The Water Quality of the Tidal Thames

ENVIRONMENT AGENCY

The Water Quality of the Tidal Thames

A Report of the Environment Agency

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Preface

One of the Environment Agency's more important duties is to compile information in order to form an opinion of the general state of pollution of the environment. There are many ways in which such an opinion could usefully be formed, but one of the most constructive is that of looking at specific areas of the environment in an integrated way. By their very nature, estuaries are complex bodies of water, and this complexity is greatly increased by the many activities which take place within them. It was for this reason that the National Rivers Authority embarked on a series of in-depth studies on the major estuaries of England and Wales, reporting on the Humber in 1993 and on the Mersey in 1995. This series has been continued by the Environment Agency, with a first report on that most important of estuaries, the Thames.

It is a good story, but one which has yet to be completed. Quite dramatic improvements have been made in the past, but pressures on the estuary remain and these need careful management. The Environment Agency is thus working closely with others to draw up plans upon which future decisions can be sensibly made, and to ensure that plans for the river upstream of the tidal limit are linked to plans for the downstream, estuarine areas. This report provides the historic and factual evaluation upon which such plans will be based.

R J Pentreath
Chief Scientist and Director of Environmental Strategy

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Cover photograph

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Executive Summary

The Thames Estuary is now considered to be one of the cleanest metropolitan estuaries in the world. A great number of articles and papers have been written for books, journals, conferences and other local and international forums on the clean-up of the Thames. This report, by the Environment Agency aims to bring together the various aspects of the historical and current water quality management of the Thames Estuary into one document.

The report focuses on the success of the Environment Agency and previous regulatory bodies in achieving a water quality in the Estuary which sustains a thriving fish population and other biological life. The setting up of the Environment Agency in 1996, takes the Estuary forward into a new era where the principal aim is to protect and enhance the environment as a whole with a view to achieving sustainable development.

I Introduction

The River Thames drains a catchment of some 14,000 sq. km, with a population of 12 million, 7 million of whom live in the London conurbation. The Thames Estuary may be defined as the river between Teddington weir and its mouth near Southend.

The pollution history, current water quality management and future environment strategy are inextricably linked to the status of London as a capital city, world business, cultural and tourist centre. In recent years considerable attention has been focused by local and national government on the Thames Estuary with a view to developing its potential as a transport artery, recreational resource and as a valuable national asset of which Londoners can be proud.

II The Legislative and Regulatory Framework

An integral part of the clean-up of the Thames Estuary has been the development of local, national and international legislation. The influence of historic legislation and the effect of today's European Union Directives, international agreements and national legislation are summarised by the Report.

III Factors which Affect Water Quality in the Thames Estuary

An estuary is a complex system of interacting processes which influence the fate of polluting matter entering it. The most important factor in water quality control in the Thames Estuary is dissolved oxygen (DO). This is affected by many factors including the amount of freshwater flow from the rivers draining into the Estuary and mixing with the sea water, the tides, the discharge of sewage effluent and storm overflows from the sewerage system. It is only through a full understanding of these interactions that effective management of the Estuary can be achieved.

IV The Pollution History and Clean-Up

The clean-up of the Thames began in the mid-19th century. Following the introduction of the water closet and the abolition of cesspits, all London's sewage was drained untreated into the Thames. Such gross pollution occurred that in the summer of 1858 Parliament had to hang lime-drenched curtains over its windows to lessen the stench. In order to remedy the situation, a combined sewage and storm water system designed by Joseph Bazalgette, was built under London and sewage outfalls downstream of the city were constructed at Beckton and Crossness. Although this improved the situation in central London, the

pollution problem was largely transferred downstream and was subsequently returned upstream on the rising tide.

Nevertheless, this was the start of over 130 years on-going development of regulation, effective legislation and enforcement practices leading to the upgrading of treatment at the sewage treatment works (STWs), strict control of industrial effluents and greater understanding of pollution, its causes and effects.

Significant investment since the 1950s, in updating and improving the major STWs, has resulted in a considerable improvement in water quality. This is evident in the much improved fish population, including the regular return of salmon, the increasing use of the Thames Estuary by anglers, for recreational boating and windsurfing and the prestigious nature of its river-side developments.

V Current Quality Management

The main factors affecting the water quality management today are:

- the discharge of treated effluent from the various STWs serving London. Beckton STWs is one of the largest in Europe. The STWs receive domestic and industrial waste from the most densely populated area in Britain;
- storm water, including foul sewage and surface water discharges from the combined sewer system;
- the effects of freshwater abstraction upstream of Teddington for public drinking water supplies on flows into the Estuary, particularly in summer;
- direct discharge of treated industrial waste water including cooling waters from power stations. (Most of London's industrial waste is discharged to the foul sewer by licence for treatment or further treatment at the STW. The number of direct discharges to the Thames is comparatively small and, as a result of past and continuing co-operation between industry and the regulatory bodies, the impact of these industrial discharges is limited).

In order to sustain the improvements in water quality, these discharges and abstractions are closely monitored and strictly managed interactively within a rigorously enforced legal framework. Crucial to the management of the dissolved oxygen levels in the summer months are Operating Agreements between Thames Water Utilities and the Environment Agency covering:

- improved STW effluent standards;
- operation of the Thames Bubbler for the alleviation of the effect of storm discharges;
- the suspension of abstraction of water above Teddington in order to provide extra flow in the Estuary at critical times.

VI Quality Compliance of the Thames Estuary

The quality of the water in the Thames Estuary is classified as 'good to fair' by the National Water Council Scheme. In 1995 the Estuary was compliant with all the statutory Environmental Quality standards except for copper and all discharges to the Estuary were compliant with their discharge consents.

As mentioned above, dissolved oxygen (DO) is the most critical parameter in the assessment of water quality in the Thames Estuary. The most sensitive period for DO is between July and September, when low freshwater flows and higher seasonal temperatures result in the development of significant DO sags downstream of Mogden and Crossness and Beckton STWs. The responsive management through the Operating Agreements ensured that the effect of these sags was not significant and that the Thames Estuary met its DO objectives for 1995. This example helps illustrate the effectiveness of the current practices in maintaining quality compliance.

VII Biology

The biology of the Estuary gives an important indicator of its health. During the years of gross pollution in the Thames Estuary there was little or no biological life in stretches of the river. With the clean-up of the Thames came the return of its fish and the development of a diverse invertebrate community. The Thames Region of the Environment Agency is examining appropriate biotic indices for measurement of this invertebrate fauna for the Middle and Lower Estuary to complement those already defined for the Upper Estuary and to further improve our understanding of its temporal change.

Some 115 different species of fish have been caught in the tidal Thames since 1964. The outer Estuary is an important spawning and nursery ground for many species of North Sea fish including those of commercial importance and, since the clean-up, adult salmon regularly return to the Thames in significant numbers.

The scarcity of birds during the period of gross pollution was a visual indicator of the poor state of the river. With improving water quality, the bird population returned. There are currently nearly 300,000 water birds which annually over-winter in the Greater Thames, making it the most important estuarine complex for birds in the UK.

VIII Future Strategy

The clean-up of the Thames Estuary has been a considerable achievement and one which should be viewed with some pride. However, the pressures on the Thames Estuary are great and to maintain this achievement and ensure that it is built upon for the future it is vital that plans are made which encompass the requirements needed to sustain the natural environment of the Estuary together with the needs of all the users of this highly valued resource.

Towards this aim, the Environment Agency has developed a Local Environment Agency Plan which, in partnership with the English Nature's Estuary Management Plan, will be central to the management and sustainable development of the Thames Estuary into the new Millennium.

Plate 1.1
The Thames Estuary

1. An Introduction to the Thames Estuary

1.1 Geography

The River Thames extends from its source near Cirencester, Gloucestershire, in the West to the mouth of the Estuary at Shoebury, Essex. The Thames Estuary receives the runoff from an area of some 14,000 sq. km and the waste water discharge from a population of over 12 million, some 7 million of whom live in the London conurbation.

The Estuary is defined as the river between Teddington Weir, located to the West of London (31 km above London Bridge), and Shoebury, just East of Southend. It is approximately 100 km in length, measured along the centre line of its navigable channel.

The tidal limit is at Teddington Weir but the river remains essentially freshwater as far downstream as Battersea. In its upper reaches the Estuary is narrow (100-200 m) and similar in appearance to a lowland river. From Teddington to London Docks the Estuary is commonly referred to as the Tideway. The Estuary remains narrow (<500 m) until Tilbury. Thereafter it widens in a bell-mouth shape reaching a width of approximately 7 km at Southend. Beyond this the vast Maplin sands stretch out along the North shore and the Medway Estuary joins from the South as the Estuary meets the North Sea.

Historically, the Thames was free to meander extensively across its floodplain and a number of these meanders, now cut off, may be seen as oxbow lakes such as that at Mortlake.

The original floodplain of the Tideway and Estuary is now restricted for most of its way by extensive confining walls. These have been built over the years in order to reclaim land, provide new docks and prevent flooding from freshwater flows and North Sea tidal surges. As a result the Thames is now narrower and this restriction has led to an increase in velocity and greater scour of the river-bed.

The Thames catchment supports a diverse range of industry, from agriculture to the manufacture of cars and pharmaceuticals, but the major influence on the water quality of the Estuary has been and remains the development of London and the associated discharge of treated sewage effluent.

1.2 Hydrography

1.2.1 Tides

The action of the tides, the ebb (fall) and flood (rise) of the water level, gives rise to the most obvious difference between inland rivers and estuaries. In the open sea the water surface rises and falls so that there is almost an identical duration of

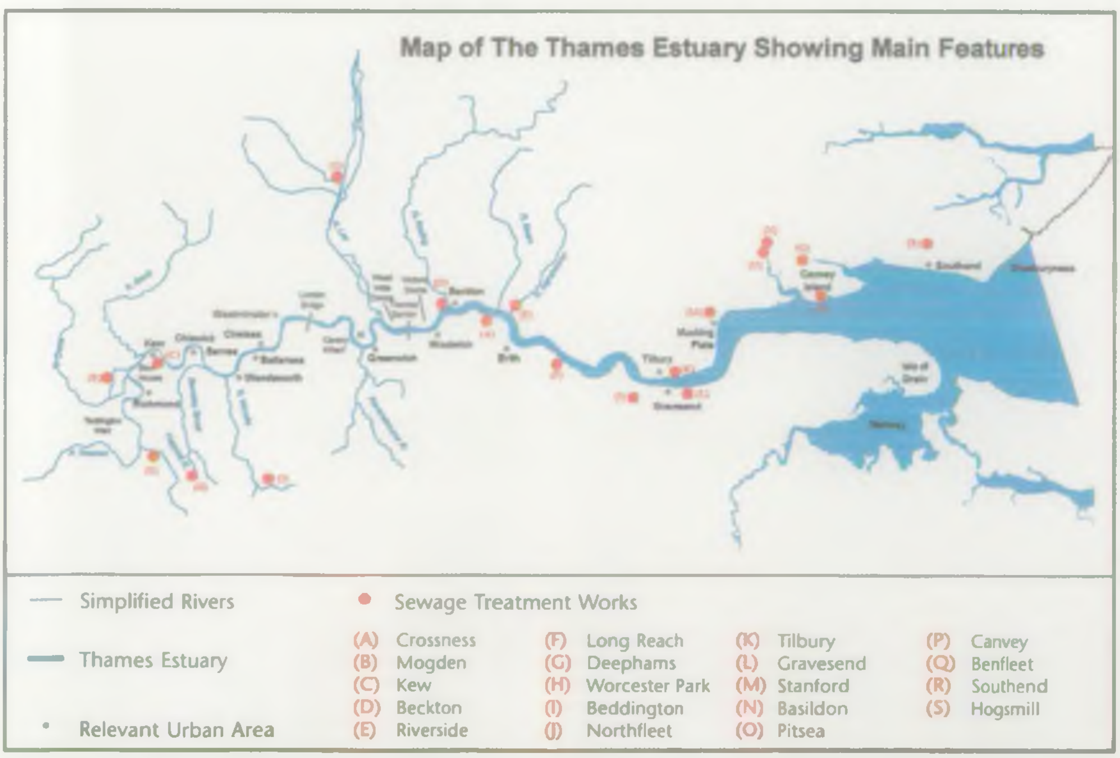


Figure 1.1
Map of Thames Estuary showing main features

Plate 1.2
The Thames Barrier

both the flood and ebb. In estuaries the effect of friction with the bed and the shore alters the duration of the ebb and flood.

In the Upper Estuary the duration of the flood tide becomes progressively shorter and the ebb tide longer with the distance above London Bridge. In effect, the upper reaches 'fill' with water more quickly than they empty. (Although the Thames is tidal between Teddington Weir and the North Sea, the water level is maintained up stream of Richmond for navigation purposes by means of a lock).

There is also a delay in the time of local high water moving up the Estuary. High water at London Bridge occurs one hour to one hour and twenty minutes after high water at Southend, whereas low water occurs about one hour to one hour and forty minutes later at London Bridge than at Southend.

The tidal range depends on the relative position of the moon and sun over a lunar month (28 days) during which time there will be tides with a large range (Spring tides) and tides with a smaller range (Neap tides). At Southend the tidal range is about 6 m for spring tides and about 3 m for Neap tides and at London Bridge 7.9 m for Spring tides and 3.5 m for Neap.

The height of the tide increases upstream. In general, the effect of freshwater flow on the level is slight except above Richmond lock, but at times of very high flow the level may be raised appreciably, even as far downstream as London Bridge.

1.2.2 Tidal Excursion

Tidal excursion is the average distance that a body of water would travel along an estuary from slack water to slack water as a result of tidal action in the absence of displacement by freshwater. The average tidal excursion in the Thames Estuary is approximately 10-11 km. It is necessary to know the tidal excursion in order to understand the dispersion of effluents in the Estuary. Water quality surveys are planned so that samples are obtained for points along the Estuary as if they were all sampled at the same state of tide (half tide).

Longitudinal mixing occurs in the Estuary due to the displacement by freshwater inputs and the action of the tides. The Thames Estuary is only slightly vertically stratified. At slack water there is little difference between the salinity at the surface and that near the bed of the river. During the run of the tide, there is a difference between the salinity mid-channel and that near the banks. For water quality purposes the fact that the Thames is vertically well-mixed means that a sample taken at one point can be considered representative of the quality at that cross section.

1.2.3 Thames Barrier

The Thames Estuary is subject to tidal surges from the North Sea which have the potential to cause flooding. To protect London from this threat and from rising water levels, the Thames Barrier was built across the Woolwich Reach of the Estuary. It was completed in October 1982. During the first ten years of operation the Barrier was closed 11

Table 1.1
Riverine inputs to the Thames Estuary

Watercourse	Flow (Megalitres/day)			
	Q95	Q50	Qmean	Q5
River Thames	554	3228	5210	17114
River Crane	2	27	48	165
Duke of Northumberland	5	29	34	77
River Brent	10	42	86	318
River Brent	18	43	96	344
Beverley Brook	20	37	48	114
River Wandle	60	143	151	270
River Ravensbourne	12	27	38	103
River Quaggy	3	8	13	41
River Lee	295	508	769	2175
River Roding	21	69	167	671
River Beam	6	13	28	99
River Ingrebourne	8	16	29	92

Q95 for 95% of the time the flow is greater than that shown
Q50 for 50% of the time the flow is greater than that shown
Q5 for 5% of the time the flow is greater than that shown
Q Mean based on all available data for a 25 year period

times to protect London. The Barrier does not have a significant influence on the water quality of the Estuary.

1.3 Freshwater Inputs

The main freshwater input to the Thames Estuary is the River Thames itself (Table 1.1) There are a number of other rivers discharging into the Estuary all of which have received polluting inputs from non-tidal reaches and most having drained the large conurbation of North or South London. In the past there have been other tributaries which drained Central London but many were used as open sewers and have now been covered and subsumed into the London sewerage system. During periods of storm they discharge into the Estuary via storm overflows. The freshwater flows over Teddington can vary considerably both between and within years; summer flows are significantly lower than winter flows.

1.3.1 Abstractions

The principal source of public water supply for Greater London is the River Thames between Windsor and Teddington. There are 11 abstraction points operated by 3 water companies, the largest of which is Thames Water Utilities Limited (TWUL) which supplies 90% of the demand.

Abstraction of water for public supply reduces the natural flow over Teddington Weir and this has considerable implications for water quality as there is less dilution for effluents discharged to the Estuary, particularly in the summer time.

The quantity abstracted is authorised by licences issued under water resources legislation and actual abstraction is managed by an operating agreement between TWUL and the Environment Agency. These recognise the need to balance the demand for public water supplies, the requirements of river users and the needs of the water environment particularly during times of drought.

London's demand for water during the summer is approximately 2000 Ml/d. This can readily exceed the natural flow in the river. To meet this demand there is a group of reservoirs close to the lower Thames abstraction points with a total capacity for up to 16900 Ml. Normally the flow over Teddington should be maintained at 800 Ml/d but this can be reduced in stages by 200 Ml/d to an absolute minimum of 200 Ml/d if the volume of water stored in the reservoirs is lower than specified threshold limits. The level of abstraction has increased over the last century from 500 Ml/d to 2000 Ml/d as shown in Figure 1.2.

1.4 Groundwater Inputs and Geology

The London Basin is a broad sagging fold in the chalk with overlying Tertiary deposits. In central London, London Clay overlays a series of sands and clays referred to as the Lower London Tertiaries.

Figure 1.2
Annual Mean Abstraction from The River Thames 1890-1994

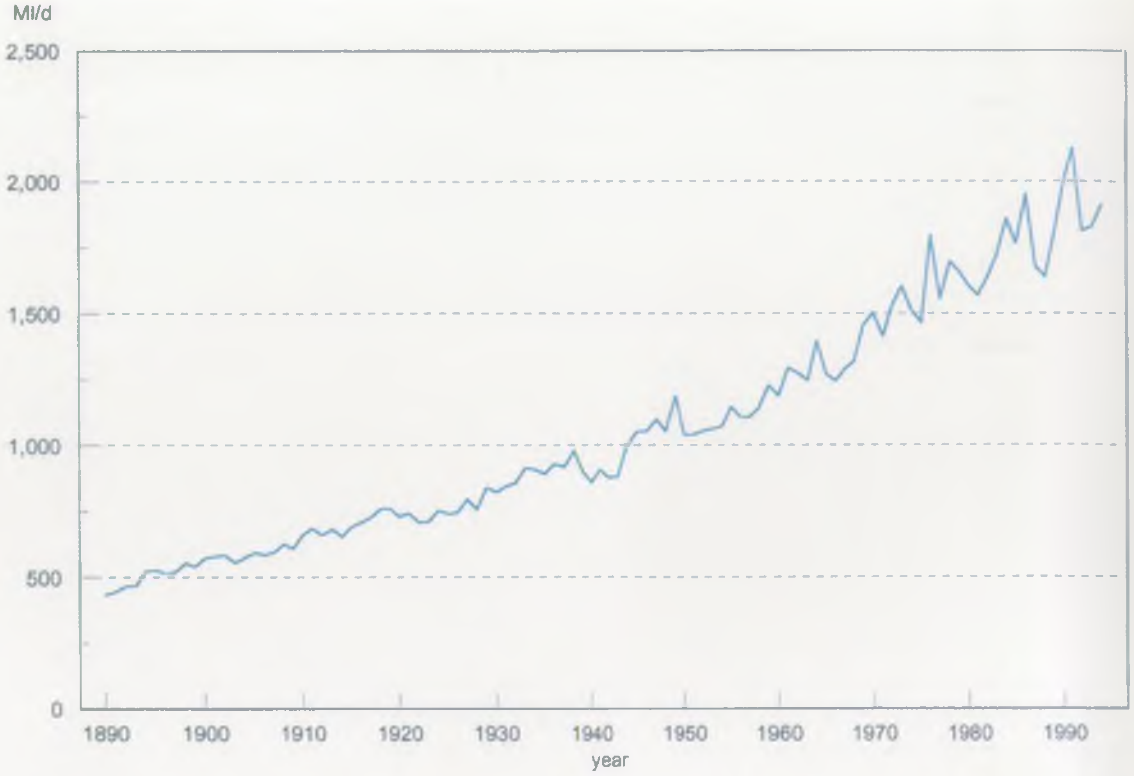
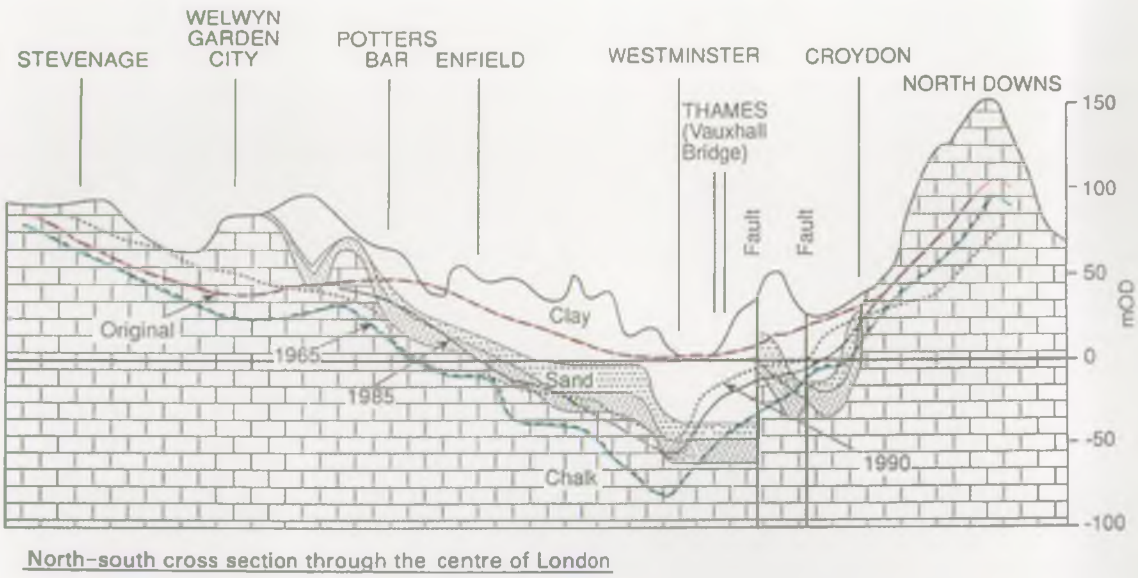


Figure 1.3
Water level changes in the Chalk and Basal Sands Aquifer



The lower deposits are sands and these together with the underlying chalk form the deep aquifer of the London Basin.

The principal source of groundwater in the aquifer is rainfall on the northern and southern Chalk outcrops. Historically most of the groundwater was discharged at springs in valleys close to these outcrops, the remainder being transmitted under the London Clay by seepage through the aquifer and issuing into the Thames Estuary downstream of the Isle of Dogs and in some areas where the clays are absent.

Exploitation of the groundwater as the population of London and demands of industry increased lowered the water levels in the deep aquifer to a minimum around 1965. Since the late 1960s groundwater levels have steadily risen as public and industrial pumping in Central London has declined. By 1988 the rise underneath much of Central London was about 20 m. Continuing rising ground water levels (at Trafalgar Square between December 1992 and December 1994 the rise averaged 2 m a year) has implication for foundations, basements and tunnels under London, it could also mean that fresh groundwater could once again issue into the lower reaches of the Thames Estuary (Figure 1.3).

The Environment Agency is monitoring the situation and is in discussion with other organisations as to how to alleviate the problem.

1.5 London

1.5.1 London's History

It is thought that the Thames was one of the main reasons that the settlement which became London developed into a major centre. The Romans recognised the early settlement around the present City of London as a valuable port. The two gravel hills, now St. Paul's and Cornhill stood above the flood plain providing a safe defensible site.

The upper reaches of the tidal Thames were fordable due to it being considerably wider and shallower than it is today and the river provided an excellent source of drinking water. The geology and geography of the area provided a site for the lowest bridging point across the river.

The Thames acted as a natural regional boundary and important transport route. Around 1190, the Corporation of the City of London was granted a Charter by King John and in 1197 the rights to the Thames, upstream to Staines, was sold to the Corporation by Richard I to raise funds. At this time London was already the largest trading centre in England with the docks on the Thames handling the rapidly growing markets in imported and exported goods.

