Ofwat

Water Framework Directive – Economic Analysis of Water Industry Costs

Final Report

Report co-funded by Ofwat and Defra as a contribution to the Collaborative Research Programme

ARUP

In association with Oxera

Ofwat

Water Framework Directive
Economic Analysis of Water Industry Costs

Final Report

November 2005

This report takes into account the particular instructions and requirements of our client. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Ove Arup & Partners Ltd
St James's Buildings, Oxford Street, Manchester M1 6EL
Tel +44 (0)161 228 2331 Fax +44 (0)161 236 1057
www.arup.com

In association with:
Oxera Consulting Ltd
Park Central, 40/41 Park End Street, Oxford OX1 1JD, UK
Tel: +44 (0) 1865 253 000 Fax: +44 (0) 1865 251 172
www.oxera.com

Job number 116954

CONTENTS

APPENDIX C
Questionnaire Results

APPENDIX D
Workshop Feedback

APPENDIX E
Interim Report Consultation Questions

APPENDIX F
Interim Report Consultation Responses

GLOSSARY

AISC	average incremental social cost
AMP4	Asset Management Plan 4 (the period between price determinations from 2005 to 2010)
ASP	activated sludge plant
BNR	biological nutrient removal
BOD	biochemical oxygen demand
capex	capital expenditure
CBA	cost-benefit analysis
CCL	Climate Change Levy
CEA	Cost Effectiveness Analysis
CRP	Collaborative Research Programme
CSO	combined sewer overflow
DEFRA	Department of Environment, Food and Rural Affairs
DETR	Department for the Environment, Transport and the Regions
EA	Environment Agency
EAC	equivalent annual cost
EU ETS	EU Emissions Trading Scheme
FDC	fully distributed cost
LRMC	long run marginal cost
metal consent	A 'metal consent' is a limit on the concentration or mass of metals (iron, aluminium) that may be discharged from a WWTW
Ml	megalitre
N	nitrate
NPC/V	net present cost/value
Ofwat	Office of Water Services
OPA	overall performance assessment
opex	operating expenditure
other quality drivers	in relation to wastewater treatment, 'other quality drivers' include nitrate or ammonia, suspended solids, oxygen demand, pesticides or similar, and colour
P	phosphorus
PE	population equivalent
PR04	periodic review 2004 (price determination process by Ofwat) applying from 2005 to 2010

PV	present value
RBD	River Basin District
RBMP	River Basin Management Plan
RPI	retail price index
STPP	sodium tripolyphosphate
STW	sewage treatment works
TON	total organic nitrogen
UKWIR	UK Water Industry Research Limited
UWWTD	Urban Wastewater Treatment Directive
VFA	volatile fatty acid
WFD	Water Framework Directive
WTP	willingness to pay
WWTW	wastewater treatment works

SUMMARY

A requirement of the Water Framework Directive (WFD) is that the cost effectiveness of potential measures to achieve the required standards should be assessed. To assist Ofwat, Arup, with Oxera, were appointed to develop a methodology to assess the costs of measures that might be taken by the water industry. These costs could be used in comparison with the costs of measures in other sectors.

The scope of the study covers two likely pressures:

- reduction of point discharge of phosphorus; and
- removal (or relocation) of water abstraction licences.

It is limited to the financial costs placed on water companies and by implication their customers.[1] It does not indicate what is and what is not cost effective or disproportionately costly.

The project has been undertaken in consultation with the water industry, whose representatives have responded to questionnaires, attended a workshop and provided additional information for the cost function analysis.

We are grateful for the positive participation of the water industry throughout this project and for the feedback and assistance provided by other contributors, including Ofwat, DEFRA, the Environment Agency (EA), WaterVoice (now the Consumer Council for Water) and Water UK.

Phosphorus removal

Work carried out by water companies

Capital investment in phosphorus removal has been undertaken widely since 1995. Companies therefore have a thorough understanding of the technologies used and their costs. Some companies also considered the wider environmental and catchment implications of their investments.

Type of improvements required

At present, the likely programme of phosphorus removal beyond 2010 is not known. The EA has identified areas at risk of phosphorous pollution, which indicates that many areas will be subject to measures to reduce pollution. Water companies believe that designation by the EA of new Sensitive Areas under the UWWTD will have significant implications for future investment in phosphorus removal.

Assessment of information already collated by Ofwat

The project team has made use of the information provided to Ofwat by water companies in their regulatory submissions (annual returns and Price Reviews). This has been supplemented with additional information from companies and the EA. Broadly, information sources appear reasonable and sufficient for future forecasting purposes, although some limited modification to Ofwat's current information requirements may be required to make clear the type of treatment process.

Cost functions for future phosphate standards

For this study, we considered a generic process model with three primary methods for phosphate removal by water companies: chemical dosing, chemical dosing plus tertiary treatment, and biological processes.

[1] By implication any environmental, resource or social costs that are reflected in the costs of running the water business that are internalised are reflected in the financial costs.

In practice, the most cost effective solution at a particular site is determined by a wide variety of factors, such as the current process technology, effluent standard and sewage chemistry. Water companies identified the potential limitations of these models, as they are based upon current phosphate standards of between 1 and 2 mg/l. Future technologies required to meet tighter consents would potentially need a step change in capital and operating costs. Current processes such as activated sludge plant (ASP's) have not been extensively used in the UK for phosphorus removal, so sources of cost information were more limited for this technology. Outputs from the cost function analysis are presented later in this summary.

Potential technology synergies

We attempted to elicit information from companies on synergies between processes, particularly in relation to joint nitrate and phosphate removal. There are currently very few cases where both nitrate and phosphate consents are applied in the UK. Water companies believed that synergies may be possible, but that these would probably be site-specific.

Water abstraction

Water resources methodology

In the Interim Report, it was proposed that current long run marginal cost (LRMC) information might be a suitable proxy for assessing the effects of reducing water abstraction. Feedback from a number of companies and Water UK suggested that there were limitations to this approach. An alternative methodology has therefore been proposed, which is based on the assessment of the costs of meeting a likely abstraction reduction scenario.

Following interest shown by companies, Ofwat wrote to companies in May 2005 asking them to take part in an exercise that would provide examples of estimations of the unit costs of re-allocating abstractions.

Ofwat received replies from two companies. One company gave figures for both an individual resource zone and for the company as a whole. In the individual zone, they forecast that the WFD would reduce deployable output by 5Ml/d from 2011-12. For the company as a whole, they predicted a reduction in their deployable output of 50Ml/d.

The estimates for the zone and for the company overall differ, with lower unit costs for the whole company than for the individual resource zone. The difference is considerable: 27p per m3 for the company's whole area, as opposed to 126p per m3 for the individual resource zone.

A second company provided a cost breakdown for the four financial years from 2002-03 to 2005-06. However, we assessed that these estimates would not be usable in assessing the costs of water abstraction relocation in 2010.

Now that a methodology has been identified and reviewed by the industry, Ofwat will endeavour in the next few months to collate information from companies to elicit cost estimates that are suitable for use in the national Cost Effectiveness Analysis in 2006.

Water industry comments

In response to our consultation, the water industry has raised the following issues:

- a perceived need to understand the sources of phosphate in the environment in more detail;
- the impact of tighter controls on future technologies and costs is uncertain;
- ensure that the appraisal considers all indirect costs and impacts in the environment (e.g. sludge treatment and disposal);
- look at more strategic (and sustainable) controls such as product reformulation;

- long term availability (and sustainability) of chemicals (particularly ferric salts) for phosphate removal; and
- water resources cost estimates should be based on site-specific information, not LRMC.

Phosphate removal cost estimates

Unit cost models were produced by Ofwat for chemical dosing and ASP processes, based on information provided by water companies (on both a regulatory basis and a voluntary basis as part of this study). Additional information was supplied by the EA.

The model estimates the cost per unit weight of phosphorus removed (£/kgP), for a range of plant types and sizes. The costs are quoted in a range and as an average representing the range of estimates obtained from the sample or the confidence limits in coefficients obtained from regression analysis.

The costs in the tables are presented at 2004 prices.

Unit cost of load removed (£/kgP), chemical dosing

	No metal consent			Metal consent		
	2.5% lower bound	Mean	2.5% Upper bound	2.5% lower bound	Mean	2.5% Upper bound
Stringent standard (just < 1 mg/l)						
Very small works (PE<2000)	76	93	114	127	146	169
Small/medium works (2000<PE<10000)	32	38	46	53	60	69
Medium/large works (10000<PE<80000)	13	15	19	21	24	28
Large works (PE>80000)	3	4	5	5	6	8
Medium consent (1mg/l)						
Very small works (PE<2000)	57	67	78	95	105	117
Small/medium works (2000<PE<10000)	24	27	31	40	43	47
Medium/large works (10000<PE<80000)	10	11	13	15	17	20
Large works (PE>80000)	2	3	3	4	4	5
Less stringent consent (2mg/l)						
Very small works (PE<2000)	31	35	41	48	56	64
Small/medium works (2000<PE<10000)	13	15	16	20	23	26
Medium/large works (10000<PE<80000)	5	6	7	8	9	11
Large works (PE>80000)	1	1	2	2	2	3

Source: Ofwat analysis

Unit cost of load removed (£/kgP), biological solutions

	Minimum	Mean	Maximum
Small/medium	16	46	112
Medium/large	8	11	14

Source: Ofwat analysis

1. INTRODUCTION

According to DEFRA,[2] the Water Framework Directive (WFD) is:

'*the most substantial piece of EC water legislation to date. It requires all inland and coastal waters to reach 'good water status' by 2015. It will do this by establishing a river basin district structure within which demanding environmental objectives will be set, including ecological targets for surface waters*.'

The measures required to attain 'good water status' are yet to be fully developed; however, for the water sector in the UK, these are likely to include reducing the impacts from pollutants such as:

- nitrates;
- phosphates; and
- priority substances.

In addition, pressures on 'good water status' will arise from water abstraction (for drinking water, industrial use, irrigation) and hydromorphology.

The WFD requires assessment of the cost effectiveness of measures to achieve the environmental standards. To assist Ofwat in their contribution to the Collaborative Research Programme (CRP) being coordinated by DEFRA, Arup, with Oxera, were appointed to develop a methodology to assess the costs of water industry measures under the WFD.

Ofwat conducted all the cost modelling in this report, under guidance from Oxera.

This project concentrated on two likely pressures:

- reduction of point discharge of phosphorus; and
- reduction in water abstraction.

The project has been undertaken in close consultation with the water industry, whose representatives have responded to questionnaires, attended a workshop and provided additional information for the cost function analysis.

We are grateful for the positive participation of the water industry throughout this project and for the feedback and assistance provided by other contributors, including Ofwat, DEFRA, the Environment Agency (EA), WaterVoice (now Consumer Council for Water) and Water UK.

1.1 Collaborative Research Programme

DEFRA, the Scottish Executive, Welsh Assembly Government and the Department of the Environment Northern Ireland have policy responsibility for the implementation of the WFD in the UK. Much of the implementation work will be undertaken by the Competent Authorities – in England and Wales, this is the EA.

Article 5 of the Directive requires the following to be carried out for each river basin district:

- an analysis of its characteristics;
- a review of the impact of human activity; and
- an economic analysis of water use.

This work has been done in accordance with the technical requirements of Annexes II and III of the Directive. The EA have undertaken the analysis of river basins' characteristics and reviewed the impacts of human activity.

[2] http://www.defra.gov.uk/environment/water/wfd/

DEFRA and the Welsh Assembly Government, as appropriate, have undertaken the economic analysis of water use. All this work must be reviewed and updated as the Directive requires but the current results are summarised in the Article 5 reports on the DEFRA website: (http://www.defra.gov.uk/environment/water/wfd/article5/index.htm).

A CRP '*Assessing Costs and Benefits of Options in River Basin Management for Implementing the Water Framework Directive*' has been established for research for the post-Article 5 work on the economic analysis for the WFD. A major work programme has been started and will run until 2008, eventually providing the tools necessary for the economic analysis for River Basin Management Plans (RBMP's).

The CRP has six sequential projects. The specific one to which this Ofwat project relates is Project 2: '*Developing Methodologies to Assess Costs and Economic Impacts Even Handedly for the Main Types of Measures'*.

Project 2 examines the economic costs of measures, and includes:

- Project 2a – to determine the approach to assessing effectiveness within the Cost Effectiveness Analysis (CEA); and
- Project 2b – to develop a methodology for assessing costs and economic impacts and the overall cost effectiveness.

The output from this project is most directly relevant to Project 2b.

1.2 The Ofwat project

Ofwat will review water industry measures in the areas of water quantity and wastewater treatment and disposal. This report to Ofwat presents a methodology for assessing the costs associated with measures for phosphate removal and reduced water abstraction.

Ofwat has indicated that the cost information within this study will contribute to the high-level assessment of cost effectiveness in 2006. This will inform the overall approach to delivering the desired environmental objectives. It will enable resources to be focused on those measures more likely to be cost effective at a generic level.

Ofwat envisages that this will not pre-empt the decisions at catchment- or site-specific level when the draft RBMP's and their associated draft programmes of measures are drawn up in 2008. At this stage, Ofwat anticipates that companies will be asked to produce cost estimates on site-specific measures.

1.3 Consultation with water companies

Water companies have provided inputs to this project through the following activities:

- answering a questionnaire on phosphate removal;
- participating in a workshop on modelling phosphate removal (1 March 2005);
- providing written feedback on phosphate removal options and on the costs of removing abstraction licences;
- providing missing data for phosphate modelling; and
- providing data on the costs of abstraction licence removal in specific areas/zones (ongoing work by the water companies).

Communication with water companies has been undertaken via Ofwat. Appendices B to F present the summary and results of these activities.

1.4 Links with DEFRA CRP project

A number of meetings have been held with representatives of Project 2 teams, the EA and DEFRA, which have included:

• DEFRA CRP Workshop	30 November 2004
• Ofwat and Project 2 meeting	7 December 2005
• Water industry workshop	1 March 2005
• Interim Report circulation	14 April 2005
• Preliminary Costs Shared with Project 2 Consultants	8 June 2005

Primarily, interfaces with Project 2 have related to ensuring consistency over the units to be used in the analysis.

Consultation with the EA characterisation team

The project team consulted with the EA characterisation team to understand the likely improvements that companies will be required to deliver after 2010.

It is likely that further studies will be needed following on from this study into areas of concern highlighted by the water industry.

2. PHOSPHATE IN THE ENVIRONMENT

2.1 Impact of phosphates on the environment

Phosphorus is an essential element for all living organisms. In people, phosphorous compounds make up the structure of bones and teeth and are fundamental to the transfer of energy within cells.

In plants, phosphorus plays an essential role in photosynthesis and all energy-recovering processes. Phosphates are also one of the main nutrients in almost all agricultural and garden fertilisers, because they are crucial for plant growth. It is because phosphates contribute to plant growth that, in certain circumstances, their release into surface waters may result in environmental problems.

Excess levels of nutrients in water contribute to the process known as eutrophication, which can lead to excessive growth of algae and water plants. In freshwater systems, phosphates are considered the main nutrients limiting the rate of plant growth. Some plant species are able to thrive in high nutrient concentrations, growing rapidly and becoming dominant, thereby changing the structure of river and lake margin plant communities.

In lakes and coastal waters, free-floating microscopic algae can take advantage of the increase in nutrient supply and multiply to such an extent that visible blooms can form.

Eutrophication of a water body has an impact on a wide variety of amenity uses such as fisheries, navigation, water sports and angling, and can impair its use as a drinking water resource. The presence of algal blooms can prevent the use of a water body for livestock watering and irrigation and they can clog water filters at treatment works.

The EA state[3] that phosphate concentrations above 0.2 mgP/l in rivers and 0.085 mg P/l in lakes can cause environmental problems in freshwaters. Even a slight change in the concentration of phosphates can have significant environmental consequences.

In general, rivers flowing through areas dominated by arable farming tend to have greater concentrations of phosphorus than similar lowland areas dominated by livestock farming. DEFRA reported[4] that in 2001, 35% of rivers in England and Wales were classified as having low or very low concentrations of phosphorus (<0.06 mgP/l), while 38% had levels greater than 0.2 mgP/l (very high or excessively high). A study of 129 lakes in England and Wales reported that 69% of lakes have total concentrations greater than 0.1 mgP/l. This suggests that the majority of lakes in England and Wales are affected by nutrient pollution.

Discharges of phosphorus to UK coastal water have reduced by approximately 30% since 1990,[5] reflecting improvements in sewage treatment and a switch to phosphate-free detergents. Inputs to rivers, however, which reflect both diffuse and point sources, appear to have increased.

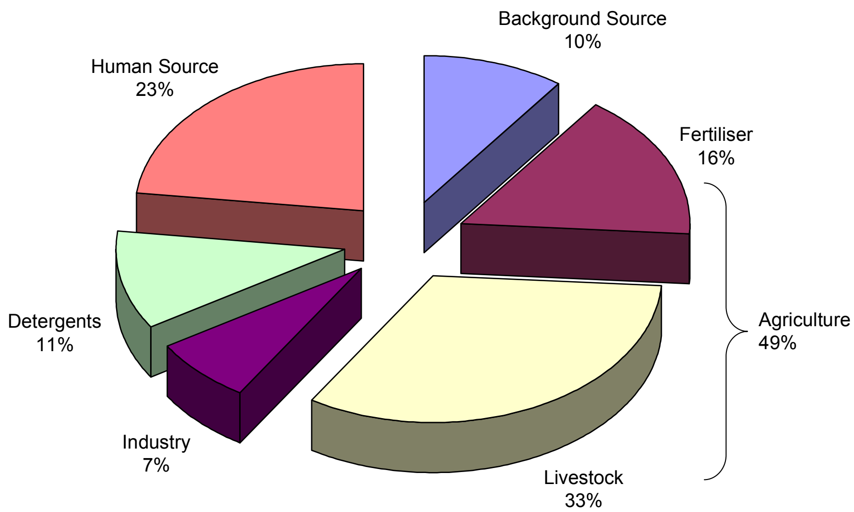
2.2 Source of phosphates

The phosphates entering rivers and lakes come from many sources. The main source of release into the environment is from anthropogenic sources, particularly from fertilisers from agricultural land and cleaning detergents containing phosphates. Other sources include sewage, food processing waste, and paper manufacturing.

[3] www.environment-agency.gov.uk
[4] www.defra.gov.uk
[5] DEFRA (2004) Mapping the Problem, Risks of Diffuse Water Pollution from Agriculture

Detergents contribute approximately 11% of total phosphate input to European surface waters, with 23% coming from human sewage, 49% from agriculture, 7% from industry and 10% from natural bedrock erosion (see Figure 1). This corresponds with the views of DEFRA, who suggest that 40-50% of phosphate input arises from agriculture.

