

Thames Tideway Tunnel
Thames Water Utilities Limited



Application for Development Consent

Application Reference Number: WWO10001

Tackling London's Sewer Overflows

Doc Ref: **8.2.6**

Cost Benefit Working Group Report

APFP Regulations 2009: Regulation **5(2)(q)**

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January 2013

**Thames
Tideway Tunnel**



Creating a cleaner, healthier River Thames

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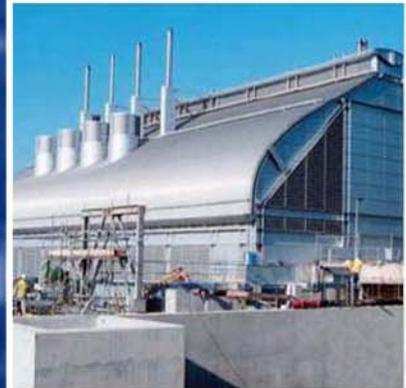
Tackling London's Sewer Overflows

Thames Tideway Tunnel and Treatment - Option Development

Cost Benefit Working Group Report

December 2006

**Thames
Tideway**



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1 EXECUTIVE SUMMARY

1.1 BACKGROUND

The major purpose of the work of the cost benefit group was to produce an assessment of the costs and benefits of the options under consideration. Early meetings of the group focussed on reviewing the changes that had taken place since the TTSS assessment to determine whether they were sufficient to drive a requirement for new survey work rather than a simple updating of the previous analysis. The group concluded that it would be beneficial to undertake a new stated preference survey and to commission a review of previous work on environmental costs and market benefits.

In all, the group commissioned three separate pieces of work (the other information required, costs of options, was provided by the solutions group).

- An assessment and valuation of environmental benefits, as defined by the objectives, modelling and compliance group, undertaken by Eftec. A stated preference study was commissioned to inform this aspect. The benefits included in this study are reduction in fish kills, reduction in elevated health risk and reduction in sewage-derived litter
- An assessment and valuation of environmental and social impacts (as identified by the environment and planning group) and market benefits, undertaken by Entec.
- A cost benefit analysis to inform the comparison of the principal two options, and variants as appropriate, undertaken by NERA.

1.2 RESULTS

All three studies reported in December 2006. The main findings were as follows;

1.2.1 An Assessment and Valuation of Environmental Benefits (Eftec)

Eftec used a contingent valuation study to elicit people's preferences expressed as their willingness to pay (WTP) to reduce the combined impacts of the CSO discharges (that is the potentially harmful impacts on fish and other wildlife, the increased health risk and the discharge of sewage-derived litter to the river) on the Tideway. The reduction in impacts were described in terms of the predicted benefits afforded by the three main alternative engineering solutions, a large diameter tunnel (7.2m) running from Hammersmith to Beckton with a spur to Abbey Mills sewage pumping station, a smaller diameter tunnel (6m) of the same length and two large diameter tunnels in the East (Hammersmith to Heathwall) and West (Abbey Mills to Beckton) of the Tideway. Respondents were also asked whether and what they would be willing to pay to ensure that part of the scheme was delivered early enough to avoid the risk of a CSO discharge from Abbey Mills sewage pumping station during the Olympics.

The questionnaire was administered to a total of 875 respondents (599 Thames Water customers and 276 customers of other water companies). This enabled the aggregation of benefits within two jurisdictions;

- The benefits jurisdiction - to identify all of the benefits afforded by the proposed Tideway improvements
- The administrative jurisdiction - to identify only those benefits held by Thames Water customers, the group most likely to have to pay for the improvements through their water bills.

Aggregation was undertaken using both a derived distance decay function with explanatory variables relating to distance from the Tideway and socio-economic class and the sample mean. The survey results are given in Table 2.1.

Table 2.1 Non-Market Benefits by Option (Eftec, 2006)

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Option	Benefits Jurisdiction (English households)		Administrative Jurisdiction (TW customer Households) ¹	
	Per household per year (£)	All households per year (£m)	Per household per year (£)	All households per year (£m)
Large diameter tunnel (7.2m)	8.52	174	13.02	66
Small diameter tunnel (6m)	4.00	82	7.44	38
Two tunnels	2.10	43	5.17	26
To avoid CSO discharge during 2012 Olympics	4.90 ^{2,3}		4.28 ^{2,3}	

All figures in 2006 prices

¹This benefits jurisdiction differs across each of the options for which willingness to pay has been estimated: for Option (1), and by implication Option 1c and Option 1c (phased), this refers to all households in England; for Option 1b this refers to all households within a 260 mile radius of the Thames, and for Option 2 refers to all households within a 170 mile radius of the Thames.

² Non-TW customers

³ Aggregated on basis of sample mean rather than distance decay relationship

WTP figures were found to be consistently higher for the larger diameter tunnel than the other two engineering options. Use of the derived distance decay function reduces the aggregate WTP compared to the values derived from the simple mean WTP. There is a positive willingness to pay for an earlier 'Olympics solution' from a proportion of the respondents.

1.2.2 Environmental Costs and Market Benefits (Entec)

Entec distinguished between environmental and social impacts during construction and operation of the different tunnel options, the most significant occurring during the construction phase. The report identifies a range of potential environmental costs arising from the tunnel, only some of which could be expressed as monetary values. The most significant of these construction impacts were the energy embodied in construction materials, including the energy required to extract, process and transport the materials to site, the social costs arising from traffic delays and the environmental costs arising from the transport and disposal of construction waste. The effect of land take on recreation, visual amenity, biodiversity and archaeology could also be important although of more minor significance.