By the beginning of the 13th Century, the population of London was estimated to be around 40,000. The main centres of population were close to the river from which much of London's prosperity derived.

Over the next 400 years London grew to become a centre of world importance. By the 1700s it was the largest city in Europe and 20 times bigger than England's next biggest city.

In 1801, the year of the first public census, the population was 959,000. Trade was responsible for London's growth and London was the world's largest port, handling the commerce for the most advanced industrialised nation.

London was a huge market for the rest of the country and, because of its purchasing power, became a centre for luxury trades such as silk weaving, silver-smithing, precision metalworking, porcelain and furniture making. The less desirable industries were located at the edges of the City. For example, white lead for paint was manufactured at Islington and along the river were foundries, tanners, soap, glue, sugar and tallow manufacturers, brick and tile works and the Royal Arsenal at Woolwich. There were a large number of breweries including those still found at Chiswick and Hammersmith.

The industrial revolution brought a huge explosion in population and manufacturing to London which peaked immediately prior to the Second World War. The population trends are shown in Table 1.2.

After the War, the 1946 New Towns Act saw the start of the building of new towns to house Londoners outside the congested Greater London Area, with the result that the population of London declined.

Post-war Britain was the world's largest exporter of motor vehicles and for London it was its largest single export, the cars being produced at Ford's Dagenham works. Food processing was another major riverside industry with Tate & Lyle's sugar refinery employing around 8,000; its main plant being at Silvertown.

Table 1.2 ***Population of London***

Year	Greater London	City of London
1700	575,000	208,000
1801	959,000	128,000
1851	2,363,000	128,000
1901	6,506,000	27,000
1939 (estimate)	9,000,000	
1951	8,193,000	5,000
1991	6,889,900	

Source: The London Encyclopaedia MacMillan 1983 and Britain 1994 an Official Handbook, 1994, HMSO.

Table 1.3
Population Density

Area	Density - people per sq. km
Greater London	4,366
West Midlands county	2,925
Merseyside	2,213

(as at mid 1991 from Office of Population & Census Survey quoted in Britain 1994, an Official Handbook, HMSO)

Around 1950 a third of the total exports from all the Commonwealth countries flowed through London. The port was bigger at this time than at any time in its past. By 1960 many of the Commonwealth countries were gaining their independence and although much of their trade continued to be with Britain the Japanese and German economies had begun to emerge as major forces in world trade. The British manufacturing industry, based around the Thames moved into a long period of gradual decline.

By the mid 1960s, these changes resulted in a considerable reduction in the amount of trade being handled by London's docks, which resulted in the closure of the first dock in 1967 and the last in 1981. Much of the industry which did survive this period relocated to traditional areas of high unemployment with a result that manufacturing employment in London fell from 1 million in 1973 to approximately half that figure ten years later. To some extent, tourism and the service industry have filled the gap.

1.5.2 London Today

Services account for over three quarters of gross domestic product in London and the South East. Over 20 per cent of people in Greater London work in banking and finance reflecting London's position as one of the world's leading centres of banking, insurance and other financial services. It is also the main media centre; the national press is largely published there and the national radio and television networks are also located in London. The resident population continued to decline into the 1990s and whilst the day time population in the City of London is around 400,000 the night time population is just over 1% of that figure. Recent work by the London Research Centre ('London 1995') suggests that the decline has halted and that there has been a real increase in population in recent years.

Over half the expenditure by overseas visitors to Britain takes place in London. Around 14 million people visit the UK and about 90% pass through London. The River Thames is an important feature

Plate 1.3
Thames Estuary at Canary Wharf

Plate 1.4
Thames Estuary at Queen Elizabeth II Bridge

providing a backdrop to some of London's most significant architecture both historic and modern. It provides space in the densely built up environment of London to view its ever changing vista both from its banks and from the many tourist boats that cruise the River.

Although London no longer supports the manufacturing industry that it did and its population has declined since its peak at the beginning of the Second World War, it still has to deal with the problems created by the most densely populated area of the country (Table 1.3).

1.6 Land Use

The upper Tideway is bounded by many historic houses with associated gardens and large public parks such as Richmond, Kew Gardens and Syon Park. Syon Park has the only remaining natural tidal meadow on the Thames upstream of the Thames Barrier and is designated a Site of Special Scientific Interest (SSSI).

These open spaces, interspersed with residential areas, make this stretch of the tidal Thames seem comparatively rural. There is considerable public access to the Thames with centres for water-based activities, moorings and riverside homes.

The more urbanised river bank characterised by flood defence walls with development behind begins around Hammersmith. Through Chelsea, Westminster and the City the North bank is characterised by the Embankment with roadway next to the river and densely built-up area behind. The Chelsea and Victoria Embankments on the North bank and the Albert embankment on the South were designed by Sir Joseph Bazalgette who was commissioned in 1855 to tackle London's sewage problems. Part of his work was to embank the Thames thus eliminating the stinking mud-flats, speeding the flow of the river, housing the sewers and reclaiming land for gardens and a roadway. The Victoria Embankment continues into the City and beyond Blackfriars.

Around Wandsworth and the River Wandle the South bank is characterised by past industrial development. The area is currently being redeveloped for both office and residential accommodation. A number of parks through central London give access to the river. These include Battersea Park which was designated a conservation area in 1988 with a small area close to the river preserved as a nature reserve since 1994. Southwark's river bank was another important industrial area. Many of these sites have been redeveloped and those remaining are intended for galleries and museums including conversion of the redundant Bankside Power Station as an annex to the Tate Gallery.

Recent developments have tended to build out into the river removing much of the tidal flats. It is considered that such development has a significant detrimental effect on both the flow of the river and the habitat for invertebrates and larval fish. The Environment Agency is currently developing a policy for the future protection and management of the foreshore.

Below Tower Bridge the nature of the land use changes as it becomes more predominantly a working river. This was the area of the London Docks. Most of the redundant docks and wharves have been redeveloped by the Docklands Development Corporation for offices, marinas and housing.

The area includes the London City Airport, Docklands Light Railway and Canary Wharf, the tallest tower building in Britain. This is also the site of the Thames Barrier (see Section 1.2.3).

Past Docklands and into Erith Marshes, the area around the river becomes more evidently industrialised with Beckton Gas Works, Ford's Dagenham motor plant on the north bank and Crossness STW on the south. The Thames then widens and is banded by marshes interspersed with industrial plants, such as the oil refineries at Purfleet and waste disposal sites at Pitsea and Mucking, down to the Port of London at Tilbury. This pattern is repeated below Tilbury but with open farmland dominating land use, before the river reaches Southend, the Medway and the North Sea.

1.7 Recreation and Transport

1.7.1 Introduction

The Port of London (comprising the tidal Thames from Teddington to a line joining Margate to Clacton) is the busiest port in the UK and 6th largest in Europe. It handles 11% of all Britain's waterborne trade, mainly as containerised traffic. The Thames remains one of the most significant rivers for freight transport in Britain along with the Forth, Humber, Mersey and the Manchester Ship Canal. Although the Tideway is still very much a commercial and industrial transport route it is also an important recreation resource.

In the last few years, both local and national government have focused considerable attention on the Thames Estuary looking at all aspects of its potential for development. In 1993, the Secretary of State for the Environment announced a 'London Pride' initiative. This drew attention to the under-utilisation of the Thames for transport and recreation and to the river's great potential as a focus for development. As a result of this initiative the "Thames Strategy" was launched in May 1995.

1.7.2 Transport

A report published in 1994 by the Department of Transport's River Thames Working Group into maximising the river as a transport artery included 14 recommendations aimed at improving the use of the Thames for freight, especially waste and passenger transport.

The Government Office of London (GOL) is currently preparing a business case for passenger services on the Thames in addition to the tourist service presently operated.

The growth in popularity of London as a port of call for liners has increased significantly in recent years and this is forecast to continue. This trade is not only financially important but makes use of the river as a transport route for visitors to London.

Plate 1.5
Angling on the Thames Estuary

As there is no requirement to register recreation craft on the Tideway it is impossible to estimate with any great accuracy the number of such craft being used for cruising in the London area. There are approximately 1500 moorings and 6 marinas on the Tideway upstream of the Thames Barrier. In addition, there are a number of piers, the busiest are in the popular tourist areas of Westminster, Charing Cross, the Tower and Greenwich.

1.7.3 Recreation

Canoeing, rowing and sailing are all popular activities on the Tideway using the upper and lower Thames around Greenwich, but avoiding the busy routes in central London. The Oxford and Cambridge 'Boat Race' is held annually on the Thames, focusing international attention on the River.

Angling is very popular in the upper Thames especially where there are quiet areas. The Middle Tideway is not as popular with anglers due to the fast flow of the river and the flood defences which make access to the foreshore difficult or impossible. On the Lower Tideway, where the foreshore is more gently sloping and accessible, angling is again popular.

The area around Southend is a popular seaside resort with European Community Designated bathing beaches at Thorpe Bay, Westcliff and Shoeburyness.

The Thames Path was designated by the Secretary of State for the Environment in 1989 and after a considerable amount of work the Path was officially opened in July 1996. The work has been done in partnership between County Councils, London Borough Councils, the National Rivers Authority and continued by the Environment Agency and voluntary bodies funded by grants from the Countryside Commission. The path runs from Kemble, near Cirencester in Wiltshire to the Thames Barrier. There are a few sections in London where creation of the path awaits redevelopment.

1.7.4 The Future

The Millennium Exhibition

A significant proposal focusing on the Thames is the bid by the London Borough of Greenwich to host the Millennium Exhibition. The site is 52 hectares of riverside land on the Greenwich Peninsula. It is London's largest development site which in the past contained a dry dock and a ship yard beside a tar works and a gas purification works.

The development of the site will involve the clean up of contaminated land with the potential for groundwater and surface water pollution. The Environment Agency will be involved to ensure suitable pollution prevention measures are in place and to negotiate maximum environmental enhancement opportunities.

Other Proposals

The "Thames Strategy" and a number of other published studies have focused the public's attention on the Thames, and London is rediscovering its river. Among the many forums, the Evening Standard newspaper has held a series of debates on the "Future of London". One of these resulted in a call for a feasibility study into making the tidal reach of the Thames non-tidal by means of a barrage. Such a proposal would have enormous water quality implications. The Environment Agency will be involved in all such proposals on the development of the Thames in order to protect or enhance the environment and to contribute to the objectives of achieving sustainable development.

1.8 Conservation Status

The Thames Estuary is part of the estuarine complex known by the Royal Society for the Protection of Birds (RSPB) (1992) as the Greater Thames. The mud flats and marshes of the Estuary are a vital link in the East Atlantic Flyway, which is a chain of migration sites for waterbirds, stretching from Arctic breeding grounds to African wintering grounds. Nearly 300,000 waterbirds over-winter in the greater Thames making it the most important estuarine complex for birds in the UK and among the five most important sites for wading birds in Europe.

The international importance of the Estuary for wildlife is recognised by the designation of Benfleet and Southend Marshes as a Special Protection Area (SPA: EO Birds Directive) Ramsar site. The Thames Estuary and Marshes are proposed as SPA and Ramsar sites, and encompass most of the South Thames Estuary and Marshes Sites of Special Scientific Interest (SSSI) and Mucking flats and marshes SSSI.

2. The Legislative and Regulatory Framework

2.1 Introduction

The water quality of the Thames Estuary is inextricably linked to the growth of London as described in the previous chapter. Although there were attempts at legislating against pollution of the river in earlier centuries, it was not until the early 1800s that serious measures were taken to rectify the situation, in the passing of an "Act for the Better Local Management of the Metropolis". By this time the water abstracted from the tidal Thames for drinking was heavily polluted, Cholera was epidemic and the river could no longer support the vast quantity of waste that was discharged to it, becoming a stinking mass devoid of life. The chronology of the local, national and international legislation on which the clean up of the Thames and its current management is based is briefly described in this section.

2.2 Metropolitan Board of Works

1855 "An Act for the Better Local Management of the Metropolis". The act set up a Metropolitan Board of Works having sewerage and drainage as one of its principal responsibilities. It was charged with a duty to construct by the end of 1860 sewers and works "for preventing all or any part of the sewerage within the Metropolis from flowing or passing into the River Thames, in or near the Metropolis"

2.3 Thames Conservancy

1857 "Thames Conservancy Act". Under the provisions of this Act the Conservators took control of the river below Staines from the Corporation of the City of London. The Act included clauses for the prevention of pollution. However, the Metropolitan Board of Works and thereafter the London County Council were exempt from their powers.

1866 The authority of the Thames Conservancy was extended upstream to Cricklade in Wiltshire and it was in the Thames above Teddington that the powers of the Conservators were used to greatest effect.

1889 London County Council (LCC) took over from the Metropolitan Board of Works.

2.4 Port of London Authority (PLA)

1902 The Royal Commission enquiry into the administration of the Port of London recommended: "the creation of a single public authority for the control and improvement of the Port and vesting in that authority the powers and property of the Thames Conservancy below Teddington"

1908 Port of London Act received Royal Assent and the Port of London Authority (PLA) took over responsibility for the Estuary from the Thames Conservators.

1920 Port of London Consolidation Act. This was derived from the 19th Century Thames Conservancy Acts and empowered the PLA: "by all lawful and proper means to preserve and maintain at all times as far as may be possible the flow and purity of the water of the tidal Thames". Discharges by the LCC were still exempt.

2.5 Pollution Prevention Acts, 1951 and 1961

The Rivers (Prevention of Pollution) Act 1951 gave new powers to the River Boards established by the Act of 1948 and to the Thames and Lee Conservancy Catchment Boards. The Act required new dischargers of trade or sewage effluent to inland water to acquire a 'discharge consent' from the river authority. This was a legal document setting limits as to the nature, composition, temperature and volume of the effluent permitted to be discharged. In addition, it became an offence to cause or knowingly permit any poisonous, noxious or polluting matter to enter a river. The Act applied only to new discharges to inland waters and discharges to estuaries and coastal waters remained exempt from regulation.

The Clean Rivers (Estuaries and Tidal Waters) Act, 1960 extended the requirements of the 1951 Act for consent, to cover new discharges to specified tidal and esturial water, it did not apply to the Thames. Again, it applied only to new or altered discharges and those discharges being made before 1960 still escaped regulation.

The Rivers (Prevention of Pollution) Act, 1961 extended the application of the 1951 Act to cover all discharges to inland waters, including those which had been made prior to 1951, but discharges to estuarine and coastal waters which had commenced prior to 1960 remained exempt.

2.6 Pippard Report, 1961

This put forward many of the recommendations which resulted in the clean up of the Thames Estuary (see Section 4.7)

2.7 Port of London Act, 1964 and 1968

The Port of London Act implemented the 1961 Pippard Report, 'Pollution of the Tidal Thames' which recommended that the PLA should be given statutory powers to control pollution (measures to be taken to render the tidal Thames inoffensive). It extended the powers of the 1951 and 1961 Acts to the Thames Estuary as far as a line from Haven Gore Creek east of Southend to Warden Point on the Isle of Sheppey.

2.8 Water Act 1973

This Act was important not for new pollution prevention measures but for the wholesale reorganization of the sewage disposal and drinking water supply industry. It removed responsibility for disposal systems from the numerous local authorities and placed them with the newly created water authorities. The Thames came under the control of Thames Water Authority.

2.9 Control of Pollution Act 1974

One of the most significant steps forward in pollution control legislation was the Control of Pollution Act (COPA), 1974. This Act finally extended controls so that existing and new discharges to inland, underground, tidal or coastal waters out to the three mile limit were covered. COPA introduced public participation in decisions, established public registers of information and allowed for private prosecutions which had previously been effectively excluded. However, the full provisions of COPA did not come into force for nearly 10 years, partly due to Government concerns over the economic costs of bringing in the new controls.

2.10 Water Act 1989 and Water Resources Act, 1991

The National Rivers Authority (NRA) was established under the Water Act, 1989. This Act was superseded by the Water Resources Act (WRA), 1991 which consolidated certain amendments arising from the Environmental Protection Act (see below) and all other water legislation prior to the 1989 Water Act. The primary pollution control duties of the NRA specified in the WRA were the achievement of Water Quality Objectives and the assessment of pollution in controlled waters. The Act maintains the primary offences of causing or knowingly permitting pollution and of discharging trade or sewage effluent to a controlled water, unless it complies with standards laid down in a consent.

2.11 Environmental Protection Act, 1990

Part 1 of the Environmental Protection Act (EPA), 1990 introduced Integrated Pollution Control (IPC) as a new system to control discharges to all media of the most toxic materials - "prescribed substances" and the most complex and polluting industrial processes - "prescribed processes". Phased implementation began in 1991 and was scheduled for completion in 1995. Her Majesty's Inspectorate of Pollution (HMIP) was designated as the enforcing body, the responsibility has now passed to the Environment Agency. The main objectives of IPC are two-fold:

i. to prevent or minimise the release of "prescribed substances" and to render harmless any such substances which are released;

ii. to develop an approach to pollution control, based on process controls at source, that considers discharges from industrial processes to all media in the context of the effect on the environment as a whole.

No "prescribed process" may be operated without prior authorisation from HMIP and subsequently the Environment Agency after the date specified in the regulations. It should be noted that sewage treatment plants are not designated as "prescribed processes" but sludge incineration is. The Act has major implications for the Thames Estuary as power stations, incinerators (for both sludge and waste) and refineries are all prescribed.

2.12 Environment Act 1995

This established the Environment Agency with operational effect from 1 April 1996, the principal aim of which is to protect or enhance the environment taken as a whole so as to make a contribution towards attaining the objective of achieving sustainable development. The Agency adopts an integrated approach to environmental protection and enhancement, taking into consideration the impact of all activities and natural resources. It is charged with delivering these environmental goals without imposing disproportionate costs on industry or society as a whole.

The Environment Agency combines and builds on the strengths of its predecessor bodies, the NRA, HMIP, the Waste Regulation Authorities (WRA) and the Waste Technical and Contaminated Land Divisions of the Department of the Environment. It aims to preserve and improve the quality of rivers, estuaries and coastal waters through its pollution control powers. It will take action to conserve and secure proper use of water resources, including both discharges and abstractions and will also be responsible for the maintenance and improvement of salmon, trout, freshwater and eel fisheries. It has powers to conserve the water environment, including areas of outstanding natural beauty or environmental sensitivity and to promote its use for recreation.

2.13 International Legislation

2.13.1 EC Directives

Whilst domestic regulation has been progressively extended and strengthened, a new dimension was introduced when the United Kingdom joined the European Economic Community (EEC) in 1973, now known as the European Union (EU).

The European Commission, which sets the legislative programme for the EU, has recognised the potential global impact of pollution as well as the purely economic aspects of different effluent standards applying to "competitors". It has established a system of Directives which require Member States to comply with certain environmental and or discharge standards. Directives are given statutory effect in England and Wales through regulations issued under relevant national legislation.

2.13.2 Dangerous Substances Directive (76/464/EC)

This Directive provides legislation to control certain dangerous substances in the aquatic environment. Two lists of families or groups of substances are set out in the annex to the Directive. List I includes substances selected mainly on the basis of their toxicity, persistence and bio-accumulation. List II includes substances which have a deleterious effect on the aquatic environment depending on the characteristics and location of the water into which they are discharged.

Subsidiary Directives have established Environmental Quality Objectives (EQOs)- referred to as Environmental Quality Standards (EQSs) in the UK for a number of List I substances. For List II substances the standards have been set nationally (see Appendices 1 and 2 for relevant List I and List II substances). The standards must be achieved in all waters.

2.13.3 Bathing Waters Directive (76/160/EC)

The purpose of this Directive is to protect the environment and public health, to reduce the pollution of bathing waters and to protect these waters against further deterioration. The standards set relate to bacteriological, sanitary, physical and chemical parameters. The relevant sites in the Thames Estuary are the three designated bathing beaches at Southend.

2.13.4 Urban Waste Water Treatment Directive (91/271/EC)

The Directive on urban waste water treatment was agreed in 1991 and is now in place and effective in the Estuary. The Directive seeks to reduce pollution in freshwater estuaries and coastal water. It sets out minimum standards and a time scale for achieving collection, treatment and discharge of urban waste water. All sewage outfalls must receive primary and secondary treatment by the year 2000 for populations over 15,000 and all STWs with a population greater than 2000 must receive secondary treatment by 2005. All TWUL STWs already have secondary treatment and Anglian Water has major capital works in progress for Southend STW.

The Directive also controls the disposal of sewage sludge. The UK will terminate the dumping of sewage sludge at sea in 1998 in line with the requirements of the directive and the undertaking given at the 1990 North Sea Conference. Incinerators are being constructed at Beckton and Crossness to deal with sewage sludge.

2.13.5 Integrated Pollution Prevention and Control Directive (96/61/EC)

The Directive is aimed at reducing and preventing pollution from existing industrial installations which have a major impact on the environment.

The Directive introduces a system of integrated pollution prevention and control (IPPC). It emphasises an integrated approach in order to achieve a high level of protection for the environment as a whole. Permits issued under the Directive will allow industrial installations to operate within specified conditions relating to the particular processes. The Directive goes beyond the IPC system now operating in the UK under the Environmental Protection Act, 1990, as it will cover a greater range of processes.

2.14 Paris Convention

The Paris Convention for the prevention of marine pollution from land-based sources into the North East Atlantic including the North Sea of which the UK is a signatory, was adopted in 1974 and entered into force in 1978. The convention introduced two lists of substances for control. The contracting countries are obliged to eliminate pollution by substances on the 'Black' list and limit pollution by substances on the 'Grey' list. This approach was adopted in the EC Dangerous Substances legislation which defines List I (Black list) and List II (Grey list)(see section 2.13.2), the lists are similar but not identical.

The Paris Commission (PARCOM) requires that it is supplied with regular monitoring data to assess the progress in reduction on inputs via rivers, industry and STWs and to ascertain the main route of input to the sea. Early data was often incomplete and based on non-standard methodologies. As a result, in 1988, a requirement for a comprehensive annual survey of selected pollutants (metals, pesticides and nutrients), based on standard methods, was established. The results of the 1990 survey (PARCOM 1992) represented the most complete study of gross riverine and direct inputs to the Convention's area up to that time.

2.15 North Sea Conference Declaration

The first North Sea Conference was held in 1984 as an international forum to make policy on the reduction of pollution of the North Sea. At the second conference, in 1987, the North Sea States committed themselves to reducing inputs of toxic, persistent and bio-accumulative substances from rivers and estuaries to the North Sea by 50% by 1995, using 1985 values as a baseline. Each country had to draw up its own priority list from a reference list of 170 substances. The UK produced a list of 23 substances known as the Red List based on the above criteria and volume of usage (see Appendix 3). Inputs from point sources (e.g. industrial discharges) were to be reduced through the application of best available technology (BAT). Diffuse source inputs, e.g. inputs from the pesticide run-off from agricultural land, were to be reduced by control on supply, use and disposal of products. The UK undertook to impose this measure on all of the UK coastline not just the North Sea.

At the third conference, in 1990, the UK along with the other participating states, undertook to apply this measure to an extended list of substances (shown in Appendix 4), known as Annex 1A. Additionally, the North Sea States agreed to:

i. reduce inputs to all environmental media (i.e. air, water and land) of dioxins, mercury, cadmium and lead by 70% within the 1985-1995 period;

ii. to reduce nutrients by around 50% between 1985 and 1995 in areas where these are likely to cause pollution;

iii. to make a substantial reduction in the quantities of pesticides reaching the North Sea with special attention to phasing out those which are the most persistent, toxic and liable to bioaccumulate;

iv. to phase out and destroy all identifiable polychlorinated biphenyls (PCBs) by 1999.

A comprehensive monitoring programme, in line with the PARCOM surveys, looks at the inputs of each substance to coastal and estuarine waters via rivers at tidal limits, via sewage and sewage effluent or direct industrial discharges downstream of tidal limits.

At the Fourth North Sea Conference in 1995 the UK reported that it had achieved the 50% reduction for many of the substances on Annex 1A. The deadline for achieving the 50% reduction for the remaining substances was extended to the year 2000.