Figure 1 Sources of phosphate



Source: Morse G K, Lester J N and Perry R (1993) The Economic and Environmental Impact of Phosphorus Removal from Wastewater in the European Community

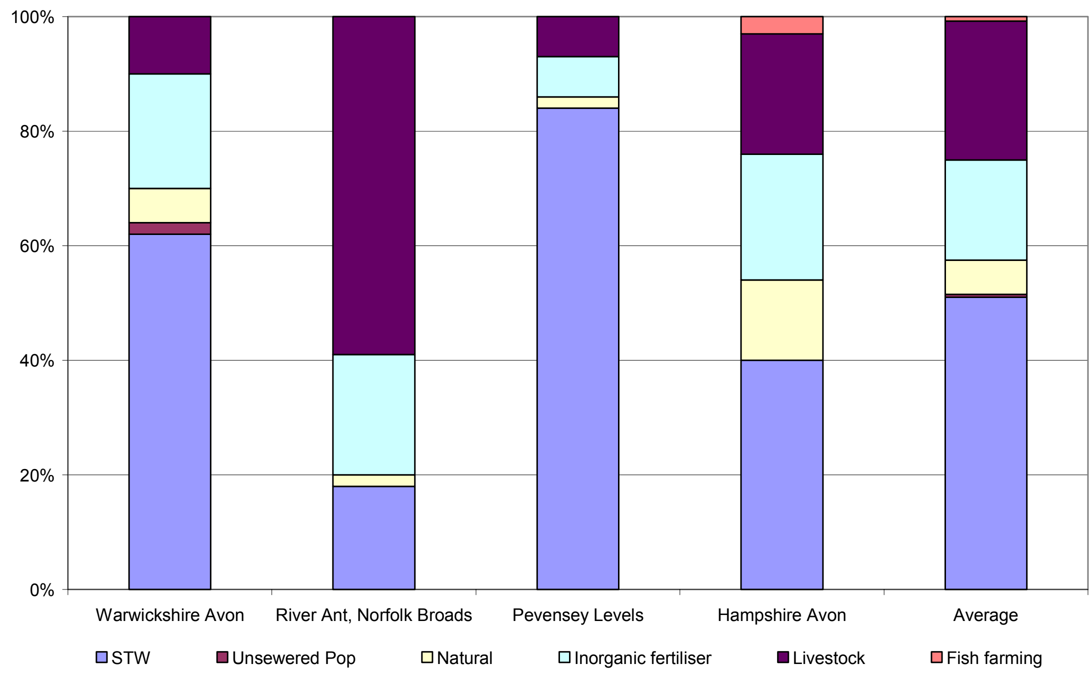
The sources of phosphate can vary significantly between catchments. The 2002 DEFRA report provided a summary of the phosphate contribution in four catchments, spanning the period 1994 to 1998 (although this may have changed since 1998 due to additional investment by the water companies). These are summarised and presented in Figure 2.

A more current estimate of the contribution of non-point source phosphorus load was provided by Macleod and Haygarth (2003),[6] which summarised data from two river catchments – Thame (Aylesbury) and Kennett (Southeast England).

	Non Point Source	Point Source
Thame	15%	85%
Thame – post P-stripping	36-53%	47-64%
Kennett	2%	98%
Kennett – post tertiary treatment	29-45%	55-71%

[6] Macleod C. and Haygart P. (2003) A Review of the Significance of Non-point Source Agricultural Phosphorus to Surface Water. Institute of Grassland and Environmental Research (IGER), pp 1-9.

Figure 2 Sources of phosphate



Source: DEFRA (2002), Directing the flow. Priorities for future water policy

The European Commission Health and Consumer Protection Directorate (Scientific Committee on Toxicity, Ecotoxicity and the Environment) reported in November 2002 on a WRc study (WRc (2002) Phosphates and alternative detergent builders, Report UC 4011), which highlighted that the amount of phosphorus in wastewater that can be attributed to detergents (where no actions for reducing sodium tripolyphosphate, STPP, in phosphate containing detergents were undertaken) is as high as 40%.

On a European average basis, the following ranges of contribution were stated:

Point Sources	50-75%
Agriculture	20-40%
Natural loading	5-15%

Clearly there is a wide variation in phosphate loading at a catchment level, which suggests that catchment-specific analysis will be required for the final CEA.

The WFD sets out a river basin management planning process. For each river basin district (RBD) a river basin management plan (RBMP) will be prepared, implemented and reviewed on a six year cycle. River Basin Characterisation required by Article 5 of the Directive is an important early part of this process which for each RBD, requires the following:

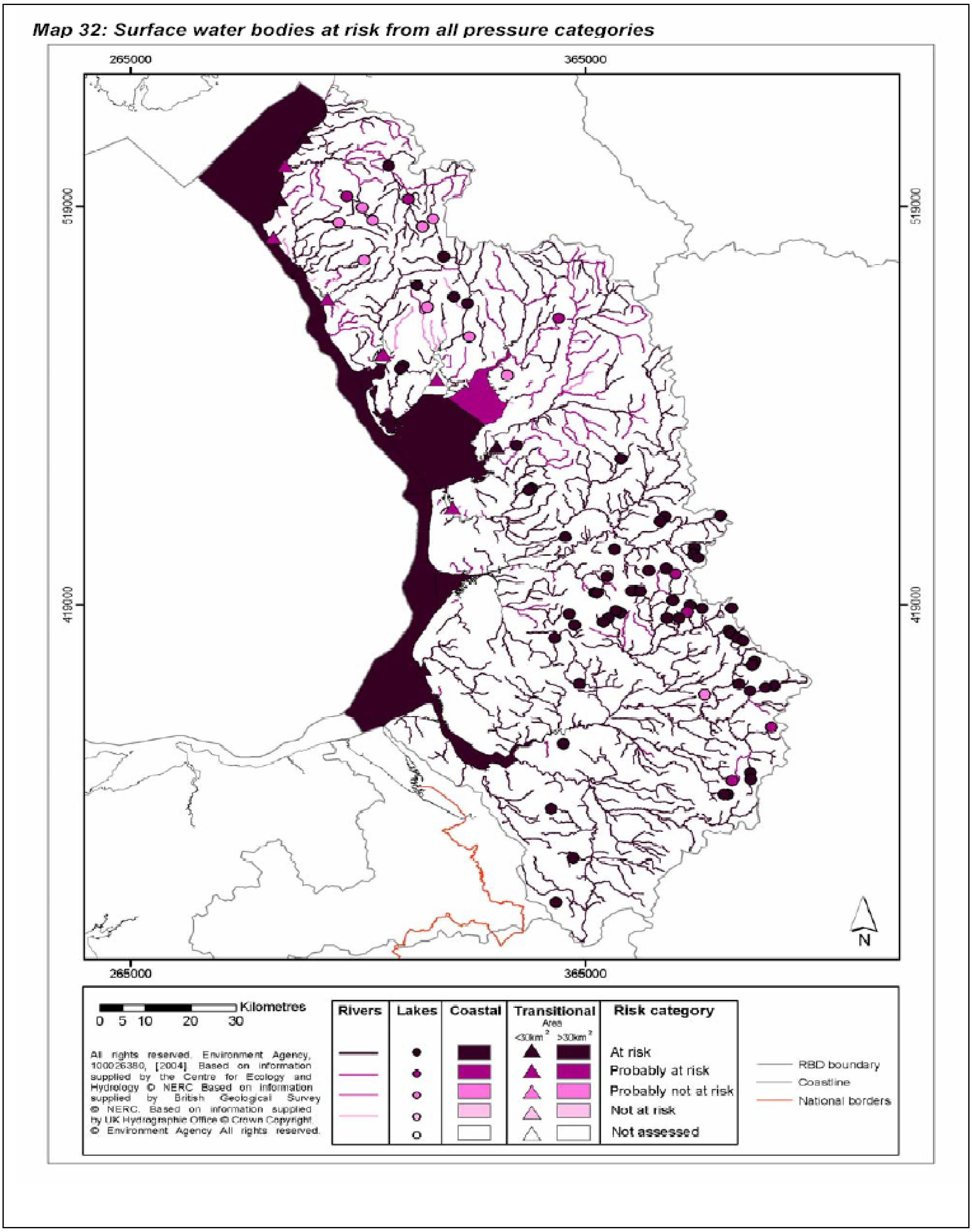
- an analysis of its characteristics;
- a review of the impact of human activity on the status of the water bodies within the RBD; and
- an economic analysis of water use.

Reports summarising, for each RBD, the analysis required by Article 5 of the Directive have now been reported by DEFRA (on behalf of the UK) to the European Commission as required by the Directive.

For each RBD, a characterisation and impact assessment has been undertaken, examining the types of water bodies, their use, assessment of current quality, pressures impacting upon them and an indication of the water bodies at risk. As an example, for the North-West RBD, the following map (Figure 3) summarises the surface water bodies at risk from all pressures (point source, diffuse, etc.).

Information for other RBD's can be found at http://www.defra.gov.uk/environment/water/wfd/article5/index.htm

Figure 3 North West RBD Article 5 Analysis



The above map shows that a large proportion of the region's surface water assets are at risk.

According to the EA, rivers with the highest concentrations are mainly in central and eastern England, reflecting the geology and higher population. In 2003, around 80% of river lengths in the Thames, Anglian and Midlands regions had average phosphate concentrations greater than the guideline value of 0.1 mgP/l.

At the lower end, regions such as Wales, North-West, North-East and South-West have the lowest percentage of rivers with phosphate concentrations greater than 0.1 mg P/l.

Figure 4 - Trends in phosphate concentrations in rivers (England and Wales)

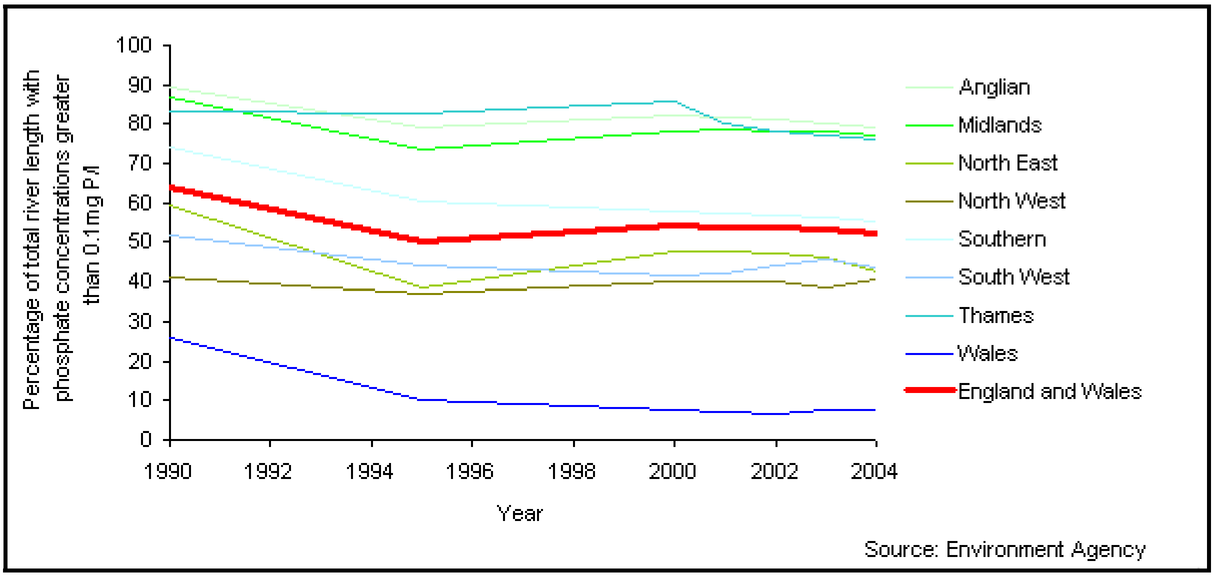


Table 1 shows the relative contribution of phosphate pollution from a number of sectors, and the following sections describe the major sources.

Table 1 Sources of phosphorus and their contribution to wastewater discharges

Phosphate source	Contribution to total phosphorus discharged
Domestic	81%
Dosing (to reduce lead in drinking water)	12%
Trade effluent	6%
Total	**100%**

Source: Comments on Interim Report by a water and sewerage company

Agriculture

Agriculture is by far the largest user of phosphate. It is one of three main plant nutrients, along with nitrogen and potassium, occurring in inorganic fertilisers.

The loss of phosphorus from agricultural land occurs mainly via overland flow and via drain flow. Phosphorus is predominantly lost in particulate form, associated with soil particles and, hence, soil erosion. The rate and amount of particulate phosphorus lost to water are affected by many factors, including the intensity and duration of rainfall, the slope of the land, the susceptibility of the soil to erosion, and the presence of subsurface pathways, such as drainage systems, and surface pathways, such as gullies, tramlines and rills.

Solubilised phosphorus is generally lost to surface waters in leachate via subsurface and drain flow and via surface runoff following rainfall.

Food and animal feed supplements

Food grade phosphates are used in many foods including dairy, meat, bakery products and soft drinks. Also, because of its high value as a nutrient, phosphate is used widely in the manufacturing of animal feed supplements.

Detergents

Until the middle of the 20th century, most domestic laundry was washed with soap-based products. In 1947, the first synthetic detergents for household use were introduced. These new products marked a major step forward in the efficiency of domestic laundry products, in terms of both hygiene and cleaning performance.

STPP is used as the base of many detergents today. The purpose of STPP is to soften water and to optimise the washing conditions for other active ingredients.

DEFRA identified trends over a period from 1998 to 2001 of declining phosphate concentrations.[7] They indicated that the decline was directly related to improvements in sewage treatment processes combined with a steady decline in phosphate-based detergents.

Future changes in detergent regulations may also have an impact on future pressures from domestic sources. From October 2005 the Detergents Regulation (2004/648/EC) will harmonise a number of rules applying to the composition, testing and labelling of detergents.

From April 2008, the European Commission must evaluate the use of phosphates in detergents, and propose legislation with a view to their gradual phase-out or restriction if necessary.[8] It is assumed that this position is the base case for the purposes of the CEA.

Other industrial applications

Apart from their role in laundry detergents, phosphates are used in dishwashing detergent formulations and in such diverse applications as metal surface treatment, corrosion inhibition, flame retardants, water treatment and ceramic production.

Water company views

Two companies have mentioned agricultural and horticultural runoff as an important source of phosphorus affecting the combined wastewater network.

As far as phosphorus load into the system is concerned, companies agree that the most important contributor is domestic use of detergents. One company has commented that the way to address this is to encourage the swapping of active ingredients in washing powders. For most companies, trade effluent of some industrial processes is a contributor but to a considerably lower degree than domestic sewage. They find that in general trade effluent has a low phosphate load.

According to one company, the main trade effluent contributors to phosphate in sewage are the following:

- food processors;
- paint stripping activities; and
- plating metal finishers.

[7] DEFRA (2004) Mapping the Problem, Risk of Diffuse Water Pollution from Agriculture
[8] www.environment-agency.gov.uk/netregs/

Comments by companies suggest that, in general, domestic sources contribute 80-95% of total phosphate loads received in sewer networks, which is around half of the total phosphate load discharged to water bodies.

3. PHOSPHATE REMOVAL

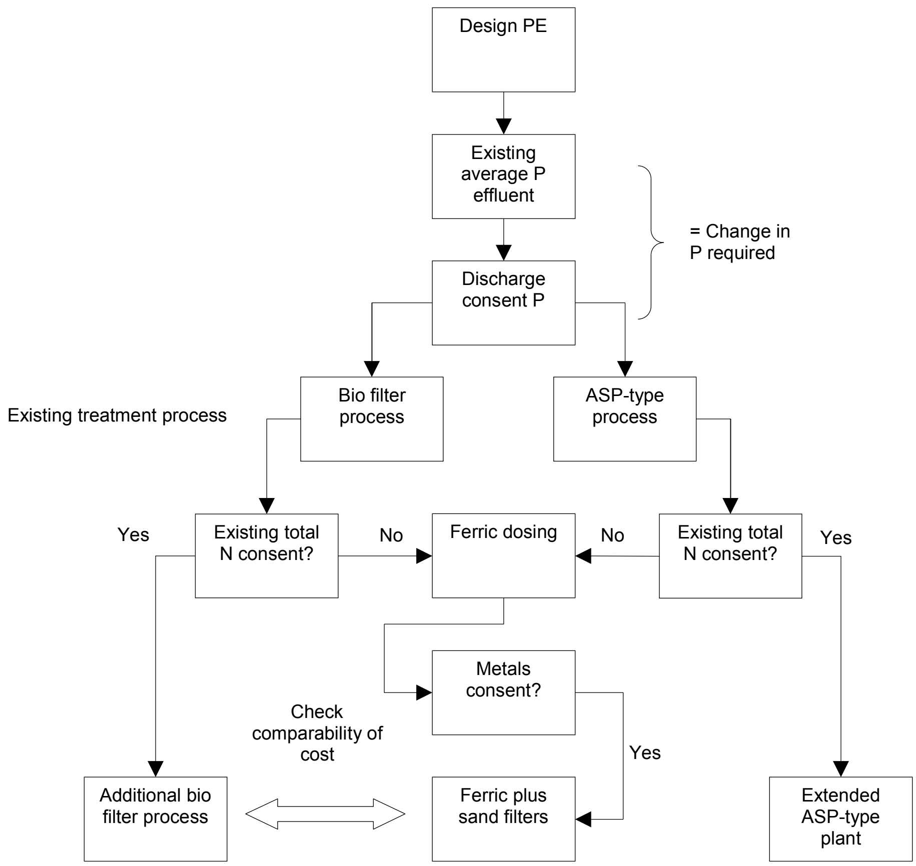
3.1 Introduction

This section reviews the main methods used for phosphorus removal, and their advantages, limitations and costs. It is primarily based on input from the project team, together with water and sewerage companies.

The technologies required for phosphate removal can be extremely complex and depend on the interaction of several site-specific factors. In order to understand the generic process for modelling purposes, Arup developed an outline decision tool, which was presented at the water industry workshop on 1 March 2005 and was subsequently included for consultation in the Interim Report.

The generic process decision flowchart is shown in Figure 5. It is important to recognise that site-specific characteristics will influence the ultimate investment decision and financial impact. The water industry is supportive of providing this site-specific information.

Figure 5 Draft process decision matrix



The intention of the flowchart was that it would be used as a guide, in conjunction with the outputs of the cost function analysis, to help those undertaking the CEA.

The flowchart was broadly accepted by the water industry as being a good generic starting point for the exercise. From later consultation, it is clear that a more detailed decision matrix would be difficult to develop, as there are a number of interrelated factors at a site level influencing the choice of process at each location.

On this basis, a more detailed process decision matrix has not been developed. However, a summary of relevant process issues raised by water companies is given below.

