Thames Tideway

Measures to protect the river environment from the adverse effects of waste water discharges

by

Professor Chris Binnie

MA, DIC, HonDEng, FREng, FICE, FCIWEM

chrisbinnie@btopenworld.com

22nd October 2013

Brockwell,

Wootton Courtenay,

Minehead

Somerset

TA24 8RN

Executive summary

Central London has a **combined sewer system** which, in 2000, had 57 overflows which spilled into the Thames up to 50 times a year causing aesthetic, environmental and health impacts.

The Tideway was required to meet the **Urban Waste Water Treatment Directive** by 2000. The aim of the Directive is to protect the environment from the adverse effects of waste water discharges.

The European Commission has taken the United Kingdom to **European Court** as it considered that the collecting systems spilled more often than "unusual conditions" as set out in Annex 1(A) of the Directive 97/271 (UWWTD). The Court ruled in October 2012 that this was so, and that the UK had not established disproportionate (excessive) cost as it had decided to implement the tunnel, and thus that the United Kingdom had failed to fulfil its obligations under the directive. During the infraction proceedings the European Commission and the Advocate general indicated that a spill frequency of 20 spills a year would be acceptable.

The **Thames Tideway Strategy Steering Group** studied the Tideway from 2000 to 2005. There are no specific numeric standards in the UWWTD so the TTSS came up with three objectives specifically focussed on the Tideway covering aesthetics, environment and health. Based on the information available then, the TTSS proposed that, to meet these objectives, three sewage treatment works be upgraded and a storage/conveyance tunnel be constructed from Hammersmith to Beckton STW at a cost of £1.7bn for the tunnel. The total cost of the tunnels has now risen to a total of about £4.8bn.

At that time, 2005, there was limited information about **sustainable urban drainage systems** and there was very limited experience of how well they worked. Thus the TTSS was unable to recommend them as a viable solution to meet a European Directive.

The **current works of upgrades** to the Tideway sewage treatment works and the Lee tunnel, will reduce the volume of spill from the current about 39 Mm3/year to about 18 Mm3/year, much reduce the number of dissolved oxygen failures, and much reduce the spills from Mogden STW which was primarily responsible for the fish kills in 2004 and 2011 in the Kew/Chiswick area..

CSO spill volumes and spill frequency, were calculated by Thames Water using their **sewer model**. This showed Hammersmith Pumping Station spilling about 50 times a year on average. Since then TW have provided their Sewage Discharge Notifications. This shows Hammersmith Pumping Station spilling about 25 spills a year. Thus the model would appear to appreciably over estimate spill frequency. It needs re-calibration against actual spill frequencies.

TW assumed that **sewer flows would increase** with increasing population and constant per capita demand. The increase by 2021 is some 2.6m3/sec, some 13% of the current 20m3/sec STW flow. The TW sewer calculations also assumed constant sewer infiltration. In reality Thames WRMPs show for the future reducing water delivered and decreasing water main leakage, and hence decreasing sewer infiltration. Together these reduce projected sewer flow by 2024 by about 2m3/sec, about 10%. Thus TW sewer analysis has overestimated future sewer flows by about 23%. This has resulted in a significant overestimate in future years of both the frequency of spills and the volume of spills.

Flow in the sewer interceptors could be reduced further by reducing the amount of **water entering the sewers** by connecting part of the sewerage system to another STW, Mogden or Hogsmill, or to the existing Thames/Lee water transfer tunnel.

The implementation of widespread **SuDs and BGI** would also increasingly reduce storm flows from entering the sewers. During the infraction proceedings, the European Commission proposed that 20 spills a year should be the limit. Appendix E of the needs report of 2010 showed that, if 50% of the impermeable area were removed, then the number of CSOs failing this limit would be 12. However, more recent analysis, and one relatively minor work, showed this would reduce to 6 failing CSOs. Recalibrating the sewer model to match actual spill records, revising the sewer flows to match the TW WRMP water supply projections, and other works might well eliminate such excessive spills entirely.

Remaining **spills from the sewers** into the Tideway could be reduced further by adjusting the CSO weir levels, removing restrictions in the sewer system, and by implementing detention tanks, vortex separators, and real time controls. Studies would need to be carried out to assess the scope and cost of such measures.

The TTSS **aesthetic objective** is to limit the pollution caused to the point where it ceases to have a significant adverse impact. The EA reported that there were few formal complaints from the public about adverse impact. In addition to reducing the storm discharges by the methods above, discharge of sewage debris in the river could be reduced by installing booms around most of the CSO outlets covering some ¾ of the spill volume. The retained debris can be collected. The existing skimmers and new oil skimmers could be used in the river to collect that which escapes or where booms cannot be fitted.

The TTSS **ecological objective** is to have a sustainable fish population. Fish are considered the most sensitive ecological species and dissolved oxygen (DO) standards have been set, based on fish trials. The current works of the improvements to the sewage treatment works, particularly Mogden STW and the Lee tunnel, go a long way towards reaching the DO standards. The post upgrade Tideway Fish Risk Model has only one failure but this seems based on the assumption that salmon who migrate through the tideway are resident most of the time. Were that anomaly to be revised then the fish suite would be sustainable. The most sensitive species in the fish suite are salmon who are now deemed as unsustainable in the short, medium and long term. No other relevant similarly sensitive fish species was identified.

In addition a fine grained **diffuser system** using compressed air or oxygen would be able to raise the dissolved oxygen levels further and provide fish refuges as has been done in the River Seine downstream of Paris and presumably approved by the EC. The existing mobile bubbler boats would supplement the fixed system and would be flexible to reach where the monitoring system showed they were required.

The Tideway is used by rowers and sailors for **recreation**. The TTSS recreation objective is to substantially reduce the number of elevated health risk days. The Tideway is not a designated bathing water and is not subject to the Bathing Water Directive. For navigation reasons, the PLA has recently banned bathing in the Tideway except with a special licence. Health impact of those in the London Docks can be mitigated by putting in water treatment of the relatively small quantities of top up water pumped into the docks. Improvements to Mogden STW will much improve water quality in the Mogden/Hammersmith stretch of the Tideway where there are many rowers. A warning system has been provided to warn rowers in the Upper Tideway when CSO spills occur, similar to the approach now permitted under the Bathing Water Directive. The rowers in the Hammersmith area are already nearly ten times less susceptible to gastric infections than the general public.

Thus it would appear that the **Combined Interim Measures** may well be able to meet the TTSS objectives set to meet the UWWTD. These works should be implementable within about two to three years. Thus a major benefit to the River Thames and Londoners would be that the river would improve, and probably meet the TTSS objectives, in 2 to 3 years, as opposed to the Tideway Tunnel which would not improve the Tideway until it is completed, press reports now giving that as 2026, 13 years away. This earlier benefit would be an appreciable benefit to the rowers and sailors.

Compared to budget **costs** of the Combine Interim Measures of about £30million, the tunnel at £4,200 million would appear to be excessive/disproportionate cost under the UWWTD BTKNEEC clause. However the costs of the Combined Interim Measures are at concept stage.

However the Court did not rule that the tunnel solution be adopted, merely that a **solution** be adopted. To meet the European Court ruling that discharge should only occur as a result of such unusual rainfall, suggested as 20 spills a year, then the sewer model would need recalibration to align with actual spill frequencies found, and, in addition to the Combined Interim Measures, there would need to be an extensive programme of Suds and BGI.

Whatever, if the measures were viable but not able to reduce the spill frequency sufficiently, then the Combined Interim Measures should still proceed and reduce the environmental impact of waste water discharges during the period the **tunnel would be under construction**.

Proper **feasibility study** and costing would be required to identify what would be feasible, and with what benefit. As has been shown by ofwat, water companies have a bias towards large capital schemes as in that way they are allowed to charge their customers more and increase profit for their shareholders, called capex bias. Thus, in my opinion, such study work would need to be carried out independently of Thames Water, albeit probably using the TW sewer models.

The Commission has since stressed in its policy **Communication** the importance of Suds and Green Infrastructure. One approach would be to adopt this plus the Combined Interim Measures. It would be open for the UK government to discuss such an approach for London with the Commission.

I recommend that such **Combined Interim Measures, along with Suds and BGI**, be studied fully, and, if found to be appropriate, discussed with the European Commission with a view to being implemented. This could result in a major reduction in expenditure at a time of difficult economic circumstances.

Contents

1.Introduction

Almost all modern urban conurbations have separate drainage systems for foul water and storm water. However, for historical reasons, Central London, loosely from Hammersmith in the west to Greenwich and the Lee valley in the east, has a sewerage system which combines both foul and storm water into one sewer pipe. This led to very serious pollution of the River Thames through London. In the 1860s a series of interceptors were built running parallel with the river to convey the combined sewage to treatment works and discharge points at Beckton and Crossness, downstream of London. However these interceptors, although large, had a finite capacity and the system was designed so that in the event of a medium sized storm , the interceptors would over flow into the River Thames. Since then London has become more built up and the roads have changed from cobbles to tarmac, much increasing the peak storm runoff. There are some 57 combined sewer overflows in the system, and under the current arrangement some of the CSOs spill into the Thames about 50 times a year. These spills have resulted in adverse environmental conditions , both aesthetically and adverse dissolved conditions for fish, and adverse health conditions for recreation.

The Thames Tideway through London was required to meet the Urban Waste Water Treatment Directive, whose aim is to protect the environment from the adverse effects of waste water discharges, by 2000.

The Tideway was studied by the Thames Tideway Strategy Steering Group (TTSSG). This group was composed of senior representatives from defra, Thames Water, Environment Agency, Greater London Authority, and ofwat in observer status, with myself as the independent chairman. The work started in 2000. Objectives for ecology, aesthetics, and health impact have been set for the Tideway as set out in the Thames Tideway Strategy Steering Group (TTSS) 2005 report.

The TTSSG reported in 2005 that, based on information available at that time, the optimum solution was a tunnel from Hammersmith to Beckton STW at a cost of £1.7bn. The Thames Tideway Tunnel would achieve these standards.

The cost of the tunnel has now escalated to about £4.2bn for the section from Hammersmith to Abbey Mills and about £0.6bn for the Lee tunnel from Abbey Mills to Beckton, a total of £4.8bn at 2011 prices.

The tunnel would increase the charges to Thames Water's sewage customers by some £80/year. This sits uncomfortably with the government Water White Paper published in December 2011 " *to protect poorer households."*

The Thames Tideway Tunnel was selected by Government in 2007 but the tunnel cannot be operational until about 2023. However the European Commission has taken out infraction proceedings against the UK for slow implementation of the measures to meet the Directive. In 2010 the European Court has found against the UK on the Thames Tideway. Thus it is possible that infraction fines could be imposed for late compliance. I am advised that they would be based partly on the *"Environmental impact of non-compliance* " and partly on the length of time between the date for completion assumed by the Commission and the environmental impact being deemed satisfactory. Presumably this would be when the Thames Tideway tunnel becomes operational or any other system reaches a satisfactory situation. My information is that these fines could be substantial. Based on the tunnel becoming operational in 2023 possibly as high as Euros 1.5bn. An assessment of what these could be is set out in Appendix E. Were the Interim measures to be implemented, then they would reduce the environmental impact of non-compliance, and hence any fines imposed.

The defra River Basin Planning Guidance Vol 2 August 2008 states "*The WFD requirement is to make judgements about the most cost-effective combination of measures."* Since completion of the tunnel is about 10 years away, and it could not provide benefit until complete and operational, should not the WFD consideration also include the interim period?

This report looks at ways that the "*environmental impact of non-compliance*" could be reduced during the interim period until the tunnel is operational. These would have to be relatively cheap and quick to implement. After completion about 2023 the tunnel would still spill several times a year and these measures, such as the booms, could also provide long term benefit. However measures which reduce the sewer flows in the interceptors, would reduce the volume of spill into the tunnel and hence reduce the energy and cost in pumping out the tunnel, as well as reduce the operational CO2 emissions.

In this report I also consider to what extent the existing STW upgrades and Lee tunnel plus the so called Combined Interim Measures, including the Suds and BGI, could meet the TTSS objectives for the Tideway and the implication of BTKNEEC.

I have discussed this report in early draft and later draft form with the Environment Agency and in working draft form three times with Thames Water and have adapted it according to their comments. However Thames Water and the Environment Agency have declined to do the analyses as to how the sewerage system could be adapted to reduce the environmental impact of waste water spills.

2. Objectives to be met

UWWTD

The objective of the Urban Waste Water Treatment Directive in Article 1 is "*to protect the environment from the adverse effects of the above mentioned waste water discharges."* The UWWTD makes no reference to any actual level of protection or any numerical standards.

In Annex 1 section D para 5 footnote 1 says *"Given that it is not possible in practice to construct collecting systems and treatment plants in a way such that all waste water can be treated during situations such as unusually heavy rainfall,"* Thus the UWWTD accepts that collecting systems can overflow during unusual rainfall events. However nowhere in the UWWTD does it specify what "unusually" means.

Note also that the Water Framework Directive which is viewed as "umbrella" water legislation was passed into law after the UWWTD and requires a more thoughtful approach to protection of the water environment than just setting an arbitrary number of CSO spills.

The footnote continues " *Member states shall decide on measures to limit pollution from storm water overflows. Such measures could be based on dilution rates or capacity in relation to dry weather flow, or could specify a certain acceptable number of overflows per year."* Thus it would appear to be open to Member States to choose the criteria to limit the pollution.

Spill frequency criterion.

There is no specific spill frequency in the UWWTD. However the Advocate General's opinion of the infraction proceedings, January 2012, states in para 48 "*the Commission did indicate that, as a rule, exceeding the limit of 20 overflows a year would be a cause for concern, suggesting a possible failure to fulfil obligations. Despite all its limitations and without prejudice to the need for a case-by-case* *assessment, a numerical criterion of that nature may be reasonable and acceptable."* Thus, whilst this criterion was not formalised by the EC or by the British Government, such a criterion would appear to be acceptable, particularly where environmental conditions would be met as shown later in my report.

TTSSG objectives

The UWWTD does not take account of the quality or size of the discharge water, for instance whether it is almost entirely sewage or almost entirely rainwater derived stormwater, or of the size or quality of the receiving water, whether it is a small stream or an ocean. Thus the TTSS decided to set specific objectives for the Tideway to achieve. The broad aspirational aim is to work towards *"To reduce the impact of intermittent sewage discharges, and to further improve water quality in the Thames tideway, to benefit the ecosystem and facilitate use and enjoyment of the river."*, Steering Group report February 2005. Page 19.

The TTSSG was advised by defra in the Working paper of March 2004. Para 28 (iv) *"For those operating in conditions less severe than storm or unusually heavy rainfall, the appropriate solution must stop the discharges from occurring in such conditions unless they are not having an adverse effect on the Tideway"*

Three specific objectives were identified by TTSS covering the three key aspects relevant to the Tideway; aesthetics, ecology, and recreation.