3. Factors which affect Water Quality in the Thames Estuary

3.1 Introduction

Before the quality of water in estuaries had been scientifically investigated in any detail it was considered that, due to the large volume of water and flushing action of the tide, estuaries had a far greater capacity to absorb polluting water than has now been shown to be the case. In 1948 the Thames Survey Committee was appointed by the Water Pollution Research Board to study the condition of the Thames Estuary. This study resulted in a benchmark report (The Effect of Polluting Discharges on the Thames Estuary, Technical Paper No. 11, HMSO 1964) containing one of the first mathematical models to predict the concentration of dissolved oxygen for polluting discharges, based on systematic monitoring. The Report provided much of the information on the processes occurring in the Thames Estuary and forms the basis for quality management and associated legislation in the Thames Estuary.

3.2 Dissolved Oxygen

Dissolved oxygen (DO) is one of the most important factors in water quality control. It is essential to the maintenance of biological life. Total de-oxygenation of river reaches results in the death of all fish and almost all invertebrate species. Even low DO concentrations may severely affect the survival of fish as the sensitivity of fish to toxic materials, such as heavy metals, is increased as the DO is reduced.

The DO concentration of water largely reflects the amount of polluting load from carbonaceous and nitrogenous materials, arising from both natural sources and waste water discharges, which are normally readily oxidised by *in situ* bacteria. These biologically controlled reactions are one of the most important factors in the management of the oxygen balance and therefore water quality of the Estuary. The organic content, i.e. the polluting potential, is commonly measured in terms of Biochemical Oxygen Demand (BOD).

In an estuary like the Thames, concentrations of DO are also influenced by factors such as freshwater flow, tidal heights and velocities, temperature, storm events, resuspension and settlement of solids, absorption rates from the atmosphere and algal photosynthesis.

These parameters will all play a part in determining the DO concentration within the Estuary. Some of the factors are entirely controlled by the natural environment, such as tides and seasonal temperatures. Other influences, like waste water discharges and freshwater flows to the tidal Thames, can be managed to benefit water quality and are the major factors in the current water quality management strategy for the Thames Estuary.

3.3 Temperature

Temperature is important in determining water quality because of its effect on other properties such as the speed of chemical reaction, microbiological activity and the solubility of gases. Oxygen is not very soluble in water and the amount held by a volume of water decreases as temperature increases. For example, freshwater at 100% saturation will support 14 mg/l of oxygen at O°C and 9 mg/l at 20°C . In sea water, with higher salinity, the oxygen saturation at 20°C is even lower, at around 7 mg/l.

With increasing temperature chemical reactions take place more rapidly thus further depleting the available DO. A rise in temperature is likely to increase the rate of metabolism of an organism, its rate of respiration and consequently its need for oxygen.

Temperature may also have a significant effect on species composition. The variety of species present at any location is a direct result of local environmental conditions of which temperature may be a key factor for some.

There are two main influences on the temperature of the water in the Estuary; climate and industrial discharges.

Most of the variation in the temperature of the Estuary is due to the effects of climate. The difference between summer and winter water temperatures at a depth of 6m is about 15°C. It follows that in the summer the Thames Estuary has lower DO levels even before other influencing factors such as waste water discharges and low diluting flows from the freshwater rivers contribute.

Power stations require large quantities of water to cool turbines and many other industries utilise water in cooling and other processes. The Estuary provides a ready source to meet these requirements and has historically drawn such industry to its banks. In 1951 there were 14 power stations on the Thames Estuary supplying public needs as well as others for industry alone. These were believed to be largely responsible for the significant increase in the average annual temperature of the river from 11-12°C in 1900 to 15-16°C in the late 1950s. Today there are only 4 power stations regularly discharging into the Estuary and the current annual mean temperature is about 13-14°C. The water used in cooling may be saturated or even to some extent supersaturated with oxygen when it is returned thus adding significant quantities of oxygen to the Estuary.

3.4 Retention Time and Freshwater Flow

The movement of pollutants in the Estuary is strongly affected by the action of the tides and therefore a discharge will not be immediately flushed out to sea. The pollutants within a discharge will move a considerable distance with an ebb tide but may return most of the way to its source on the next flood. The tidal excursion in the middle reaches of the Thames averages 13 to 14 km but the net daily seaward movement of a discrete body of water in summer is only 1 to 2 km.

The seaward drift of water is due to the input of freshwater flow at the head of the Estuary as well as the flow from other tributaries and effluent entering the Estuary. The main impact on flushing time in the Estuary is the freshwater flow over Teddington Weir. Longer retention times are fundamental to the problems created by discharges from London's STWs. This is an important factor for water quality in the upper and middle Tideway in that the pollution potential of any discharge is fully realised before the pollutant can reach the Lower Reaches or the sea where dilution is greatest.

The average time for water to pass from Teddington to the seaward reaches of the Estuary may vary between 3 weeks under high flows to greater than 3 months during low flows.

The influence of freshwater flow can also be seen by the difference in saline intrusion up the Estuary in a given low and high flow situation (Figure 3.1).

3.5 Re-suspension and Settlement of Solids

Suspended solids enter the Estuary via rivers, from sewerage and industrial effluent and from the sea. Those originating from the rivers and sea will be made up of both inorganic and organic solids in proportions dependent on the amount of effluent and to what extent they have already been oxidised.

Large amounts of organic material are moved up and down the Estuary by the action of the tide, the solids settling out as sediment onto the river bed when critical velocities are reached, usually at slack tide. The material may then be resuspended during the ebb or flood tide. There is also greater resuspension of sediments during spring tides than neap tides due to greater current velocities. This is particularly apparent in the Middle Reaches around Beckton and Crossness STWs where there is a fairly mobile sediment.

The pattern of settlement varies over the Estuary depending on tidal effects, river flows and the shape of the river bed. In some areas of the Estuary, as in the tidal basin at Tilbury, deposition is greater than erosion so that comparatively stable deposits of mud are formed. In the Upper Reaches, between

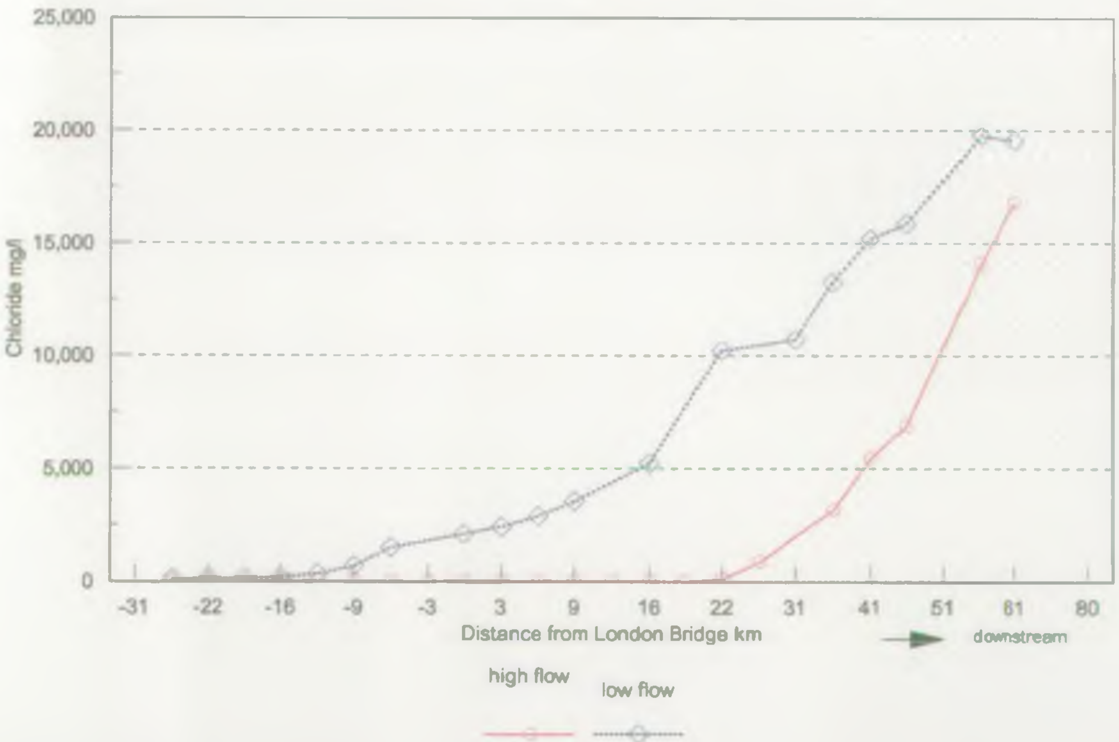


Figure 3.1
Chloride Profile of the Thames Estuary Showing Saline Intrusion for High and Low Flow Conditions

Teddington and London Bridge, there is very little mud deposited and the bed is more gravelly in nature.

The resuspension of sediments affects water quality by:

i. the release of anoxic sediment;
ii. the resuspension of organic material;
iii. release of potentially toxic substances.

These processes create an oxygen demand in the water column resulting in a deterioration of water quality.

Metals such as cadmium attach themselves to particulates (partitioning) and are therefore depleted from the water when the solids settle. On resuspension, oxidation of the metal which has been attached to sediment occurs.

In winter, maximum suspended solid concentrations tend to occur in the middle Estuary whereas in summer, the maximum occurs further upstream.

The effect of suspended solids on the oxygen balance is complex due to the constant settlement and resuspension of material under varying conditions.

3.6 Photosynthesis/Respiration and Eutrophication

Phytoplankton is a generic term given to a wide range of microscopic, aquatic micro-organisms which derive their energy from photosynthesis. They are ubiquitous in most bodies of water and provide the main food source for larval invertebrates and young fish near the bottom of the food chain. Some species of phytoplankton naturally produce toxins which can be harmful to human and marine life. The population and activity of these relatively simple organisms is largely controlled by physical factors i.e. light and temperature, but is also influenced by the nutrient content of the water.

Waters in which the level of nutrients has increased such that the growth of algae is no longer limited can be described as eutrophic (meaning 'well feeding'). Eutrophication has not been considered to be a problem in the main body of the Estuary due to its strong tidal flows, salinity variations and high turbidity, which preclude the development of any significant algal blooms. However algal blooms have occurred in some of the enclosed waters such as London Docks.

The main relevance of phytoplankton, in terms of the Estuary, is in relation to their ability to convert inorganic material to organic matter, oxygenate the water through photosynthesis and deoxygenate through respiration and decomposition.

In winter months the effect of biological activity is insignificant due to low temperatures and limited light. But under warm light conditions, phytoplankton washed down from the freshwater Thames could potentially exert a significant effect on the upper Thames Estuary DO levels. Not all the phytoplankton can survive in the Estuary and the decomposition of those which cannot will exert an immediate oxygen demand. This demand could be sufficient to remove significant amounts of oxygen from the water under certain conditions. A similar situation could occur when resident marine and estuarine species of phytoplankton in the estuary die in large numbers because of a change in their environment.

Phytoplankton photosynthesis occurs when there is a sufficient intensity of light. This produces oxygen which can lead to supersaturated DO levels. Under subsequent dark conditions this DO may be used up by respiration (a process which occurs 24hr a day) leading to little overall effect. If during the day time the underwater light regime is not adequate, respiration may continue and DO levels will be reduced, although not to the extent achieved by the decomposition of phytoplankton.

A worst scenario for the upper Thames is when during a hot dry summer there is a sudden change in weather conditions such as a summer storm event which causes a reduction in light and a sharp rise in turbidity and change in colour of the water. The sudden increase in phytoplankton activity in terms of respiration and the die off and decomposition of resident populations and blooms washed in from the freshwater Thames can lead to considerable de-oxygenation of the water. In the summer of 1986 parts of the river became anoxic following intense rainfall. Phytoplankton activity was considered to be a significant contributing factor to this event.

3.7 Oxygen Absorption from the Atmosphere

The rate of absorption of oxygen into water is affected by climatic and physical factors. The rate of absorption increases as temperature falls. It is also known that the rate of absorption increases with the movement or agitation of the water since this increases the rate of formation of new absorption surfaces. The main effect of the wind is that it increases the movement and area of the water surface through the generation of waves.

3.8 Sewage Treatment Works and Storm Water Effects

3.8.1 Discharges of Organic Matter

When organic matter is discharged into a river, as is the case from a STW, it is normally decomposed biologically by the action of micro-organisms. This can occur under both aerobic and anoxic conditions.

In the presence of an ample supply of oxygen the carbonaceous organic compounds are converted to carbon dioxide and water. More complex organic compounds, such as proteins, place additional demands on the oxygen supply in order to complete the oxidation of nitrogenous compounds. The amount of oxygen required by micro-organisms to breakdown the carbonaceous organic matter is the Biochemical Oxygen Demand (BOD).

3.8.2 Effective Oxygen Load

The standard 5 day BOD test does not take account of the oxygen requirement for nitrification. Nitrifying bacteria grow at a slow rate and the effect of their action is not normally important for 8-10 days with raw waste water samples. In the Thames Estuary, due to long retention times, the whole course of oxidation can take place before the pollutant is flushed out to sea. It is also the case that with treated effluents the effects of nitrification may become apparent after a day or two due to large numbers of nitrifying bacteria in the effluent. It is therefore evident that BOD is not always an adequate measure of the oxygen demand. The concept of Effective Oxygen Load (EOL) measured in tonnes/day takes account of the oxidisation of carbonaceous and nitrogenous material present and is equivalent to:

(1.5 BOD mg/l + 4.5(ammoniacal + organic N)mg/l * flow Ml/d)/1000

3.8.3 Oxygen Sag

The impact of EOL on the quality of the Estuary is dependant on the volume of good quality, high DO content water to dilute it and so varies with local conditions and season. A high EOL has a greater impact in the summer than in winter.

When a sewage effluent discharges to a watercourse and oxidisation by micro-organisms begins, the oxygen level in the water falls as the oxygen is used up. If the de-oxidation rate exceeds the reaeration rate from the atmosphere, incoming freshwater flow and photosynthesis, then the oxygen deficit persists. If the BOD of the polluting material is not too high it will gradually be completely oxidised and if reoxidation of the river takes place then the oxygen levels will recover and a characteristic 'sag' curve will be produced.

In the Thames Estuary, a sag occurs as a result of discharges from the large TWUL STWs. The DO sag minimum or Critical Point occurs in the middle Tideway approximately 22 km below London Bridge, downstream of Beckton and Crossness STWs but upstream of the works at Long Reach. The exact

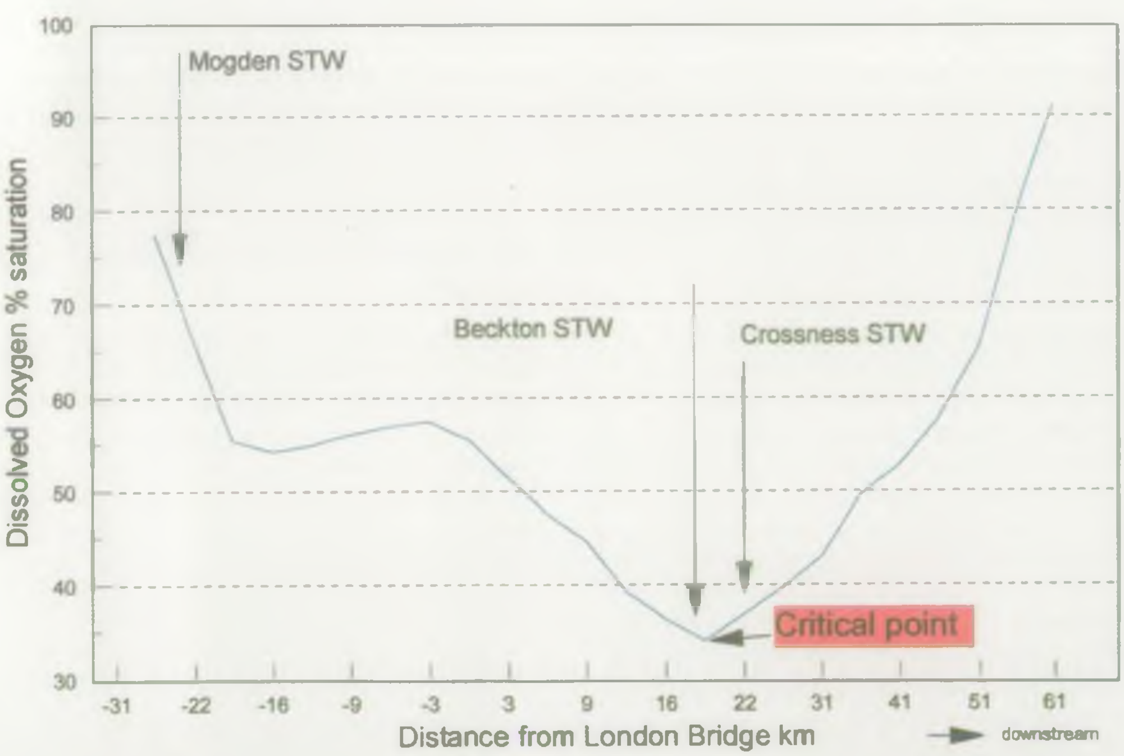


Figure 3.2
Typical Oxygen Sag Curve Showing the Critical Point

position of the sag can be altered by other factors particularly flow from the freshwater Thames (Figure 3.2).

Providing that the BOD of the organic matter is not too high, and the quality of the receiving water is good, then the water quality balance can be maintained. If the organic loading is too great, as may occur when storm sewage and surface water are discharged following a large storm event and when the DO levels of the receiving water are already low, then anoxic conditions could occur with the resulting death of higher biological life.

Under anoxic conditions, the breakdown is much more complex and complete stabilisation of organic matter cannot be achieved. The first stage of the process is carried out by acid-forming bacteria, the second by methane-formers. These latter will only metabolise within the pH range 6.5-7.5. Over-production of acids by the fast-acting, acid-formers can result in low pH with the result that the production of methane is stopped. This leaves the process at a point where unpleasant and odiferous compounds are present e.g. hydrogen sulphide. Such conditions were common in the Upper Reaches of the Thames Estuary during the 19th Century and early 20th Century but have not occurred in the last 30 years.

3.9 Contaminants

A contaminant is a substance which is present in a higher concentration than the natural background level. A substance becomes a pollutant if found at a concentration which causes harm. The main contaminants occurring in rivers, including the Thames, are nutrients (e.g. nitrogen and phosphorus), metals (e.g. lead, mercury, copper, cadmium), pesticides (e.g. Lindane) and other organic micro-pollutants (e.g. PCBs).

3.9.1 Metals, Pesticides and Other Organic Micro-pollutants

Pollutants such as metals, pesticides and other organic micro-pollutants can have a significant effect on the quality of an estuary and the marine biota. Their potential effects on fish and aquatic invertebrates include both direct toxicity and indirect effects, at sub-lethal levels, by enhancing the risk of disease or affecting reproductive potential or competitive ability.

London has never been a major centre for the heavy industry associated with large, point source discharges of metals. Most of London's trade effluent is treated at the STW and those industries which do discharge to the Tideway are required to meet consent standards so as not to cause a significant effect. The main inputs of metals to the Tideway are via the STW as a result of discharge by industry, domestic sources (e.g. zinc in toiletry and medical products, copper from water pipes) and diffuse inputs (e.g. lead from vehicle emissions, zinc in vehicle tyres, copper and lead from roofs, all of which will be washed into the combined sewage system during rain).

The potential pollution from pesticides in London is more likely to be from urban, non-agricultural uses, particularly via herbicides used for weed clearance on railways and roads. Domestic use of pesticides is also a factor given the high density of London's population, (e.g. fly sprays, ant killers and wood preservatives). The inputs to the Thames Estuary are almost all diffuse inputs via STWs, there are no known significant industrial point source discharges.

3.9.2 Nutrients

The occurrence of nutrients, such as nitrogen and phosphorus, as contaminants is important because of concern over their potential under certain conditions to cause unnatural and excessive algal growth in estuaries and seas, a process known as eutrophication (see Section 3.6). On the death of the algae there can be a depletion of DO resulting in the destruction of the benthic organisms.

The main use of nitrate and phosphate in the UK is as agricultural fertiliser. However, significant quantities of phosphates are used in domestic detergents which are drained to STWs and another significant source is waste from the human body.

In the Thames Estuary, the main source of the nitrate load is from the freshwater Thames as a result of diffuse inputs e.g. the direct run-off and leaching of fertilisers from farmland and via STWs. The phosphate load is derived principally from the STW as a result of the large domestic input as indicated above.

3.9.3 Aesthetics

Although litter and debris do not normally affect the chemical water quality of the river it is aesthetically displeasing and can pose a danger to people and wildlife.

It is perceived as a serious environmental issue and influences our perception of the quality i.e. a lot of rubbish must mean a polluted river. This is certainly not true for the Thames Estuary where, although litter remains an unsightly problem, the river is generally of a good chemical quality. For details on the initiatives to clean up the river see Section 5.9.6.

4. Pollution History and the Clean Up

4.1 Introduction

The pollution of London's rivers has been of concern since at least Medieval times. For example an Act in 1383 ordered those with latrines over the Walbrook to pay the Lord Chancellor two shillings a year for cleaning the river and an Act of 1388 made it illegal to 'corrupt or pollute ditches, rivers, water and the air of London or elsewhere'. However, with no adequate enforcement or means of disposal of the waste, together with an ever increasing population, the Acts were largely ineffectual and London's waste became a growing problem. The Census of 1841 indicated that there were over 270,000 houses in Central London. Most of these would have had a cesspit below, which more often than not overflowed. Nightmen were employed to remove the 'soil' from within London to be used on market gardens and agricultural fields as manure.

The tidal Thames was, no doubt, considerably polluted by this time but up to the turn of the 19th Century there are records of up to 3,000 salmon per season from the river being sold at London's fish market. Salmon were recorded in the Thames up to 1833.

The upper part of the river was used to supply drinking water to London with little or no treatment and somewhat surprisingly there were no complaints about the quality of the water to the 1821 Select Committee on the Supply of Water to London. Nevertheless, by 1827 a pamphlet entitled 'The Dolphin or Grand Junction Nuisance' wrote 'the water taken up from the River Thames between Chelsea Hospital and London Bridge, for the use of the inhabitants of the Metropolis, being charged with the contents of more than 130 public sewers, the draining from dunghills and lay-stalls, the refuse from hospitals, slaughter houses, colour, lead-gas and soap works, drug mills and many factories, and with all sorts of decomposed animal and vegetable substances, rendering the said water offensive and destructive to health, ought no longer to be taken up by any of the Companies from so foul a source'.

4.2 Cholera Epidemics

In 1831 London's first cholera epidemic occurred resulting in over 6,000 deaths. In 1848-9 some 14,000 died out of 30,000 cases. There were a further 10,675 deaths in 1854 and in 1866 there were over 5,000 deaths in just 3 weeks. It was not until the third epidemic that the incidence of cholera was linked to the water supply. It was discovered that the worst hit areas of Southwark and Vauxhall obtained water from an area of river contaminated by City sewage and sewage from ships.

Cholera had apparently been reintroduced from ships arriving from the Baltic and discharging their sewage into the Thames. This discovery put further

Plate 4.1
A series of satirical cartoons were published in newspapers and journals depicting the state of the River Thames in the 1800s. 'Monster Soup' a 'Microcosm dedicated to the London Water Companies'.

Plate 4.2
Faraday giving his card to Father Thames: "and we hope the dirty fellow will consult the learned Professor".

pressure on the authorities to improve the state of London's sanitation and water supply.

4.3 Metropolitan Commissioners of Sewers 1847

After the introduction of water closets around 1810, cesspits became inadequate to cope with the additional load. There was an increasing drainage of cesspits into the rainfall carrying street sewers but commonly the cesspits overflowed through floor boards to the houses above. In order to try and rectify this appalling state of affairs the Metropolitan Commission of Sewers was set up in 1847. It amalgamated the 8 separate local bodies responsible for sewers and decreed that all cesspits should be abolished. The effect of this was that the waste from some 200,000 cesspits was discharged to main sewers and underground streams and into the Thames.

As a result, by the middle of the Century, during a time of a very rapid increase in industrialisation within London and a growing population placing even greater demands on the inadequate system, no fish of any kind could survive in the Middle Reaches of the river.

4.4 Metropolitan Board of Works

Between 1848 and 1855 six successive Commissions of Sewers were appointed to seek a solution to the problem. In 1855 the Commissions were replaced by the Metropolitan Board of Works. The Board considered many proposals including those which involved no sewerage discharge to the Thames but all waste being piped away from Central London to be converted to manure for agricultural use. It was the plan of the Board's own Chief Engineer, Joseph Bazalgette, which was finally adopted.