Table 2 Process options and constraints

Parameter	Options	Consequences
Influent phosphorus load	Average	Influent load is not the most important issue to consider when designing a new plant. Reducing load through industrial pre-treatment may cause operational problems
	High	High influent load helps meet percentage removal standards
Influent biochemical oxygen demand (BOD) load (carbon)	High	If at large site, ASP may be the solution
	Low	Supplementary carbon dosing (methanol) may be required to remove phosphorus (P) load, with secondary potential odour effects
Phosphorus standard level	Normal (>0.5 mg/l)	Current technologies applicable
	High (<0.5 mg/l)	May require new technologies to meet standards, at disproportionately higher cost
Phosphorus standard type	Annual average	ASP can be unsuitable for this consent due to seasonal variation
	Percentage	May be difficult to achieve percentage compliance in wet weather
Urban Wastewater Treatment Directive (UWWTD) designation	None	Phosphorus consents unlikely to be imposed by the EA
	Sensitive Area	The EA likely to require phosphate standards at WWTW discharges; future level unknown
Current process	Biological filter	More likely to need tertiary treatment
	ASP/biological nutrient removal	Ferric dosing more likely to be an appropriate solution, maybe with an extended ASP
Process solution	Ferric dosing	Supply constraint for chemical (rising prices) and environmental regulations. Easy to retrofit
	Ferric + tertiary treatment (sand filter)	Likely to need tertiary treatment whenever ferric dosing used to meet metals consents, which are likely to be imposed
	Bolt-on ASP	Lower capital expenditure (capex) than biological filter, higher operational expenditure (opex) Needs large site, may need external carbon source and high capex compared with biological filter
	ASP + ferric	ASP's may need some ferric dosing for trimming of process
	Extended biological filter	Stand-alone solution unlikely without ferric dosing, except at smaller works

Parameter	Options	Consequences
	Extended biological filter + ferric dosing	Most expensive (capex) solution for larger sites, needs lots of land area to build, but can be cost effective at smaller works
	Phosphate recovery	No market, difficult to remove from some sludges
	'New technology'	No companies identified any new technologies that are being developed for phosphate removal
Tertiary treatment	Required	Driven by existing process, current consent, catchment issues and compliance risk. More likely if ferric (or other metals) used.
	Not required	Unlikely if ferric (or other metals) used for phosphate removal
Chemical used	Ferric salts	Preferred, as cheaper than alternatives Supply constraint
	Aluminum salts	More expensive than ferric (capex and opex) Not preferred solution by the EA
Size of works	< 100,000 PE	For small sites, biological filters can be cost effective
	> 100,000 PE	ASP more likely solution, but needs high strength sewage
Synergies	Total organic nitrogen (TON) + P consents	May be synergies, but no marginal data Unlikely to include bio-P removal due to problem sludges Sites built to remove nitrate (N) may not remove P without further investment Costs arise from additional recycles, sludge, odour and external carbon source

It is also important to remember that most of the technologies discussed will be retrofitted to an existing treatment works. As such, the type of process currently used, its performance and any site constraints (such as land and power supply) will affect the eventual solution chosen. On a 'greenfield' site, the choices (for the same input parameters) may well be different.

For the purpose of the high-level assessment of cost effectiveness in 2006, Ofwat anticipates that the generic cost information will be sufficiently robust to enable a comparison between the costs of delivering phosphate removal by the water industry and those in other industry sectors.

However, Ofwat envisages that this will not pre-empt decisions at catchment- or site-specific level when the draft RBMP's and their associated draft programmes of measures in 2008 are drawn up. At this stage, Ofwat thinks that it will be necessary to ask companies to produce cost estimates on site-specific specified outputs/consents.

3.2 Options for reducing phosphates discharged via WWTW

Some phosphate load is discharged from combined sewer overflows (CSO's), which release untreated wastewater in times of high storm water flows.

Yorkshire Water reported that they have already undertaken some investigation in this area, which found that 15% of organic loading in the Humber Estuary arose from intermittent discharges and 17% from wastewater treatment discharges (i.e. a similar proportion from both sources).

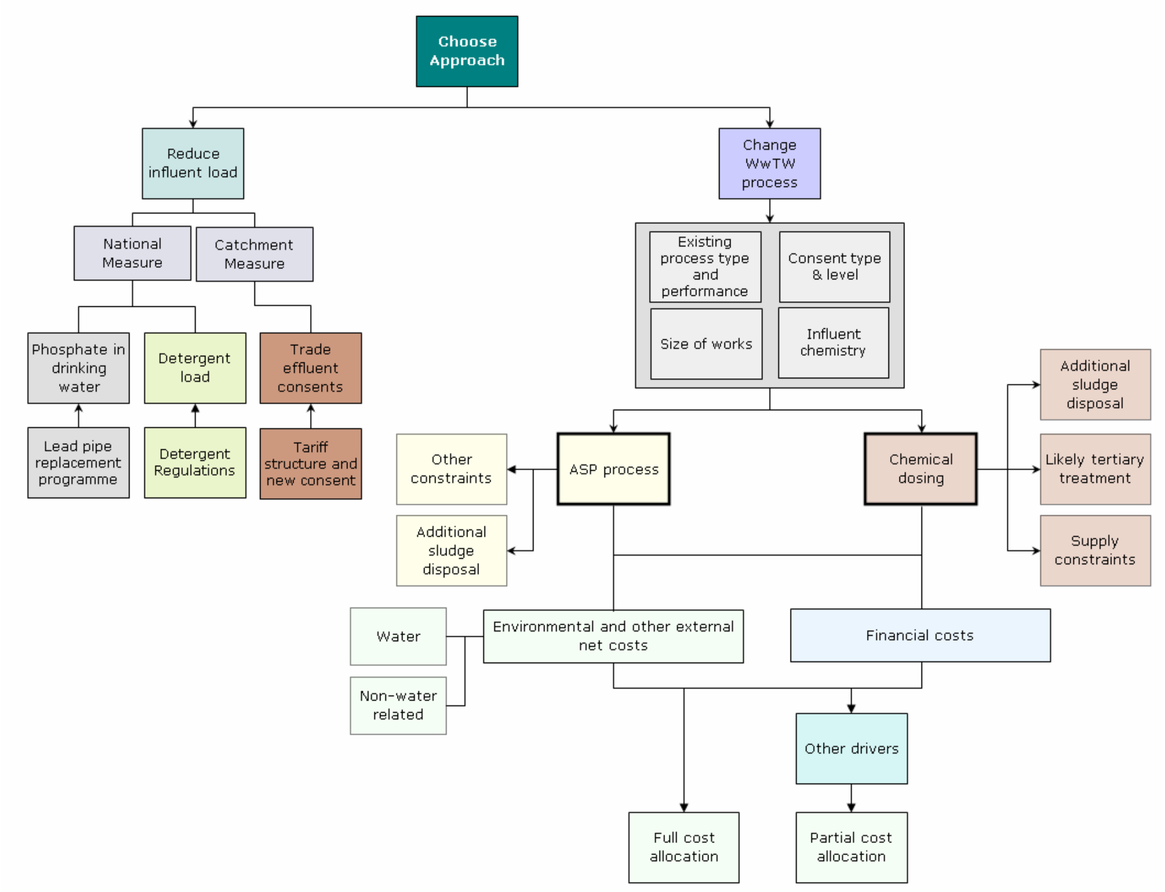
Reduction in the release of phosphates from CSO's is beyond the remit of this study; however, this is one of the measures that will require further investigation in the CRP. This future investigation will be undertaken by Ofwat.

This being the case, for the purposes of this study, there are only two ways to reduce the phosphate loading discharged from WWTW's:

- reducing the load of phosphorus received by WWTW's; and
- increasing the quantity of phosphorus removed by the WWTW's.

These two options are illustrated in Figure 6, together with some of the implications of each, which are discussed in more detail in the following sections.

Figure 6 Options to reduce phosphate



3.2.1 Reducing the load of phosphorus received by WWTW's

There are some potentially controllable sources of phosphate in the influent received by WWTW's, but these sources are mostly outside the direct control of water companies. Actions to address them involve government policy in water and in other sectors. The three most important controllable sources are:

- industrial and domestic phosphate detergent use;
- trade effluent at its industrial source; and
- drinking water dosing with phosphate.

Reduction in industrial and domestic phosphate detergent use

Phosphate is an ingredient in some detergents. In certain locations where the industrial use of detergents has been intensive, such as in textiles manufacture, detergent phosphate has been the dominant source and has had a major and highly visible effect on the environment. Changes to detergent formulations and use have been effective in the past, lowering phosphate emissions.

It may therefore be possible to reduce phosphate use in industry and domestic detergents. This option may be discussed further in other WFD studies and should be assessed before water companies are required to solve the problems, but is not explored further here because it does not involve the water industry directly.

The Team assessed that the analysis of cost implications of addressing P upstream requires a separate study and therefore in agreement with Ofwat did not explore this area further.

Reduction of drinking water dosing with phosphate

Phosphate is added to drinking water in some locations to reduce the rate at which lead in piping and solder dissolves into drinking water, where it is toxic to human health by causing long term cardiovascular and brain damage. Limits to the concentration of lead in drinking water are set out in the Drinking Water Directive, and, in many locations, phosphate dosing is the cheapest method of compliance.

Therefore a reduction in phosphate dosing of drinking water would, in many locations, necessitate much greater expenditure on lead pipe replacement and require a significant change in legislation to facilitate the statutory replacement of pipework within private households.

Ongoing research at Ofwat is looking at two case studies in order to assess the economic case for a different (faster) lead pipe replacement that would reduce the need for orthophosphate dosing. Once finalised, the results will be made available to the CRP steering group.

Greater pre-treatment of trade effluent at its industrial source

Similarly, the on-site pre-treatment of effluent by industry before its discharge to sewer, or its full treatment on site before discharge to surface waters, reduces the phosphate load conveyed to WWTW's. Pre-treatment is relatively common for large industrial installations. However, the standard tariff for charging for load discharged (the 'Mogden Formula') does not contain a component for phosphate load, and there is therefore little incentive to install a pre-treatment works to remove phosphate.

Water companies added that there is potential for reducing phosphate inputs into the sewer network by revising trade effluent consents. At present, these consents only deal with volume, BOD and Suspended Solids loads. However, revision of trade effluent consents would require modification to water company licences, specifically the Mogden Formula.

Companies were supportive of this move, which provides a step towards implementing the 'polluter pays' principle of the WFD. It will also allow more efficient removal of concentrated loads at source, promoting opportunities for recovery and use of clean technologies.

One water company noted that this could have a detrimental effect on existing treatment processes, particularly those based on percentage reductions in load (such as UWWTD consents). This could have the effect of increasing operating costs, or requiring additional, more sophisticated processes to be deployed to meet current consents.

However, this is the case for all biological processes, which rely on a delicate balance of loadings to operate efficiently.

3.2.2 Increasing the quantity of phosphorus removed by WWTW's

Current technologies

The likely solutions fall into two principal types:

- chemical precipitation (chemical dosing, usually ferric salts); and
- biological nutrient removal (BNR) process (e.g. ASP).

Chemical dosing can be carried out using either iron or aluminium salts to precipitate the phosphates as hydroxides that are recovered in the waste sludge streams.

BNR involves the use of an anaerobic section within an activated sludge process. This anaerobic process relies on the availability of a readily biodegradable carbon source for effective operation. It may be necessary to supplement the crude sewage with an external source if there is insufficient in the incoming flow.

Most sewage does not have a sufficient amount of volatile fatty acids (VFA) to provide sufficient phosphate removal and it may be necessary to develop on-site fermentation of indigenous sludges to provide the VFA source required for the BNR process. Around 12% to 25% of sludge can be converted to VFA's by fermentation. Molasses can be added to assist with fermentation. Some trade effluent products, such as waste from soft drinks manufacturing and brewery waste, can be a useful addition to the anaerobic stage of the BNR process, when available.

This technology is well proven and can be particularly relevant where the site is already subject to total nitrogen consents, as the anaerobic process can retrofit into the existing process.

Even where BNR systems are being operated, chemical dosing is often installed as either a back-up process or to provide some form of fine phosphate control.

The majority of current phosphate removal technology is based on chemical precipitation, primarily using ferric salts. Companies have identified that these are generally cheap to install and operate, and the process is easy to retrofit to existing processes.

Alternative biological processes, such as ASP's, are less common, perhaps having fewer than ten sites across England and Wales.

ASP's are generally more expensive to build and operate than basic chemical dosing, so they tend to be built only where chemical dosing is not a feasible solution. Companies with experience of ASP processes stated that they required a high organic carbon content in the influent for successful operation (e.g. from a brewery, industrial process or supplementary pre-treatment dosing).

The selection of the phosphate removal route is influenced by the following factors:

- the existing treatment process;
- the discharge consent parameters;
- the size of the treatment system;
- availability of carbon source;
- requirements for a total nitrogen consent;
- power supply availability;
- site access; and
- sludge disposal strategies.

The following paragraphs include some of the comments by companies on the different processes.

One company noted that even without specific removal processes, some proportion of the phosphate will be removed from existing treatment processes into the sludge stream. This is due to the natural take-up of nutrients by the biological treatment process. However, this natural take-up is insufficient to meet the requirements of a 1 mgP/l consent, accounting for a reduction of 1-3 mg/l of a predicted influent concentration of around 5-30 mg/l.

Two companies noted that the chemical reduction of phosphate is the preferred initial choice of treatment, as the technology is relatively easy to retrofit to existing treatment processes and is less expensive than other technologies, particularly on works with a population equivalent (PE) of less than 10,000.

Within chemical reduction, ferric dosing is most common, but, in some instances, other precipitants such as aluminium salts may be used. One company noted that aluminium dosing may be required where site-specific wastewater chemistry dictates that ferric dosing may not be effective. However, aluminium salts may be subjected to more stringent discharge consents.

One company noted that chemical dosing can often be less effective at filter works where the management of sludge and sludge liquors may allow for re-dissolving of the precipitated phosphate.

On biological processes, one company said that they had historically rarely used biological processes due to the limitation on the size of their works.

On the question of whether unit costs are constant, two companies identified that the costs of phosphate removal were not linear, but that step changes in costs occurred. This was related to the process technology used, but was also a function of business-specific approaches to managing the risk of consent failure.

Future technologies

Many companies noted at the workshop, and in subsequent responses, that the shortage of ferric chemicals was a concern, which would be likely to result in a different balance of process technologies in the future (with less reliance on purely chemical dosing). Companies thought that this problem would be exacerbated by the likely requirement under the WFD for phosphate removal, which would increase demand for the chemical.

In addition, many companies were concerned that chemical dosing is not a sustainable solution, which was already identified by their quality regulators. One company noted that metal consents would be likely to be imposed in all circumstances where ferric (or alum) dosing was implemented.

Under the Dangerous Substances Directive, iron is classified as a List 2 substance, which would require consent for discharge. The value of the consent limit would be determined by the characteristics of the receiving water course. Currently these limits are set as 'absolute' values making failure of the consent a potentially high probability.

Companies had differing opinions on whether future technologies would be different.

Assuming the same standards applied (1-2 mg/l), most thought that their current process solutions would apply. One company suggested that a mixed 'biological plus chemical dosing' process was more likely in the future. We believe that this is their response to reducing their reliance on ferric dosing, which is their current preferred solution.

One company suggested that a combined 'biological plus chemical dosing' process was expensive and would only be economic if a site rebuild was required for another driver.

They identified that this required a large site and may only be suitable to specific (high strength) sewage quality. Often, chemical dosing would be required in combination to provide added process security.

Furthermore the need for tertiary treatment to achieve suspended solids consent standards and therefore phosphorus may be required at sites where solids discharge is an issue. Phosphorus in effluent from activated sludge or biological filtration type processes will largely be in an insoluble form i.e. associated with suspended solids. Therefore, suspended solids removal to more stringent consent standards may be needed to achieve the phosphorus consent standard.

Two companies noted that if future standards were higher, new process technologies would be required, which would be more expensive than historical solutions. This has the potential to reduce the applicability of any cost models developed from previously completed schemes.

Two companies identified a related issue: a high influent P load helps to achieve percentage removal consents (such as UWWTD consents). One of these companies noted that current P load may not significantly influence the costs (in fact, high P loads make removal easier and more efficient). The other company observed that the potential for upstream industrial pre-treatment may actually increase water company costs due to the same issue (decreasing P loads makes removal more difficult).

3.2.3 Combined pressures

One company commented that even if a site rebuild were required to meet an N consent, they would be unlikely to include biological-P removal if a subsequent P consent was imposed, due to the cost of sludge treatment.

Companies only had developing (if any) experience of TON consents. There were conflicting views on whether there were any operating synergies from their combination with P consents.

One company suggested that the additional costs of TON+P consents would be:

- recycles within existing processes;
- additional tankage (additional volume of process units);
- odour control (site-specific); and
- external carbon source (e.g. potential nutrient dosing would be required).

3.3 Secondary consequences – sludge disposal

The need to carry out phosphate removal at the sewage treatment works (STW) will concentrate the phosphates into the waste sludge produced at the site. These phosphates can readily combine with other components in the sludge to produce Struvite (magnesium ammonium phosphate). The formation of this material can cause severe operational problems through blockages of pumps and pipelines.

Furthermore, to prevent the release of phosphates back into the sludge liquor streams requires careful design and operation of sludge handling systems. Digesting sludge produced from the BNR process, while not impossible, can result in around 20% of the phosphate being released for re-treatment in the main stream process. This would force the treatment system to be larger than might first be imagined.

However, Struvite-type material is rich in nutrients and, should a commercial market be developed, this treatment process may become more acceptable to the water companies.

It is anticipated biological phosphate removal will have a limited effect on the volumes of sludge produced or the disposal routes. However, the use of chemical dosing will also create precipitates of other components that might add significantly to the sludge volume and mass and could impact on the sludge disposal route.

3.4 Implications for the water industry

For the water industry, the potential implications of tightening standards for phosphate at WWTW's could be significant. The standards could be tightened in three ways:

- at locations already designated under the UWWTD;
- tightened standards under the Habitats Directive; and
- designation of new catchments as Sensitive Areas under the UWWTD.

Where standards are tightened significantly (above the 1-2 mg/l consents common today), water companies have suggested that existing treatment processes are unlikely to be suitable. This will require development of new technologies, with potentially significantly higher capex and opex than current technologies and a greater uncertainty in terms of delivery.

For areas newly designated under the UWWTD, the requirement for new capital investment will depend upon the extent of additional designation. One company identified that this requirement could be very significant (c. £500 million investment). Other companies noted that the extent of investment hinged crucially on the definitions of 'good water status'.

Three companies identified their areas at risk of significant future investment associated with tightening phosphate standards. Another company noted that historically they have completed many phosphate removal schemes. They felt that nitrate removal schemes would be a higher risk to their company in the future (primarily because they had less experience with nitrate removal than with phosphate removal).