The **aesthetics** objective was *"To reduce the frequency of those discharges that cause significant aesthetic pollution, or to limit the pollution caused, to the point where they cease to have a significant adverse impact."*

The **ecological** objective set in the Thames Water report Objectives and Compliance Working Group Report 2006 is *"To limit ecological damage by complying with the DO standards specified in the table above."* The Table above is,

Dissolved Oxygen (mg/l)	Return period (years)	Duration (tides)
4	1	29
3	3	3
2	5	1
1.5	10	1
Note: The objectives apply to any continuous length of river >=3km. Duration means that the DO must not fall below the limit for more than the stated number of tides. A tide is a single ebb or flood. Compliance will be assessed using the network of Automatic Quality Monitoring stations (AQMS)		

This table had been prepared following lethality studies on a suite of fish thought to be representative of those fish actually in the Tideway. Thus the Table is focussed on the specific conditions of the Tideway.

The main recreational users of the Tideway are rowers and sailors. The objective set by the TTSSG for **health and recreation** is *"To help protect river users by substantially reducing the number of "elevated health risk " days following CSO discharges."*

"To ensure that a solution has sufficient flexibility to accommodate future effects brought about by climate change and other factors."

"To comply fully with the requirements of BTKNEEC."

In Annex 1 the UWWTD directive says "*The design, construction and maintenance of collecting systems shall be undertaken in accordance with the best technical knowledge not entailing excessive costs, notably regarding;*

- *limitation of pollution of receiving waters due to storm water overflows."*

The defra Working Paper written by its lawyer and submitted to TTSSG states in para 30 "*The BTKNEEC requirement does not introduce a cost/benefit analysis that would allow for a decision not to provide any solution at all. Rather, it demands that the best technical knowledge be used to provide a solution that meets the requirement. If there is more than one solution to the problem, there would be a strong argument that any solution more costly than the least expensive could be viewed as excessive cost, so long as the solution chosen fulfils the objective and requirements of the directive."*

The TTSS looked at a number of alternative complete approaches, such as storage, screens etc and concluded that the Tideway tunnel would meet the objectives reliably.

At the time there was little knowledge of, or experience of, the SuDs and blue green infrastructure approach and, on the basis of the information available concluded that such an approach was not viable. Since then such methods have developed and there are now examples of this and other techniques in a number of other countries. Thus an option of the upgrade of the sewage treatment works, the construction of the Lee tunnel and certain in sewer and in river measures is considered below.

Water Framework Directive

The Tideway is classified by the Water Framework Directive as a heavily modified water body. That is supposed to reach good ecological potential. The Tideway Fisheries review states on page 30 "*It is a HMWB with Moderate Ecological Potential"*, and "*good status will not be met in the middle reaches, even with the solutions in place."* page 37. Thus it seems almost certain that under the Interim Measures proposed the Tideway would continue to be moderate status. Thus it would meet the WFD requirement of no derogation of status, which I understand is now set as the condition in 2008.

European Commission Communication on Green Infrastructure-Enhancing Europe's Natural Capital.

On 6th May 2013 the European Commission issued its Communication on Green Infrastructure, COM(2013)249 final. This was after the NPSWW was issued by the British Government. This Communication states" *The roadmap identifies investing in GI as an important step towards protecting natural capital. The EU Biodiversity Strategy to 2020 includes a commitment for the Commission to develop a GI strategy....It also helps avoid relying on infrastructure that is expensive to build when nature can often provide cheaper more durable solutions....GI solutions are particularly important in urban environments in which more than 60% of the EU population lives. GI features in cities deliver health-related benefits such as clean air and better water quality....In the Commission's proposal for the Cohesion fund green Infrastructure is specifically identified as one of the investment priorities...The Commission is committed to developing an EU GI Strategy that helps to conserve and enhance our natural capital and to achieve the Europe 2020 objectives...By the end of 2013, the Commission will develop technical guidance setting out how green Infrastructure will be integrated into the implementation of these policies from 2014 to 2020...Green Infrastructure can contribute significantly to achieving many of the EU's key policy objectives."*

Thus the European Commission has, since the decisions by the British Government on the NPSWW, swung behind a policy of Green Infrastructure.

Review of alternatives

The letter from the European Commission to Mr Roland Gilmore of 1st July 2013 states "*However any proposal made by the United Kingdom to remedy the excessive spills occurring in London will also need to look at the potential environmental impact of the solution proposed and the viable alternatives under the requirements of Directive 2011/92/EU on the effects of certain public and private projects on the environment."*

Directive 2011/92/EU requires for projects which "*are likely to have significant effects on the environment* " , Article 1.1, to have "*an outline of the main alternatives studied by the developer and an indications of the main reasons for his choice, taking account of the environmental effects*." Article 5.3 d.

The Aarhus Convention on Access to Information, Public Participation in Decision-Making, and Access to Justice in Environmental Matters was signed by the European Community on 25th June 1998 and ratified on 17th February 2005. Article 6(2) requires public participation on major projects to be carried out in an "*adequate, timely and effective manner*".

Thus an outline of the main alternatives studied must be provided. Presumably, to meet this requirement, this must take account of current technology and up-to-date information.

3. Benefit provided by works being constructed post TTSS

The works already under construction or completed include upgrading of the Mogden, Beckton, and Crossness STWs and increasing the storm water tanks to reduce the spill frequency.

Mogden STW

On 3rd August 2004 there was a storm event which resulted in many thousands of fish deaths in the Kew area downstream of the Mogden STW outfall but well upstream of Hammersmith.

The EA report Tideway Pollution Event August 3, 2004 states "*The circumstances that made the August 3 event more significant in terms of the severity of the fish kill were probably due to the very high flows received by the Mogden sewage treatment works, causing exceptional operating conditions at the works and leading to large discharges of partially treated sewage....this reinforces the view that the discharge from Mogden STW was a principal contributory factor to the fish mortality. "*

The partially treated sewage is probably activated sludge. Activated sludge is particularly "hungry" for oxygen and is capable of greatly reducing the oxygen content in the river. This appears to be supported by the statement in Solutions Working Group Report Vol 2 December 2006, page 12 *"Due to the poor performance of the final tanks and thereby to minimise the amount of solids discharged to the River Thames..."*

Although the Hammersmith pumping station may have contributed to the lowering of the dissolved oxygen level, with the main storm being over the Mogden STW catchment, dead fish being found at Kew, a short distance downstream of the Mogden outfall but several kms upstream of the start of the Tideway CSOs, and the oxygenation bubblers not being able to reach the most polluted part of the river at the tidal limit which is well upstream of the Mogden outfall, all indicate this was an event primarily generated by Mogden STW.

The National Policy Statement for Waste Water February 2012 page 18 lists the species killed in the August 2004 fish kill as *"comprising mainly bream, roach, perch, carp, dace, and flounder"*. Interestingly none of the species now listed by defra and the EA as of concern are included in the list of species killed in the 2004 event. Also there are no salmon although August is a time for salmon migration.

In September 2004 fish counts were done in the vicinity of Beckton, many kms downstream of the fish kill area. *"Instead of finding a significant reduction in fish in the area*" compared to September 2002 "*numbers had increased five-fold. It is surmised that some fish may have been able to run ahead of the hypoxic front and were forced downstream, thereby protecting them. In this case, the fish might be expected to gradually spread back into the affected regions when conditions became more favourable."* Thames Tideway strategy: Fish and Ecology Objective August 2005.

This indicates that more fish may be able to survive such conditions and that even the 2004 fish kill may have been sustainable. Thus, with the improvements to the Mogden STW recently completed, the upper Tideway should be more likely to be sustainable for all fish.

July 2009 fish kill event

There was another fish kill event at the beginning of july 2009 when 20,000 m3 of raw sewage escaped into the Thames killing fish in the river in the river at Kew and Brentford. This was caused by a CSO at the Mogden STW spilling following heavy rain. The BBC reported "*Thames Water's re-oxygenation vessel has been at the site of the spillage since Friday and the company's hydrogen peroxide station at Barnes is also being used to ensure other fish survive the waste discharge."*

June 2011 fish kill event.

There was another fish kill reported on the 5^{th} and 6th June 2011. The NPSWW states, page 18, that 900,000 m3 of storm sewage was released into the River Thames causing 26,000 fish deaths. TW have told me that the impact of this event was primarily due to Mogden STW but possibly with a contribution from Hammersmith Pumping Station.

The EA have provided me with two press releases they issued. "*The incident happened after the heavy rain over the weekend caused the release of more than 250,000 tonnes of storm sewage into the river from combined sewer overflows and at least 200,000 tonnes of storm sewage from the Mogden Sewage Treatment Works in Isleworth...fish deaths along a kilometre of river."* The press release some three weeks later stated. *"More than 26,000 fish were killed along a 2 kilometre stretch of the river between Barnes and Chiswick."* Thus the fish kill occurred over a 1-2km stretch, roughly between Chiswick Bridge and Barnes Bridge, which are 1 to 2kms apart. This is downstream of the Mogden STW outfall but significantly, about 3km, upstream of the start of the Tideway CSOs. Thus it is difficult to conclude that the Hammersmith pumping station outflow had a significant effect on the fish kill.

As a response to the 2011 fish kill in the Chiswick area, Thames Water have said " *I do need to assure you that once the extension is completed in March 2013 the works will be able to handle a similar situation without even using its storm tanks, let alone discharging to the river."*

Mogden spill frequency pre upgrade.

Thames Water now issue Sewage Discharge Notifications whenever Mogden STW or Hammersmith Pumping Station discharge. This is intended as a rower notification. However it makes interesting reading. There are a few duplicates when notifications are issued within a few minutes of each other so these duplicates need to be rationalised. I have gone back for the last 60 events. Between 5th December 2012 and 24th March 2013, ie a 3.6 month period there were 34 Mgden spills. Thus Mogden STW, prior to the upgrade, was spilling about 110 times a year.

Mogden post upgrade spill frequency

Since completion of the STW upgrade at the end of March 2013 I find the following Mogden STW spills
event 1,20th October
event 4 13th october,
event 6 24th August
event 10 30th july
event 16 29th May (although recorded only for Hammersmith in this schedule but known to have spilled from Mogden as well.)
14th April
This makes 6 events in nearly 6 months, ie about 12/year. This is a dramatic improvement.

The event on 28th May 2013 was a heavy rainstorm such that the storm tanks filled but the STW became tide-locked by a very high spring tide and no normal discharge could take place. Some 80,000 m3 of storm flow was discharged into the river. However the EA reported that "*the discharge did not have a significant effect on Tideway water quality. This was evident from the water quality monitoring of the estuary: Dissolved Oxygen saturation in the upper Tideway remained above 80%, which as we know is pretty good. We did not receive any reports from the public of any of the normal polluting effects that we might expect to be associated with discharges, such as fish in distress, or dead.*" Darryl Clifton-Dey email 6th September 2013. 80% dissolved oxygen content would be about 8 mg/l, well above the threshold of any of the objectives.

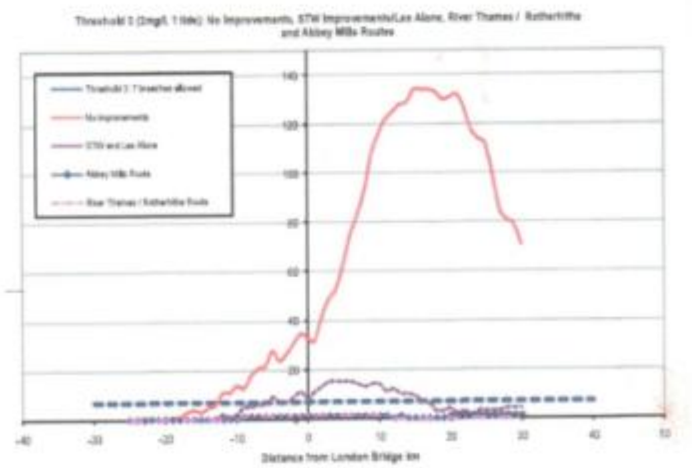
Thus it would appear that the Mogden STW upgrade means, first that the spill frequency has reduced from about 110 times a year to about 12 times a year, within the limit of 20 times a year suggested by the European Commission, and the associated low dissolved oxygen conditions, the main source of fish kills in the Upper Tideway, has been dealt with.

Crossness STW

In addition to the benefit of improved effluent quality, the storm tank overflow at Crossness STW would be reduced from 308,000 m3/year to 50,000 m3/year, see Table of performance in Appendix A.

Lee tunnel benefit

Once all the upgrades and the Lee Tunnel are completed, about April 2015, the volumes of stormwater discharged to the river will fall from about 39 Mm3/year on average to about 18 Mm3, less than half, see Table in Appendix A provided by Thames Water. Modelling of the river system has been done by Thames Water and shown in the Needs report 2010. Plots have been prepared of the number of breaches in the 34 years of modelling on the y axis and the distance upstream and downstream of London Bridge on the x axis. The plot above shows the situation with the 2mg/l standard. The red line shows the number of breaches with the current CSO and STW system. The standard to be obtained is shown by the dark blue horizontal line. The mauve line shows the



situation after the Lee tunnel and STW improvements have been completed. This shows that the current works go a long way towards meeting the required dissolved oxygen standards. The situation with the other three standards is set out in Appendix A.

However, it is believed that this modelling was done with the assumption that the per capita demand for water would remain the same and that household water use would rise in line with population thus the base sewer flows would be increased by quite a few percent. Since then TW have shown in their draft Water Resources Management Plan 2013 that water use per person would be reduced due to demand management measures such as the provision of more water efficient appliances and the implementation of much more metering (which generally reduces water use by about 10%) and then by the implementation of incentive tariffs which would reduce PCC even further. Thus the base flows in the sewers would reduce, in turn reducing the amount and frequency of CSO spills in the future such as when the Lee tunnel has been completed about 2015. Thus the model over-predicts the numbers of failures that would occur.

4. Reducing flows into the sewers

In this section I look at the assumptions made by Thames Water on the flows in the existing sewer model, then look at the actual Thames Water water supply projections, and then look at ways that the flows into the sewers could be reduced even further.

This can be done by reducing water use, the use of Sustainable Urban Drainage Systems(SuDS) and Blue Green Infrastructure, and also by diverting the sewer flows to other catchments.

Comparison of modelled sewer spills with records of actual spills.
Thames Water sewer model was run for a large number of rainfall events, I believe 154, over a number of years. The output of the model was used to predict how often each CSO would spill and what volume would be spilt. This was then adjusted to provide frequencies and volumes in an average year. This output for each CSO is shown in the Table in Appendix A. For instance Hammersmith pumping station was found to spill on average 50 times a year.

It was this model output which the Environment Agency used to assess which CSOs were causing unacceptable impact.