During tunnel operation some of the potentially most significant environmental issues are considered within the Entec study. Of the environmental impacts assessed by Entec, the potentially most significant was the reduction in flood risk, although there is considerable uncertainty surrounding the levels of risk and the values associated with the potential impact. The effect on biodiversity was noted as being of minor significance because of the potential loss of intertidal mud flats and rough grassland and reedbeds at Beckton sewage treatment works, although this impact could not be valued.

The report also concluded that there was a potential minor market benefit associated with reduced use of the bubbler and skimmer vessels and chemical dosing of peroxide, currently undertaken to counteract the effect of the CSO's.

A summary of the financial benefits and non-financial costs derived by Entec (2006) is reported in NERA (2006) and reported below in Table 2.2.

Table 2.2 Costs and Financial Benefits by Option (NERA, 2006)

Option	Financial Costs: Capex (£m)	Financial Costs: Opex (£m)	Financial Benefits (£m)	Non-Market Costs (£m)
1a	2364	366	41	108
1b	2262	347	40	99
1c	2453	356	41	108
1c phased	2460	363	42	109
2a	1816	310	30	61
2b	1878	361	30	65
2c	1907	314	30	57

All figures in 2006 prices totalled over 60 years

For comparison the financial costs from the Solutions group (Capex and Opex) are also presented. It is evident that the financial benefits and non-financial costs identified by Entec (2006) are considerably less than the financial costs of the different engineering options.

1.2.3 Tideway Tunnel Cost Benefit Analysis (NERA)

NERA used the outputs described above to undertake a cost benefit analysis.

All cost and benefit figures were monetised over a 60 year time horizon. Changes in prices were allowed for, where these might be expected to be different from general inflation, and adjustments made where appropriate for differences between factor and market prices. The Green Book recommended discount rate of 3.5% real per year for the first thirty years and declining thereafter was used to produce the comparative figures of Net Present Value and Benefit Cost Ratio shown in Table 2.3 below.

Table 2.3 Cost Benefit Measures by Option (NERA 2006)

Option	Benefits jurisdiction (All England ¹ households)				Administrative jurisdiction (TW customer households)			
	NPV (£ million)	NPV Rank	Benefit/Cost ratio	Benefit/Cost ratio rank	NPV (£ million)	NPV Rank	Benefit/Cost ratio	Benefit/Cost ratio rank
1a	2009	1	2.04	1	-423	1	0.78	1
1b	14	4	1.01	4	-980	7	0.47	4
1c ²	1970	2	2.00	2	-463	2	0.76	2
1c phased ²	1882	3	1.92	3	-550	3	0.73	3
2a	-447	5	0.69	5	-826	4	0.42	5
2b	-502	6	0.66	6	-881	5	0.41	6
2c	-516	7	0.66	7	-895	6	0.40	7

All figures in 2006 prices

¹This benefits jurisdiction differs across each of the options for which willingness to pay has been estimated: for Option (1), and by implication Option 1c and Option 1c (phased), this refers to all households in England; for Option 1b this refers to all households within a 260 mile radius of the Thames, and for Option 2 refers to all households within a 170 mile radius of the Thames.

²1c does not include any Olympic related benefit estimate in this table

None of the options have a positive NPV for the administrative jurisdiction. However as noted by NERA, 'a full cost benefits analysis takes account of all benefits, whoever receives them', hence it is appropriate to consider the benefits jurisdiction. This does not imply that an

intervention should go ahead if it passes a cost benefit test on this basis since other considerations, such as distributional impacts, will come to bear in making that decision.

For the benefits jurisdiction, three variants of option 1 (a, c and c phased) have a positive NPV and are cost beneficial. However there is little difference between them on cost benefit grounds.

Switching analysis was also undertaken. For the benefits jurisdiction, for the three highest ranking options, costs would have to approximately double relative to the benefits for the NPV to fall to zero. Conversely, benefits for these options would have to fall by approximately half for them to cease to be cost-beneficial.

A number of sensitivity tests were applied to these results, including changes to the time horizon, financial costs, monetised non-financial costs, financial benefits, non-financial benefits and the assumed cost of private financing. Although both a poor outturn on costs or an alternative view of the status of the WTP benefits could reduce the NPVs or cost-benefit ratios, only one of the sensitivity tests alters the rankings of the options significantly. This exception occurs when a higher willingness to pay to reduce the likelihood of a CSO discharge in time for the Olympics is applied. This led to a significantly higher NPV (£4138m) and cost benefit ratio (3.02) for option 1c (phased) than for options 1a and 1c (applied to the benefits jurisdiction). However this conclusion must be treated with an element of caution because the median WTP for this option was zero showing that if extra spending for the Olympics option had come up as a referendum, half the sample would have stated zero WTP. Further, the statistical validity of the Olympics WTP has not been explored in sufficient detail as yet because of time constraints.

The Cost Benefit working group are satisfied that the cost benefit analysis studies have been undertaken to a high standard. However the nature of the both the task itself and the methodologies used are uncertain and, despite the high quality of the current studies, a number of significant uncertainties remain. These are discussed in detail in the Cost Benefit working group report.

2 BACKGROUND

In a letter from the Minister of State for Climate Change and Environment dated 27th July 2006, Thames Water was asked to lead and deliver a detailed assessment and costing of two options to deal with London's sewage overflows and improve sewage treatment systems in order to meet the requirements of the Urban Wastewater Treatment Directive (UWWTD).

