NRA

National Rivers Authority
Anglian Region

Regional Strategic Options Study
Final Report

Component 7
River Trent to Rutland Water Transfer

WS Atkins

April 1993

WS Atkins

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ANGLIAN REGION

REGIONAL STRATEGIC OPTIONS STUDY

COMPONENT 7 - RIVER TRENT TO RUTLAND WATER TRANSFER

FINAL REPORT

APRIL 1993

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NRA ANGLIAN - REGIONAL STRATEGIC OPTIONS STUDY
COMPONENT 7 - RIVER TRENT TO RUTLAND WATER TRANSFER

EXECUTIVE SUMMARY

WS Atkins was appointed by the Anglian Region of the NRA in August 1991 to carry out a regional water resource Strategic Options Study (SOS) examining the feasibility, cost and environmental implications of particular engineering options. Figure 1.1 shows the two principal options in the Regional Strategic Options Study, namely transfers from the lower Trent to Norfolk, Essex and Thames Region (Components 1-3, 5 & 6) and a pumped storage river regulation reservoir at Great Bradley, near Newmarket (Component 4). As a supplementary study, Atkins was appointed in December 1991 to consider the bulk transfer of up to 400 tcmd of water from the River Trent at Nottingham to Rutland Water (Component 7). This report presents this supplementary study.

Abstractions at Nottingham would have a greater impact on the Trent than abstractions from the tidal reach, particularly at times of low flow. Unless low flow restrictions on abstractions were introduced, the main impacts would include derogation of Staythorpe Power Station licence for cooling water abstraction and worsened conditions for coarse fisheries between Nottingham and Newark during low flow periods. British Waterways would also oppose increased abstraction upstream of Torksey (the most downstream abstraction point for Component 1) mainly on the grounds that it would worsen the already difficult siltation regime.

For abstraction at Nottingham the downstream Shelford site would have less impact on the Trent than abstraction at Thrumpton (see Figure 1.2). Shelford is downstream of mainly non-consumptive users including the National Watersports Centre and abstraction at Shelford would not reduce dilution of sewage effluent from Stoke Bardolph STW.

Rutland Water storage could be used to accommodate seasonal limitations on Trent abstractions.

The high levels of nutrients in the Trent water indicate that treatment to remove phosphates before discharge into Rutland Water would be necessary. This is currently the case for existing inputs from the Welland and Nene. Maximum chloride, nitrate and ammonia levels in the Trent at Shelford equal or exceed EC and UK limits for water intended for public supply but blending and storage in Rutland would improve water quality. Continuous water quality monitoring would be required for abstraction at the Shelford site due to the risk of pollution from the Stoke Bardolph Sewage Treatment Works.

For operation with both 3 and 6 months pumping from the Trent, a preliminary Net Present Value (NPV) analysis indicates that the least cost route would be for abstraction at Shelford and pipeline to Rutland Water via a disused rail tunnel near Scalford (Route 2.1b). Use of the rail tunnel would reduce the cost of pumping over an escarpment. These costs include only a nominal £1M for purchase of the rail tunnel which is reported to be in private ownership. The actual cost of purchasing the tunnel would be a matter for negotiation with the tunnel owners. A survey would be required to confirm the condition of the tunnel. The disused tunnel is also likely to be a bat roosting site which could constrain methods of working and timing of construction.

NPV costs for six months pumping and capital cost estimates for Routes 2.1 (a) not using, (b) using the disused rail tunnel and (c) constructing a new low level tunnel instead of using the disused rail tunnel are given below:

TABLE A - NPV and Capital Costs (CC) for Route 2.1

Transfer Capacities		100 tcmd		200 tcmd		300 tcmd		400 tcmd	
		NPV	CC	NPV	CC	NPV	CC	NPV	CC
Pipeline over escarpment	(a)	43	32	74	46	-	-	-	-
Disused rail tunnel	(b)	36	29	63	46	89	61	114	78
Low level tunnel	(c)	-	-	-	-	101	72	120	79

Cost of Route Options in £M (- indicates not competitive)

The ranking of route options for 3 months pumping per annum is similar.

Should the disused railway tunnel become uneconomic following a survey or negotiation with its owner then route 2.1(a) is the least cost option for lesser transfer capacities but 2.1(c) for higher capacities.

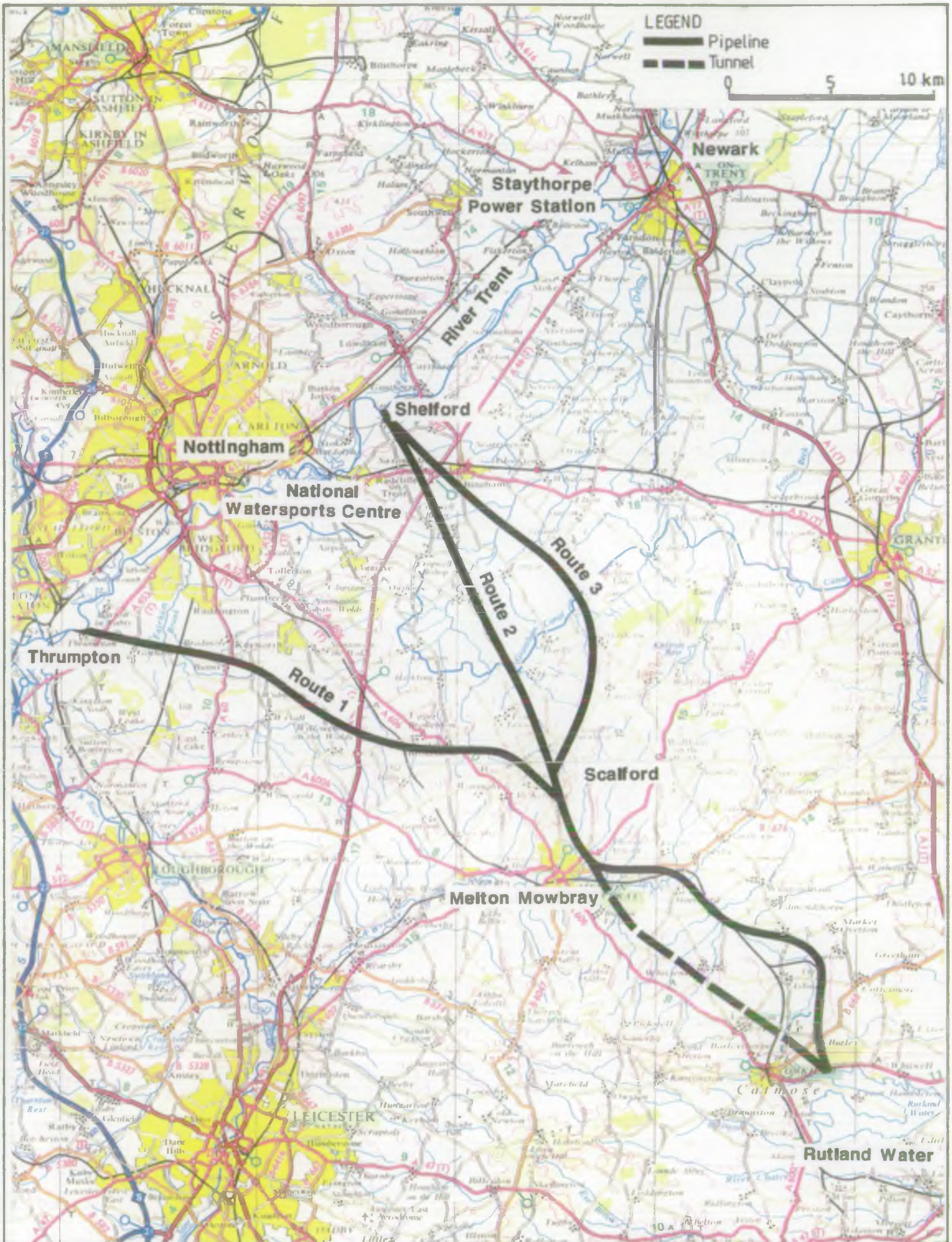
Current and proposed coal mining activity precludes tunnelling in the area north of Asfordby, however the vicinity of the disused rail tunnel near Scalford should be unaffected.

Routing generally along a disused railway line (Route 3) is not preferred as it has no significant cost advantage and would have environmental impacts as there are lengths which have value as a nature refuge including a cutting which is a SSSI.

The programme for implementation could take about 4 years and would require acquisition of a license to abstract from the River Trent possibly involving Public Inquiry. Planning Permission for the intake and pumping station would be required. Both the NRA and water companies have existing powers to lay pipelines.

Further work is recommended to investigate the level of organic contaminants arising from Nottingham trade effluent. The possible increase of nitrate levels in Rutland Water due to higher Trent nitrate levels and reduced residence time should also be investigated.

WS/Atkins	NRA NRA Anglian Region	**STRATEGIC OPTIONS STUDY** **STRATEGIC TRANSFER LINKS - NEW AND EXISTING**	**Figure 1.1**



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STRATEGIC OPTIONS STUDY

COMPONENT 7 - PRINCIPAL ROUTES

Figure 1.2

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1.0 INTRODUCTION

1.1 General

In November 1991 WS Atkins was appointed by the Anglian Region of the National River Authority (NRA) to carry out a regional water resource Strategic Options Study (SOS) examining the feasibility, cost and environmental implications of a number of engineering options to increase regional water resources. The Main Report (Final Report Volumes 1 and 2, January 1993) considers two principal engineering options which are the transfer of water from the River Trent to Essex and the construction of a river regulation reservoir at Great Bradley near Newmarket.

WS Atkins were subsequently instructed, as an extension of the SOS, to study a transfer option from the River Trent near Nottingham to Rutland Water. This option is seen as a possible partial alternative to the transfers considered in the Main Report which included lesser transfers to Rutland Water en route to Essex. This Nottingham-Rutland transfer (component 7 of the Strategic Options Study) is presented as a separate report as required by the supplementary Terms of Reference.

1.2 Terms of Reference

The Terms of Reference of the study are attached in Appendix A. The net transfer capacities of the Trent-Rutland link under consideration are 100, 200, 300 and 400 tcmd. (Minutes of Meeting No.2, 19.12.91)

1.3 River Trent to Rutland Water Transfer Option

The two major options considered in the Strategic Options Study Main Report (submitted separately) are the transfer of water from the lower Trent to the southern part of Anglian Region and the construction of a river regulation reservoir at Great Bradley near Newmarket (see Figure 1.1). The alternative Trent-Rutland link considered in this report would have the following major benefits :

- Rutland Water storage could be used to accommodate seasonal limitations on Trent abstractions.

- The Trent-Rutland link could be constructed relatively quickly.

There are also some disbenefits to this route :

- NRA's policy is to prefer abstractions immediately upstream of the tidal limit to leave water in river for users. Thus lower Trent abstractions are preferable to abstractions near Nottingham.

- In itself it would not meet the water requirements of the southern or eastern part of the Anglian Region as there is no transfer link beyond Component 7 to these areas.

- Abstraction would be upstream of Staythorpe Power Station. This is a direct cooled station and therefore has a large abstraction licence.

- There would be an increased risk of pollution to Rutland Water by pumping Trent Water directly into it.

2.0 ROUTE OPTIONS

2.1 Introduction

Two abstraction locations on the Trent have been considered, upstream and downstream of Nottingham. Initially three basic route alignments were considered from the River Trent to Rutland Water. These routes were developed and adjusted to suit pipeline or tunnel sections and the resulting route alternatives are shown in plan on Figures 2.1 and 2.4. The basic routes are :

Route 1 - (Figure 2.1) Abstraction upstream of Nottingham, near Thrumpton, then across the Vale of Belvoir to Melton Mowbray and south to Rutland Water, either by pipeline through the Vale of Catmose, or more directly by tunnel. An additional predominantly tunnel route (1.6) skirts west of the planned area of mining activity north of Asfordby.

Route 2 - (Figure 2.4) Abstraction downstream of Nottingham, near Shelford, then southwards to Melton Mowbray and on to Rutland Water, either by pipeline through the Vale of Catmose, or more directly by tunnel. A tunnel section (route 2.6) skirts the eastern fringe of the planned area of mining activity.

Route 3 - (Figure 2.4) As Route 2 but using the route of the disused railway track across the Vale of Belvoir.

Details of the environmental aspects as they affect the route options are presented in Chapter 5.0.

Alternative combinations of pipelines and tunnels have been considered for each of the routes to identify the least cost option. Tunnel sections have been proposed through the escarpment and topographic peaks. Compared with the pipeline alternatives, the use of tunnels reduces the total pumping head and results in lower pumping costs. However, the capital cost of tunnel construction is significantly higher and therefore total costs have to be considered in determining the least cost option.

At our request National Coal produced a report which highlighted the areas of past and proposed mining. As proposed coal mining would preclude tunnelling, certain sections of tunnel have to be diverted. The possible diversions have been shown on Figures 2.1 and 2.4 (routes 1.6 and 2.6).

2.2 Route 1

By pipeline this possible route follows the most direct line from the River Trent to Rutland Water, given the topography south of Nottingham. As a pipeline, it traverses the Vale of Belvoir and ascends the escarpment through a valley thereby reducing the summit height. It also avoids the built-up areas of Gotham, Bunny and Widmerpool. The route crosses the escarpment and passes to the east of Melton

Mowbray. If the route is taken as a pipeline then from east of Melton Mowbray it follows a similar route to the existing railway along the Vale of Catmose. The pipeline passes to the east of Ashwell and then southwards to Rutland Water. If however, a tunnel from Melton Mowbray is considered then a more direct route is possible to Rutland Water, passing between Whissendine and Langham in a north west, south east direction. This possible route discharges at the north east corner of Rutland Water, just east of Oakham.

As mentioned in Section 2.1 this route has been considered as different combinations of pipelines and tunnels,to find the most economical solution. The variations include the whole route as a pipeline and a tunnel, for comparison purposes. The sections taken are governed largely by the topography. Figures 2.2 and 2.3 show the general long sections and schematics of the different combinations for Route 1.

Table 2.1 - Route 1 - Pipeline/Tunnel Alternatives

Route Alternatives	Section	Length (km)
1.1 (a) (b) uses disused rail tunnel	Pipeline Pipeline (including length through tunnel)	49.6 (a) 53.0 (b)
1.2	Pipeline to B Tunnel	13.9 31.6
1.3	Pipeline to B Tunnel to G Pipeline to J Tunnel	13.9 13.4 6.2 12.0
1.4	Pipeline to B Tunnel to G Pipeline	13.9 13.4 20.0
1.5	Tunnel	45.5
1.6	Pipeline to T Tunnel	14.5 31.8

Route 1.1(b) uses a disused rail tunnel under the escarpment near Scalford. This reduces the total pumping head along this length of the route and so some saving to the pumping costs is made.

2.3 Route 2

This possible route has an abstraction point on the River Trent, north of Shelford and then follows the most direct route to Melton Mowbray. From Melton Mowbray Route 2 follows similar pipeline and tunnel routes to that of Route 1.

This route has also been considered as a combination of pipelines and tunnels. Route 2.1(b) and 2.4(b) use the disused rail tunnel, near Scalford to reduce the static head and so reduce the pumping costs along this length of the route. Route 2.1(c) uses a deep tunnel constructed near the disused rail tunnel. This alternative was considered since using the disused tunnel may not be feasible.

The pipeline/tunnel combinations are governed by the topography. Figures 2.5 and 2.6 shows the schematics of the various combinations considered for Route 2.

Table 2.2 - Route 2 - Pipeline/Tunnel Alternatives

Route Alternatives	Section	Length (km)
2.1 (a) (b) uses disused rail tunnel (c) includes 2.0km of low level tunnel	Pipeline	45.7 (a) (45.7)(b) (45.7)(c)
2.2	Pipeline to C Tunnel	18.5 24.6
2.3	Pipeline to C Tunnel to G Pipeline to P Tunnel	18.5 5.7 5.7 13.2
2.4 (a) (b) uses disused rail tunnel	Pipeline to J Tunnel	31.1 12.0
2.5	Pipeline Tunnel	43.1
2.6	Pipeline to U Tunnel to V Pipeline	18.9 10.0 15.0

2.4 Route 3

This possible route also has an abstraction point on the Trent, near Shelford. It the joins the disused railway track south of Bingham and follows the rail track southwards to Melton Mowbray. The rail track route is approximately 3kms longer than the direct route across the Vale of Belvoir.

The longer length using the rail track was considered because there might have been the possibility of partially burying and landscaping over the pipeline along the disused track to reduce costs.

Although British Rail owns most of the 17.5km disused rail track concerned, some sections are in private ownership. Most of the rail track has been returned to agricultural use and so a partially buried pipeline along the disused track is not considered viable.

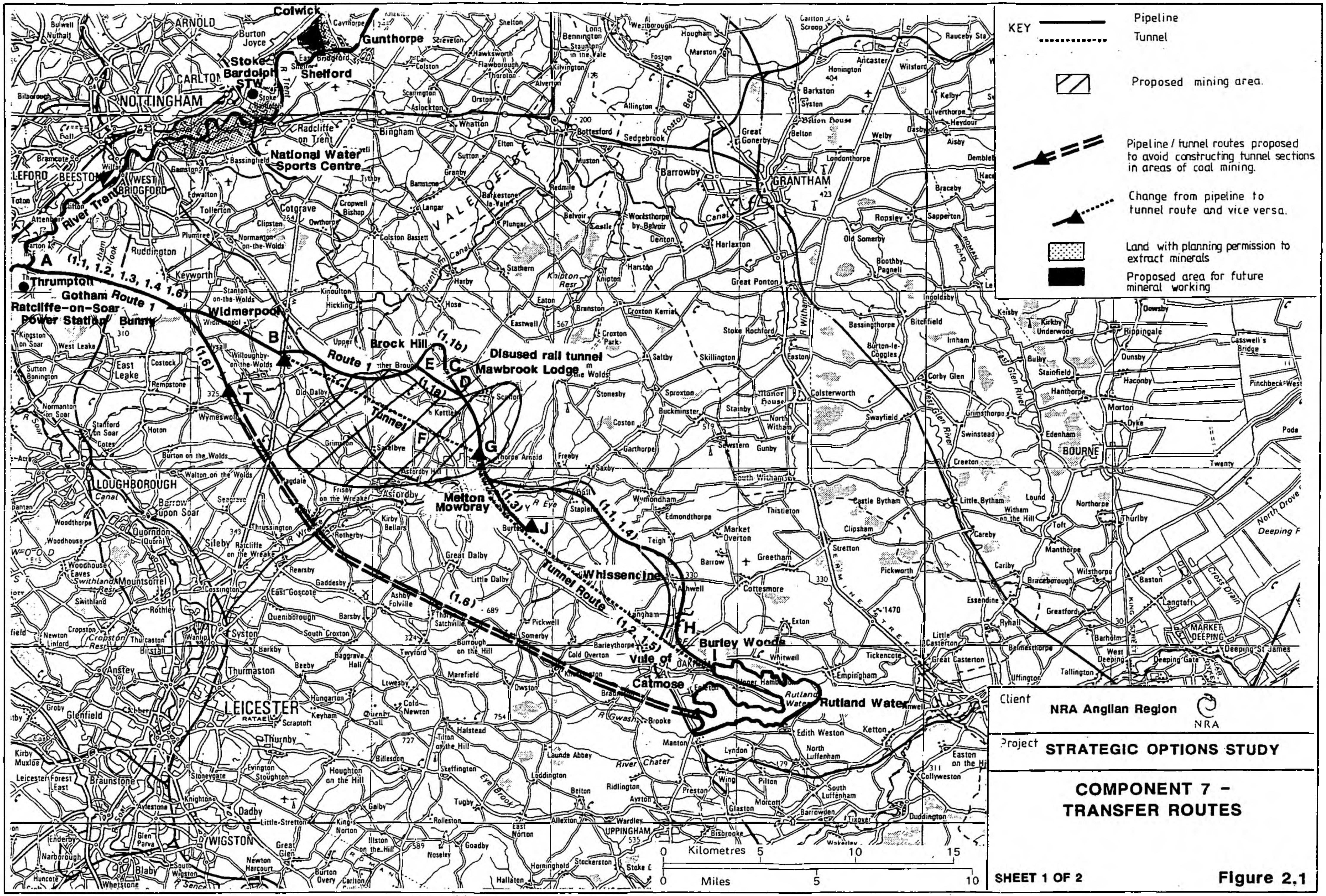
All route alternatives use the disused rail tunnel between Brock Hill and Mawbrook Lodge. British Rail has advised us that this disused rail tunnel passed into private ownership about twenty years ago. A survey of the tunnel would be required to assess its condition. At present there is no access to the tunnel available. A nominal cost has been included for purchase or use of the tunnel.