Bazalgette's scheme involved a network of sewers on three levels, on both sides of the river, running down to reservoirs and outfalls on the north bank at Beckton and on the south bank at Crossness. Sewage and surface water were to be moved by gravity and on the lower levels by pumps. During heavy rainfall excess flows would discharge directly to the river. It was considered that the sites of the two main outfalls would be far enough downstream of Central London, with sufficient dilution not to cause unreasonable offence to anyone. The sewage was discharged on the ebb-tide.

There had been criticism of the scheme by the Board's referees who considered that it was inadequate with respect to the quantity of sewage that the main sewer was designed to carry and it was suggested that the outfalls should have been placed further downstream. In 1858, the Board was absolved from the need for Government approval and made exempt from the control of the Thames Conservancy, which had been set up in the previous year. This was also the year of the 'Great Stink' when during the hot, dry summer the windows of the Houses of Parliament had to be draped with curtains soaked in chloride of lime to mitigate the disgusting smell emanating from the river. Many tons of chalk lime, chloride of lime and carbolic acid were tipped into the river but with little effect.

Work on the scheme began with the outfalls which were completed in 1864, followed by completion of the Thames Embankments in 1875. The commissioning of the outfalls did lead to an improvement in the Central London area but the problem was transferred downstream to Barking, adjacent to the outfalls. This was confirmed by a Public Inquiry of 1869 which looked at the complaints of Barking residents. After the enquiry, the Thames Conservancy attempted to introduce legislation that would have prevented the discharge of untreated sewage to the Estuary. This was opposed by the Board of Works and a compromise Navigation Act was passed that included a clause to make the Board of Works keep the Thames free of mud banks that might arise from the discharge from outfalls.

The Thames Conservators argued the case that the condition of the river was as bad as before the construction of the outfalls except that 'the nuisance which was formally brought down from London on the ebb is carried up to London on the flood' . The Board of Works rejected this argument.

In 1882 a Royal Commission was appointed to look into the complaints being received with respect to the state of the Thames around the outfalls. Its first report, in 1884, was largely one of detailing the state of the Estuary and noted that it was devoid of fish and in hot weather it 'caused serious nuisance and inconvenience' The second report, also in 1884, looked at methods of remedying the situation and experiments by the Board of Works began that year into methods of treatment. In 1889 precipitation works were completed at Beckton and in 1891 at Crossness.

4.5 London County Council

During 1889 the Board of Works was replaced by the London County Council who carried out an examination of the whole system. Although the precipitation work had improved the state of the foreshore, there was no immediate restoration of the Estuary. This was considered to be in part due to the discharge of storm sewage. Work was carried out on improvements to the capacity of the sewers and new intercepting sewers were built which considerably reduced the discharge of storm overflows. At last in the 1890s there were reports of a much cleaner river and an increase in fish life. In 1895 plentiful supplies of whitebait reached the London market and both salt water and freshwater fish were found along the Estuary.

London continued to grow. As the population and number of industries increased so did the flows from the existing Beckton and Crossness outfalls as well as that from smaller works which had also been built.

In 1935 Mogden STW came into operation at the top of the tidal Thames replacing 27 smaller inefficient works which were already overloaded. Tributaries of the Estuary were also becoming severely polluted due to the outward growth of London adding to the water quality problems. In 1934 and 1935 complaints were once again being voiced about the foulness of the water.

4.6 Port of London Authority

The Port of London Authority which had taken over responsibility for the Thames Estuary from the Thames Conservancy in 1908 had like the Conservators before it no powers of pollution prevention over the London County Council. Concern was such that there was considerable discussion between the bodies and the Ministry of Health, which had overall responsibility for the control of river pollution. Experiments in further treatment of the effluent were carried out and as a result activated sludge plants were constructed at Beckton. Unfortunately shortly after these were brought into operation they were badly damaged during an air raid in 1940 and were not returned to full use until some years after the war due to fuel shortages. Extensive bomb damage to sewers during the Second World War further added to the problems of improving water quality. For much of the 1950s the river was anoxic for large stretches and devoid of life.

4.7 Thames Survey Committee and the Pippard Report

In 1947 it was reported that the Thames suffered its worst summer conditions yet recorded. At this time there were several factors of concern:

i. the LCC due to national restrictions on capital investment were only able to support a minimum programme of improvements to their works and were anxious that other factors affecting the DO content should be investigated;

ii. increasing amounts of water was being used for industrial cooling, particularly at power stations and the water being 'returned' to the Thames was of a much higher temperature. This had resulted in an upward trend in mean river temperature since the 1920s;

iii. increasing amounts of water were being abstracted upstream of Teddington during periods of low flow.

These factors, but particularly that of heated discharges, resulted in the setting up of the Thames Survey Committee in 1951 under which a wide ranging investigation was carried out by the Water Pollution Research Board (Technical Paper No 11, HMSO, 1961). This study was undertaken alongside that of a committee appointed by the Minister of Local Government and Planning, chaired by Professor Pippard, which was required to "consider the effects of heated and other effluents and discharges on the condition of the tidal reaches of the River Thames". There was a free exchange of information between the two committees. The 'Pippard' report, 'Pollution of the Tidal Thames', was published in 1961.

Among its many recommendations, the Report suggested:

i. an environmental improvement target to maintain aerobic conditions all year round in the tidal Thames;

ii. advisory standards of treatment for the STWs on the Thames Estuary;

iii. aeration of some cooling water discharges;

iv. an extension of the powers of the Rivers (Prevention of Pollution) Acts, 1951 and 1960, to the PLA.

The Report led to a more effective legislative framework which enabled the control and enforcement of discharge quality standards and resulted in investment in sewage treatment, in particular to reduce organic loads discharged from the two largest STW by the introduction of full biological treatment.

4.8 Recent History 1960 to 1989

4.8.1 1960 to 1970 Water Quality Improvements

By 1964, a completely rebuilt Crossness STW was providing full treatment for daily flows of approximately 440 Ml/d and by 1974, an extended Beckton, one of the largest works in the UK, was fully treating average daily flows of around 800 Ml/d. Sewage works improvements went hand-in-hand with improvements in the quality of the effluent from direct industrial discharges, or where treatment was too difficult or expensive, their diversion to foul sewer.

Direct industrial discharges accounted for about 9% of the total polluting load to the Thames in 1952-53 and only a small number of these discharges were likely to have an appreciable effect. The largest had its discharge stopped by the PLA in 1957. Between 1950 and 1980, a number of closures reduced the industrial pollution load on the Thames. These included two sugar refineries, two gas works, two flour mills and a major chemical works. There has also been a continuing tightening of consents for industrial discharges. Figures 4.1a and 4.1b show the reduction in polluting load (tonnes/day) to the Estuary over the period 1950 to 1990 and the corresponding improvement in DO concentration.

The introduction of biodegradable detergents in the 1960s also brought about improvements to the quality of the Estuary. Synthetic detergents, which had been widely used from 1949 onwards, interfered with the efficiency of STWs and as they were not being broken down in the treatment process, levels of surfactant built up on the river surface. This restricted the reaeration of the surface and thus reduced the capacity of the river for self purification to a minimum, contributing to its anoxic state.

In 1966, the Pippard Committee's improvement target for the Thames was achieved. Subsequently, in 1972, the Third Report of the Royal Commission on Environmental Pollution made further water quality recommendations, resulting in the development of a system of water quality management for the Estuary involving objectives and standards; a pollution budget which allowed for setting Consent standards for industrial and sewage treatment works discharges on an equitable basis for dissolved oxygen and more stringent trade effluent controls.

4.8.2 1970s Storm Water Overflow Problems

In the 1970s, two summer storm events provided the first indication of another water quality problem in the Tideway which had considerable implications for the continuing restoration of the Estuary.

On 20 June 1973 and 17 August 1977, following very heavy rainfalls over London, the Estuary was severely depleted of dissolved oxygen due to abnormally high discharges of storm water. This resulted in large fish kills. In a heavily polluted estuary the effects of such an event would have been less noticeable, but in the cleaner Tideway the results were very serious.

Figure 4.2 shows the dissolved oxygen profiles in the Estuary before, during and after the event of August 1977. Although only limited quality data was available during the storm event of 17 August, the effects of the storm inputs on the levels of dissolved oxygen in the Tideway were apparent even on 22 August, 5 days later. It is estimated that a total of 4 million tonnes of stormwater and sewage were discharged during the 1977 event.

Following these incidents, and after consultation, the then Thames Water Authority and other regulatory bodies put forward two remedial options:

i. reduce the pollution load reaching the Tideway. This would involve increasing the capacity of London's sewerage system and providing extra treatment at the major STWs. Storm rainfall over London can cause the flows in London's combined drainage system to increase five-fold from dry weather flows of 3000 Ml/d to 15000 Ml/d.

ii. Accept that storm sewage discharges are inevitable, given the drainage situation in London and treat the oxygen depleting effects of the discharges by oxygenating the Estuary.

The practical and cost implications of the first option made it untenable; to improve London's drainage infrastructure would necessitate major disruption within the City and the costs of the work would have been massive with estimates ranging

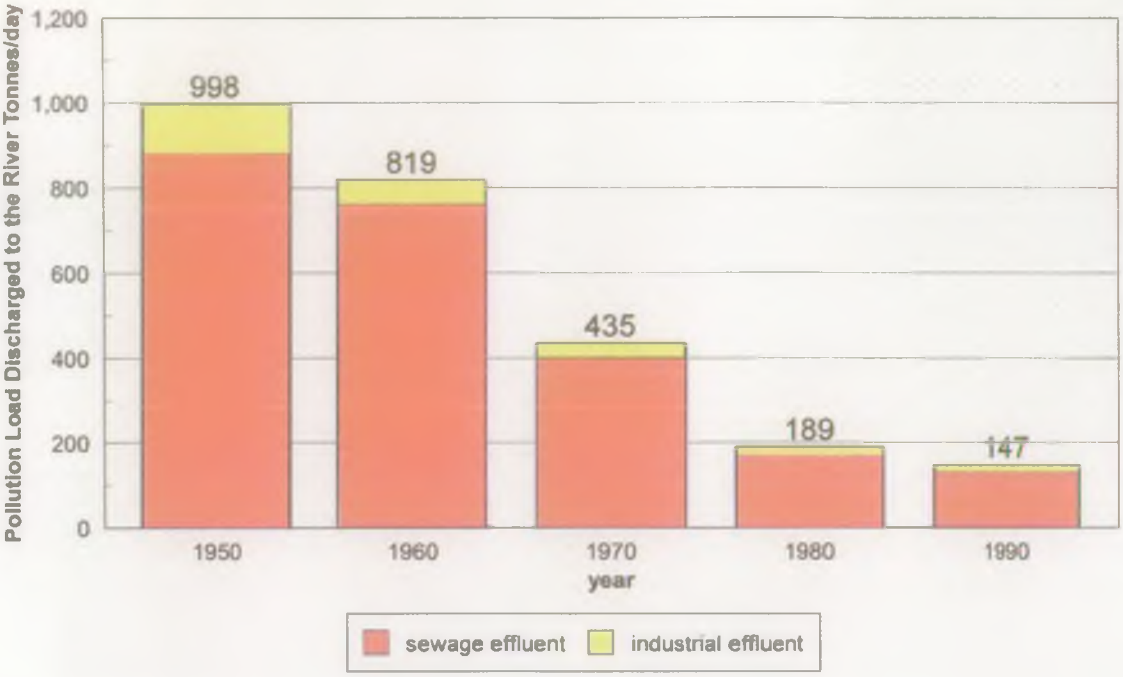


Figure 4.1a
Decrease in Polluting Load Discharged to the Estuary

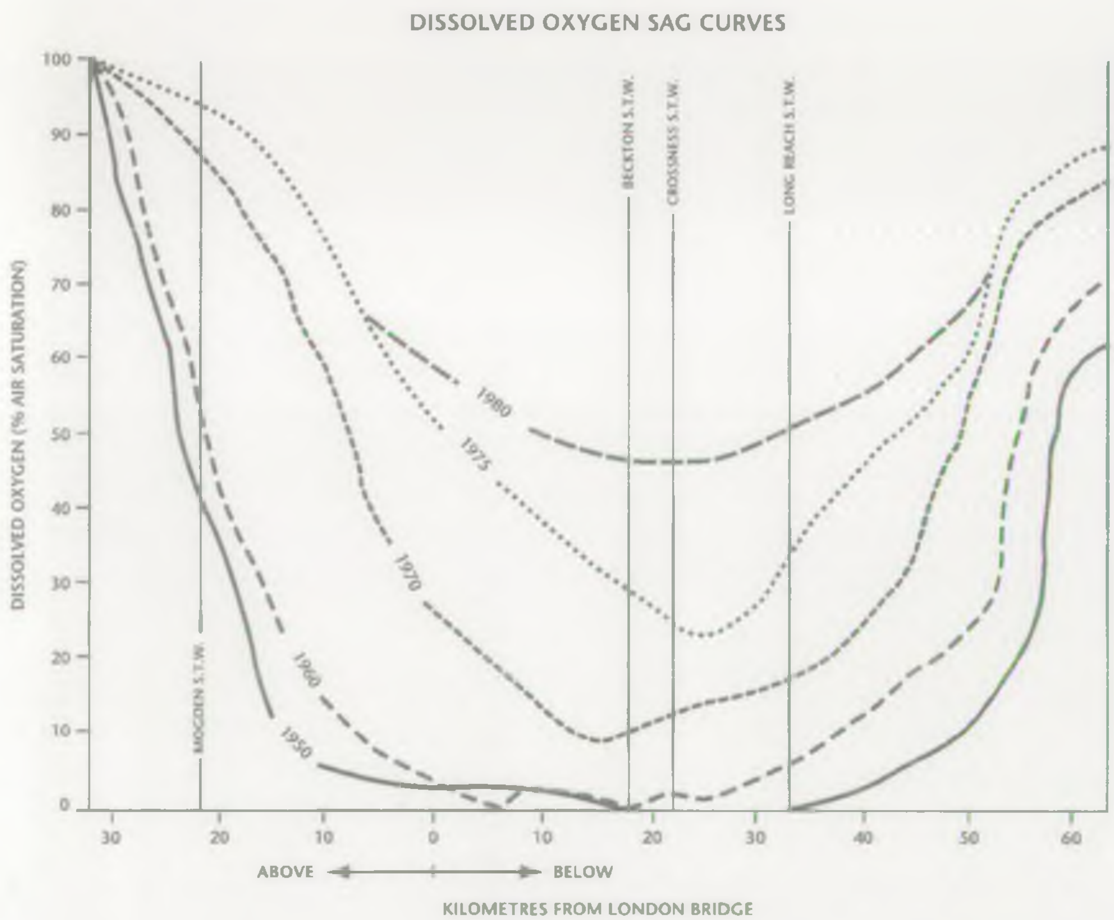
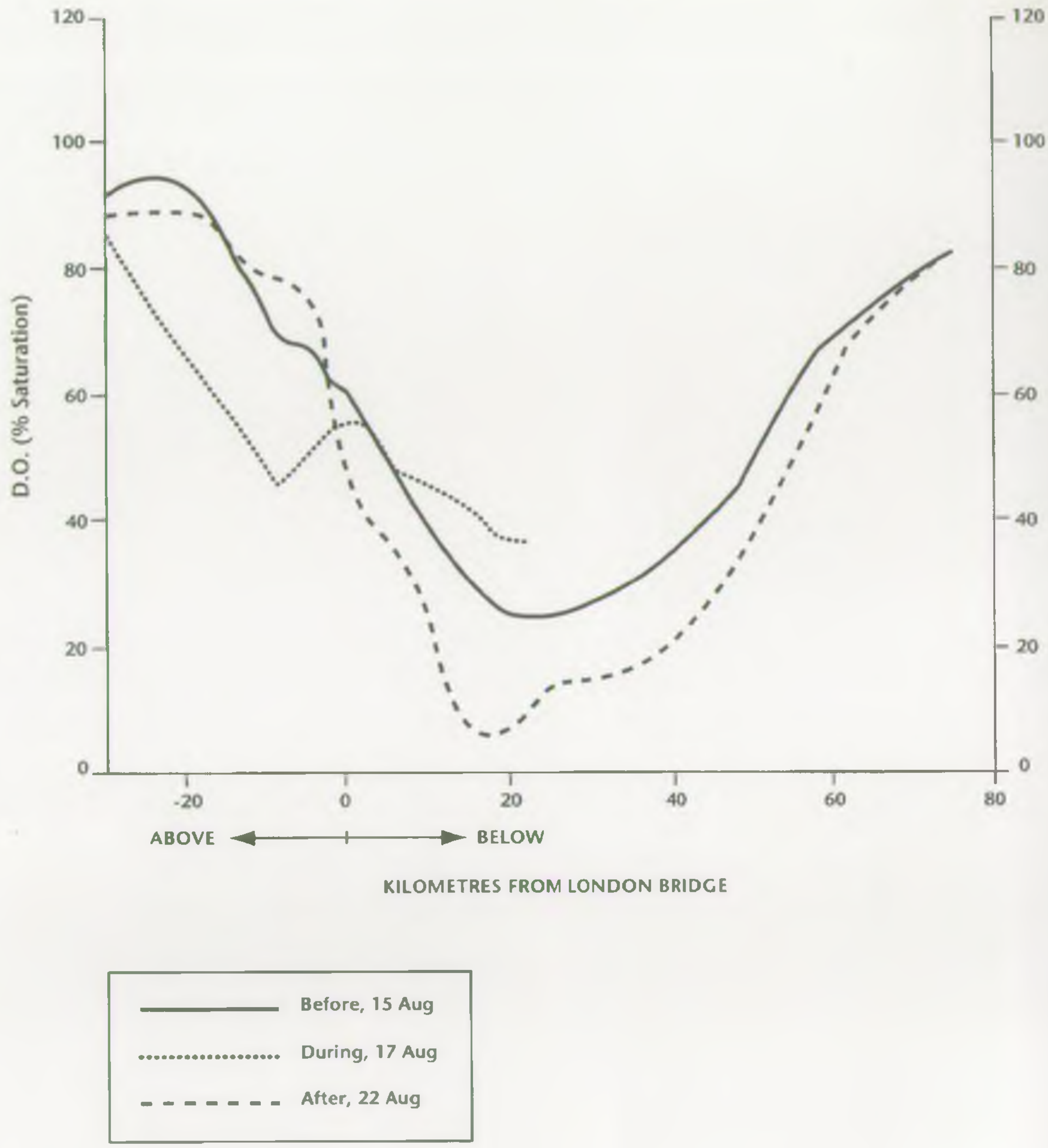


Figure 4.1b
Dissolved Oxygen Levels in the Tidal Thames between 1950 and 1980, April - September mean

Figure 4.2
Dissolved Oxygen Profiles of the Estuary before, during and after a storm event in 1977



upwards from 500 million at mid-1970s prices. The major advantage of the second option, treating the problems of oxygen depletion *in situ* was that resources could be targeted during the few critical periods in summer low flow conditions. The development of a 'Thames Bubbler' was initiated.

4.8.3 Thames Bubbler

Given the average (10-11 km) tidal excursion in the Thames, a mobile source of oxygen was required to maintain contact with the minimum DO zone. In 1980 the prototype Thames Bubbler was launched, the oxygen injection equipment mounted on a converted Thames barge. It had been calculated that, to provide protection against a 1 in 10 year storm, 30 tonnes of oxygen per day for 5 days would be required. The prototype Thames Bubbler only had a 10 tonnes per day capacity, but despite this the trials of the Bubbler proved it to work effectively and it prevented several major fish mortalities during the 1980s.

In the summer of 1986, with the prototype Bubbler out of action, intense rainfall following a long, hot, dry period lead to parts of the river in Central London became anoxic and numerous fish kills were reported. It was calculated that even if the prototype had been available it would not have had the capacity to prevent all the fish mortalities which occurred. This event confirmed the original requirement for a 30 tonne capacity Bubbler and in 1989 the current Thames Bubbler II was launched by Thames Water (Plate 4.1). The Bubbler is now subject to an operating agreement between the Environment Agency and the Water Utilities (see Current Management, Operating Agreements Section 5.5).

4.8.4 The 1980s

Despite great improvements in the management of the Thames water quality in the 1960s and 1970s, a further significant deterioration occurred during the 1980s. In the summers of 1986, 1987 and 1988, the Estuary failed its water quality objectives.

The reason for the decline was an increase in the organic loads discharged from the major Thames Water Authority STWs. Operational cost saving and the need for refurbishment meant that actual sewage works performance had deteriorated significantly, although consent standards were still achieved.

The effects of this deterioration prompted a review of the water quality strategy for the Estuary at the beginning of 1989. This resulted in the current management strategy for the Thames Estuary which is the subject of the next chapter.

Plate 4.3
The Thames Bubbler

5. Current Quality Management of the Thames Estuary

5.1 Introduction

Following the 1989 water quality review various initiatives were taken to enable better management of the Estuary. These included new water quality objectives and operating agreements.

5.2 Water Quality Objectives

The water quality objectives set in the 1970s did not protect against incidental lower DO levels which were lethal to fish and other aquatic life. Reaches could still achieve their water quality objectives with DO levels of 0% for up to 4 days in any quarterly period. This was because the standards were only specified as means and 95 percentiles.

The result of the 1989 Water Quality Standards Review was:

i. the formulation of revised water quality objectives for the Estuary which redefined the chemical standards (specifically DO) to fulfil more adequately the requirements of the river and protect against fish mortalities. The geographic limits of the three Tideway reaches were also revised to reflect more adequately the salinity related distribution of fish populations within the Estuary;

ii. the introduction of more stringent effluent standards for the major Tideway STWs during the summer, to enable compliance with the new water quality objectives during the critical periods of low flow and high temperatures. The standards were implemented by an operating agreement established between Thames Water Utilities and the National Rivers Authority at the time of water privatisation. Two other Operating Agreements cover flows over Teddington Weir and the operation of the Thames Bubbler.

For water quality management purposes the Estuary is divided up into three reaches, the Upper, Middle and Lower Estuary. Each of these reaches has a different salinity range and supports different biological communities. The water quality objectives and standards incorporate chemical and biological requirements and integrate the needs of both local water quality and the EC Directives. Where the Estuary already meets or is better than the set objective there is a commitment to maintain that quality.

The objectives for DO recognise that there is:

i. a minimum value which is lethal to Estuary life;

ii. a higher value below which life is possible but in a state of stress or reduced health.

It is known from past experience that concentrations can fall as low as 5% saturation for short periods of time during storm events without causing fish mortalities. Given the frequency of storm events, it is accepted that DO levels of 10% saturation may occur for 5% of the time (four days in any quarter) without prejudicing the general quality objectives or biological standards.

The standards and objectives for the reaches are given in Table 5.1.

5.3 Monitoring

5.3.1 Introduction

For an assessment of the water quality to be made, chemical samples are taken from the river. Regular sampling of the Thames Estuary has taken place for over 100 years; this enables long term trends in water quality to be assessed.

Today regular monitoring of the Estuary is carried out at a range of sites for a large number of different parameters to meet the following requirements:

i. quality management, day to day and long term to measure compliance against environmental quality standards set for the Estuary and to feed the information so gained into the active daily management of the system;

ii. to meet statutory monitoring requirements arising out of national and international commitments (e.g. EC Directives, North Sea Declaration etc.)

iii. to assess the impact of discharges on the environment

iv. to assess the effect of pollution incidents

v. to measure environmental concentrations and trends in water sediment and biota.

River run spot samples are taken from a boat (mid channel at 6 m depth) and analysed for a wide range of parameters required to assess estuarine water quality. These are carried out weekly during the summer and fortnightly in the winter at an average of 25 sites between Richmond Lock and Southend. The run may be continued further into the Estuary when required for other regulatory purposes.