Paragraph (f) of the letter stated that “(the work must include) an assessment of all costs and benefits (including environmental and social costs and benefits) of the options and variations. Given the time period, it is expected that this assessment will be largely based on existing analysis by The Thames Tideway Strategic Study. However this will be dependent on whether the results of the existing analysis are applicable to the current situation. Issues that will need to be considered include the length of time that has elapsed since the willingness to pay study and the assessment of the current baseline from which to undertake the assessment of costs and benefits. This work should comply with the HMT Green Book.”

The letter also noted the importance of other key contributors such as Ofwat and the Environment Agency. Thames Water responded by setting up a suite of working groups to manage the different workstreams.

The Tideway Tunnel Cost Benefit Working Group, re-established for this piece of work, met for the first time on 24th August 2006. The group was chaired by Yvette de Garis, Head of Environmental Sustainability, Thames Water and membership comprised the following organisations; Ofwat, Environment Agency, Defra and CCWater. Secretariat and project management services were provided by Thames Water.

The terms of reference for the group were agreed as follows;

1. To contribute relevant inter-disciplinary expertise to the study in order to assist Thames Water in addressing cost benefit requirements, in particular paragraph (f) of Ian Pearson's letter to Jeremy Pelczer dated 27th July 2006;
2. To agree any new study requirements associated with the current project by review of the previous assessment by the TTSS and any other new work, and to agree whether, and how, they can be used to inform new studies;
3. To agree a methodology of approach, and a scope of work for commissioning appropriate contractors, which addresses (1) and (2) above, meets the requirements set out in Ian Pearson's letter and is achievable within the timeframe;
4. To review progress updates, and make technical comment as appropriate;
5. To review draft results of analyses and propose amendments as appropriate.

3 STUDIES COMMISSIONED

The major purpose of the work of the cost benefit group was to produce an assessment of the costs and benefits of the options under consideration. Early meetings of the group focussed on reviewing the changes that had taken place since the TTSS assessment to determine whether they were sufficient to drive a requirement for new survey work rather than a simple updating of the previous analysis. The group concluded that it would be necessary to undertake a new stated preference survey for several reasons;

Firstly that the baseline had changed since the TTSS reported. Funding had been awarded within the AMP4 determination to upgrade the main Tideway sewage treatment works discharges so that some improvements of current water quality in the Thames Tideway could be expected;

Secondly the environmental benefits arising from further improvements over and above this new baseline, were different to those investigated previously;

Thirdly, the question to be investigated through a stated preference survey has been further developed to distinguish between two broad engineering options, rather than the individual attributes to be improved through a variety of intervention mechanisms.

Therefore it was concluded that a further willingness to pay (WTP) survey was required. In all, the group commissioned three separate pieces of work (the other information required, costs of options, was provided by the solutions group).

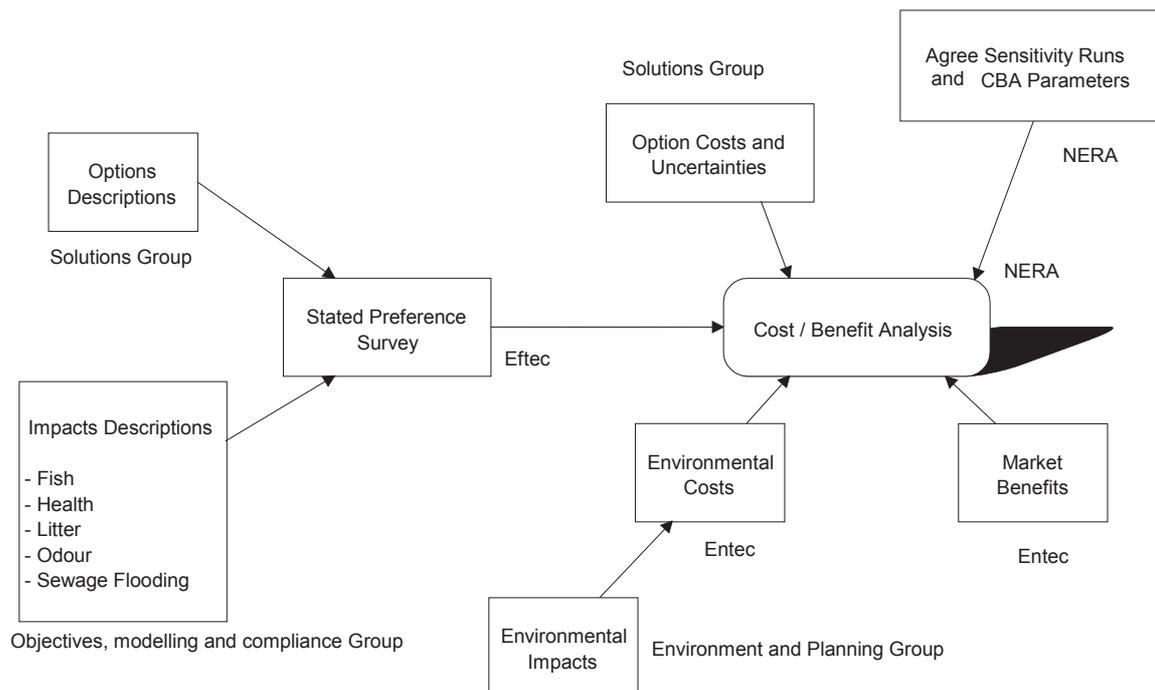
- An assessment and valuation of environmental benefits, as defined by the objectives, modelling and compliance group. A stated preference study was commissioned to inform this aspect. The benefits included in this study are reduction in fish kills, reduction in elevated health risk and reduction in sewage-derived litter
- An assessment and valuation of environmental and social impacts (as identified by the environment and planning group) and market benefits.
- A cost benefit analysis to inform the comparison of the principal two options, and variants as appropriate.