From Melton Mowbray this route would follow a similar route to those of Routes 1 and 2.

This route is analysed in various combinations as given in Table 2.3. Figure 2.7 shows the route long section and the tunnel/pipeline schematics.

Table 2.3 - Route 3 - Pipeline/Tunnel Alternatives

Route Alternatives	Section	Length (km)
3.1	Pipeline to Q Pipeline along rail track to G Pipeline	5.0 21.0 21.1
3.2	Pipeline to Q Pipeline along rail track to G Tunnel	5.0 19.0 21.1
3.3	Pipeline to Q Pipeline along rail track to G Pipeline Tunnel	5.0 21.0 4.2 14.9



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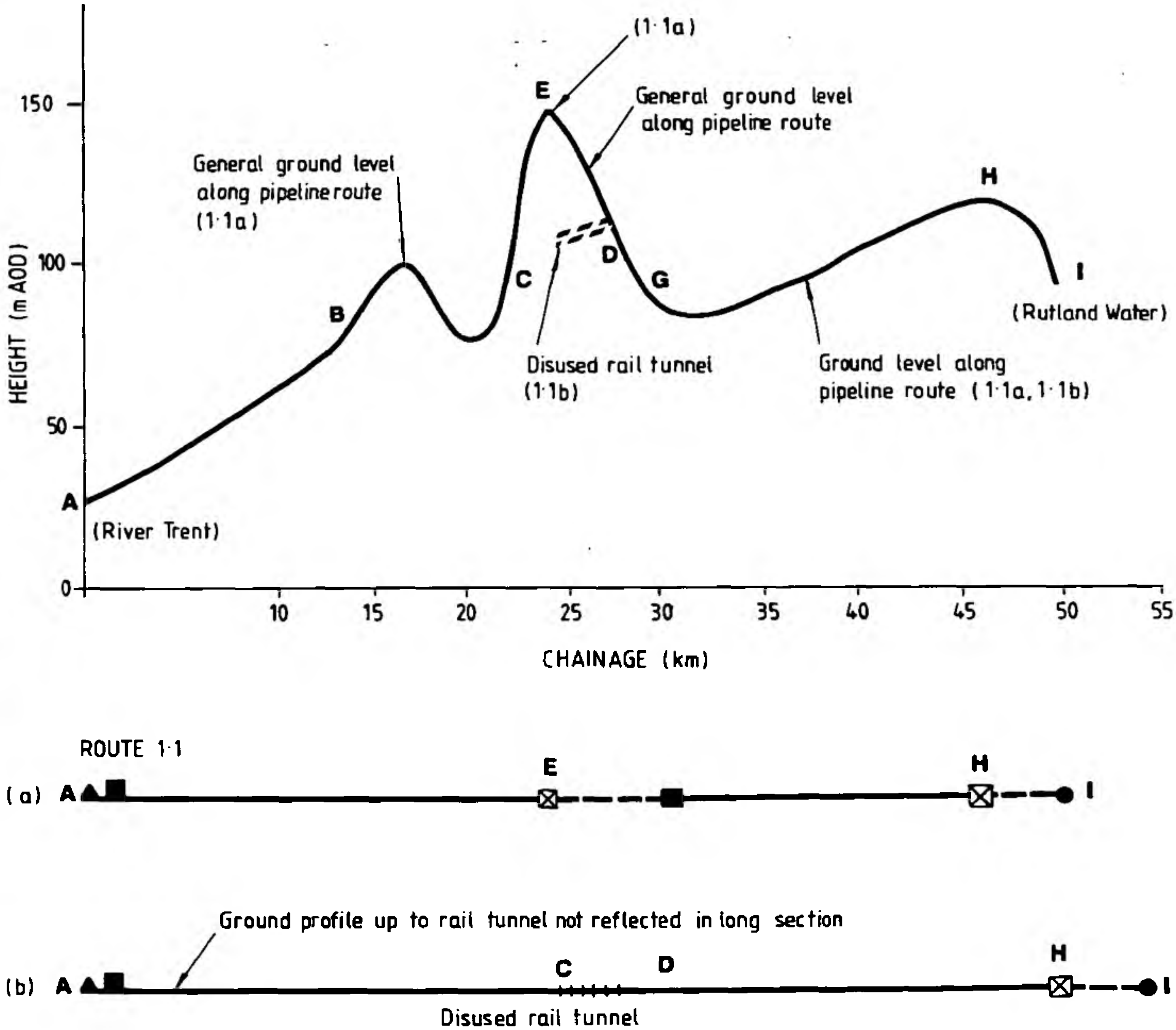
COMPONENT 7 - TRANSFER ROUTES

SHEET 1 OF 2

Figure 2.1



KEY FOR SCHEMATICS:

- ▲ Intake structure
- ■ Pump station
- ⊠ Break pressure tank
- ● Outfall structure
- □ Shaft pumping station
- Solid line: Pump main
- Dashed line: Gravity main
- Hatched line: Tunnel
- Arrowed line: Intake / outake shaft

NOTE: Route 1·6 (along significantly different alignment) is not shown

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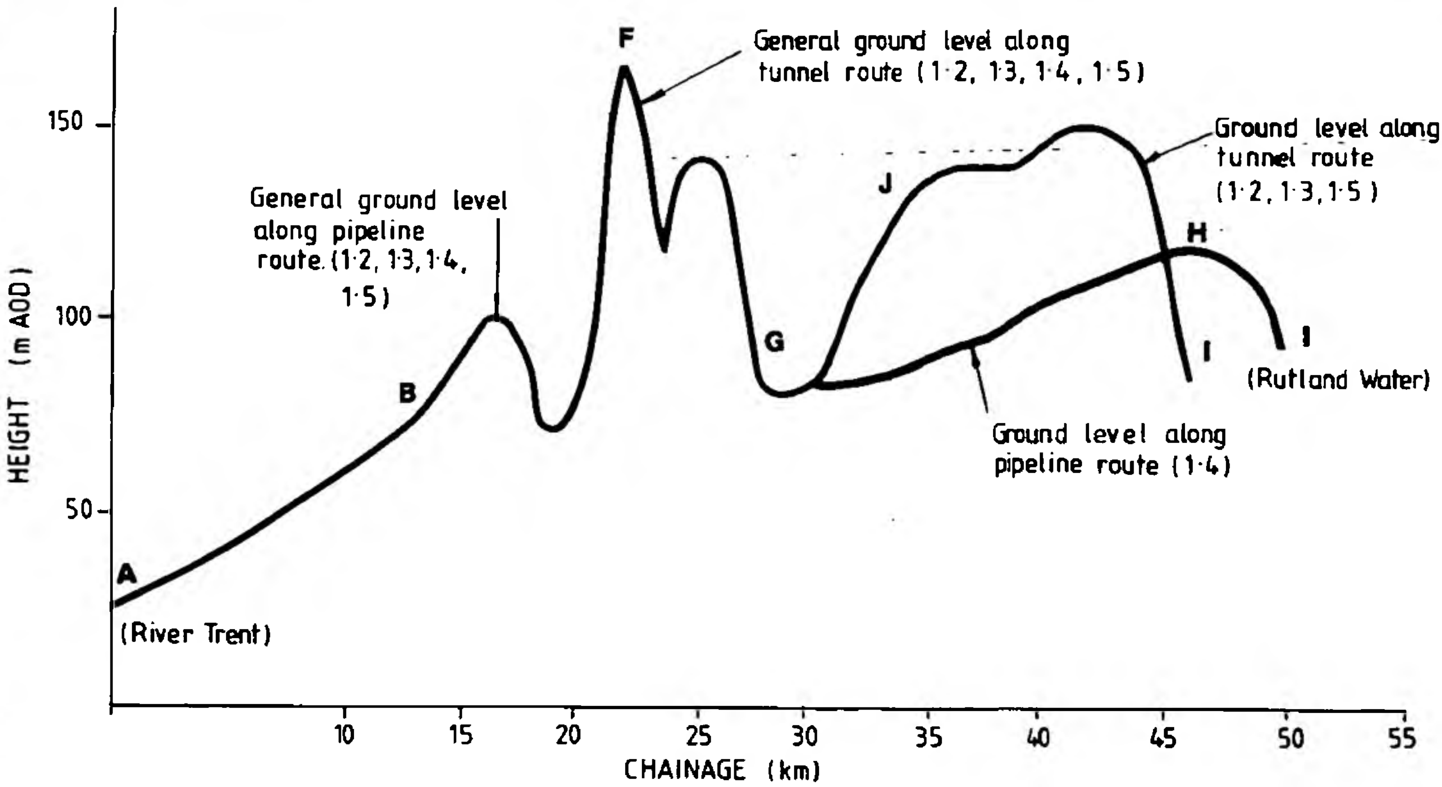
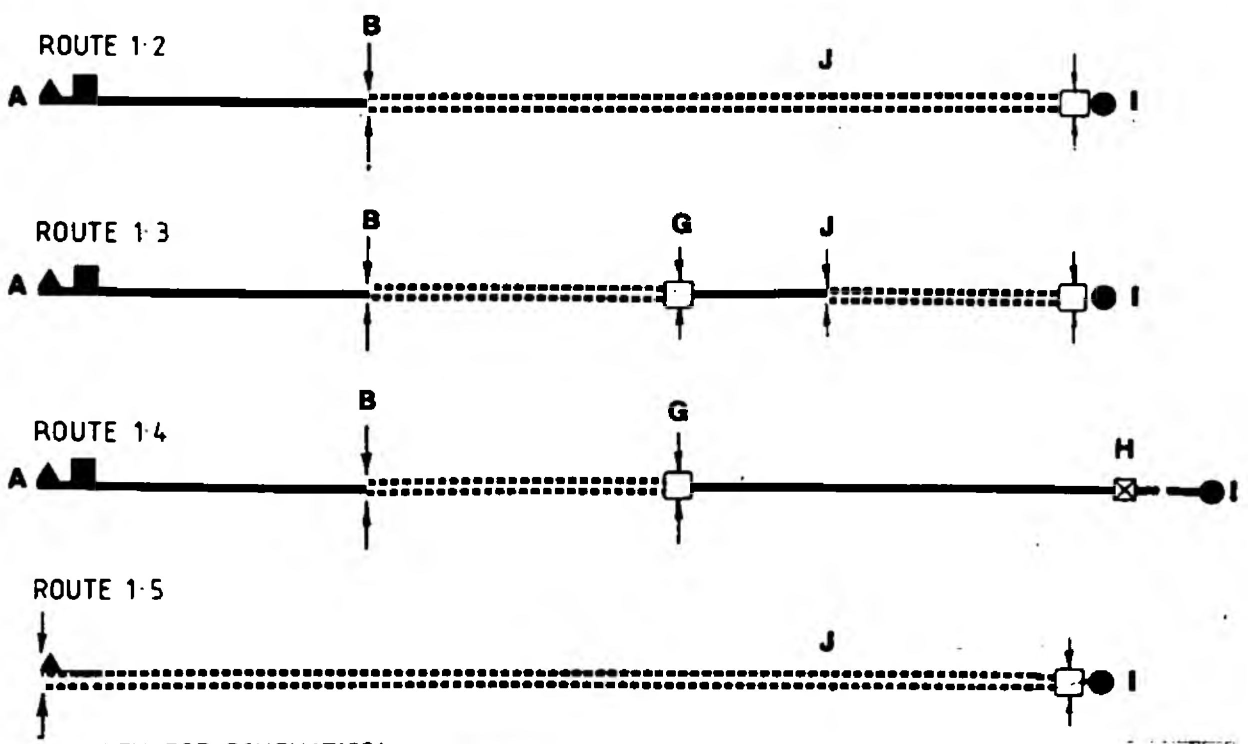
ROUTE 1.1 – LONG SECTION FOR GENERAL ROUTE AND SCHEMATICS

Figure 2.2





KEY FOR SCHEMATICS:

▲	Intake structure	———	Pump main
■	Pump station	— — —	Gravity main
⊠	Break pressure tank	:::::::::	Tunnel
●	Outfall structure	→←	Intake / outake shaft
□	Shaft pumping station		

NOTE: Route 1·6 (along significantly different alignment) is not shown

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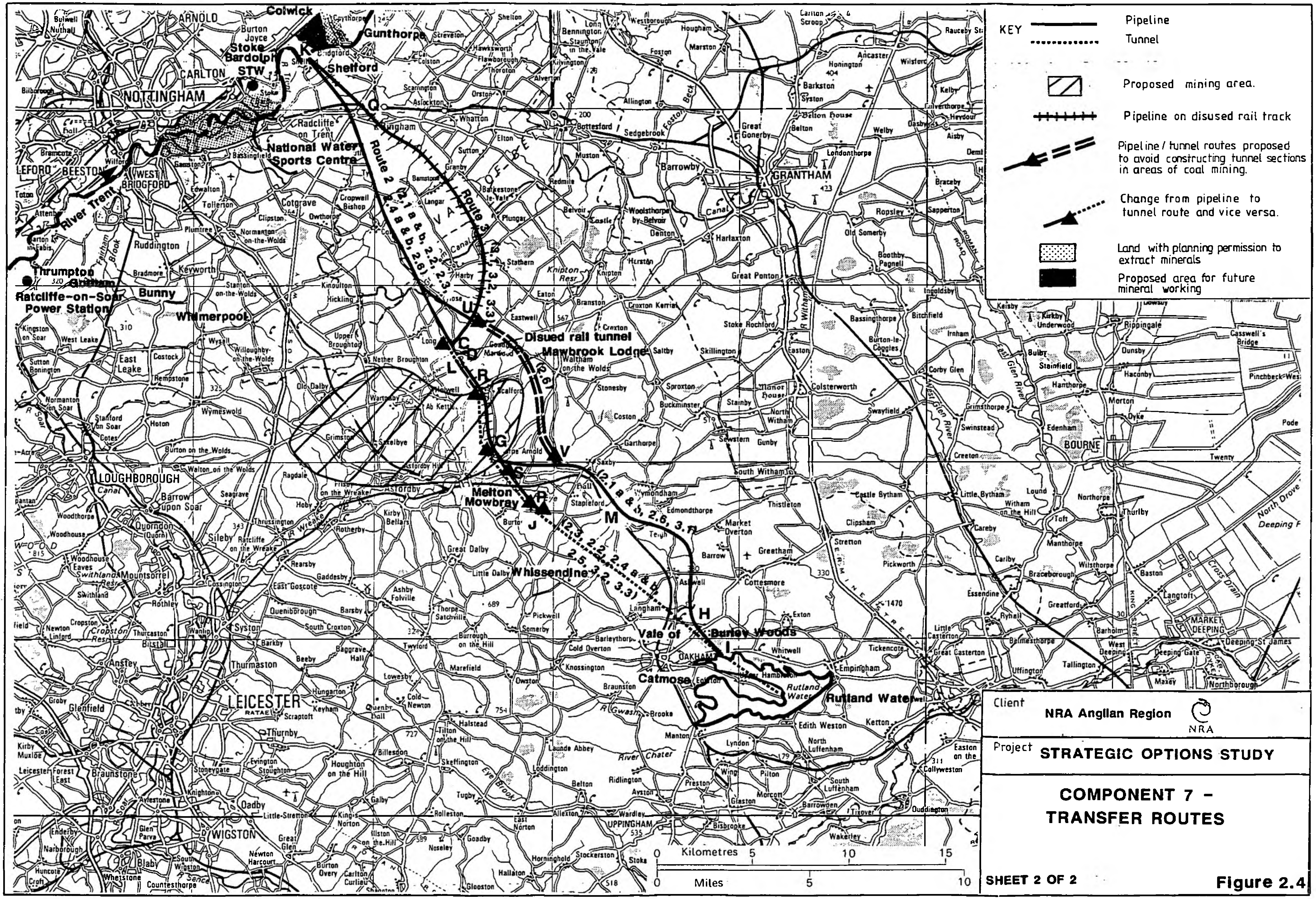
STRATEGIC OPTIONS STUDY