Table 5.1 ***Standards and Water Quality Objectives for the Reaches of the Thames Estuary***

Reach	Quality Objective	Chemical Standard	Biological Standard
Teddington to Battersea	Passable to migratory fish. Maintenance of a coarse fishery within the physical constraints of the Estuary. Aesthetically pleasing appearance.	In any quarterly period the dissolved oxygen value to be greater than 40% sat for 80% of the time. Greater than 10% for 95% of the time. Minimum DO 5% sat. Maximum temperature 25°C. Compliance with EC Dangerous Substances Directive, Daughter Directives & Red List Standards.	Self supporting dace fishery as indicated by fish of the year. BMWP score greater than 25.
Battersea to Mucking	Passable to migratory fish. Maintenance of a euryhaline fish population consistent with the physical characteristics of the Estuary. Maintenance of a commercial eel fishery. Aesthetically pleasing appearance.	In any quarterly period the dissolved oxygen value to be greater than 30% sat for 80% of the time. Greater than 10% for 95% of the time. Minimum DO 5% sat Maximum temperature 25°C. Compliance with EC Dangerous Substances Directive, Daughter Directives & Red List Standards.	Minimum of 9 species of fish to be identified during power station intake surveys. Data from commercial eel returns to be examined as a potential future standard
Mucking to Seaward Limit	Passable to migratory fish Maintenance of a marine fishery consistent with the physical characteristics of the Estuary. EC Designated Bathing Beaches to be satisfactory. Aesthetically pleasing appearance.	In any quarterly period the dissolved oxygen value to be greater than 60% sat for 80% of the time. Greater than 10% for 95% of the time Minimum DO 5% sat. Maximum temperature 25°C. Compliance with EC Dangerous Substances Directive, Daughter Directives, Bathing Beach and Bathing Waters directives & Red List Standards	Suitable standards to include measure of commercial fish catches and protection of marine nursery grounds to be evolved over next 2 years.

Monitoring is carried out for metals and organo-pollutants in accordance with the requirements of the relevant legislation. This includes sampling of sediments and biological organisms.

During the bathing season from May to September samples are regularly taken of bathing water from the three designated bathing beaches of Southend, in accordance with the EC Bathing Water Directive.

5.3.2 Automatic Quality Monitoring System (AQMS)

In a very polluted estuary the occasional pollution incident has little obvious effect. But now that the Thames Estuary is of a quality to sustain a thriving fish and invertebrate population, maintenance of water quality is essential if these sensitive indicators of pollution are to survive.

Routine sampling of the tidal Thames provides information on the long-term background level of pollution but may miss completely any rapid fluctuation in dissolved oxygen due to a pollution incident, such as results from storm overflows after a high rainfall event.

In order to take remedial action, immediate information is required on the essential water quality parameters of the Estuary; DO, temperature and electrical conductivity (used as an indicator of salinity). The Automatic Quality Monitoring System was developed in the 1980s to provide this vital information.

There are 9 AQMS operating on the tidal Thames positioned in the vulnerable reaches affected by the major sewage treatment works and storm overflows. The data is relayed by telemetry to the Regional Headquarters where alarm systems are monitored on a 24 hours basis. Data can also be accessed at local offices and from home using telephone modem-linked, computers.

5.3.3 Other Monitoring Requirements

In addition to quality information data is required on rainfall and flows in the Estuary.

5.3.4 Rainfall

One of the critical pollution events on the Tideway is the discharge of storm sewage. In order to predict the likelihood of such an event and therefore be in a position to take the necessary action to reduce the resulting effect, data is assessed from the Rainfall Radar Network. This provides 24 hour information on rainfall from a series of rain gauges across the catchment.

5.3.5 Flow Gauges

Freshwater flow is continually gauged at downstream sites on all the significant rivers entering the Tideway. This is particularly important for the freshwater Thames because of the effect of abstraction on the flow and the legal requirement to maintain a minimum flow over Teddington Weir. This information is relayed to the Regional Control Room.

5.4 Water Quality Models

Mathematical models are used to provide greater understanding of the processes occurring in the Estuary. The first 'Thames Model' was developed during the investigation of the Tideway in the late 1950s (Technical Paper No 11, HMSO, 1964) and this allowed the effects of polluting discharges to be predicted.

The model in current use for the Thames Estuary is QUESTS developed by the Water Research Centre. It is a one-dimensional, time dependent hydrodynamic model which can predict flows and water levels throughout the Estuary. The flows are then used to calculate the transport of material. The model can look at salinity, temperature, sediment, biochemistry, Escherichia coli and metals.

The data gathered through routine monitoring of the tributaries and effluents discharging to the Thames is fed into the model and the predictions compared with measurements from the AQMS or Boat Run surveys. This enables calibration constants to be adjusted and the model refined.

The model can be used to look at current problems and has been used to look at the effects of proposed new discharges to the Tideway, such as the temperature effect of discharges from power stations, the effects of changing flows over Teddington Weir and storm water discharges on the water quality in the Estuary.

5.5 STW Discharges, River Flow, Storm Discharges and Operating Agreements

The four most important factors with respect to the current water quality management of the Thames Estuary are:

i. the quality of the effluent from the TWUL STWs (Table 5.2);

ii. freshwater flow over Teddington Weir (Table 5.4);

iii. the temperature of the water in the Estuary;

iv. the occurrence of storm water discharges.

Table 5.2
Loads discharged from STWs

STW	Distance from London Bridge (km) (i)	Average Flow (Ml/d)	Load EOL (tonnes/d)
Mogden	24	420	8.6
Kew	19	46	0.7
Beckton	-18	1000	26
Crossness	-22	550	24
Riverside	-24	137	17.5
Long Reach	-31	190	26
Northfleet	-40	9	2.1
Tilbury	-44	31	4.7
Gravesend	-45	13	9.3
Canvey	-59.7	5	1.5
Pitsea	-57.6	6	0.3
Basildon	-57.6	18	1.5
Benfleet	-64.4	5	0.4
Southend	-71.8	37	18.7

(i) positive values are upstream of London Bridge and negative values are downstream.

Table 5.3
Industrial Inputs

Industry	Distance from London Bridge (km) (i)	Average flow Ml/d	EOL tonnes/d
Lots Road Power Station	9	285	cooling water
Tunnel Refineries	-10	6	0.5
Tate and Lyle	-15	41	1.8
Barking Power Station	-20	1,500	cooling water
Ar-Jo Wiggins	-29	10	0.7
Purfleet Board Mills	-31	10	4.3
Little Brook Power Station	-32	5,073	cooling water
Empire Paper Mills	-35	10	1.2
Proctor and Gamble	-36	10	0.2
Bowater Scott	-41	8	1
Tilbury Power Station	-42	2,727	cooling water
Mobil Refinery	-56	214	5.5
Shell Refinery	-58	388	7.5

(i) positive values are upstream of London Bridge and negative values are downstream.

With the exception of temperature which is controlled by discharge consents, management of these factors is largely achieved through the Operating Agreements between the Environment Agency and TWUL. In looking at the influences on the Estuary, it is helpful to describe the effects on the Upper, Middle and Lower reaches separately, followed by a discussion of the use of Operating Agreements and storm water discharges.

5.5.1 Upper Reaches

The Upper Tideway responds rapidly to many variables. The most important of these are freshwater flow, algal growth, the discharge from Mogden STW and water temperature. Freshwater flow over Teddington Weir is a major factor which affects water quality in the Upper reaches, (Figure 5.2), particularly relating to the ability of the river to accommodate the discharge from Mogden STW. During periods of drought the volume of flow from Mogden STW can be twice as large as the flow over Teddington.

The discharge from Mogden STW dominates the water quality in the Upper Reaches. Small changes in the ammonia content of the effluent have a very significant effect on the river. As freshwater flow increases and water temperature decreases, the effect of the Mogden discharge lessens and there comes a point, normally in the winter, when this effect becomes almost unnoticeable. Conversely, at times of low Teddington flow, the effluent has a greater detrimental effect. The EOL from Mogden can be greater than that from the freshwater Thames, although there does appear to be a threshold point, beyond which a lessening of flow does not cause further deterioration of the river, provided that the effluent remains of very good quality.

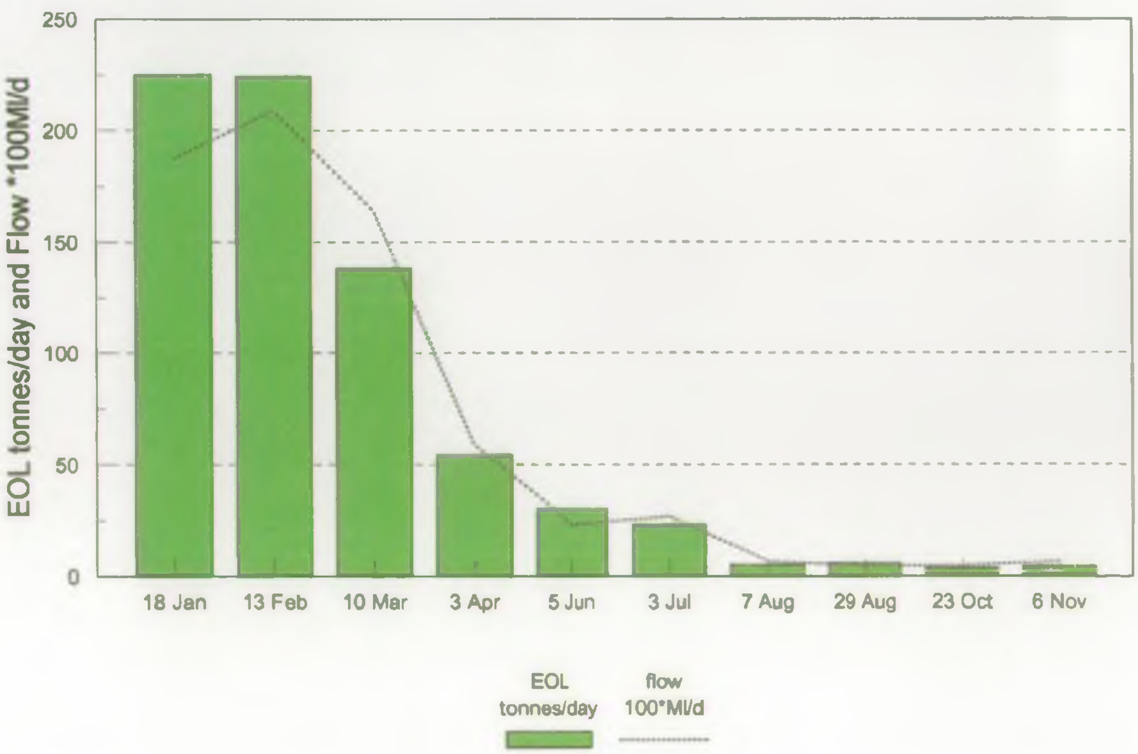
The Upper Reaches do not receive any significant organic load from industrial sources either directly or via the tributaries (Table 5.3).

Table 5.4
Freshwater Inputs

Watercourse	Distance from London Bridge (km) (i)	EOL (tonnes/d) from average flow
Thames	30	16.32 (ii)
Crane	25	0.25
Duke of N'Land	24	0.18
Brent	21	0.63
Beverley Brook	13	0.65
Wandle	11	1.31
Ravensbourne	-7	0.16
Lee	-11	6.89
Roding	-19	0.89
Beam	-23	0.30
Ingrebourne	-25	0.34

(i) positive values are upstream of London Bridge and negative values are downstream.
(ii) the range of flows and consequently the EOL over Teddington weir varies significantly during the year.

Figure 5.2
Effective Oxygen Load from the Freshwater Thames in Relation to the Flow for 1995



At certain times of the year, especially in the period April to June, the river supports large populations of diatomaceous algae. (See Section 3.6)

5.5.2 Middle Reaches (London Bridge - Mucking)

More than 80% of the total polluting load from STWs serving London and its suburbs is discharged from the TWUL STWs operated at Beckton, Crossness, Long Reach and Riverside. The combined average volume of sewage effluent discharged from these works is almost 2000 Ml/d. Although treated to a high standard, these discharges have a significant effect on water quality, particularly DO levels (Figure 5.3). In addition, there is the discharge from Deephams STW via the River Lee.

Modelling of the discharges into the Estuary shows that after the critical inputs of Beckton and Crossness, Riverside is the next most significant input despite being only 60% of the load of Long Reach. The impact of Riverside is increased due to its discharge being only 4km downstream of the 'Critical Point' whereas the river has begun to recover from its DO sag by the time Long Reach discharges 10 km downstream.

Small changes in the freshwater flow have no effect but prolonged high freshwater flow and low temperatures have a pronounced beneficial effect in the winter months. The river is particularly sensitive to changes in the ammonia load discharged from Beckton and Crossness STWs and there is a significant variation in DO levels during the Spring/Neap tidal cycle.

Industrial inputs constitute less than 8% of the total organic load in the Middle Reaches, most of which is due to the discharge from Purfleet Board Mills.

5.5.3 Lower Reaches (Mucking - Seaward Limit)

By comparison, the STWs situated in the Lower Reaches have relatively little effect. Gravesend and Northfleet are operated by Southern Water and the other six STWs by Anglian Water. The combined average daily volume from all these works is less than 150 Ml/d. Nearly 80% of the total organic load from sewage effluent to this reach is discharged at Southend via a long sea outfall. This is the most seaward STW discharge of any significance. However, monitoring has shown that in terms of chemical effect e.g. DO, this effluent and that of the other works, has little impact on the main body of the Estuary due to the effective dilution and dispersion.

Southend STW is significant with respect to the three designated bathing waters in the Southend area and compliance with the EC Bathing Waters Directive (Section 6.3.2).

The only two significant industrial inputs are from the Mobil and Shell Oil Refineries. As a result of adequate treatment these have been found to have no significant effect on DO levels in the Estuary.

5.6 Summer Conditions and Improved Operating Standards for STWS

For over half the year from October to May, under typical conditions, the water quality of the Estuary is good. The higher flows over Teddington Weir and

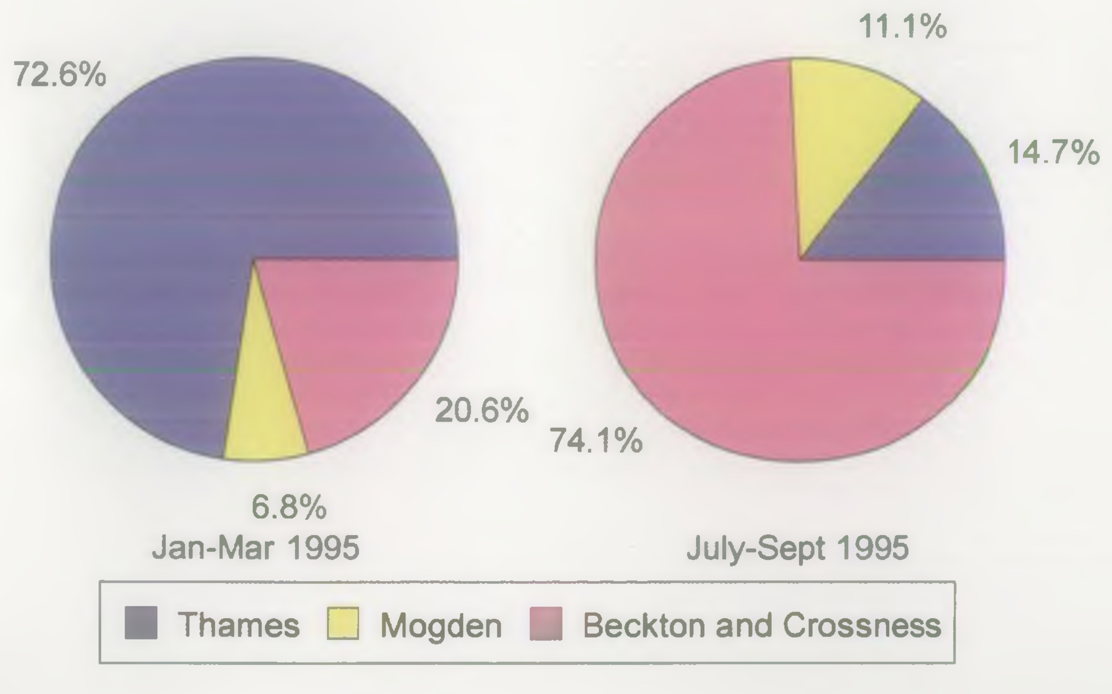


Figure 5.3
The Percentage Load Contributed to The Tideway by the Freshwater Thames, Mogden, Crossness and Beckton STWs in a High and Low Flow Period.

Table 5.5
Consent Standards for STWs in the Thames Estuary

STW	BOD mg/l		Ammonia NH_3 as N mg/l	
	Consent as 95 percentile	Summer (median)	Consent as 95 percentile	Summer (median)
Mogden	23	11	7	1.0
Kew	16	5	7	0.5
Beckton	22	6	6	1.0*
Crossness	25	10	16	7*
Riverside	31	15	44	20
Long Reach	50	20	53	25

** these values are given as guidelines. The total Effective Oxygen Load from Beckton and Crossness must not exceed 55 tonnes per day as a median value over the period of operation. This allows for some flexibility in the operation of these two works.*

from the tributaries, and the seasonal lower temperature of the water mean that there is good dilution and high DO levels. Therefore, providing discharges are within their consents, the Estuary is not critically sensitive to the effects of the polluting loads from STWs.

As the water temperature rises in summer, so the sensitivity of the Estuary increases. When the water reaches a threshold temperature of approximately 15 degrees C, and this coincides with a spring tide where high tidal velocities cause resuspension of sediment, then a marked reduction in DO occurs. Reductions of 10 to 15% have been measured.

It is speculated that this is due to increased bacteriological activity at higher temperatures with the re-suspended organic material providing a platform for nitrifying bacteria to oxidise nitrogen sources. This marks the start of 'summer conditions' where nitrogenous loads must be reduced in order to maintain river quality objectives for DO. It is during this period that the provisions of an Operating Agreement are in force.

During the summer months freshwater flows are severely reduced and river temperatures rise. Compliance with the consent standards for the major STWs is not sufficient to protect water quality due to the greatly reduced dilution available, the increased retention time and the higher temperature which causes a more rapid oxidation of organic material by bacterial activity. In order to ensure adequate oxygen reserves, i.e. 30% saturation, during the summer, the main STWs are required under the Agreement, to increase their level of treatment to produce effluent of a much higher standard. Both Consent Standards and improved summer standards are shown in Table 5.5.

5.7 Storm Water Discharges

Much of central London is served by a combined drainage system receiving both foul drainage from domestic and industrial premises and surface water. The benefit of this system is that any spillage, whether from industry or road traffic accidents will be transferred to STW where the discharge can be treated. The disadvantage is that when heavy rain falls over London the sewers cannot contain the extra flows generated resulting in the discharge of storm sewage. During the summer months, when storms follow hot sunny periods, this can have a severe effect on water quality as occurred during the 1970s (see section 4.8.2).

The amount of storm sewage discharge depends on the rainfall intensity, duration and the path of the storm. The quality of the storm discharge is extremely variable but generally the BOD ranges from 50-150 mg/l and the ammonia from 2-15 mg/l. A fairly heavy storm will generate in excess of 2000 Ml of storm sewage which may have an oxygen demand of 50 tonnes in the first day (Griffith & Lloyd, 1985).

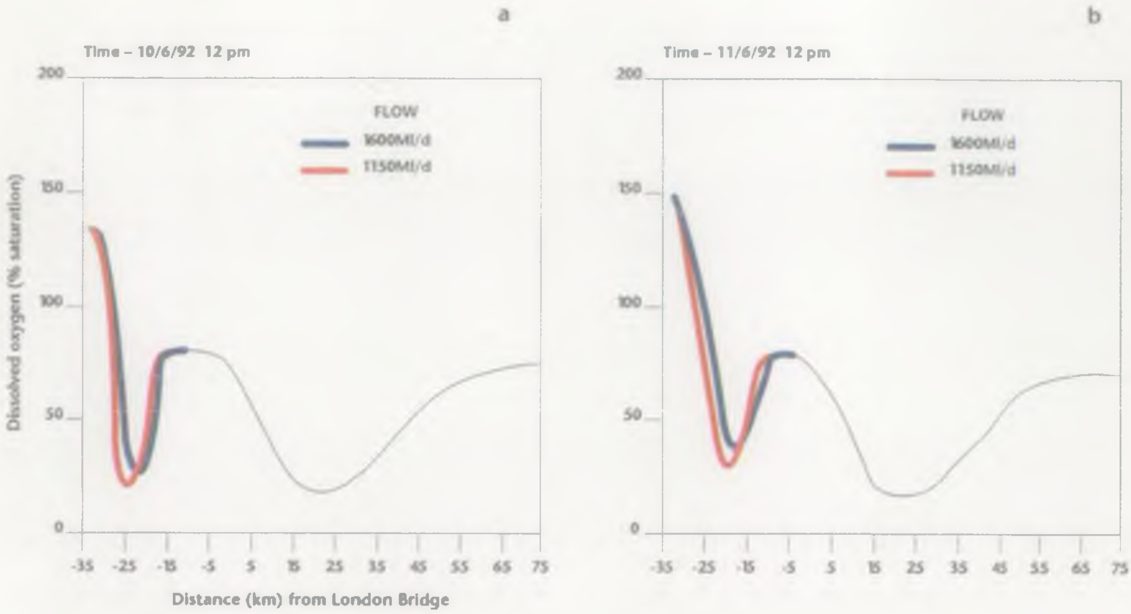
The effect of these discharges is to produce a rapid decrease in DO level. The DO sag curve that normally results will depend on such factors as storm intensity, duration and location. This sag can be traced down the Estuary using AQMS.

In the Upper Reaches, Mogden STW, Western and Hammersmith Pumping Stations are the key sources of storm sewage input. They can be considered as equally significant in their potential to cause serious water quality problems in the upper Tideway, particularly when flows over Teddington are low.

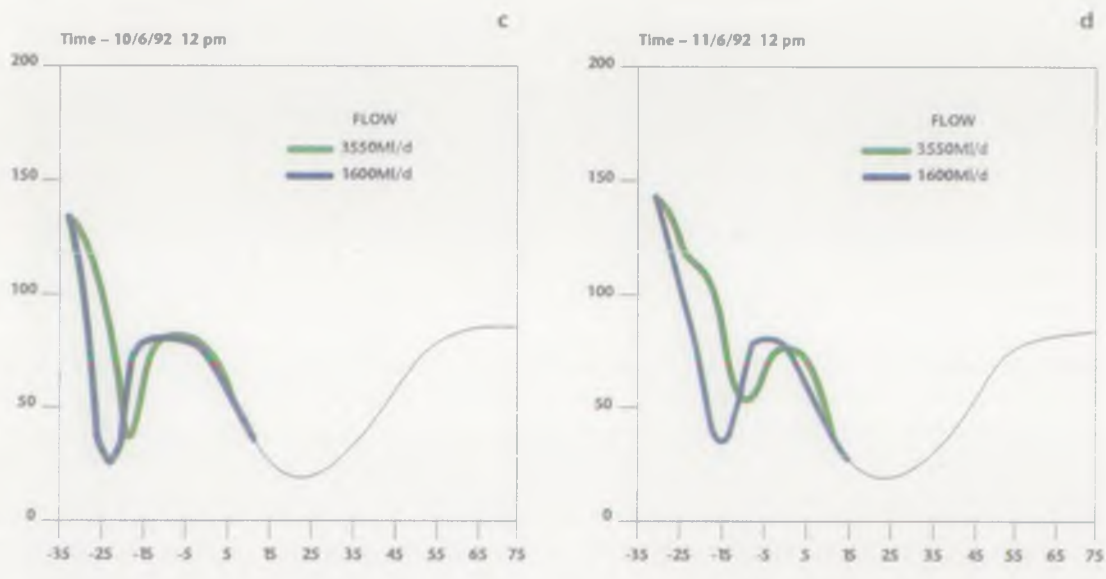
In the Middle Reaches, the discharge from STWs, pumping stations and the River Lee cause a deterioration in quality but not as rapidly as in the Upper Reaches. The residual storm load from the Upper Reaches will also exert an effect.

As already discussed, the Thames Bubbler was developed to mitigate against the effects of such storm events. An Operating Agreement allows the

Figure 5.4
Modelled Effects of Reducing Abstraction on Dissolved Oxygen during a Storm Event



Effect of the flow over Teddington being increased from 1150Ml/d at the time of storm to 1600 Ml/d on the storm dissolved oxygen sag on day 1 and day 2



Effect of the flow over Teddington being increased from 1600Ml/d to 3550 Ml/d (no abstraction) on the dissolved oxygen sag on day 1 and day 2

Environment Agency to call out the TWUL-owned Bubbler when it considers, from data gathered, that a storm is imminent which is likely to cause oxygen loss in the Tideway to less than 30% saturation. The Environment Agency accompanies TWUL on the Bubbler and provides it with the information required to enable the most effective use of reoxygenation to be made.

