although this will depend on the nutrient status of the transfer water. It will also depend on where along the recipient river, water was abstracted from, as the phytoplankton population will differ. This could be controlled with appropriate discharge consents. Release water may have less nutrients although it will depend on residence time. The advantages of storing the transfer in gravel pits prior to discharge is that there will be a further reduction in sedimentation. It is also possible to contain pollution incidents, which would not be possible with direct discharge.

SEVERN-THAMES TRANSFER

PROJECT DESCRIPTION

The components of this option comprise:

- low lift pumping station on the River Severn at Deerhurst;
- bankside reservoir of 3 days storage capacity, for sedimentation purposes and for covering emergency closure for pollution events; storage 1200 Ml.
- high lift pumping station adjacent to reservoir to lift water up Cotswolds escarpment to around 150 m AOD.
- 2.0 m diameter pipeline for 53 km from Deerhurst to Buscot, with a high point at the Birdlip gap of 260 m AOD; pumped pipeline on the northern leg, and gravity pipeline south from the escarpment;
- break tanks and highlift pumping station at around 150 m AOD to lift water up to escarpment crest at 260 m AOD.
- bankside reservoir of 3 days storage capacity at Buscot; storage 1200 Ml, for miding of water, further sedimentation;
- river discharge structure.

For the sub-option where the Severn transfer water is discharged direct to the Abingdon/Drayton reservoir, the following changes are required:

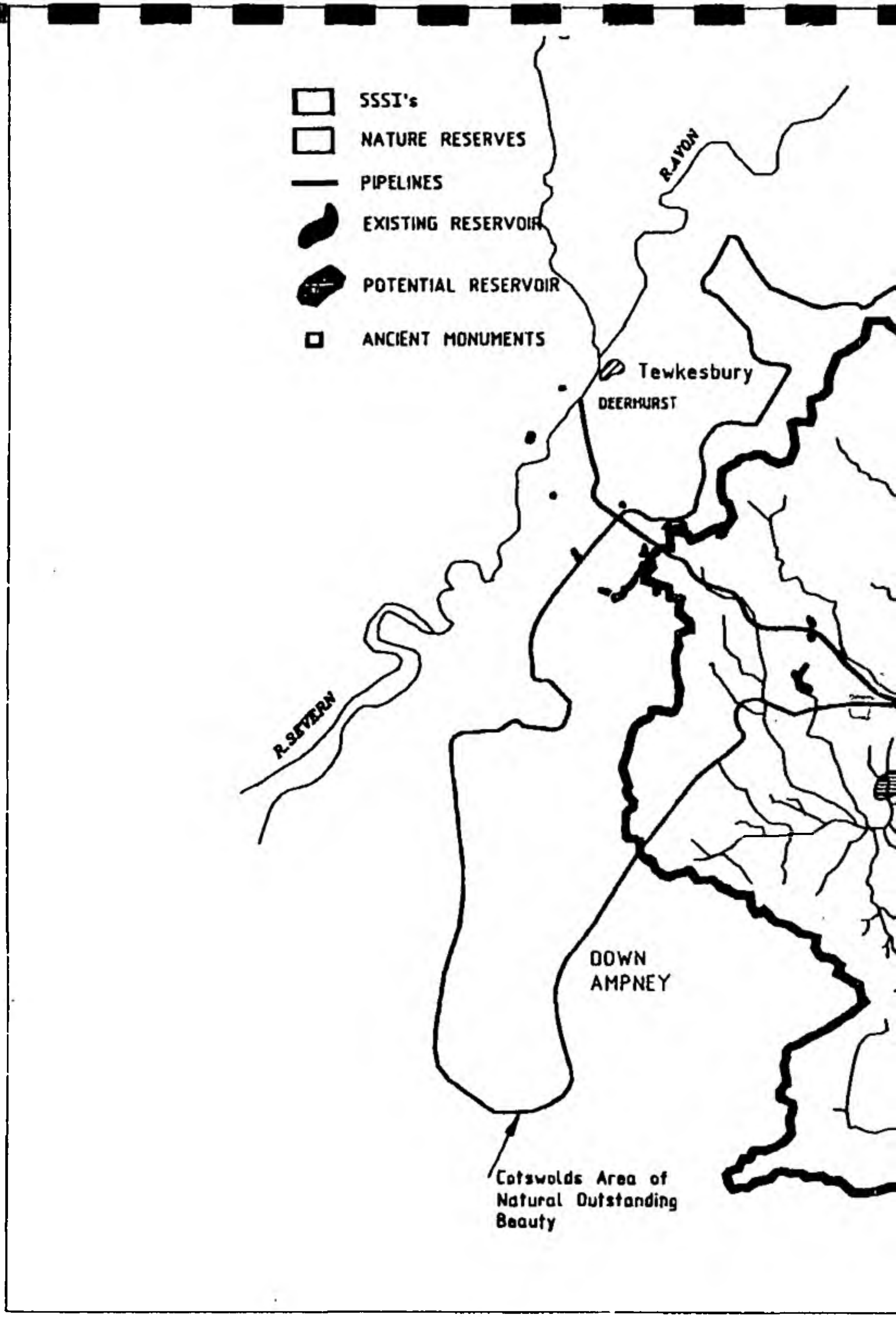
- 21 km extension of the 2.0 m diameter pipeline from Buscot to the reservoir;
- discharge/entry structures into the reservoir;
- no bankside storage at Buscot; however the river discharge point will be needed for emergency closure/drainage purposes.

PLANNING AND DEVELOPMENT

Impacts will result from the construction of pipeline and tunnel for the transfer, and from land-take for the construction of treatment facilities (including bankside storage), pumping stations and discharge infrastructure.

The planning policy context for this option is not a significant issue apart from the national designation of the Cotswold Hills Area of Outstanding Natural Beauty, through which any pipeline route must pass. This issue is evaluated under the heading landscape impacts.

Land-take for bankside storage at the Severn abstraction point at Deerhurst may be considerable, involving up to 40 ha of bunded reservoir. There will also be a number of pumping stations required which will each involve planning impacts requiring detailed appraisal. Finally, infrastructure for discharge into the Thames at Buscot, if this element of the option is pursued, will also have a planning impact through land-take, and its relationship to existing residential and recreational development use there.


SSSI's
NATURE RESERVES
PIPELINES
EXISTING RESERVOIR
POTENTIAL RESERVOIR
ANCIENT MONUMENTS
R.AVON
Tewkesbury
DEERHURST
R.SEVERN
DOWN AMPNEY
Cotswolds Area of Natural Outstanding Beauty

SEVERN - THAMES TRANSFER

Planning effects during construction will be significant, with impacts for each of the elements mentioned above, and potentially major impacts at tunnel construction points. Pipeline impacts are likely to be temporary in character and less significant.

With the level of detail currently available it is not possible to identify site specific development impacts, however, a broad constraints map for pipeline routing has been prepared.

AGRICULTURE AND DRAINAGE

Land-take at Deerhurst and Buscot will affect agricultural land of good quality located in the river valley. With the need for up to 40 ha to accommodate settling lagoons and associated works there are potentially significant effects on farm viability which must be further evaluated. Elsewhere, pumping stations, pipelines and access for new infrastructure may involve severance of fields, or at the least interference with agricultural practices, on either a temporary or permanent basis. More detailed design of pipeline routes will need to take account of these potential impacts.

Local disturbance of drainage systems may result, but as with other options, straightforward mitigation through appropriate engineering is possible. Potentially more significant are effects arising from lost flood capacity at Deerhurst, together with the possible increased frequency of inundation of farmland and a rising water table due to higher levels in the Thames.

Inquiry should be made of NRA Severn Trent Region in order to confirm whether the loss of up to 40 ha of flood plain at Deerhurst will be significant in terms of flood control, as the creation of bunded reservoirs in similar locations in the Thames region has been identified as a potential problem.

With regard to the possibility of loss or lowering of quality of river-side agricultural land, NRA-TR Drainage are of the opinion that impacts are unlikely to be significant in policy terms. As mentioned with reference to Abingdon reservoir, the importance of protecting agricultural land has reduced significantly, and in fact, the opportunity for nature conservation gains in the form of wetlands and water meadows along the river may be a significant positive impact of increased flows in the Upper Thames. It should be noted however, that compensation claims may be made in certain circumstances by farming interests. The potential significance of these should be assessed within NRA-TR.

LANDSCAPE AND VISUAL

The pipeline route between the Severn and the Thames will need to pass through the Cotswold Hills AONB and therefore impacts, particularly at the construction stage, are potentially severe and more contentious than might have been the case in areas with no landscape designations.

The transfer is likely to be a pipeline from Deerhurst to a point just south of Cheltenham. This length will have significant landscape and visual impacts during construction, but these will be temporary and with proper restoration should not involve long term residual effects.

From Cheltenham it is anticipated that there will either be a bored tunnel through to the dip slope of the Cotswolds, or further pipeline following essentially the same route. From the landscape and visual impacts point of view both options will involve significant temporary impacts. Tunnelling will require periodic construction sites and the removal and disposal of large quantities of spoil,. The pipeline will involve the cutting of a swathe through the countryside, but the construction period will probably be shorter.

On balance it is felt that tunnelling will create fewer landscape and visual impacts overall, and will also avoid impacts on nature conservation features on the surface. It would be desirable to adopt this method of transfer through the AONB if engineering and cost criteria permit.

The landscape around Buscot is sensitive, consisting of low lying meadows fringed with willow, and attracts a significant amount of recreational use. The installation of pipeline and discharge/treatment infrastructure will have potential for significant impacts during construction, and longer term if bankside installations are required.

The option of an extended pipeline to a new reservoir at Abingdon has been discussed elsewhere in this report, and it is necessary therefore to consider any impacts which might result from this. The additional length of transfer would be by pipeline and would involve cut and cover similar to that from Deerhurst to Cheltenham.

Significant temporary impacts would arise during construction and for a period after until restoration was complete. As for other routes, it would be desirable to avoid passing through woodland where clearance would take much longer to recover. A positive landscape and visual effect would result from transfer direct to Abingdon through the avoidance of potentially detrimental works at Buscot. Depending on the type, extent and permanence of such works, their avoidance could be a significant benefit.

RECREATION AND AMENITY

Significant impacts will arise during construction where pipeline/tunnel works are in close proximity to footpaths, roads and residential areas. The designation of the Cotswolds AONB reflects the importance of the area for recreation. Detailed consideration of routing will need to take account of these constraints, but it is not possible at this stage to be specific about impacts apart from the fixed locations at Deerhurst and Buscot.

The River Severn at Deerhurst has public footpaths along both banks and there is a complex network of footpaths and bridleways in the vicinity. Dependent on the precise location of infrastructure for water abstraction and treatment there is significant potential for short and long term impacts on the recreational resources of the location, and on the amenity of users and residents. A golf course lies approximately 1 mile north east of Deerhurst and enjoys views over the river, and will form an added receptor.

Buscot enjoys a similar level of recreational use with riverside footpaths, a popular public house and National Trust ownership of Buscot itself. In addition the river is very popular with boating enthusiasts and is used intensively partly as a result of the presence of a small marina at Lechlade.

Construction operations at these sites will need to take account of these pressures, but most significant impacts are likely to arise from permanent installations. Location and design of structures will therefore be critical.

ARCHAEOLOGY AND HISTORY

As with other environmental constraints for this option it has not been possible to identify specific impacts at this stage due to the fact that only broad corridors and not precise routes have not been identified. As with most areas of the British Isles however, the broad route corridors are likely to be rich in archaeological and historical remains. Lechlade in particular has well researched archaeological features and any development within close proximity to the Severn or Thames is likely to encounter archaeology of a number of different periods.

As a consequence pipeline route corridors will need to be refined and narrowed according to other environmental constraints, and a detailed desk review should be carried out to identify known features in proximity to the route. Where unavoidable disturbance to known sites is involved then provision for full and proper excavation of remains will be required. Elsewhere a watching brief will need to be maintained for recording new evidence which may be discovered as construction continues. Techniques for studying the archaeology of pipeline construction are well established and negative impacts can therefore be avoided or satisfactorily mitigated.