ROUTE 1 - LONG SECTION FOR GENERAL ROUTE AND SCHEMATICS

Figure 2.3


KEY
Pipeline
Tunnel
Proposed mining area.
Pipeline on disused rail track
Pipeline / tunnel routes proposed to avoid constructing tunnel sections in areas of coal mining.
Change from pipeline to tunnel route and vice versa.
Land with planning permission to extract minerals
Proposed area for future mineral working
Colwick
Gunthorpe
Stoke Bardolph STW
Shelford
NOTTINGHAM
National Water Sports Centre
River Trent
Thrumpton
Ratcliffe-on-Soar Power Station
Route 2
Route 3
(2.1a & b, 2.2, 2.3, 2.4 & b, 2.6)
(3.1, 3.2, 3.3)
Disued rail tunnel
Mawbrook Lodge
Melton Mowbray
Whissendine
(2.1a & b, 2.6, 3.1)
(2.3, 2.2, 2.4 & b, 2.5, 3.2, 3.3)
Vale of Catmose
Burley Woods
OAKHAM
Rutland Water
GRANTHAM
LOUGHBOROUGH
LEICESTER
BOURNE
Kilometres 0 5 10 15
Miles 0 5 10
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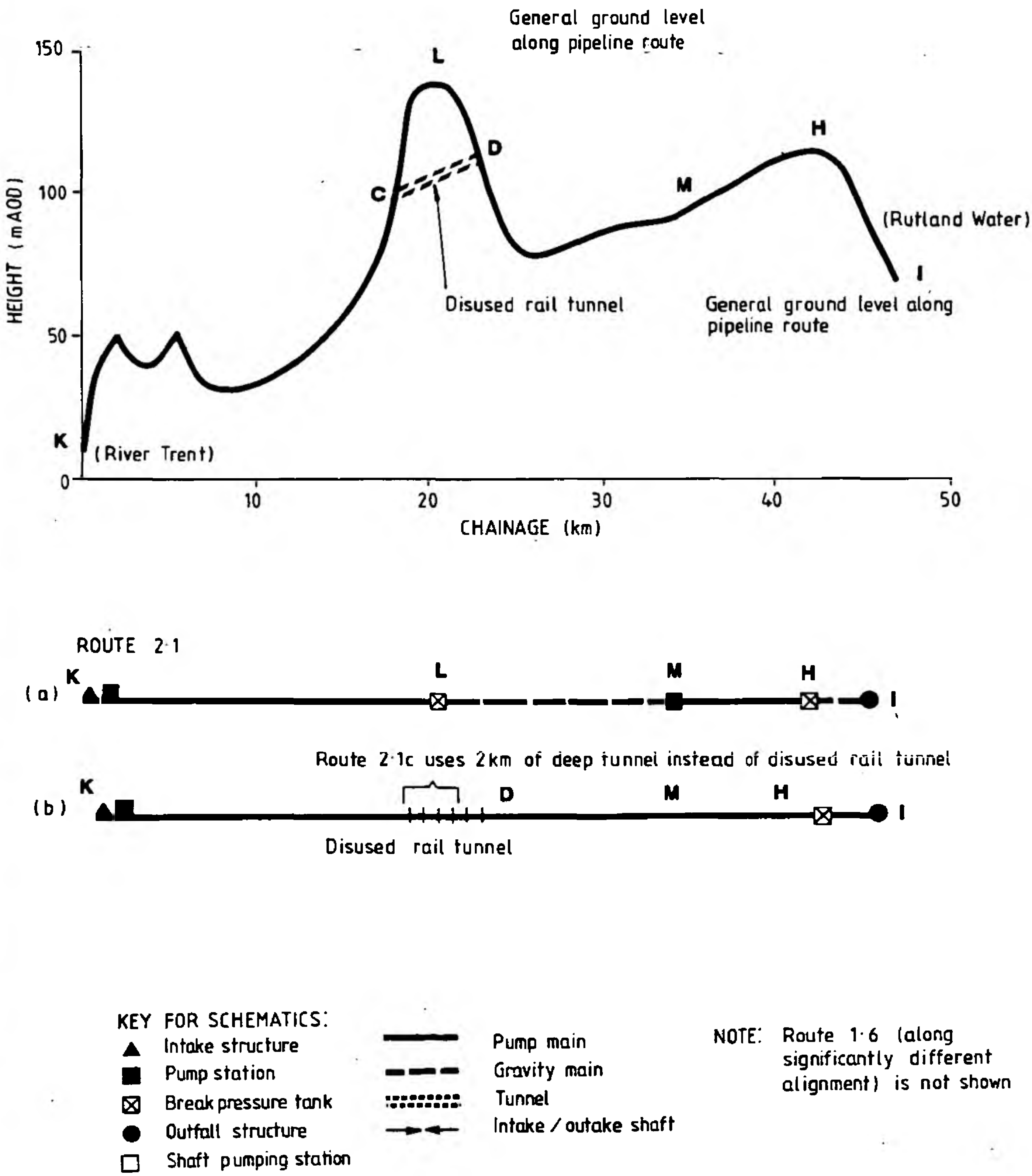
SHEET 2 OF 2

Figure 2.4



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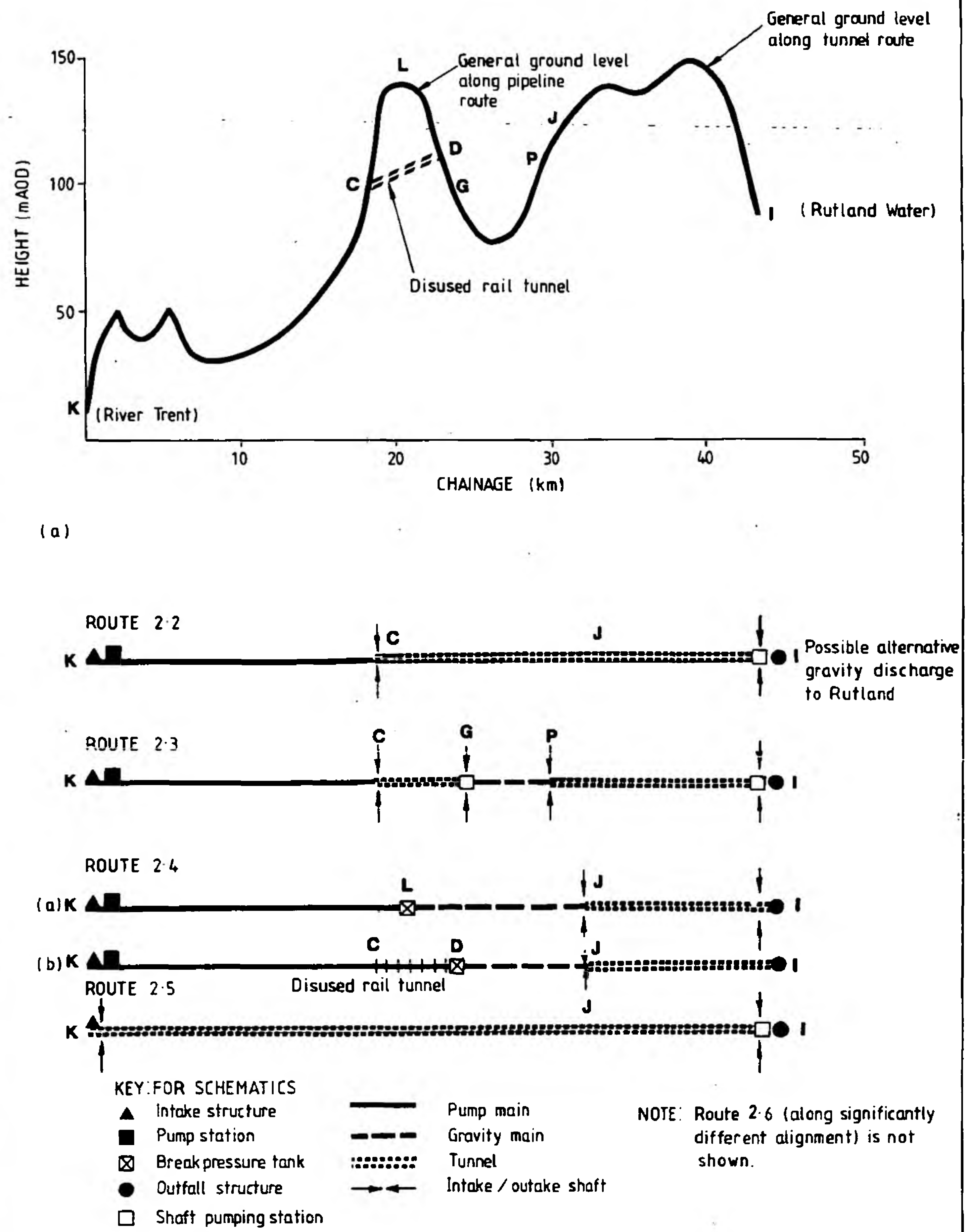
ROUTE 2.1 - LONG SECTION FOR GENERAL ROUTE AND SCHEMATICS

Figure 2.5



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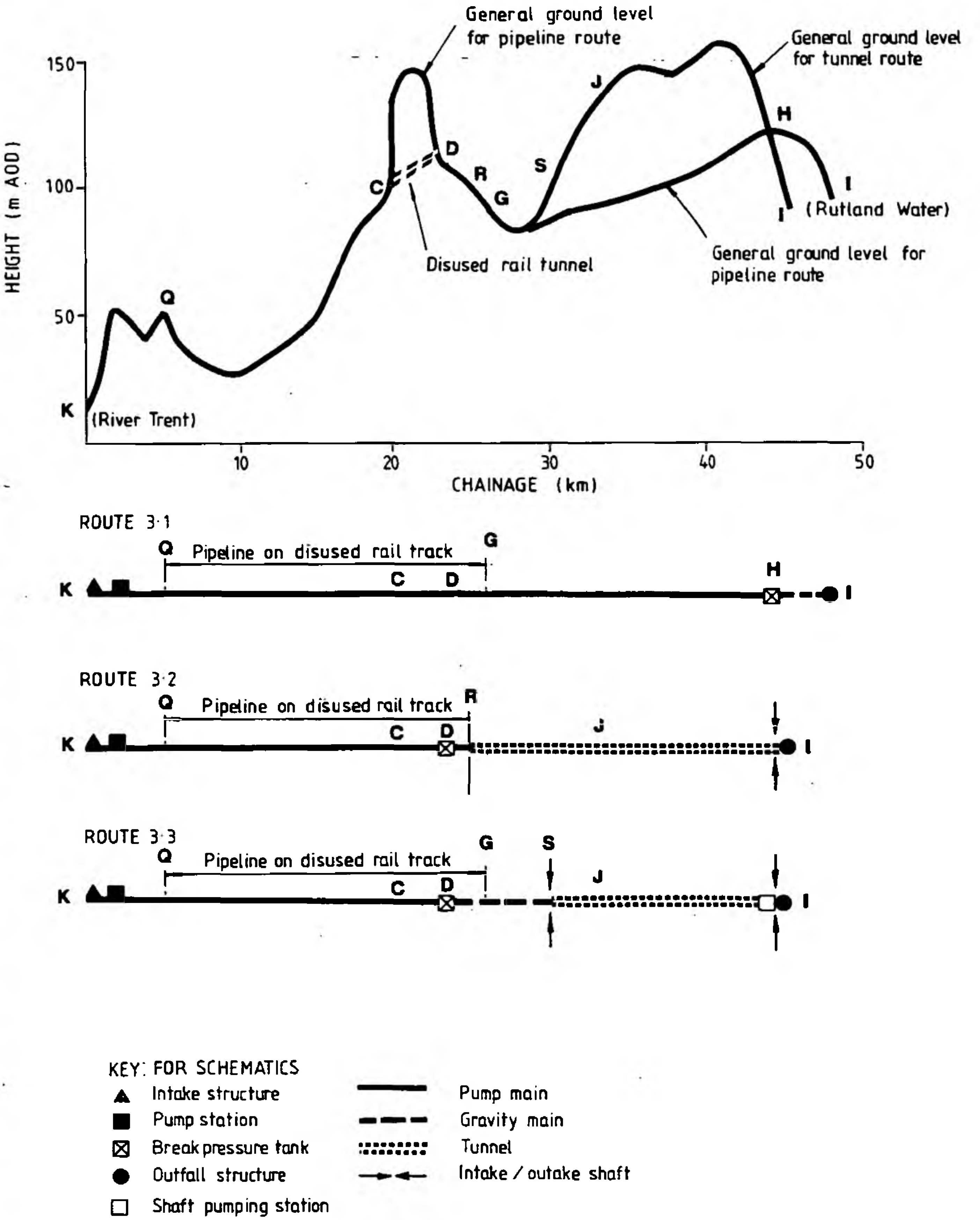
ROUTE 2 – LONG SECTION FOR GENERAL ROUTE AND SCHEMATICS

Figure 2.6



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STRATEGIC OPTIONS STUDY

ROUTE 3 – LONG SECTION FOR GENERAL ROUTE AND SCHEMATICS

Figure 2.7

3.0 ENGINEERING DETAILS

3.1 Introduction

In this section the engineering details and hydraulic principles common to all route options are considered.

3.2. Transfer Pipelines

3.2.1 Pipeline Size Selection

Generally for this outline feasibility study pumping mains have been sized assuming a flow velocity of 1.5 m/s for pipes up to 1.2m diameter and 2.0 m/s for larger diameters. Optimisation of pipe sizes with respect to total capital and operating costs has not been considered at this stage.

Gravity mains have been sized on headloss and acceptable velocity criteria. Friction head loss has been estimated using the Hazen-Williams formula. The roughness coefficient C=135 has been adopted.

To avoid steady state negative pressures in pipelines break pressure/balancing tanks have been included where required by the topography. Discharge from the break pressure/balancing tanks is by gravity. A stilling basin or other flow energy dissipating device at the Rutland Water outlet is included to avoid erosion.

On route alternatives 1.1, 1.6, 2.1, 2.4, 2.6, 3.1, 3.2 and 3.3, the size of the initial stretch of pipeline to the escarpment has been based on a maximum working pressure of 20 bar for steady state conditions. Any remaining pipeline on these routes has been based on a maximum working pressure of 16 bar for steady state conditions. For steel pipes the increase in costs for the higher pressure pipe would be slight. If ductile iron is used, the costs for pipe fittings for a 20 bar system, are significantly more than for a 16 bar system.

For details on duplication of pipelines, pipeline materials, river intakes and crossings refer to the SOS Final Report January 1993.

3.2.2 Geology

The report of the geological desk study is included in Appendix B and the principal conclusions affecting pipelines are as follows :

Route 1 crosses areas of peaty alluvium before rising onto the Wolds which, in parts, are capped with a thick sheet of chalky boulder clay. It then traverses the Vale of Belvoir which comprises of clays of the Lower Lias before climbing obliquely to the escarpment which flanks the southern edge of the Vale.

Routes 2 and 3 commence in the sandy sites of Keuper Marl formation before passing over peaty loam and stony boulder clay. These routes also cross the Lias clays of the Vale of Belvoir before ascending the southern escarpment of Marlstone Bed Rock.

All the predominantly pipeline routes merge at Scalford. The northern approaches of Route 2 and 3 to the escarpment of the Marlstone Rock Bed appears to be more favourable than that taken by the southern Route 1, which makes an oblique ascent. An oblique ascent is more likely to initiate or reactivate ground instability.

The common route approaching Rutland Water has been adjusted to avoid the landslip strata of the Inferior Oolite.

In order to identify any unstable slopes, further work should include a search of the UK Landslides database followed by airphotos interpretation and engineering geomorphology mapping.

3.3. Tunnelling

Generally favourable tunnelling conditions could be expected for all routes except in the areas of proposed coal mining. The geology for all routes is similar, being largely carbonaceous mudstones (marls) and clays but with horizons of the very much stronger sandstones and limestones.

If tunnels for the full length of routes 1 and 2 were considered they would commence in Keuper Marl (Mercia Mudstone) and, at about 25km along their lengths would pass beneath the escarpment of the Marlstone Rock Bed. The tunnels would re-emerge at Rutland Water in Upper Lias. The location of the outfall at Rutland Water has been chosen to ensure that the Inferior Oolite along the north of Rutland Water is not traversed as this is not a suitable tunnelling medium.

High productivity tunnelling relies to a great extent on the presence of competent strata and also on there being adequate space for excavation, spoil handling, and lining operations.

Tunnel diameters are therefore normally fixed by other factors rather than hydraulic capacity for the range of flows being considered. For this reason, with drives up to 4km, a 2.54m diameter tunnel has been adopted as a general optimum size. This diameter has been used successfully in the London Ring Main Project with drives of up to 5km being completed successfully.

Any hydraulic oversizing which results means that tunnelling is not economic for the lower transfer capacities under consideration but becomes relatively more economic as the transfer capacity increases.

Smaller diameters can be considered if the tunnel is constructed using pipejacking. However this is not suitable for long drives, and is considered only for crossings, ie rivers, roads which cannot be closed and rail tracks. A schedule of the crossings for each route is given in Appendix D.

3.4 **Transfers Using Watercourses**

There are two watercourses in the area of the study which might be considered for transfers. These are the River Soar and the Grantham Canal.

The River Soar flows from Hinckley, south of Leicester, to the River Trent at Thrumpton, thus flowing in the opposite direction to the transfer considered in this report. Abstraction from the Soar of $4.6m^3/s$ (400 tcmd) would have a significant effect on the river with its mean flow, at Kegworth, of $13m^3/s$ (1123 tcmd). In comparison the River Trent, has a mean flow of $85.1m^3/s$ (7353 tcmd) at Colwick. Thus, the River Soar would not be a suitable watercourse for abstraction in this transfer.

The Grantham Canal is a long, disused canal from Trent Bridge, Nottingham , to Grantham. Since the canal was built purely to serve the agricultural communities of eastern Nottinghamshire, it pursues a rather circuitous route. Certain lengths of the canal have now been drained.

Therefore, neither of these watercourses appear suitable for use in connection with this transfer.

3.5 **Summary of Coal Mining Report**

A report by British Coal on past and proposed coal workings in the vicinity of the transfer routes is included in Appendix C.

It is reported that at the northern end of routes 2 and 3 there was coal mining before 1989. Any ground movement from these workings should now have ceased. The Cotgrave Colliery does not affect either routes 2 or 3 and there is no other mining in the vicinity of the routes at present. Coal mining, however, is planned at the Asfordby Colliery and the extent of this proposed working area is shown on Figures 2.1 and 2.4. Further reserves of coal in this area may be worked in the future.

Detailed routing and design of transfer schemes affected by coal workings would have to be developed with British Coal at the appropriate stage. Construction of a pipeline with adequate provision for flexibility to cope with likely ground movement should not be a problem. However tunnels above coal workings are precluded where possible disruption could occur caused by ground movement above collapsed workings. There is also the possibility of methane arising from coal measures becoming a hazard during the construction or operation of a transfer scheme. This would have to be carefully considered at design during subsequent stages.

There are a number of initial route alternatives with tunnel sections crossing the area of proposed coal mining. They include routes 1.2, 1.3, 1.4, 1.5, 2.2, 2.3, 2.5, and 3.2. Routes 1.6 and 2.6 are aligned to avoid tunnelling in the area of proposed mine workings.

The initial route corridors defined for the coal report were widened and confirmation was obtained that the diverted tunnel sections of routes 1.6 and 2.6 are not affected by proposed mining.

4.0 POSSIBLE IMPACT OF ABSTRACTION ON THE RIVER TRENT IN THE NOTTINGHAM AREA

4.1 Introduction and Reference to Main Report

The Main Report has considered the River Trent generally downstream of Newark, and the possible impacts of abstraction at Torksey or Newark.

The proposal to abstract at Nottingham would also reduce flows in the river below Newark and would therefore have similar effects to those detailed in the Main Report. In particular the Main Report highlights concerns about changes to the tidal silt regime in the Newark-Torksey reach due to abstractions above Torksey during Trent low flow periods. British Waterways (BW) have said that they would strongly oppose any increased abstraction upstream of Torksey and this therefore includes the possible Nottingham abstraction. BW have experienced serious siltation problems in the Torksey-Newark reach during 1991-92 with a need for major dredging to maintain navigation depths. This was thought to be partly due to the lack of higher winter flushing flows to remove sediment. Exacerbation of the siltation problem might be minimised by increased winter-only abstractions at Nottingham. This chapter concentrates on the impact of the possible abstractions on the river between Nottingham and Newark. The impact is considered for low flow conditions in the River Trent when the effects of abstractions would be greatest.

4.2 Uses of the River Trent between Nottingham and Newark

This reach of the river is used intensively for a wide variety of purposes including angling, navigation, recreation, power generation and effluent disposal.

The entire reach is designated as a Cyprinid Fishery under the EC Freshwater Fisheries Directive and supports an abundant and diverse coarse fish population. It is considered by many to be one of the finest coarse fishing rivers in the country. It represents a major regional resource providing enjoyment for a very large number of anglers.

The Trent is a navigable river as far upstream as Shardlow, above Nottingham. British Waterways (BW) are the navigation authority and the river is mainly used by pleasure craft. BW expect there to be a continued increase in the numbers of craft using the river.