In addition to alleviating the effects of storm water discharges, the Operating Agreement covers the use of the Bubbler for pollution incidents caused either by TWUL STWs or other sources which might result in serious DO depletion.

5.8 Freshwater Flow

With respect to both storm water and STW discharges, an improvement in the DO levels of the Upper Reaches of the Estuary can be achieved by greater flow over Teddington Weir. The third Operating Agreement covers reduction or suspension of abstraction in the Lower Thames in order to achieve a greater freshwater flow over

Teddington. The Environment Agency may request such action when it considers, as in the other two Agreements, that there is a threat to the DO level in the Estuary.

TWUL may decline to take such action if it considers that there is a serious shortage of water resources in the London area or such a shortage is imminent. However, it is required to use its best efforts to comply with the request as soon as is reasonably practicable.

The effects of a suspension or reduction in abstraction and subsequent increase in flow can be seen in the dissolved oxygen profiles modelled during a storm event in June 1992 shown in Figure 5.4. The benefit of the increased flow is a reduction in the magnitude of the sag and faster movement down the river. This provides higher background levels of DO as a buffer to the effects of further storms.

As a result of the Operating Agreements and improvements to Mogden and Crossness STWs, the quality of the Tideway can be maintained within its objectives under most conditions (Figure 5.5). However, the Environment Agency is constantly reappraising the situation and continuing to gain experience in new methods to increase the flexibility and robustness of the system.

5.9 Heavy Metals and Organic Micro-Pollutants

5.9.1 Introduction

The point sources of heavy metals and pesticide pollutants to the Thames Estuary are via the sewage treatment works. Control of industrial discharges to sewer is through trade effluent consents imposed by the Water Utilities.

5.9.2 Dissolved Metals

Considerable reductions of metals, such as mercury, were achieved in the Thames Estuary STWs in the 1970s. Tighter control and better treatment of industrial effluents since this time has resulted in substantial reductions of cadmium and mercury to the North Sea from the UK as a whole. The average levels of mercury, cadmium, arsenic, chromium, nickel and lead in the Estuary are well below the EQS limits. The average concentration of dissolved zinc approaches its EQS limits and copper has, in some periods, exceeded the limit at 2 points in the Upper and at 2 points in the Lower Estuary. The sources of copper and zinc are largely diffuse, as for example the use of copper in water pipes and of zinc in many toiletries.

The concentrations of most metals detected in the river and STW effluents are at very low levels. Monitoring since 1991 of loads discharged from STWs and rivers does not show any significant trend either up or down.

5.9.3 Pesticides and Organic Micro-pollutants

The use of pesticides increased in the 1940s with the introduction of synthetic compounds, such as DDT and Dieldrin. It was not until the late 1950s and early 1960s that the extent of the environmental problems associated with the use of such compounds began to be understood. These early pesticides were extremely persistent and were found to accumulate in animal bodies. The use of DDT in the UK was banned in 1984 and Dieldrin in 1989.

Figure 5.5 ***Dissolved Oxygen Profile, May-September mean, showing improvement since 1989***

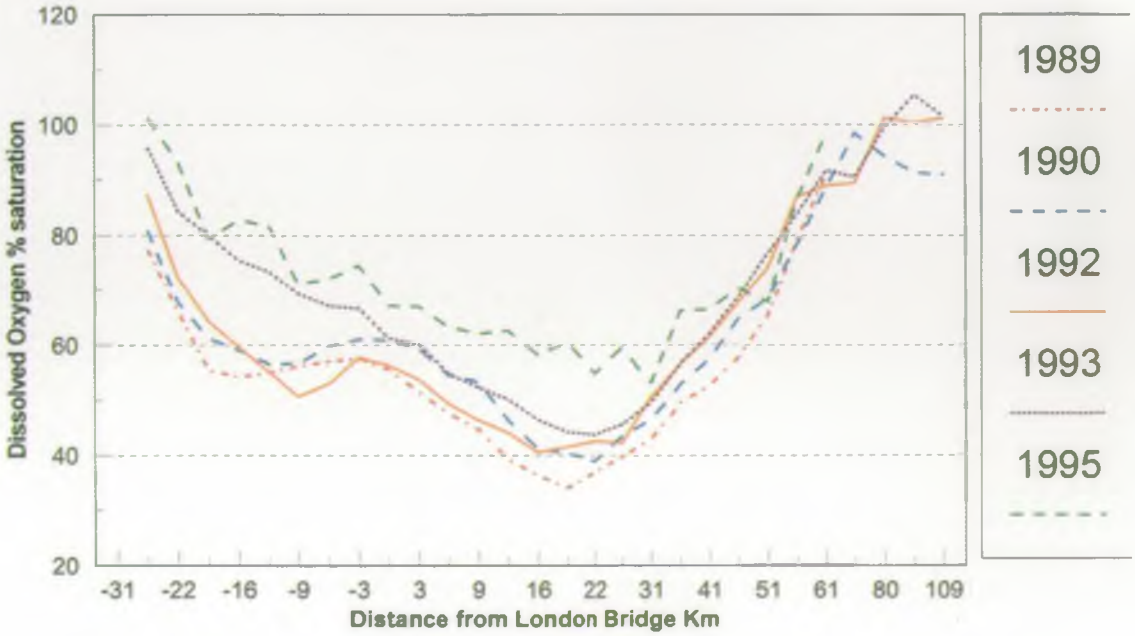


Table 5.6
Loads of Organic Micro-pollutants in Sewage and the Estuary between 1991 and 1995

	1991	1992	1993	1994	1995
			Lindane (kg)		
Sewage	74	67	62	39	33
Rivers	15	26	50	16	11
Total	89	93	112	55	44
			Atrazine (kg)		
Sewage	227	159	125	41	36
Rivers	223	172	155	43	26
Total	450	331	280	84	62
			Simazine (kg)		
Sewage	306	366	213	26	52
Rivers	159	104	129	43	53
Total	465	470	342	69	105

There are now 450 different pesticide active ingredients approved for use in the UK. However, the introduction of new pesticides which are less persistent and require lower application rates together with the more efficient use of older pesticides and the banning or tighter control of some pesticides has contributed to a reduction in occurrence in the environment.

For those substances controlled under the Dangerous Substances Directive for which EQSs have been established, the long term average concentrations are all well below the relevant EQS limits with the exception of Lindane.

Lindane is an isomer of hexachlorocyclohexane(HCH) and is a persistent organochlorine pesticide widely found in trace concentrations in sewage effluents from heavily urbanised areas. Lindane is found in both the tributaries of the Thames and the STWs discharging to the Estuary. The Estuary has marginally failed its EQS limits at Barnes and London Bridge over the last few years. However, as Table 6.1 shows, Lindane was compliant in 1995. The sources are considered to be entirely diffuse. It is used in human health products, such as head lice treatments, in wood preservatives for industrial and home use, as well as horticultural, agricultural and forestry applications. Improper disposal of domestic substances containing Lindane contribute to the problem of diffuse inputs.

Recent monitoring data shown in Table 5.6 suggests that there has been a reduction in the amount of Lindane being discharged to the Estuary since 1993. This could account for the 1995 compliance with the Lindane standard in the Estuary as shown in Table 6.1. The reason for this reduction is unknown but may be due to the increasing awareness of the problem of Lindane in the environment and the move to less persistent pesticides.

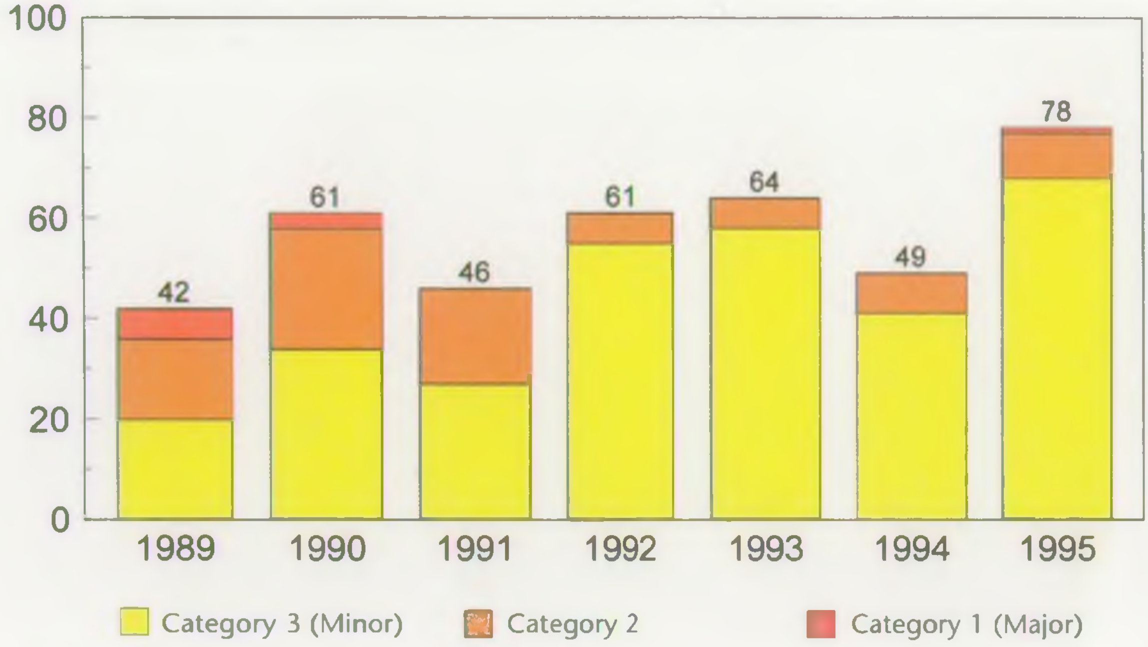
The Environment Agency will continue to bring to the Government's attention the problem of Lindane and any other pesticides of concern in the aquatic environment with a view to achieving stricter control procedures.

Of those substances controlled under Annex 1A of the North Sea Conference Declaration, the most significant inputs to the North Sea from the Thames Estuary have been Lindane (as discussed above), Simazine and Atrazine. Simazine and Atrazine, which were widely used for urban weed control, were banned for non-agricultural use in September 1993. Monitoring data (Table 5.6) shows the subsequent effect of this ban with a significant reduction in load to the Tideway.

5.9.4 Nutrients

The Environment Agency is involved in the implementation of two EC Directives concerning the control of nutrient inputs to surface waters. The Urban Waste Water Treatment Directive (91/271/EC) addresses the issue of pollution from point source discharges, particularly STWs. In contrast, the Nitrate Directive (91/676/EC) is intended to reduce water pollution by nitrate from agricultural (primarily diffuse) sources. Under the Urban Waste Water Treatment Directive, if a water is designated as sensitive, that is the water is affected by eutrophication, then STWs will be required to install phosphorus reduction treatment by the end of 1998. The Thames Estuary has not been defined as a sensitive area and therefore currently there are no plans for phosphorus or nitrogen reduction.

Figure 5.6
Thames Tideway Pollution Incidents 1989-1995



The Nitrate Directive has been implemented by the designation of Nitrate Vulnerable Zones. In these areas a code of good agricultural practise and certain restrictions on numbers of livestock apply. Emphasis has been placed on rivers supplying potable water. To date there has not been a problem in the Thames Estuary associated with eutrophication, so none of the provisions of these directives regarding nutrients have been applied.

5.9.5 Pollution Incidents

Figure 5.6 shows the number of pollution incidents in the Thames Tideway between 1989 and 1995. Although the number of incidents shows no significant reduction over this period, the vast majority of incidents were classified as minor(Category 3), and the number of major incidents has decreased.

Oil spillages are perceived as a great potential threat to the Thames Estuary ecosystem. Out of 37 prosecutions for pollution on the tidal Thames between 1979 and 1994, 23 were for oil spills. The proximity of the major oil refineries at Coryton and Shellhaven to sensitive ecosystems constitutes a considerable potential risk. Downstream of Tower Bridge the PLA has joined with the oil industry to form the Thames Oil Spill Clearance Association (TOSCA), which provides a unified response to oil pollution incidents. Between Teddington and Tower Bridge the Environment Agency and PLA provide incident reporting and response cover. The Environment Agency is also working with the British Oil Spill Control Association (BOSCA) to provide an accreditation scheme for oil spill response contractors to ensure rigorous standards are maintained in this high profile area of pollution alleviation, where fast and effective responses are critical.

5.9.6 Aesthetics

Litter, everything from plastic debris to mattresses and car parts, is a considerable problem in the Thames Estuary. Every year around 3,000 tonnes of rubbish are removed by PLA barges. As well as the work of the PLA, a number of other initiatives are aimed at improving the aesthetic quality of the Thames. ThamesClean is a project operated by the Tidy Britain Group in partnership with the Environment Agency with the aim of reducing litter in the Thames and its tributaries. This aim is achieved through research, practical clean ups, campaigning, enforcement and education. With respect to the plastic debris, many of the large STWs on the Estuary have added fine screens which act as filters and reduce discharge of plastic items. Cessation of sewage sludge disposal at sea in 1998 will also remove a major source of sewage-derived litter.

6 Quality Compliance of the Thames Estuary

6.1 Introduction

Since the late 1970s the quality of the Thames Estuary has been assessed against both statutory and non- statutory objectives. The statutory objectives are those that are defined in the EC Directives. The non-statutory objectives are those derived by Thames Water Authority in 1977. These were based on the recommendations of the Third Royal Commission and a scheme devised by the Department of the Environment and the National Water Council (NWC). The standards were revised in 1989 to more adequately meet the needs of the Estuary.

6.1.1 Estuary Classification

The scheme devised by the Department of the Environment and the NWC classifies estuaries into good, fair poor and bad quality classes (A-D) on points awarded under the headings of biological, aesthetic and chemical quality.

In 1995 the Thames Estuary was classed as Good(A) for 27.2 km and classed as Fair(B) for 83.9 km of its total length.

The scheme is very subjective and although it provides a national standard it is not considered to be adequate for the rigorous control required in the day-to-day management of the Thames Estuary. More detailed standards have therefore been developed (Section 5.2).

6.2 Dissolved Oxygen Compliance

As discussed in Chapter 5, the most significant factors in maintaining the DO levels in the Estuary are the freshwater flows over Teddington Weir and the water temperature. As can be seen in the compliance tables for DO in the 4 quarters of 1995 (Figure 6.1), the most critical period was as usual the third quarter. During this time, the DO sag as a result of the discharges from Mogden STW and Beckton and Crossness STWs is very pronounced. The Tideway was fully compliant with the DO objectives in 1995.

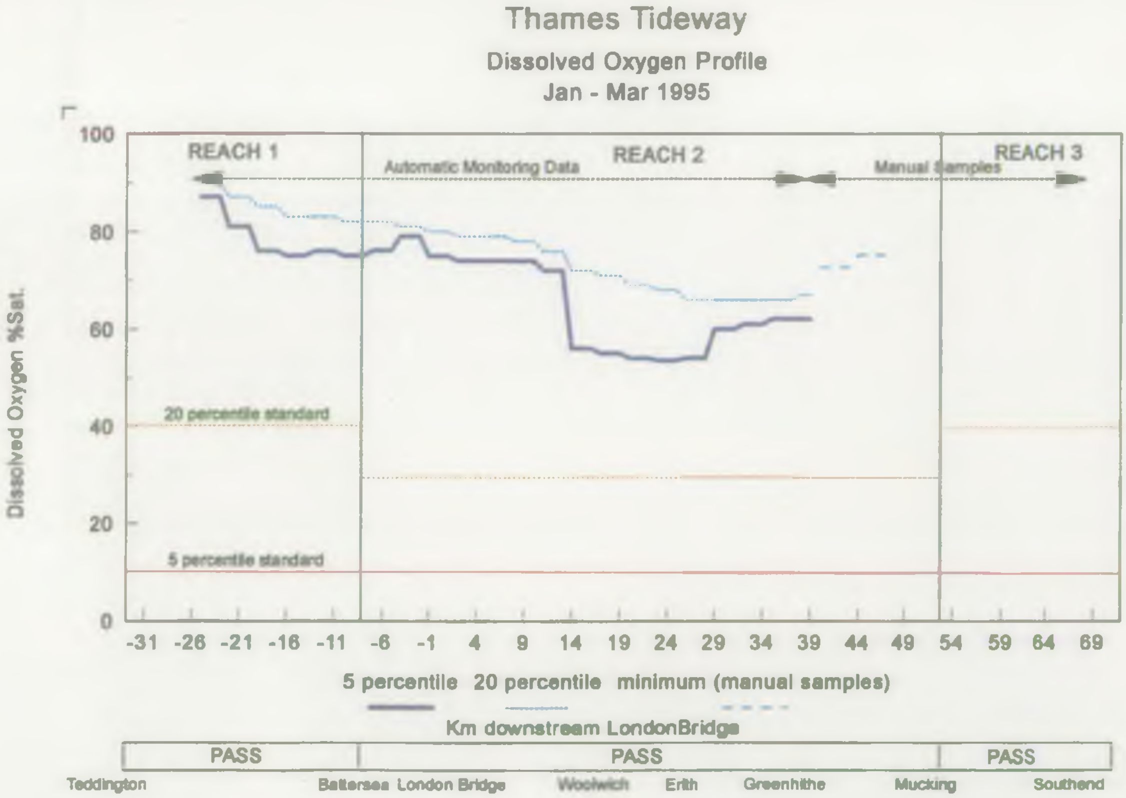
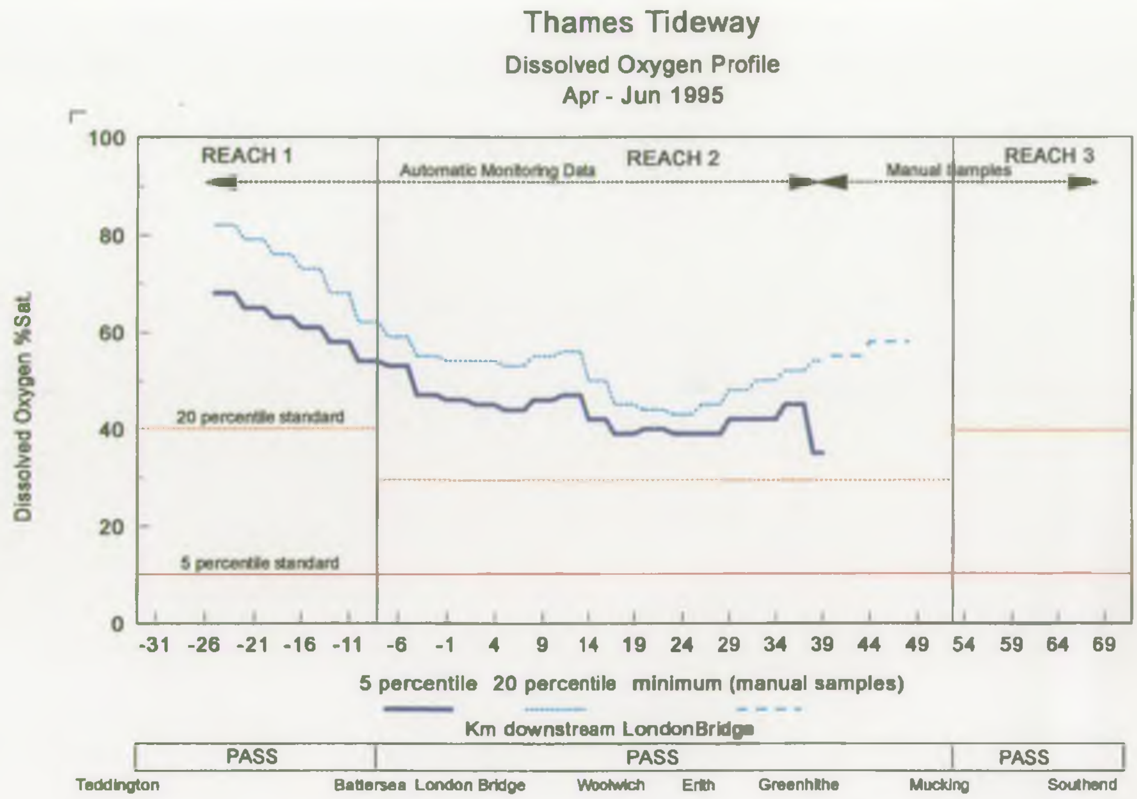
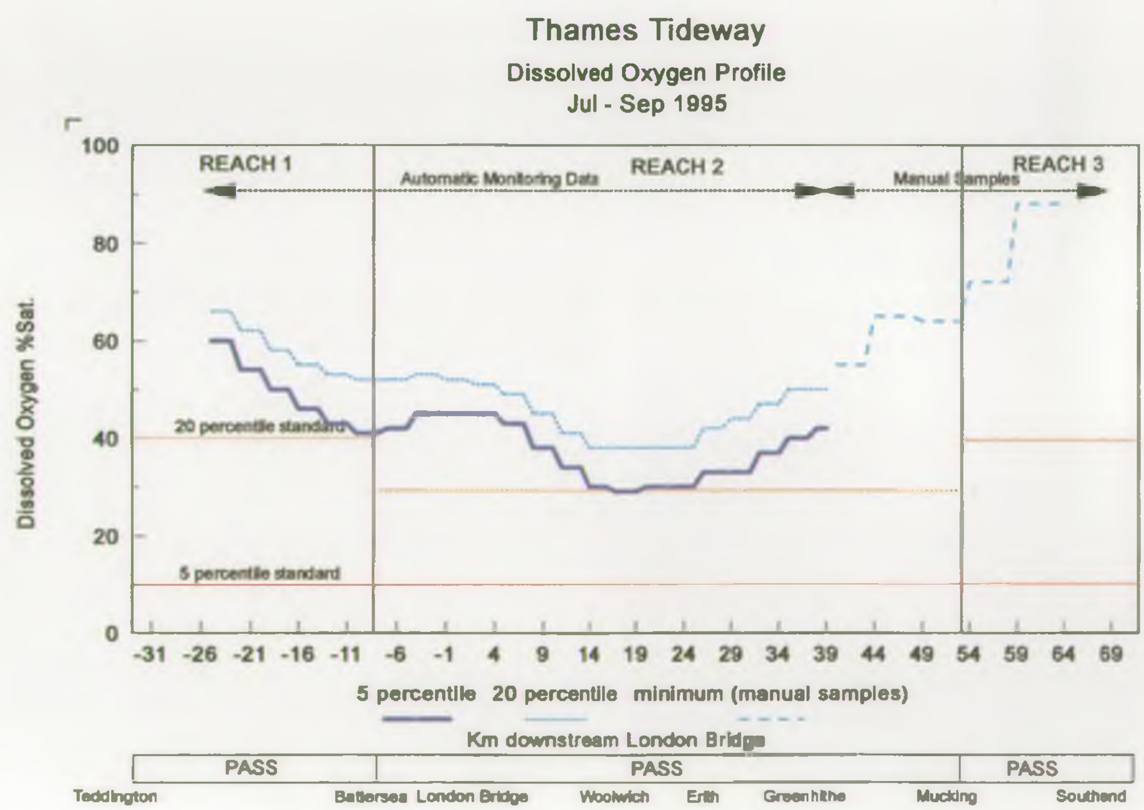
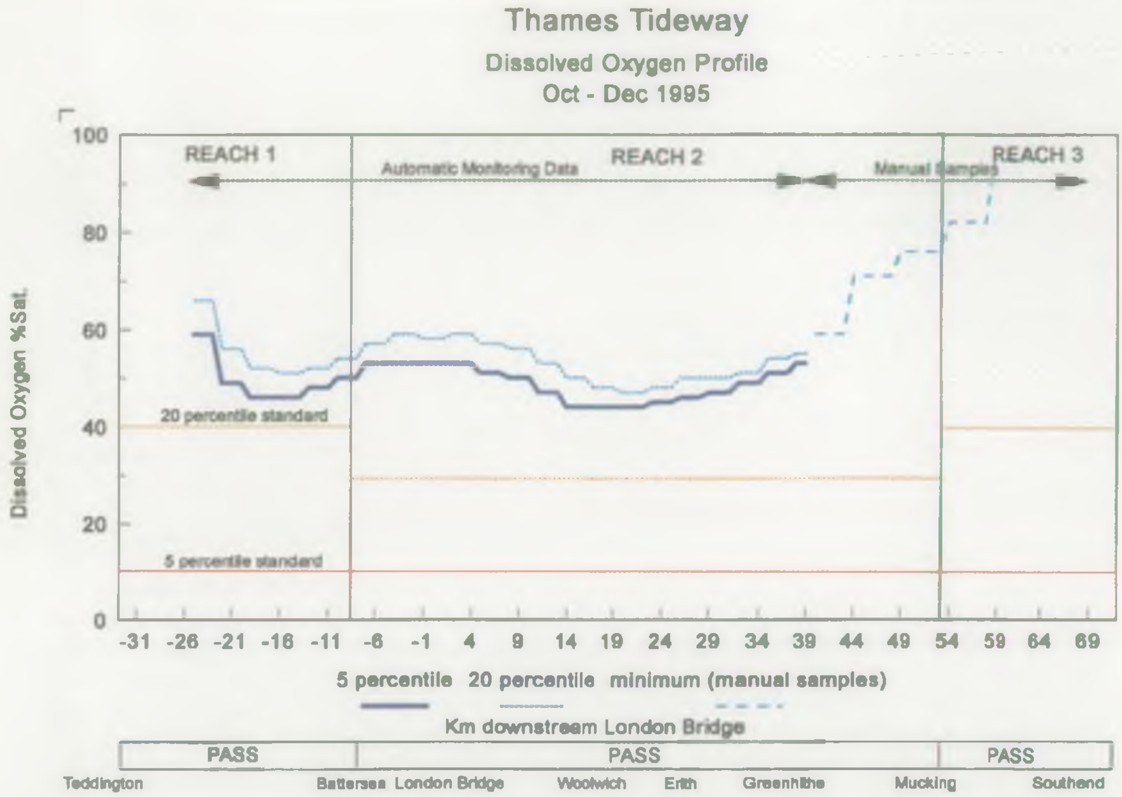


Figure 6.1 *Dissolved oxygen compliance for each quarter of 1995*
continued overleaf

Figure 6.1 *continued*
Dissolved oxygen compliance for each quarter of 1995







6.3 Compliance with Environmental Quality Standards

6.3.1 List I and List II Dangerous Substances

The Department of the Environment Circular 7/89 gave statutory effect to the EC Dangerous Substances Directive (76/464/EC) and instructed the competent authorities on the implementation of the Directive and on the requirements of certain decisions on the control of Dangerous Substances under the Paris Convention.