Thames Water now provide Sewage Discharge Notifications which are relayed to anglers and rowers and can be accessed through the Thames Anglers Conservancy. This gives information as to when

Hammersmith Pumping Station spills. The period from 1st October 2012, to 24th October 2013 ie 12.6 months, then Hammersmith pumping Station spilt 27 times, ie 25 times a year on average.

This compares with the 50 times a year quoted in the TW CSO spill frequency analysis for Hammersmith. CEH, in their September 2013 Hydrological summary state that for the Thames catchment this period up to 1st October 2013 has 107% of average rainfall so it is wetter than normal. Thus one would have expected the number of spills during this period to have been above the average. This does seem to show evidence that the spill frequency in the TW model for Hammersmith of 50 times a year is very likely to be appreciably higher than reality and the real figure could be about half that shown in the TW Table in Appendix A.

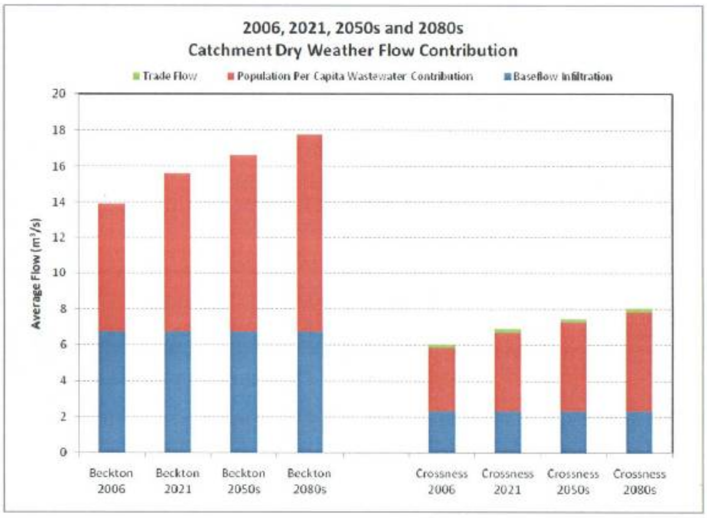
Further it might not take much adaptation, such as suds and BGI, to get below the spill frequency below that quoted by the EC of 20 spills a year.

Thus, in my view, this is strong evidence from TW that the sewer system model should be looked at again to recalibrate against the more recent actual spill data. One could then use the revised model to identify what measures would be needed to meet the EC spill frequency criterion.

Basis of TW calculation of sewer dry weather flows

Population and Wastewater Flows

Thames Water



Wastewater Profile	Per capita (L/head/day)	Catchment
Beckton Combined	200	Beckton
Beckton City	150	Beckton
Beckton Separated	150	Beckton
Crossness Combined	200	Crossness
Crossness Partially Separat	155	Crossness
Crossness Separated	155	Crossness
Fraser Rd (Separated)	145	Crossness

Assumptions:

1. Population change based on latest GLA projection to 2030 and ONS from 2030 to 2050
2. No change to per capita rating
3. No change in baseflow infiltration
4. No change in impervious connected area
5. Point 2, 3 and 4 subject to compliance to other TW work such as SOLAR values

Thames Water have given figures for dry weather flow (DWF) for 2011, 2021, and 2031.However the only basis I can find is on image 13 of the presentation given to me on 30th September 2011. This shows the Beckton dwf rising from about 13.9 m3/sec in 2006 to about 15.8m3/sec in 2021 and about 17.8 m3/sec in 2080s.To the side the image states "*no change to per capita rating*." Further the image says *"No change in baseflow infiltration"* Infiltration is made up of both leakage and rainwater/groundwater infiltration.

This is an increase of some 14% by 2021 and 30% by 2080. This was reported to lead to a "*near continuous CSO overflow*" in the later years and is one of the reasons provided by the EA for the requirement for the full tunnel. It would appear that these sewer flows are the ones used in the TW sewer modelling.

Sewer and interceptor flows are driven by flows going into the sewers and this is due to household use, leakage, and non leakage infiltration. The last is likely to be driven by rainfall and to be largely similar on an annual basis. Thus sewer dry weather flow should correlate with water delivered to households and with leakage .

The area sewered to the Tideway interceptors is similar to, but somewhat smaller to that, supplied by Thames Water with water, so, judging by eye, a factor of about 85% of the water delivered ending up in the sewers would seem to be a reasonable assumption.

The analysis of water projected to be supplied by Thames Water is given in the Thames Water Water Resources Management Plans (WRMP) 09 and dWRMP13, table WRP4-FP. This shows water delivered in 2007/8 as 1633 Ml/d and in 2024/5 1537 Ml/d, a 100Ml/d reduction. Therefore the water delivered, and hence reaching the sewers, is projected to go down during this period rather than up as in the TW analyses and publicity material. As an illustration see the spill volume from the Falcon brook pumping station that due to the increasing population from 2006 to 2021 the spill volume increases from 709,000 to 779,000, a 10% increase. This should be a decrease due to less water being delivered to customers.

Thus, contrary to the Thames Water assumption when doing its sewer and spill analysis of increasing sewer flows, one would expect a reduction of sewer and interceptor flows of about 100Ml/d, more than 1 m3/sec, resulting in a significant reduction in volume and frequency of CSO spill. The sewer analysis should be re-run taking account of the actual conditions projected by TW.

Reduce flow into the sewers further by reducing water use.

A further way to reduce sewer flows would be greater demand management. As an illustration the sewer analysis would have been done when TW had set a limit of 80% on metering. In its Strategy discussion document TW says it will meter all homes by 2030. Increased metering, along with other demand management methods, would reduce sewer flows further, and provide greater capacity to accept storm flows.

In additon, further demand management measures could be adopted, such as more non-household water audits. The cost of doing this has been considered only for the water supply benefit. Thus, including the reduction in sewage dry weather flow, would increase the available storm water capcity and hence the benefit of doing greater demand managment and make it economic to do more demand management measures.

Reduce flow in the sewers by reducing water main leakage and infiltration into the sewers.

All water main systems leak and some of the leakage is collected by the sewer and interceptor system.

The figure shown for leakage in London in the TW WRMP09 for 2007/8, probably the base year for the strom sewer flow analysis was 590 Ml/d. This dropped to 539 Ml/d in JR2011, and is projected to drop to 478 Ml/d in 2024/5, a reduction of about 110 Ml/d.

So how much leakage infiltrates into the sewer system ? This is difficult to answer. However about half the Beckton and Crossness catchment are is underlain by London Clay so minimal leakage would go into the ground. Instead much would be picked up by the granular surround of the water mains and the granular surround of the sewers, thus any sewer weakness could readily lead to water that had leaked infiltrating into the sewer system.

I have a plot of Becton STW inflows from 2005 to 2008. This shows an average in 2005 of about 15.0 m3/sec, dropping to an average in 2008 of about 12.5 m3/sec. I believe this was a period when TW were making a great effort, and being successful, in lowering their leakage. This reduction of about 2.5 m3/sec is equivalent to about 216 Ml/d. I have figures for leakage in 2004/5 of 804 Ml/d and in 2008/9 564 Ml/d, a drop of some 240 Ml/d. Assuming leakage is split by population then Becton and Crossness is about 85% of the London WRZ. Thus one would expect a drop of about 204 M/d in the Beckton and Crossness catchment. Beckton takes much more of the flow than Crossness. Thus, it would appear from this that almost all the leakage returns to the sewer system.

A reasonable assumption might be that 2/3 of the leakage reaches the sewers and interceptors. On this assumption the sewer flows by 2022/3 would reduce by about 70 Ml/d. Although the dWRMP14 shows no further leakage reduction, my understanding is thatat the stakeholders meeting in September 2013 TW said that they now plan to reduce leakage by a further 50Ml/d by 2040. Thus, on the assumption of 2/3 leakage infiltrating into the sewers, there would be another 30Ml/d reduction in sewer and interceptor flow, making a total reduction of about 100Ml/d. This would further reduce the sewer and interceptor flows, creating further capaicity for storm flows and hence fewer number of CSO spills and less volume overflowing into the river.

One of the aspects is what proportion of leakage enters the sewerage system. Sir Ian Byatt, the previous Director General of Ofwat has said in his Thames Tunnel: A Critique of a flawed Project " *A further contribution would be to reduce the considerable infiltration of ground water into the sewers. ...What seems to have happened in the intervening 24 years"* since privatisation " *is an accelerated deterioration in the smaller feeder sewer network that, coupled with continuing high urban leakage, is exacerbating infiltration into the sewerage system. .. I know of no evidence that Thames has investigated this or that sewer infiltraiton is seen as a problem. It would be perverse to reward Thames with a major increase in RCV as a consequence of its decision to improve its profitability by neglecting maintenance of the sewerage network."*

Whatever the projected reduced leakage of some 70Ml/d by 2024/5 and some 100 Ml/d by 2040 will reduce infiltarion into the sewer system and increase spare interceptor capacity, thus reducing CSO spill volumes and frequency.

Sustainable Urban Drainage Sytems and Blue Green infrastructure

One way to reduce storm runoff into the sewers is Sustainable Urban Drainage Systems and Blue Green infrastructure.

"Our increasingly impermeable built landscape heightens the flood risk during heavy rainfall. Surface water run-off in urban areas overloads the combined sewers, causing the overflows to spill into watercourses.Suds alleviates the problem by mimicking the way rainfall drains away in nature. Measures include soakaways, balancing ponds, wetlands, and permeable drainage channels known as swales, all of which reduce the total rainwater volumes reaching the conventional surface water drains, combined sewers and rivers, and attenuate peak flows. ...permeable surfaces used for pavements, roads or car parks and even sedum roofs can be incorporateed into urban environments...Planning Policy Statement 25 (Development and Flood Risk) which states that local authorities should give priority to the use of Suds when deciding applications" Victoria Joy, legal director at Addleshaw Goddard. However this only applies to properties where a planning application has to be made, a limited number each year.

Some of these these water storage areas could be in gravel or plastic box strutures designed to be under streets or car parks. Of note is that much of the area between the River Thames and an east/west line through Hyde Park is underlain by river terrace gravels which could enhance soakaways and be able to allow infiltration during storm rainfall conditions, thus reducing storm runoff further. A similar situation occurs south of the river with the line runnng loosely east west through Brixton.

Such techniques were looked at by TTSS but had not been sufficiently developed then and there was little experience of them at the time of the TTSS consideration in 2002. Thus the TTSS was not able to recommend such an approach as being a viable option to meet the UWWTD.

Later policy decisions

The European Commission has promulgated in May 2013 its Communication on Green Infrastruture – Enhancing Europe's Natural Capital. "*Green infrastruture can contribute significantly to achieving many of the EU's key policy objectives...The European Commission adopted today a new strategy for encouraging the use of green infrastructure , and for ensuring that the enhancement of natural processes become a systematic part of spatial planning*."

The use of SuDs, green infrastructure and Integrated Water Resource Management (IWRM) is the way that many European and American cities are now going to overcome similar problems. BGI, with the planting of trees and other vegetation,would also improve the environment in london, should reduce summer temperatures, and should improve the health of the inhabitaants. This is one of the major benefits of such a scheme in phildelphia. Should not London do more than it is at present?

Thames Water in its Strategy Discussion Document page 17 states "*We will take steps to reduce the amount of rainwater that enters our sewers."* As a strategy in the short term (2015-2020) page 19 *"A major part of this long-term goal will involve working with the Environment Agency and local authorities to promote and install sustainable drainage systems."*

The defra National Policy Statement for Waste Water states on page 8 "*The Government is taking measures to reduce the demand for new waste water infrastructure in England by requiring the use of sustainable drinage systems (SuDS) to reduce run-off in the built environment."*

Pilot areas in West London in Appendix E.

This approach was studied in Appendix E to the 2010 Needs report, for three pilot areas, and appreciable reductions in storm runoff were found. The report is difficult to understand but on page 42 quotes a reduction in CSO overflow of greater than 50%.

The analysis in the Annex 1 focussed very much on spill volume reduction in extreme events. "*The December typical year and October 2000 events represent the most severe recorded rainfall events for the typicl year and 154 event rainfall series respectively."*page 1. However this event has a return period of approximately one in four years. This is indeed an "unusual" event and one in which an overflow would not be in breach of the UWWTD. The analysis focused on spill volumes and makes little reference to the spill frequency

In 2.3.7 of Annex 1, the results are shown of the modelling if 50% of the impermeable area was "removed " from the catchment. This shows that the number of spill events would reduce at Frogmore from 29 to 10 and at Putney Bridge from 33 to 16. Both these are within the spill frequency of 20 suggested by the European Commission at the infraction hearings to meet the UWWTD.

For West Putney the number of spills is shown as reducing from 59 to 52. I have been told Gilmore/Binnie email 14th October 2013, but I cannot verify, that about 40% of the storm water of the catchment disharges to the Beverly Brook. This would appear to be correct as the 2010 TW model output shows 26 spills a year with no impermeable area reduction. Thus, with reductions in the impermeable area, it would appear reasonable to expect spill frequency of the West Putney CSO to drop below 20 spills a year. If so then all three Putney CSOs, including one included in the Appendix E Annex 1 table as spilling many times, would meet the guideline spill frequency under these conditions.

The study was done under the direction of Prof Richard Ashley of the Pennine Water group. However he has said in his email to me of 9th October 2013;

"1. TOR too narrow - only to reduce spill volumes and frequencies - no other benefits eg flooding, aesthetics and only RWH using barrels
2. study too high level - we could not investigate eg local infiltration measures - we were told these would not be viable - for the areas we were given to look at as supposedly being the most 'ideal' for SuDS
3. time and resources did not allow individual SuDS to be defined and gross assumptions for 'blanket' applications had to be made and scaled up
4. no contact with councils, public or others allowed to test viability or look for synergies and mainstreaming (linking SuDS to other developments)
5. CH2M Hill did all the modelling so we had to presume they did it right
6. SuDS had to be considered as an 'all-or-nothing' option not a partial option as everyone else has done. Even then, significant partial benefits were shown in the modelling, with some overflows eliminated completely."

Reference point 2,"*local infiltration measures deemed not viable*." The British geological Survey map of the area shows much of the study area underlain by impermeable London Clay and head, probably also impermeable. However about one third of the area is underlain by Kempton Park Gravel, Taplow Gravel, Boyn Hill Gravel, and Black Park Gravel. Thus this aspect of the study may well under estimate the benefit. Thus such a study could well warrant doing in more detail and focussing more on the frequency of spill events.

Application to the entire LTT model

From page 48 of Annex 1 to Appendix E an analysis was done of reducing the impermeable area of the LTT model by 50%, see Table 4.1. This showed a considerable reduction in both spill volumes and spill frequency. Excluding Abbey Mills, which will be connected to the Lee Tunnel, there are still 12 CSOs that are shown in the table as spilling more frequently than 20 times a year on average, the number proposed by the european Commission in the infraction procedings.