The Trent is an important recreational amenity, particularly through Nottingham, providing riverside walks and other basic amenity interest. However, the single most important facility is the National Watersports Centre at Holme Pierrepont. This is operated by the Sports Council and is of national, as well as regional importance. The Centre includes the prime artificial canoe slalom course in the country, with water being supplied directly from the River Trent. The course is the home training ground for the British Olympic canoe slalom team and attracts canoeists from all over the country. It is currently being promoted regionally as a white water rafting venue, aimed at attracting non-canoeists and, in particular, the disabled community. It is used throughout the year with the heaviest use being in the summer. Future use is expected to continue increasing, with plans to floodlight the course in order to extend opening hours.

There are two power stations operating in this reach of the River Trent, Ratcliffe-on-Soar at the Trent/Soar confluence, and Staythorpe upstream of Newark. Ratcliffe is a modern, large, baseload station and is an important part of PowerGen's generating capacity. The power station uses evaporative cooling and therefore has a relatively small abstraction licence (217 tcmd), although substantial river flows are required to dilute the thermal effluent load. A flue gas desulphurisation (FGD) plant is also under construction at Ratcliffe. This would increase discharges of chlorides, sulphates and nitrates to the river. Staythorpe is an older, direct cooled station and therefore has a large abstraction licence (3211 tcmd). There are also proposals to build a new Combined Cycle Gas Turbine power station at Staythorpe, which is primarily direct cooled but has the facility for evaporative cooling.

There are six other power stations operating along the River Trent. Upstream of Ratcliffe-on-Soar, there is Drakelow which is direct cooled but has the facility for evaporative cooling; Willington and Castle Donnington, both of which are direct cooled. Downstream of Staythorpe there are three power stations - High Marnham, Cottam and West Burton - all of which use evaporative cooling methods.

The River Trent, from Trentlock near Thrumpton to Shelford, receives sewage effluent from the East Midlands towns of Leicester (via the River Soar), Derby (via the Derwent) and Nottingham, direct to the Trent from Stoke Bardolph STW. River flows are required to dilute this effluent, particularly from Stoke Bardolph STW.

4.3 Existing Flow Regime

As has been mentioned in the Main Report, the Trent receives substantial effluent discharges, providing a significant net artificial flow input. For example, at Colwick Gauging Station in Nottingham, the Dry Weather Flow (ie 7 day Mean Annual Minimum) is 2400 tcmd, with artificial influences accounting for 750 tcmd of this figure. The Dry Weather Flows at the Thrumpton and Shelford abstraction points are estimated at 2250 tcmd and 2580 tcmd respectively.

During drought periods, the summer flow in the Trent can drop significantly. In 1976 the 7 day low flow at Colwick was 1340 tcmd, and in 1990 it was 1870 tcmd. The return period of these events are estimated at 50 years and 10-15 years respectively.

4.4 Possible Impacts of the Possible Abstraction

(a) River Flows

The possible abstractions of 100, 200 or 400 tcmd would be exports from the Trent catchment and therefore fully consumptive as regards to the Trent. Table 4.1 shows the abstractions as a percentage of different flow conditions in the River Trent.

Table 4.1 - Abstractions as a percentage of different flow conditions in the River Trent

Abstraction Amount (tcmd)	Abstraction as Percentage of Flow			
	DWF at Thrumpton (2250 tcmd)	DWF at Shelford (2580 tcmd)	1976 low flow at Colwick (1340 tcmd)	1990 low flow at Colwick (1870 tcmd)
100	4.4	3.9	7.5	5.3
200	8.9	7.8	14.9	10.7
400	17.8	15.5	29.9	21.4

Assuming that the flow at Shelford is the same as the flow at Colwick typical abstraction rates of 100, 200 or 400 tcmd represent 4, 8 or 16 % respectively of Dry Weather Flow. However, during drought periods, such as 1976 these would rise to 7.5, 15 or 30% respectively.

The effect of the abstraction on the frequency of low flows can be seen in Table 4.2.

Table 4.2 - Effect of Abstraction on the frequency of low flows

Abstraction Amount (tcmd)	Return Period (Yrs) of flows as low as	
	1976	1990
0	50	10-15
100	70*	15-20
200	100	20-25
400	200	35-40

* ie. a 100 tcmd abstraction would change a current 1:50 year low flow event to a current 1:70 year event.

(b) Water Depths and Velocities

The water depths upstream of Colwick are maintained for navigation by Colwick Sluices, and abstraction would therefore have a minimal effect on water levels in this area. The locks at Newark cannot operationally control the upstream water level but would maintain the water levels between Newark and Colwick to some degree. Downstream of Newark the abstractions could reduce water depths during Dry Weather Flow conditions by up to 10% for an abstraction of 400 tcmd; this would rise to over 15% during drought conditions.

Upstream of Colwick, flow velocities would reduce by approximately the same percentage as the reduction in flow volume. Downstream of Colwick the reduction in velocity during Dry Weather Flow conditions would be approximately 6% for an abstraction of 400 tcmd.

(c) Water Quality

There are a number of significant effluent discharges to the River Trent in the reach under consideration. Both Thrumpton and Shelford are downstream of Ratcliffe-on-Soar power station and the rivers Soar and Derwent. Shelford is also downstream of Stoke Bardolph STW at Nottingham. However an abstraction at Thrumpton would reduce the dilution available to this major effluent discharge. The low flows of recent summers have already contributed to high ammonia concentrations in the

Trent from Stoke Bardolph as far downstream as Newark. These concentrations have been above the limits set out in the EC Freshwater Directive. Any reduction in low river flows would therefore increase the severity of this problem and also the standard of treatment required at the sewage works in order to alleviate it.

The high levels of both nitrates and phosphates in the Trent could lead to, or increase, eutrophication problems in the Rutland Waters. Algal blooms already occur in the receiving waters, they could intensify, leading to a large diurnal fluctuation in dissolved oxygen and a substantial BOD upon the decay of the algae. The high phosphate concentrations from the Trent could also exacerbate the occurrence of blue-green algae later in the summer. At present, algal blooms are not a major problem on the Trent. This is probably due to a combination of relatively high flow velocities and poor clarity of the water. In the Rutland Water, suspended solids would settle and water clarity would improve, thus allowing algae to flourish. It would therefore be necessary to treat Trent water to remove phosphate before it is discharged into Rutland Waters. This aspect is considered further in Chapter 5.

4.5 River Users

4.5.1 Navigation

The reduction in flows, and hence depth, in the reaches below Newark Sluices could be a cause for concern to BW. The reduction in depth during low flows would be 10 to 15% for the 400 tcmd abstraction rate, but only 2 to 3% for the 100 tcmd rate. It is likely that the lower rate would not present a problem to BW, and this would probably also be the case for the 200 tcmd rate. However the larger abstraction rate of 400 tcmd could lead to difficulty in the maintenance of the statutory minimum navigation depth.

The possible impact of abstractions on the tidal silt regime in the Newark-Torksey reach during low flow periods has already been mentioned together with BW's opposition to abstractions above Torksey (for more details see the Main Report).

4.5.2 Fisheries

The coarse fishery from Nottingham to Newark has suffered considerably during the recent drought. The problems of "clumping" of fish has disrupted match fishing and the issue has been reported in the national press. NRA Severn Trent region consider the problems to be due to a combination of reduced flows and clearer water as well as the high ammonia concentrations. The possible abstraction at times of low flow would make all of these conditions worse and increase the frequency with which they occur.

4.5.3 Recreation

The canoe slalom course at Holme Pierrepont has flow requirements of up to 1815 tcmd. The adjoining rowing course has also abstracted up to 170 tcmd in recent summers to alleviate algae problems. There is therefore a flow requirement at

Holme Pierrepont of almost 2000 tcmd, the flow being returned to the river some distance downstream of Colwick Sluices. The Sluices themselves are not watertight and even when closed allow in the region of 1100 to 1500 tcmd to pass through them. Therefore if the flow in the Trent falls below 3100 to 3500 tcmd the canoe slalom course is unable to operate to its full potential. This has happened during recent summers, with the operation of the slalom course severely restricted and limited to a few hours each day.

The possible abstraction at Thrumpton during periods of low flow would increase the frequency and severity of these restrictions. The impact of the abstraction could be mitigated by improving the watertightness of the Colwick Sluices.

4.5.4 Power Generation

Since both potential abstraction points are downstream of Ratcliffe-on-Soar Power Station, this should be unaffected by the proposals. However, Staythorpe Power Station is downstream of both the possible abstraction locations. The licence held by Staythorpe is for 3211 tcmd, well in excess of the Dry Weather Flow in the river. The granting of any new abstraction licence not tied to a high prescribed flow would therefore derogate the Staythorpe licence. NRA-Severn Trent Region are in the process of reviewing licensing policy for the Trent and would be discussing this with the power generators. In practical terms, any upstream abstraction would restrict the availability of water for abstraction by Staythorpe and, perhaps more importantly, reduce the diluting flow in the river for its cooling discharge. It is likely that an abstraction rate for 100 tcmd would have little material effect whereas 400 tcmd would start to affect the operation of the station during periods of low Trent flows.

4.5.5 Conservation

The major area of conservation interest in this area of the Trent are the Attenborough Gravel Pits which are a Site of Special Scientific Interest. However there are a number of other areas of old gravel working alongside the river which also have high conservation value.

The main area of concern would be thel sensitivity of the gravel pits to a small reduction in existing river levels. This is unlikely to be a cause for concern with the lower abstraction rate of 100 tcmd as the water levels are maintained by Colwick Sluices but a more detailed study would be required to assess the impact of the larger abstraction.

4.6 **Conclusions**

The River Trent supports a wide variety of users, all of which could be affected to some extent by abstraction, particularly if this occurred during low flow periods. The impact of the lower rate of 100 tcmd could be marginal, representing only 4% of the Dry Weather Flow in the river at Nottingham. It is likely, however, that the larger rate of 400 tcmd would have a noticeable effect on many of the river users.

Both potential abstraction points are upstream of Staythorpe Power Station and the granting of a licence without a low flow restriction condition would derogate the power station's abstraction licence.

NRA-Severn Trent region are currently considering their licensing policy for the River Trent. The report on the Trent Licensing Policy Review prepared by WS Atkins for NRA-ST concluded that future licences should be linked to a low flow restriction, probably set at, or slightly above, 1990 flow conditions. The linking of the licence to a minimum residual flow would remove the majority of the impacts discussed in this section. The possible abstraction amounts are a negligible proportion of winter flows in the Trent and winter abstraction should therefore have a minimal impact on the river. Seasonal limitation on Trent abstractions could be overcome by the use of storage at Rutland Water through increased transfers during the winter months. This would ensure that no abstraction of water from the Trent, during the low river flow regimes in the late spring and early autumn would be required.

An abstraction at Thrumpton would have a greater impact, affecting a larger number of users, than the Shelford site. In addition to the effects discussed previously, the Thrumpton site is upstream of the reach of the Trent which runs parallel to the Nottingham and Beeston Canal. Up to 140 tcmd may be diverted into the canal to meet a demand for industrial cooling water. The water is returned to the Trent further downstream but there remains a reach of river with a reduction of flow of 140 tcmd. The Thrumpton abstraction would therefore be in addition to this amount thus the Shelford site is therefore preferable in order to minimise the impact on the River Trent.

5.0 ENVIRONMENTAL ASPECTS OF TRENT TRANSFERS TO RUTLAND

5.1 Effects on Use of Water for Potable Supply and Irrigation

The general water quality characteristics of the River Trent at Nottingham and Gunthorpe are given in Table 5.1, the nearest sampling points to the points of abstraction for transfer routes 1 and 2/3 respectively. For comparative purposes, water quality data for the existing abstraction sites for Rutland Water on the River Nene at Wansford and the River Welland at Tinwell are also included. Water quality characteristics at the Nottingham sampling location are thought to be influenced by discharges from sewage treatment works in the Beeston area which are downstream of the point of abstraction for transfer route 1. However the nearest upstream sampling location is at Ratcliffe-on-Soar, upstream of the Ratcliffe on Soar power station. The point of abstraction for transfer routes 2/3 would be situated 1.5 kilometres upstream of the Gunthorpe sampling point and could, therefore, be affected to a greater extent by the Stoke Bardolph STW.

Maximum chloride concentrations at both sampling locations on the Trent do not exceed the EC guideline standard of 200 mg/l for water intended for public supply, although maximum concentrations of 200 mg/l have been recorded at Gunthorpe; this limit may therefore be slightly exceeded at the possible Shelford abstraction point, as this abstraction location is 1.5 kilometres upstream of the sampling point. It should also be noted that any future flue gas desulphurisation effluent discharged, for example, from Ratcliff power station, might increase levels of chlorides, sulphates and metals. Maximum chloride concentrations within both the Rivers Nene and Welland are well within the EC guideline limit of 200mg/l.

Nitrate concentrations are broadly similar at both sites on the Trent and are high, with mean concentrations of 9.3 mg/l. The maximum concentrations of 11.5mg/l exceed EC and UK limits for potable abstraction (11.3mg/l). Average phosphate concentrations at Nottingham are also high with maximum concentrations at both sites (3.3 -3.4 mg/l) exceeding the limit specified in the Surface Water Classification Regulations, 1989. Such relatively high nutrient levels could exacerbate periodic algal growth problems that are currently experienced at Rutland Water and therefore would require ameliorative measures.

Average nitrate concentrations in the rivers Nene and Welland are some 15-30% lower than those recorded on the River Trent. However maximum concentrations are high and an increased nitrate input from the Trent, coupled with reduced residence times in Rutland Water, might result in the MAC of 11.3mg/l being exceeded. Phosphate concentrations within the River Welland are low, with maximum concentrations of 1.6mg/l well below the UK potable abstraction limit of 2.2 mg/l. However, high phosphate concentrations are present within the River Nene, where average values of 2.1mg/l are close to the UK limit with maximum concentrations as high as 3.7 mg/l. Such relatively high phosphate levels are likely to account for existing algal growth problems at Rutland Water.

Control of algal growth at Rutland Water is currently achieved by the use of ferric sulphate (to precipitate phosphorous) dosed into the pumped water input from the Welland/Nene. However research programmes may show that the use of ferric sulphate in this way is not acceptable but rather off-line treatment should be used. Destratification equipment (air bubble guns) is also installed help to prevent the recycling of phosphorus from sediments. Removal of all the phosphorus at or before the reservoir inlet is generally viewed as more economic than a high degree of phosphate removal at sewage treatment works discharging effluent to the rivers which supply a pumped storage reservoir. It is certain that the potential extra phosphorus loading imposed on Rutland Water by Trent Water transfers would require off-line treatment of water before input to control the occurrence of algal blooms.

Maximum ammonia concentrations at Gunthorpe exceed EC and UK limits for water intended for public supply of 1.5mg/l as a result of discharges from Stoke Bardolph STW. Ammonia concentration at Nottingham and on the rivers Nene and Welland are below the public supply limits.

There would be an increased risk of polluting Rutland Water in abstracting directly below Stoke Bardolph STW. The Trent in this section is Class 3.

Trace organic contaminants from Stoke Bardolph STW may be significant. Abstracting directly downstream of the STW introduces a significant risk of pumping short term (acute) pollution and/or long term chronic problems. Further information is need on the likely constituents of the STW effluent.

There could be streaming of Stoke Bardolph effluent along one side of the river. The location of an abstraction site downstream of the STW should be where the river is fully mixed to avoid higher effluent concentrations or reduced dilution of effluent.

5.2 Fisheries and Aquatic Ecology

As the receiving water in this instance would be a water supply reservoir, rather than another watercourse, the physical water quality and biological implications of transfers for fisheries and aquatic ecology are not thought to be significant. For example, alterations to water velocities and currents in a river can be highly significant, whereas discharges to reservoirs have only a localised effect on currents. The main exception relates to any increase in the incidence of algal blooms which could give rise to large diurnal fluctuations of oxygen or growth of toxic algae with consequent adverse effects on the aquatic ecology.

Rutland Water is designated a SSSI and Ramsar Site/Special Protection Area by virtue of its importance for birdlife supporting internationally important populations of gadwall and shoveler (The Wildfowl and Wetlands Trust, 1991). Some bird species depend on the reservoir solely as a refuge, whereas other such as grebe and dabbling duck obtain food from the reservoir. Increased nutrient levels might also have adverse consequences for waterfowl and waders. Where eutrophication results in a shift in habitat structure and species composition, there might be adverse consequences for birds. This issue requires careful consideration and emphasises the need to control nutrient inputs to the reservoir.

In addition to the water quality problems outlined above, there have recently been a succession of winters when the designated bird sanctuary/refuge areas have been dry. Investigation is required into the effect of transfers on reservoir water levels. However it is considered unlikely that the transfer of Trent water during low flow periods would have adverse effects for Rutland Water levels. In the unlikely event, it may be that some stipulation of appropriate water reservoir water levels may be required.

5.3 Effects on Terrestrial, Natural and Biotic Resources

Transfer route 1 pipelines pass close to the Gotham Hill pastures and the Holwell Mouth SSSI's but would not adversely affect either site. Rutland Water is also a SSSI and a Ramsar Site as discussed above. The Attenborough Gravel Pits SSSI and Nature Reserve lies a short distance downstream of the possible Route 1 abstraction point. A separate channel conveys water into the disused pits. Any abstraction proposal would need to ensure sufficient residual flow to protect the interest of the reserve as well as other uses. Route 2 also passes within 2 kilometres of Holwell Mouth SSSI but there should be no adverse effects. However, the section which utilises the disused railway tunnel between Brock Hill and Melton Mowbray might cause disturbance of roosting sites for bats; their presence or absence would need to be confirmed by site surveys. Route 3 also uses this length of disused railway tunnel and might similarly affect currently unknown bat roosting sites. English Nature have no records of bats for the tunnel sections affected, although their protected species section in Peterborough advise that the likelihood of bat roosting or hibernation sites being present in tunnels is very high. Consequently site specific surveys would be required well in advance of construction. The presence of bats might constrain methods of working (to avoid air quality deterioration in the tunnels) or the timing of works to avoid the breeding and hibernation periods (summer and winter respectively).

The Barnstone Rail Cutting SSSI would also be adversely affected by Route 3. This site supports the largest known British population of a nationally scarce moth. This site also supports a diverse range of beetles, flies and other moths. In general, disused railways can be of significant ecological interest, particularly in intensively farmed areas, and serve as important wildlife refuges. For example, badger setts are often associated with railway cuttings. Both badgers and bats are afforded protection under the Wildlife and Countryside Act, 1981.

The Nottinghamshire Minerals Plan, available from 3 November 1992, identifies large portions of the Trent Valley as suitable for exploitation of sands and gravels. This should be taken into consideration in the more detailed assessment of route alignments. The infrastructure associated with any of the routes is unlikely to have significant effects on individual land holdings or agricultural land usage generally.

5.4 Effects on Local Communities or Recreation

Short sections of proposed routes 1 and 2 adjacent to the River Trent and the west of the A46(T) fall within the Nottingham Green Belt but this is not thought to represent a significant constraint. There are no specific protective planning designations applicable to the Vale of Belvoir in Nottinghamshire (and including Belvoir ridge as it is sometimes referred to) although the villages which are established along the springline at the base of the ridge are of some historic interest. Similarly, in Leicestershire, general countryside policies apply to the area traversed by alternative routes; the Vale of Belvoir in Leicestershire is designated as part of an area of particularly attractive landscape. However, appropriate permanent landscaping measures would be required along the lengths of each route.