Three separate sets of consultants were appointed to undertake the work identified above, under the guidance of the Cost Benefit working group. These were;

- Eftec: the assessment and valuation of environmental benefits;
- Entec: the assessment and valuation of environmental and social impacts and market benefits (excluding environmental benefits considered by Eftec)
- NERA: cost benefit analysis of tunnel options

The relationship between these studies and the other work packages that ran concurrently on the Tideway Tunnel are shown in the following flow chart.

Figure 1: Flow Chart showing the relationship of other studies with the Cost Benefit Studies



4 RESULTS

All three studies reported in December 2006. The main findings of each study were as follows.

4.1 AN ASSESSMENT AND VALUATION OF ENVIRONMENTAL BENEFITS (EFTEC)

Eftec sought to establish the economic value of reducing the main impacts associated with discharges from the combined sewer overflows into the Tideway, that is the potentially harmful impacts on fish and other wildlife, the increased health risk and the discharge of sewage-derived litter to the river. A contingent valuation study was used to elicit people's preferences expressed as their willingness to pay to reduce the combined impacts of the CSO discharges on the Tideway. The reduction in impacts were described in terms of the predicted benefits afforded by three alternative engineering solutions, a large diameter tunnel (7.2m) running from Hammersmith to Beckton with a spur to Abbey Mills sewage pumping station, a smaller diameter tunnel (6m) of the same length and two large diameter tunnels in the East (Hammersmith to Heathwall) and West (Abbey Mills to Beckton) of the Tideway. Respondents were also asked whether and what they would be willing to pay to ensure that

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part of the scheme was delivered early enough to avoid the risk of a CSO discharge from Abbey Mills sewage pumping station during the Olympics.

The questionnaire was administered to a total of 875 respondents (599 Thames Water customers and 276 customers of other water companies). This enabled the aggregation of benefits within two jurisdictions (areas);

- The benefits jurisdiction - to identify all of the benefits afforded by the proposed Tideway improvements (consistent with HMT Green Book guidance and the letter from the Minister)
- The administrative jurisdiction - to identify only those benefits held by Thames Water customers, the group most likely to have to pay for the improvements through their water bills. This is relevant to the consideration of the possible distributional consequences and how they should be paid for.

Aggregation was undertaken using a derived distance decay function with explanatory variables relating to distance from the Tideway and socio-economic class. Distance and socio-economic class data were derived from a Geographical Information system database based on UK Census Enumeration Districts. Distance and socio-economic class were not the only determinants of variation in WTP, other statistically significant variables included income, level of education, membership of an environmental group and order of presentation of the engineering options (for the smaller diameter and two tunnel options). However, for the purposes of aggregation only those variables for which information was available from the UK Census could be included.

Aggregation was also undertaken using the sample mean WTP.

The unit and aggregate WTP results are presented in Table 3.1. Several points are worthy of note as follows;

1. WTP figures are consistently higher for the larger diameter tunnel than the other two engineering options
2. Use of the derived distance decay function reduces the aggregate WTP compared to the values derived from the simple mean WTP.
3. There is a positive willingness to pay for an earlier 'Olympics solution' from a proportion of the respondents.

Table 3.1: Unit and aggregate WTP for Tideway CSO options using distance decay functions (Eftcc 2006)

	WTP function aggregation				Simple mean WTP aggregation			
	Administrative jurisdiction (TW customer households)		Benefits jurisdictions (English households)		Administrative jurisdiction (TW customer households)		Benefits jurisdictions (English households)	
	Unit WTP (£ /hh/year)	Aggregate WTP (£m / year)	Unit WTP (£ /hh/year)	Aggregate WTP (£m / year)	Unit WTP (£ /hh/year)	Aggregate WTP (£m / year)	Unit WTP (£ /hh/year)	Aggregate WTP (£m / year)
Large tunnel (7.2m)	13.02	66	8.52	174	24.66 (22.41 - 26.91)	123 (112 - 135)	22.55 (20.75 - 24.35)	461.2 (424 - 498)
Small tunnel* (6m)	7.44	38	4.00	82	19.03 (16.11 - 21.95)	95 (81 - 110)	17.96 (15.70 - 20.52)	367 (321 - 420)
Two tunnels**	5.17	26	2.10	43	20.09 (17.11 - 23.07)	100 (86 - 115)	17.55 (15.24 - 19.86)	358 (312 - 406)
To avoid CSO happening during 2012 London Olympics** *	n.e.	n.e.	n.e.	n.e.	4.28 (3.17 - 5.39)	n.e.	4.90 (3.86 - 5.93)	n.e.

Note: Figures in brackets are 95% confidence intervals, and all estimates exclude protest zeros (those responses which were judged to reflect considerations other than the changes presented in the questionnaire e.g. dissatisfaction with the institution providing the change). The estimates in the table do not have confidence intervals as there was no time within the project to estimate these which need a rather long process called 'boot strapping'.