However the most frequent one is West Putney at 52 spills a year. As shown above, this appears to be incorrect, under the later analysis only having some 26 spills a year under current conditions. Thus, reducing the impermeable area, should reduce the spilll frequency below the 20 spill frequency limit.

Acton Storm relief is shown as spilling 21 times a year. There was work done some years ago of disconnecting part of the Acton catchment into storm and foul sewers. However this was never completed. Completing this work could result in the spill frequency from Acton becoming within the limit.

Frogmore Bell Lane Creek would only spill a small amount 4,200m3 and 21 times a year. By other means, such as a retention tank, this CSO could probably be reduced to be within the allowable frequency.

Savoy street is shown in Appendix E as currently spilling 47 times reducing to 34 times if the impermeable areas are reduced. However the later 2010 modelling, see Appendix A to this report, shows it only spilling 18 times a year under present conditions.

The Holloway CSO is shown in the Appendix E modelling as currrently spilling 49 times a year reducing to 41 times a year. The later modelling shows Holloway CSO spilling only 8 times a year under current conditions.

The Greenwich CSO is shown in Appendix E as spilling 45 times a year, reducing to 37 times a year. However in the later modelling under the post STW works conditions the spill frequency is shown as dropping to 28 spills a year.

Thus the Table in Appendix E does appear to overestimate the spill frequencies for a number of the CSO that are shown to spill in excess of the limit. However there would appear 6 other CSOs to be which spill too often.

One of these is Hammersmith Pumping Station which is shown as spilling 50 times a year at present and to only reduce to 43 times a year with 50% reduction in impermeable area. However the spill frequency shown in the Sewage Discharge Notifications as shown earlier in this chapter , is that the real spill frequency during the last year when CEH quoted catchment rainfall as 107% of the long term average , as 25 times a year. The conclusion is that the sewer model overpredicts the spill frequency which might well be as low as half that shown.

Problems in implementing Suds and BGI development

It must be recognised that such a course of action would require to be implemented by a number of different authorities and householders. For instance householders/housebuilders would need to put in green roofs, rainwater butts and soakaways in new or renovated properties. However redevelopment of London is only about 2% of properties a year so after 10 years only about 20% would be expected to be revised. However I am informed that many of the roads need repair and the provision of permeable surfaces with storage underneath could procede much quicker. However there would be significantly increased disruption.

Unlike the tunnel solution, benefit does occur from the very beginning of such a programme; the speed at which the programme is implemented is a matter for others but the most cost effective approach, as in Philadelphia, is to develop a 20-25 year programme which integrates these works with others, thus minimising costs. Thus such an approach would make a continuing reduction in storm spillss which would also be able to mitigate any increase in storm runoff resulting from climate change.

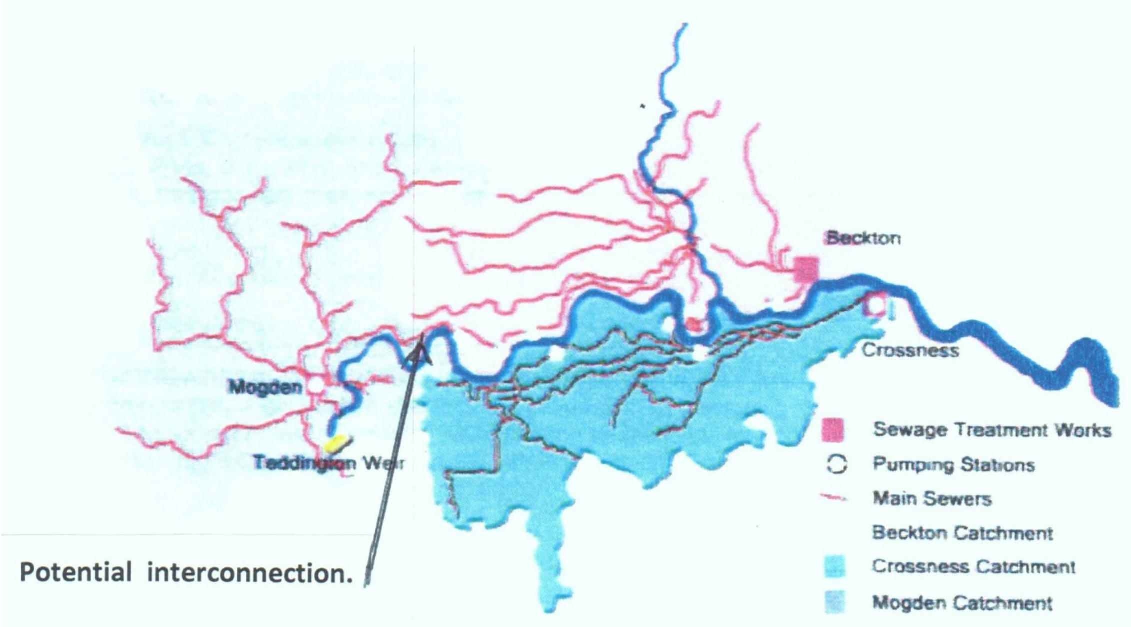
The costs of Suds and BDI measure are not included in the estimated costs of the Combined Interim Measures as their costs are not known and would increase progressively and be spread over a longer period.

Appendix E states on page 3 "*It is expected that the passing of the Flood and Water Managment Act 2010 could address some of these major impediments for new developments and areas undergoing redevelopment. The Act, however, does not deal specifically with retrofitting altered stormwater* *managment measures and how these would be dealt with still remains to be seen."* A change in the legislation could make implementation of Suds and BGI both easier and quicker.

Reduce flow into the interceptor sewer system by diverting storm flows to other catchments.

Another way to reduce the spill volume is to reduce the catchment flowing to the interceptors and the Tideway CSOs. I have identified three options.

Figure 4.1 Catchment areas draining to Mogden, Beckton and Crossness STWs



Divert to the Mogden STW catchment

The plan of the sewerage network above shows a Mogden main sewer coming almost as far as Hammersmith. Connecting this sewer to the Hammersmith sewers and passing the flow to Mogden could reduce the flows in the Beckton interceptors. However I have been told by Thames Water that the sewer connecting Chiswick to Mogden STW may become fully loaded during large storm conditions. However this may not occur during smaller events thus might be able to reduce the number of spills elsewhere. This would need study. There may also be other similar connections that can be made. Such arrangements ought to be investigated.

Divert to the Hogsmill STW catchment.

One way for augmenting water resources considered in the rdWRMP09 is to divert some of the flow going from the Wandle valley sewer to Crossness STW, to flow to the Hogsmill STW works upstream of central London. Such a scheme was identified in the dWRMP 09. It was called Hogsmill B with a 20Ml/d (1/4 cumec) diversion.

This would both increase the flow over Teddington Weir, and thus could be used to augment the water resources for London, as well as reducing the dry weather flow in the southern interceptors by about ¼ m3/sec and reducing the CSO spill volumes from them. This dual benefit should be looked at and taken account of in the various cost benefit analyses in the water supply dWRMP and the sewer system analyses.

Connect to the existing Thames / Lee raw water tunnel.

There is a tunnel under the Beckton and Crossness sewer catchment that connects the Hampton intake upstream of Teddington Weir to the Lee Valley reservoirs, see plan below. It is normally used for conveying raw water abstracted from the River Thames to the Lee Valley reservoirs. The Institution of Civil Engineer paper by Cuthbert and Wood on The Thames-Lee Tunnel Water Main 1962 states its capacity as 120mgd, about 500Ml/d or 6m3/sec. However the Cascade LTOA report quotes the abstraction licence as direct from the river to the tunnel with a capacity of 682 Ml/d, a substantial amount. The ICE paper states that there are access shafts at about one mile spacing. The route crosses under the Beckton sewer catchment.

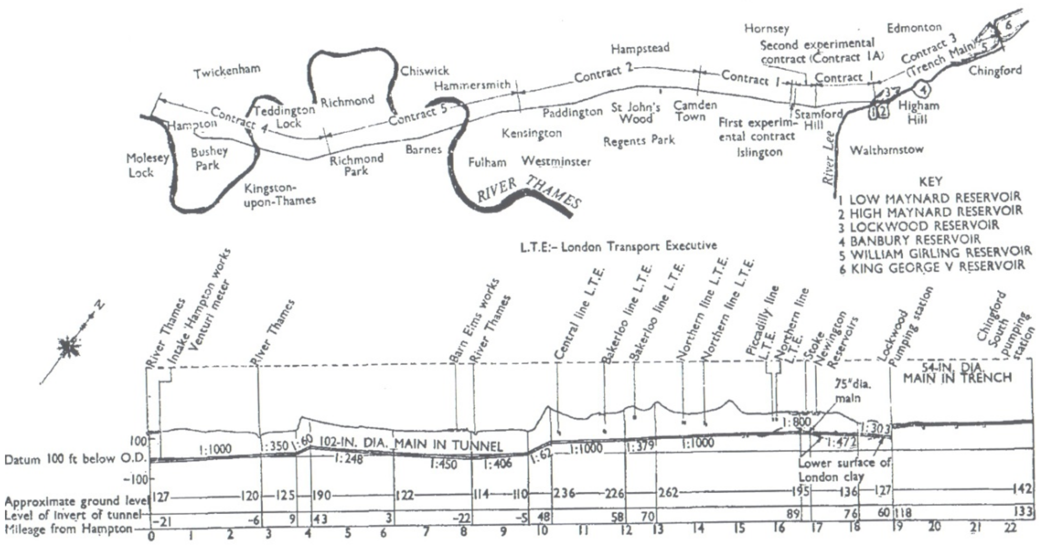


FIG. 1 (above)—PLAN OF THAMES–LEE TUNNEL MAIN (below) LONGITUDINAL SECTION

CUTHBERT AND WOOD ON THE THAMES–LEE TUNNEL WATER MAIN 259

Were it possible to divert storm water into this tunnel, then it would reduce the flow to the sewer interceptors. A separate storm water system would need to be identified, and possibly developed, and connected. Places that could be considered might be based on Holland Park, Kensington Gardens, and Hampstead Heath. It is possible that inlet screening would be necessary. Delivery would be to the Lee Valley reservoirs where considerable dilution and some natural treatment would occur. Coppermills water treatment works provides advanced water treatment.

Such a scheme could also collect runoff during a dry spell and provide some increase in water resources. I believe such a system has not yet been considered but should be.

Summary

Thus Thames Water, in its analysis of interceptor spills, assumed an appreciable increase in sewer flows, some 2.6 m3/sec, some 13% of the current 20 m3/sec by 2021. Sewer flows are based on water delivered to customers and infiltration, predominantly that coming from water main leakage. However instead of going up, the TW WRMPs show water delivered and leakage going down by 2024 by some 170Ml/d, some 2m3/sec, 10%, and are projected to go down further. Thus TW have over-estimated the flows in the interceptors by some 23%, thus significantly overestimating the spill volumes and frequency.

There are also ways of reducing the flows into the sewers such as diverting sewer flow to other catchments and implementing SuDs and BGI.

5. Suggested measures in the sewer system

Remove restrictions in the sewer network.

Restrictions in the sewer network can result in more flow being discharged to the local river than necessary.

Appendix B to the Needs report 2010 describes the situation in a number of other cities , mostly European. On page 37 it describes that "*80 flow restrictions were eliminated*" in Hamburg. It is likely that there are also restrictions in the London system. It is not clear who has looked at this in London, what was the outcome, how many remain, and what benefit would be obtained in reducing CSO spills by eliminating them.

The London sewer network is almost entirely concrete and brick with fixed sizes. This was developed over a a long period so what was considered optimum many years ago, maybe as much as a century, may well not be optimum today. The TW sewer model is now much better and more accurate than at the time of the TTSS study in 2004. It could be used to analyse for such restrictions.

As an example I understand that there are a few known restrictions in the London sewer system. For instance I understand that the connection between the Fleet sewer and the lowest interceptor sewer is only about 3 foot across and that this restricts flow in the Fleet sewer from flowing into the low level interceptor, irrespective of whether there is spare capacity in the interceptor. This results in a larger spill from the Fleet CSO than necessary. Whilst enlarging the connection may not be easy, because it lies directly below the Blackfriars Bridge road interchange, this illustrates one action that could be taken in the intermediate time to reduce spill volumes.

Whilst the restrictions along the lowest interceptor sewer may have been studied as part of the Tideway Tunnel project, there may well be restricitons in higher parts of the sewer network that could be changed beneficially, thus reducing flows in the low level interceptors and hence CSO spils or moving the sewer overflow further downstrem so associated spills would have less impact. Thus, as part of the Combined Interim Measures, it is proposed that the sewer network be studied to identify the restrictions and whether they could be altered to provide benefit to the system and reduce CSO overflows.

Real time control and detention tanks.

There are many interconnections between the sewers and the interceptors. At present these operate with a fixed weir. However the levels of the weirs were constructed many years ago and may no longer be optimum. Of importance, many of the most polluting storms are localised summer thunderstorms when the river flows are lowest. Thus conditions will vary appreciably from one storm to another. Thus there may be spare capacity in an interceptor because the rain has not fallen in part of the catchment draining to it.

It is reported in Needs case Appendix B that in Barcelona storm events are managed using real time control (RTC) and detention tanks. A RTC system is being developed in Paris. Page 6 also lists RTC as also being implemeted in Lisbon, Marseilles, Vienna. Many cities have also built detention tanks to assist RTC and minimise CSO spill.

The Thames Water Strategy discussion document of about 2012 states on page 19 "*Our strategy also includes the increased use of innovative, real-time control and monitoring systems. We have alreday begun installing this technology, which will help us to manage our network more actively and take swifter action to avoid operational problems."*

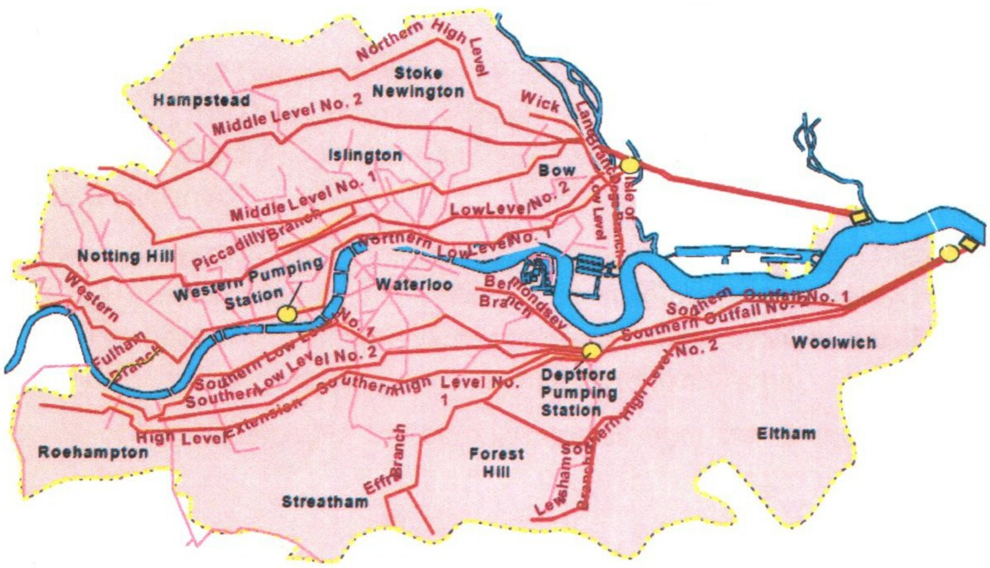


Figure 1.4: The Beckton Sewer Catchment

In particular in London there is a system of trunk sewers going down the historic "valleys" and interceptors going largely horizontally to carry away flow to the east. The levels of the interconnector structures are fixed. Therefore they are not able to adapt to the different conditions of summer thunderstorms. Thus there is likely to be appreciable scope for passing more flow down the interceptors and less CSO spill into the river. For instance, if more sewer storm flow in the Notting Hill or Hampstead area could be retained in the upper interceptors, then there would be less flow in the Low level sewer and hence less CSO storm spill. These measures would require moveable weirs with actuating motors.