The disused railtrack used by Route 3 is thought to be predominantly owned by British Rail, who held much of the local rail lines in anticipation of British coal opencasting large areas of the Vale of Belvoir. However, Bingham town council have purchased the section in immediate vicinity to the town and this is now used as a public walkway. Appropriate landscaping measures would therefore be required. In some sections, there has been a complete return to agriculture usage and the pipeline would have to be buried accordingly.

The local communities in this area are somewhat sensitive to development proposals following the public inquiry during the late 1980s into the site of a new local mine headworks at Asfordby to the west of Melton Mowbray. Consequently effective community liaison in this area would be of particular importance.

Close to Rutland Water the route chosen should not result in great disruption of recreational usage of Burley and Rushpit Woods.

Table 5.1 - Water Quality Characteristics or the River Trent, in the vicinity of possible transfer locations to Rutland Water - Component 7

Water Quality Characteristics	River Trent - Nottingham (Mean/Max)	River Trent - Gunthorpe (Mean/Max)	River Nene - Wansford (Mean/Max)	River Welland - Tinwell (Mean/Max)
	N=46	N=45	N=93	N=94
pH (pH units)	7.9/8.6	7.9/8.7		
Conductivity (us cm)	896/1110	998/1220	8.1/8.9	8.1/8.9
Suspended Solids [Turbidity-FTU]	16.8/102	16/55	1040/1261	880/1159
Temperature (°C)	11/19	11.4/21	13.9/78.5	7.6/38
Dissolved Oxygen*	10.6/8.0	10.8/8.3	12.1/21.6	12/21
Dissolved Oxygen (% saturation)	/	/	9.8/6.1	10.1/6.9
BOD	3.7/6.5	4.3/7.5	88/64	92/64
Ammonia	0.3/0.8	0.97/1.85	3.3/10.0	2.5/5.3
Total Oxidised Nitrogen	9.3/11.5	9.2/11.5	0.13/0.4	0.08/0.8
Orthophosphate	2.2/3.4	1.6/3.3	8.2/14.9	6.1/30.5
Sulphate	/	/	2.1/3.7	0.8/1.6
Chloride	107/163	134/200	189/239	155/192
Alkalinity	156/194	183/189	86/115	60/92
NWC Classification	2	3	203/230	201/240
			2	1B

* Mean/min

N = No. of Samples

/ = data is not available

Units are mg/l unless otherwise stated

6.0 COST ANALYSIS AND RESULTS

6.1 Introduction

A broad NPV estimate of costs has been carried out for capital and operating costs to determine the least cost option. All estimates of costs are consistent with the SOS Final Report. A broad NPV analysis has been made to permit initial comparison of pipelines with tunnels as the most economic means of transfer. This was considered necessary for the Trent-Rutland Option because of the topography of the route. However it is emphasized that these NPV estimates are approximate only, since no optimisation of pipe sizing with respect to construction and pumping costs has been made and neither has a sensitivity analysis on the variation of power costs been carried out. Such detailed analyses are currently outside the scope of this study.

The capital cost of the options has been calculated based on updated Water Research Centre, Technical Report TR61 cost functions for pipelaying, pump plant and structures, river intakes and outfalls, and costs developed as part of the Geotechnical Desk Study (Appendix B) for the tunnelling works. The inflation factor used to adjust TR61 cost functions (November 1976) to Q3/92 (Third Quarter) was 2.88. An allowance of £1M has been included where applicable for either purchase or cost of using the disused rail tunnel. The actual cost would be a matter for negotiation with the owners.

Cost estimates include for phosphate stripping at an off-line treatment works prior to discharge to Rutland Water.

Due to the conceptual nature of the scheme, and the resulting coarseness of the cost estimates, a contingency of 20% has been added to all of the capital cost elements to allow for unforeseen circumstances, including additional compensation and public utility costs which cannot be predicted at this stage. A standard value of 12% of the capital construction cost has been added to the individual route alternatives to allow for design and supervision costs

The estimated operating costs include pumping, staffing and maintenance costs and the cost of chemicals for the phosphate stripping plant. The pumping costs are based on a unit rate of power of 7 p kw/h. This figure was estimated from the latest East Midlands Electricity handbook on tariffs for the supply of Electricity, 1 April 1992. No sensitivity analysis on power cost variations has been carried out at this stage.

Appendix E gives the results of the capital and operating costs and of the NPV analysis.

6.2 NPV Analysis

The discounting period has been taken as 60 years (the asset life of civil structures), and the discount rate is taken as 6%. As required by the Terms of Reference no phasing in the capacity is assumed. It is assumed solely for the purpose of this analysis that construction takes two years. All M&E plant is assumed to have an asset life of 20 years and so is replaced at the end of this period. All costs are discounted to the third quarter of 1992 (Q3 1992)

6.3 Results

The outline costings are set out in detail in Appendix E and the capital cost, operating and total NPV costs are summarised in the following tables (6.1 to 6.4).

Routes 1.2, 1.3, 1.4, 1.5, 2.2, 2.3, 2.5 and 3.2 are not considered viable as these alternatives have tunnel sections crossing the area of proposed coal mining (see Section 3.5)

Viable route alternatives listed in the following tables are described below for reference :

Route 1.1 a&b - Abstraction near Thrumpton, pipeline across the Vale of Belvoir to Melton Mowbray and on to Rutland Water. Route 1.1b uses the disused rail tunnel near Scalford.

Route 1.6 - Abstraction near Thrumpton, pipeline, then tunnel around proposed coal mining area of Asfordby to Rutland Water.

Route 2.1 a,b&c - Abstraction near Shelford, pipeline across the Vale of Belvoir to Melton Mowbray and on to Rutland Water. Route 2.1b uses a disused rail tunnel. Route 2.1c uses a deep tunnel in place of the disused rail tunnel.

Route 2.4 a&b - Abstraction near Shelford, pipeline across the Vale of Belvoir to south of Melton Mowbray and then tunnel to Rutland Water. Route 2.4b uses a disused rail tunnel.

Route 2.6 - Abstraction near Shelford, pipeline across Vale of Belvoir to escarpment, tunnel around proposed coal mining area and pipeline to Rutland Water.

Route 3.1 - Abstraction near Shelford, pipeline on disused rail track to Melton Mowbray and then as pipeline to Rutland Water

Route 3.3 - Abstraction near Shelford, pipeline across the Vale of Belvoir along disused rail track to Melton Mowbray. Tunnel from south of Melton Mowbray to Rutland Water.

Table 6.1 - Initial Capital Costs of Viable Schemes

Flow	100 tcmd	200 tcmd	300 tcmd	400 ycmd
Cost	(£M)	(£M)	(£M)	(£M)
Route 3.1 (using disused rail tunnel)	29	46	61	78
Route 2.1b (using disused rail tunnel)	29	46	61	78
Route 2.1a	32	46	71	95
Route 1.1b (using disused rail tunnel)	36	59	77	101
Route 1.1a	33	58	75	100
Route 2.1c (using a deep tunnel)	40	57	72	79
Route 2.4b (using disused rail tunnel)	56	67	77	93
Route 2.4a	57	73	83	97
Route 2.6	56	69	87	104
Route 3.3	68	83	92	112
Route 1.6	114	118	128	134

<u>NOTES</u>

° The initial capital cost of route 1.1b (using the disused rail track) is slightly more than route 1.1a as 1.1b is approximately 4km longer

Table 6.2 - Operating Costs for 6 month Pumping Regime for Viable Schemes

Flow	100 tcmd	200 tcmd	300 tcmd	400 tcmd
Cost	(£M)	(£M)	(£M)	(£M)
Route 3.1 (using disused rail tunnel)	1.3	2.5	3.7	4.4
Route 2.1b (using disused rail tunnel)	1.0	2.1	3.2	4.4
Route 2.1c (using a deep tunnel)	1.1	2.2	3.5	4.6
Route 2.1a	1.3	2.5	4.1	5.3
Route 1.1b (using disused rail tunnel)	1.3	2.5	4.0	5.2
Route 1.1a	1.5	2.9	4.9	5.5
Route 2.4b (using disused rail tunnel)	0.9	1.8	2.9	3.7
Route 2.4a	1.1	2.1	3.2	4.2
Route 2.6	1.5	2.9	3.2	5.1
Route 3.3	1.0	2.2	2.9	3.8
Route 1.6	0.7	1.6	2.1	2.7

NOTES

Costs include for pumping, staffing and maintenance and chemical costs.

Figures for a 12 months pumping regime are double those for 6 months and similarly figures for a 3 months pumping regime are half those for 6 months.

Table 6.3 - Comparison of NPV for Viable Schemes (3 months of pumping)

Flow	100 tcmd	200 tcmd	300 tcmd	400 tcmd
Cost	(£M)	(£M)	(£M)	(£M)
Route 3.1 (using disused rail tunnel)	30	51	70	89
Route 2.1b (using disused rail tunnel)	30	50	69	88
Route 2.1c (using a deep tunnel)	39	60	79	92
Route 2.4b (using disused rail tunnel)	51	66	80	97
Route 2.4a	53	72	87	104
Route 2.1a	34	53	82	108
Route 1.1b (using disused rail tunnel)	37	63	86	112
Route 1.1a	36	63	87	113
Route 3.3 (using disused rail tunnel)	61	79	93	114
Route 2.6	52	72	90	113
Route 1.6	96	106	117	125

Table 6.4 - Comparison of NPV for Viable Schemes (6 months of pumping)

Flow	100 tcmd	200 tcmd	300 tcmd	400 tcmd
Cost	(£M)	(£M)	(£M)	(£M)
Route 3.1 (using disused rail tunnel)	39	63	94	115
Route 2.1b (using disused rail tunnel)	36	63	89	114
Route 2.1c (using a deep tunnel)	46	75	101	120
Route 2.4b (using disused rail tunnel)	57	77	99	118
Route 2.4a	59	85	106	131
Route 2.1a	43	74	108	138
Route 1.1b (using disused rail tunnel)	45	79	111	143
Route 1.1a	45	81	120	147
Route 3.3 (using disused rail tunnel)	67	94	111	138
Route 2.6	66	90	110	143
Route 1.6	101	116	131	142

Table 6.5 - Comparison of NPV for Viable Schemes (12 months of pumping)

Flow	100 tcmd	200 tcmd	300 tcmd	400 tcmd
Cost	(£M)	(£M)	(£M)	(£M)
Route 3.1 (using disused rail tunnel)	53	89	138	168
Route 2.1b (using disused rail tunnel)	48	89	128	167
Route 2.4b (using disused rail tunnel)	68	100	132	166
Route 2.1c (using a deep tunnel)	60	104	144	176
Route 2.1a	59	105	158	207
Route 1.1b (using disused rail tunnel)	61	111	160	207
Route 2.4a	72	111	146	183
Route 1.1a	63	114	169	214
Route 3.3 (using disused rail tunnel)	79	121	147	186
Route 1.6	108	134	156	177
Route 2.6	72	125	150	204

7.0 CONSTRUCTION PROGRAMME

7.1 Introduction

The construction of a large pipeline scheme such as the Trent to Rutland Water Transfer would require a number of statutory steps to be followed before construction could commence. The following section discusses these statutory requirements on the assumption that the NRA would be the promoters of the scheme.

7.2 Abstraction Licences and Discharge Orders

Water would have to be abstracted from the Trent through Nottingham. The promoters would therefore require an abstraction licence. A discharge order would be necessary into Rutland Water.

The application for the abstraction licence would be considered by the Secretary of State for the Environment. Due to the potentially large abstraction volumes being considered, the Secretary of State might decide to call a Public Inquiry. The licence might be granted with the proviso that abstraction is constrained by a minimum flow in the River Trent.

7.3 Planning Permission

The NRA have pipelaying powers under the 1991 Water Resources Act and water undertakers have similar powers. Town and Country planning permission is not normally required for the laying of buried pipelines. However, the structures associated with the intakes from the River Trent and the outfall to Rutland Water, break pressure tanks, and the pumping stations, would all need planning permission.

7.4 Land Access for Construction Work

Access to the land could be gained under the powers of the 1991 Water Resources Act. This requires notice to be served on the owners and occupiers three months before entry. Most of the land owners and occupiers would have been identified earlier in the project to allow access for site investigation and surveying.

7.5 Construction Programme

The construction programme for all options would, to a large extent, be controlled by the pipework material adopted. There are more suppliers of large diameter steel pipes than there are of large diameter ductile iron pipes.

Plant for the pumping stations would probably have a contract period of about 18 months to allow for fabrication and installation. This would not be incompatible with the possible tunnelling and civil works programme.

It is therefore reasonable to expect that it would take two summer seasons to complete the construction works for the project. Civil and tunnelling works (if necessary) might continue through the intervening winter to allow for the installation of the mechanical and electrical plant in the second summer.

7.6 Overall Project Procurement

The pre-tender award works, which would include the abstraction licence and discharge order; planning permission and site investigation, could take between one and one and a half years. Although an environmental assessment is not required for pipelines, one would probably be carried out as part of the planning process for this Trent to Rutland Water link. Construction works might extend over one and a half to two years for routes not involving major tunnel lengths. Both these durations assume a minimum of delays caused by the statutory processes, unforeseen ground or weather conditions or material supply delays. It would appear, therefore, that a period of three to four years should be allowed from the decision to proceed with the project, to the transfer being operational.

8.0 CONCLUSIONS

Preferred Routes

- Capital and operating cost estimates were prepared and a broad NPV cost analysis was carried out for all viable route alternatives. The NPV results indicated that for both 3 and 6 month pumping regimes, Route 2.1 would be the most economic route alternative. There are three variations to this alternative :

  2.1a - Pipeline from Shelford to Rutland Water over the escarpment
  2.1b - As route 2.1a except using a disused rail tunnel to avoid the escarpment
  2.1c - As route 2.1b but using a deep tunnel instead of the disused rail tunnel

- Of these three variations Route 2.1b, which uses the disused rail tunnel, would be the most economic for 3 and 6 months pumping. These costs include £1M for possible purchase and/or maintenance of the rail tunnel which has been in private ownership for the past twenty years.

- If the use of the disused rail tunnel is unacceptable due to its condition, or the cost of its purchase and maintenance is prohibitive, then for 3 and 6 months pumping per year, Route 2.1a would be the most economic for flows of 100 tcmd and 200 tcmd. Route 2.1c would be the most economic for the higher capacities of 300 and 400 tcmd.

- The lowest initial capital costs listed in ascending order for the scheme are given in the following table:

Table 8.1 - Summary of Lowest Initial Capital Cost Schemes

Flow	100 tcmd	200 tcmd	300 tcmd	400 tcmd
Cost	£(M)	£(M)	£(M)	£(M)
Route 3.1	29	46	61	78
Route 2.1b	29	46	61	78
Route 2.1a	32	46	71	-
Route 2.1c	-	-	-	79

- Route 3 would cross the Vale of Belvoir along a disused rail track. A partially buried and landscaped pipeline was considered but would not be viable as part of the track is in private ownership and a large proportion of the remaining track has been returned to agricultural use. Thus, the pipeline along this route would have to be totally buried. This would negate any cost saving which might have been possible from partially burying the pipeline.

Environmental Conclusions

- Route 3 along the disused rail track would be likely to have the greatest ecological impact of the pipeline routes. This route would affect Barnstone Rail Cutting SSSI which supports a diverse range of beetles, flies and moths. Disused railways generally can be of significant ecological interest serving as wildlife refugees. For these reasons, Route 3 is not a preferred option even though route 3.1 (via the disused rail tunnel) is one of the least cost route alternatives.

- The disused rail tunnel is likely to be a bat roosting site. This could constrain methods of working and the timing of construction.

Possible Impacts on the Trent

- All of the above routes would abstract water from the Trent at Shelford, downstream of Nottingham which has a lesser impact on the River Trent than the alternative abstraction point at Thrumpton, upstream of Nottingham.

- Abstractions from the Trent at times of low flow would have the following possible impacts :

  Abstraction at Thrumpton (Route 1) could increase restrictions on the use of the Holme Pierrepont National Watersports Centre although the impact of the abstractions could be mitigated by improving the watertightness of the Colwick Sluices. In this report no allowance in the costings have been made for improvements to the Colwick Sluices.

  Abstraction at Thrumpton (Route 1) would reduce the dilution available at Stoke Bardolph STW and increase the severity of high ammonia concentrations on the Trent. This could affect the standard of treatment required at the sewage works.

  The implication of abstractions from either site on the Trent coarse fishery could be significant, due to reduced flows and resulting higher ammonia concentrations, especially for higher abstractions at periods of low flow.

  Abstraction at either site would restrict the availability of cooling water at Staythorpe Power Station and reduce the diluting flow in the river for its cooling discharge. The higher abstraction rate of 400 tcmd could materially affect the operation of the station.

Reduction in water levels in gravel pits of high conservation value could be of significant impact for higher abstractions at Thrumpton.

- British Waterways have indicated they would strongly oppose any proposals to increase abstractions upstream of Torksey due to the potential exacerbation of siltation problems in the tidal Torksey-Newark reach. Also a reduction in navigation depths below Colwick Sluices due to higher abstractions at periods of low flow would be a cause for concern to BW.

Water Quality Conclusions

- A Flue Gas Desulphurisation (FGD) plant is under construction, on the Trent, at Ratcliff Power Station. This is upstream of both the possible abstraction points on the Trent. This discharge would probably increase the temperature of the river water, and might increase concentrations of chloride, sulphate and nitrate in the River Trent.

- Maximum chloride concentrations in the Trent at Nottingham approach or equal the EC guidelines standard of 200 mg/l for water intended for public supply. Recorded maximum nitrate concentrations exceed EC and UK limits for potable water abstraction.

- Phosphorous removal from Trent water would be required to control algal growth. Although current transfers from the Welland and Nene are dosed with ferric sulphate (to precipitate phosphorous) at their discharge to Rutland Water this method may not be acceptable and rather off-line treatment for phosphate stripping would be required. These costs are included in the estimates.

- There is a risk of pollution to Rutland Water by abstracting at the Shelford site just downstream of Stoke Bardolph STW (Routes 2 and 3). The river Trent is classified as Class 3, in this reach. Continuous water quality monitoring and probable improvements to Stoke Bardolph effluent would be necessary.

Operational Aspects

- Restrictions on abstraction from the River Trent due to seasonal limitations would probably govern the operation of this transfer. However, the available storage facilities of Rutland Water might be used to overcome seasonal limitations on abstractions.

Implementation Programme

- The programme for the scheme to be operational would probably take between 3 to 4 years. This includes 1-1½years for pre-tender award works and 2 years for the construction work. The pre-tender award works include for obtaining an abstraction licence, a discharge order, planning permissions and site investigation. A Public Inquiry might be called for by the Secretary of State for the Environment.

Suggested Further Work

Further investigation is recommended for the following :

- The level of organic contaminants from trade effluent at Nottingham.

- The possible increases in nitrate levels in Rutland Water which could arise from the higher nitrate levels in Trent Water coupled with reduced residence times.

- A study to assess the impact of possible water level changes on environmentally sensitive gravel pits alongside the Trent.

- Geological desk study to include a search of the UK Landslides Database followed by airphotos interpretation and engineering geomorphological mapping to identify possible hazards along the preferred pipeline route.