TERRESTRIAL ECOLOGY

Physical Effects

A number of impacts are associated with pipeline construction, however it is difficult to predict the full extent of these at this stage. The types of impacts that might arise include changes in hydrology and soil structure. These might be significant where the pipeline lay adjacent to ecologically significant wetlands or where soil structure (drainage/water retention) played a major role in the structure of vegetation communities. Provided that these issues are recognised at an early stage there should be no reason why appropriate mitigation measures could not be developed.

Loss or fragmentation of Habitats

This will be the principal cause of ecological impacts and an initial assessment of Sites of Special Scientific Interest for 5 km either side of the proposed route has been carried out. Wherever possible the pipeline should avoid sites of ecological importance that have national or regional status. Furthermore, attempts should be made to avoid features of natural history interest such as ancient woodlands and unimproved meadows. At present the preliminary alignment of the pipeline directly affects 2 SSSIs and possibly a third depending on the extent of landtake needed by the works.

Construction work may result in temporary disturbance to animal communities and care will be needed to minimise these. Of particular note are impacts on protected species such as Badgers and Great Crested Newts. Where effects are temporary, mitigation measures can be put in place in most instances. Revegetation strategies will be necessary after construction. Details of such approaches are widely available and should be recommended as part of environmental mitigation measures.

AQUATIC BIOLOGY

The environmental impacts of the Severn-Thames transfer will depend principally on the magnitude and frequency of the transfer volume and the quality of water from the donor river. The flow conditions produced in the Upper Thames by a transfer of 200 ml/d would be within the natural variation already experienced by the river. However the monthly mean flow at Buscot would be doubled in August and September. Transfer volumes in the region of 400 ml/d at Buscot, would result in flows exceeding monthly maximum flow in July, August and September and approaching monthly maximums in June, October, November and December.

There have been few studies pertaining to the effect of catchment transfers on the aquatic biology of the donor and recipient rivers. Most discussions of the ecological and fisheries effects of the river transfer have taken place at the planning stage and thus tend to be predictive with no post-transfer data to confirm the predicted effects.

The most obvious effects would be long term increases in flow velocity, changes in water chemistry and short term velocity fluctuations which may adversely affect both slow and fast flow fish, invertebrate and macrophyte species.

Physical impacts

Flow regime and velocity
Coarse fish found in the Thames are those typical of slow flowing lowland rivers and flow velocities may be critical for some species. Carp, bream and tench require slow flows for successful completion of the early stages of their life cycle. For species such as bream and roach, spawning takes place in dense weeds in very shallow water. This could be affected by un-seasonally high volumes of water during summer.

Large increases in flow velocity can sweep away the juvenile life stages of both fish and aquatic invertebrates. Changes will be particularly acute if the higher flow is sustained for long periods and occur during the summer.

Fish, invertebrates and plants have certain flow velocity requirements and they inhabit places where the flow regime is suitable for them most of the time. They can survive temporarily adverse flow conditions if they are of short duration, seeking shelter during flood flows in eddies or behind obstructions or sometimes burying into the substrate. Increased velocity can scour salmon and trout redds, washing away newly hatched alevins, and could result in the movement of cyprinid fish species to slow flowing reaches within the recipient river. The Thames is an EC designated Cyprinid fishery.

Salmon, trout, and grayling inhabit faster flow velocities than carp, bream and tench. Changes in flow velocity could bring about changes in fish populations even though the maximum velocity induced may well still be within the pre-transfer maximum during flood flows. The latter occur only temporarily whilst transfer flows are more long term.

Flow velocities affect invertebrate fauna through shifting of bed material, and destruction of fauna, or its occlusion by siltation, downstream displacement of certain species, and alteration in the texture of the river bed. This could result in subtle changes in species composition, favouring those with higher velocity preferences. It could also result in the removal of detritus and detritus feeders. The effects of changing flow velocity on river beds are complex and depend upon a number of different factors which need further research.

Sudden introduction and cessation of large intermittent transfer flows are thought to be particularly damaging as this could affect both slow and fast flow species. Migratory salmonids have the most critical flow requirements; non-migratory salmonids and coarse fish are less susceptible.

Obviously the rate at which a transferred flow is introduced into and arrested from a recipient river is important. It has been suggested that flow alteration should not exceed rates normally occurring in natural floods and build-up and die-down should occur over 24 hours.

Despite a number of predictions in the UK no attempts have been made to carry out audits on existing transfer schemes. Invertebrate data relating to the Ely-Ouse to Essex transfer is sparse. There is some evidence that the sudden surge of water in the recipient streams at the onset of transfer had a similar effect on invertebrates to that of a natural spate. Boon (1976) found that populations of *Gammarus* were markedly reduced following an increase in flow caused by experimental release of Ely Ouse water to the River Colne. Responses of invertebrates to chemical changes brought about by the scheme remains undocumented.

Temperature
There may be a number of temperature dependent effects depending on whether the donor water was significantly lower than the recipient water. Effects could include retarded life cycles and growth rates.

Macrophytes
Certain macrophyte species typical of still and slow waters will be less tolerant of prolonged higher flow rates. At higher rates of discharge the type of vegetation could change, especially if it results in changes in the depth of channel, nature of river bed and amount of turbulence.

Transfer and Recreation
Angling is thought to be the only recreational activity likely to be affected by the proposed scheme, for the reasons outlined above.

Benefits of increased flows include maintaining flows in dry weather periods which would be beneficial to aquatic fauna, fisheries and anglers alike. In addition there may be benefits to Thames-side meadows.

Chemical Impacts

The information that has been provided on the Thames and Severn water quality indicates that the Thames between Busot and Swinford has higher alkalinity and hardness than the lower Severn and a much lower chloride and suspended solids content. Bankside storage of Severn water will assist in reducing suspended solids.

Possible biological effects of changes in water quality include effects on salmonids whose numbers have increased in the Thames over recent years. Changes in water quality could alter the homing response of upstream migratory salmonids. The 'homing' of migratory fish such as salmon and sea trout to their natal rivers and streams to spawn could be affected by inter-basin transfers, as the changes in water quality could add a 'foreign smell' if in operation during the smolt or adult migration period. If transfer is continuous and occurs all the year round, homing would not be affected.

River transfers will tend to run north-west to south-east, with soft waters transferred into hard water. Water hardness pH and correlate strongly with distributions of some macroinvertebrate taxa and species assemblages. *Gammarus pulex*, several species of mollusc, some ephemeropteran and net spinning caddis are absent from acidic soft waters. However in most hard water the calcium concentration is well above the limiting level for hard water invertebrate species and a dilution with softer water such as the Severn transfer it is unlikely to have a great effect on invertebrate fauna. The RIVPACS model has not yielded conclusive results on the likely species changes that will occur.

Other important considerations include possible pollution incidents in the Severn river and how such incidents may be controlled. A serious incident occurred in the Ely Ouse transfer when a release of trichlorobenzoic acid (TBA) to the Ely Ouse was transferred to the Stour resulting in the failure of tomato crops irrigated from the river.

Biological Impacts

One factor of particular relevance to all of the transfer options is that of algal production. Phytoplankton tend not to develop into severe 'bloom' proportions in northern European rivers because their generation time is a few days and the discharge of even slow rivers is only in the order of a few weeks. Thus relatively few algal generations occur during transit from source to mouth. Even so there are large enough populations in the lower reaches to cause problems near the sea. In large rivers such as the Severn and Thames the retention time is sufficiently long for large populations of planktonic algae to build up. When water is transferred from the bottom end of a river to the upstream end of another, it further increases the effective length and retention time. Introduction of Severn water containing high densities of algae could speed up the time in which maximum population levels were reached and extend the zone of maximum density further upstream.

Problems of this nature have occurred on the Ely-Ouse transfer scheme. Blooms have tended to increase pH values, and reduce O_2 levels at night, by respiration and decomposition.

The Thames and Severn have similar algal floras, and both rivers can produce high spring densities. Recent research by the Institute of Freshwater Ecology (IFE) (Reynolds, pers comm) has confirmed this.

Disease/Parasite transfer
Due to canal systems linking the Thames to the west, the biological differences between the Thames and Severn systems appear to have diminished. NRA Fisheries department do not consider this to be a major concern.

Predators transfer
The Ely-Ouse transfer scheme resulted in the transfer of the predator fish zander. However, since this fish is already present in the Thames and fish species are similar in the Thames and Severn, transfer of undesirable fish is unlikely to present problems.

Further research requirements
It would be advantageous if pre-transfer surveys and monitoring of the effects of post-transfer operations were carried out. Other areas of research which would be particularly relevant to inter-basin transfers include the response of upstream migration of salmonids to changes in flow regime, the potential of transfers to

disrupt the homing of migratory salmonids, and the spawning requirements of fish in relation to flow velocities.

SEVERN-THAMES TRANSFER AND ABINGDON RESERVOIR

Transferring water from the Severn and placing it into the reservoir rather than either directly into the Thames at Buscot or into storage at Buscot would appear to be preferable from an environmental point of view. The upper Thames is a relatively unspoilt part of the Thames river (although suffering from effluent from Swindon) and it would be difficult to transfer more than 200 Ml/d without resulting in significant adverse impacts. From a biological point of view putting water from the lower end of the Severn into the middle reaches of the Thames is preferable to placing it into the upper reaches. This will reduce retention time and thereby reduce the possibility of algal blooms. In addition the overall quality of the lower Thames is closer to that of the lower Severn due to the presence of effluents and there is therefore less likelihood of impact on invertebrates and fisheries.

ANGLIAN TRANSFER - THAME INCLUDING RESERVOIR AT WADDESDON

PROJECT DESCRIPTION

This sub-option involves the following works:

- intake on the Great Ouse, below the discharge point of the Anglian region transfer;
- pumping station adjacent to intake, maximum rate 100 Ml/d;
- 1.0 m diameter pipeline for 73 km to discharge to a reservoir at Waddesdon;
- 17 m high dam, and saddle dam at Waddesdon providing storage of 30,000 Ml;
- gravity pipeline of 1.4 mm diameter from reservoir to the river Thame in the Waddesdon to Shabbington reach, passing through the Shabbington gauging station, maximum release 200 Ml/d;
- possible minor channel works to the river Thame;
- measures to aerate/circulate the reservoir waters to prevent stratification and eutrophication.

The reservoir at Waddesdon would involve the following works:

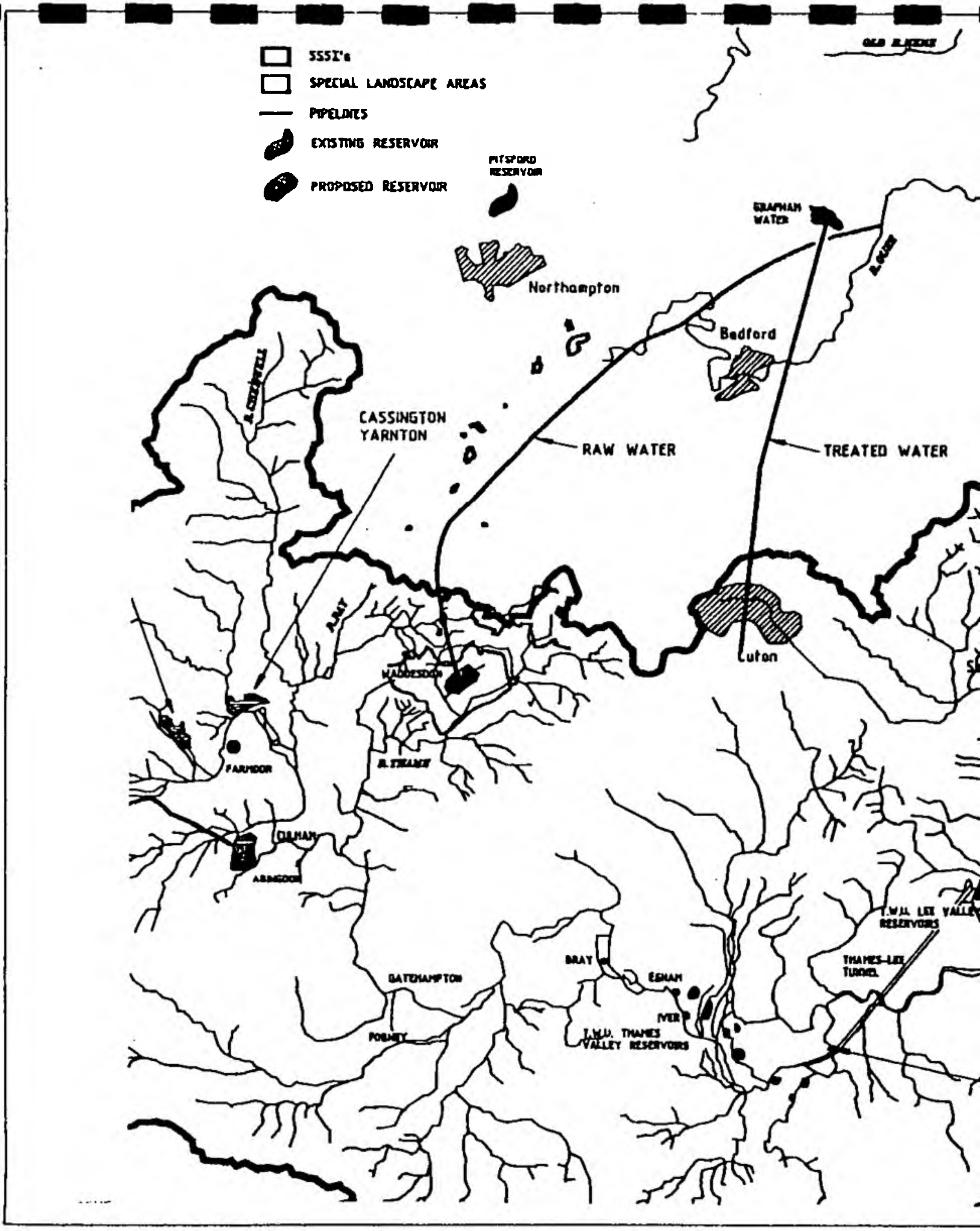
- 17 m high main embankment approximately 1200 m long;
- 5 m high saddle dam approximately 600 m long.

INTRODUCTION

Many of the broad impacts identified within the Abingdon/Drayton reservoirs and the Severn-Thames transfer options are equally applicable to this option in terms of the laying of pipeline and possible construction of a reservoir. The chief difference from these is in terms of the scale of the receiving river. The river Thame is much smaller than the Thames and therefore has less ability to absorb impact or change without a significant change to it's own character. This is applicable primarily to in-river characteristics, but is to an extent also relevant to broader environmental elements. In addition the landscape to Waddesdon is considerably more sensitive than at Abingdon thus leading to greater potential for negative impacts.

PLANNING AND DEVELOPMENT

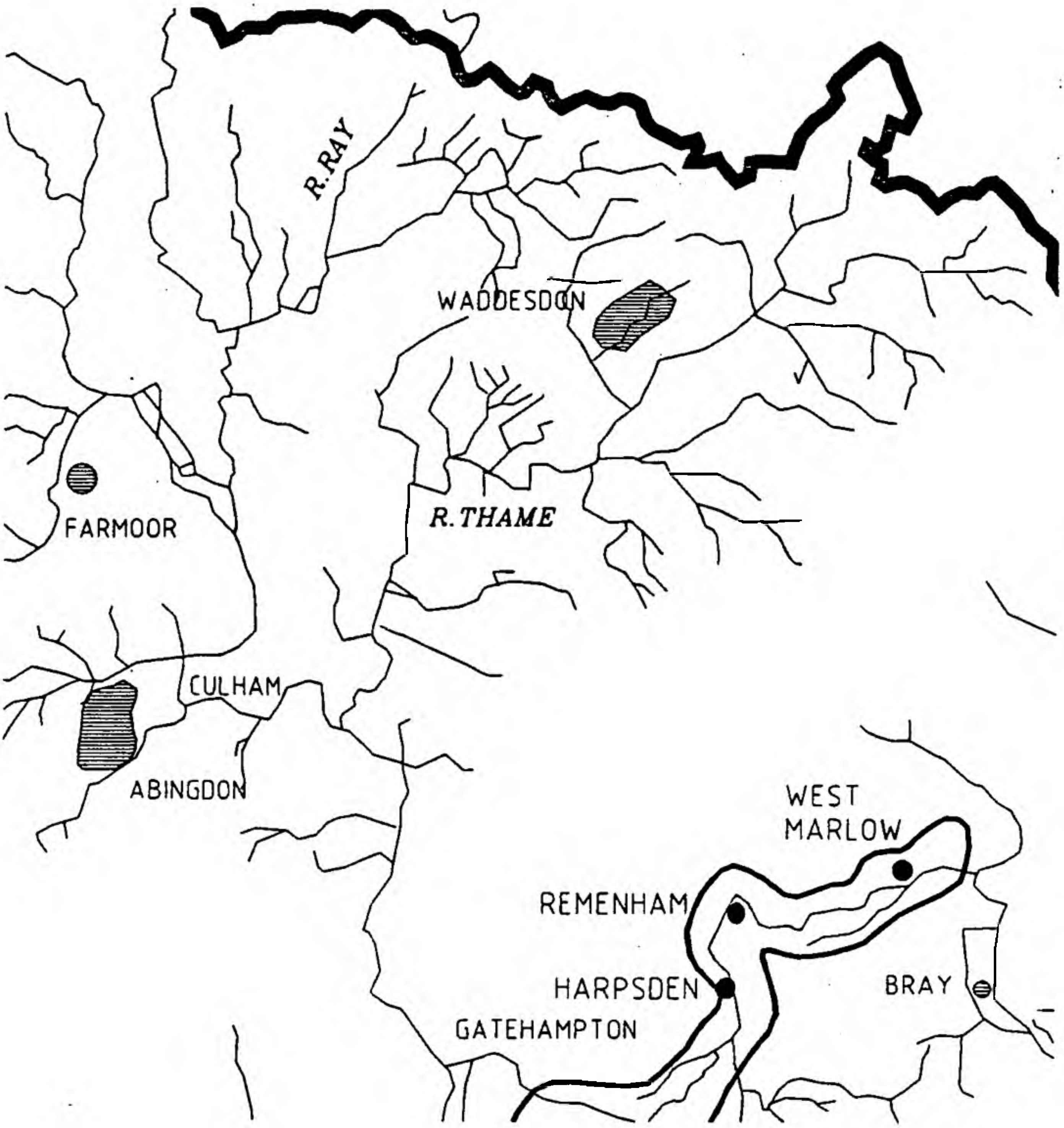
As stated, the broad impacts of pipeline and infrastructure provision will be similar to those identified for the Severn-Thames transfer option. The pipeline will not however, pass through any designated landscape areas, apart from at Waddesdon where the pipeline and proposed reservoir will lie within an Area of Attractive Landscape identified by the Buckinghamshire Structure Plan.



SSSI's
SPECIAL LANDSCAPE AREAS
PIPELINES
EXISTING RESERVOIR
PROPOSED RESERVOIR
PITSFORD RESERVOIR
Northampton
Bedford
CASSINGTON
YARNTON
RAW WATER
TREATED WATER
Luton
R. RAY
FARMOOR
CULHAM
ABINGDON
R. THAMES
BRAY
EGHAM
IVER
T.W.U. THAMES VALLEY RESERVOIRS
GATEHAMPTON
T.W.U. LEE VALLEY RESERVOIRS
THAMES-LEE TUNNEL

ANGLIAN TRANSFERS TO THAME
AND FROM GRAFHAM WATER

Reservoir at Waddesdon



This policy is significant in relation to the reservoir proposed and if the option were pursued, early discussion with the planning authorities would be required in order to establish their attitude to the proposal in relation to the policy context.

Development impacts at the reservoir site would be significant and potentially greater than at Abingdon as a larger amount of material might have to be imported to the site for construction. One road might require realignment, and up to seven households would require resettlement.

AGRICULTURE AND DRAINAGE

Up to 6 km^2 of agricultural land would be lost for the reservoir, mostly of grades 3A and 3B. While significant, the loss is unlikely to be as contentious as when the proposal was last discussed with MAFF in the 1970s, however, objections made at that time are likely to remain, if perhaps less forcible. It is important to note that up to 7 farmsteads would be inundated, involving significant compensation.

Similar local impacts on agricultural operations and drainage will arise from the pipeline, to those identified in the Severn-Thames option. These will largely be temporary in nature, or can be satisfactorily mitigated through appropriate engineering solutions.

LANDSCAPE AND VISUAL

Very significant impacts will arise from the reservoir aspect of the option, due to the structure proposed and the quality of the surrounding countryside. The reservoir proposed in the 1970s involved an embankment height of up to 41 m which would have a major landscape and visual impact within the high quality countryside present. For this study an embankment height of only 17 m is proposed.

Construction impacts associated with the reservoir are also likely to be more significant than at Abingdon, primarily due to the topography and quality of the existing countryside, but also because access to the site is poorer - and more sensitive to change. Impacts relating to pipelines will be temporary in nature and similar to those covered in the Severn-Thames transfer.

A detailed analysis of the reservoir site and its surroundings should be undertaken to identify existing features and characteristics and to establish key views. This will then enable a comprehensive analysis of visual and landscape impacts, essential if this option is to be taken forward.

RECREATION AND AMENITY

A minimum of 7 footpaths would be either lost entirely or require major realignment around the periphery of the reservoir. Due to the attractive nature of the countryside, and the increased recreational use attracted by the National Trust property, Waddesdon Manor, this is considered to be a significant negative impact.

This will to an extent be offset by the positive effects of increased leisure and recreation opportunities on the new water body. It is debatable however whether such uses are appropriate to the location, given the poor and sensitive access routes.

ARCHAEOLOGY AND HISTORY

There is little known archaeology on the reservoir site, but as with the other options, development of the reservoir and the laying of pipelines are likely to uncover features of interest. Therefore, prior to detailed route design a full desk survey of archaeology, followed up by field evaluation as necessary should be undertaken.

English Heritage will be concerned at the potential impact of the reservoir on the setting and historic landscape of Waddesdon Manor, the listed National Trust property about 750 m to the north of the proposed water body. From information currently available it is thought that there will not be direct visual impacts, but concern will remain. An appropriate study should be undertaken to confirm that impacts will not be significant.

Apart from this specific item the main remaining concern will be the inundation of buildings comprising the 7 farmsteads. These have not been evaluated at this stage, but these is significant potential for 1 or more to include listed structures, with consequent significant impact.

TERRESTRIAL ECOLOGY

Reservoir site

There are no SSSIs in the proposed outline area for the Waddesdon reservoir. However, there may be sites of local or county importance, and the precise location of any such sites would need to be determined from the county naturalist trust. The local trusts may also be able to provide additional relevant information on the presence of protected species which may be affected.

There do not appear to be any wetland sites in the general area of Waddesdon that may be affected by changes temporary or otherwise in the groundwater regime through construction.

Pipeline impacts

The broad alignment of the pipeline has been proposed. This tentative route does not directly pass through any SSSIs although there are a number within a 10 km corridor. These are outlined in the accompanying figure. Pipeline impacts will be as outlined in other options.

AQUATIC BIOLOGY

The maximum transfer rate into the Thame would be 200 Ml/d. This transfer rate would be within the river's maximum flows in all months except July and September. It does however represent at least a doubling of mean flow in the summer and autumn months. The effects of this increase in flow are similar to those defined under the Severn-Thames transfer option. Benefits would include reasonable summer flows during periods of low flow. Impacts on fisheries and macroinvertebrate fauna and macrophytes will be similar to those defined in the Severn-Thames transfer option. However, the Thames does experience problems with siltation and excessive weed growth and therefore an increase in flows may have positive effects on current siltation patterns.

The biological and chemical effects of this transfer are difficult to predict in view of the sequence of interbasin transfers and will need further consideration. It will be necessary to fully consider water quality impacts on aquatic biology and fisheries when further information becomes available from the anglian region studies.