*: The benefits jurisdiction for the small tunnel is the population in the area up to 260 miles from the Tideway, where predicted WTP reaches zero.

**: The benefits jurisdiction for the two tunnels is the population in the area up to 170 miles from the Tideway, where predicted WTP reaches zero.

***: The estimates for this under the 'benefits jurisdiction' in fact refer to non-TW customers

4.2 ENVIRONMENTAL COSTS AND MARKET BENEFITS (ENTEC)

Entec distinguished between environmental and social impacts during construction and operation of the different tunnel options, the most significant occurring during the construction phase. The report identifies a range of potential environmental costs arising from the tunnel, only some of which could be expressed as monetary values. The most significant of these construction impacts were the energy embodied in construction materials, including the energy required to extract, process and transport the materials to site, the social costs arising from traffic delays and the environmental costs arising from the transport and disposal of construction waste. The effect of land take on recreation, visual amenity, biodiversity and archaeology could also be important although of more minor significance.

During tunnel operation some of the potentially most significant environmental issues are considered within the Entec study. Of the environmental impacts assessed by Entec, the potentially most significant was the reduction in flood risk, although there is considerable uncertainty surrounding the levels of risk and the values associated with the potential impact. Effects on biodiversity were noted as being of minor significance because of the potential loss of intertidal mud flats and rough grassland and reedbeds at Beckton sewage treatment works, although this impact could not be valued.

The report also concluded that there was a potential minor market benefit associated with reduced use of the bubbler and skimmer vessels and chemical dosing of peroxide, currently undertaken to counteract the effect of the CSO's.

For many of the valuations reported Entec gave high, low and median estimates and note the considerable uncertainty associated with all estimates.

A summary of the values and significance of environmental and social effects during construction is given in Table 3.2. The equivalent values during operation are given in Table 3.3. The market benefits arising from a reduction in activities undertaken to counteract the effects of the CSOs are also given in Table 3.3.

The CB working group were particularly interested to see information on the carbon footprint of each option summarised in the Entec report. The emissions of carbon dioxide associated with each option are reproduced below in Table 3. The emissions associated with treatment of captured sewage are based on use of electricity for 80% requirement with an assumed level of zero emissions from the other 20% (assumed to be provided by wind power for this assessment). The figures relating to energy generated are savings, where lower emissions of carbon dioxide may be expected as a result of the tunnel. The calculations show the maximum saving assuming zero emissions from carbon dioxide from biomass (the additional sewage captured by the tunnel).

For many impacts it is difficult to differentiate between the different engineering options. However, in general, both market benefits and environmental costs tend to be higher for the single tunnel options as these options impact through the more congested and heavily populated parts of central London.

Table 3.2 Summary of the values and significance of environmental and social effects during construction (Entec 2006)

	Valuation method	Value for options					Comments	Significance
		1a	1b	1c	2a	2b		
Requirement for materials and people								
Abstraction, processing and transport of materials to site	Benefit transfer of values from a combined method study based on the impact pathway approach	£8.0m- £26.7m	£7.0m- £23.4m	£8.2m- £27.2m	£5.4m- £18.0m	£4.5m- £14.9m	£4.9m- £16.4m	Negative environmental effect Moderate or major significance
Employment	Qualitative assessment						Relates to the costs of embodied energy only Considers concrete and steel only Including other social and environmental costs may increase these estimates by 60% to 100% of the value	Positive market and social effect Minor significance to UK economy
Construction processes								
Requirement for land	Recreation	£0.9m- £1.9m	£0.9m- £1.9m	£0.9m- £1.9m	£0.8m- £1.7m	£0.8m- £1.7m	£0.8m- £1.7m	Negative social effect Minor significance
	Visual effect						Likely to be an overestimate as assumes at minimum that all designated open space is used for recreation	Negative social effect Minor significance

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	Valuation method	Value for options					Comments	Significance
		1a	1b	1c	2a	2b		
	Biodiversity						Most significant impact expected at Beckton, with other potential impacts where there is disturbance to the intertidal area	Negative environmental effect Not expected to be significant
	Archaeology and cultural heritage							Negative effect Unlikely to be significant
Noise and vibration	Qualitative assessment							Negative social effect Minor significance
Energy use for tunnel boring	Benefit transfer of values from a combined method study based on the impact pathway approach	£5.0m- £15.1m	£5.0m- £15.1m	£5.1m- £15.3m	£3.4m- £10.4m	£3.4m- £10.4m	Includes energy for tunnel boring and lifting material to the surface Assumes that energy is from electricity Uncertainty reflects wide range of values associated with external costs of carbon	Environmental cost Moderate or major significance
Delays to traffic		£27.5m	£27.5m	£27.5m	£2.7m	£2.7m	Taken from calculations in the Planning and Environment Working Group report (2006)	Negative environmental and social effect Major significance for Options 1, minor significance for Options 2
Generation of waste								
Transport of		£9.6m	£7.4m	£9.7m	£7.8m	£6.2m	Assumes all waste taken by 11 tonne	Environmental cost

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	Valuation method	Value for options					Comments	Significance	
		1a	1b	1c	2a	2b			2c
construction waste							HGV to handling site, then by barge to sites 60km from London Applies external costs per tonne km to outward and return journeys Applies European average values for external cost	Moderate significance	
Disposal of construction waste		£6.7m- £9.6m	£5.1m- £7.4m	£6.8m- £9.8m	£5.2m- £7.4m	£4.0m- £5.8m	£3.9m- £5.7m	Assumes all waste goes to landfill (worst case scenario) Value based on disamenity of landfill Much of the environmental cost may be included in the financial costs as a result of the landfill tax	Environmental cost Moderate significance