From an investment perspective, the following issues were identified by companies as potential consequences of further designation of Sensitive Areas or tightening of existing phosphate consents:

- current treatment technologies may not be sufficient to meet more stringent standards. New technologies may be required;
- companies expect additional supply constraints on chemicals (such as ferric) currently used for phosphate removal. This may push a move towards alternative technologies; and
- phosphate removal will significantly increase the quantity and type of sludge produced, which is likely to require additional investment in sludge treatment and disposal technologies, possibly including additional incinerators.

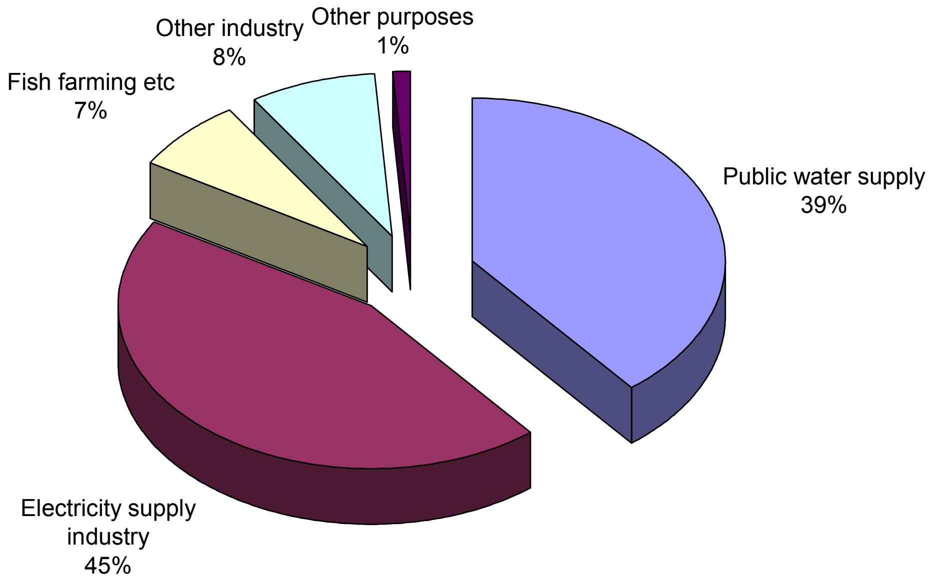
It is anticipated that designated water bodies under the UWWTD will form part of the baseline with regards to the CEA.

4. WATER ABSTRACTION

4.1 Effects of water abstraction

Water abstraction in England and Wales is undertaken primarily for public water supply and for electricity generation. In 2002, over 80% of water abstraction was used for these two purposes, as shown in Figure 7.

Figure 7 Sources of water abstraction, 2002



Source: Arup from Environment Agency data

4.2 Implications of reducing abstraction

Water companies abstract water for public consumption from two primary sources:

- surface water (rivers, lakes); and
- groundwater (underground aquifers).

At present, the EA is responsible for issuing licences for water abstraction (both surface and groundwater licences). One company said that they were not expecting licence abstraction reductions in the 2004 water periodic review (PR04) period (2005-10).

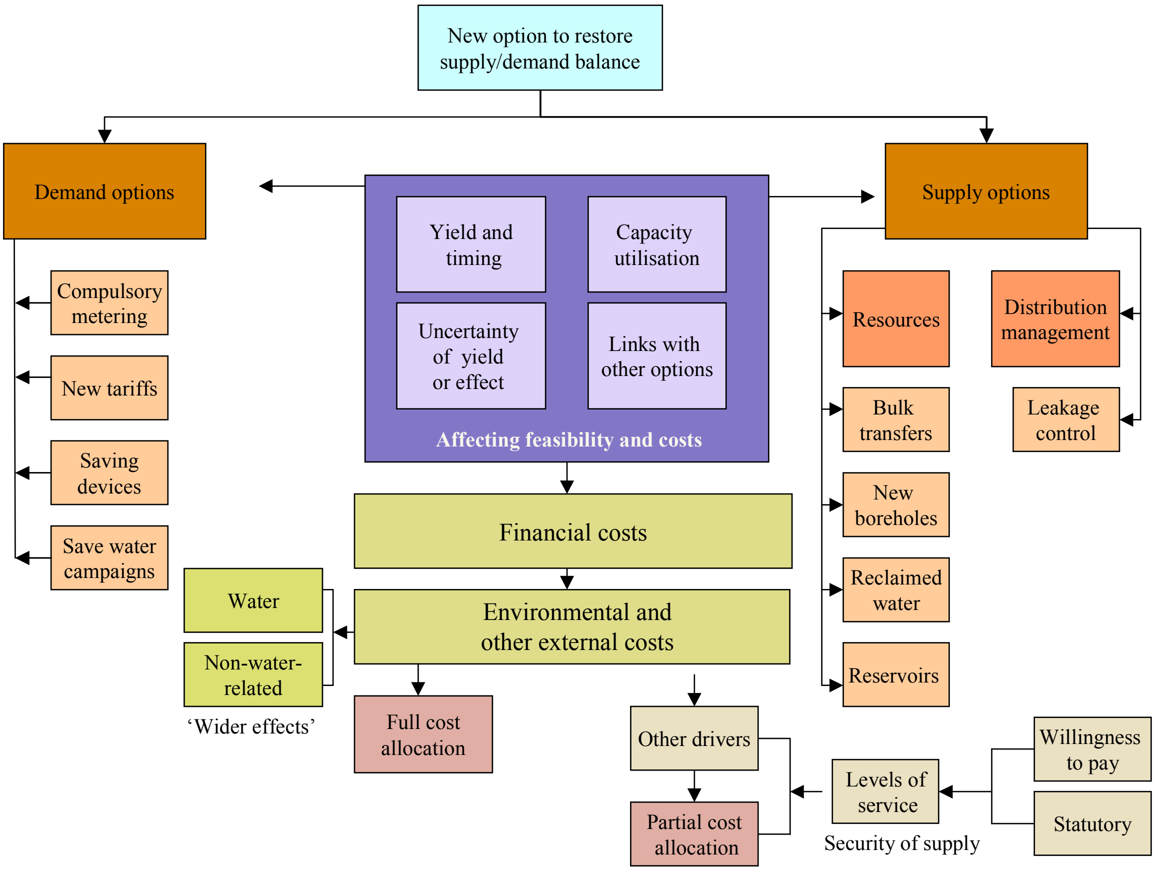
Companies said that from 2012, the EA will have the power to remove or reduce licences on the basis of environmental damage. The companies noted that they might find themselves wanting to introduce changes to licensed abstraction that could significantly affect supply/demand balance, but it is still uncertain what those changes might be. They added that current re-assessments of groundwater resources might have a significant impact on the supply/demand balance in their region. Companies are likely to be required to reduce water abstractions as a result of WFD implementation. This will require them (with the EA and Ofwat) to reconsider their supply/demand balance and to examine options for replacement of the lost resource.

Plans to meet increased future demand may include a mixture of measures, such as:

- development of new resources (e.g. boreholes, reservoirs, desalination plants);
- increased utilisation of existing resources;
- flow augmentation;
- water reclamation;
- habitat management;
- leakage reduction;
- demand management; and
- aquifer storage and recovery schemes.

The precise consequence of any limitation on abstraction results from a complex interaction of issues such as the availability of alternative resources and network capacity constraints. Estimating the financial and economic costs of such a limitation will therefore require the assistance of water companies to develop robust estimates (see Figure 8). Leakage control would include activity undertaken by private householders as well as for water companies.

Figure 8 Abstraction licence reduction or removal costs



5. ECONOMIC ANALYSIS

5.1 Relevance of costs: types of WFD analysis

Reduction in phosphate discharges and water abstraction reduction are two of the measures considered for compliance with ‘good water status’ by 2015 under the WFD. The costs of such measures are used in three types of analysis relevant to the WFD:

- CEA;
- Distributional analysis; and
- Cost-Benefit Analysis (CBA).

These types of analysis are relevant for the determination of derogations or the design of alternative objectives (other than good water status) by 2015.

The relevant costs are those additional costs attributable to the WFD only. However, costs that arise from other legislation but contribute to compliance with the WFD are also of interest. This section describes the three types of analysis, highlighting the costs that need to be identified to carry them out. It also discusses how to go about finding the costs attributable to the WFD.

5.1.1 Cost effectiveness

For the purpose of cost effectiveness, the social costs of a measure have to be calculated according to the following steps.

- Calculate the private costs (often referred to as financial costs).
- Adjust these for future predictable changes in market conditions (e.g. demand changes in input markets) and for transfer payments, including the effect of market imperfections.
- Calculate the non-water external costs or benefits, or wider benefits, and subtract these from the above costs.
- Discount the private and other social costs at the relevant social cost of capital rather than the private cost of capital.

5.1.2 Distributional impacts

Distributional impacts are assessed to understand how different parts of society bear the costs of a new measure.

The costs of phosphate removal will affect water companies and their customers. Particular importance is likely to be attached to low-income customers in areas where water bills are already relatively high.

Based on the current ‘regulatory contract’, companies are likely to be able to pass through a high proportion or all of the costs of phosphate removal to customers.

5.1.3 Cost-benefit analysis

The CBA takes the economic or social costs calculated in the cost-effectiveness exercise and compares them with the benefits achieved through the measures. In broad terms, the benefits are the valuation of ‘good ecological status’ (which includes morphological, physio-chemical and biological characteristics). They include the externalities or wider benefits that are water-related, such as angling, biodiversity and in-stream recreation.

In terms of phosphate reductions, the benefits are more specific and should be restricted to those that can be attributed solely to phosphate reduction. Again, the contribution of the EA is required to finalise the benefit assessment in each river basin.

5.2 Costs attributable to the WFD

The objective of the study is to provide a methodology to identify the additional private and other social costs of the following measures to comply with the WFD:

- reducing phosphates in point-source discharges; and
- reduction of water abstraction licences from water companies.

In the case of phosphate removal, the starting point is the private and other social unit costs of reducing phosphate discharged to rivers by the water industry under current legislation. This is the 'business as usual' or counterfactual against which the costs to comply with further phosphate removal under the WFD would need to be compared.

In the case of reducing water abstraction licences, the starting point is the current water resource plans based on the projections behind the supply/demand balance exercise. Such resource plans are the 'business as usual' against which the costs of meeting demand under new water resource plans with fewer resources in terms of abstraction licences are compared.

In both cases the final result will provide the additional costs resulting from compliance with the WFD. These are the relevant costs for the CEA.

Private and other social cost requirements

The private costs are required for the calculation of the distributional impact. They are also the starting point for the calculation of total social costs.

The social costs are required for the CEA of measures to meet the WFD.

The social costs are also required for the CBA test of disproportionality.

5.3 Private cost adjustments

The current costs of phosphate removal or abstraction withdrawal may not reflect the actual private costs of compliance with the WFD in 2006 or 2008, for the following reasons:

- dynamic effects;
- the impact of technology; and
- the treatment of joint and common costs.

5.3.1 Dynamic effects

The costs incurred today may differ from those incurred tomorrow. The relevant costs for the WFD are those at the time the costs are expended. Relative market prices may change between now and the date of expenditure. The causes of this movement in prices are numerous, including changes in the level of demand or in the cost of supply (for example, as a result of improvements in productivity).

Short run increases in demand and price inflation

If the capital programme for the WFD is so great that it causes a significant increase in the level of demand experienced by suppliers, prices may rise. In this case, costs calculated today could be lower than those prevailing when the WFD's costs are expended. The price increase could reflect the higher costs of meeting a greater volume of demand in the presence of capacity constraints, in which case the price would reflect economic costs.

The process to follow is:

- identify significant components of cost;
- define the relevant market for inputs;
- estimate the share of market demand accounted for by Directive expenditure, and ascertain whether it is significant; and
- assess whether a short run increase in demand is likely to lead to higher production costs.

The main recipient of capital programme expenditure is the construction industry. However, given the size of this market, the effect is not likely to be significant, except perhaps in localised markets and in peak periods of water industry activity and possibly in specialised services. One company argues that, at such times, scarcity of suitable contractors results in price increases. Table 3 below shows the share of the capital programme in comparison with the construction industry as a whole for the six years between 1998 and 2003. It can be seen that, on average, the water industry contributes to only 5% of the construction industry activity. The maximum contribution in these six years has been 6%.

Table 3 Water and sewerage new work as a % of all construction industry new work

Year	Water (£m)	Sewerage (£m)	Total water and sewerage (£m)	Construction industry (£m)	Water and sewerage as a % of construction industry
1998	915	759	1,674	32,336	5
1999	962	805	1,767	35,468	5
2000	1,252	911	2,163	37,540	6
2001	1,177	675	1,852	39,832	5
2002	1,317	830	2,147	45,234	5
2003	1,094	775	1,869	49,646	4
Average					5
Maximum					6
Minimum					4

Sources: From the DTI (2004) Construction Statistic Annual, Table 2.8, p. 40, and Oxera calculations

However other pressures on the construction industry, including increases in demand due to major developments such as the Olympic games, the construction of the Crossrail link, and Heathrow's Terminal 5, might result in increases in construction prices faced by the water industry. If this turns out to be significant at a point in time, there may be a case for quantifying adjusting cost estimates. Quantifying these possible effects is beyond the scope of this study.

Effect on demand for sewerage services

It could be argued that as prices for sewerage services rise, the quantity demanded will fall, and the total costs of meeting Directive standards may shrink (depending on the elasticity of demand). The quantity could fall because industrial customers pre-treat their effluent or develop their own sources of raw water, but householders are not in a position to do this. It could also fall because of reduced consumption of water by all metered users. The effects are likely to be small unless the price rises caused by the Directive are large. However, in the case of trade effluent, one company noted that although pre-treatment may reduce the total cost of meeting the Directive due to lower loads, such pre-treatment may result in an increase in treatment costs due to the reduction of the organic strength necessary to facilitate phosphate treatment.

Input price trends

Where input price trends do not follow the retail price index (RPI), prices may rise or fall in real terms over time. For example, wages prices tend to grow faster than retail prices, while prices of information technology tend to fall relative to retail prices. Future input prices could be adjusted for their likely changes in levels relative to retail prices.,

5.3.2 Treatment of joint products and common costs

When there are joint products and common costs, consideration should be given to the proportion of the costs that should be attributed to the product in question. This is an issue of particular relevance when calculating the costs of phosphate removal and abstraction withdrawal.

The following definitions will aid understanding of the underlying issues.

The costs incurred in a line of business can be classified into the following three types:

- direct;
- joint; and
- common costs.

Joint and common costs are often referred to collectively as indirect costs.

Each cost type is described in the following paragraphs.

Direct costs – refer to costs, including capital costs and other expenses, which can be directly and exclusively attributed to phosphate removal.

Joint costs – strictly speaking, these costs are incurred when phosphate removal simultaneously involves other outputs (such as BOD removal). Joint costs arise in settings in which the costs of two or more outputs cannot be separated – when an increase in phosphate removal will necessarily mean a corresponding increase in another output.

Common costs – these arise when phosphate removal is produced together with another output, even though it could be produced separately. Typical examples are salaries and other overheads.

Phosphate removal is likely to involve joint costs to the extent that any treatment works is able to treat for phosphorus and other pollutants at the same time. Particularly for some minimum level of treatment, it may not be possible to separate the treatment of phosphorus from that of other substances. For enhanced phosphate treatment, there would also be costs that could be considered as common, in the sense that, although the nutrients are treated at the same time, it may be possible to separate phosphorus from other pollutants and treat only for phosphorus. Furthermore, costs such as overheads will be common to all pollutants.

To understand which costs should be allocated to compliance with the WFD, the following additional concepts are necessary:

- stand-alone costs;
- incremental costs and
- fully distributed costs (FDC's).

Incremental cost – the increase in cost associated with producing a specified increment of phosphorus removal.

Stand-alone cost – the cost that would be incurred if phosphorus removal were the only requirement.

FDC's – the costs attributed to phosphorus when all costs have been fully distributed (allocated) between activities. The FDC therefore includes direct costs and some common and joint costs.

- the incremental cost of a product would include its direct costs and possibly an identifiable portion of common costs. Joint costs are excluded;.
- the stand-alone cost of a product would include the direct costs, most of the common costs and all joint costs.
- the FDC's would include direct costs, an allocated portion of common costs and an allocated portion of the joint costs.

Application of cost concepts

In the context of the allocation of additional costs arising from the WFD, the FDC's are a good starting point. If costs are allocated on the basis of FDC's then the range should be the following:

- the lower limit will be the incremental cost; and
- the upper limit will be the stand-alone cost of phosphate removal.

When further phosphate is being removed and there are no additional drivers such as nitrogen, the full cost of the additional removal, even if treatment removes other pollutants, should be allocated to phosphates. However, if nitrogen removal is also a requirement then the FDC's will be relevant and joint and common costs should be allocated to each driver.

In this case, there are several methods that can be used to allocate joint and common costs (indirect costs):

- input-based;
- output; and
- value-based.

Input-based cost drivers

Common costs can be apportioned using activity-based costing based on inputs employed. These could include:

- number of employees;
- time spent;
- wage bill;
- raw material costs; and
- floor space used.

Value-based cost drivers

Here, joint costs are allocated based on demand factors, leading to the lowest distortion to output. The factors could be:

- prices;
- revenues; or
- consumers' willingness to pay.

Alternatively, an equi-proportionate mark-up can be applied equally across all outputs.

5.4 Social/economic costs

5.4.1 Divergence of costs (market prices) from opportunity costs

Economic costs, and thus the cost estimates underpinning the river basin assessments, are not the same as financial costs (as reflected in market prices) when prices do not reflect the true opportunity costs of the resources used. Total social or economic costs include private (or financial) costs adjusted for transfer payments and for external costs such as environmental and health costs. Another important issue is the discount rate. Future social costs are discounted at social discount rates rather than at private discount rates (private cost of capital).[9]

When estimating costs, it is important to ask whether the divergence between financial and economic costs is significant, what the reasons are for this divergence and whether it can be corrected. The possible causes of divergence, include:

- externalities (including environmental and wider economy effects);
- taxation;
- discount rates;
- transaction costs associated with changes to systems, education and training; and
- monitoring and enforcement costs from government agencies.

The following paragraphs discuss the top two causes.

5.4.2 Externalities

The supply of water and collection and treatment of wastewater uses energy, minerals and transport. These all generate environmental impacts, but to some extent they are reflected in market prices by economic instruments that seek to apply the polluter pays principle. To the extent that the price adjustments imposed by the economic instruments reflect the true value of the externality and that the scope of the impact is mapped by the scope of the instrument, no further adjustments have to be made. Where this is not the case, these environmental costs can be considered separately and then added to the total costs of complying with the Directive. The externalities that should be reflected in the CEA calculations are those that are non-water derived, i.e., not resulting from the effects of the WFD on water. The main externalities are odour (not covered in table 4), greenhouse gas emissions, and noise and road congestion, in both construction and operations. Economic instruments cover the largest impacts of the latter three. However estimates would be required for odour but this is beyond the scope of this study.