The Thame is an EC designated Cyprinid fishery in accordance with the EC Directive 78/659/EEC from Cuddington stream to the Thames, although both fish and invertebrate populations are influenced by the poor performance of the Aylesbury STW. The BMWP scores in general fail to meet those predicted. However water quality improves further downstream and at Dorchester bridge (SU 57909390) actual scores meet and exceed those predicted. It would appear that the transfer could, subject to water quality, improve the river.

ANGLIAN TRANSFER - GRAFHAM INCREASE

PROJECT DESCRIPTION

- expansion of pumping station on the Great Ouse, and transfer pipeline to Grafham Water;
- additional low lift pumping station and treatment plant for 100 Ml/d abstraction from Grafham Water;
- a 1.0 m diameter treated water pipeline paralleling the 2 existing Three Valley Water Company pipelines to Luton.

INTRODUCTION

The environmental effects of this option, considered at this stage, are restricted to the development of a new treatment works, and possible changes in the characteristics of Grafham Water in terms of greater and more frequent fluctuations in level.

PLANNING AND DEVELOPMENT

Impacts are likely to be restricted in extent as the development relates to existing features and infrastructure rather than new installations. The size and precise location of the required treatment works will need careful attention in order to minimise any extension a attendant development away from the reservoir into the countryside.

LANDSCAPE AND VISUAL

Impacts will arise in connection with the construction of the treatment works, and, perhaps more significantly, in connection with periods of water level drawdown associated with transfers to the Thames region. The latter may be particularly noticeable in terms of views of the reservoir, with extensive areas of muddy foreshore visible at low water times.

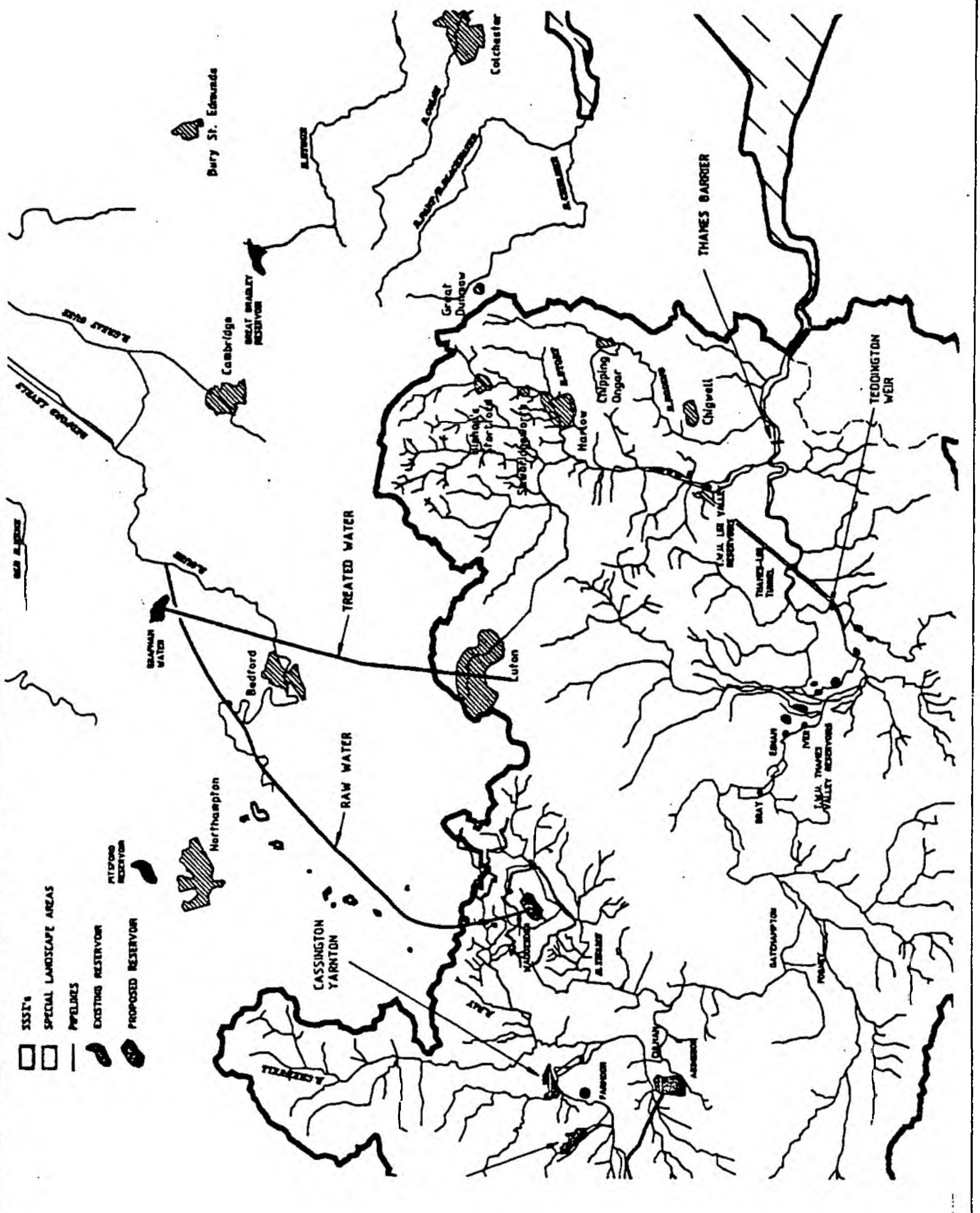
Such impacts have been raised as significant by objectors in relation to other reservoirs, operating and proposed, in the country. Therefore it is important that the amount of fluctuation be identified at an early stage of project design in order to address visual impact issues.

As already stated, impacts associated with the new treatment works are likely to be small in scale and easily mitigated within the context of existing reservoir infrastructure and extensive landscape works.

RECREATION AND AMENITY

Grafham Water is intensively used for leisure and recreation, and forms a recreation resource of regional significance. Activities represented on and around the water body include: sailing, windsurfing, fishing, cycling, walking and birdwatching. Future plans include the provision of a pleasure boat, and the establishment of a nature trail network.

ANGLIAN TRANSFERS TO THAME AND FROM GRAFHAM WATER



Impacts of the proposed scheme on the recreation aspects of the site will be most significant in terms of their effects on water level within the reservoir. Construction of the treatment works can be accommodated within the overall reservoir complex without significant effect on the recreational use.

The degree of water level fluctuation has not been quantified at this stage, but the activities most likely to be affected are sailing, windsurfing and fishing. These will be affected primarily in terms of ease of access to the water itself with the extensive muddy foreshore potentially causing problems for all these users in the event of significant drawdown.

The reservoir is used for sailing training to Olympic Standard, and has also been the venue for national championships on a number of occasions. It will be important therefore to quantify potential effects at an early stage.

ANGLIAN TRANSFER - RODING TRANSFER

PROJECT DESCRIPTION

Common works required for this sub-option are:

- increase in pump capacity at Kennett Pumping Station by 200 Ml/d;
- increase the transmission capacity by 200 Ml/d between Kennett Pumping Station and Kirtling Green (or Great Bradley reservoir) by the construction of a 1.4 m diameter main;
- increase in intake pump capacity at Wixoe Pumping Station on the Stour;
- improve hydraulic regime of River Pant from Great Sampford to Great Bardfield.

Discharge of 100 Ml/d to the river Roding would involve:

- reduction of Stort transfer pipeline beyond the Roding to 1.0 m diameter;
- 1.0 m diameter pipeline for 17 km to a discharge point on the river Roding below High Ongar;
- possible moderate river training works downstream of the discharge point;
- river intake/pumping station near Chigwell.

PLANNING AND DEVELOPMENT

Very similar comments apply to this option as for the Stort/Lee, the proposed pipeline running through similar countryside including part of two Special Landscape Areas. It is anticipated that development impacts will be limited, apart from during the construction phase when issues such as traffic, new accesses and disposal of any spoil arising should be addressed.

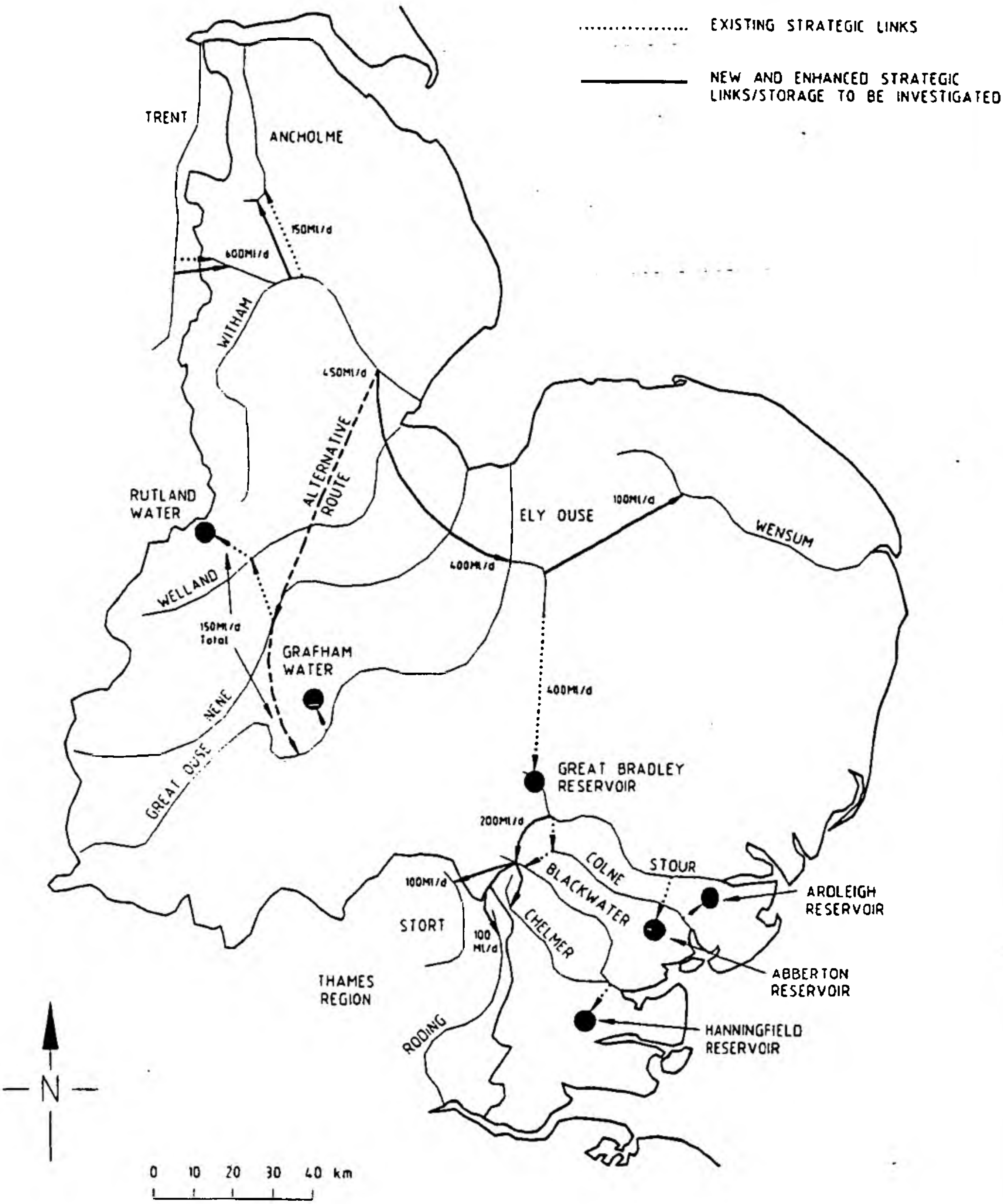
AGRICULTURE AND DRAINAGE

The land involved is uniformly Grade 2 - Good Quality, and similar comments apply as with the Stort/Lee option, it will be important to minimise any impacts on farms on the pipeline route, by good practice and satisfactory restoration.

The Hatfield Forest is an important area for recreation and is an SSSI primarily for its Ancient Woodland interest.