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WATER RESEARCH CENTRE, (1977). Technical Report TR61, Cost Information for Water Supply and Sewage Disposal.

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UK and EC LEGISLATION

Council Directive concerning the quality required of surface water intended for the abstraction of drinking water (75/440/EEC)

Council Directive relating to the quality of water intended for human consumption (80/778/EEC)

Council Directive concerning urban wastewater treatment (91/271/EEC)

Council Directive concerning the protection of waters against pollution by nitrates (91/676/EEC)

The Water Supply (Water Quality) Regulations, 1989

The Surface Water (Classification) Regulations, 1989

Council Directive on the quality of fresh waters needing protection or improvement in order to support fish life.

The Water Resources Act 1991

Use has also been made of the provisional water quality standards associated with relevant river uses as outline in the December 1991 NRA publication on proposals for Statutory Water Quality Objectives (SWQO's)

APPENDIX A

TERMS OF REFERENCE

23 January 1992

NRA

National Rivers Authority
Anglian Region

Our Ref: BB/JC/656/04/00

C Binnie Esq
W S Atkins (Water) Limited
Consulting Engineers
Woodcote Grove
Ashby Road
Epsom
Surrey LT18 5BW

Dear Chris

Regional Strategic Options Study

Further to my letter to you of 23 December 1991, Roger Cook has asked me to confirm that the work being done by W S Atkins (Water) Limited on the Trent to Rutland bulk water transfer option should be the subject of a separate report and not included in the main report dealing with the original Terms of Reference options.

Yours sincerely

B Barton
Project Engineer (Water Resources)

WP-2/JC20JAN/26

ROGER HYDE
Regional General Manager

Kingfisher House
Goldhay Way
Orton Goldhay
Peterborough
PE2 5ZR
Tel: 0733 371811
Fax: 0733 231840

23 December 1991

NRA

National Rivers Authority
Anglian Region

Mr C Binnie
W S Atkins Limited
Consulting Engineers
Woodcote Grove
Ashley Road
Epsom
Surrey KT18 5BW

Our Ref: BB/CMD/656/04/00

Your Ref: CJAB/SLK/174

Dear Chris

Regional Strategic Options Study

Thank you for your letter of 9 December 1991 and I apologise for the slight delay in replying, but it seemed desirable to deter a response until after the meeting with Tim Askew last Wednesday, 18 December.

I confirm that Items 1 to 4 in your letter are to be appended to the original Terms of Reference for the project and that work on Items 1, 2 and 4 should proceed without delay.

A management decision may have to be taken to decide whether the results of the work on Item 1 (the Trent to Rutland bulk transfer link) is to be included in the main report or dealt with as a separate matter. I will let you know as soon as possible how we wish to proceed. It became clear at the 18 December 1991 meeting that the topography along the possible Trent to Rutland routes is a considerably more important factor than it is for transfer routes within the Anglian Region.

Yours sincerely

B Barton
Project Engineer (Water Resources)

cc: R Cook, NRA, Peterborough

WP-1/23DECCMD/8

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CJAB/SLK/174

9 December 1991

Dr Barry Barton
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Anglian Region
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Orton
GOLDHAY
Peterborough PE2 OZR

Dear Barry

STRATEGIC OPTIONS STUDY

I was sorry not to meet you on my visit to Peterborough last Wednesday. A number of instances arose where it was considered appropriate to extend our brief by the addition of minor studies not included in the original fee estimate.

1) There is a possible alternative of abstracting water near Nottingham and pumping across to Rutland. Abstraction could be either just upstream or just downstream of Nottingham. Because this alternative might be proposed by Anglian Water Services it was considered appropriate to consider this in the Phase I work as a possible alternative.

2) The Trent licensing policy study has identified an appreciable number of environmental implications of abstraction on the Trent. Since Nick Flew was involved in some aspects of this for Severn Trent Region it was appropriate that he wrote a section on this for the Strategic Options Study Report.

3) The public presentations to the interested parties and the media were very helpful to promote the appropriate public understanding but were not originally envisaged. These included drafting of text, obtaining and preparation of slides, rehearsals and the actual presentation.

4) Arising from the public meeting it has been agreed to hold meetings with the Parish Councils, District and County Councils affected by Great Bradley. The Parish and District Councils were not included in our list of organisations with whom to liaise. (page 29 of the offer).

We understand we are to proceed with these works now.

Yours sincerely
for WS Atkins Water

C J A Binnie

National Rivers Authority (Anglian Region)

REGIONAL STRATEGIC OPTIONS STUDY

Consultants' Terms of Reference

The Anglian Region's future Water Resouces Strategy (included as Appendix A) identifies various strategic options in response to increasing demands for water within the region for domestic, industrial and agricultural use. These options, which are in line with a recently completed national study, include what are seen by the Authority as the two principal engineering options, namely the wider use of River Trent water and a new reservoir at Great Bradley.

The role of the Authority's Engineering Consultant within the proposed regional Strategic Options Study is to establish in broad terms the engineering feasibility, environmental implications and costs (both capital and revenue) for a matrix of sub-options. These will then be used by the Authority to assess and establish an optimal regional strategy to meet expected demands for water within the region up to the year 2011 and to project forward as far as 2031. Budgetary estimates and outline assessments are therefore required, rather than precise cost estimates and detailed environmental analyses, to provide an overall framework for subsequent more detailed studies.

Associated hydrological and water resource studies (including assessment of yields) are being undertaken in-house and are therefore not part of these Terms of Reference. There will be full liaison between the Consultant and the officer responsible within the region for these studies.

This study will consider, assess the feasibility and evaluate the costs and environmental implications of the engineering works required for the bulk transfer and storage of raw water, as outlined in the following sections (1) to (6).

1) Works required to increase the nett transfer capacity of existing Trent Witham Ancholme Scheme installations, as follows:

i) Trent to Witham (via Fossdyke Canal) at Torksey P.S. by
a)50tcmd b)100tcmd c)200tcmd d)300tcmd e)400tcmd f)600 tcmd
The higher transfer rates given above are intended to allow for the quantities of water required under (2) below.
A partial alternative to increasing the capacity of the Torksey P.S./Fossdyke Canal link could a supplementary link from the Trent to the upper Witham in the Newark area.

ii) Witham to Ancholme at Short Ferry P.S. by
a)50tcmd b)100tcmd c)150tcmd.

Major cost thresholds or other significant constraints should be identified, namely the points at which pipeline or pumphouse duplication, channel enlargement etc. would be triggered. The operational implications in (ii) above of not increasing the capacity of Toft Newton Reservoir should also be considered, or conversely, any increase in the capacity of the reservoir necessary to maintain existing levels of service should be assessed.

A brief description of the existing Trent Witham Ancholme Scheme is given in Appendix 2.

2) Works required to transfer Trent-supported water from the River Witham upstream of Grand Sluice, Boston southwards to the Ely Ouse river system in order to enhance the resources available in the Ely Ouse above Denver Sluice and to meet future demands further south via the existing Ely Ouse-Essex Scheme, a brief description of which is given in Appendix 3.

Transfer capacities are those required to make
a)100tcmd b)200tcmd c)400tcmd
available at Denver over and above any existing natural or enhanced flows in the Ely Ouse at that point.

The transfer routes proposed by the Consultant may consist of any suitable combination of large diameter pipelines or tunnels and/or existing river or drainage channels. In the latter case possible operational losses and water quality problems should be taken into account.

Two alternative transfer strategies should be considered, as follows:

i) A direct transfer from the Witham to the Ely Ouse (various sub-options should be evaluated), and

ii) A route which would permit a total of
a)50tcmd b)100tcmd c)150tcmd
to be made available en route for abstraction by Anglian Water Services at:

a) _either_ Tinwell P.S. (on the R.Welland above Stamford) _or_ Wansford P.S. (on the R.Nene above Peterborough) for transfer to Rutland Water reservoir, _and_
b) Offord P.S. (on the R.Great Ouse above Huntingdon) for transfer to Grafham Water reservoir

The apportionment of this en route resource allocation to Anglian Water Services should vary independently from a minimum of zero to a maximium discharge of 100tcmd to each river, over and above any natural flow in those rivers above those points. These Tinwell/Wansford and Offord quantities are additional to the quantities required at Denver.

3) Works required to transfer Trent-supported water from the Ely Ouse (or the Cut-Off Channel) above Denver Sluice in order to enhance the resources available in the River Wensum for public water supply abstraction upstream of Norwich.

Transfer capacities are those required to make
a) 50tcmd b)100tcmd
available in the Wensum over and above any natural flow in that river. Careful consideration should be given to the ecological effects of introducing Trent-supported water into the River Wensum.

4) A pumped storage river regulation reservoir at Great Bradley on the upper reaches of the R.Stour near Haverhill intended to increase the yield of the Ely Ouse Essex Scheme by introducing a major raw water storage component into the scheme.

This proposed reservoir was the subject of a report prepared by Messrs Binnie & Partners in 1970 for the then Essex River Authority on a feasibility study carried out for a reservoir at Great Bradley. Binnies' report considered eight separate options, ranging in size from 15mcm to 104mcm storage capacity and based on a combination of two embankment locations and four top water levels.

This study will review and update Messrs Binnies' report and will specifically:

a) reassess the technical proposals in the 1970 report in the light of modern geotechnical knowledge and developments,

b) produce revised estimates of the cost of the various options identified in the 1970 report updated to 1992 price levels, and

c) consider (over and above the geotechnical implications dealt with in (a) above) the hydrogeological implications, either adverse or beneficial, of any seepage from the reservoir through the underlying boulder clay and into the chalk aquifer beneath, and

d) assess the local environmental impact of such a reservoir.

5) The works required for the transfer of a total of
a) 50tcmd b)100tcmd c)150tcmd d)200tcmd
from the Ely Ouse Essex Scheme's existing discharge point on the River Blackwater at Great Sampford to the upper reaches of the Rivers Roding and Stort in the Thames Region of the National Rivers Authority in order to provide additional resources for South Essex and East London.

In this context consideration should also be given to any need to modify or enlarge the transfer capacity of:

a) the channel of the River Stour between a reservoir at Great Bradley and Wixoe P.S.,

b) Wixoe P.S.,

c) the transfer pipeline between Wixoe and Great Sampford via Lakehouse balancing tank, and

d) the channels of the Rivers Roding and Stort downstream of the discharge points.

The apportionment of the total transfer between the Roding and the Stort should vary independently from a minimum of zero to a maximum discharge of 100tcmd to each river.

Major cost thresholds or other significant constraints should be identified as in (1) above. A further constraint may be the capacity of the existing pumping station/tunnel/pipeline link between Blackdyke P.S. on the Cut-Off Channel and the discharge via Kennett P.S. to the Upper Stour at Kirtling Green, although the level at which the capacity of this link becomes a constraint will depend upon the storage capacity provided by the proposed reservoir at Great Bradley and allied hydrological factors. Consideration of any increase in the capacity of this link is currently outside the scope of this study, but may be introduced at a later date depending upon the outcome of the separate hydrological investigations.

The Consultant should be aware that a detailed reassessment of the transfer capacities of the various components of the existing Ely Ouse-Essex Scheme is currently in hand, the results of which should be available early in 1992.

6) In connection with (5) above, the works required for the transfer of
a) 50tcmd, b)100tcmd, c)200tcmd
from the Ely Ouse-Essex Scheme's discharge point at Great Sampford to the upper reaches of the River Chelmer, as an alternative to the existing river regulation discharge to the River Blackwater at Great Sampford, (i.e. if 50tcmd is discharged to the Chelmer then the discharge to the Blackwater will be reduced by a corresponding amount).

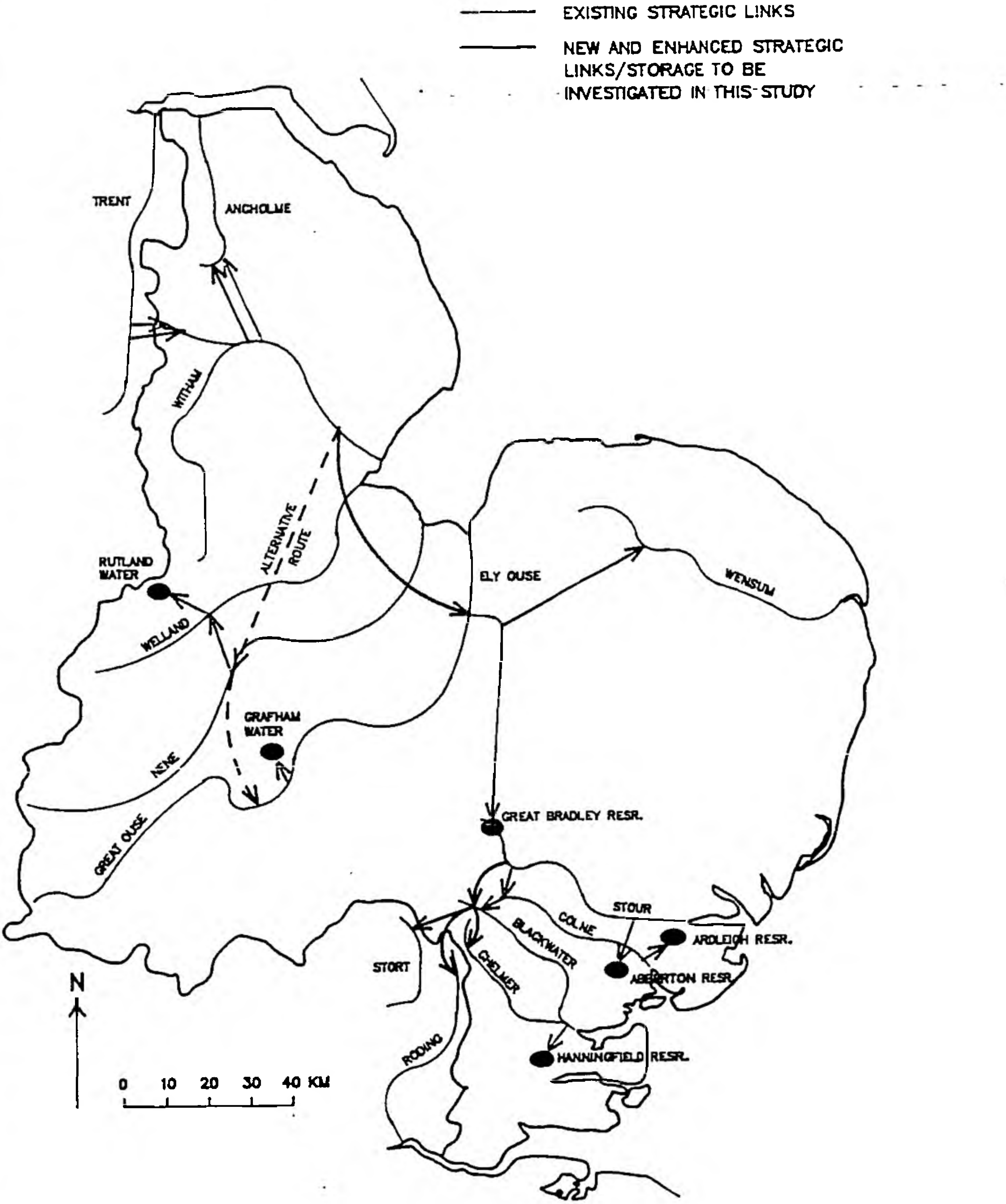
In this context consideration should also be given to any need to enlarge the capacity of the channel of the River Chelmer downstream of the discharge point.

This study will also address the overall operational implications (including water quality considerations and system control procedures to minimise transmission losses) of a major water resource system incorporating the elements outlined in (1) to (6) above for the bulk transfer of raw water from the Trent via Torksey, Denver and Wixoe to Essex and East London. The desirability of having an element of bulk storage in the system at Great Bradley for operational and control purposes (irrespective of hydrological and system yield considerations) will also be assessed.

The appointed Consultant will commence work on this study within one month of the date of appointment and will aim to complete the study and issue his formal report to the Authority before the end of October 1992, or such other date as to be agreed before the appointment is made. A initial total of ten bound copies of the report and any appendices will be required.

During this study the consultant's Project Manager will hold monthly progress meetings with the Authority's Regional Manager (Water Resources) or his delegated representative. A draft version of the consultant's report will be presented for discussion and agreement one month before the date of issue of the consultant's formal report.

BB 21/8/91 (Rev.F)



REGIONAL STRATEGIC OPTIONS STUDY

APPENDIX B

GEOTECHNICAL DESK STUDY

1.0 INTRODUCTION

This report provides a brief overview of geological and geomorphological conditions within the area of a proposed water conveyance between the River Trent at Nottingham and Rutland Water, Figure 1.

The proposed routes are;

(a) River Trent, south of Nottingham, to Rutland Water by tunnel or cross country pipeline.

(b) River Trent, north of Nottingham, to Rutland Water by tunnel or cross country pipeline.

(c) River Trent, north of Nottingham, to Rutland Water along the disused rail track from Bingham to Melton Mowbray (similar to route (b))

The overview is based on perusal of the readily available information listed in Section 5.

2.0 GEOLOGICAL SETTING

2.1 Physiography

The three route options commence at around 18m OD in the Trent Valley, traverse the Vale of Belvoir and ascend an escarpment of around 150m in altitude. The routes remain on the higher ground before descending into the reservoir at an elevation of around 70m OD, Figure 2.

2.2 Solid Geology

The routes traverse a gently SE-dipping sequence of Jurassic and Triassic strata, Figure 2, comprising;

Formation Name	Principal Character	Approx thickness
Inferior Oolite (Jurassic)		
Linconlshire Limestone	sandy limestones	≤40m
Lower Estuarine Series	sands, silts and clays	≤8m
Northampton Sand	ferruginous sandstones or "ironstone"	≤21m
Lias (Jurassic)		
Upper Lias	clays	≤76m
Middle Lias	clays and silts capped by a distinctive horizon or hard calcarious sandstone the "Mudstone Rock Bed"	≤35m
Lower Lias	clays with occasional thin limestones	≤200m
Keuper (Triassic)		
Keuper Marl or Mercia Mudstone	red and green marls (calcareous mudstones) with gypsum and occasional thin sandstones (skerries)	≤280m

The strata are affected by minor faulting and gentle flexuring.

2.3 Superficial Deposits

Apart from the Trent Valley substantial accumulations of alluvial materials occur around Bingham (route options B and C) and in the vicinity of Melton Mowbray (all options).

Boulder Clay occurs on higher ground around Willoughby-on-the-Wolds (route option A), around Melton Mowbray (all options) and on the approaches to Rutland Water.

Minor accumulations of glacial sand and gravels occur near the valley floor around Melton Mowbray.

2.4 Hydrogeology

In general there are no major strata aquifers within the study area which is dominated by impermeable marls and clays. However, the more brittle sandstone and limestone horizons provide limited aquifers and water issues from outcrops of the Marlstone Rock Bed, the Northampton Sand and Lincolnshire Limestone. These issues have a bearing on hillside stability, referred to in the following section.

Within the superficial deposits, river gravels in the Trent and Welland valleys represent important water sources.

2.5 Geomorphology

The thin but hard horizons of calcareous ferruginous sandstone, the Marlstone Rock Bed and the Northampton Sand Ironstone give rise to prominent NW facing escarpment features.

Other less significant escarpments are caused by limestone horizons in Lower Lias clays and the limestones of the Inferior Oolite Series.