Greenhouse gas emissions from combustion plant are subject to the EU Emissions Trading Scheme (EU ETS), whose tradeable allowances for the emission of 1tCO_2 are currently priced at €20tCO_2,[10] equivalent to £50/tC. This price effect is passed through to electricity prices (to some extent) by the electricity generators, where it is combined with the Climate Change Levy (CCL) of 0.43p/kWh (equivalent to £40/tC). The industry faces the full rate of the CCL (except where it generates its own electricity).

The government's best estimate of the value of the climate change externality is about £85/tC in 2005 money,[11] but is to be revised.[12] Thus energy consumption by the water industry is subject to economic instruments that broadly reflect the impact of greenhouse gas emissions.

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9 HM Treasury The Green Book: Appraisal and Evaluation in Central Government, January 2003
10 Evolution Markets, market commentary, June 2005
11 Clarkson R. and Deyes K. (2002) Estimating the Social Costs of Carbon Emissions, HM Treasury and DEFRA, Government Economic Service Working Paper 140
12 DEFRA is expected to publish revised estimates shortly

The main suppliers to the water industry relevant to this study, the construction materials and chemicals industries, also face the CCL and the EU ETS, although some pay a heavily discounted levy rate in exchange for improvement targets.[13] Thus greenhouse gas emissions associated with production of goods for consumption in the water industry are already incorporated into market prices.

Road transport has impacts on the climate, on health through accidents and air quality, and on local amenity and the economy as a result of noise and road congestion. While these impacts vary greatly with location, the externalities are on average compensated by the taxes paid by motorists over and above the cost of maintaining the road network in the long term.[14]

Landfilling of waste has an impact on climate (although this is limited as a consequence of gas flaring and energy recovery) and on local amenity. It is subject to taxation in the form of the Landfill Tax. This is now £15/tonne for active waste, in real terms comfortably above the initial rate of £7/tonne when the tax was introduced in 1996. That initial rate was designed to cover the externalities of landfill,[15] so that now under the higher rate, the externalities of landfill are much less than the tax rate applied. The excess of around £8 in prices of 1996 is a transfer to the Exchequer and thus should be deducted from costs.

Aggregates extraction creates visual disamenity on the landscape as a result of extraction onshore, and can create noise and dust. To reflect this, an aggregates tax was introduced in April 2002. The level of the tax was based on a study of the environmental impact of aggregates extraction. The tax has remained unchanged and probably still broadly reflects the environmental costs of extraction.

Table 4 summarises the environmental impacts covered by the economic instruments on fossil fuel use, transport, landfill and aggregates extraction.

[13] Sorrell, S. (2002) The Climate Confusion: Implications of the EU Emissions Trading Directive for the UK Climate Change Levy and Climate Change Agreements, Science and Technology Policy Research Unit, University of Sussex, November

[14] Oxera (2000) The Wider Impacts of Road and Rail Investment, March; Institute for Transport Studies (2001), Surface Transport Costs and Charges, Great Britain 1998, report for the DETR, July

[15] See the original study on the environmental costs of landfill, CSERGE, Warren Spring Laboratory and EFTEC (1993), Externalities from Landfill and Incineration, HMSO. See, also, Cambridge Econometrics, Eftec and WRc (2003), A Study to Estimate the Disamenity Costs of Landfill in Great Britain, DEFRA, February

Table 4 Externalities at least partly covered by economic instruments

Impact	Instrument			
	Aggregates tax	Landfilling: Landfill Tax	Energy use: CCL and EU ETS	Transport: Road fuel and vehicle taxes
Global warming	–	✓	✓	✓
Ozone depletion	–	–	×	✓
Natural ecosystem effects from acidification and eutrophication	–	–	×	✓
Health effects of air pollution	–	–	–	✓
Buildings and materials damage from acidic and particulate pollutants	–	–	–	✓
Improved crop yields due to nitrogen oxides deposition	–	–	–	–
Disamenity from aggregates extraction	✓	–	–	–
Traffic accidents (debatable)	–	–	–	✓
Traffic congestion	–	–	–	✓
Traffic noise	–	–	–	✓
Sensory disamenity	–	✓	×	–

Source: Oxera

5.4.3 Taxation

Market prices could over- or underestimate resource costs if they include taxes or subsidies. Taxes artificially increase market prices and thus have to be deducted. However, taxes designed to internalise negative externalities should not be deducted (e.g. carbon tax on energy consumption). Subsidies artificially lower market prices and thus have to be added back to provide an accurate indication of the use of resources.

Estimates of financial costs should be in market prices; estimates of social cost should be at factor cost.

As far capital expenditure is concerned, at business plan stage water companies report the costs of purchasing capital inputs excluding indirect taxation (i.e. at factor cost).

5.4.4 Information on relevant costs

Available information

Water companies already provide a significant amount of information to Ofwat, both for annual reporting (June Returns) and as part of the periodic review process, which occurs on a five-yearly cycle. This information is discussed in section 6.2 below.

In this study, a questionnaire was used to elicit the extent of information available on phosphate removal. A copy of the questionnaire template is included in Appendix B.

Analysis of current information from Ofwat

Ofwat has a dataset containing phosphorus removal projects put forward by companies in their AMP4 business plans. For each project, the dataset contains information on the following set of parameters:

- population PE (scale variable);
- consented dry weather flow (scale variable);
- current treatment type (production type);
- additional treatment type, e.g. chemical dosing (production type);
- effluent consent level (quantum of load removed);
- operating cost; and
- capital cost.

6. PHOSPHATE COST MODELLING[16]

6.1 Introduction

6.1.1 Description of data and data collation process

The dataset used to carry out the modelling was extracted from Ofwat database C5-2 that water companies submitted to inform the Final Determinations at PR04. Ofwat used the database to capture sewerage service scheme-specific information during PR04. The information, albeit not always complete, included:

- capex and opex for the scheme;
- policy drivers;
- brief description of work proposed (i.e. type of assets to put in place); and
- proposed consent standards for parameters.

This information was later integrated, with help from the EA, to include consented dry weather flow.

Following on from water companies' comments on the need to include increased sludge costs, Ofwat examined the water companies' business plans. This analysis revealed that companies could be split into three categories:

a) companies that fully reported sludge costs within the project-specific capex and opex forecast;

b) companies that reported partially the costs of sludge within the project's costs and partially reported them under a generic sludge costing line; and

c) companies that reported minimal sludge costs because they had spare sludge treatment capacity built during AMP3 period.

In so far as this exercise is aimed at deriving average water companies' costs to deal with P in sewage effluent, sludge costs are to be included. Ofwat therefore used the information in business plans to:

1) allocate the generic costing line to individual projects; and
2) inflate the costs of those companies that reported only minimal sludge costs.

Modelling was carried out solely for sites where the only parameter in the discharge consent for which a standard is being imposed or tightened is phosphorus.

Estimates of the unit costs of phosphorus removal were obtained using two approaches, which are explained below. In both cases, the costs are based on consent standards of an annual average of 1-2 mg/l of phosphorus. It is difficult to estimate what the WFD-derived consents may be, and therefore how to calculate the increment. Water companies have observed that the costs of meeting more stringent standards are not linear. As noted by one company, unit costs may rise with tighter consents.

Ofwat sought help from companies in order to assess the likely step change in costs related to very stringent standards (e.g. below 0.5 mg/l). Results of this exercise are reported in section 6.2.

The variables considered in estimating the costs arising from new works were the following.

- net present costs (NPC's);

[16] This section draws upon OXERA "Oxera (2005) Review of econometric cost modelling of chemical phosphorus removal works" prepared for Ofwat, October, available at www.ofwat.gov.uk.

- equivalent annual costs (EAC)
- the cost of one unit of load removed (i.e. £ per kg of phosphorus removed.);[17]
- PE served;
- consented dry weather flow;
- loads removed annually;
- phosphorus standard required;
- unit labour cost;
- construction input price index;
- energy price index;
- binary variable to assess whether a site had a phosphorus standard already in place; and
- binary variable to assess whether, in addition to chemical dosing, tertiary treatment is to be put in place.

Ofwat initially also used a number of constructed variables (i.e. influent load, effluent load and load removed); while these attracted some criticism from water companies, when presented with the estimates for load removed, companies did not amend those figures except in a few instances. When companies provided their estimates for load removed, Ofwat replaced the calculated load removed with the companies' estimates.

Ofwat assessed that there were two modelling strategies using one of two combinations of scale variables – one employing PE and consented dry weather flow, and the other utilising load removed only.

Ofwat tested both modelling strategies. The PE scale variable was counterintuitive from an economic viewpoint, indicating potential data problems. Ofwat therefore opted for the models that included load removed.

6.1.2 Methodology

Two alternative approaches are possible to obtain unit cost measures for more stringent phosphorus standards:

- unit cost approach; and
- econometric cost function approach.

Unit cost approach

The first approach involves simple unit cost measures, similar to those employed by Ofwat for modelling small STW. [18] A rough estimate of the unit cost of new processes can be obtained by segmenting the sample by size of works and dividing the cost figures by the amount of phosphorus removed by those works (i.e. the treatment complexity).

This gives a range of estimates from which upper and lower bounds and a sample average is calculated. The unit costs are the full costs, with no sharing of joint costs with other drivers.

The unit cost has a standard composition, one element of which is phosphorus. Thus, a cost per unit of phosphorus removed can be estimated. This may be an overestimate of the incremental cost of phosphorus removal, but provides an initial indication of the value to be expected. It may even be an accurate estimate, if the only way to reduce phosphorus discharged is to increase operating and maintenance expenditure across all activities at the works.

Following a similar approach, cost estimates have been calculated for biological technologies.

[17] This was calculated as [equivalent annual cost/(daily load removed * 365)]
[18] Ofwat Water and Sewerage Service Unit Costs and Relative Efficiency, January 2005

Cost function approach

The second approach involves econometric modelling, and is better suited to controlling for differences between works. To derive total costs and unit cost figures for representative treatment works (e.g. small, medium and large), a functional relationship derived from the econometric models is used.

The next section describes the econometric methodology to estimate the cost functions in more detail. Ofwat sought clarifications from companies as to the proposed approach and responses to the draft final report circulated in July showed that they were broadly content with such an approach.

6.1.3 Methodology used for cost function approach

Ofwat has used the data discussed above to obtain the variables that can be used in modelling the costs of new or extended treatment works, and to quantify the impact of relevant cost drivers on the costs of new works.

The methodological framework employed is that of a cost function. The costs of phosphorus removal are modelled with the functional relationship:

cost = f(scale, quantum, technique)

where:

- Cost is the cost of new treatment works.
- Scale is the amount of sewage treated and represented by, for example, PE.
- Quantum is the proposed phosphorus ceiling.
- Technique is an indicator of whether either chemical dosing or biological treatment only is used, or whether other techniques are employed in addition.

Ofwat has modelled two main options for treatment (one biological and one chemical). It assumed that biological and chemical works have different cost functions.

6.1.4 Model search strategy

The importance of each cost driver in affecting costs is determined using regression analysis using the general-to-specific modelling approach. This approach begins with a general regression model, which contains all the variables that are believed to have explanatory power. The general model is then systematically simplified (using statistical significance tests) until a model is produced in which all variables are statistically significant. Due to the small size of the dataset, a full general model cannot be estimated. Instead, where more than one candidate measure of a cost driver is available (e.g. scale), different general model specifications are systematically tested separately to arrive at several preferred or specific models. These are then compared to arrive at an overall preferred model (or models). To be considered robust and reliable, the model must also pass a number of tests for model misspecification. The final model or models can be used as a predictor of phosphorus removal costs in future projects.

Ofwat's models are detailed below.

Chemical dosing

Model 1

Log EAC= $\alpha + \beta_1$ log (load removed pa) + β_2 log(proposed phosphorus standard)+ α_1 chemical dosing only

Model 2

Log unit cost = $\alpha + \beta_1$ log (load removed pa) + β_2 log(proposed phosphorus standard)+ α_1 chemical dosing only [19]

Model testing

Ofwat tested the candidate models using the following tests:

- Jarque-Bera for testing the normality of residuals;
- Breusch-Pagan and White tests for heteroscedasticity;
- RESET test for functional form and general misspecification;
- MacKinnon et al. Pe test for testing log versus level functional forms; and
- Cook's distance for the detection of outliers.

The exclusion of 12 outlying observations reduced the initial sample of 239 observations to 227. The model elicited for this sample was robust to all tests listed above except to Cook's distance testing for outliers. The exclusion of all outliers would reduce the sample by a further 14 observations (i.e. to 203).

Ofwat considered further 24 observations assessed to be statistical outliers. Eliminating these would halve the large works in the sample. This may indicate that while these observations are outliers statistically, they are not on economic grounds.

In light of the robustness of the model that uses using 227 observations and the comparable cost estimates elicited using the models with or without some statistical outliers, Ofwat opted to include the 24 observations in the modelling. Further to a water company comment that the general cost function might not be robust in forecasting costs for small works, they tested this claim.

A model inclusive of binary variables that capture whether a site belongs to one of the four STW categories was elicited (three dummy variables were used). The predictions of EAC's elicited using the model with the binary variables and those of the general model were compared and showed no significant difference.

Ofwat also tested the constancy of parameters across the sub-sample of small works and the full sample of works using the Chow test. Non-constancy of parameters was rejected.

Finally, Ofwat considered how the predicted cost for works smaller than 2000 PE compares to the predictions for other works sizes, and with the predicted costs for other works sizes.

The testing of whether the underlying cost structure for small works materially differs from that of other works did not support the company's claim.

Ofwat investigated the returns to scale in the cost model and the constant returns to scale hypothesis was rejected.

Further details on the modelling are provided in the OXERA note "'Review of econometric cost modelling of chemical phosphorus removal works" October 2005, available on Ofwat's web site (www.ofwat.gov.uk).

Cost drivers

In the early part of the project, the water companies were sent a questionnaire, in which one question related to the cost modelling of phosphate removal. The results from this questionnaire are presented in Appendix C, but are summarised here.

[19] Model 2 is simply a mathematical transformation of Model 1

- For capital cost, the most influential factors are: the existing treatment process, consent limit, and land availability.
- For operating cost, the most influential factors are: chemicals (type, cost), sludge, energy, and existing treatment process.

Some of these parameters have been used in the cost function analysis presented above (treatment process, consent limits). None of the companies mentioned size of the works as being an important factor determining the cost of phosphorus removal.

6.2 Presentation of outputs/ results

6.2.1 Unit cost estimation based on econometric models

Table 5 shows the unit cost of one unit of load removed by works that employ chemical dosing under new phosphate treatment standards. The models have been used to estimate the unit cost for several scenarios – namely for phosphate consents of different standard (stringent, medium and less stringent) and for small and medium treatment works. The table also differentiates between unit costs according to whether a metal consent is agreed; when a metal consent is implemented, unit costs are higher due to the additional costs arising from tertiary treatment. Table 5 also shows the 95% confidence interval around the mean or central cost estimate.

Table 5 Unit cost of load removed (£/kgP), chemical dosing

	No metal consent			**Metal consent**		
	2.5% lower bound	Mean	2.5% Upper bound	2.5% lower bound	Mean	2.5% Upper bound
Stringent standard (just < 1 mg/l)						
Very small works (PE<2000)	76	93	114	127	146	169
Small/medium works (2000<PE<10000)	32	38	46	53	60	69
Medium/large works (10000<PE<80000)	13	15	19	21	24	28
Large works (PE>80000)	3	4	5	5	6	8
Medium consent (1 mg/l)						
Very small works (PE<2000)	57	67	78	95	105	117
Small/medium works (2000<PE<10000)	24	27	31	40	43	47
Medium/large works (10000<PE<80000)	10	11	13	15	17	20
Large works (PE>80000)	2	3	3	4	4	5
Less stringent consent (2 mg/l)						
Very small works (PE<2000)	31	35	41	48	56	64
Small/medium works (2000<PE<10000)	13	15	16	20	23	26
Medium/large works (10000<PE<80000)	5	6	7	8	9	11
Large works (PE>80000)	1	1	2	2	2	3

Source: Ofwat analysis

Table 6 shows the unit cost of load removed of sewage works that employ biological solutions to treat sewage to new phosphate standards. Company feedback has shown that small biological works may not be economical; however, the small sample used for this analysis includes three works (30% of the small sample) serving less than 2000 PE.

Table 6 Unit cost of load removed (£/kgP), biological solutions (based on equivalent annual cost)

	Minimum	**Mean**	**Maximum**
Small/medium	16	46	112
Medium large	8	11	14

The figures in Table 6 are derived from an extremely small number of observations (nine) and are only indicative.

6.2.2 Cost modelling for combination of pressures

Process technologies, such as BNR's, will generally be adopted by water companies that are required to deliver total organic nitrogen consents. However, most of these have the added potential, under certain conditions, to remove a significant proportion of any phosphate load in the wastewater, with a low marginal cost compared with alternative processes.

For the wider CEA, account will need to be taken of the economies of scope that arise from certain combinations of measures, such as nitrogen and phosphorus removal.

The model will also need to account for circumstances where the limiting nutrient for eutrophication is phosphate rather than nitrates. In this case, it would appear more appropriate to include most, if not all, the cost of a process that removes both nitrates and phosphorus to the limiting nutrient (i.e. phosphorus). One company has mentioned that in their area the limiting nutrient for eutrophication has been phosphate.

Figures reported in Table 5 and 6 related to asset improvements to achieve tighter phosphorus standards only. However, before the 2006 CEA exercise, Ofwat will carry out further analysis, to seek to assess the likely magnitude of the economies when more than one parameter is being addressed.

6.3 Testing the models' results and assumptions with water companies

Ofwat wrote to ten companies on 23 August 2005 requesting their help in testing cost estimates for the removal of phosphorus to achieve particular standards. They received replies from five companies, with one declining to take part and the remaining four agreeing to participate.

Ofwat asked the companies to select three of their STW that fell into the three size bands (<10000 PE, 10000-80000 PE and 80000-250000 PE) being used in the draft final report. For each of these works, they asked for estimates of capex and opex to achieve P consents of 1 mg/l and 0.4 mg/l. Ofwat also asked if they could indicate what consent standard would trigger the use of technologies other than chemical dosing or BNR.

Ofwat also requested that the companies provide their views on the asset life assumptions used in calculating the present value of costs. Ofwat's assumptions were that the civil engineering component of the investment would be 50% of capex, the mechanical component 45% and the electrical component 5%. The asset lives of these components were assumed to be 60, 20 and 10 years respectively.

Not all four companies (referred to below as A to D) were able to complete the full exercise, but the information they provided is summarised below:

Companies' responses

Company A said that the major cost elements of conventional treatment are:

- access road improvements to permit chemical tankers (small sites in particular);
- improvements to storm separation and treatment;
- improvements to settlement tanks;
- sand filters;
- additional sludge handling and storage;
- dosing plant; and
- enhanced power supply and standby generation.