Detention tanks were looked at by TTSS but rejected as a single solution as there was not sufficient space and such a system could not by itself meet the objectives. However, in conjunction with RTC, detention tanks in the less developed areas, particularly south of the Thames, could be looked at as part of RTC. This would need to be assessed.

Whilst I understand that TW has looked at RTC in regards to the lowest interceptors that spill into the Tideway Tunnel , my understanding is that little study has been done of the higher level interceptors.

The sewer model should be run to see what benefit could be obtained from RTC, with or without detention tanks. Were any such measures found to be sufficiently beneficial in reducing CSO spill they should be implementable within about three years, the time scale being considered for the Combined Interim Measures.The Suds and BGI would continue to be devloped progresively over a lnger time period.

Vortex separation of sewage debris

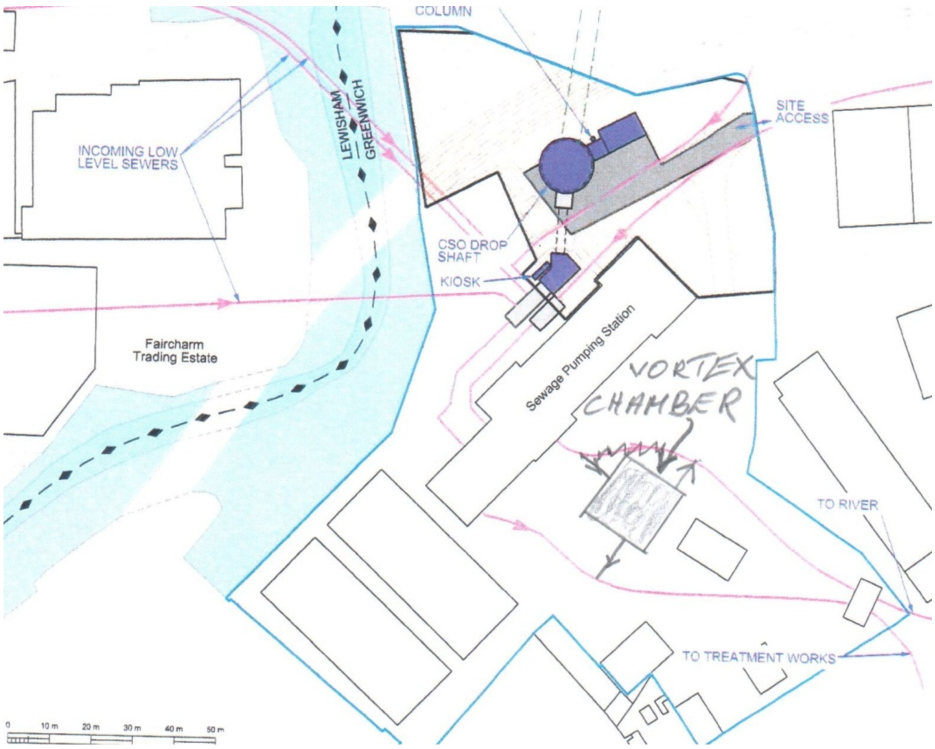
It is the mostly "floatables" that give rise to most of the aesthetic impact. A vortex can help to separate out the floatables from the remainder of the storm water flow.

Such a system was looked at by Thames Tideway Strategy Steering group in 2003. However, at the time, experience of such a system was limited, most systems needed a significant driving head which is not generally available in London, and such a system would not reduce the frequency of spill events. Thus it could not provide a total system.

However a vortex separation system could provide part of a suite of interim measures. Since then I have identified a vortex system Hydrospin, provided by Steindardt of Germany.

This system has been tested and found to result in concentrations of floatables of 85% to 99%. The Steindart web site states on page 4 the "*1,000 installations already operate successfully.*" Thus the system does appear to have good potential and operating experience such that it warrants considering.

For instance such a system could be considered for Greenwich Pumping Stations where there is both pumping head and a good pass forward flow, see plan below. This pumping station would discharge about 4 Mm3 a year, see Table of Performance in Appendix A. This is one quarter of the post Lee tunnel annual baseline overflow of about 18Mm3/year. Thus such a system, if feasible, could have a significant benefit to the visual impact in the Greenwich and Thames Barrier locations where there are many tourists and the discharge is into a particularly visually sensitive area.



A possible location of the vortex chamber is shown in the plan above.Thames Water have provided me with the designflows from a 15-year 120-minute event of Heathwall 12 m3/sec and Greenwich 36m3/sec. These are very large flows and would need very large vortex structures. However, a shorter return period would be much more appropriate.

Both options may well be outside the cost range for interim measures on their own. The TW Table of performance shows the post tunnel situation as an annual spill four times a year of 571,000m3 lasting 35 hours. Therefore there would still be an appreciable quantity spilling into a prime tourist area. Thus, in this case, there would continue to be a significant impact on the tourism area. This would need to be taken account of in the assessment as to whether the expenditure would be worthwhile or whether it would form part of the permanent works.

Were a vortex system not be feasible or economical, then an alternative could be to install screens here as set out in my Project Justification Report. It might be possible to reuse one of the screens that are currently at Abbey Mills and will be redundant on commissioning of the Lee tunnel. Whilst the volume of screenings at Abbey Mills was lower than expected, screens would take out much of the obvious sewage litter at this site which is particularly sensitive.

Consideration should also be given to installing such vortex systems at other CSOs where there is both sufficient pumping head to drive the vortex and space to build the vortex. However this may not be feasible elsewhere. Whatever vortex chambers for the sort of flow in the London sewers would be expensive or there may well not to be sufficient space elsewhere.

Optimise CSO spill levels.

One measure which Thames Water have examined as part of their planning for the tunnel is the level of the overflow weirs of the CSOs. These are, anyway, to be altered to minimise spill at some CSOs so that the fewest drop shafts are needed.

As an interim measure the sewer model could be run and the CSO weir levels adjusted to provide optimum interim conditions. TW declined to do so.

Cost of in-sewer systems.

Until further information is available it is not possible to provide any estimate of the cost of such in-sewer measures to reduce discharge to the Tideway of polluting matter. As a budget for removal of restrictions, reductions in contributing flow, Real Time Control, and raising some CSO weir levels, I have allowed a budget of £7m. Some of these works would also benefit the long term.

If the estimated remaining cost of some of the works such as the vortices, exceeded a certain sum, assumed by me to be about £3m but subject to review, then those proposed works are unlikely to meet the cost benefit for Combined Interim Measures. However they could still be implemented as an early part of the long term measures.

6. Effect on aesthetics

Objectives

The TTSS adopted as an objective *"To reduce the frequency of operation and limit pollution from those discharges which cause significant aesthetic pollution, to the point where they cease to have a significant adverse effect."* This was re-endorsed in the TTTT Objectives report of December 2006.

Impact of sewage litter

It is generally accepted that sewage derived litter makes up 10% of the total litter. This figure is from the Tidy Britain Group**.** There is limited evidence to support this figure but it is a generally used figure. Thus 90% of the litter/debris is not sewage derived.

"*Shortly after discharge floating matter disseminates relatively quickly so the plug of sewage effluent moves unnoticed with the ebb and flood of the tide."*HPA Recreational Users report page 52.

However some condoms, panti-liners and blue plastic cotton buds do occur. There is also a brown oil build up on boats in certain parts of the tideway. This is believed by some to be sewage derived but could also be from cooking oil, car oil, or other sources.

Jacobs Babtie Review for ofwat.

As part of their review Jacobs Babtie team did a trip on the Thames on 31st August 2005 and reported "*...several days after the most recent rainstorms, floating debris was seen in several locations. The slicks that the TTSS describes in its reports were observed, and, on close inspection, it was clear that some of the debris contained in them was sewage-derived. However, our opinion is that it would not be immediately apparent to a casual observer that the debris was any more than windblown litter and vegetation- a fact reflected in public responses obtained during the TTSS*." Independent review for ofwat Feb 2006 page 8.

Jacobs Babtie continue on page 9 "*In addition to the slicks, litter was seen to have accumulated on the banks of the Tideway. However much of this is coarse debris which is likely to have originated from sources other than the CSO discharges. Much of the bankside of the Tideway is overlooked from adjoining residential and commercial buildings or is accessible to the public, albeit access to the actual waterside is made only infrequently. Numerous leisure vessels provide visitors to London with river tours. Thus bankside litter deposits may be considered a very visible aesthetically feature from the public standpoint."*

In which case the collection of all litter by skimmers would be a significant aesthetic improvement.

The DETR 1997 guidance on the UWWTD states to identify an unsatisfactory CSO it would need to have "*a history of justified public complaint*." The Environment Agency have stated " *the number of formal complaints regarding sewage debris is relatively few."*Bain email. Thus there do appear to be only a few complaints from the public.

On page 11 Jacob Babties quote from the eftec report The Market Benefits of Options for the Thames Tideway appended to the TTSS Cost Benefit Working Group Report which they say states

> *"...although reducing CSO events would be associated with reduced amounts of sewage litter, this is currently only a small (10 per cent) proportion of the total litter and debris in the Tideway at any one time, and what there is appears to be invisible much of the time, at least as far as individual perceptions are concerned.*
>
> *This is one of the findings of the SP (TTSS's stated preference survey) as well as being the view expressed by consultees from the London property market. We might expect certain river users to notice a difference, in particular those who come into close contact with the water, such as rowers, houseboat owners and those who frequently walk by the river. However, in general the public are unlikely to detect much visible difference, and this includes owners of riverside property who, as we have just argued, tend to partake in river-based activities from a greater distance... The Thames is a tidal river downstream from Teddington, and levels of suspended silt and mud in the water are naturally high and always will be. Reducing CSO events will not have any impact in this regard.*
>
> ***Therefore, little aesthetic change in the water is to be expected due to Tideway Strategy options, and this, together with the low correlation between riverside residence and***

involvement in river-based water sports, suggests that any impact of the Tideway options on property prices is likely to be minor."

These statements were made about the baseline in 2006. Since then the baseline now includes the Lee tunnel, in itself removing more than half the spill volume, as well as improvements to the water quality and storm overflows from the 5 London sewage treatment works. Thus the effect from sewage litter would be even smaller for the new baseline.

On the Tideway Tunnel, Jacobs Babtie concluded: *"in general the public are unlikely to detect much visible difference."* From implementing the Tideway tunnel

Environment Agency Assessment

It is very difficult to identify which CSOs are providing debris that results in a significant adverse effect. The Environment Agency developed a protocol. This identified areas of the river which are sensitive to aesthetics impact. In broad terms these were the river from Kew down to Westminster, around Greenwich, and around the Thames Barrier.

The EA then assumed that "*the volume of discharge is a key factor in determining the extent of the adverse aesthetic impact created by a particular outfall. Thames Water sewer models were used to estimate the mean volume discharged from each for 21 historic rainfall events. CSOs that discharged an average of greater than 50,000 m3 were assumed to make a significant contribution to the aesthetic impact, whilst those that discharged less than 1,000m3 were assumed to cause no significant impact. CSOs that discharged between 1,000 m3 and 50,000 m3 were assessed for the nature of the area into which they discharged, by reference to figure 1... 35 CSOs were deemed to be unsatisfactory because of the contribution they make to the aesthetic impact of storm sewage discharges."*

I have not been able to find any specfic analysis to support the choice of 50,000 m3/year as the level at which a CSO must have an adverse impact. Thus I believe this analysis is a subjective assessment.

Thus, although the Environment Agency have identified 35 CSOs as contributing to the aesthetics impact, that impact does appear to be relatively low. This should be taken into account when assessing the environmental impact of non-compliance.

In river control of sewage debris

General system

In various places a floating boom has been used to concentrate the floating litter/debris which is then collected and disposed of. One such installation is at Cardiff Harbour, see the last page of Apendix C. It may be possible to provide similar booms at the Thames CSOs, thus concentrating the floating sewage litter so it can be retained when a spill occurs and not escape into the river.

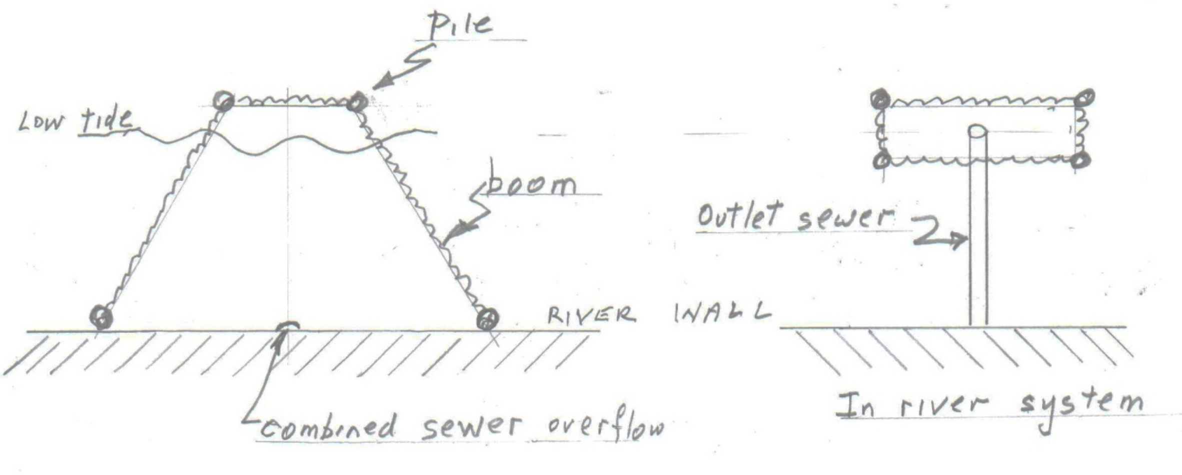
I have been in touch with Bolina Booms who supply such booms. The booms would need to both float at high tide and to retain the collected debris when part of them are sitting on the foreshore during low tide. The proposed arrangement consists of vertical piles in the form of a trapezium with the long side the shore and the short side in the river and parallel with the river flow. The booms would be flush faced Bolina environmental booms fitted with alternate kite floats to keep the boom stable and upright when dried out at low water. The boom would be kept in position by four piles at each point of the trapezium/rectangle with floating collars around them to move with the tide. Concern has been expressed as to whether the booms could cope with the 5m tidal range in the Tideway. However, Bolina Booms believe that, with the collar system shown below, this should not be a problem

Picture of a typical boom installation

The debris within the booms would need to be collected. It is proposed that this be done by a floating craft. This could be by having a trash trap at the outlet of the boom which is then lifted up by a mechanical grab with fine mesh. For the finer debris a fish pump could be used to suck up the surface water in a similar way to that used for moving fish from one tank to another.