The Circular set standards for List I substances, which were selected mainly on the basis of their toxicity, persistence and bioaccumulation, and List II substances which can also have deleterious effects on the aquatic environment but whose effect is more dependent on the characteristics and location of the water into which they are discharged. The standards are expressed as annual mean concentrations. Sampling to assess compliance is carried out at 6 sites down the Estuary. Tables 6.1 and 6.2 show that there were no failures to comply with the Environmental Quality Standards (EQSs) except for copper.

6.3.2 1995 Compliance with the Bathing Water Directive

Three bathing waters at Southend have been designated under the EC Bathing Waters Directive. They are Thorpe Bay, Shoebury East and Westcliff. Monitoring for compliance against the standards set in the Directive is carried out between May and September. Table 6.3 shows the compliance for the period 1991 to 1995. All three bathing waters complied with the relevant standards in 1995.

6.4 1995 Compliance with Discharge Consents

In 1995, all discharges into the estuary from Water Company sewage treatment works were compliant with their consent conditions. Six discharges from trade premises and other sites failed to meet their conditions in 1995. The Agency has investigated the causes and expects improved compliance in future.

Table 6.1
Mean concentration of List I Substances in the Thames Estuary, 1995

		Sampling Site					
Substance	**EQS ug/l**	**1**	**2**	**3**	**4**	**5**	**6**
Mercury	0.3*	0.10	0.08	0.09	0.05	0.03	0.01
Cadmium	2.5*	0.11	0.21	0.25	0.17	0.19	0.09
Chloroform	12	0.24	0.19	0.19	0.11	0.05	0.73
Carbon Tetrachloride	12	0.08	0.05	0.06	0.05	0.06	0.06
1,2-Dichloroethane	10	0.48	0.48	0.52	0.52	0.50	0.50
Trichloroethene	10	0.11	0.08	0.08	0.05	0.05	0.05
Tetrachloroethene	10	0.19	0.17	0.26	0.09	0.05	0.05
HCH total	0.02	0.016	0.013	0.010	0.008	0.008	0.008
Hexachlorobenzene	0.03	All isomers for all sites below the limit of detection					
Hexachlorobutadiene	0.1						
Trichlorobenzene total	0.4						
Pentachlorophenol	2						
DDT total	0.025						
Aldrin	0.01						
Dieldrin	0.01						
Endrin	0.005						
Isodrin	0.005						

Sampling Sites: 1 Barnes 17.7 km above London Bridge
2 London Bridge (LB)
3 Erith 26.6 km below LB
4 Mucking 53.2 km below LB
5 Chapman Buoy 62.5 km below LB
6 No.2 Sea Reach 77.6 km below LB
** dissolved metal*

Table 6.2
Mean Concentrations of List II Metals in the Thames Estuary, 1995

		Sampling Site					
Substance	**EQS ug/l**	**1**	**2**	**3**	**4**	**5**	**6**
Arsenic	25*	0.83	1.45	2.21	2.14	1.56	1.17
Chromium	15*	0.83	1.19	0.88	0.77	0.7	0.43
Copper	5*	6.29	5.07	3.82	4.4	6.1	8.18
Iron	1000	30.2	21.9	13.6	5.96	6.5	7.58
Lead	25*	1.41	1.66	0.78	0.44	0.25	0.22
Nickel	30*	4.83	4.85	5.23	3.48	2.69	1.33
Zinc	40*	14.7	16.1	22.8	22.5	23.7	15.2

** dissolved metal*

Table 6.3
Compliance with the Bathing Water Directive 1991-1995

	1991	1992	1993	1994	1995
Shoebury East	Pass	Pass	Pass	Pass	Pass
Thorpe Bay	Pass	Pass	Pass	Fail	Pass
Westcliff	Fail	Pass	Pass	Pass	Pass

7. The Biology of the Thames Estuary

7.1 Introduction

Estuaries are amongst the most fertile and productive environments in the world, sustaining an abundant and varied wildlife. The diverse physical, chemical and biological conditions found within an estuary create a wide array of habitats each supporting an associated community of plant and animal species. They are also potentially a physiologically stressful environment because of fluctuating flows and salinity.

The Thames Estuary comprises a complex mosaic of habitats including subtidal, intertidal mudflats, tidal creeks, saltmarshes, reedbeds and grazing marshes. As well as these natural estuarine habitats, those created by human intervention can also support a varied wildlife such as areas of riverside wasteland, docks and hard walls created by confinement of the river. These habitats are all linked by the movement of water, sediment and nutrient transfer as well as species movement.

The importance of the Estuary for wildlife is demonstrated by the large areas which have been designated under national and international legislation. Although such designations are primarily to protect birds, they recognise the need to protect the habitat and food supply upon which birds depend.

The water quality objectives of the Estuary incorporate both chemical and biological standards (see Section 5.2). The three designated reaches recognise the different biological communities supported by different salinity ranges and the chemical standards are set to allow the passage of migratory fish. The biology of an estuary can give an important indication of its health. During the periods of gross pollution of the Thames in the middle of the 19th Century, the fishery of the inner Estuary died out. In the 1950s, at certain times of the year, only eels could survive. The Thames has been cleaned up to such a degree that it now supports a significant fish population; 115 species have been recorded. Changes in the presence, abundance and diversity of communities can indicate pollution or appear as a result of changes adjacent to the river such as development. The following section looks briefly at the quality and the importance of invertebrates, fish and birds in the ecosystem of the Thames Estuary.

7.2 Invertebrates

Macroinvertebrate communities form an important part of the Estuary ecosystem and are vital for the maintenance of both estuarine bird and fish populations. Of the three Tideway reaches only the freshwater Upper Reaches has a biotic standard specifically related to invertebrates. Thames Region has been examining ways in which a more appropriate biotic set of indices than the standards currently used could be applied in the Middle and Lower Reaches. The new standards are likely to be based on invertebrate diversity at a number of sites along the river.

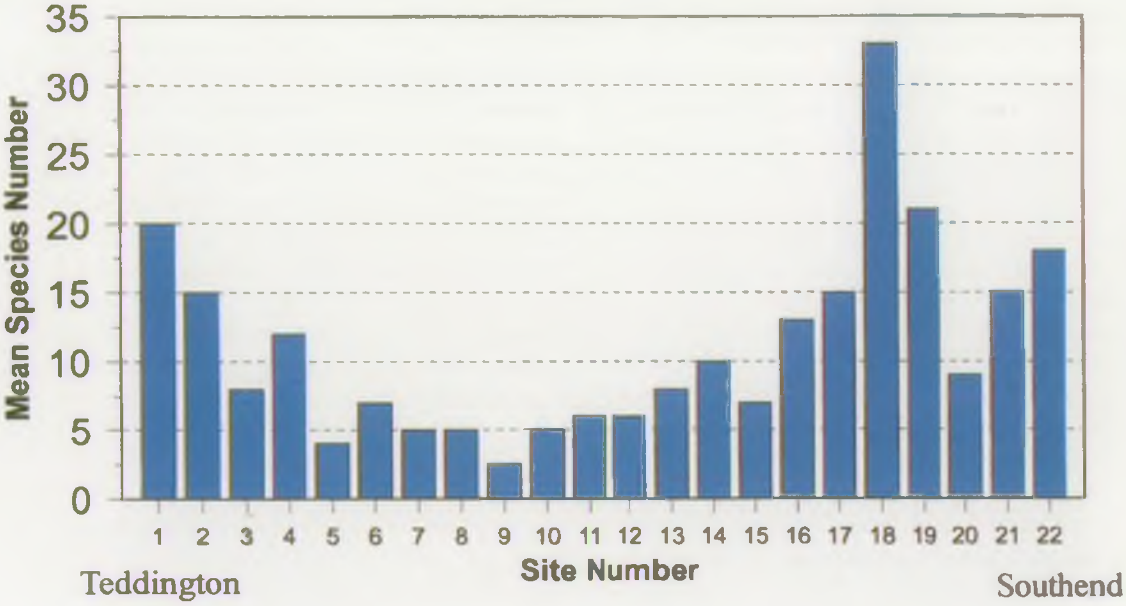
Biologists from the then TWA first charted the general changes in the fauna of the tidal Thames following the improvement of the major STWs in the 1970s (Andrews & Rickard, 1980; Andrews, 1984). However, very little co-ordinated quantitative work was undertaken from this time until the Thames Estuary Benthic Programme (TEBP) was started by the NRA in 1989. The purpose of the TEBP was to assess the current pollution status of the Estuary and to provide a baseline against which the effects of water quality on the benthic macroinvertebrate community could be measured. The intertidal and subtidal macrofauna were sampled quarterly at 22 sites along the Estuary from the tidal limit at Teddington Weir (site 1) downstream to Sea Reach, near Southend (site 22) (Figure 7.1).

The Thames is currently freshwater to Battersea and almost fully seawater beyond Southend. Between these points there is a gradual change in salinity as the freshwater mixes with water from the North Sea in what is called the brackish water (euryhaline) zone.

Most animals avoid the brackish water zone preferring either freshwater or fully marine environments. Only a minority of the species recorded in the Thames are able to survive in brackish water and they do so because they are specifically adapted to exist in these conditions. The volume of freshwater flow over Teddington Weir affects the extent of this zone downstream. Under low flow conditions increased saline intrusion will result in a reduction in freshwater species with a corresponding increase in marine animals.

Of the 350 freshwater estuarine and marine macrofaunal species recorded since the TEBP started, the mean number of species present at any one site shows a marked change along the Estuary and varies between 3 species at Beckton (site 9) to 33 at Chapman Buoy (site 18). The distribution is attributed largely to changes in salinity, tidal flow, sediment type, habitat diversity and water quality.

Figure 7.1
Mean Macroinvertebrate Species Numbers from Thames Estuary Benthic Programme in 1994

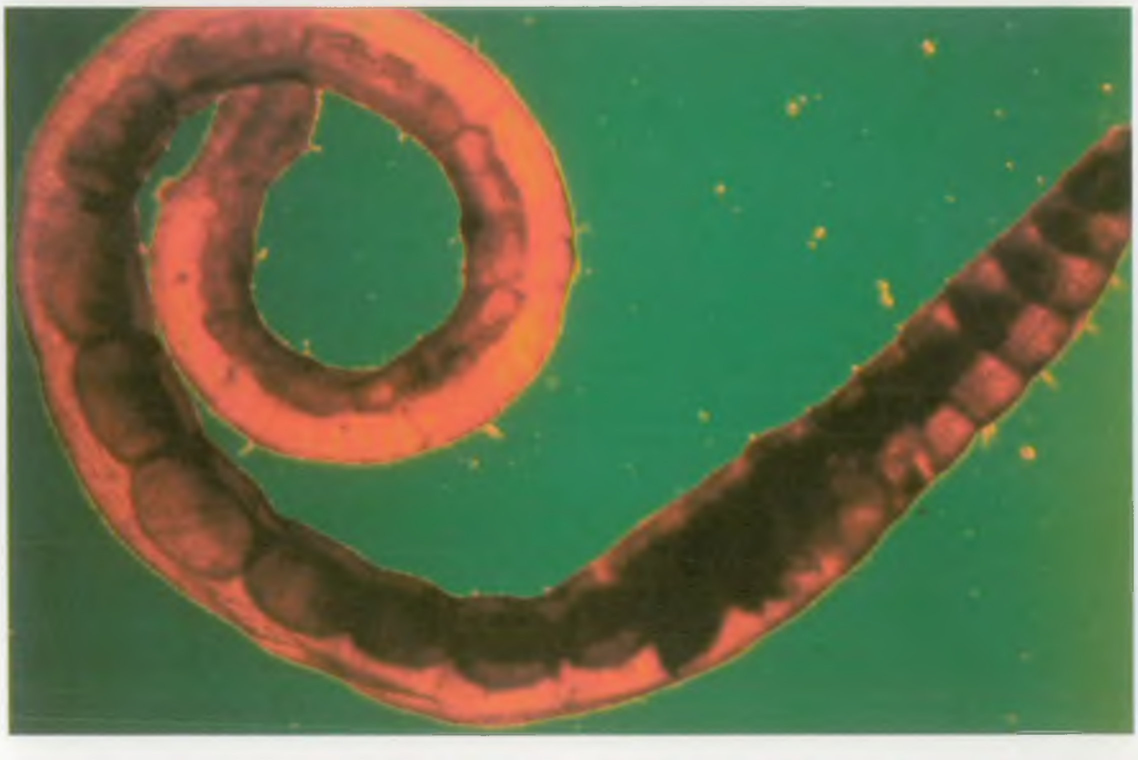


7.2.1 Upper Reaches

The river at Teddington supports a relatively diverse community of freshwater macrofauna typical of a site with fast flow over a substrate of gravel and mud. Caddis fly larvae, mayfly nymphs, snails, leeches, shrimps, beetles and oligochaete worms are typical (Plate 7.1). The volume of flow over Teddington Weir has a significant effect and under low flow conditions the macrofaunal community can be considerably depleted. This is a result of a complex combination of factors of which small changes in salinity is thought to be the most significant.

Moving down the Estuary to Kew, a restricted freshwater macrofaunal community which is capable of tolerating slight fluctuations in salinity is recorded. This includes snails, shrimps, leeches, molluscs and chironomid larvae. Oligochaete worms are present in fairly large numbers reflecting the organic enrichment in this area arising from

Plate 7.1
Oligochaete worm



Oligochaete worms (rarely greater than 20mm). Several species are encountered in the Estuary. Different species have a different preference for levels of salinity and some can also tolerate very low levels of oxygen in the water. The number of worms in the Thames has declined over recent years. The improvements in water quality have increased the levels of oxygen in the water allowing a greater variety of animals to utilise the river and these have predated upon the worms. They are present throughout the Estuary but can be found in large numbers in mud banks such as at Woolwich and Crossness.

Mogden STW. Under high freshwater flow conditions the species in this area will be supplemented by more freshwater species such as the mayfly larvae and under low flow conditions penetration of euryhaline crustaceans from the mid-Estuary is common.

In the lower part of this zone extreme salinity fluctuations, fast river flow and a lack of suitable habitat provide harsh physical conditions for colonisation. Excessive scouring reduces sedimentation of fine mud and further reduces habitat diversity. Stones, boulders and debris are the main substrates. The macrofaunal community is dominated by snails and estuarine crustaceans such as the common estuarine shrimp (*Gammarus zaddachi*) and the brown shrimp (*Crangon crangon*). London Bridge is the lowest limit for representatives of the freshwater macrofauna with the water hoglouse and mayfly larvae only occasionally being recorded.

7.2.2 Middle Reaches

A more typical estuarine fauna is found in this zone dominated by oligochaete worms. It is in this zone that the major STWs of Beckton and Crossness discharge. Sampling from within this zone indicates there are a number of sites which show a high degree of 'stress'. At Crossness, the macrofaunal community is indicative of an area of relatively stable mudflats significantly influenced by organic enrichment. Oligochaete worms form a large part of the macrofaunal community and are present at high densities.

7.2.3 Lower Reaches

The Lower Estuary zone is an area of brackish water tending towards full seawater. The sediment in this zone is mainly sand, mud and shells. Samples taken as part of the TEBP at Chapman Buoy indicate that this site has the most diverse invertebrate community recorded in this zone and as a result the site has a high conservation value. Factors which encourage this high diversity are the relatively undisturbed, stable sediment (firm sandy mud with bivalve shells, stones and bored wood), high salinity and depth of water. Species recorded include polychaete worms, crustaceans, molluscs, sea anemones, sea spiders and echinoderms. Very few of the species which are considered to be indicative of organic pollution are present at Chapman Buoy.

7.3 Fish of the Thames Estuary

Estuaries, such as the Thames, play a crucial role in the life cycle of many fish providing a rich food source and protection from predation for these and many other marine species. Recent fisheries surveys have indicated the importance of the Thames Estuary as a nursery ground for the juvenile life stages of commercially important fish such as bass, sole and grey mullet. The Estuary also supports a number of important fisheries, both recreational and commercial. A total of 115 species have been recorded in the tidal Thames to date. Around 10% of the species recorded are specifically estuarine and dependant on such habitats for their existence.

Fish species that regularly use the Estuary during parts of their life cycle can be divided into the following categories:

i *Catadromous and anadromous*
those species that move from freshwater to sea or from sea to freshwater for spawning;

ii *Freshwater*
those species that typically occur and breed in freshwater;

iii *Estuarine*
those species that spend a majority of their life cycle in or close to estuaries;

iv *Marine estuarine dependant*
marine species that require an estuarine stage in their life cycle;

v *Marine straggler*
marine species abundant in the marine environment but only infrequently found in estuaries.

7.3.1 Fish Monitoring Programme

Much of the historic fish data for the Thames Estuary is based on fish surveys undertaken at the cooling water intake screens at power stations. Biologists working for the then TWA first began comprehensive surveys of the West Thurrock power station screens in 1974, although some sampling had been carried out since 1963. The monitoring programme continued under the NRA and in recent years has been augmented by a trawling programme and intensive survey work on the margins of the river between Richmond and West Thurrock. The work is being continued by the Environment Agency.

More detailed and specific surveys are also undertaken to monitor the success of the Thames salmon stocking programme since its initiation in the 1970s. The main method of monitoring these fish has been via a fish trap facility at Molesey, one of the lower freshwater weirs.

Most fish require a high water quality to survive and, as already noted, fish were absent from parts of the river for periods during the 19th Century and 20th Century until the results of the clean-up of the Thames became evident in the 1960s. In 1963 the only species recorded at the West Thurrock power station was the eel. The eel was among the first to take advantage of the improved water quality and, as one of the most pollutant tolerant fish, quickly expanded up to the tidal limit at Teddington. The weirs of the Thames and its tributaries are now the major obstacle to the eel's further expansion into the Thames catchment.

The flounder was also an early coloniser and can now be found throughout the brackish areas of the Lower Thames. Some 19 species of freshwater fish and 92 marine fish have migrated to the Estuary over the last 25 years. Many of these, like the sunfish (*Mola mola*) are true vagrants and not true colonisers, but enter the Thames Estuary because of unusual currents and climatological extremes. In the case of the sunfish, the 1976 drought brought a semi-tropical fish to higher latitudes and provided a relatively saline Thames Estuary because of the lowered freshwater input.

The Estuary now belongs to the truly euryhaline fish (those that can tolerate varying salinities) with the smelt being perhaps the most unusual and internationally recognised as rare. Bass, twaite shad and allis shad are also fish that need a clean estuary for part of their life-cycle and their presence in the Estuary is of great ecological value: the bass have an additional economic value as much sought after sport fish.

By 1978 the number of marine and euryhaline species which had been caught in the tidal Thames had increased to 53 and currently stands at 115. Appendix 5 lists the species caught since 1964 between Fulham and Tilbury.

The history of the fish population of the tidal Thames has been well documented by Wheeler (1979) and the progressive recovery by Huddart and Arthur(1971a&c) and Sedgewick and Arthur (1979).

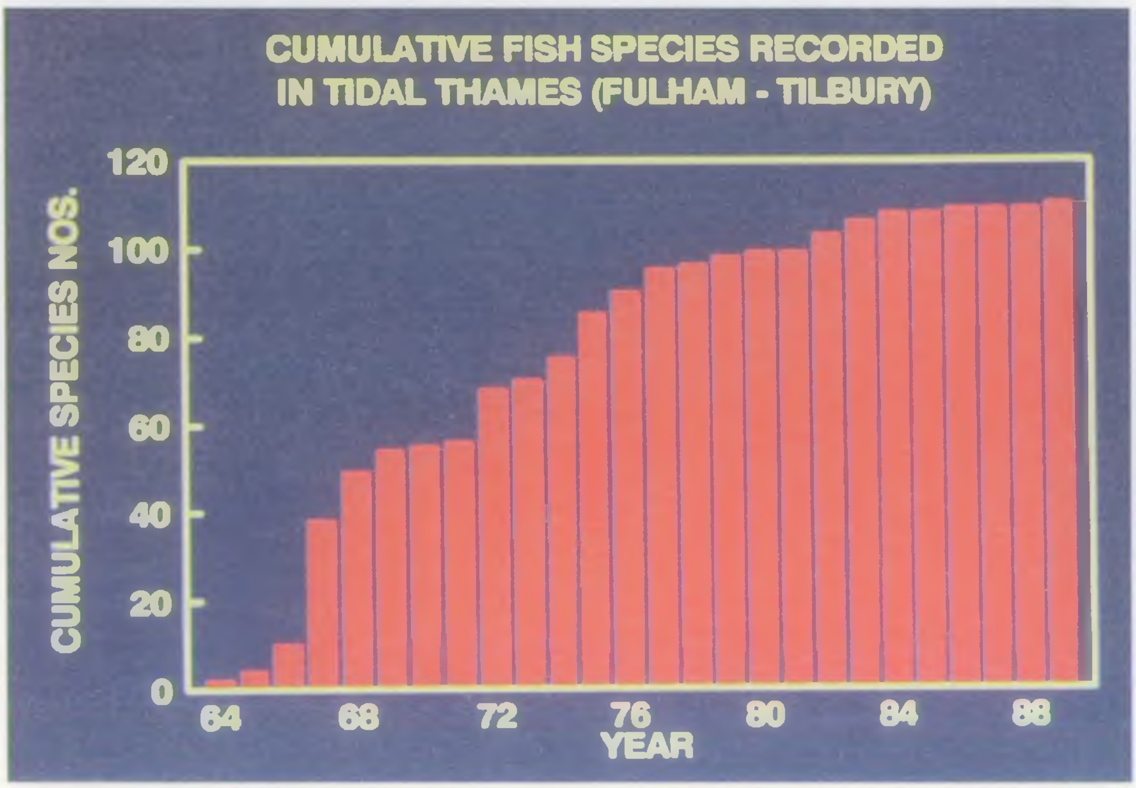
Data gathered since 1974 show that the fish population showed a sustained improvement up to 1982 but from 1983 to 1991 no significant trend could be detected (Figure 7.2). The effects of major incidents, such as the exceptionally heavy rain storm over London in 1986 which led to parts of the river in Central London becoming anoxic, can be clearly seen in the detailed records but is not apparent in the cumulative data.