They considered that capital costs would be likely to be split as follows: 70% mechanical and electrical, 5% instrumentation, control and automation and 25% for the civil engineering component. They envisaged a real terms increase in opex of 2% year on year due to the rising costs of chemicals and power. Costs for the proposed 0.4 mg/l standard would depend on whether the consent was expressed as an annual average or a 95 percentile. They were not able to suggest costs for alternative technology at this time.

Company B gave quite detailed information on the technology they thought would be necessary to achieve a 0.4 mg/l P consent. The method used would depend on whether consents for iron and aluminium were maintained at current levels. If they were maintained, tertiary sand filtration for full flows should suffice. Ferric salts would be dosed to remove the bulk of the phosphorus so that the concentration in the effluent was less than 1 mg/l. This would then be reduced to 0.4 mg/l with the use of polyaluminium chloride.

Wastewater with low alkalinity would need pH correction. The likelihood of this increases as the P standard to be met reduces: with a 0.4 mg/l consent, it is more likely that pH correction would be required, with magnesium hydroxide being used to achieve this.

Company B estimated an approximate 50:50 cost split between civils, and mechanical and electrical components. They also proposed to discount the value of civils components over 20 years and use in the calculation residual values, to take account of changes in technology.

Regarding the differing suggested consent standards, Company C considered that 1 mg/l P should be achievable with primary and secondary chemical dosing, provided the plant was operated correctly. This also depended on the consent limit for iron in the effluent discharged to the receiving watercourse. If a P limit of 0.5 mg/l were imposed, a tertiary treatment process such as a sand filter would be needed to remove residual solids and chemical dosing increased. The company judged that it would be possible to achieve a consent of 0.4 mg/l if there were an enhanced solids removal process such as membrane technology. However, they did not have any experience of operating works in this configuration, although they nonetheless provided a cost estimate for the suggested solutions.

Company D considered that chemical dosing and sand filters could be used to meet a future P standard of 1 mg/l. This would depend on chemical availability and permissions. BNR, with chemical dosing back-up, would be needed to meet a future P standard of 0.4 mg/l. They would have concerns about using chemical dosing alone to achieve a P standard of 0.5 mg/l (or less) and also for the residual chemicals in the final effluent.

Issues around the present value (PV) calculations

Ofwat used the companies' feedback to test whether changes to the present value calculations, in particular asset life assumptions, would substantially change the results. In total, Ofwat tested their assumptions against four different sets of assumptions provided by the companies. Of these four, one exceeded Ofwat estimates by 16% on average, while one set materially changed the results assuming residual values for 50% of the initial investment in the last year of a 20-year time horizon analysis. On average, the estimates using this set of assumptions were 38% lower than those obtained using Ofwat assumptions. The PV of costs arrived at using the other two alternative sets of assumptions were on average within 6% of the Ofwat estimates.

Ofwat noted the difference of its results compared with those using a residual value in the PV calculations. However, Ofwat considers that the use of residual values is open to debate.

For example, residual values can be assessed by considering the salvage value of the assets. In this particular case, the question would be: if you shut down a STW containing assets/components that could continue working for a meaningful length of time, could you plausibly sell any of those assets or re-use them at some other location? Because of site and functional specificity of the assets, plus the costs associated with any redeployment, this would appear highly doubtful for many water company assets.

A comparison of the modelling exercise with water companies' site-specific cost estimates

Four water companies, using their costing methodologies, provided capex and opex estimates for achieving 1 mg/l P standard at three STW serving a PE below 10000, between 10000 and 80000 and above 80000.[20]

[20] One of the companies provided a site that just fall short of serving more than eighty thousand PE, however Ofwat for the purposes of this exercise and having four sites for each STW band kept this site in the third band.

Ofwat used these expenditure estimates for calculating the present value of costs and EAC's. They used the model to elicit for the same sites the EAC's and present value of costs. The comparison of present value of costs estimates is reported in Table 7 below.

Table 7: Comparison of model estimates of present value of costs with estimates using water companies' forecast. Reported figures are water companies' estimates as % of model estimates

STW's bands	Company A	Company B	Company C	Company D
Works (PE<10000)	52%	54%	120%	32%
Works (10000<PE<80000)	73%	80%	104%	38%
Works (PE>80000)	150%	78%	133%	54%

The above Table indicates that the model estimates can over- or under-predict the water companies' estimates at any given sites.

Overestimation is indicated by a percentage below 100% and underestimation is a percentage above 100%. However, for the twelve sites, the average model estimate is 19 % above the water one.

Step changes in costs of tight standards: water companies' input to the analysis

Ofwat used company responses to the 23 August 2005 letter to assess an indicative estimate of cost increases related to a tightening of the P standards to 0.4 mg/l. The 0.4 mg/l threshold was identified as a threshold level at draft final report stage; however, some companies have since indicated that a standard of 0.5 mg/l could also involve a step change in costs (i.e. non-linearity of the cost function).

Companies provided estimates of capex and opex to achieve the 0.4 mg/l standard at nine sites, three for each treatment works size band. Company B did not submit cost estimates for 0.4 mg/l standards; consequently, it was not possible to carry out the analysis for this company. Ofwat used these expenditure estimates and their own assumptions to calculate the present value of costs for both 1 mg/l and 0.4 mg/l standards. They then compared the cost estimates obtained. Albeit only indicative, the comparison results are reported in Table 8 below.

Table 8: Comparison of present value of costs to achieve 1 mg/l and 0.44 mg/l standards at the same sites. Reported figures are PV costs to achieve 0.4 mg/l as % of PV costs to achieve 1 mg/l

STW's band	Company A	Company C	Company D	Average increase for the three works bands
Works (PE<10000)	133%	289%	182%	201%
Works (10000<PE<80000)	127%	374%	184%	228%
Works (PE>80000)	173%	539%	196%	302%

Although only preliminary, the results in Table 8 indicate that companies' assessment of the likely increase in costs related to a tightening of the P standard to 0.4 mg/l on average would more than double (i.e. 244%) the costs of achieving a standard of 1 mg/l, and is highly dependent on works size.

7. WATER RESOURCE COST MODELLING

7.1 Introduction

One way to achieve good water status is to reduce abstractions from water bodies. Abstraction reduction has two positive effects on habitats: by restoring water to the catchments, it directly improves aquatic life; and by improving dilution of pollutants, it reduces their negative impact on habitats.

One of the measures to achieve good ecological status under the WFD is therefore to reduce abstraction.

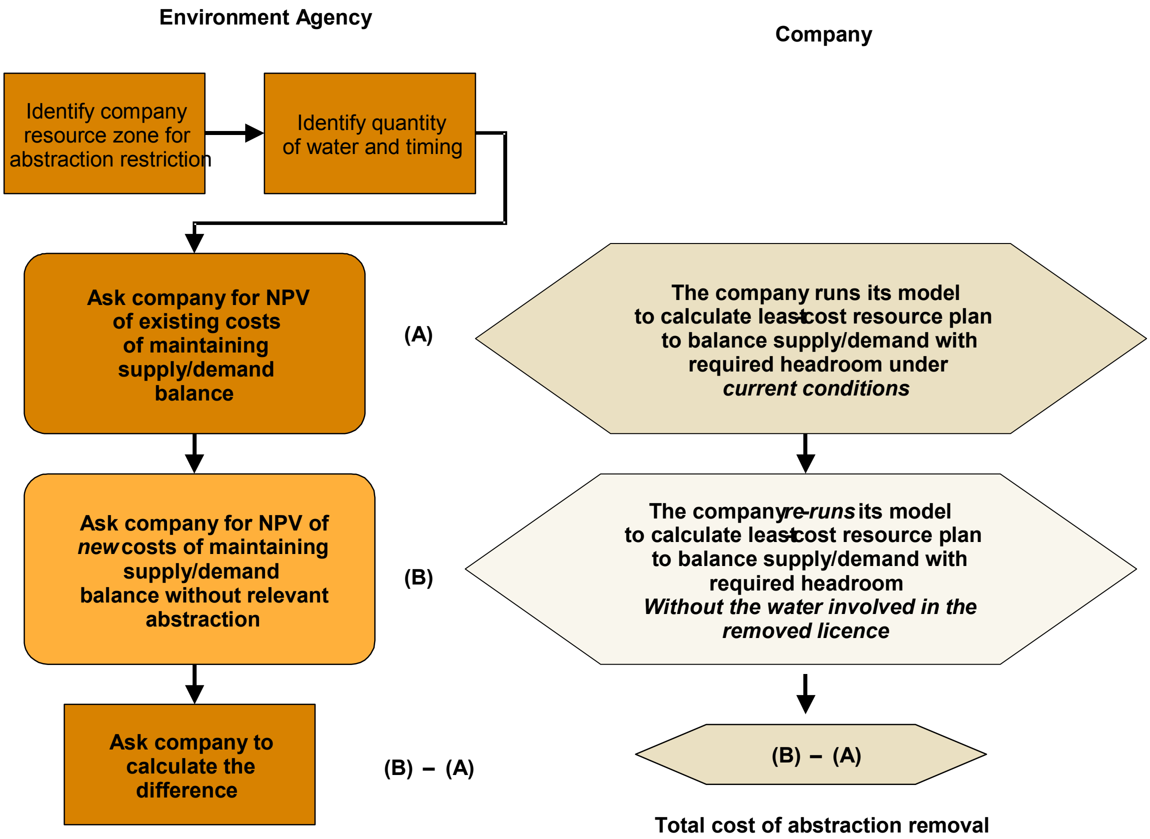
The impact of abstraction reduction is likely to be very different for each company. One company commented that the initial assessments on the EA's programme of 'restoring sustainable abstractions' are largely uncertain, especially in relation to surface water and reservoirs. However, the current understanding on groundwater is that the impact could be in the range of 130-140 Ml/d. This would have a significant impact and no actions have yet been, or are being, undertaken except for investigatory work.

7.2 Step changes

When calculating the effect of abstraction licence withdrawal, account has to be taken of step changes in costs. In some cases, relatively expensive options might be needed to address the supply/demand balance, while, in others, they might not. For example, a calculation of removing 20 Ml/day may result in a certain additional cost; however, if more is removed, the total additional cost may be much higher. When assessing the costs of abstraction licence removal, the estimator will need to undertake the following steps, illustrated in Figure 9:

- identify the company resource zone where abstraction removal will occur;
- detail the timing and amount of water to be removed;
- ask the company for the total social cost (including environmental) of maintaining the supply/demand balance and maintaining headroom, over a suitable planning horizon (e.g. 25 years) under its current resource plan. This will be expressed as a net present value (NPV) (A);
- ask the company to re-run its resource plan model on the basis of replacing the lost water with new options on the supply or demand side;
- calculate the total cost of the new resource plan (B); and
- calculate the difference in total cost (B – A).

Figure 9 Steps in the calculation of the cost of abstraction reduction



Source: Oxera

It may be decided that it is useful to have the unit cost of the measure in terms of m^3 (or Ml) of water removed. As the relevant cost is the additional cost arising from implementation of the WFD, the calculation will involve taking the total additional cost calculated above and dividing it by the NPV of the total amount of water removed (in m^3).

The calculations of the resource plans under current conditions and under abstraction reduction should follow the steps provided in the UKWIR guidelines on balancing supply and demand.[21]

The calculations can be undertaken using either:

- a simplified form (less accurate); or
- a more sophisticated form (better representation).

The cost to the water companies of withdrawing abstractions from a river basin can be seen as the cost of the next lowest-cost resource or combination of resources (e.g. leakage control, bulk supplies or new reservoirs) to provide the original amount of water. It is a concept of opportunity cost and varies by location, amount of water taken and timing of when the water is required. External non-environmental and environmental costs and changes in consumer surplus can be added to provide a *social* cost.

[21] UKWIR (2002) The Economics of Balancing Supply & Demand Guidelines

To arrive at such a cost, the simplified form takes into account a ranking of schemes in ascending order of average incremental social costs (AISCs). The procedure involves the removal of the specific abstraction as one of the options in the current resource plan, and its replacement with new options that restore the amount of water withdrawn in the new resource plan (see Figure 10).

Figure 10 Simplified AISC calculation

Current Resource Plan

Option	Year	AISC
Option D	Year 5	25 p/ m^3
Option C	Year 3	20 p/ m^3
Option B	Year 1	15 p/ m^3
Option A: Abstraction	Year 1	12 p/ m^3

NPV= 400

New Resource Plan

Option	Year	AISC
Option E	Year 5	30 p/ m^3
Option D	Year 5	25 p/ m^3
Option C	Year 3	20 p/ m^3
Option B	Year 1	15 p/ m^3
~~Option A: Abstraction~~	~~Year 1~~	~~12 p/ m^3~~

NPV= 500

Source: Oxera

In this simplified model, the result of the abstraction licence withdrawal will be to remove a relatively cheap resource, with an AISC of 12 p/m^3 in year 1, and to replace the water with a more expensive resource, with an AISC of 30 p/m^3 in year 5. The change in costs is 18 p/m^3.

The UKWIR guidelines on balancing supply and demand, and the UKWIR main report on the supply/demand balance, provide essential background information.[22]

With the use of more sophisticated models, it is possible to arrive at least-cost plans with lower NPV than with a simple AISC decision rule. It is possible to account for synergies between options, which is particularly important when options have a high proportion of fixed costs. The order of the schemes selected may be different when such a technique is used. For example, the current and new resource plans arrived at under such a technique could show a different order in the selection of the schemes, and yet deliver a lower NPV on costs than using the simple AISC decision rule (see Figure 10).

The new resource plan is shown above with the same relative order for options C, B, and D. Once the abstraction licences are removed, the new resource plan not only has to include the additional option E, but may also rearrange the order of existing options. For example, if E has a large proportion of fixed costs, and, in option D, all costs are variable, the optimised plan may result in a full utilisation of E and no utilisation of D.

[22] UKWIR (2002) The Economics of Balancing Supply & Demand, Main Report

7.3 Other adjustments

The above may not, however, represent the cost of withdrawn water where the following arise.

- Circumstances have changed since the year when the resource plan was calculated.
- There are joint and common costs when schemes serve more than one purpose (e.g. resources and quality).
- There is an interaction with the costs of downstream activities such as treatment and distribution.

7.4 Examples of calculations from companies and issues arising

Following the interest shown by companies, on 16 May 2005 Ofwat wrote to companies asking them to take part in an exercise that would provide examples of estimations of the unit costs of re-allocating abstractions.

One company gave figures for both an individual resource zone and for the company as a whole. In the individual zone, they forecast that the WFD would reduce deployable output by 5 Ml/d from 2011-12. For the company as a whole, they predicted that it will decrease their deployable output by 50 Ml/d. The predicted shortfall will be met by a combination of leakage reduction and sources enhancement.

The methodology adopted to calculate the unit cost of achieving this reallocation for the company as a whole and for the zone is the simplified form described above. The estimates for the zone and for the company overall differ with lower unit costs for the whole company than for the individual resource zone. The difference is considerable: 27p per m^3 for the company's whole area, as opposed to 126p per m^3 for the individual resource zone.

Ofwat will endeavour in the next few months to collate information from companies to elicit cost estimates that are suitable for use in the national cost-effectiveness analysis in 2006.

APPENDIX A

Terms of Reference

A1. TERMS OF REFERENCE

Objectives

The purpose of the work is to pave the way to develop analytical tools that allow Ofwat to input to the DEFRA and EA first iterations of the CEA.

This study should review existing work and assess limitations and issues around elicitation of cost functions to forecast total cost of improving the quality of treated sewage effluent (i.e. achieving tighter standards) and improve the sewer network to reduce environmental impacts of sewage outflows. Changes to one or more parameters and quantity of sewage treated ought to be considered and major limits to developing models for forecasting the costs of single parameter changes or simultaneous changes to several parameters should be identified. The study will look in depth at one parameter change and for this it will elicit a cost function.

The study should also help Ofwat review the work carried out on the water supply and demand balance and assesses the usefulness of the existing methodology in estimating the cost of measures aimed at reducing environmental impacts of water companies' abstractions.

In light of the review of existing methodologies, available information, testing for one parameter within the overall CEA framework, the study will provide recommendations as to how to structure the follow-up study to elicit cost estimates for changes in one or more parameters and the quantity of sewage treated.

Scope

The study shall include but not be limited to:

- reviewing relevant work already carried out by water companies;
- eliciting a preliminary view from EA risk assessment team as to the type of improvements that companies are most likely to be required to deliver;
- assessing the usefulness of the information already collated by Ofwat;
- assess major issues around developing cost functions to analyse the delivery of tighter standards and/or changes in treatment capacity, as well as network enhancements to reduce the frequency and impact of sewage outflows;
- identify the limits, to the extent that this is feasible within the scope of this project, imposed by currently available information on the choice of analytical tools (e.g. the functional form);
- review the work carried out by companies to identify and take advantage of synergies between different activities at the same sites (e.g. synergies between maintenance and quality enhancement work);
- help in reviewing the suitability of existing methodologies used in the economics of water supply and demand balance to elicit costs of reducing the environmental impact of water companies' abstractions.

Approach

The CONTRACTOR should review the work carried out to date by water companies on cost analysis and assess the usefulness of the companies' approach for this project. Depending on the findings of this review, the CONTRACTOR may recommend the use of some aspects of the companies' analysis in development of the methodological framework to elicit costs of water industry environmental improvements. The CONTRACTOR will collect the relevant information from the companies. Ofwat will facilitate this task by liaising with companies and identifying key individuals and/or departments to be contacted.

The CONTRACTOR should seek from the EA characterisation team, other key EA members of staff and UK Technical Advisory Group members clarification as to which environmental improvements water companies are most likely to be asked to deliver in order to contribute to the achievement of the WFD environmental objectives. Following the collation of this information the CONTRACTOR should discuss and agree with Ofwat the improvements to focus the cost analysis on.

The CONTRACTOR should acquire familiarity with the theoretical underpinnings of the methodological framework of the DEFRA and EA approach to CEA and the elicitation of costs for other industries. This approach is being developed by the EA/DEFRA-led CRP Project 2b. To gain familiarity with the outputs of Project 2b is important in order to work on a methodology for eliciting water industry cost estimates that are comparable with those elicited for other industries and can readily be inputted into the CEA framework developed for DEFRA/EA.

The CONTRACTOR should ascertain the robustness of the cost function elicited for one parameter change, engaging in this assessment the appropriate water industry representatives and other stakeholders indicated by Ofwat.

Key tasks
In order to meet these objectives, it is expected that the study will need to include the following tasks.

I. Review of water companies' relevant work. This will involve contacting appropriate individuals within companies to discuss their approach to cost function analysis and collect relevant material that companies are willing to provide.