The area has been subjected to the effects of intensive periglacial activity with which are associated the following geomorphological features and on-going processes;

Features	Engineering significance
A. Superficial structural disturbances	
Frost shattering	creates new fractures, increases deformability and permeability and reduces bulk density
Glacial shear.	promotes surface instability
Hill creep	may require deeper foundations
Ice wedges and involutions	sudden, unexpected replacement of one material by another with different properties

Features	Engineering significance
Frost mounds, pingos	ditto, especially hazardous where peat deposits occur
Chemical weathering (e.g. decalcification)	alteration of geotechnical properties of material (pipes and shallow-holes in Chalk may be related to periglacial processes)
B. Mass movements	
Cambering and bulging	gulls and bulge fractures create permeable zones of potential leakage requiring remedial measures
Landsliding	possible reactivation of fossil slides be inadvertent slope engineering
Mudflow (solifluction) activity	possible reactivation of low-angle flows by inadvertent slope engineering or by drainage changes. *Slip surfaces* may be present
C. Properties of periglacial deposits	
Sorted soils (loess)	wind-blown silt is characteristically metastable and can collapse when flooded
Unsorted soils (solifluction)	non-uniform soils, variable in nature and extent and erratic in their engineering behaviour. Not usually shown on geological maps. May contain *slip surfaces*

Of particular significance is the frequency of recorded incidence of landslides in the Lower, Middle and Upper Lias and the incidence of cambering and valley bulging in the overlying Inferior Oolite Series. The latter processes involves the gradual sinking and drifting of fractured blocks of competent strata into underlying plastic clays. Valley bulging involves the squeezing up of plastic clay formations in the floor of valleys flanked by overlying competent strata.

These processes are particularly noted in the area of Rutland Water.

3.0 ENGINEERING IMPLICATIONS

3.1 Routes A and B - tunnel

For the purpose of this preliminary overview routes A and B are considered together because both options traverse similar geology, figures 1 and 2.

The tunnels would commence at the base of the keuper marl (Mercia Mudstone) formation riding down with the dip of the beds for some 10 kms before levelling off to rise upwards through the geological succession and beneath the Vale of belvoir. At about 25 km the tunnels would pass beneath the escarpment of the Marlstone Rock Bed, the deepest point, with a cover of approximately 100m.

The tunnels would re-emerge in the geologically complex area of Inferior Oolites which form the ground around Rutland water.

Tunnelling conditions are expected to be generally favourable being largely carbonaceous mudstones (marls) and clays but with horizons of very much stronger sandstones and limestones. Portal or shaft conditions will be much poorer where the ground is weakened by weathering. The disturbances to the strata at the Rutland Water end will require careful consideration to determine the least difficult path for the final 5 km of the tunnel route.

3.2 Route A - pipeline

Shortly after leaving the Trent Valley this route crossed Ruddington Moor which comprises some 5 km of peaty alluvium drained northwards by the Fairham Brook.

Afterwards the route rises onto the Wolds which, in these parts, are capped with a thick sheet of chalky boulder clay.

The route then traverses the Vale of Belvoir comprising clays of the Lower Lias before climbing obliquely to the escarpment cap by the Marlstone Rock Bed. Around

Holwell the route traverses an area of worked out opencast ironstone pits and it will be necessary to consider the nature of backfill, if any.

Around Melton Mowbray the route is across chalky boulder clay with glacial sands and gravels and alluvium in the valley of the River Eye.

The route then rises again over hills composed of Lias clays turning eastwards and into the geomorphologically complex area of cambered and landslipped strata of the Inferior Oolite Series.

3.3 Routes B and C - pipeline

These two options are considered together as they differ only in that route C adopts the course of an abandoned railway.

The routes commence in sandy soils of the Keuper Marl (mercia mudstone) formation then passing over limited accumulations of peaky loam and stoney boulder clay in the vicinity of Bingham.

Turning south east the routes traverse the Lias clays of the Vale of Belvoir before ascending the escarpment of the Marlstone Rock Bed where the old railway entered an eight hundred metre long tunnel.

Thereafter, routes B and C combine with A, refer to Section 3.2.

4.0 CONCLUSIONS AND RECOMMENDATIONS

There is little to differentiate between tunnel routes A and B, the greatest area of envisaged difficulties being at the SE end where the combined route enters the disturbed strata of the Inferior Oolite Series.

Of the pipeline routes, both traverse a measure of soft ground at some point before merging at Salford. The northern approach, routes B and C, to the escarpment of the

Marlstone Rock Bed appears to be more favourable than that taken by the southern route, A, which would appear to be making an oblique ascent.

It is an important consideration in pipeline routing to avoid the oblique ascent of slopes especially where clays are involved because of the tendency for the trench to initiate or reactivate instability. This is particularly important in the region around Rutland Water where it will be worthwhile to seek routes away from potentially unstable slopes.

It is recommended that the next phase of desk study be extended to include a search of the UK Landslides Database followed by airphotos interpretation and engineering geomorphological mapping to identify the hazards before finally defining the optimum pipeline route.

For the tunnel options it will be necessary to research specific borehole data from the British Geological Survey Borehole Records Section.

5.0 REFERENCES

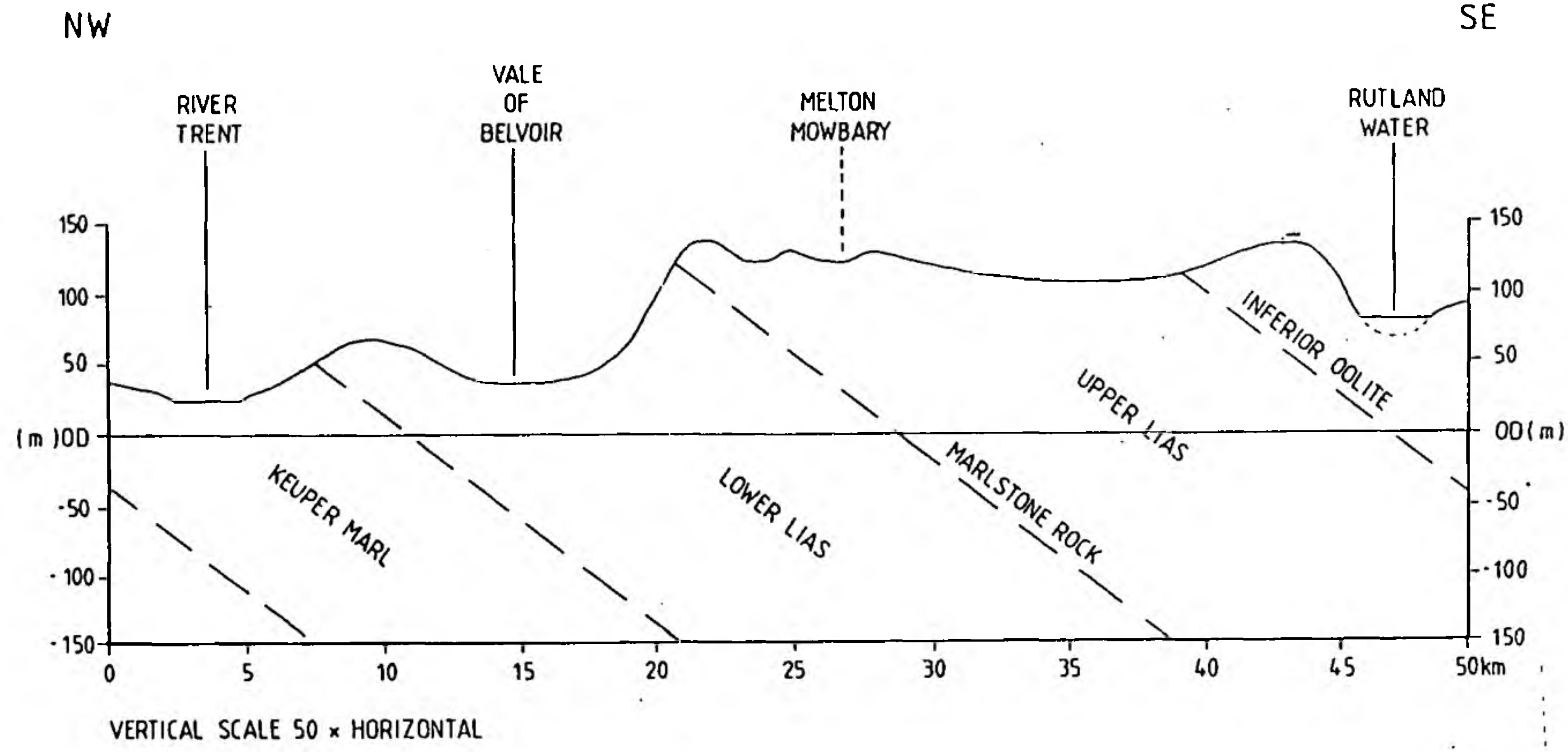
British Geological Survey	1:625,000 Solid South Sheet
" " "	1:625,000 Quaternary Map Sheet
" " "	1:50,000 Sheet 126
" " "	1:50,000 Sheet 142
" " "	1:50,000 Sheet 157
" " "	Hydrogeology

British Geological Survey	Regional Guide "Central England"
" " "	Sheet Memoirs "126 - Newmark & Nottingham"
" " "	Sheet Memoirs "142 - Melton Mowbray"

DOE (1990) Planning Guide PPG14 "Development on Unstable Land"

Forester A, et al (eds) (1991) "Quaternary Engineering Geology Geological Society Engineering Geology Special Publications No 7

Ordnance Survey 1:250,000 Routemaster 6.



WS/Atkins

Project	NRA ANGLIAN REGION : STRATEGIC OPTIONS STUDY TRENT TO RUTLAND WATER - GEOTECHNICAL DESK STUDY	Scale 1:250 000 H 1:5000 V	Drawn / Date APR. '92	Checked / Date 13/4/92	Authorised / Date
Title	SKETCH SECTION THROUGH STUDY AREA , REF. FIGURE 1.	Job No. K1098-086/92046		Figure B2	

APPENDIX C

COAL MINING REPORT

British Coal Corporation,
Mining Reports Office,
Ashby Road, Burton on Trent,
Staffordshire DE15 0QD
Telephone: 0283 550606
Telex: 341741 (CBTD G)
DX 29281 BRETBY

British COAL

This matter is being dealt with by P.D.Welding
Survey Department (Ext. 31124)

W.S.Atkins Water,
Woodgate Grove,
Ashley Road,
Epsom,
Surrey.
KT18 5BW

Our Ref : SR86909-92

Your Ref : K1089/22/CO/RVAS/CCP/200

Date : 15th September 1992

Dear Sir,

N. R. A. Anglia.

Thank you for your letter of 11th September regarding the above.

I have checked our records, and find that our previous report bearing our reference as above, adequately describes the mining circumstances of the widened corridor.

I hope the above meets your requirements, but should you need further information, do not hesitate to contact me. We make no charge for this information.

Yours faithfully,

P. D. Welding.

for K. Leighfield
Chief Surveyor and Minerals Manager

British Coal Corporation
Mining Reports Office
Ashby Road, Burton on Trent,
Staffordshire, DE15 0QD
Telephone: 0283-550606
Telex: 34171 (CBTD G)
DX 29281 BRETBY

British COAL

W S Atkins Water
Woodcote Grove
Ashley Road
Epsom
Surrey
KT18 5BW

This matter is being dealt with
by K.Rowe
Survey Dept. (Tel. 0283-550606 Extn. 31124)

Our Ref: SR086909-92

Your Ref: K1098/22/CO/RVAS/

Date: 18th June 1992

Dear Sir,

Coal Mining Report
N R A - Anglia.

I refer to your enquiry dated 1st June 1992 in connection with the above.

Past Underground Coal Mining

Four seams of coal have been mined at approximately 350m to 700m depth under or within the vicinity of the site, the last date of working being 1989.

Ground movement from these past workings should by now have ceased.

These workings are located at the northern end of the site.

Present Underground Coal Mining

There are no workings presently taking place within influencing distance of the site.

Future Underground Coal Mining

British Coal's plans provide for workings to take place in the Deep Main seam at approximately 490m to 540m depth in October 1993 to June 1997.

These workings will be from the Asfordby Colliery at the southern end of the site.

The approximate location and extent of Asfordby's working area is indicated on the attached plan.

Further reserves of coal are available in this area and it is anticipated that such reserves may be worked at some future date.

British Coal reserves the right to alter and amend its working proposals at any time should it be deemed necessary to do so.

British Coal have no record of having issued any notice of proposals relating to underground coal mining operations under S.46 of the Coal Mining Subsidence Act 1991.

Shafts and Adits

According to our records, which may not be complete, 19 shafts are situated under or close to the site.

Two of these shafts afford underground access at Asfordby Colliery.

The remaining 17 shafts were sunk for the purpose of gypsum mining, and consequently lie outside British Coal's authority.

Continued....

Surface Geology

The site is clear of such faults, breaklines or fissures recorded on plans held by British Coal known to affect the stability of the site.

Opencast Coal Mining

British Coal have no proposals for opencast coal mining in the vicinity of the site.

The site is not situated within or adjoining an area for which an application has been made or is intended to be made in the near future by British Coal for planning permission under Town and Country Planning legislation in respect of the extraction of coal by opencast methods.

The site is not situated within or adjoining an area from which coal has been extracted by British Coal or their licensees by opencast methods.

Claims for Subsidence Damage

British Coal have no such record of a claim having been made or pursued in respect of this site.

There is no "Stop Notice" under Section 16(2) of the Coal Mining Subsidence Act, 1991, or any agreement with a claimant for the deferment of repairs relating to this site.

Blight Payments

British Coal have no record of any payment having been made under the Coal Mining Subsidence Act 1991 equivalent to the difference between the value of the site and its unblighted value.

Preventive Works to Existing Buildings

British Coal have no record of asking any person to execute preventive works under S.33 of the Coal Mining Subsidence Act 1991.

Preventive Measures to New Buildings

British Coal's records indicate that the site lies within an area in respect of which a notice has been published under paragraph 6 of the 2nd schedule to the Coal Act 1938.

British Coal's records indicate that the site lies within an area in respect of which a notice has been published under Section 2 of the Coal Industry Act 1975.

The Secretary of State in exercise of the powers conferred on him by S35(1) of the Coal Mining Subsidence Act 1991 has made an Order that Notices under S2 of the Coal Industry Act 1975 published or deemed to have been published before 30th November 1991 shall, subject to S35(2), cease to have effect for the purpose of S34 of the 1991 Act on 30th November 1992.

British Coal have until 30th November 1992 to publish a Notice under S35(2) of the 1991 Act.

British Coal have no record of being notified of any proposal relating to the construction of the site under S.34(2)(a) of the Coal Mining Subsidence Act 1991.

British Coal have no record of making any proposals under S.34 of the Coal Mining Subsidence Act 1991 as to the materials for and the method of construction of the buildings, structures or works as appear to them to be desirable for minimising damage in the event of subsidence.

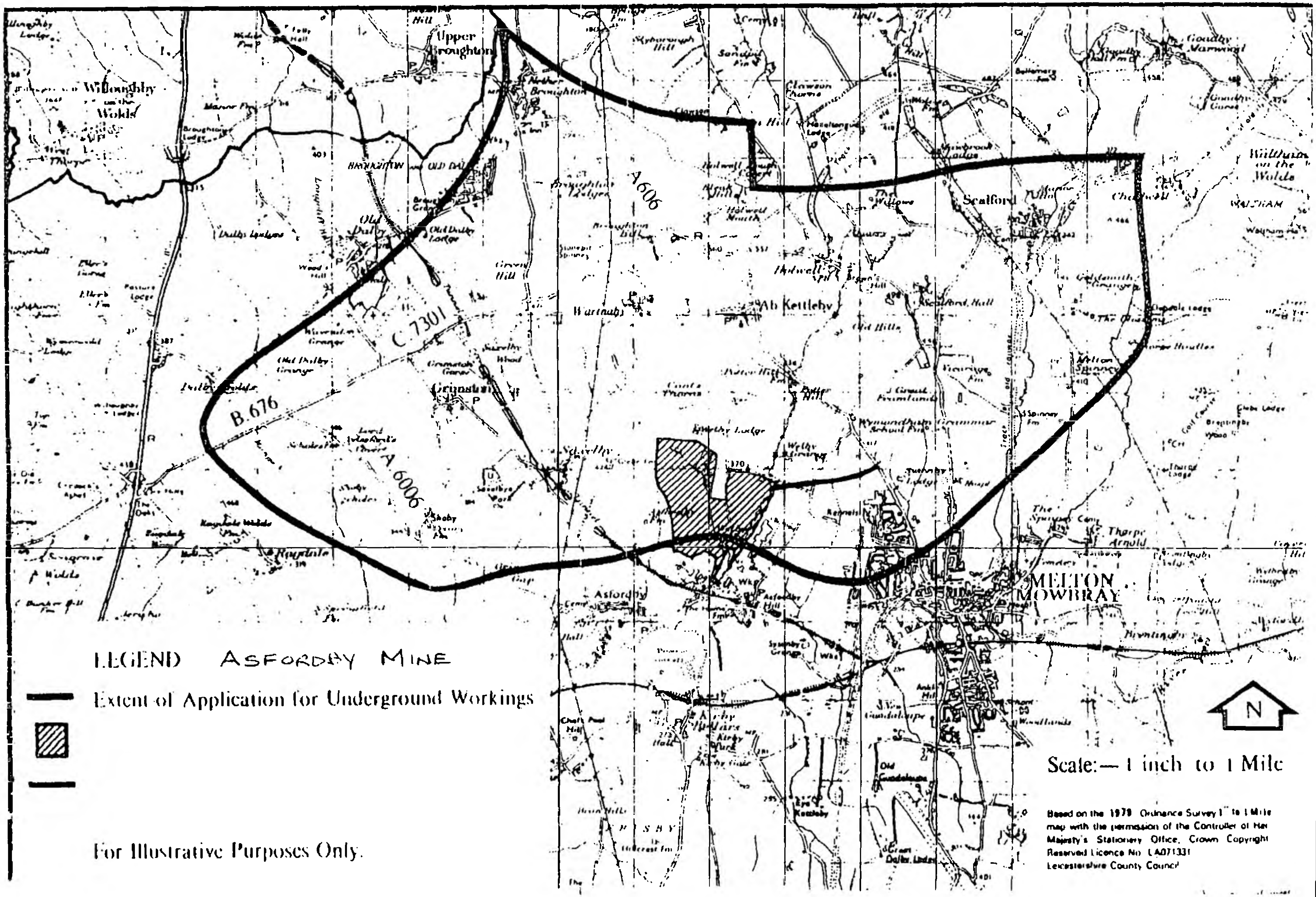
The fee for this information is £80.00 + V.A.T. = £94.00, for which you will be invoiced seperately.

Continued....