7.3.2 Thames Salmon

Although the occasional adult salmon was recorded in the tidal Thames from 1974 onwards, TWA began in 1978 a programme to restore salmon to the Thames. This work continues as the Thames Salmon Rehabilitation Scheme in association with the Thames Salmon Trust.

The main basis of the scheme was the introduction of juvenile salmon to the catchment and monitoring their performance. The scheme has now sustained

Figure 7.2 Cumulative Fish Species Recorded in Tidal Thames (Fulham-Tilbury) 1964-1989



a regular run of salmon in the order of 200 fish per year since 1982. In 1993 there was a record return of 338 salmon (Figure 7.3).

The life-cycle of the Atlantic salmon requires a high standard of environmental quality throughout the catchment. The species is anadromous with spawning in the freshwater tributaries producing juveniles which grow and migrate to reach feeding grounds at sea where they become adults. The adults return to their home river after one to three years to spawn and continue the life-cycle. Such a life history requires suitable environmental conditions to be present in the sea, estuary, main river and nursery tributaries. The fastidious requirements of the salmon make the species a powerful indicator of environmental quality and the biological health of the catchment.

The monitoring of adult salmon returns, near to the head of the tide, has enabled analysis of adult salmon migration in relation to Tideway environmental quality. Work has been undertaken to analyse adult return from 1982 to 1990 in relation to various factors including DO, temperature and river flow. The results of the analysis indicate that the situation is complex and that all three factors may have been limiting migration within the Tideway in recent years (Figure 7.3).
It should be noted that the migratory period for the returning salmon is April to November, with the key period being July and August. The summer migration in the South of England coincides with the period of reduced Tideway environmental quality due to reduced river flow and increased water temperature.

7.3.3 Current status

Fish survey data gathered from the Thames Estuary over the last 20 years suggest that after a period of recovery, the fish community has now reached a state of fragile equilibrium which can be perturbed by changes in environmental parameters. Consideration of the fish community as a whole, therefore, is a sensitive indicator of biological estuarine quality.

Further work is required to establish a clear link between human activities and the fish communities in the Estuary. It is important that relationships between water quality measurements and fish community characteristics are examined to determine the status of the Thames Estuary. Extensive data on a number of water quality parameters have been collected and there is considerable information available concerning the fish populations. Individual species, such as flounder and smelt, have also been identified as possible biological tools for water quality monitoring. Further study, particularly of the latter, will be required to assess their suitability in this role.

There are a number of potentially important factors which may be having highly significant impacts on the estuarine ecosystem and call for further study. The most important of these is the fate and role of persistent contaminants and their ecological effects upon populations and bioaccumulation within estuarine food chains. There is insufficient knowledge on current levels of these contaminants, their trends and possible sub-lethal effects. An assessment of these will allow a better

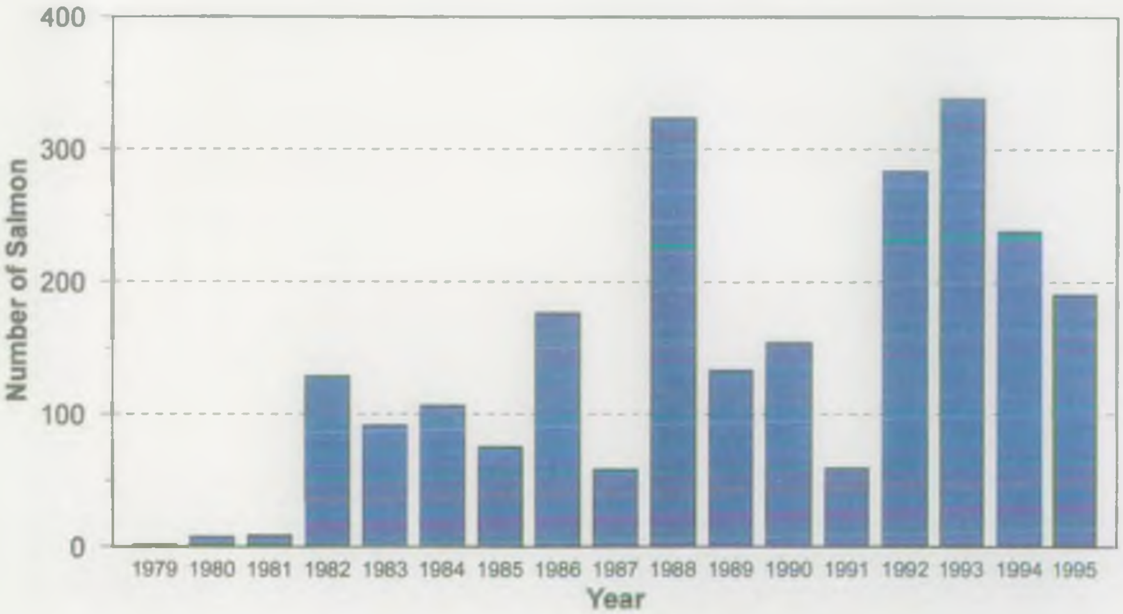


***Figure 7.3** Confirmed Annual Returns of Salmon in the Thames Estuary, 1979-1995*

understanding of the complexities of the Thames Estuary environment and enable efficient management plans to be developed to mitigate current and future problems.

7.4 Birds

Birds are at the top of the food chain and their scarcity in the Thames Estuary during the periods of gross pollution was a visual indicator of the lack of fish and invertebrate communities in the river. As the water quality of the river has improved and animal and plant life re-colonised the area, many species of wildfowl and wading birds began to over-winter on the Thames. Currently nearly 300,000 water birds over-winter in the Greater Thames (see also section 1.8 Conservation Status) making it the most important estuarine complex for birds in the UK. Species of wildfowl and waders are found in numbers which are of international and national importance, the Thames being part of a chain of sites on their migratory routes. The intertidal mudflats, salt marshes, reedbeds and grazing marshes provide varying habitats meeting needs of different species. Even the hard walls in urban areas are a source of green algae for swans, species of duck and provide valuable nesting sites.

8. Achievements, Priorities and Future Developments

8.1 Achievements

The most dramatic improvement in the water quality of the Thames Estuary occurred in the 1950s and 1960s as a result of:

- massive investment in the rebuilding of Crossness STW and the extension of Beckton STW, providing full treatment for a combined flow of approximately 1240 Ml/d together with improvements in other STWs;
- the control of industrial discharges through diversion to foul sewer and the imposition of tighter standards on effluent discharged to the river;
- the introduction of biodegradable detergents;
- the introduction of objectives and standards for the Estuary.

Through these measures, the Thames Estuary, which had effectively been dead for nearly 40 years in certain stretches, began to come back to life and fish started to return.

These achievements also formed a firm foundation on which further improvements in the water quality of the Estuary have been made:

- management of the problem of summer stormwater overflows through the building of the Thames Bubbler;
- reduction of heavy metals from the STWs;
- review of the quality objectives and standards, to more adequately meet the requirements, to sustain the increasing biological life and diversity, and the aspirations for further improvements in water quality in the Estuary;
- imposition of standards and improvements as a result of EC Directives and International initiatives;
- tighter control of the critical factors affecting the water quality of the Estuary through operating agreements between the TWUL and the Environment Agency which cover abstraction, effluent standards and the operation of the Thames Bubbler.

8.2 Local Developments

There is a continuing dialogue between the Environment Agency and the Water Utilities regarding the level of treatment at STWs. The major improvements planned or in progress currently are:

- Southend-on-Sea Sewage Works. An extended sewage works providing full secondary biological treatment will be built by 1998 to enable the provisions of the EC Bathing Water and UWWT Directives to be met;
- Southend-on-Sea Sewerage System Upgrades. At times of storm the sewerage system in Southend overflows. The system is being upgraded so that the number of overflows is reduced significantly, and that any remaining overflows only operate (at most) once in five years. The improvements will be complete by 1998;
- Mogden STW. This serves West London and at times of storms much of the flow bypasses the works and enters the Thames Estuary as a storm discharge. There are plans to extend the STW so that twice as much flow can be treated than is presently possible;
- Fine Screening of Effluents. The Environment Agency has identified the need for the fine screening of all treated sewage effluents discharging to the Estuary. This includes Mogden, Kew, Beckton, Crossness, Riverside, and Long Reach STWs. This will enhance the aesthetic nature of the Estuary by reducing the sewage-derived plastic debris;
- Bubbler II. The Thames Bubbler is used to counteract the effect of severe storms on Tideway water quality. If the Bubbler breaks down, or becomes unavailable, there is a risk of fish kills occurring. A second Bubbler is being built to provide greater reliability of cover and improve protection of the Estuary. Alternative improvements, including the use of hydrogen peroxide as an oxygenating agent, are also being considered.

8.3 National Developments

8.3.1 Statutory Water Quality Objectives

A national system of water quality management which could be imposed through legislation as statutory water quality objectives on all controlled waters including the Thames is being considered by the Government. A pilot scheme is currently being tested in 8 river catchments across the Country. The approach is designed to provide a framework for a national policy on water quality. It will be the duty of the Environment Agency to ensure that the objectives of this national policy are achieved at all times. Any such objectives will be required to have three main components:

i) the uses of any particular stretch of water will need be categorised and a set of water quality standards, to protect those uses, defined;

ii) where an EC Directive applies to a particular stretch of water, there will be a need to ensure compliance with the provisions of the Directive;

iii) where a stretch of water receives a discharge containing a prescribed substance, as defined in the 1990 Environment Protection Act, the standards set for that substance must be met.

Progress with such a scheme in estuaries awaits the results of the freshwater catchment trials.

8.3.2 General Quality Assessment (GQA)

Research work is being carried out to develop a new GQA scheme for estuaries to assess the existing quality of a stretch of water, chemically, biologically, and in terms of nutrients and aesthetics. This will not be part of the statutory scheme, but will be used by the Environment Agency for assessment and reporting of water quality status.

8.4 The Future

8.4.1 Local Environment Agency Plans and the Estuary Management Plan

Central to the Environment Agency's future strategy for the Thames Estuary will be the Local Environment Agency Plan (LEAP) and the Estuary Management Plan (EMP).

The Environment Agency is preparing LEAPs as successors to the NRA's Catchment Management Plans (CMPs) for all catchment areas in a rolling five year programme. Each LEAP will have an expanded remit and will cover air quality, water and contaminated ground as well as water management. The Plans will enable the Environment Agency, and others, to take individual catchment needs into account, balancing these with national objectives to protect areas of high environmental value and to enhance those areas which require it. The development of each LEAP involves widespread consultation on current resources within the area, current and future pressures on the local environment and identification of key issues of concern. An agreed, costed 5-year action Plan is then drawn up between all partners and its implementation is monitored through annual audits.

The Environment Agency is currently preparing the Thames Tideway LEAP.Consultation Report, to be published later this year, covering the upstream part of the tidal Thames from the tidal limit at Teddington downstream to Tower Bridge.

For the Estuary between Tower Bridge, Southend and the Isle of Grain, the Environment Agency is participating with a number of other organisations in the 'Thames Estuary Management Plan' (EMP). This work is co-ordinated by English Nature as part of its national 'Estuaries Initiative'. The draft consultation EMP was launched in July 1996 and will replace the need for an Environment Agency LEAP in this area.

The draft EMP includes recommendations for Water Quality covering local and broadly-based issues. The principal recommendations of the draft EMP are:

- to improve reliability of compliance with dissolved oxygen standards in the Middle Reaches of the Estuary through investigating the use of the Thames Bubbler and other options for reducing the impact of the combined sewerage outfalls (storm water);

- to seek to ensure that the Environment Agency policy with respect to water quality objectives is clearly defined and that water standards are appropriate through reappraisal of chemical and biological water quality standards and further research into the relationship between Tideway quality and its ecology;

- to support initiatives to maintain and improve microbiological water quality through continued monitoring of designated bathing beach areas, and identifying any 'high risk' areas with respect to existing contact water sports and support initiatives and research into the health risks associated with recreational waters;

- to seek further methods to prevent oil from entering the aquatic environment, to minimise environmental damage by expanding the Environment Agency's pollution prevention scheme and support the maintenance and development of TOSCA;

- to reduce the incidence of all forms of litter in the Thames Estuary through review of existing services and projects and to continue aesthetic monitoring through the GQA scheme with a view to setting aesthetic standards for the Thames Estuary.

There are also 13 principle recommendations in the Fisheries section of the EMP with the aim of seeking 'to ensure that the high quality fisheries resource now associated with the Thames Estuary, reflecting quality improvements in the past thirty years, is protected and enhanced for the benefit of future generations'.

8.5 Conclusion

The clean-up of the Thames has been a considerable achievement and one that can be viewed with some pride.

The challenge now is to ensure that this achievement is maintained and built upon. As the Thames Estuary Environment Management Plan recognises, 'nowhere in the country are environmental pressures and competing demands for space and resources greater than on Thames-side'. To achieve 'an Estuary which is valued as a place to live, work and relax: an environmental asset and a focus for economic growth' it is vital that resources are managed in a sustainable way. The Environment Agency, in undertaking its mission to provide a better environment in England and Wales for present and future generations, is taking up this challenge.

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Glossary of Terms

Anoxic	devoid of free oxygen.
Aquifer	an underground water-bearing layer of porous rock.
Benthic	referring to life in or on the sea or river bed.
Biochemical Oxygen Demand (BOD)	is the amount of dissolved oxygen consumed by chemical and microbiological action when a sample effluent is incubated for 5 days at 20°C (a test originally devised by the Royal Commission on Sewage Disposal in 1912).
Catchment	the area of land which is drained by a particular river system.
Ebb tide	is the part of the tidal cycle from high water to low water, i.e. when the level falls and the water flows seawards.
Effective Oxygen Load (EOL)	is a measure of oxygen load which takes account of the oxidisation of both carbonaceous and nitrogenous material.
Environmental Quality Objectives (EQOs)	are categories relating to the use of particular stretches of water. For each use an associated series of quantitative standards applies.
Environmental Quality Standards (EQSs)	are concentrations of substances in the receiving water which must not be exceeded if the water is to be suitable for a particular purpose or use, or to achieve a certain level of protection for aquatic life.
Flood tide	is the part of the tidal cycle from low water to high water i.e. when the water level rises and off-shore water flows into the estuary.
Flushing time	is the time taken for the freshwater and associated contaminants to pass out to sea. It depends to a large extent on the size of the estuary and the relative volume of freshwater discharged into it.
Heavy metals	is a general term for those metals which are toxic when present in elevated concentrations. These include elements such as zinc, copper, lead, nickel and mercury, all of which are commonly used by industry.
Hydrography	is the study of water bodies and their movements.
Inter-tidal	refers to differences occurring between tides.
Ionic strength	is a measure of the concentration of dissolved constituents. High ionic strengths give rise to more reactions in the water.
Invertebrate	animals without a backbone.
Neap tides	are smaller tides which occur when attractive forces of the moon and sun are not acting together (approximately at the first and third quarter of the lunar month - 7 days apart from spring tides).
Nitrification	the bacterial oxidation of ammonia to form nitrate, a process which uses dissolved oxygen.
Oxidation	is the chemical breakdown of complex compounds for example by bacterial action.

pH	is a measure of the balance of acidity or alkalinity of the water.
Plankton	microscopic drifting organisms in water which can include the egg and larval stages of some species of fish.
Prescribed process	is a process or part of a process which releases at least one prescribed substance at a level greater than background concentrations.
Prescribed substance	is any substance the release of which, into the environment, is subject to control under the EPA (1990). The list of prescribed substances for release to water is essentially the same as the UK 'Red List'.
Primary production	is the conversion of energy from the sun into carbon compounds by photosynthesis.
Salinity	the extent to which salts are dissolved in water.
Spring tides	are the larger tides occurring when the attractive forces of the moon and sun are working together (at new and full moon - 7 days apart from neap tides).
Supersaturated	the situation when the apparent concentration of dissolved oxygen in water exceeds the saturation value, for example, due to the evolution of oxygen within the water by photosynthesis.
Suspended solids	fine particulate solid matter, of organic or inorganic origin, held in suspension within a volume of water.
Tidal cycle	is the time between successive low or high waters, typically about 12 hours 30 minutes.
Tidal excursion	is the distance travelled by a body of water between low and high tide.
Tidal range	is the difference in height between low and high tide.

Glossary of Abbreviations

AQMS	*Automatic Quality Monitoring Station*
BAT	*Best Available Technology*
CMP	*Catchment Management Plan*
COPA	*Control of Pollution Act*
EC	*European Community*
EMP	*Estuary Management Plan*
EPA	*Environmental Protection Act*
EU	*European Union*
DO	*Dissolved Oxygen*
GQA	*General Quality Assessment*
HMIP	*Her Majesty's Inspectorate of Pollution*
HMSO	*Her Majesty's Stationery Office*
IPC	*Integrated Pollution Control*
IPPC	*Integrated Pollution Prevention and Control*
km	*kilometres*
LCC	*London County Council*
LEAP	*Local Environment Agency Plan*
m	*metres*
Ml/d	*Megalitres per day*
NRA	*National Rivers Authority*
PARCOM	*Paris Commission*
PCB	*polychlorinated biphenyl*
PLA	*Port of London Authority*
STW	*sewage treatment works*
TEBP	*Thames Estuary Benthic Programme*
TOSCA	*Thames Oil Spill Clearance Association*
TWA	*Thames Water Authority*
TWUL	*Thames Water Utilities Limited*
WRA	*Water Resources Act*
ug/l	*micrograms per litre*
UWWT	*Urban Waste Water Treatment Directive*

APPENDIX 1

Dangerous Substances Surface Water Regulations 1989 and 1992

EQSs for List I Substances under the Classification of Coastal Waters and Relevant Territorial Waters (DS2 and DS3)

Substance	Annual Mean (ug/l)
Aldrin	0.01
Dieldrin	0.01
Endrin	0.005
Isodrin	0.005
Cadmium and its compounds	2.5 (dissolved cadmium)
Carbon Tetrachloride	12
Chloroform	12
DDT (all isomers)	0.025
DDT (pp isomers)	0.01
Hexachlorobenzene	0.03
Hexachlorobutadiene	0.1
Hexachlorocyclohexane (all isomers)	0.02
Mercury and its compounds	0.3 (dissolved mercury)
Pentachlorophenol and its compounds	2
1,2 Dichloroethane	10
Trichlorobenzene	0.4
Trichloroethene	10
Tetrachloroethene	10

APPENDIX 2

Natural Environmental Quality Standards for List II Metals for the Protection of Salt Water Life

Substance	Annual Mean (ug/l)
Lead	25 (dissolved)
Chromium	15 (dissolved)
Zinc	40 (dissolved)
Copper	5 (dissolved)
Nickel	30 (dissolved)
Arsenic	25 (dissolved)
Vanadium	100 (total)
Iron	1000 (total)

APPENDIX 3

U.K. Red List

Mercury and its compounds	Trichlorobenzene
Cadmium and its compounds	Polychlorinated biphenyls
Gamma - Hexachlorocyclohexane	Dichlorvos
DDT	Atrazine
Pentachlorophenol	Simazine
Hexachlorobenzene	Tributyltin compounds
Hexachlorobutadiene	Triphenyltin compounds
Aldrin	Trifluralin
Dieldrin	Fenitrothion
Endrin	Azinphos - methyl
1,2 - Dichloroethane	Malathion
	Endosulfan

APPENDIX 4

Annex 1A Substances

Mercury - all compounds	1,2 - Dichloroethane
Cadmium - all compounds	Dichlorovos
Copper	Atrazine
Zinc	Simazine
Lead	Tributyltin compounds
Arsenic	Triphenyltin compounds
Chromium	Fenitrothion
Nickel	Azinophos - methyl
Drins	Azinophos - ethyl
HCH	Fenthion
DDT	Malathion
Pentachlorophenol	Parathion
Hexachlorobenzene	Parathion - methyl
Hexachlorobutadiene	Trichloroethylene
Carbon tetrachloride	Tetrachloroethylene
Chloroform	Trichlorobenzene
Trifluralin	Trichloroethane
Endosulfan	Dioxins

APPENDIX 5

Fish Species of the Thames Estuary

The fish species listed below have been caught in the tidal River Thames between Fulham and Tilbury since 1964. The list is not necessarily indicative of the species that are currently present.

Freshwater	**Euryhaline**	**Marine**	**Marine (cont.)**
Barbel	Bass	Anchovy	Mullet, Golden
Bleak	Eel	Angler Fish	Mullet, Red
Bream	Flounder	Blue Mouth	Mullet, Thick-Lipped
Bullhead	Lampern	Brill	Mullet, Thin-Lipped
Carp	Lamprey	Butterfish	Norway Bullhead
Carp, Crucian	Salmon	Catfish, Channel	Pilchard
Chub	Shad, Allis	Cod	Pipefish, Broad-Nosed
Dace	Shad, Twaite	Conger Eel	Pipefish, Great
Goldfish	Smelt	Dab	Pipefish, Nilsson's
Grayling	Stickleback, 3-sp	Dab, Long Rough	Pipefish, Snake
Gudgeon	Stickleback, 10-sp	Dory	Pipefish, Straight-Nosed
Loach	Trout	Dragonet	Pipefish, Worm
Minnow	Trout, Rainbow	Eckstrom Topknot	Plaice
Perch		Garfish	Pogge
Pike		Goby, Black	Pollack
Roach		Goby, Common	Poor-cod
Rudd		Goby, Leopard	Pouting
Ruffe		Goby, Painted	Ray, Sting
Tench		Goby, Rock	Rockling, 5-bearded
Hybrid -		Goby, Sand	Rockling, 4-bearded
Roach*Bream		Goby, Sand (*P. lozanoi*)	Rockling, 3-bearded
		Goby, Transparent	Rockling, Northern
		Goldsinny	Rockling, shore
		Gurnard, Grey	Sand Eel
		Gurnard, Red	Sand Eel, Greater
		Gurnard, Streaked	Sand Eel, Raitt's
		Gurnard, Tub	Sand-smelt
		Haddock	Scad
		Hake	Scaldfish
		Herring	Sea Bream, Black
		Ling	Sea Horse (*H. hippocampus*)
		Lumpsucker	Sea Horse (*H. ramulosus*)
		Mackerel	Sea Scorpion, Long Spine

Freshwater	Euryhaline	Marine	Marine (cont.)
		Sea Scorpion, Short Spined	Trigger-Fish
		Sea Snail	Weever, Lesser
		Sea Snail, Montagu's	Whiting
		Sea Stickleback	Whiting, Blue
		Sea Skipper	Wrasse, Ballan
		Smooth Hound	Wrasse, Corkwing
		Sole, Dover	
		Sole, Lemon	
		Solenette	
		Sprat	
		Tadpole-Fish	

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MANAGEMENT AND CONTACTS:

The Environment Agency delivers a service to its customers, with the emphasis on authority and accountability at the most local level possible. It aims to be cost-effective and efficient and to offer the best service and value for money.

Head Office is responsible for overall policy and relationships with national bodies including Government.

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For general enquiries please call your local Environment Agency office. If you are unsure who to contact, or which is your local office, please call our general enquiry line.

ENVIRONMENT AGENCY GENERAL ENQUIRY LINE
0645 333 111

The 24-hour emergency hotline number for reporting all environmental incidents relating to air, land and water.

ENVIRONMENT AGENCY EMERGENCY HOTLINE
0800 80 70 60

ENVIRONMENT AGENCY

The Thames Estuary is now considered to be one of the cleanest metropolitan estuaries in the world. This report, by the Environment Agency, brings together the various aspects of the historical and current water quality management of the Thames Estuary into one document. The report focuses on the success of the Environment Agency and previous regulatory bodies in achieving a water quality which sustains thriving fish populations and other biological life. The report shows ways in which the current quality will be protected and enhanced into the next millennium.

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