Table 3.3 Summary of the values and significance of environmental and social effects during operation (Entec 2006)

	Valuation method	Value for options				Comments	Significance
		1a	1b	1c	2a		
Improved water quality							
Biodiversity						Effects on aquatic ecology are considered in the stated preference survey undertaken for Thames Water	
Effect on commercial fisheries	Qualitative assessment					Some potential improvement to fishing, although the extent of effect in comparison to other influences is uncertain	Potential market benefit Limited significance
Recreation-angling	Qualitative assessment					Potential cross-over with stated preference survey reflecting value by river users- therefore excludes social benefits	Potential market benefit Limited significance
Other recreation	Qualitative assessment					Potential cross-over with stated preference survey reflecting value by river users- therefore excludes social benefits	Potential market benefit Limited significance
Human health						Human health is considered in an associated study undertaken for Thames Water	
Use of Thames bubblers		£0.9m-£1.3m	£0.9m-£1.3m	£0.9m-£1.3m	£0.6m-£0.8m	Assumes no need for bubblers or peroxide dosing with tunnel Range reflects reduction or removal of need for skimmers	Market benefit for Thames Water Minor significance
Reduction in flood risk							

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	Valuation method	Value for options					Comments	Significance
		1a	1b	1c	2a	2b		
Flood risk	Avoided cost from flood events or alternative flood protection	£0-£19.7m	£0-£19.7m	£0-£19.7m	£0-£4.5m	£0-£4.5m	A small number of properties are expected to experience some reduction in risk Uncertainty reflects uncertainty over extent of reduction in risk and wide range in values	Social benefit Very minor to major significance, although wide range of uncertainty
Reduction in sewage litter								
Visual effect							This is considered within the stated preference survey and therefore is not included within this study	
Abstraction	Qualitative assessment						Includes effects on maintenance expenditure	Potential market benefit for small number of abstractors Minor significance
Navigation	Qualitative assessment							No significant effect identified
Operation of the tunnel								
Land requirements for infrastructure	Recreation	£85k	£85k	£85k	£79k	£79k	Likely to be an overestimate as assumes that all land is used for recreation	Social cost Very minor significance
	Visual effect							Limited new structures not expected to have a significant social effect
	Biodiversity							Potential negative environmental effect

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	Valuation method	Value for options					Comments	Significance
		1a	1b	1c	2a	2b		
Energy for operation	Benefit transfer of values from a combined method study based on the impact pathway approach	£0.2m-£0.5m	£0.2m-£0.5m	£0.2m-£0.5m	£0.2m-£0.5m	£0.1m-£0.3m	£0.2m-£0.5m	Not expected to be significant Environmental cost Very minor significance
Water for tunnel flushing	Qualitative assessment							Not considered to be significant
Odour	Qualitative assessment							Negative social effect
Noise	Qualitative assessment							Not expected to be significant Negative social effect Not considered to be significant
Treatment and disposal of captured sewage								
Energy for treatment	Benefit transfer of values from a combined method study based on the impact pathway approach	£0.3m-£0.9m	£0.2m-£0.7m	£0.3m-£0.9m	£0.2m-£0.5m	£0.3m-£1.0m	£0.2m-£0.5m	Environmental cost Very minor significance
Additional sewage sludge disposal	Energy from sludge	£5k-£19k	£5k-£19k	£5k-£19k	£4k-£15k	£4k-£15k	£4k-£15k	Potential environmental benefit Very minor significance Does not include market benefits that are reflected in the financial cost estimates Benefit reflects lower emissions from biomass compared to average UK electricity generation mix of fuels

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	Valuation method	Value for options				Comments	Significance	
		1a	1b	1c	2a			2b
Transport of ash	Benefits transfer of values from a European study of external costs of freight transport	£4k	£4k	£4k	£3k	£3k	£3k	Environmental cost Very minor significance
Disposal of ash	Benefits transfer of external costs of landfill	£2k-£3k	£2k-£3k	£2k-£3k	£2k	£2k	£2k	Environmental cost Very minor significance
								Reflects disamenity value of landfill Does not include other external costs of landfill Range of uncertainty is equivalent for all options

Table 3.4 Summary of carbon dioxide emissions

Issue	Section	Carbon dioxide emissions (tonnes)					
		1a	1b	1c	2a	2b	2c
Embodied energy	Section 2.1.1	590,202	515,968	601,298	397,232	327,981	362,665
Energy for tunnel boring	Section 2.2.3	181,126	181,048	183,849	124,539	124,480	130,927
Carbon dioxide emissions (tonnes per year)							
Energy for tunnel pumping	Section 3.4.2	6,318	6,549	6,318	5,458	3,200	5,458
Energy for treatment of captured sewage	Section 3.5.1	8,437*	7,021*	8,437*	4,718*	9,817*	4,718*
Energy generated	Section 3.5.2	< -256#	< -256#	< -256#	< -205#	< -205#	< -205#

* These figures assume zero carbon dioxide emissions on 20% of the energy requirement

These figures are maximum savings assuming zero carbon dioxide emissions from energy from biomass

4.3 COST BENEFIT ANALYSIS OF TUNNEL OPTIONS (NERA)

NERA took the outputs of the studies by Efec and Entec described above, together with the costs of the engineering options derived by the solutions group given in Table 3.5 below, and undertook a costs benefit analysis.