Picture of a variable water level boom.

Below is a sketch of the iitial boom arrangment when the CSO is in the river wall and also when the CSO is out in the river.



Category 1 CSOs that operate frequently and have an adverse environmental impact	Category 2 CSOs that do not operate frequently but which have an adverse environmental impact	Category 3 CSOs which have no significant environmental impact	Category 4 CSOs that operate frequently but have been assessed as having no adverse environmental impact
Acton	Stamford Brook	LL1 Brook Green	London Br
W Putney	N W Relief	Falcon Br Relief	Isle of Dogs P/S
Hammersmith P/S[1]	Wick Lane	Horseferry	Canning Town P/S
Putney Bridge	Church St	Wood St	
Frogmore	Queen St	Goswell St	
Jews Row	Smith St	Pauls Pier	
Falcon Br P/S	KSP	Battle Br	
Lots Rd P/S	Grosvenor	Beer Lane	
Ranelagh	Savoy St	Iron Gate	
Western P/S	Norfolk St	Nightingale	
S W Relief	Essex St	Union Wharf	
Heathwall P/S		Wapping Dock	
Clapham		Cole Stairs	
Brixton		Bell Wharf	
Regent St		Ratcliffe	
Northumberland St		Blackwall Sewer	
Fleet		Henley Rd	
N E Relief		Store Rd	
Deptford			
Greenwich P/S			
Abbey Mills P/S			
Charlton			
Holloway			
Shad Thames P/S			
Earl P/S			
TOTAL 25	TOTAL 11	TOTAL 18	TOTAL 3

Location of boomed CSOs

As can be seen above in 2004 the Environment Agency considered 36 CSOs as unsatisfactory. However there have been a number of changes since then. Because of these changes a number of CSOs in the Table of performanace now have zero discharge. These are Abbey Mills, Wick Lane, Church St, Queen St, and Norfolk St. I understand that West Putney has been measured for over a year and has minaml foul sewage and should be reconsidered.

Constructing a boom system costs money and anyway a CSO with a low spill volume would not be worthwhile booming. In the TTSS the EA had taken 1,000 m3/year as the limit below which adverse impact would not occur. Arbitarily I have taken a limit of 3,000m3/year as an economic cut off point point. This would remove a number on the EA category 2 list of CSOs that do not operate frequently but which have an adverse environmental impact viz Stamford Brook, Smith St, KSP, Grosvenor ditch, Essex St,and Charlton from the list of those to be boomed. The only two schemes left in category 2 are NW Relief 4,100m3/year and Savoy St, 8,500m3/year. From the Admiralaty chart the outlet from the NW Relief looks to be in the river. Holloway is a CSO spilling about 8,000m3/year into the Tideway well downstream of Tower Bridge so the river is large and should be able to absorb the impact. The two Jews Road CSOs have a combined discharge of 10,000m3/year with a spill duration of 7 hours/year. Thus, for an interim measure scheme, it is unlikely to warrant premanent booming them but rather a floating skimmer.

An outlet on the bed of the river makes booming more problematical with the high tidal currrents in the Thames. From the Admiralty Chart it would appear that Hammersmith, Heathwall, SW Relief, Lots Rd, Clapham, and Brixton have outlets on the bed of the river at or near low water and any boom might obstruct navigation to/from adjacent wharves or bridges. For the time being I have assumed that these could not be boomed.However it might be possible to alter the outlet in a way that enabled them to be boomed and this should be considered.

From the Admiralty chart it would also appear that Acton, Falcon bridge, and Greenwich also have outlet near low water. However it would appear that a boom here is unlikely to obstruct navigation. The question then is how quickly will the floatables rise to the surface. I have no information on this. I have had, therfore, to make a broad assumption. I have allowed for a rectangle 5m by 25m with the long side parrellel with the tidal flow.

Frogmore CSO discharge is into the River Wandle. I have allowed for an angled boom across the Wandle with a length of 50m.

Tideway indicative boom layout

Site name	CSO	Vol/year	Spill time	Against wall	Distance to chart	Min width m	In river
	no	k m3	hrs/year		datum m	bridges/river	dimensions
Acton	1	300	163				5m x 25m
W.Putney	5	35	119	Y	30m		
Putney bridge	6	70	111	Y	30m	40	
Frogmore	7	100	130	River Wandle		50	
Falcon Br P/S	9	780	291				5m x 25m
Ranalegh	14	300	153	Y	60m		
Western P/S	15	2,300	228	Y	30m		
Regent St	22	25	19	Y	zero		
Northmbrlnd	23	80	47	Y	zero		
Fleet (B bridge	27	570	83	Y	10m		50m
NE Relief	29	800	300	Y	40m		
Deptford	32	1,900	343	Y	40m		
Greenwich	33	4,000	240				5m x 25m
Shad P/S	28	100	69		50m		
Earl P/S	31	600	207		40m		
Total		11,960					

CSOs unlikely to be viable				
Hammersmith	4	2,300	690	
Heathwall	16	700	240	
Brixton	20	270	137	
Clapham	19	14	15	
Lots rd	10	1,200	410	Pier
	Total	4,484		

That would result in 15 CSO discharges into the Thames and Frogmore into the Wandle being boomed. The result is that, based on the TW Table of Performance, about 75% of the overflow that is classified by the EA as having an adverse environmental impact would be boomed, thus much restricting the amount of sewage debris that would enter the free flowing Thames. Should the EA wish to have the small category 2 CSOs boomed as well, this would be studied.

Approval

Approval from the PLA and the Environment Agency would be needed for the planning, implementation, and technical aspects of these measures. However those that I believe would obstruct of hinder navigation have not been included in these proposals which should mean easier discussions with the PLA.

Cost

Bolina booms have quoted a budget price of £1,246,000 for the supply, assemble and instlling the above instalation including piles and piling and including Lot's Road which has subsequently appeared to be a restriction on navigation.

They have made this offer subject to good acccess to set up pontoons into the Thames near the site and that each site is accessible by river from one to another. They have also excluded the cost of licences to work in the river or the provision of Health & Safety files. They have also made the quote subject to site survey for possible extras including wall seals, engineering design, ground investigation, UXO surveys, permits and permissions, planning aplications and licences plus possible delays due to inopportune weather or tidal conditions. Making a broad brush allowance of £3/4m for these elements and some contingencies would bring the boom cost to £2m.

The layout of the discharge at Mogden STW is unknown. Spills there will still occur on rare occassions, see the event of 28th May 2013. Subject to the site layout, it might be possible at low cost to provide booms there to collect any floating debris, thereby reducing even further the potential impact on the Tideway rowing and sailing boats and other features.

Retained sewage litter collection.

There are various methods of taking the sewage debris from within the boom. One method is a Trash Trap. This collects the trash in a metal mesh container which can be lifted out by a barge and boom arm and emptied into the hole of the collector vessel.

General Description

The 'Trash Trap' is constructed in galvanized steel with a metal mesh basket. The basket incorporates small holes to allow the movement of water to continue whilst collecting the floating debris. Typically 1t capacity but can be made to different sizes depending on application

The Trash Trap is a useful complimentary tool to OPEC's boom range.

In general booms can only be used as a temporary measure to act as a containment barrier against floating debris.

Another method if the retained sewage debris is small is to use a fish handling vacuum pump as supplied by Afak Techniek BV of Holland. This is normally used to move fish from one tank to another but should be suitable for collecting floating debris and water into a nearby barge.

Such systems would be operated from a powered work boat with a lifting arm and a cargo bay and a screened water discharge system, probably during the upper part of the tidal cycle to provide floating access to the boom structures.

I have no knowledge about the cost of such a powered work boat but assume that about £1m would be a reasonable budget.

In-river litter collection

The main in-river collection system would be skimmers which would collect floating litter, including that not sewage derived, thus reducing sewage litter and also improving the general appearance of the river.

Thames Water have two such vessels Clearwater 1 and Clearwater 2 which cost £4m and were commissioned in September 2007. They were designed to operate as far upstream as Kew and to navigate London's bridges. In operation, the screens sit 450mm deep below the river surface. Debris is directetd on to the screens by the inner hulls of the vessel, where the debris is picked up by mechanical screening equipment and conveyed to the rear of the vessel where it is drained ready for disposal into a refuse barge. In March 2008, after 6 months service Thames Water stated " *The vessels which have collected over 40 cubic metres of litter from the River Thames since September 2007 have greatly contributed to improving its environmental and aesthetic quality, ensuring it is fit for river users, and for this years Oxford and Cambridge boat race crews. To date, the skimmer vessels have been a real success story, enabling us to collect large volumes of litter, which overflows from the sewers during periods of heavy rain."*

Thus the overall aesthetic effect has been beneficial. Thus, with the Lee tunnel and the STW upgrades removing more than half the spill volume, and the potential addition of vortices, screens, and booms controlling some 80% of the remaining overflow, it is likely that no extra litter skimmers would be needed. Thus the craft would continue to operate but now concentrating in the areas where booms may not be able to be installed, likely to be Hammersmith, Lots Rd, and Heathwall.

There is also a problem of oils which form a film on boats. This could be car oil, cooking oil, or sewage derived. I understand that there are skimmers developed to collect oil and similar, so they should be provided. Provisionally I have assumed that four such oil skimmers would be required. However their effectivness should be established and, if need be, more provided.

Fig 3.1 – Typical Oil Skimmer

Approvals

Such a scheme of booms would need the approval of the Environment Agency and the PLA.

Implementation period

Such a scheme of booms and skimmers should be implementable within about two to three years.

Cost

The current two litter collectors cost £2m each so I have assumed that the smaller oil skimmers would cost a similar amount, say £2m.

7. Protection of the ecology.

Objective "*to limit ecological damage by complying with the dissolved oxygen standards specified in table 1*"

The Thames Tideway Tunnel and Treatment (TTTT) report, 2006 Vol 1 Objectives states "*since it is generally recognised that fish are the most sensitive indicator of ecological quality, the decision was taken to derive standards that are protective of relevant fish species.*" Thus to achieve sustainable fish the following standards were set.

Table 3 DO Standards for the Tideway

Dissolved Oxygen (mg/l)	Return Period (years)	Duration (tides)
4	1	29
3	3	3
2	5	1
1.5	10	1

These were arrived at following trials of the dissolved oxygen sensitivity of the various fish species in the fish suite, the most sensitive of which were salmon. The trial results are shown below.

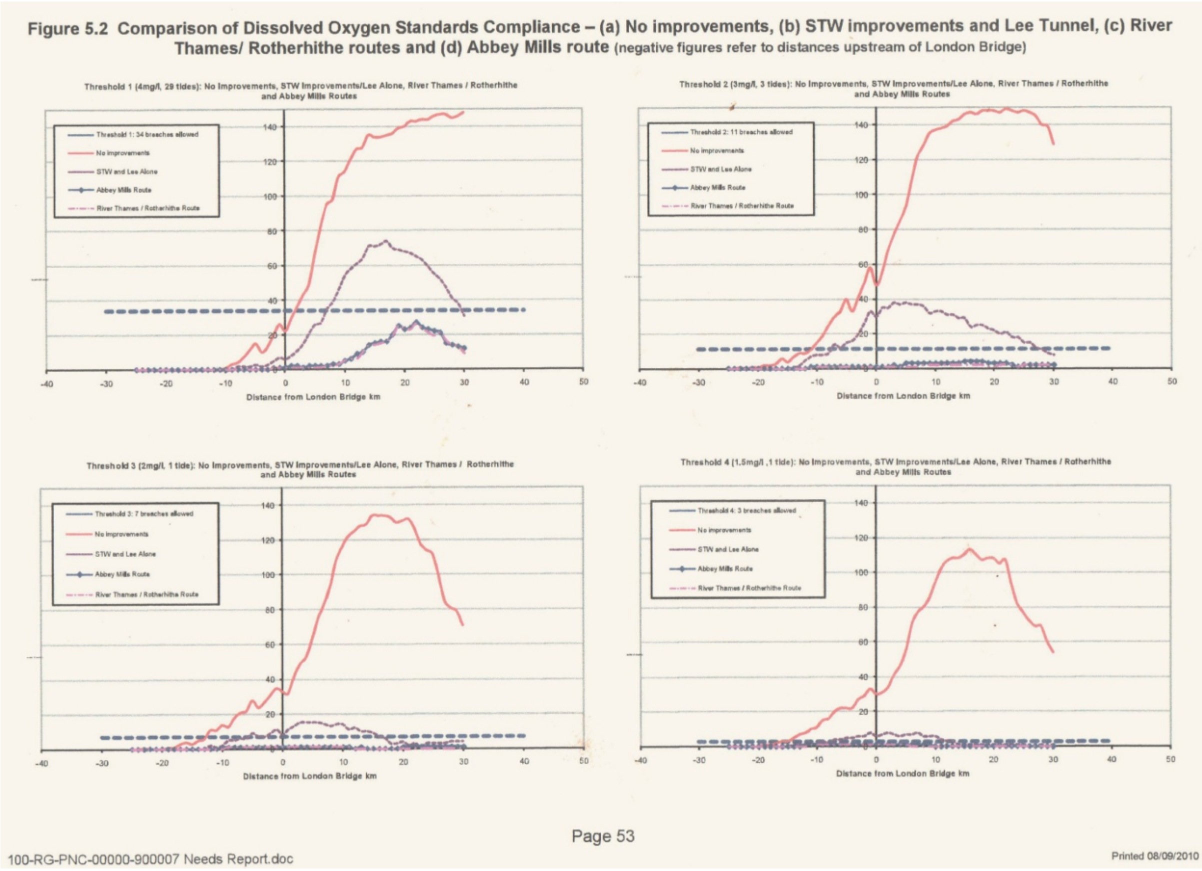
Since then WFD standards have been set which are similar. However "*The TTSS standards should apply as the proposed WFD standards are best suited to managing continuous discharges*." TTT vol 1 page 8.