II. Collect companies' views on what they regard as their most likely environmental problems post-PR04. Consider this information alongside that provided by EA and UK Technical Advisory Group under task III to form a view as to the improvements that companies will be required to deliver.

III. Consultations with appropriate EA staff and UK Technical Advisory Group members and assessment of most likely areas of improvements that companies will be required to deliver.

IV. Acquire familiarity with the cost analysis carried out for other industries within the context of the WFD CEA (DEFRA and EA work on cost). Seek consistency with this analysis (i.e. cost estimates for different industries potentially affected by WFD ought to be comparable). This task will involve participating in meetings as required and considering relevant documents prepared for the CRP Project 2a and 2b.

V. Theoretical review of relevant aspects of production economics and selection of appropriate functional forms.

VI. Analysis of information that Ofwat currently collates from companies (e.g. June Returns, Business Plans) and identification of information gaps.

VII. Use of currently available information to elicit cost function for one parameter (this will probably be phosphorus). This will be used to contribute to the CEA methodology testing in April 2005. In eliciting this cost function the CONTRACTOR should be mindful of the influence on costs of local/regional differences.

VIII. Ascertain the robustness of the findings of the cost function analysis carried out for one parameter. This assessment will involve water industry representatives and other stakeholders indicated by Ofwat. The CONTRACTOR is required to assess the most cost effective way to carry out the validation exercise. Results from the validation exercise and assessment of the water industry cost methodology within the overall CEA framework should be considered and if necessary used to change some of the analysis before making recommendation in the final report.

IX. Help Ofwat review of existing methodologies used by the industry to elicit costs of reducing the environmental impacts of water companies' abstractions.

Deliverables
The CONTRACTOR is required to produce three main outputs:

- An interim report
- A draft final report
- A final report.

APPENDIX B

Questionnaire

B1. QUESTIONNAIRE

B1.1 Water Framework Directive Cost Effectiveness Analysis

Introduction

A Collaborative Research Programme (CRP) has been established to address the needs of the UK in meeting the requirements of the Water Framework Directive. This programme involves DEFRA, Scottish Executive, the Environment Agency, SNIFFER, SEPA, English Nature, DTI and UKWIR.

The project, Assessing Costs and Benefits of Options in River Basin Management for Implementing the Water Framework Directive, will run from April 2004 to March 2007. The project has six sequential projects, of which, Project 1 has been completed, and Project 2 is under way. The objectives of these projects are summarised as follows:

Project 1: developing a better understanding of how economic analysis can best be used to support the decision-making processes leading to the selection of measures to be included in the Programme of Measures

Project 2: determining how to assess costs and economic impacts for each of the distinctly different sectors for which control measures will need to be appraised in River Basin Management Plans (RBMP's) (agriculture, water industry etc).

Project 2 has different components: the first two are Project 2a, which focuses on determining the approach to assessing effectiveness within CEA; while Project 2b is focused on developing a methodology for an even-handed assessment of costs and economic impacts.

Studies will follow to complete Project 2.

The Ofwat project

As part of the CRP, numerous organisations are providing contributions, some of which are in kind. Ofwat is contributing to the CRP project through participation in the Steering Groups and workshops, and is undertaking a separate study, which will primarily feed into Project 2b.

The aim of this phase of the Ofwat study (ending May 2005) is to provide an input, in the short term, into the development and testing of the methodology for the cross-sector CEA. In the longer term, it will input into the first iteration of the cross-sector CEA.

The Ofwat study will review water industry measures in the areas of water quantity and wastewater collection, treatment and disposal. The first-stage objective will be to derive a cost function for one trial measure (phosphorus removal) and changes in water abstraction. A follow-up study (post-May 2005) will examine other measures relevant to WFD. The study will include assessment of the level and quality of information already available to Ofwat and the water companies.

Ofwat have appointed Arup and Oxera to manage the provision of information to the CRP project, through consultation with the water industry, collection and analysis of information.

Their terms of reference briefly comprise:

- Reviewing relevant work already carried out by water companies
- Eliciting a preliminary view from the EA risk assessment team as to the type of improvements that companies are most likely to be required to deliver
- Assessing the usefulness of the information already collated by Ofwat

- Assessing major issues around developing cost functions to analyse the delivery of tighter standards and/or changes in treatment capacity, as well as network enhancements to reduce the frequency and impact of sewage outflows
- Identifying the limits, to the extent that this is feasible within the scope of this project, imposed by currently available information on the choice of analytical tools (e.g. the functional form)
- Reviewing the work carried out by companies to identify and take advantage of synergies between different activities at the same sites (e.g. synergies between maintenance and quality enhancement work)
- Helping in reviewing the suitability of existing methodologies used in the economics of water supply and demand balance to elicit costs of reducing the environmental impact of water companies' abstractions

Purpose of this questionnaire

This questionnaire is the first formal part of the information-gathering process with the water industry, and as such, forms an important part of the input into the overall project.

The key objectives for this project are:

- Develop a framework for assessing the costs of water company measures for:
  - Improving the quality of sewage effluent
  - Reducing the impact of sewerage system overflows
  - Reducing environmental impacts of water abstraction
- Elicit a cost function for one parameter (probably phosphorus)
  - Develop functional form
  - Identify and fill information gap(s)
  - Test the methodology and quality of the data
  - Assess robustness and usefulness in the context of the WFD CEA analysis
- Review existing methodologies and information for eliciting the costs of reducing the environmental impacts of water abstractions
  - Review existing methodologies (e.g. LRMC/AISC)
  - Assess usefulness in the context of the WFD CEA analysis

We are seeking your views on the following broad areas:

- What work has the industry done in considering the implications of the WFD
- What types of measures does the industry anticipate delivering to deal with WFD drivers?
- Has the industry the cost information to be able to price these measures?
- What are the most significant generic and local cost drivers that affect each of these measures?
- What are the financial and economic impacts if other sectors should deliver environmental improvements, which might for instance, reduce the requirement for effluent treatment.

Next steps

Following examination of the questionnaire responses, an industry workshop is being held on 1 March 2005, to examine these issues in more detail. Thereafter, a more detailed information-gathering exercise will be undertaken, which will focus on more specific issues.

B2. QUESTIONS

Who has responsibility in the company for cost modelling of the wastewater capital programme, who would be our key point of contact for this WFD project?

Name: ______________________________

Position: ______________________________

Company: ______________________________

Address: ______________________________

____

____

Telephone: ______________________________

The initial phase of this project is examining phosphorus removal as a trial input into the CEA methodology. Has the company undertaken any investigation of the marginal costs of P removal in wastewater treatment?

Yes ☐ No ☐

Do you have an opex cost model which deals specifically with phosphorus removal?

Yes ☐ No ☐

Is this disaggregated into cost components such as energy, transport, sludge, chemicals? (Y/N):

Energy

Sludge treatment

Sludge transport

Sludge disposal

Chemicals

Waste disposal

Maintenance

Labour

Others (list)

What do you believe are the most important site-specific factors that influence the cost of delivering a phosphorus removal (e.g. current treatment process, land availability, ground conditions etc).?

Capex	**Opex**	
1.	1.	Most important
2.	2.	
3.	3.	
4.	4.	
5.	5.	Least important

What are the secondary consequences of P removal (e.g. sludge treatability, other process benefits/ disbenefits) that would need to be taken account in the cost model/ economic appraisal?

1.
2.
3.
4.
5.

Has the company, through other studies, considered the wider economic (environmental, social and financial) impact of P removal?

Yes ☐ No ☐

Do you have any other comments on issues associated with cost modelling of P removal that you want to add at this stage (e.g. future technology change)?

Yes ☐ No ☐

APPENDIX C

Questionnaire Results

C1. QUESTIONNAIRE RESULTS

Seven of the ten water and sewerage companies responded to our questionnaire and their anonymous responses are summarised as follows.

- A majority of companies (5/7) have completed some investigation of the marginal costs of P removal.
- An equal number of companies (5/7) have developed an opex cost model specifically for P removal. Most companies can provide some level of disaggregation of their opex data, principally into components of energy, sludge treatment, sludge transport, sludge disposal, and chemicals. To a lesser extent, some companies can also supply component data for maintenance, labour and waste disposal costs.
- Fewer companies (4/7) have undertaken further studies of the wider economic impact of P removal.

This demonstrates that some companies are already thinking about the issue of phosphate removal, which supports our perception that the water industry has access to high-quality cost information on its business. We hope to be able to gather and utilise this information as part of the current Ofwat project.

Scores were calculated for each company, based on a scale of 1-5 (1-least important, 5-most important). This methodology was used for Figure 11 and 12.

Figure 11 Factors affecting capex

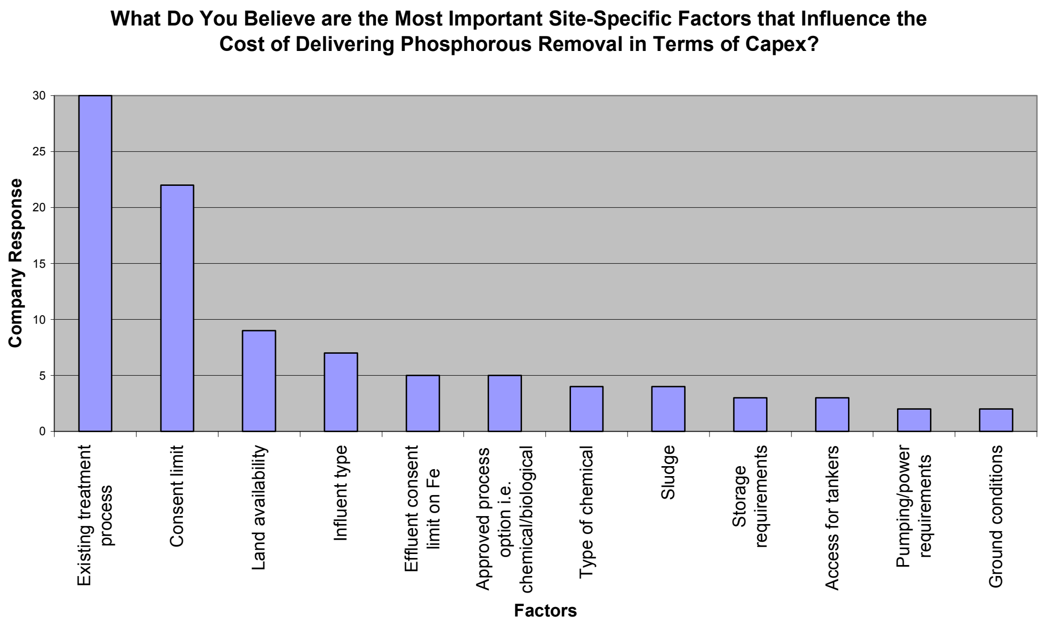


Figure 12 Factors affecting opex

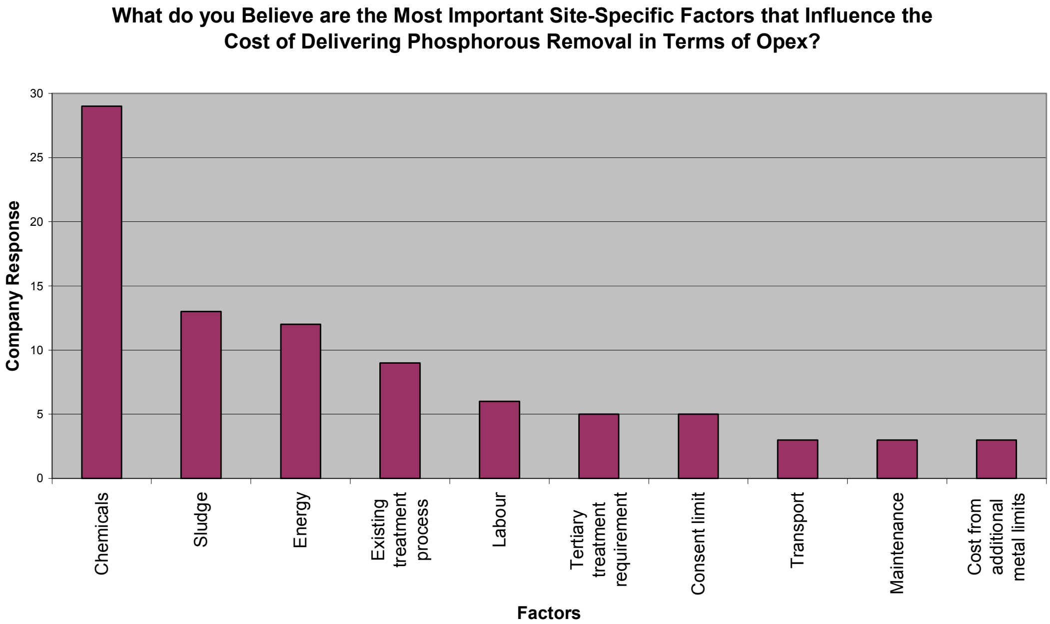


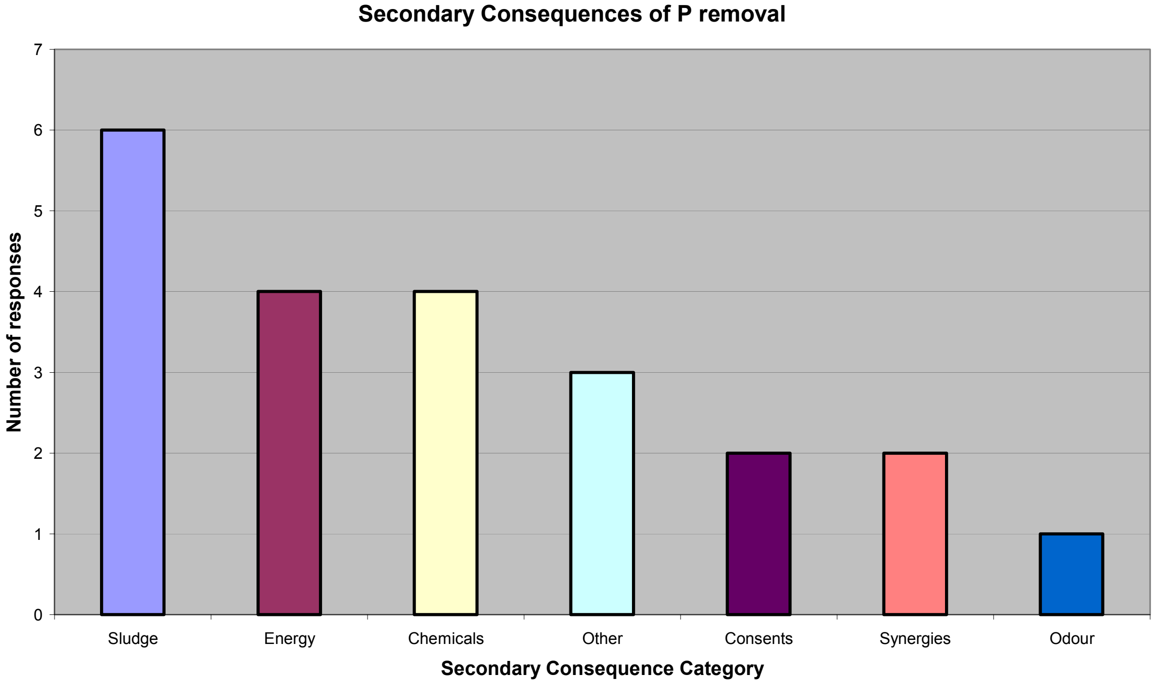
Figure 13 Secondary consequences of P removal

Company a	Company b	Company c	Company d	Company e	Company f	Company g
For BNR, possible synergies with other process improvements (e.g. N reduction)	Regulatory approval for chemical dosing	Transport/ cost of additional sludge	Sludge: quantity, quality and treatability	Increase in sludge volume	Increased sludge, more problematic sludge nature	Additional transport
Possible reduction in chemicals for odour control	Lack of availability/ sustainability of chemicals in scale required	Benefit to odour/ digestion if ferric salts used	Metal limits on consents	Increase sludge dry solids	Risk of suspended solids non-compliance if tertiary treatment not used	Increased energy use
Use of BNR might reduce sludge digestion performance	Energy consumption/ CO_2 emissions	Additional power, esp. if tertiary treatment	-	Need for good settlement and auto-desludging	Chemical hazards and availability	Odour implications
Sustainability of chemical v. biological P reduction	Power – security of supply over national grid	-	-	Need for plant automation	Consent compliance risk (OPA)	-
Subsequent need to P-dose potable supplies for lead standards	Aggregate/ concrete requirements sustainability	-	-	Safety measures for chemical handling	Sustainability – energy, transport	-

Response ‘Sustainability – energy, transport’ from Company f was attributed to both ‘Energy’ and ‘Sludge’ in Figure 14.

We have summarised the responses on secondary consequences of P removal into a number of categories, as shown in Figure 14.

Figure 14 Secondary consequences categories



In the above graph, the ‘other’ category includes a diverse range of individual responses that were difficult to classify within a single category, such as the need for plant automation.

The above information helps to validate our modelling approach, particularly in relation to the factors that affect both the capital and operating cost of phosphate removal. In addition, understanding the secondary consequences of phosphate removal will assist us in obtaining further information, which will form part of the output from this study.

APPENDIX D

Workshop Feedback

D1. WORKSHOP FEEDBACK

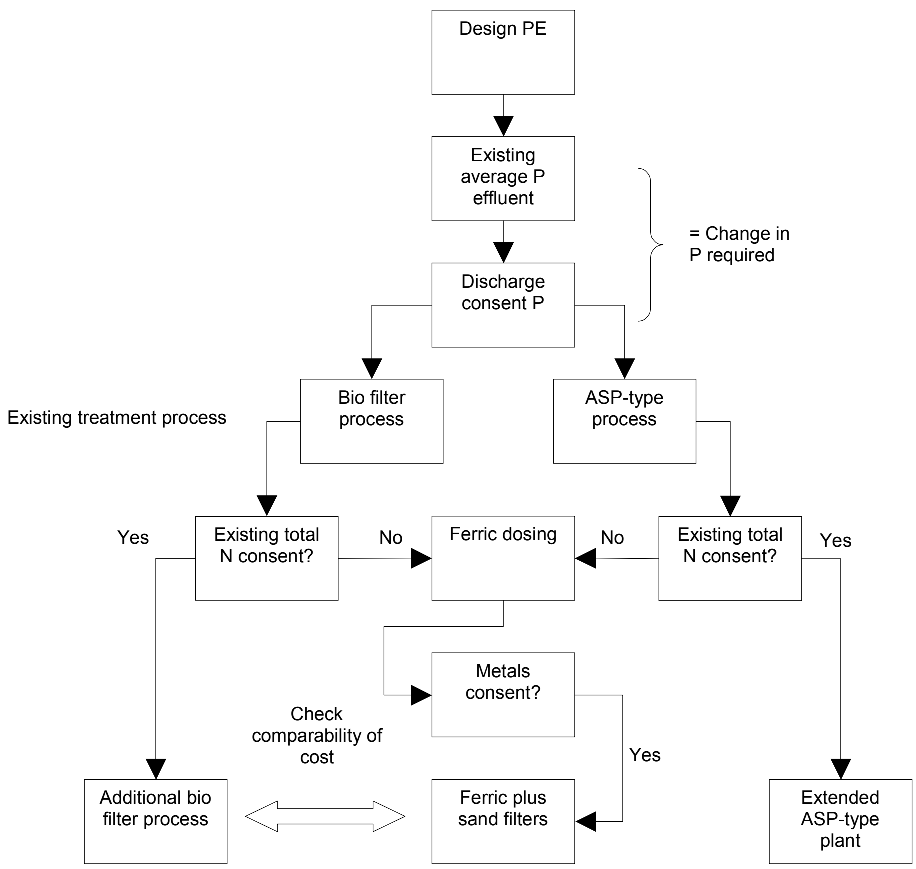
A workshop was held on 1 March 2005 with representatives of all the water and sewerage companies in England and Wales, together with a representative from one of the water-only companies. The workshop was both an opportunity to update the industry on the progress of the DEFRA CRP and the Ofwat project, and a chance for a closer dialogue with the industry on a number of specific issues. Attendees were also present from the EA, DEFRA, Ofwat and academia.