Table 3.5 Financial Costs by Option (NERA, 2006)

Option	Financial Costs: Capex (£m)	Financial Costs: Opex (£m)
1a	2364	366
1b	2262	347
1c	2453	356
1c phased	2460	363
2a	1816	310
2b	1878	361
2c	1908	314

All figures in 2006 prices totalled over 60 years

All cost and benefit figures were monetised over a 60 year time horizon. Changes in prices were allowed for, where these might be expected to be different from general inflation, and adjustments made where appropriate to make the costs and benefits comparable. The Green Book recommended discount rate of 3.5% real per year for the first thirty years and declining thereafter was used to produce the comparative figures of Net Present Value and Benefit Cost Ratio shown in Table 3.6 below.

Table 3.6 Cost Benefit Measures by Option (NERA 2006)

Option	Benefits jurisdiction (All England ¹ households)				Administrative jurisdiction (TW customer households)			
	NPV (£ million)	NPV Rank	Benefit/Cost ratio	Benefit/Cost ratio rank	NPV (£ million)	NPV Rank	Benefit/Cost ratio	Benefit/Cost ratio rank
1a	2,009	1	2.04	1	-423	1	0.78	1
1b	14	4	1.01	4	-980	7	0.47	4
1c ²	1970	2	2.00	2	-463	2	0.76	2
1c phased ²	1882	3	1.92	3	-550	3	0.73	3
2a	-447	5	0.69	5	-826	4	0.42	5
2b	-502	6	0.66	6	-881	5	0.41	6
2c	-516	7	0.66	7	-895	6	0.40	7

All figures in 2006 prices

¹This benefits jurisdiction differs across each of the options for which willingness to pay has been estimated: for Option (1), and by implication Option 1c and Option 1c (phased), this refers to all households in England; for Option 1b this refers to all households within a 260 mile radius of the Thames, and for Option 2 refers to all households within a 170 mile radius of the Thames.

²1c does not include any Olympic related benefit estimate in this table

None of the options have a positive NPV for the administrative jurisdiction. However as noted by NERA, 'a full cost benefits analysis takes account of all benefits, whoever receives them', hence it is appropriate to consider the benefits jurisdiction. This does not imply that an intervention should go ahead if it passes a cost benefit test on this basis since other

considerations outside the scope of this work, such as distributional impacts, will come to bear in making that decision.

For the benefits jurisdiction, four variants of option 1 (a, b, c and c phased) have a positive NPV and are cost beneficial. Options 1a and 1c are almost indistinguishable on cost benefit grounds and option 1c(phased) is also fairly close with an NPV figure within 10%. These three highest ranking options (in cost benefit terms) are ranked the same under each benefits jurisdiction.

Switching analysis was also undertaken. For the benefits jurisdiction, for the three highest ranking options, costs would have to approximately double relative to the benefits for the NPV to fall to zero. Conversely, benefits for these options would have to fall by approximately half for them to cease to be cost-beneficial.

A number of sensitivity tests were applied to these results, including changes to the time horizon, financial costs, monetised non-financial costs, financial benefits, non-financial benefits and the assumed cost of private financing. Although both a poor outturn on costs or an alternative view of the status of the WTP benefits could reduce the NPVs or cost-benefit ratios, only one of the sensitivity tests alters the rankings of options significantly. This exception occurs when a higher willingness to pay to reduce the likelihood of a CSO discharge in time for the Olympics is applied. This leads to a significantly higher NPV (£4138m) and cost benefit ratio (3.02) for option 1c (phased) than for options 1a and 1c (applied to the benefits jurisdiction). However this conclusion must be treated with an element of caution because the median WTP for this option was zero showing that if extra spending for the Olympics option had come up as a referendum, half the sample would have stated zero WTP. Further, the statistical validity of the Olympics WTP has not been explored in sufficient detail as yet because of time constraints.

These sensitivity tests were also presented as two scenarios to illustrate the effects of the different factors in combination. Scenario 1 included those factors that tended to reduce the NPV and cost benefit ratios. Scenario 2 included those factors that tended to increase the NPVs and cost benefit ratios. Again, although the tests demonstrated that the value of the NPV and cost benefit ratios could change, neither changed the rankings of the options.

5 RESIDUAL UNCERTAINTIES

The Cost Benefit working group are united in their view that the studies undertaken as part of this project are of a high professional standard. However there are a number of features of the methodologies adopted that should be appreciated when interpreting the results presented here. Several of these were investigated through the sensitivity tests undertaken by NERA (2006). There are some disagreements between members of the working group about the implications of these uncertainties and these are noted where appropriate.

5.1.1 Would a more realistic representation of other choices/priorities in the survey have reduced the estimated benefits?

Water companies have recently begun to evaluate customers' willingness to pay for service improvements through an approach which asks respondents to provide valuations in the context of the full range of services (e.g. leakage reduction, drinking water quality, river water quality etc) that they provide. This allows respondents to trade off between various services and there is some evidence in the literature that the value of benefits elicited from such surveys when summed over all services valued is lower than would have been the case if all services had been valued separately. Hence it is possible that the WTP elicited from a survey that focuses on a single issue – as is the case here – might be higher than the same WTP elicited from a survey that places the Tideway issue in the context of other choices facing water customers (such as, for example, security of supply). Further, concerns were expressed within the CB working group that the risk of overvaluation would be greater for non-Thames Water customers as for them the valuation question would open up issues of transfers across company boundaries, so that the major investment options of both their own water company and those of other companies would form the logical choice set.