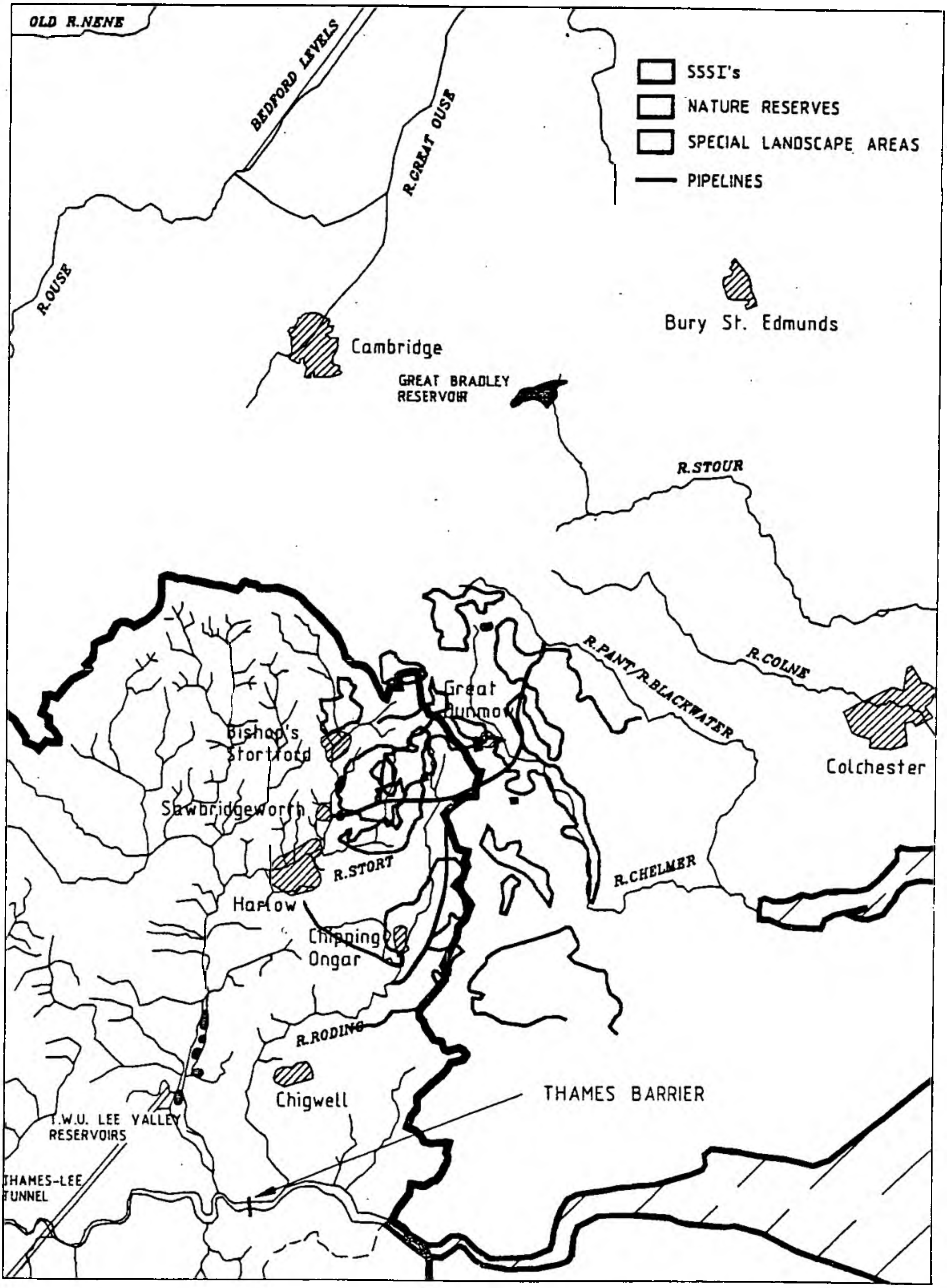
LANDSCAPE AND VISUAL

The route passes through the south western edge of the Hatfields SLA and therefore similar potential impacts would arise as for the Stort/Lee option. The route would also pass through part of the Roding Valley SLA, characterised by an open valley landscape with arable farming right up to the river's edge. The higher ground away from the river is well wooded, and pipeline through this



STRATEGIC OPTIONS UNDER CONSIDERATION WITHIN ANGLIAN REGION

ANGLIAN TRANSFER ELY OUSE-ESSEX SCHEME



vegetation would require very careful treatment in order to minimise long term impacts.

Overall, the same comments apply as for the Stort/Lee option, apart from the fact that there may be an intrinsic advantage to this option, if a Trent-Essex transfer is pursued, in that should avoid canalisation of the Roding upstream of Ongar. If however it transpires that canalisation is still required then no advantage will accrue, and indeed there may need to be canalisation downstream of High Ongar which would result in very significant impacts.

RECREATION AND AMENITY

No significant impacts are expected other than the largely temporary pipeline impacts during construction which have already been described. As already stated it would be very important to avoid impacts on Hatfield Forest.

ARCHAEOLOGY AND HISTORY

Similar comments apply as for other pipeline options, but it should be noted that greater potential exists for significant impacts due to the extensive Roman settlement and road building in the area.

TERRESTRIAL ECOLOGY

There are several SSSIs in the 10 km pipeline corridor and these are illustrated in the accompanying figure.

Other pipeline impacts are as before, with little long term impact following the initial disturbance of the construction stage.

AQUATIC BIOLOGY

Affects of chemical change on aquatic biology will depend on a number of factors including the nutrient status for the Trent-support water from the Ely Ouse. Much of the River Roding is classified as a NWC Class 1b although there are stretches of Class 2. Introduction of Trent-supported water (originally abstracted from a Class 2 river) may give rise to a deterioration in water quality and resultant adverse effects on fish populations. However, this is still very speculative at this stage, and would need detailed consideration at a later stage.

The potential environmental impacts of inter-basin transfer have been outlined in more detail in relation to the Severn Thames transfer. It is more difficult to make precise comments however, due to the complicated mixtures of water which would arise from this transfer.

Macroinvertebrates

The biotic class of the Roding varies along its stretch but is largely classified as Biotic C. Many of the BMWP scores fail to meet those predicted.

Fisheries

The Roding is an EC designated Cyprinid fishery from source to Brookhouse Brook in accordance with EC Directive 78/659/EEC. The typical Roding fishery comprises a mixed chub, dace, and roach population.

The transfer could not be discharged to the natural channel of the Roding north of High Ongar, as the existing capacity north of this point is such that significant channel modifications would be required in order to accommodate flows up to 100 Ml/d. Even downstream of High Ongar, discharge could require significant modification of the existing channel would be required to accommodate transfers of up to 100 Ml/d. Mean monthly flows at High Ongar (between 1963/1991) range from a high of approximately 100 Ml/d in January to a low of 10 Ml/d in June. Hence a transfer volume of 100 Ml/d would represent up to a ten-fold increase in the Roding discharge at Ongar. This would probably have significant implications for downstream fisheries.

Likely impacts have been outlined in detail in Severn Thames Transfer option, however possible impacts would include, displacement of stocks, scouring and alteration of spawning areas, alteration of ecological regime with a consequential shift in fish species composition.

ANGLIAN TRANSFER - STORT/LEE TRANSFER

PROJECT DESCRIPTION

Common works required for this sub-option are:

- increase in pump capacity at Kennett Pumping Station by 200 Ml/d;
- increase the transmission capacity by 200 Ml/d between Kennett Pumping Station and Kirtling Green (or Great Bradley reservoir) by the construction of a 1.4 m diameter main;
- increase in intake pump capacity at Wixoe Pumping Station on the Stour;
- improve hydraulic regime of River Pant from Great Sampford to Great Bardfield.

Discharge of 200 Ml/d to the river Stort would involve:

- intake and pumping station at Great Bardfield on the river Pant, for 200 Ml/d;
- 1.4 m diameter pipeline for 28 km from Great Bardfield to the river Stort at Sawbridgeworth;
- river discharge structure,
- possible river training works and alterations to navigation structures.

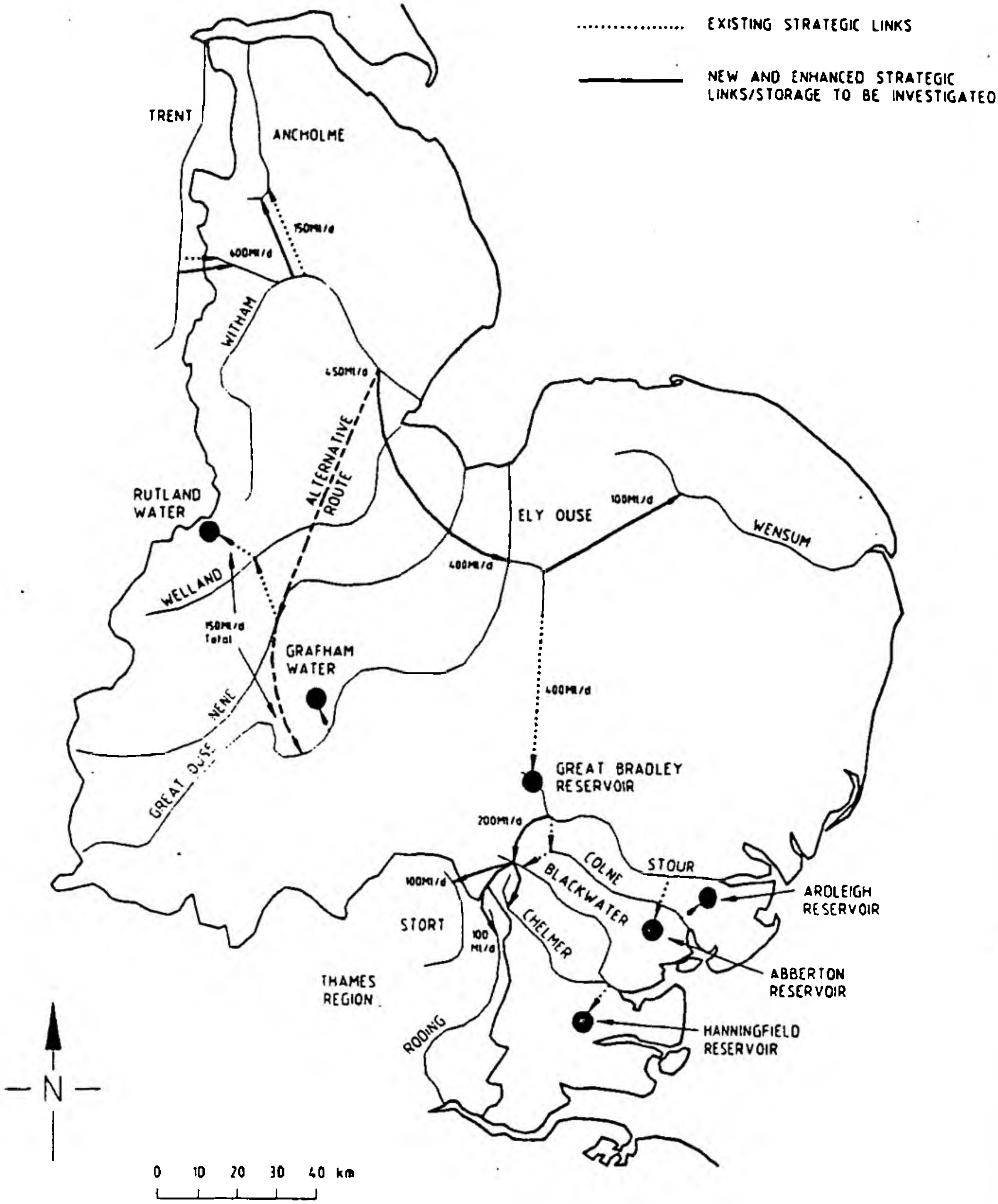
Discharge of 100 Ml/d to the river Stort would involve:

- reduction of Stort transfer pipeline beyond the Roding to 1.0 m diameter;
- 1.0 m diameter pipeline for 17 km to a discharge point on the river Roding below High Ongar;
- possible moderate river training works downstream of the discharge point;
- river intake/pumping station near Chigwell.