In the afternoon workshop sessions, the attendees were asked to give their views on three specific topics:

- modelling work to date;
- proposed process selection flowchart and input sheet;
- issues surrounding the modelling of other potential measures such as CSO's/intermittent discharges.

At the workshop, we also presented a generic decision flowchart, which we used to validate our own understanding of the general decisions made by the water companies when designing a new phosphate removal plant. This information will form part of the background working of the model and input sheet.

Figure 15 Draft process decision flowchart



The flowchart was broadly accepted by the water companies as being a good generic starting point for the exercise, with the following observations.

- Some companies have both a biological media filter and ASP processes in parallel; thus, the distinction is not so clear as presented above.
- Ferric is not the only chemical used, so a more generic description of ‘chemical dosing’ is preferable.
- Choice of process will also be determined by the space available and the relative economics of each option.

Companies considered that biological media filters were unlikely to be economic. They are more expensive to build and operate than alternatives and are not as robust a process as BNR.

Feedback from the workshop was positive, with a number of issues being raised during the day, summarised as follows.

- Water companies were concerned about the long term economics and sustainability of chemical dosing, particularly as prices had increased significantly in the recent past.
- Effects on sludge are more associated with treatability than volumes.
- ‘Demand management’ of P loads – companies considered that the introduction of trade effluent consents might influence this, but would require a change in the licensing regime; companies were also concerned about a potential loss of revenue.
- The effects of the introduction of combined consents (e.g. for nitrogen or ammonia) also need to be considered in the cost model – there are potential synergies.
- Water companies noted that the remaining life of the assets was important in deciding the type, scale and cost of any new treatment process.
- Where new consents are introduced, water companies may consider moving the load discharge to another less sensitive location (e.g. discharge of septic tank loads).
- Is phosphate recovery an economically viable option?
- Does the agricultural sector fully appreciate the beneficial levels of phosphate content of sludge currently applied to their land?

All of these issues were considered as part of our completion of this project.

APPENDIX E

Interim Report Consultation Questions

E1. INTERIM REPORT CONSULTATION QUESTIONS

The following is the text with the questions sent to companies in the Interim Report. The section numbers refer to sections of the Interim Report.

We would appreciate feedback from the water industry on the following questions, some of which have direct reference to further detail in this report (where indicated). These will help us to capture a wider industry perspective as part of this study and will be summarised in our final report to Ofwat and the wider CRP.

1. Do companies have any comments on our proposals for modelling of phosphate removal and issues raised on water resources during this first pilot study of Cost Effectiveness Analysis? (**Sections 4 and 5**)
2. Is your company developing or proposing to use any new technologies relating to phosphate removal (for example, phosphate recovery) which may materially change the cost of delivering this treatment in the next 5-10 years? What are these new technologies and to what extent will these increase or decrease current levels of capex and opex from the most appropriate alternative solution (such as ferric dosing or BNR)? (**Section 3.1**)
3. We will welcome information from water and sewerage companies on the degree of vulnerability of water bodies in their area, and whether abstraction licences or discharge consents have been removed as a result and what action they have had to take. (**Section 3.3**)
4. Can companies provide cost information which reveals the marginal cost of phosphate removal in circumstances where TON consents are deployed? (**Section 3.4**)
5. Do companies agree that trade effluent consents and plumbosolvency dosing are the most obvious interfaces with the water industry in reducing phosphate loads entering the wastewater network? Are there other areas where the water industry has the potential to directly influence phosphate loads entering the wastewater network? What are these? (**Section 3.5**)
6. What do you regard as your most likely and significant environmental problems after 2010? If possible, please provide an indication of the scale of potential investment that may be required. (**Section 5.3**)

7: Do companies believe that further research is required into the sources of phosphate load entering the wastewater network? (**Section 5.4**)

8: What component of phosphate loads in the sewer network do companies believe arises from domestic loads (e.g. washing powders)? (**Section 5.4**)

9: Do companies agree with the completeness and adequacy of our proposals for further data capture as part of this project? (**Section 5.7**). Will you be able to provide the required information as part of this project?

If there are any other comments or views which you would like to make in relation to this Interim Report or the wider CRP, please feel free to direct these to Arup, Oxera or Ofwat.

APPENDIX F

Interim Report Consultation Responses

F1. INTERIM REPORT CONSULTATION RESPONSES

<u>Question 1</u>: *Do companies have any comments on our proposals for modelling of phosphate removal and issues raised on water resources during this first pilot study of CEA? (**Sections 4-5**)*

Eutrophication remains a water quality issue and phosphate control is a key driver in AMP4 under the Habitats Directive
Concerned that current policy can drive unsustainable investment decision-making without clear understanding of goals that can be achieved and commitment to wider catchment management issues
Biological solutions less likely. Tertiary treatment driven by existing process, current consent and catchment issues
Current P load is not a design parameter. High loads are easier to meet percentage removal standards. Key drivers are target consent, consent type and current process (filter works more likely to need tertiary treatment)
Capex/ opex are not continuous functions – they are driven by a step change in process, triggered by assessment of non-compliance risk
Concern at using LRMC costs. Company have very large demand zone compared with other companies (1600 Ml/d). Removal of 10-20% of resource would therefore have a significant impact that would mean costs escalate sharply above LRMC
Study assumes that chemical dosing (ferric or alum) is an available option for removal of phosphorus within context of WFD, but shortage of chemicals, rising prices and metals associated with dosing are of concern to environmental regulators
Concern has been expressed about the use of LRMC, due to build-up being related to 'small changes' in company's demand
Noted that a 10-20% being proposed, above which LRMC estimates could not be used. Estimating the 10% lower bound is too high for automatic inclusion – suggest 5%, or use of specific estimates for licence removals
Additional sludge treatment needs to be considered
ASP's have lower capex than biological filters, but higher opex and lower overall NPC. ASP's also more likely to meet the type of consents used by EA than media filters
Process choice – site-specific chemistry is a factor. Would prefer to use ferric chemicals, but may have to use alum, which is more expensive in opex and capex
Relevance of LRMC not recognised, as cost of providing new resources could be much higher than LRMC
Banded design capacities for the model dues should be small enough to reflect range of works in industry (i.e. should include <250, 250–1000, etc)
For sites < 100000 PE, biological filters can be more cost effective than ASP's
Study pre-supposes that chemical dosing (ferric/alum) is an available option in removal of phosphorus as requirement of WFD – but these are of concern to environmental regulators
Shortage of such chemicals for phosphorus removal
Claim science linking ecological status with nutrient loadings not well developed
Recommend study be developed in order to consider impact of intermittent discharges upon water qualities when costing implications of meeting WFD
Intermittent discharges can contribute significant pollution load – point source may not adequately reflect the costs that would be incurred to reduce phosphorus loads to meet requirements of the WFD

Concern at using LRMC for costing. Removal of licence would have substantial (rather than marginal) effect on inputs
Suggest examining cost effects of removing specific water abstraction licences
Requirement for step change in the degree of investigation of the costs of removing abstraction licences and requirement for alternative supplies
Refusal by EA for chemical dosing and stringent metal consent standard may mean that chemical dosing is **not** feasible. Not currently reflected
Unlikely that sufficient chemical could be made available even at additional costs for short to medium term
Use of phosphorus load per PE can overestimate the influent load. Alternative is to review against average P mg/l in WFD
Data capture does not incorporate implications that widespread phosphorus removal would have upon treatment costs for additional sludge produced. Sludge treatment needs to be assessed at regional level
LRMC is irrelevant for this study and the consequences of removing an abstraction licence will not be marginal, but step change. Alternative approach is needed
ASP's more expensive to operate than traditional filters (power).
Need to recognise that improved effluent quality comes with rising incremental cost
Plants built to meet nitrogen limits may not significantly reduce phosphorus as well. Not all sewage influents are suitable for biological P removal, and existing ASP's may need chemical addition to assist with this process.
Current cost data based on 1-2 mg/l consents, which may not be applicable in the future (if they are more onerous). Future costs may be disproportionately higher
Modest extent of P reduction through any sewage works, as P will be bound to the sludge produced, even without specific P reduction requirements
No comment

<u>Question 2</u>: *Is your company developing or proposing to use any new technology relating to phosphate removal (for example phosphate recovery) which may materially change the cost of delivering this treatment in the next 5-10 years? What are these new technologies and to what extent will they increase or decrease current levels of capex and opex from the most appropriate alternative solution (such as ferric dosing or BNR)? (**Section 3.1**)*

Process selection generally driven by standards. 1-2 mg/l is the norm, therefore chemical dosing predominates or rarely biological removal
Assuming effluent targets at current levels, don't anticipate departure from current processes. Higher standards would require more novel and resource-demanding processes
Looked into possibility of mitigating costs of treatment and making processes more sustainable through phosphate recovery – no market at present and recovery from sludge can be problematic
Chemical dosing – predominates, economic to retrofit to both ASP and filter sites, but less effective at filter works. Generally achieved using iron salts, key issue is supply of iron salts (waste product from steel industry). The step change in both capital & operating costs arises where tertiary treatment is required (driven by type of consent, existing process constraints, influent quality)
Biological removal – large site required (only two such sites in company's region), seasonal variability (often unsuitable for annual average consents), suitable for specific applications only (needs high strength sewage, e.g. brewery); otherwise external carbon source may be required, high capital costs and therefore future application limited
No proposal to use new technology relating to P removal or phosphate recovery
No proposal to use new technology to phosphate recovery
Anticipate that rising cost of dosing will lead to installation of biological and chemical systems at sites to minimise costs of operation & capital investment
No proposal to use new technology
No proposal to use new technology other than chemical dosing or BNR
No proposal to use new technology
No proposal to use new technology

<u>Question 3</u>: *We will welcome information from water and sewage companies on the degree of vulnerability of water bodies in their area, and whether abstraction licences or discharge consents have been removed as a result and what action they have had to take. (**Section 3.3**)*

No comment
No comment
Water abstraction – key date is Water Act 2012 when the EA can remove/reduce licences on the basis of environmental damage, but onus on EA to compensate for reductions.
Initial assessments on the EA's programme of restoring sustainable abstractions are largely uncertain, though groundwater reductions could be 130-140 Ml/d. This would cause significant impact and no actions yet been taken
Discharge consents – factors affecting additional phosphorus removal from sewage works are: • Four-yearly reviews by EA of no. of significant rivers seem unlikely to create new Sensitive Areas under the UWWTD • EU identified the River Humber as one showing eutrophication, and River Trent is major input to the Humber – would be affected • WFD Common Implementation Strategy activity on eutrophication working to harmonise approach, may well support EU rather than UK approach
EA analysis for WFD showed Rivers Trent and Severn subject to significant pressures as a result of point sources of nutrients
No consents removed to date. Main action resulting has been installation of phosphorus control at works > 10,000 PE discharging to Sensitive Areas
No comment
Humber estuary and North Sea at risk of 'Sensitive Waters' under UWWTD. Either would drive significant investment at largest and complex WWTW
No comment
No comment
No comment

<u>Question 4</u>: *Can companies provide cost information which reveals the marginal cost of phosphate removal in circumstances where TON consents are deployed? (**Section 3.4**)*

No examples of phosphate and nitrate are required at given site
Generally, phosphate is limiting nutrient for eutrophication in inland waters
Primary source of nitrate is generally diffuse/agricultural
Point-source treatment would not be sustainable or have environmental benefit
Even if plants were rebuilt to meet N standards, still unlikely to include Bio-P removal due to cost of sludge handling
No information to reveal cost of P removal where TON consents are employed
Until very recently, no TON consents applied
Costs would be associated with additional recycles within process, changes to sludge treatment, odour control and additional external carbon source
There are synergies, but no marginal cost data. Could provide, but based on small sample only
No comment
Cannot provide details at this stage
No comment
Plants built to meet nitrogen limits may not significantly reduce phosphorus as well
Not all influent sewages are suitable for a bio-P reduction plant
Cannot assume that nitrifying plant can be modified in such a way without additional chemical addition
No comment

<u>Question 5</u>: *Do companies agree that trade effluent consents and plumbosolvency dosing are the most obvious interfaces with the water industry in reducing phosphate loads entering the wastewater network? Are there other areas where the water industry has the potential to directly influence phosphate loads entering the wastewater network? What are these? (**Section 3.5**)*

Phosphate primarily arises from domestic sources
Some trade inputs such as food processors, paint stripping activities, plating/metal finishers, but smaller fraction
Domestic element – primarily washing powder
Would be gain in alternative product selection/swapping ingredients, but market intervention required
Have looked at plumbosolvency dosing and found that it has little contribution in comparison with other sources
Trade effluents generally not high in levels of phosphate – so limits action water industry can take
Greater education of public in use of detergents required to reduce P loads entering sewer
Alternative detergents may be option. Requires influence outside the water industry
Own evidence suggests that trade and plumbosolvency dosing account for around 20% of incoming load
Agree that plumbosolvency and trade effluent are most obvious interfaces with industry
Do not experience significant loads of P from trade waste except at one site
Majority of phosphates entering system are from diffuse agricultural sources and domestic loads.
Washing powders high in P have significant impact
No comment
Majority of phosphates entering systems are from domestic and diffuse sources
Agricultural/horticultural runoff is another source of phosphorus to combined wastewater and watercourses directly
No comment
No mention of investigating marketing restrictions on, say, phosphorus in washing powders
No comment

Question 6: *What do you regard as your most likely and significant environmental problems after 2010? If possible, please provide an indication of the scale of potential investment that may be required. (**Section 5.3**)*

No comment
Will hinge crucially on requirements of WFD and the definition of 'good water status'. Number of water bodies designated as 'heavily' or 'artificially' modified
Likely areas will be removal of phosphorus and nitrogen, removal of dangerous substances and reduction of endocrine-disrupting compounds
Most significant problem would be removal of total oxidised nitrogen from sewage, which is more significant than P removal due to less experience and certainty over outputs, indicating preliminary capital cost is £145m and operating costs of £18.3m
N removal will generate operational and supply problems since current treatment is methanol dosing
Higher expenditure could result from tighter constraints for Priority Hazardous Substances or endocrine disruptors under WFD
No comment
Most significant potential obligation is WFD and Directives
Potential designation of Humber Estuary as Sensitive Water that would require additional £500m investment
EA map displays areas at risk of failing WFD objectives for nutrients. Remains great risk for company
No comment
No comment
No comment

Question 7: *Do companies believe that further research is required into the sources of phosphate load entering the wastewater network? (**Section 5.4**)*

Ample research in public domain on sources of phosphate
P load entering sewer is well understood
Funding required to monitor trade discharge from phosphorus levels and loads
Yes, further research required
No comment
Industry completed range of R&D activity in this area
Phosphorus is one of many compounds, so would benefit from additional research in this area.
R&D required to control at source issues, additional legal and other powers required to undertake such measures, and resources to enforce new controls
No comment
No comment
No comment

<u>Question 8</u>: *What component of phosphate loads in the sewer network do companies believe arises from domestic loads (e.g. washing powders)? (**Section 5.4**)*

No comment
Portion of P load arriving in sewer network from domestic sources is believed to be in region of 90-95%, although answer to Question 5 contradicts this
Nearly all phosphate loads in the sewer network arises from domestic loads, estimated between 80% and 90% and significant proportion is related to domestic washing powders
Trade customers not measured for P, but do not perceive this as an operational problem or contributing to high loads
No comment
Some R&D been completed historically to review diffuse source loads
No comment
No comment
No comment

<u>Question 9</u>: *Do companies agree with the completeness and adequacy of our proposals for further data capture as part of this project? Will you be able to provide the required information as part of this project? (**Section 5.**7)*

No comment
Will endeavour to provide information where we can
Stringent metal consents applied at specific sites may preclude chemical dosing as a feasible option
There is an existing shortage of chemicals and prices are rising. Will be exacerbated by more widespread usage through requirements of the WFD
Anticipate rising cost of dosing and installing both biological and chemical systems in parallel at a site. Solution unlikely to be simple dosing and have different capital and operating profits
Additional sludge treatment needs to be included
No comment
Data capture does not incorporate impact that widespread phosphorus removal would have on treatment costs for additional sludge produced. Recommend further development in order that costs are more reflective of likely investments. Needs scenario options for scale to be used if there is a possibility of regional obligations
No comment
No comment
No comment

Others: *Other issues raised in response to the Interim Report*

Experience of nutrient removal over 30 years. AMP2 and 3, majority of sites > 10,000 PE have phosphorus control, some half of inland PE
Target concentrations in rivers and lakes are very stringent. Have carried out some investigation to assess the impact of historic investment. Concern that future investment will not achieve objectives, but will attract all environmental disbenefits
None
None
Do not see the relevance of divergence of prices from opportunity costs to the water industry. If principles applied even-handedly across sectors, financial and economic costs will converge
Taxes [that internalise externalities, such as the landfill tax] should not be ignored, as these are normally cheaper and more economically efficient than using environmental standards for each sector
Construction industry capacity is unlikely to be of material relevance
None
None
Funding provided by Ofwat is based on cheapest solution (e.g. ferric dosing)
Disagree that externalities are covered by economic instruments. If it is agreed that noise, odour and greenhouse gas emissions are significant factors, these must be represented in any model
Previous peaks of construction activity have led to increasing prices
Industrial pre-treatment may actually increase the cost of treatment for the undertaker, by reducing the organic strength necessary to facilitate biological P removal
Do economic instruments (fuel tax and vehicle excise duty) really cover environmental and social costs of issues such as traffic noise?
Is RPI the correct index? Should it be construction output price index or construction price index?