However, it is difficult in such wide-ranging surveys to give respondents sufficient information on the environmental benefits in question to enable them to be considered on an equal footing with more tangible water services. There is concern that environmental benefits will be under-represented and under-valued. So while such approaches are useful in informing water company planning they might be less appropriate for informing environmental policy decisions.

Thames Water is undertaking a survey of all its services for PR09 but such studies are complex to test and design and therefore it was not possible to produce any results of this type in the timescale of the current study. Instead the working group took the decision to commission a study to evaluate the single issue of improvements to the quality of the Tideway and build into the questionnaire specific reminders to the respondents that they should consider their WTP in the context of other water service improvements that would cause their water bills to rise. It is not possible to evaluate how effective these prompts were in leading towards more considered WTP responses. If ineffective it is expected that the results of the survey would represent an upper bound to respondent's valuations. It is probably more likely that the prompts had some effect leading to responses that were neither as a low as a mixed service survey nor as high as a single issue survey might be expected to yield.

5.1.2 Given that the environmental outcomes are uncertain do the benefits overstate respondents' willingness to pay for them?

The environmental impacts of the alternative solutions are themselves uncertain and generated through a combination of expert knowledge and mathematical modelling. The valuation of the impacts is based on the best information available at the time of the study. The wording used in the questionnaire was developed to try and convey these impacts in an

unbiased way and presented the uncertainty in our knowledge so that it would be taken into account when respondents gave their valuations.

5.1.3 Would the use of alternative aggregation procedures alter the results?

The application of the distance decay function has a significant impact on the aggregate WTP, giving a much lower value than the sample means. This is considered to be the correct way of estimating benefits. Using an alternative aggregation (the sample mean) would reduce benefits but would ignore costs and benefits which are pertinent to the decision at hand. The time constraints associated with this study entail that those implications could not be fully explored. Concerns were expressed within the CB working group about the robustness of aggregation through the derived distance decay relationships, due to both their extension beyond the TW supply area and the fact that the distance decay functions derived for the TW and non TW customers separately were not statistically significant. However, these sub-sample functions have coefficients that are in the same direction (negative for distance and positive for higher socio-economic groups) and similar in magnitude to the function established for the entire sample. Consequently, it was concluded that the absence of statistical significance was most likely to be due to either too few sample points or too small a sample rather than indicating an absence of a true distance decay effect.

5.1.4 Would aggregating the Olympics WTP values with a distance decay function alter the results?

In the timeframe available for this study it was not possible to derive the distance decay relationships for the Olympics WTP values. In aggregating these values the sample means have therefore been used. It would be possible to generate these relationships at a later date, if required.

5.1.5 Would a longer timeframe affect the results?

The base case assessment used an appraisal period of 60 years. A 100 year appraisal period was also tested to reflect the longevity of the principle asset (tunnel(s)). This resulted in an increase in NPVs and cost benefit ratios but left the rankings of the options and the options that were cost-beneficial unchanged.

5.1.6 Would less conservative assumptions about optimism bias affect the results?

A sensitivity test was undertaken to evaluate the effect on the results of including an upward adjustment of all construction costs (with the exception of land and resource costs) of 66% (representing the upper bound of the range of optimism bias adjustment for non-standard civil engineering projects recommended by the Treasury Green Book). This resulted in a reduction in NPVs and cost benefit ratios and option 1b moved from being cost beneficial to not. However the overall ranking of options was unchanged.

5.1.7 Would the consideration of health impacts in QALY terms alter the results?

The government Guide on Managing Risks to the Public emphasises the Quality Adjusted Life Year (QALY) as a tool for cost effectiveness analysis. Unfortunately it has not been possible to obtain a robust QALY based valuation for this study. NERA (2006) has undertaken a hypothetical calculation within their assessment which suggests an NPV of £1.5m. However they also note that this figure cannot be used as a direct cross-check with the WTP figures since there is no way of evaluating what proportion of estimated WTP is attributable to health benefits.

5.1.8 Would assumptions about the regeneration of the areas affect the results?

NERA (2006) note that the volume of discharges arising from the Abbey Mills sewage pumping station is very large and that this is discharged into a smaller tributary of the

Tideway, the River Lea. It is suggested that regeneration of this area through the Thames Gateway project may increase the importance of improvements in this area. However this is not an issue on which it is feasible to put an explicit monetary value without further study.

5.1.9 Did non-TW customers state unrealistic WTP given that they were unlikely to ever have to pay these amounts under the current regulatory regime?

There was no evidence from the survey results to suggest that the non TW respondents found the survey unrealistic. Also, once distance from the tidal Thames was accounted for in the analysis, the results demonstrated that being a TW or other water company customer was not a significant determinant of WTP.

5.1.10 Did the order in which the options were presented to respondents affect their WTP?

In theory this should not affect respondents' WTP but cognitively it may give rise to an ordering/information provision effect for the option ordering combinations. To eliminate any cognitive bias the order in which the options were presented to respondents was varied and the responses averaged from those given when a particular option was asked first and second.

6 REFERENCES

Eftec (2006) Thames Tideway Stated Preference Survey
Entec (2006) Environmental costs and market benefits of reducing combined sewer overflows
NERA (2006) Thames Tideway Cost Benefit Analysis

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