It should be noted that 4mg/l one week standard "*was selected to ensure protection against chronic effects; these would include e.g. effects such as depression of growth and avoidance of hypoxic area.*" Tideway Fisheries Review Jacobs 2009 page 5. Thus the 4mg/l standard would not cause any fish mortality but could delay any salmon trying to migrate at the time of any failure of Threshold 1.

As can be seen from the histogram below the threshold 1, 4mg/l standard, is not driven by fish mortality but largely by avoidance, particularly by during their annual migration.

"*The major influence on the "chronic" standard of 4mg/l is the performance of the STWs, and the planned upgrading largely achieves this standard.*" TTT vol 1page 8.

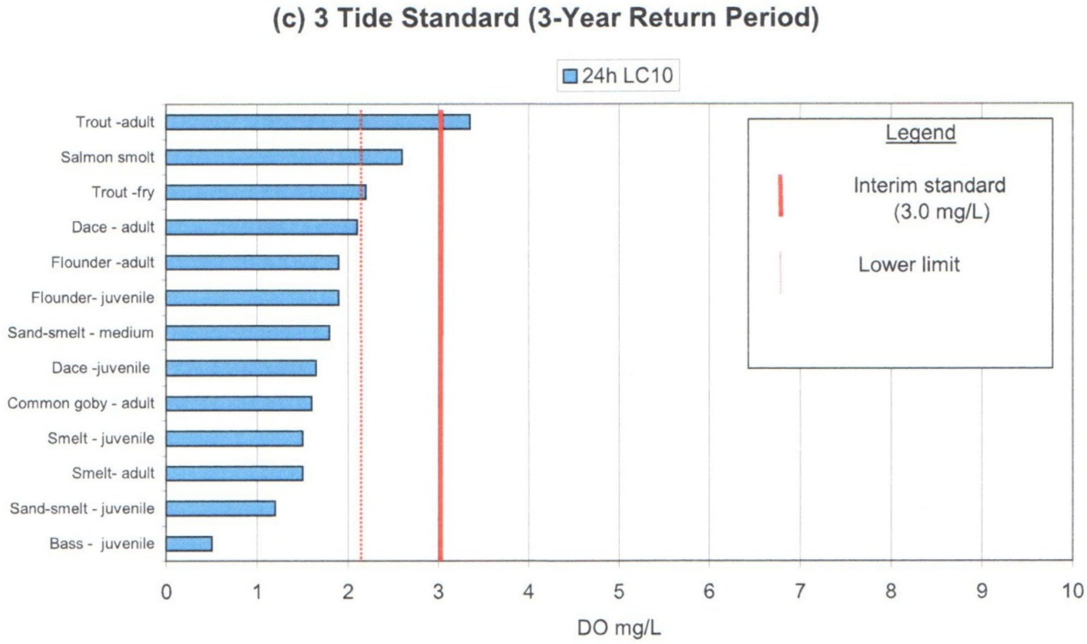
Post the Sewage treatment works upgrades and the Lee tunnel the dissolved oxygen failures, mauve line, are much reduced but still exist, as shown in the plot below.



Threshold 1, 4mg/l, is only there in that salmon tend to avoid such conditions. It is not there to protect against any fish mortality. Looking at the plots of the Threshold 3 and 4 criteria, the lower two graphs, then one would **currently** expect regular extensive fish kills in the river downstream of London Bridge. I have been unable to identify such reports. There have been reports of considerable fish kills in the Chiswick area on 3rd August 2004 and in 2011. Those fish kills were caused by Mogden STW effluent, probably activated sludge carry over and that has now been dealt with. Thus one could speculate that the model may well over predict the impact on fish or that fish find ways to avoid such polluted areas. There is some evidence to support that view as after the 2004 event fish species are reported by Dr Turnpenny to have moved downstream.

Actual objective

It is obvious that the real objective is *"to limit ecological damage by ensuring that fish species are sustainable."* Thus, as the study progressed, the objective switched to ensuring fish species were sustainable using a Fish Risk Model.



Prior to the TTSSG study there had generally been a reasonable return of salmon to the river, about 100 to 300 a year between 1980 and 1995, hence salmon were included in the suite of fish considered. The numbers in the table were adopted as *"the most sensitive species "* salmon *" showing significant mortality at 3mg/l and behavioural impacts at less than 4 mg/l."*TTT Vol1 December 2006 page 7. However if Threshold 1, 4mg/l once a year is purely to reduce behavioural impact on salmon, then is it not a weak driver for a major project costing some £4billion ?

Salmon post 1996

However post 1996 the salmon numbers crashed despite continued stocking by the Environment Agency. The average in recent years for those in the Molesey Weir trap has been less than 10/year.

Ability of salmon to reach the spawning grounds

The analysis of the weirs on the River Thames shows that many are not conducive to salmon migration and the percentage entering the river that would make it to the main spawning grounds in the River Kennet is less than 10%. The report of the Regional Fisheries, Ecology, and recreational Advisory Committee in 2010 states about the Thames weirs *"Under these efficiency rates, for every 100 salmon that make it into freshwater, only nine will reach and successfully swim over Blakes weir, the first on the river Kennet."*

The Environment Agency investigated the habitat for spawning in the Kennet and Lambourn. *" There appears to be little "text-book" spawning habitat and sedimentation is clearly an issue in many areas." " The results suggest that the Kennet system provided marginally suitable Atlantic salmon and brown trout spawning habitat ."* [1]Having only marginal spawning habitat is clearly a serious disadvantage to re-establishing a naturally sustainable salmon stock. The propellers of the boats on the Kennet & Avon Canal also stir up sediment which adversely affects habitat and spawning.

Although many thousands of salmon fry have been released into the Thames in recent years, there is no record of any salmon having returned and successfully spawned in the catchment.

---

[1] RFERAC September 2010 page 6.

Medium term salmon sustainability

Thus there are effectively almost no salmon in the Tideway. The EA state "...*it is very unlikely that a self sustaining salmon population is viable in the Thames over the short to medium term (ie next ten years)*." The EA have now "*halted current annual rearing and stocking of juvenile salmon.*"

Long term salmon sustainability

"*Species such as salmon are already close to their physiological limits due to the interaction between temperature and oxygen.*" TTT vol 1 page 8.

Post 2023 adverse temperature conditions would affect any returning salmon. According to Turnpenny and Liney,2006 the lethal temperature for salmonids is 27.8C but the Freshwater Fish Directive says for salmonids the temperature should not exceed 21,5C. Solomon has shown that salmon did not enter the Avon River when the temperature was above 21C. In the Thames "*Migration is under-represented at temperatures above about 22.5 C in July, 22 C in August, and 19 C in September.*" Solomon 2011. Turnpenny et al 6-14 says "*Summer temperatures in the ...Thames can reach 23-24 C.* " With climate change temperatures are likely to rise 2 to 3C in the long term.

In March 2010 the Atlantic Salmon Trust held a conference on "Managing River Flows for Salmonids: Evidence-based Practice. This states on page 74 concerning the climate change effect on the freshwater environment "*An increase in the water temperature will accelerate embryonic and alevin development during the winter and lead to earlier emergence of fry from the gravels. Survival of eggs and alevins in upland rivers could be reduced should expected higher winter rainfall generate more frequent river spates resulting in wash-out of the embryos...Reduced flows and increased river/estuary temperatures will inhibit and delay the movement of adult spawning salmon into freshwater environment. Increased temperatures will reduce the amount of suitable thermal habitat for returning salmon. Reproductive success and fecundity may be reduced at higher water temperatures... There is also reason to expect northward movement of the thermal niche of anadromous salmonids with decreased production and* ***population extinction in the southern part of the distribution areas.***" My emboldening.

Regarding the marine environment it states "*A mis-match in prey availability during entry into the marine environment may reduce post-smolt survival and growth. Changes in sea surface temperatures may also reduce the amount of suitable thermal habitat required for suitable growth and development of salmon in the sea..*"

In October 2011 a Salmon Summit was held at La Rochelle to discuss the latest scientific findings of the SALSEA project. Dr Kevin Friedland gave a paper on behalf of the ICES North Atlantic Salmon Working group, entitled "How climate and post-smolt growth control marine mortality in Atlantic salmon: the potential effects of a changing climate on the marine survival of Atlantic salmon."

Dr Friedland concluded "*Ocean thermal conditions in key post-smolt nursery areas are expected to continue to change,* ***making marine survival unsustainable*** *for segments of the stock complexes from both north America and Europe*." My emboldening.

To my question by email asking if the stocks referred to included southern England, Dr Friedland replied on 16th December 2011 "*The analysis was for southern tier European Stocks , so that would include stocks from England.*"

"*With predicted continuing background temperature rises associated with climate change, it is not clear that there is any real chance of salmon runs improving in the future.*" Tideway Fisheries Review

Sustainable mortality

In the 2010 Tideway Fisheries Review by Dr Turnpenny it was stated that there were sustainable mortality rates for different species varying from 10% mortality up to 30% mortality for salmon, bass and 20% for dace. This assumes that fish with more reproductive year classes are able to sustain a higher mortality in a single year.

However it also assumes that the fish species are resident in the Tideway. That is so for most fish species. However migrant species such as salmon, are only in the Tideway for a limited period, spending much of their life a sea, migrating up through the Tideway and then spending the last part of their life in freshwater to spawn.

Other sensitive species

The dissolved oxygen standards could still be appropriate if other fish species took the place of salmon. Sea trout are similar to salmon but there are also few of them. Apart from 2009 the average number entering the Thames over the previous decades has been about 15. The TTSS considered this too small a number to be included as a fish of conservation interest.

Lamprey and eel can tolerate low dissolved oxygen conditions. Sturgeon are being introduced to the Gironde in south west France but it is likely to be many decades if not a century before temperature and other conditions in the Thames would be suitable for them. Twaite shad are rare visitors, and are reported to be more tolerant of low dissolved oxygen content than salmon. Thus no alternative DO sensitive fish species was identified.

Fish risk model

Dr Turnpenny developed a fish risk model.

Table 3-9 ***Expected fish mortalities with Thames Tunnel (Solution 1c) and the Lee Tunnel (TTSS and TTTT Summary Report, December 2006) in place, at the proposed Interim Standard levels of 1.5, 2.0, 3.0 and 4.0 mg DO L^{-1}, from the Tideway Fish Risk Model. Solution 1c includes AMP4 STW upgrades.***

Solution 1c with AMP4 + Lee Tunnel Solution - 2020

Species	Lifestage	Standard 4 1.5 mg L^{-1} (6h in 10y)			Standard 3 2.0 mg L^{-1} (6h in 5y)			Standard 2 3.0 mg L^{-1} (18h in 3y)			Standard 1 4.0 mg L^{-1} (1 wk per y)			No. of >10% PL Effect @1.5mgL^{-1}	No. of Reproductive Age classes	Sustainable Mortality %*
		Mortality Rate	Risk Factor	**Population Level Effect**	Mortality Rate	Risk Factor	**Population Level Effect**	Mortality Rate	Risk Factor	**Population Level Effect**	Mortality Rate	Risk Factor	**Population Level Effect**			
Salmon	Smolt	100%	0.01	**<10%**	100.0%	0.02	**<10%**	<10%	0.07	**<10%**	<10%	0.09	**<10%**	3	3	30
	Adult	100%	0.10	**10.3%**	100.0%	0.21	**20.7%**	90.0%	0.69	**61.7%**	<10%	1.00	**<10%**			
Bass	Young Fry	10%	0.05	**<10%**	<10%	0.08	**<10%**	<10%	0.16	**<10%**	<10%	0.15	**<10%**	0	10	30
	Juvenile	10%	0.10	**<10%**	<10%	0.20	**<10%**	<10%	0.67	**<10%**	<10%	1.00	**<10%**			
Sand smelt	Egg/fry		0.03	**<10%**		0.08			0.24			0.12		0	2	10
	Juvenile	10%	0.10	**<10%**	<10%	0.21	**<10%**	<10%	0.71	**<10%**	<10%	1.00	**<10%**			
	Adult	10%	0.10	**<10%**	<10%	0.21	**<10%**	<10%	0.70	**<10%**	<10%	1.00	**<10%**			
Dace	Egg/fry	100%	0.04	**<10%**	85.0%	0.05	**<10%**	<10%	0.12	**<10%**	<10%	0.10	**<10%**	0	4	20
	Juvenile	30%	0.14	**<10%**	<10%	0.25	**<10%**	<10%	0.67	**<10%**	<10%	0.35	**<10%**			
	Adult	10%	0.13	**<10%**	<10%	0.24	**<10%**	<10%	0.67	**<10%**	<10%	0.33	**<10%**			
Smelt	Egg/fry		0.04	**<10%**		0.09			0.15			0.12		0	7	10
	Juvenile	40%	0.10	**<10%**	40.0%	0.21	**<10%**	<10%	0.71	**<10%**	<10%	1.00	**<10%**			
	Adult	40%	0.07	**<10%**	40.0%	0.17	**<10%**	<10%	0.68	**<10%**	<10%	1.00	**<10%**			
Flounder	Egg/fry		0.00	**<10%**		0.00			0.00			0.00		0	0	30
	Juvenile	50%	0.10	**<10%**	15.0%	0.21	**<10%**	<10%	0.70	**<10%**	<10%	1.00	**<10%**			
	Adult	40%	0.08	**<10%**	15.0%	0.19	**<10%**	<10%	0.72	**<10%**	<10%	1.00	**<10%**			
Common goby	Egg/fry	0%	0.00	**<10%**	<10%	0.00	**<10%**	<10%	0.00	**<10%**	<10%	0.00	**<10%**	0	2	10
	Juvenile	40%	0.10	**<10%**	<10%	0.21	**<10%**	<10%	0.71	**<10%**	<10%	1.00	**<10%**			
	Adult	40%	0.00	**<10%**	<10%	0.00	**<10%**	<10%	0.00	**<10%**	<10%	0.00	**<10%**			

Total PL Effects occurrences >10%	3
Total PL Effects 'not sustainable'	1

The TFR states on page 28 that once the STW upgrades and the lee tunnel are operational, "*It is seen from Table 3-4 that only a single "not sustainable" case results and two marginally sustainability.*"

The marginally sustainable are smelt juvenile and adult which at the 2mg/l standard have a population effect of 8% compared to an allowable level of 10%, ie marginal but not a failure.

The one failure is salmon at the 3mg/l where a 90% mortality is assumed with a risk factor of 69%. As I understand it this implies that 69% of the whole salmon stock are resident in the Tideway at the time of the event. First salmon return to the river after one or two seasons in the North Atlantic. Below is the frequency of trap catches at Molesey weir.