PLANNING AND DEVELOPMENT

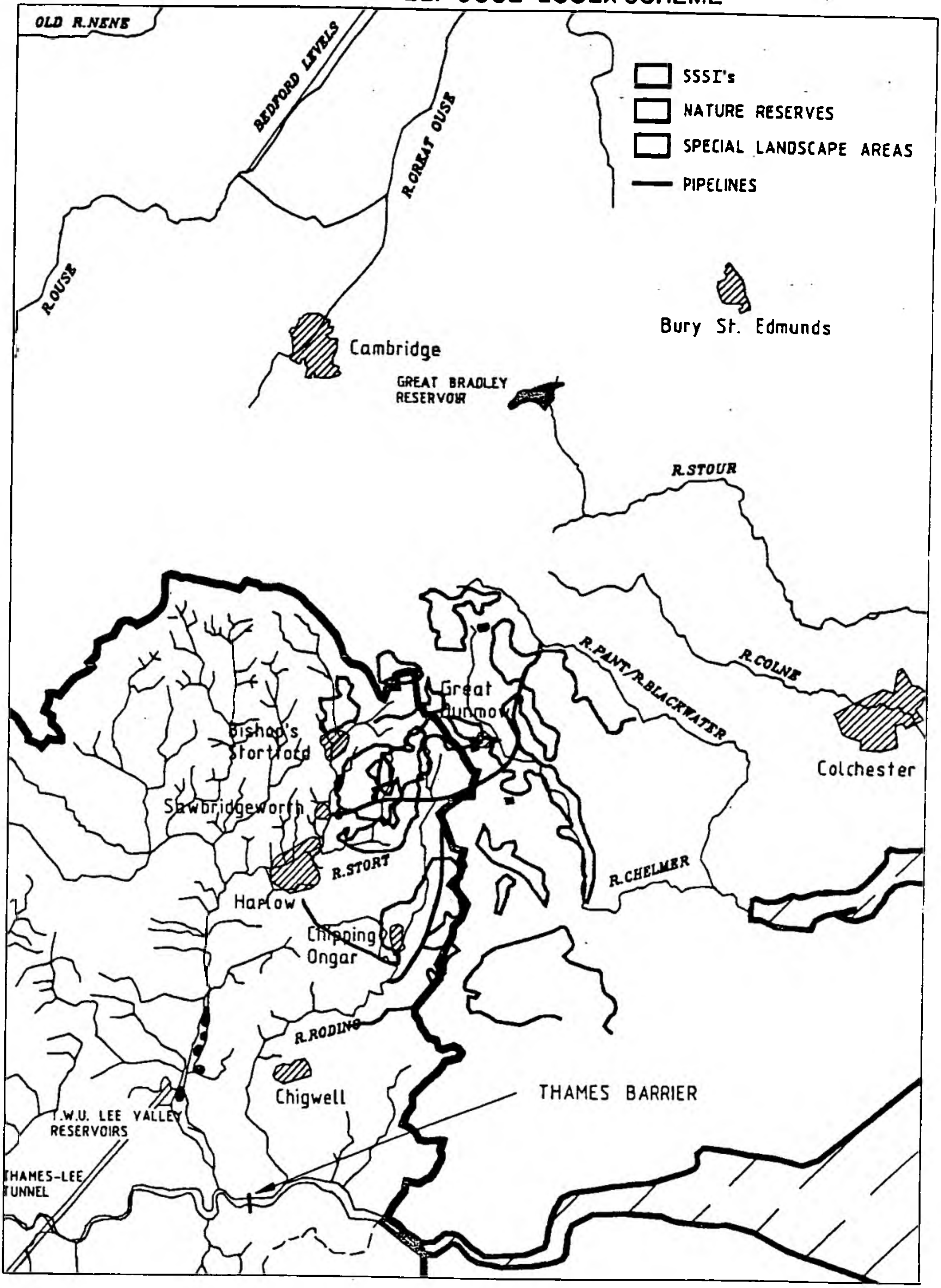
The main impacts arising from this option will be linked with the installation of pipeline from near Wixoe to Great Dunmow and then west to discharge to the Stort, just south of Bishops Stortford. Development impacts are however, anticipated to be limited apart from during the construction stage when similar characteristics will apply as for other pipeline options, notably the Severn-Thames transfer involving disturbance through traffic, access, earth-moving etc.

There are a number of landscape designations within Essex, and the pipeline route would pass through a number of Special Landscape Areas in including Stour Valley SLA, Pant Valley SLA, Chelmer Valley SLA and Hatfield SLA. Due to the temporary nature of impacts associated with pipeline routes it is anticipated that these county-level designations areas would not be subject to major impacts after construction was complete. The areas are identified on the accompanying constraints map, and the landscape implications are discussed in more detail under the landscape and visual section.



STRATEGIC OPTIONS UNDER CONSIDERATION WITHIN ANGLIAN REGION

ANGLIAN TRANSFER ELY OUSE-ESSEX SCHEME



The route would also pass through the Stort Valley Nature Conservation Zone identified in the Essex Structure Plan. This is a policy designation designed to help protect, in this case, Hatfield Forest SSSI and is identified on the constraints map. It would be essential for the pipeline to avoid this zone.

AGRICULTURE AND DRAINAGE

The areas through which the pipeline will pass are uniformly Grade 2 of the Agricultural Land Classification and are under intensive cultivation. Similar issues of largely temporary disturbance of farming practices will arise as for other pipeline options, but it should be remembered that they are likely to be more critical in this area due to the importance of the land for arable farming.

LANDSCAPE AND VISUAL

As stated, the proposed pipeline would pass through a number of Special Landscape Areas most of which are centred on the river valleys of the area. These are characterised by greater variation in topography than much of the surrounding areas, together with woodland and hedgerow features. The Hatfields SLA is characterised by extensive historic woodland areas edged by water meadows on the Stort to the west.

These landscapes are all sensitive, and due to the importance of the woodland and hedgerow components, are particularly sensitive to impacts associated with the installation of pipeline. This high potential for longer term negative impacts requires early mitigation if the option is pursued, by very careful and detailed design of routes.

As with other pipeline options, impacts at the construction stage are potentially significant and would require mitigation by good site management practice and proper restoration of sites following installation.

The option has been considered on the assumption that no channel improvements will be required on the Stort or Lee rivers and therefore no negative landscape or visual effects would result to these rivers themselves. In the event that channel improvement or even canalisation were required, then significant impacts would result, which would need very careful evaluation. Such impacts would almost certainly be strongly resisted by the various environmental organisations such as the Countryside Commission, English Nature etc.

RECREATION AND AMENITY

It is not considered that this option will give rise to significant impacts, provided pipeline routes through Hatfield Forest, in particular, are avoided, as this is a popular recreation area.

There may be positive impacts resulting from increased flows in the summer through the Lee Valley Park in particular which is a regional attraction, centred around the river and gravel pit network.

ARCHAEOLOGY AND HISTORY

As with other pipeline options, careful evaluation of archaeological potential will be necessary, and mitigation measures taken as appropriate.

As already stated, impacts on the historic landscape of Hatfield Forest should be avoided.

TERRESTRIAL ECOLOGY

Pipeline impacts

There are several SSSIs in the 10 km pipeline corridor and these are illustrated on the constraints map. These are from north to south West Wood, High Wood, Garnetts Wood, Hatfield Forest, Thorley Flood Pound and Sawbridgeworth. Possible pipeline impacts have been outlined in detail in the Severn-Thames option Other sites of nature conservation should be recorded prior to finalising a route.

AQUATIC BIOLOGY

The potential environmental impacts of interbasin transfers have been outlined in more detail in the Severn-Thames option. However the Stort/Lee are significantly smaller rivers than the Thames and therefore transfers to such rivers, depending on the transfer flows, may have significantly more adverse impacts. These may lead to complete change of the character of the rivers in order to increase their carrying capacity to match the transfer flows.

The Stort fisheries largely comprise roach, chub and pike and a number of stretches are EC designated Cyprinid fisheries 78/659/EEC. Proposed transfer rates are expected to be in the region of 100 Ml/d and will be released to the Stort downstream of Bishops Stortford. This would mean that maximum monthly flows would be exceeded for 7 months of the year, which could result in significant impacts occurring. The river downstream of Bishop Stortford becomes formalised in the shape of a navigation channel, to the confluence with the River Lee, although interspersed along the navigation channel are remnants of the old river course. Habitat availability along this stretch of the river is extremely poor which has already had significant effects on the fisheries. Poor flow as a result of the large numbers of locks between Bishops Stortford and the river Lee has backed water up resulting in increased siltation, and has also resulted in adverse impacts upon fisheries. It is unlikely that increased flows will have a positive benefit on siltation patterns if the locks remain in place.

The upper part of the catchment between Langley and Stanstead Mountfitchet is a small river and is suffering from low flows, drying up in places during summer. Although increased flows would benefit this stretch of the Stort the channel does not have the capacity to accommodate 100 Ml/day.

The BMWP scores at all stations failed to meet the predicted scores in 1991, however were particularly poor around Bishops Stortford where the predicted score was 155 and actual scores ranged from 40-95.

The changes to water quality and consequential effects on aquatic biology are difficult to predict in view of the sequence of interbasin transfers.

Benefits of increased flow in the summer will depend on the extent of low flows, if any, currently experienced by the river downstream of Bishops Stortford.

Impact Summary Sheets

THAMES-SIDE GROUNDWATER

Planning and Development

- Limited impacts as very little infrastructure required.

Agriculture and Drainage

- No significant impacts anticipated

Landscape and Visual

- Potentially some limited, temporary impacts during construction.
- Need for satisfactory restoration following pipeline installation.

Recreation and Amenity

- Minor impacts during construction phase possible due to recreational use of river and footpaths.
- No other impacts likely.

Archaeology and History

- Minor impacts possible, but unlikely to be significant.

Terrestrial Ecology

- No SSSIs in vicinity of pumping sites although sites of local or county importance may be present.
- Need to ensure that abstractions do not adversely affect groundwater fed surface water courses.

LONDON BASIN GROUNDWATER

Planning and development

- No significant detrimental impacts anticipated.
- Beneficial impact of lowering and stabilising groundwater levels.

Landscape and Visual

- No significant impacts anticipated.

Recreational and Amenity

- No significant impacts anticipated.

Archaeology and History

- Some limited potential for minor archaeological disturbance. Unlikely to be significant.

Terrestrial Ecology

- No significant impacts envisaged.

RESERVOIR AT ABINGDON/DRAYTON

Planning and Development

- Significant impact through major land-take.
- Impacts during construction, creation of new access roads and the need to divert an existing road.
- Traffic impacts during construction and, possibly, arising from recreational use.
- Pressure for recreational development on completion.
- Emergency planning impacts through potential flood hazard.

Agriculture and Drainage

- Land-take of agricultural land a significant impact, but partially mitigated by the fact that most of the land is lower quality - Grades 3 and 4.

Landscape and Visual

- Impacts from bunds and from new water body partially mitigated by low lying flat surrounding landscape.
- Severe negative impacts during construction.
- Pipeline between Thames and reservoir will create significant temporary impacts.
- On completion the reservoir may have positive visual impacts as perceived by recreational users.

Recreational and Amenity

- Negative impact through loss/diversion of existing footpaths.
- Positive impact through creation of new footpaths and major new recreational resource.
- Negative impact on the amenity of local residents particularly during construction but also in the longer term.
- Significant negative impact on residents who require relocating due to inundation.

Archaeology and History

- Significant potential for impacts on archaeology, requiring detailed evaluation..
- The setting of one listed building will be affected.

Terristrial Ecology

- Significant impacts on downstream sites of nature conservation. Interest if the reduction in Thame's side is considerable.

- Conservation gain through the creation and extensive water body. Potential for creation of additional habitat around reservoir perimeter.

- Construction impacts unlikely to be significant.

Aquatic Biology

- Increase in sedimentation likely to result in subtle changes to macroinvertebrate fauna.

- Potential adverse effects on fisheries of siltation patterns altered significantly.

- Potential temperature effects on fauna growth and primary production. Dependent on reservoir offtake.

- Changes in water quality arising from storage.

- Eutrophication and production of algal blooms in reservoir. Dependent in part on reservoir management.

- Potential benefits of regulated flow in the summer period.