Yours faithfully

K. Leighfield

K. Leighfield
Chief Surveyor and Minerals Manager


Upper Broughton
Nether Broughton
Willoughby on the Wolds
Old Dalby
Grimston
Ab Kettleby
Wartnaby
Scalford
Asfordby
MELTON MOWBRAY
Thorpe Arnold
Kirby Bellars
A 606
A 6006
B.676
C.7301
LEGEND ASFORDBY MINE
Extent of Application for Underground Workings
For Illustrative Purposes Only.
Scale:— 1 inch to 1 Mile
Based on the 1979 Ordnance Survey 1" to 1 Mile map with the permission of the Controller of Her Majesty's Stationery Office. Crown Copyright Reserved Licence No. LA071331 Leicestershire County Council

APPENDIX D

ROUTE SCHEDULES

TABLE D.1 Pipeline schedules for Route 1

Item	Route 1.1a		Route 1.2		Route 1.3	
	Pumping Main	Gravity Main	Pumping Main	Gravity Main	Pumping Main	Gravity Main
Length of Main (km)	24.0+14.5	8.5+2.6	13.9	-	20.1	-
Length of Tunnel (km)	-	-	-	31.6	-	25.4
Intake Water Level (mAOD)	24	-	24	-	24	-
Summit Level (mAOD)	140	-	80	-	85	-
Outlet Water Level (mAOD)	-	87	-	87	-	87
Booster Pump Station (No)	1	-	-	-	-	-
Break Pressure Tanks (No)	2	-	-	-	-	-
Railway Crossings (No)	3	1	1	-	2	-
River Crossings (No)	1	1	-	-	1	-
Tidal River Crossings (No)	-	-	-	-	-	-
Stream Crossings (No)	26	1	9	-	14	-
Major Road Crossings (No)	5	1	2	-	3	-
Minor Road Crossings (No)	26	5	7	-	11	-
Notes :						

TABLE D.1 (continued) Pipeline schedules for Route 1

Item	Route 1.4		Route 1.5		Route 1.6	
	Pumping Main	Gravity Main	Pumping Main	Gravity Main	Pumping Main	Gravity Main
Length of Main (km)	13.9+17.4	2.6	-	-	14.5	-
Length of Tunnel (km)	-	13.4	-	45.5	-	31.8
Intake Water Level (mAOD)	24	-	-	24	24	-
Summit Level (mAOD)	120	-	-	-	100	-
Outlet Water Level (mAOD)	-	87	-	87	-	86
Booster Pump Station (No)	-	-	-	-	-	-
Break Pressure Tanks (No)	1	-	-	-	-	-
Railway Crossings (No)	2	1	-	-	-	-
River Crossings (No)	1	1	-	-	-	-
Tidal River Crossings (No)	-	-	-	-	-	-
Stream Crossings (No)	16	-	-	-	-	-
Major Road Crossings (No)	3	1	-	-	2	-
Minor Road Crossings (No)	20	-	-	-	5	-
Notes :						

TABLE D.2 Pipeline schedules for Route 2

Item	Route 2.1a		Route 2.2		Route 2.3	
	Pumping Main	Gravity Main	Pumping Main	Gravity Main	Pumping Main	Gravity Main
Length of Main (km)	20.0+10.0	13.1+2.6	19.0	-	19	5.7
Length of Tunnel (km)	-	-	-	24.1	-	5.2+13.2
Intake Water Level (mAOD)	15	-	15	-	15	-
Summit Level (mAOD)	140	-	80	-	90	-
Outlet Water Level (mAOD)	-	87	-	87	-	87
Booster Pump Station (No)	1	-	-	-	-	-
Break Pressure Tanks (No)	2	-	1	-	-	-
Railway Crossings (No)	2	1	1	-	1	-
River Crossings (No)	2	1	2	-	2	-
Tidal River Crossings (No)	-	-	-	-	-	-
Stream Crossings (No)	26	-	12	-	12	-
Major Road Crossings (No)	3	1	2	-	2	-
Minor Road Crossings (No)	33	5	21	-	21	-
Notes :						

TABLE D.2 (continued) Pipeline schedules for Route 2

Item	Route 2.4a		Route 2.5		Route 2.6	
	Pumping Main	Gravity Main	Pumping Main	Gravity Main	Pumping Main	Gravity Main
Length of Main (km)	20	11.1	-	-	18.9+12.4	2.6
Length of Tunnel (km)	-	12	-	43.1	-	10.0
Intake Water Level (mAOD)	15	-	-	15	15	-
Summit Level (mAOD)	140	-	-	-	120	-
Outlet Water Level (mAOD)	-	87	-	87	-	87
Booster Pump Station (No)	-	-	-	-	1	-
Break Pressure Tanks (No)	1	-	-	-	1	-
Railway Crossings (No)	1	-	-	-	2	-
River Crossings (No)	2	1	-	-	6	-
Tidal River Crossings (No)	-	-	-	-	-	-
Stream Crossings (No)	12	1	-	-	10	-
Major Road Crossings (No)	2	1	-	-	2	2
Minor Road Crossings (No)	21	5	-	-	16	0
Notes :						

TABLE D.3 Pipeline schedules for Route 3

Item	Route 3.1		Route 3.2		Route 3.3	
	Pumping Main	Gravity Main	Pumping Main	Gravity Main	Pumping Main	Gravity Main
Length of Main (km)	44.5	2.6	24	-	24.1	6.2
Length of Tunnel (km)	-	-	-	21.1	-	14.8
Intake Water Level (mAOD)	15	-	15	-	15	-
Summit Level (mAOD)	120	-	120	-	120	-
Outlet Water Level (mAOD)	-	87	-	87	-	87
Booster Pump Station (No)	-	-	-	-	-	-
Break Pressure Tanks (No)	1	-	1	-	1	-
Railway Crossings (No)			1	-	1	-
River Crossings (No)	3	-	-	-	-	-
Tidal River Crossings	1	-	-	-	-	-
(No)	-	-				
Stream Crossings (No)			3	-	3	3
Major Road Crossings (No)	14	-	1	-	1	1
Minor Road Crossings (No)	2	1	5	-	5	4
	16	1				
Notes :						

APPENDIX E

COST ESTIMATES

APPENDIX E - Cost Estimates

E.1 Introduction.

This appendix describes the cost estimates for the capital and revenue costs. For more detail refer to the SOS Final Report - Volume 1 Appendix B.

The capital cost of the options has been worked out based on TR61 functions for pipelaying, pump plant and structures, and river intakes and outlets, and costs developed by the Geotechnical Desk Study (Appendix B) for the tunnelling works. Cost functions in TR61 (November 1976) have been adjusted to Q3 92 (Third Quarter) by and inflation factor of 2.88. An allowance of £1M has been included, where applicable, for either purchase or maintenance of the disused rail tunnel. Due to the conceptual nature of the schemes, and the resulting coarseness of the cost estimates a contingency of 20% has been added to all of the capital cost elements to allow for unforseen circumstances including additional compensation and public utility costs which cannot be predicted at this stage. A value of 12% of the capital construction cost has also been added to the individual route alternatives to allow for design of supervision costs. Physical obstacles such as railway lines, main roads that probably cannot be closed, main rivers have been scheduled (Appendix C) and a sum for crossing them is included. Indicative vertical alignments were developed to identify the possibility of gravity pipelines rather than pumping mains. Further minor alignment changes (such as avoiding built-up areas, environment and archaeological sites) have been accounted for by a 10% increase in the overall route length.

The operating costs considered here are the pumping costs and the cost of chemicals for the phosphate stripping plant. The pumping costs are based on a unit rate of power of 7p. This figure was calculated from the latest East Midlands Electricity handbook on tariffs for the supply of Electricity, 1 April 1992. However a lower negotiated rate may be possible. No sensitivity analysis on variable power cost has been carried out at this stage. A factor of 25% of the power cost has been included to allow for staffing, maintenance, materials, tools etc.

Once the capital, operating costs and costs of replacing M&E plant had been calculated, NPV analysis was carried out. The capital and M&E replacement costs were discounted as single sums whereas the pumping and chemical costs, which are incurred annually, were discounted as annuities.

E.2 Capital Cost Comparison between the Route Alternatives for each Route Option

Costs for Routes 1, 2 and 3 have been summarised in Table E.1, E.2 and E.3 comparing the costs of routes with varying length of pipelines and tunnels.

Table E.1 - Capital Costs for Route 1

	Route 1.1a		Route 1.1b		Route 1.2		Route 1.3		Route 1.4		Route 1.5		Route 1.6	
Flows (tcmd)	200	400	200	400	200	400	200	400	200	400	200	400	200	400
Costs(£M)	58	100	59	101	118	136	109	131	81	116	147	149	118	134

Note Cost includes for pipeline and/or tunnel, major crossings (pipejacks), intakes, outfalls, pumps, pumping stations, inlet and outlets shafts, intermediate shafts and borehole pumping stations a phosphate stripping plant and an allowance for purchase/maintenance of the disused rail tunnel (where applicable) and design and supervision and a contingency.

As can be seen there is no material change in the initial capital expenditure for Route 1.1 from using the tunnel.

Table E.2 - Capital Costs for Route 2

	Route 2.1a		Route 2.1b		Route 2.1c		Route 2.2		Route 2.3		Route 2.4a		Route 2.4b		Route 2.5		Route 2.6	
Flows (tcmd)	200	400	200	400	200	400	200	400	200	400	200	400	200	400	200	400	200	400
Costs (£M)	46	95	46	78	57	79	101	118	97	119	73	97	67	93	148	150	69	104

Notes

1. Cost includes for pipeline and/or tunnel, major crossings (pipejacks), intakes, outfalls, pumps, pumping stations, inlet and outlets shafts, intermediate shafts and borehole pumping stations a phosphate stripping plant and an allowance for purchase/maintenance of the disused rail tunnel (where applicable) and design and supervision and a contingency.

2. Nominal amounts for pump installation were included at Rutland Water in Route 2.4, as our calculations indicate that only a very limited amount of pumping may be necessary here.

The large difference in capital cost for 400 tcmd for route 2.1a and b is largely due to an increase in pipe size from 1700mm internal diameter to 1800 mm.

The difference in capital cost for Routes 2.4a and b due at 400 tcmd is due to the cost function used which does not have a linear relationship between length and cost for a given diameter. Therefore, the cost of a pipeline considered on two lengths is more than if the pipeline is considered as one whole length.

Table E.3 - Capital Costs for Route 3

	Route 3.1		Route 3.2		Route 3.3	
Flows (tcmd)	200	400	200	400	200	400
Costs (£M)	46	78	91	112	83	112

Notes

1. Cost includes for pipeline and/or tunnel, major crossings (pipejacks), intakes, outfalls, pumps, pumping stations, inlet and outlets shafts, intermediate shafts and borehole pumping stations a phosphate stripping plant and an allowance for purchase/maintenance of the disused rail tunnel (where applicable) and design and supervision and a contingency.

2. Nominal amounts for pump installation were included at Rutland Water in Route 2.4, as our calculations indicate that only a very limited amount of pumping may be necessary here.

The cost of tunnels is not as sensitive to flow as is the case with pipelines because the size of the tunnels is fixed by the tunnelling technique rather than the required flow capacity. The relative cost of the tunnels therefore is a function of the lengths only.

Pipeline costs reflect the size of the pipe adopted, the ground conditions and number of major crossings envisaged. The ground conditions for all routes are very similar, being mainly marl and lias.

E.3 Effects of Varying the Level of Pumping

The NRA may choose to pump from the Trent during the winter months or may even decide to restrict pumping further depending on availability of water and the demand. Tables E.4, E.5 and E.6 summarises the results for varying the level of pumping for each option. These figures include the additional 25% for staffing, maintenance, materials, tools and also chemical costs.

As mentioned in Section E.1 the cost of power is taken as 7p/unit.

Table E.4 - Operating Costs for Route 1

	Route 1.1a		Route 1.1b		Route 1.2		Route 1.3		Route 1.4		Route 1.5		Route 1.6	
Flows (tcmd)	200	400	200	400	200	400	200	400	200	400	200	400	200	400
Operating costs (£M) for														
12 months	7	11	5	11	3	5	3	6	5	9	2	4	3	6
6 months	3	6	3	5	1	3	2	3	2	4	1	2	2	3
3 months	1	3	1	3	1	1	1	1	1	2	0.5	1	1	1

Table E.5 - Operating Costs for Route 2

	Route 2.1a		Route 2.1b		Route 2.1c		Route 2.2		Route 2.3		Route 2.4a		Route 2.4b		Route 2.5		Route 2.6	
Flows (tcmd)	200	400	200	400	200	400	200	400	200	400	200	400	200	400	200	400	200	400
Operating costs (£M) for																		
12 months	6	11	4	9	5	9	3	6	3	7	4	9	4	8	2	5	6	10
6 months	3	5	2	4	2	5	1	3	1	3	2	4	2	4	1	2	3	5
3 months	1	3	1	2	1	2	1	2	1	2	1	2	1	2	1	1	1	3

Table E.6 - Operating Costs for Route 3

	Route 3.1		Route 3.2		Route 3.3	
Flows (tcmd)	200	400	200	400	200	400
Operating costs (£M) for						
12 months	4	9	4	8	5	8
6 months	2	4	2	4	2	4
3 months	1	2	1	2	1	2

E.4 NPV Results

Tables E.7 to E.12 give results of the NPV analysis. These tables presented cover transfer capacities 200 tcmd and 400 tcmd only. The NPV for operating costs is the sum of the NPVs for pumping, staffing, maintenance, materials and chemicals (for the phosphate stripping plant).

Table E.7 - NPV Results for Route 1 for all year pumping

	Route 1.1a		Route 1.1b		Route 1.2		Route 1.3		Route 1.4		Route 1.5		Route 1.6	
Flows (tcmd)	200	400	200	400	200	400	200	400	200	400	200	400	200	400
Total operating NPV (£M)	68	135	63.5	127.5	34	64.5	39.5	70.5	59	103.5	23	51	38	69
Total NPV for M&E replacement (£M)	0.5	1	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Capital Cost NPV (£M)	45.5	78	47	78.5	95	109	88	105	64.5	92.5	119.5	121.3	95.5	107.5
Total NPV (£M)	114	214	111	207	129.5	174	128	176	124	196.5	143	172.5	134	177

Table E.8 - NPV Results for Route 1 for 6 months of pumping

	Route 1.1a		Route 1.1b		Route 1.2		Route 1.3		Route 1.4		Route 1.5		Route 1.6	
Flows (tcmd)	200	400	200	400	200	400	200	400	200	400	200	400	200	400
Total operating NPV (£M)	35	68	31.5	63.5	17	32.5	19.5	35.5	29.5	51.5	13	26.5	20	34
Total NPV for M&E replacement (£M)	0.5	1	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Capital Cost NPV (£M)	45.5	78	47	78.5	95	109	88	105	65	92.5	119.5	121	95.5	107.5
Total NPV (£M)	81	147	79	143	112.5	142	108	141	95	144.5	133	148	116	142

Table E.9- NPV Results for Route 1 for 3 months of pumping

	Route 1.1a		Route 1.1b		Route 1.2		Route 1.3		Route 1.4		Route 1.5		Route 1.6	
Flows (tcmd)	200	400	200	400	200	400	200	400	200	400	200	400	200	400
Total operating NPV (£M)	17	34	15.5	32.0	8.5	16.5	9.5	17.5	15	26	5.5	12.5	9.5	17
Total NPV for M&E replacement (£M)	0.5	1	0.5	1.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Capital Cost NPV (£M)	45.5	78	47	78.5	95.5	109	88	105	64.5	92.5	119.5	121	95.5	107.5
Total NPV (£M)	63	113	63	111.5	104.5	126	98	123	80	119	125.5	134	105.5	125

Table E.10 NPV Results for Route 2 for all year pumping

	Route 2.1a		Route 2.1b		Route 2.1c		Route 2.2		Route 2.3		Route 2.4a		Route 2.4b		Route 2.5		Route 2.6	
Flows (tcmd)	200	400	200	400	200	400	200	400	200	400	200	400	200	400	200	400	200	400
Total operating NPV (£M)	68	132	51.5	105.5	58.5	113	33.5	75.5	35.5	78	51.5	105.3	45.5	91.7	26	57	70	121
Total NPV for M&E replacement (£M)	0.5	1	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	0.5	0.7	0.5	0.6	0.5	0.5	0.5	1
Capital Cost NPV (£M)	36	74	36.5	61	45	62	81.5	94	78	95	58.5	77	53.5	73.7	120	122	54.5	82
Total NPV (£M)	104.5	207	88.5	167	104	176	115.5	170	114	173.5	110.5	183	99.5	166	146.5	179.5	125	204

Table E.12 - NPV Results for Route 2 for 6 months of pumping

	Route 2.1a		Route 2.1b		Route 2.1c		Route 2.2		Route 2.3		Route 2.4a		Route 2.4b		Route 2.5		Route 2.6	
Flows (tcmd)	200	400	200	400	200	400	200	400	200	400	200	400	200	400	200	400	200	400
Total operating NPV (£M)	34	65	25.5	52	29.5	57	16.5	34.5	17.5	39	26	52.5	23	44	13	28	35	60.5
Total NPV for M&E replacement (£M)	0.5	1	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1
Capital Cost NPV (£M)	39	72	37	61.5	45	62	81.5	94	78	95	58.5	77.5	53.5	73.5	120	122	54.5	81.5
Total NPV (£M)	73.5	138	63	114	75	120	98.5	129.5	96	134.5	85	130.5	76.5	118	133	150	90	143

Table E.13 - NPV Results for Route 2 for 3 months of pumping

	Route 2.1a		Route 2.1b		Route 2.1c		Route 2.2		Route 2.3		Route 2.4a		Route 2.4b		Route 2.5		Route 2.6	
Flows (tcmd)	200	400	200	400	200	400	200	400	200	400	200	400	200	400	200	400	200	400
Total operating NPV (£M)	16.5	35	12.5	26.5	14.5	29	8.5	18.5	10	19.5	13	26.5	11.5	23	7	14	17	30.5
Total NPV for M&E replacement (£M)	0.5	1	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1
Capital Cost NPV (£M)	35.5	72	37	61	45	62	81.5	94.5	78	95	58.5	77	53.5	73.5	120	122	54.5	81.5
Total NPV (£M)	52.5	108	50	88	60	92	90.5	113.5	88.5	115	72	104	65.5	97	127.5	136.5	72	113

Table E.14 - NPV Results for Route 3 for all year pumping

	Route 3.1		Route 3.2		Route 3.3	
Flows (tcmd)	200	400	200	400	200	400
Total operating NPV(£M)	51.5	106	52.5	91	54.5	96
Total NPV for M&E replacement (£M)	0.5	0.5	0.5	0.5	0.5	0.5
Capital Cost NPV (£M)	37	61.5	73	89.5	66	89.5
Total NPV (£M)	89.0	168	126	181	121	186

Table E.15 - NPV Results for Route 3 for 6 months of pumping

	Route 3.1		Route 3.2		Route 3.3	
Flows (tcmd)	200	400	200	400	200	400
Total operating NPV (£M)	25.5	53	26	45.5	27.5	48
Total NPV for M&E replacement (£M)	0.5	0.5	0.5	0.5	0.5	0.5
Capital Cost NPV (£M)	37	61.5	73	89.5	66	89.5
Total NPV (£M)	63	115	99.5	135.5	94	138

Table E.16 - NPV Results for Route 3 for 3 months of pumping

	Route 3.1		Route 3.2		Route 3.3	
Flows (tcmd)	200	400	200	400	200	400
Total operating NPV (£M)	13	26.5	11	23	12	24
Total NPV for M&E replacement (£M)	0.5	0.5	0.5	0.5	0.5	0.5
Capital Cost NPV (£M)	37	61.5	73	89.5	66	89.5
Total NPV (£M)	50.5	88.5	84.5	113	78.5	114