REDEVELOPMENT OF STAINES RESERVOIR

Planning and Development

- Impacts on the built up areas during construction arising from aggregate export from the site.
- Limited impact otherwise due to the fact that development will be within existing curtilage of the site.

Agriculture and Drainage

- No impacts.

Landscape and Visual

- Severe local impacts due to increased height of bunds.
- Severe temporary impacts due to construction work on bunds.
- Other works within site screened by existing bunds.

Recreation and Amenity

- Severe temporary recreation impact due to draining of reservoir, no long term impact.
- Severe construction impacts on local amenities due to import and export traffic for aggregate and construction materials.

Ecology

- Severe temporary impact due to draining of reservoir, no long term impact.

REUSE OF EFFLUENT DISCHARGED TO THE TIDAL THAMES

Planning and Development

- Very limited impacts as most new infrastructure likely to be accommodated within existing works.

Landscape and Visual

- Minor temporary impacts during construction.

Recreation and Amenity

- Potential impact on recreational/amenity value of William Girling/George V Reservoirs if treated effluent from Deephams STW discharged there. Impact likely to be more public perception related than real however.

- Similar potentially significant public perception issue attached to discharge to river and to this option in general.

Archaeology and History

- Some limited potential for impacts, which can be mitigated as necessary by proper evaluation and recording.

Aquatic Ecology

- William Girling and George V Reservoirs are Sites of Nature Conservation Interest and therefore perceived impacts of treated effluent discharge from Deephams STW would require addressing. Effects on ecology in reality are unlikely to be significant however.

- Failure of the Mogden STW would cause major impacts on water quality in the Thames, and thus satisfactory emergency/back up arrangements would be required.

- Quality of effluent being discharged would be a key issue including possible variations in this quality.

- No significant benefit in flows over Teddington would result as additional flows arising from this option would be cancelled out by corresponding greater abstraction upstream.

(SEVERN-THAMES TRANSFER AND) GRAVEL PIT STORAGE

Planning and Development

- Limited impact because sites will be exhausted workings.
- Important that water is acceptable after use - this is not currently the case at Down Ampney.

Agricultural and Drainage

- Loss of land not an issue unless preferred restoration to agriculture, as at Down Ampney.
- Loss of flood plain storage critical factor where above ground bunding proposed. Would be resisted by NRA-TR flood control.

Landscape and Visual

- Limited impacts as development will already have taken place.
- Creation of water body within agricultural area is a significant landscape impact, but not necessarily detrimental.
- Visual impacts will be similar to reservoir proposals if significant above ground bunding proposed.

Recreation and Amenity

- Significant recreational benefits from the water body created.
- No other impacts anticipated.

Archaeology and History

- No impacts anticipated.

Aquatic Biology

- Impacts difficult to define at this stage.

  Physical

  - Potential disruption to spawning of coarse fish due to altered flow regime.
  - Invertebrate drift.
  - Scouring of macrophytes, and fish redds.
  - Washing away newly hatched alevins.

  Chemical

  - Potential disruption to 'homing of migratory fish'.

- Species changes through introduction of 'softer water' likely to be moderate rather than severe, RIVPACS modelling not conclusive.

Biological Impact

- Changes to Phytoplankton communities in the Thames potential for algal blooms due to extended retention time.
- Disease/Parasite transfer unlikely to be significant.
- Predator transfer - not applicable.

Pipeline Impacts

- A large number of SSSIs are present in the 10 km wide corridor for the pipeline and these should be avoided where possible.

Severn-Thames transfer and Abingdon reservoir

- Introduction of Severn water into middle Thames rather than upper Thames is less likely to result in significant impacts on phytoplankton population.
- Water quality of lower Thames is of a more similar quality to water quality in River Severn, than that which occurs in the upper Thames.

Severn-Thames transfer and Gravel Pit Storage

Terrestrial Ecology

Stanton Harcourt

There are 2 sites of nature conservation importance within the defined area. One SSSI and one LNR.

Cassington-Yarnton

2 SSSIs lie within the defined area.

Down Ampney

There are no SSSIs or LNRs within the defined area.

Conservation Gain

Like reservoirs, gravel pits provide nature conservation opportunities, although there is greater potential that drawn down will conflict with nature conservation.

Aquatic Biology

- Potential for eutrophication particularly as gravel pits likely to be shallow. Need for appropriate discharge consents.
- Reduction in sedimentation, through settlement, and depending on retention time potential for reduction in nutrients.

SEVERN THAMES TRANSFER

Planning and Development

- Significant impacts during construction through traffic, new access requirements and construction sites.
- Potential for impacts where surface structures required, particularly in the AONB.
- Land-take for bank side storage at the Severn will result in significant impact.
- Disposal of spoil for tunnelling activities.

Agricultural and Drainage

- Significant negative impact through loss of up to 40 ha good quality land at Deerhurst, and possibly at Buscot.
- Potential for farm interference during construction of pipeline sections.
- Impacts should be largely temporary.
- Potentially significant loss of floodplain area at Deerhurst, requires further evaluation.
- Other significant drainage impacts unlikely.

Landscape and Visual

- Severe temporary impacts during construction of pipeline/tunnel through the AONB.
- Need for adequate restoration of works following pipeline laying.
- Tunnelling preferred to pipeline where possible as this will minimise surface disturbance.
- Extension of pipeline to Abingdon, missing out Buscot, felt to be an advantage.
- Riverside installations will have a significant, permanent landscape and visual impact.

Recreation and Amenity

- Severe temporary impacts where construction sites near to footpaths, river, residential areas etc.
- Potentially severe long-term impacts at Buscot and Deerhurst due to riverside infrastructure. Both sites have extensive recreation etc.
- Need for routing to take account of such uses.

Archaeology and History

- No specific impacts but high potential for archaeological disturbance. Evaluation required as part of route design.

ANGLIAN TRANSFER - THAME INCLUDING RESERVOIR AT WADDESDON

Planning and Development

- Broad impacts as for Severn Thames Transfer.
- Route passes through Area of Attractive Landscape and proposed reservoir at Waddesdon lies within AAL.
- 7 farmsteads would require relocation, potentially leading to pressure for new development in the countryside.
- Need for improved access through sensitive surroundings.

Agriculture and Drainage

- The proposal for Waddesdon reservoir involves loss of 6 km^2 of land, mostly 3A and 3B. This loss would be a major impact.
- Loss of 7 farms a significant impact.

Landscape and Visual

- Severe impacts of reservoir during construction with many viewpoints from surrounding countryside.
- Impacts from reservoir at completion due to prominent water body and embankment up to 17 m high.
- Temporary impacts from pipeline construction.
- Impacts from new access which would probably be a widened existing lane.

Recreational and Amenity

- Significant negative impact through loss of at least 7 footpaths.
- Significant positive impact through new water based recreation facility.

Archaeology and History

- Little known archaeology on the reservoir site but significant potential exists for the site and pipeline routes as for the other options. Detailed evaluation required.
- English Heritage will be concerned to ensure that no detrimental impacts accrue for Waddesdon Manor to the north of the reservoir site.

Terrestrial Ecology

- No SSSIs present in the outline area for Waddesdon reservoir. Other sites of more local importance may be present.

- There are a number of SSSIs within the defined 10 km corridor for the pipeline and these should be avoided where possible.

Aquatic Biology

- Possible impacts arising from increased flow:
    - displacement of fish stock
    - changes in water quality
    - invertebrate drift
    - scouring of macrophytes
    - disruption to spawning beds
- Benefits
    - reasonable summer flows during low flow periods
    - reduced siltation.

Conclusion

This option contains all the same impacts as the Abingdon reservoir .proposal, but with greater pipeline length and set within an attractive, designated landscape. In addition, aquatic impacts on the Thame are likely to be more significant due to the lesser ability of the small river to accommodate change, compared with the Thames.

ANGLIAN TRANSFER - GRAFHAM INCREASE

Planning and Development

- No significant impacts anticipated.

Agriculture and Drainage

- No significant impacts anticipated.

Landscape and Visual

- Minor impacts possible but can be accommodated within existing reservoir mass.

Recreation and Amenity

- Potentially significant impacts on the very intensive recreational use at Grafham through fluctuations in water level. The amount of change requires evaluation.

Archaeology and History

- No impacts anticipated

ANGLIAN TRANSFER - RODING TRANSFER

Planning and Development

- No significant impacts are anticipated.
- In terms of policy context the pipeline passes through several Special Landscape Areas.

Agriculture and Drainage

- Land is uniformly Grade 2 - Good quality.
- No major land-take is anticipated.
- Impacts are likely to be temporary in nature, restricted to the construction phase.

Landscape and Visual

- Route passes through two SLAs both of which have significant woodland elements. Pipeline routing through these requires very careful design.

Recreation and Amenity

- No significant impacts anticipated.

Archaeology and History

- Impacts will be as for other pipeline options and require evaluation as part of route design.

Terrestrial Ecology

- There are several SSSIs in the 10 km pipeline corridor and these should be avoided if possible.

Aquatic Biology

- Transfers and 100 Ml/d will represent up to a 10 fold increase in the Roding discharge at Ongar. This could have significant implications for fisheries and other aquatic biota, as outlined in previous options.
- Effects of changes in water quality of aquatic biology is difficult to assess due to sequence of interbasin transfers. However much of the Roding is Class 1b whereas the Trent supported water in Class 2, this could lead to a deterioration in water quality.

ANGLIAN TRANSFER - STORT-LEE TRANSFER

Planning and Development

- General impacts will be similar to those anticipated for Severn Thames Transfer.
- Pipeline passes through a number of Special Landscape Areas identified in the Essex Structure Plan.

Agriculture and Drainage

- Land Classification uniformly Grade 2 - Good Quality, and under intensive arable cultivation.
- Impacts anticipated to be temporarily in nature, arising during construction.

Landscape and Visual

- Potentially significant impact on SLAs particularly as most have significant woodland component, requiring careful routing.
- Significant temporary impacts during construction.
- Assumes no channel improvement on Stort or Lee rivers. If this were to take place then major negative impacts would result.

Recreation and Amenity

- No significant impacts anticipated.
- Important to avoid pipeline through Hatfield Forest.
- Possible minor benefit to Lea Valley Park through improved flows in summer.

Archaeology and History

- Potential impacts as for other pipeline options - evaluation required.

Terrestrial Ecology

- There are several SSSIs in the 10 km pipeline corridor and these should be avoided where possible.

Aquatic Biology

- Proposed transfer rates in the region of 100 Ml/d would result in the maximum monthly flows being exceeded for 7 months of the year. Significant impacts on fisheries and aquatic biota could from this transfer. These are outlined in other options. However large stretches of river downstream of Bishops Stortford are already impacted due to construction canalisation.

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APPENDIX 6

OUTLINE OF WATER RESOURCES MODELLING

Regional Water Resource Development Options.

Scenarios to be modelled in Phase II of the Study.

Scenario 1.

Involves internal solutions.

1.1 - Groundwater - Thames-side (70 Ml/d), London Basin, Rising groundwater (both 181 Ml/d average, 295 Ml/d peak).

1.2 - Drayton Reservoir: 100,000 Ml storage, 450 Ml/d flow constraint, 600 Ml/d maximum abstraction augmentation at 600 Ml/d.

1.3 - Staines re-development: 10,000 Ml extra storage.

1.4 - Effluent re-use: 50 Ml/d from Deephams, up to 400 Ml/d from Mogden.

Scenario 2.

Internal solutions and Severn-Thames transfer.

2.1 - Groundwater as in 1.1.

2.2 - Drayton reservoir as in 1.2.

2.3 - Severn-Thames transfer: transfer at rate of 400 Ml/d.

2.4 - Effluent re-use: as in 1.4

Scenario 3.

Mainly external solutions.

3.1 - Groundwater as in 1.1.

3.2 - Severn-Thames transfer: Transfer at 200 Ml/d into gravel pit storage of 25M m^3 at Buscot, augment at 400 Ml/d.

3.3 - Anglian transfer: 100 Ml/d transferred to gravel pit on the River Thame (30M m3), augment at 200 Ml/d . 100 Ml/d directly to the River Stort (linked to Thame augmentation). Revocation of Essex Bulk supply (90.0 Ml/d)

3.4 - Effluent re-use: as in 1.4.

WATER RESOURCE MODEL

The model is run to derive a resource value to the various zones given levels of service as agreed with OFWAT . These are Level 1 restrictions 1 in 6 years , Level 2 restrictions 1 in 20 , Level 3 restrictions 1 in 50 years and Level 4 restrictions 1 in 100 years . For the base run,to obtain levels of service on a par with the above guidelines this means that demands for London have to be constrained to 1970 Ml/d (current actual demand 2136 Ml/d) . For the base run the Sunnymeads licence is set to it's 1989 values (i.e None to Lee Valley , Annual licence at 53092 ML) . This model run gave the following levels of service :

Number of days

YEAR	LEVEL 1	LEVEL 2	LEVEL 3
1921	204	185	25
1922	63	32	7
1929	75	-	-
1934	206	193	54
1943	28	-	-
1944	168	138	24
1945	30	-	-
1949	112	14	-
1976	150	116	21
TOTAL	1036	678	131

LONDON DEMAND SUPPORTED 1970.0 Ml/d

We have assumed that for any resource options modelled the level of service should be no worse than the current value , allowing for some trade off between frequency of restrictions and the duration of restrictions. To determine the resource value of any option the demands for all demand centres were increased , in yearly steps , until the levels of service fall below the above values .

NORTH LONDON ARTIFICIAL RECHARGE SCHEME

The development of the Enfield/Haringey artificial recharge scheme was modelled by increasing the recharge and abstraction rates to the North London aquifer .Increasing the annual licence such that total abstraction a year is restricted to 90 Ml/d (if used all year round). The initial storage was set to a realistic value . The figures used were supplied from Groundwater Resources and Licencing and were obtained from observed and model data . With London demand increased by 92.6 Ml/d the model gave the following levels of service :

	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL DAYS	766	590	248

LONDON DEMAND SUPPORTED 2062.6 Ml/d
DEMAND SATISFIED UNTIL 1993/1994
RESOURCE VALUE 92.6 Ml/d

SOUTH LONDON GROUNDWATER

The development of the South London artificial recharge scheme was modelled by the addition of recharge and abstraction rates to the South London aquifer .The Annual licence was set to limit the abstraction to 60 Ml/d (if used all year) . The Sunnymead licence was increased to its maximum value as the Enfield/Haringey development takes demands beyond 1991 . With London demand increased by 77.7 Ml/d the model gave the following levels of service :

	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL DAYS	832	603	225

LONDON DEMAND SUPPORTED 2140.3 Ml/d
DEMAND SATISFIED UNTIL 1995/1996
RESOURCE VALUE 77.7 Ml/d

LONDON BASIN - LICENCE POTENTIAL + RISING GROUNDWATER

Groundwater Resources and Licensing estimate that there will be an increased yield of 60 Ml/d in the London basin - 30 Ml/d from rising groundwater and 30 Ml/d from full use of existing licences . The split between the North and South is 41.7 Ml/d & 18.3 Ml/d (from observed and model data). The model accurately predicts the existing public water supply yield of 92 Ml/d and the following changes are necessary to give the increase in yield :

[illegible] [illegible]
[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

LOCATION	PRESENT YIELD	REVISED YIELD
Lee/Upper Lee	12.3 Ml/d	+ 11.4 Ml/d
Lee/Lee Wells	12.9 Ml/d	+ 4.8 Ml/d
Lee/New River	27.6 Ml/d	+ 25.5 Ml/d
		+ 41.7 Ml/d
Darent/Thames res.	9.9 Ml/d	+ 4.5 Ml/d
Darent/Kent Wells	30.0 Ml/d	+ 13.8 Ml/d
		+ 18.3 Ml/d
	92.7 Ml/d	+ 60.0 Ml/d

To model the 40.0 Ml/d decrease in yield of the Darent and Cray 26.2 Ml/d was switched from the Kent Wells demand zone to the Thames reservoir demand zone . The rest of the 40 Ml/d is accounted for with the increase in yield due to the rising groundwater. This switch between Thames reservoir demand centre and the Kent Wells demand centre was introduced from 1996 onwards .

With London demand increased by 70.0 Ml/d the model gave the following levels of service :

	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL DAYS	833	604	237

LONDON DEMAND SUPPORTED 2210.3 Ml/d
DEMAND SATISFIED UNTIL 1998/1999
RESOURCE VALUE 70.0 Ml/d

NEW THAMES SIDE SOURCES

New Thames side sources were introduced to give a total increase of yield of 70.0 Ml/d as follows :

SOURCE --->	DEMAND CENTRE	YIELD
Remenham	Henley	5.0
	Watford/St. Albans	10.0
West Marlow	Slough	5.0
	High Wycombe	5.0
Harpsden	Henley	7.5
	South Oxon.	7.5
Sheeplands	Reading	30.0

DRAYTON RESERVOIR DEVELOPMENT

The addition of a new reservoir at Drayton was modelled using the reservoir option subroutines. These operate to the following basic rules :

1) Calculate if augmentation release is required . This is done by looking at current Lower Thames Reservoir storage and comparing this with a target level . If the current level is below the target level then augment from the reservoir (limited by pump capacity and requirement)

2) If not augmenting then abstract from river (limited by pump capacity or flow constraint)

3) Supply upstream as required (limited by pump capacity and requirement)

Reservoir volume set at 100,000 Ml pump capacity for augmentation and abstraction set at 600 Ml/d flow constraint set to 450 Ml/d .
Upstream supply pump capacity set to 100 Ml/d . Cotswold licence revision as follows :

	Reduced to
Latton	19.78 Ml/d
Ogbourne	4.55 Ml/d
Axford	4.36 Ml/d
Baunton	3.14 Ml/d
Ashton Keynes	5.80 Ml/d
	37.63 Ml/d

This represents a decrease in yield of 42 Ml/d and , along with the Drayton/Farmoor link , gives a potential upstream supply of 82 Ml/d .

With London demand increased by 200.0 Ml/d the model gave the following levels of service :

	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL DAYS	881	525	162

LONDON DEMAND SUPPORTED 2410.3 Ml/d
DEMAND SATISFIED UNTIL 2012
RESOURCE VALUE 200.0 Ml/d

STAINES REDEVELOPMENT

This was modelled by increasing the storage capacity of the Thames North reservoirs by 10000 Ml .

With London demand increased by 70.0 Ml/d the model gave the following levels of service :

	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL DAYS	893	569	199

LONDON DEMAND SUPPORTED 2480.3 Ml/d
DEMAND SATISFIED UNTIL 2016/2017
RESOURCE VALUE 70.0 Ml/d

STAINES REMOVED AS DRAYTON BECOMES AVAILABLE

This was modelled to determine how far Drayton on its own could support demands while Staines reservoir is being redeveloped .

With London demand at 2319.0 Ml/d the model gave the following levels of service :

	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL DAYS	928	497	134

LONDON DEMAND SUPPORTED 2319.0 Ml/d
DEMAND SATISFIED UNTIL 2006/2007
RESOURCE VALUE 108.7 Ml/d

This resource value represents the 200.0 Ml/d resource of Drayton less the 91.3 Ml/d resource value of the existing Staines reservoirs .

With Staines reinstated and redeveloped the London demands can be increased to 2480.3 Ml/d (as above) . These resource values are assuming that Staines is used for only 100 days per year . However if there is more use than this the resource value will be reduced in proportion (i.e at 365 days per year resource value of existing Staines reservoirs is 25.0 Ml/d while the redevelopment has a resource value of 20.0 Ml/d) .

EFFLUENT REUSE - DEEPHAMS AND MOGDEN

This was modelled by feeding Deephams directly to the Lee Valley reservoirs and by feeding Mogden directly to the Thames North reservoirs . In practice Mogden would be fed in above Teddington thereby allowing higher abstractions to Thames North , Thames South and Thames/Lee tunnels . This was found to be to difficult to adequately model hence the above method was used .

With Deephams on its own at a pump capacity of 50.0 Ml/d London demands could be increased by 35.0 Ml/d

	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL DAYS	884	567	173

LONDON DEMAND SUPPORTED 2515.3 Ml/d
DEMAND SATISFIED UNTIL 2018/2019
RESOURCE VALUE 35.0 Ml/d

With Mogden on its own at a pump capacity of 90.0 Ml/d London demands could be increased by 61.7 Ml/d

	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL DAYS	907	588	161

LONDON DEMAND SUPPORTED 2542.0 Ml/d
DEMAND SATISFIED UNTIL 2020
RESOURCE VALUE 61.7 Ml/d

With Deephams + Mogden at a pump capacity of 130.0 Ml/d London demands could be increased to by 98.1 Ml/d

	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL DAYS	906	589	171

LONDON DEMAND SUPPORTED 2578.4 Ml/d
DEMAND SATISFIED UNTIL 2020 +
RESOURCE VALUE 98.1 Ml/d

SEVERN TRANSFER

Flows at Hawbridge were supplied by NRA Severn region and represent the naturalised flow taking into account Lake Vyrnwy , Llyn Clywedog , and the major nett abstractors from the Severn .

The transfer to Thames is according to following :
- determine if transfer is required (triggered by Lower Thames storage levels or a requirement at reservoir)
- transfer what is available (restricted by Severn flow)
- transfer at pump capacity (200 , 400 Ml/d)

Firstly a direct transfer with no storage was modelled . This transfer was triggered by the Lower Thames storage levels such that if storage levels were below the monthly target levels then the transfer was started (according to above rules).

With a pump capacity of 200 Ml/d the London demands could be increased by 85.0 Ml/d giving the following levels of service :

	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL DAYS	870	614	258

LONDON DEMAND SUPPORTED 2295.3 Ml/d
DEMAND SATISFIED UNTIL 2004/2005
RESOURCE VALUE 85.0 Ml/d

With a pump capacity of 400 Ml/d the London demands could be increased by a further 50.0 Ml/d giving the following levels of service :

	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL DAYS	918	688	308

LONDON DEMAND SUPPORTED 2345.0 Ml/d
DEMAND SATISFIED UNTIL 2008
RESOURCE VALUE 135.0 Ml/d

With Drayton reservoir as outlined above a transfer from Severn was introduced thus :
1) If abstracting below pump capacity (i.e flow < flow constraint + pump capacity) look to Severn for transfer . The same rules apply for the transfer as outlined above .

With London demand at 2562.8 Ml/d the model gave the following levels of service :

	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL DAYS	1029	692	265

LONDON DEMAND SUPPORTED 2562.8 Ml/d
DEMAND SATISFIED UNTIL 2020 +
RESOURCE VALUE 152.5 Ml/d

SEVERN TRANSFER + ANGLIAN TRANSFER

This involved modelling a gravel pit at Buscot which is filled with the transfer from the Severn . Gravel pit operated as Drayton reservoir with augmentation pump capacity of 400 Ml/d transfer pump capacity of 200 Ml/d .

With London demands at 2361.5 Ml/d the model gave the following levels of service :

	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL DAYS	905	676	288

LONDON DEMAND SUPPORTED 2361.3 Ml/d
DEMAND SATISFIED UNTIL 2009
RESOURCE VALUE 151.0 Ml/d

The next stage of this scenario was to bring in a Anglian transfer to the following :

1) Reservoir on the Thame (100 Ml/d transfer , 200 Ml/d augmentation) . Operated as Drayton reservoir

2) Directly to the Stort (100 Ml/d)

3) Replace the Essex Bulk supply from Thames with a Anglian supply (90.9 Ml/d)

Firstly the model was run with just 1 & 2 being used . With London demands increased by 152.5 Ml/d the model gave the following levels of service :

	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL DAYS	905	712	277

LONDON DEMAND SUPPORTED 2513.8 Ml/d
DEMAND SATISFIED UNTIL 2018/2019
RESOURCE VALUE 152.5 Ml/d

The model was then run with then Essex Bulk supply removed . With London demands increased by 90.9 Ml/d the model gave the following levels of service :

	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL DAYS	902	728	329

LONDON DEMAND SUPPORTED 2604.4 Ml/d
DEMAND SATISFIED UNTIL 2020 +
RESOURCE VALUE 90.9 Ml/d