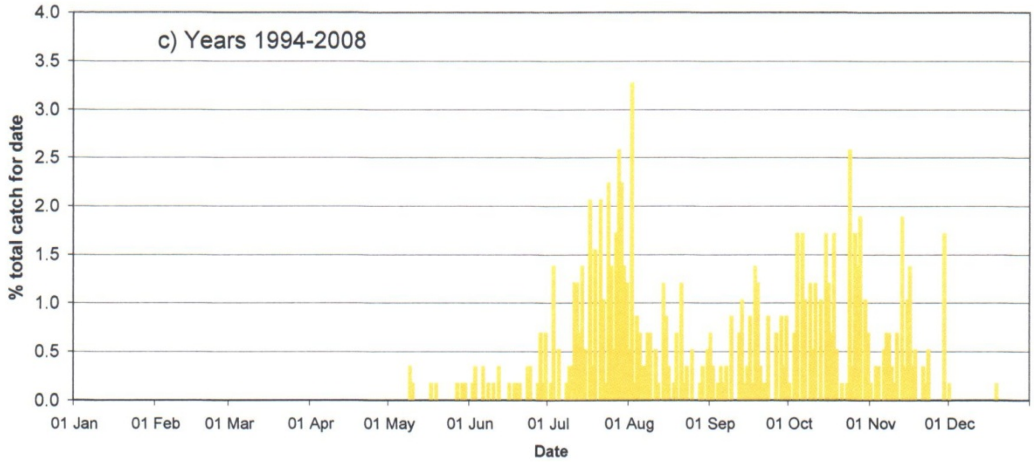


Figure 3.1. Seasonal pattern of trap catches at Molesey, totals for date. a) 1986-1996, b) 1986-1993, and c) 1994-2008.

Salmon are migrants over a period of from June to November, see Solomon page 15 above. It should not normally take a salmon more than a few days during this period to swim the length at risk. Some salmon at certain times of the year can be put off from traversing due to temperature or dissolved oxygen conditions. However the fish trials showed salmonids have a good ability to avoid hypoxic zones. Further the percentage mortality allowed for salmon is 30%, Tideway Fisheries Review 2009 page 23.

Considering this one number, 69%, then this must assume all the salmon would be resident in the Tideway during the period when spills are occurring. This is clearly in error as slamon migrate through the Tideway.

The only comparison figure is that for the east /west tunnel. This is a tunnel that goes less than half the distance of the main tunnel. Crudely, this reduces the base spill volume from about 18Mm3/year to about 13Mm3/year. Thus one might expect the percentage of salmon affected to be only a small amount larger than for the East/ West tunnel. The proportion affected by the East West tunnel is 16%. The number of 69% does seem to be a mistake. Were that to be rectified then, once the STW upgrades and Lee tunnel were completed, then the fish species would meet the Fish Risk Model criteria and thus be sustainable, and meet the ecological objective.

Thus the current works would meet the TTSS ecological objective of achieving sustainable ecology.

Further dissolved oxygen improvement.

Objective

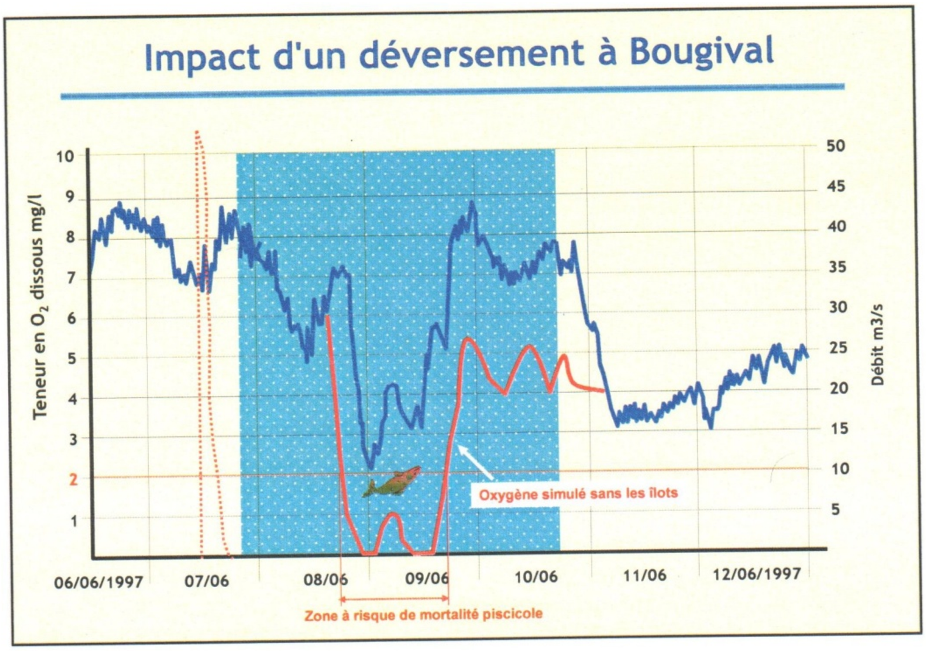
The objective of the Combined Interim Measures is, within a limited budget and in a short time, to improve the dissolved oxygen conditions in the river and reduce the impact on fish. One way that this can be done is by injecting air or oxygen into the river through fine grained diffusers.

Evidence from elsewhere

The Cardiff Harbour coarse diffuser system, see Appendix C is designed to inject air into the water column to turn the water over rather than to inject air into the water body itself. This is done by having on land air compressors pumping air through pipes laid on the bed of the harbour connected to coarse diffusers. This has worked satisfactorily for several years. Thus this demonstrates that an air injection system using on land air compressors linked to pipes and diffusers can be put in place on the bed of the harbour and can operate satisfactorily on a large scale.

In the upper Tideway, a land based oxygen injection system has been used to raise the dissolved oxygen content in the Chiswick/Barnes stretch of the upper Tideway to reduce dissolved oxygen sags emanating from the historic Mogden STW. I believe this is actually based on the Mogden effluent outfall. It has been utilised in the past to reduce the impact of Mogden storm tank discharges into the Upper Tideway. Thus it has shown that such a system can work.

In Paris the French have used a system of pipes and diffusers to inject oxygen to raise the dissolved oxygen content of the River Seine, see Appendix B for details. This has been used to raise the dissolved oxygen content of the Seine by about 2 mg/l, see image below showing the modelled dissolved oxygen content of the river following a storm in red and the actual conditions achieved in blue.



This shows the substantial benefit that occurred. Thames Water has stated that the Paris system only provides an island of raised dissolved oxygen. However, since its introduction, salmon are reported to be now returning to the River Seine. Thus such a system does appear to meet the objective of significantly improving environmental conditions.

Dryden air/oxygen injection system.

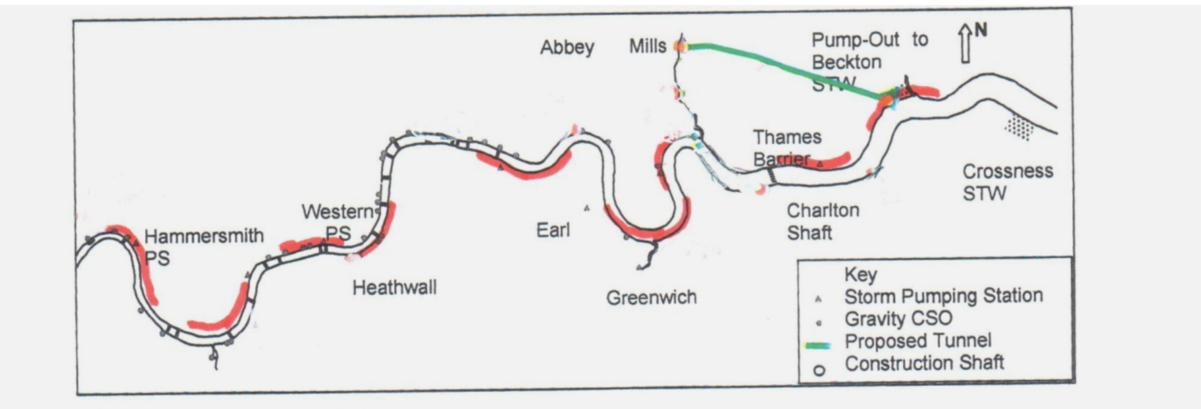
Dryden Aqua make fine bubble diffusers. Their web site page headed lake & pond aeration, states *"Dryden Aqua manufacture a very fine bubble diffuser that has its own internal ballast. The diffusers are semi flexible tube type diffusers that have the best of ceramic diffusers and membrane diffusers but without the disadvantages...Air is passed through the diffusers and the fine diffusion cloud of air passes through the water... The aeration system will dissolve oxygen into the water, one diffuser code 6.2.10 diffusing 10cum/hr of air will add at least 25 kg oxygen to the water per day..."*

System

The diffusers proposed would not be the coarse discs used in Cardiff harbour and elsewhere to turn bodies of water over, but fine bubble air diffusers designed to increase the oxygen content of the water body. The large surface area of the fine bubbles aids oxygen transfer through the bubble water interface, but also because more water is moved there is also an increased transfer between the surface of the water and the air. Each diffuser is designed to input 1kg of oxygen from the air to the water each hour. More details are given about the system in Appendix D.

Locations

Places where Thames Water own, or have access to, land such as at existing pumping stations, or land obtained for the tunnel construction sites, could be appropriate for on shore air blower or oxygen generation systems. Possible locations were identified as at the pumping stations at Hammersmith PS, Carnwath Road tunnel site, Falconbrook PS, Western PS, Heathwall PS, Shad PS, Chambers wharf, Earl PS , Greenwich PS, Isle of Dogs PS, Woolwich PS , and Becton STW. See plan below for the provisional sitting of the diffuser installations and the lengths covered.



Benefits for fish

Dryden Aqua comment by email" *We went through a similar exercise for the Manchester ship canal, which is on the same scale... The diffusers will create a path for the migratory fish will follow. Also if the aeration system does not maintain a complete path, each air diffuser can act as a life support* *island of oxygen to support the fish. One diffuser can support around 1 tonne of fish, and will provide a safe zone during period of heavy pollution or during the DO drop that will occur at night."*

Monitoring

A near real time monitoring system would be provided, similar to that at Cardiff Harbour, to measure the dissolved oxygen content in the river every 15 minutes and to give prompt warning of any issues and unusual dissolved oxygen conditions. There are already several monitoring points in the river but it may be necessary to provide a few more.

Floating bubblers

Should a dissolved oxygen sag become an issue then the monitoring system would enable the two existing mobile bubblers to be despatched promptly. (See the front cover for a picture of one of the bubblers.) However this would only be a standby measure and not part of the routine measures to raise dissolved oxygen levels in the river.

Thames Water , in their Stage 2 consultation in the note on options page 3 state "*We currently use "mobile" boats to reduce the impact of untreated sewage overflowing to the River Thames...so our bubbler boats inject oxygen into the river helping fish survive sewage discharges...There are severe limitataions as to where these boats can go due to tides and bridge heights."* That may be true at present when the most damaging condition is an overflow of final tank effluent from Mogden STW which can then be taken upstream by the tide.

However the Needs case modelling figure 5.2 , see Appendix A of this document, shows that, with the Mogden STW improvements and the Lee tunnel, the base case, there would be no half tide failure further upstream than 8kms above London Bridge. With a half tide flow of another 7km, there would be no failure of the standard further upstream than 15kms. This is downstream of Hammersmith Bridge. Thus Hammersmith Bridge would generally be the upstream limit of operation during the interim period.

Admiralty chart 3319 gives the tidal depths upstram of Hammersmith Bridge can drop as low as 0.7m on a spring tide and there is seldom 2m charted depth. Downstream of Hammersmith Bridge the water depth is appreciably greater, charted depth generally being about 2m. The chart also gives bridge clearances at Highest Astronomical Tide (HAT), the highest spring tide expected in any one year and lasting only an hour or so. The chart gives a minimum clearance at HAT of 4.5m (Albert Bridge). However Hammersmith Bridge (south) is only 3.1m clearance at HAT. Studying the pictures of the bubblers, see front cover of this report, it would appear that the bubblers are unlikely to be significantly constained when operating downstream of Hammersmith Bridge, as they would during the interim period.

Cost

The cost of the diffuser system is estimated by Dryden Aqua at some £10m. In addition I consider it appropriate to allow for a contingency element, and the enhanced monitoring system. Thus I consider an appropriate budget cost for this system to be about £12m.

Upper Tideway

In the unlikely event that a serious spill occurs from Mogden STW such that dissolved osygen conditions in the upper Tideway were threatened, then the existing oxygen injection system could be used.

Conclusion

Fish were assumed to be the best indicator of ecological health.

Fish can withstand a certain mortality and still be sustianable. The post STW upgade and Lee tunnel fish risk model, once corrected for one anomoly, would show that the fish species would be sustainable.

The suite of fish on which the dissolved oxygen standards were based has as its most senssitive fish species salmon. However, since 1996 salmon numbers have crashed. They are no longer considered sustainable in the short to medium term and because of temperature and marine conditions are not likely to survive in the long term. Thus there must be great doubt as to the sense in including them in the fish suite. Should that be so then the standards would relax to the next most sensitive fish species, in the suite chosen dace.

To raise the dissolved oxygen further, a system based on injecting air or oxygen through fine grained diffusers to raise the dissolved oxygen content could not be developed and work satisfactorily to raise the dissolved oxygen sag and alleviate the environmental impact further.

Considering the potential benefit in reducing the environmental impact, it does seem t worthwhile revising the fish risk model, considering the reason for including salmon in the fish suite, and modelling the provision of air/oxygen injection system. At the moment the EA is refusing to do this, despite a requirement in the River Basin Management Plans guidelines to assess the benefit of any combination of measures.

8. Recreation and health protection.

Objective set by the TTSSG *"To help protect river users by substantially reducing the number of "elevated health risk " days following CSO discharges."* The TTT in 2006 changed this to "*To help protect river users by substantially reducing the elevated health risk due to intermittent sewage discharges."*

The HPA Thames Recreational Users Study 2007 page 48 "*As a background level the 95% concentrations of indicator organisms in the upper tideway permanently remain above the WHO microbiological standards for recreational waters and thus represent a potential health risk to recreational users."* Thus neither the tunnel nor other similar measures can change this situation. However "*there appears to be evidence of an improvement in water quality as you move downstream from Kew to Putney*". Thus current CSO spills appear to have limited microbiological effect.

Bathing.

On 1st July 2012 the Port of London Authority enacted *"a new byelaw to control swimming in the busiest part of the Thames between Putney Bridge and Crossness by making it necessary to get the prior consent from the harbour master." "Here you encounter a fast running tide, bridges and eddies which can drag a person underwater in a trice. And there are also passenger vessels which* carry *over six million people a year and 1,000 tonne barges carrying freight."*

Putney to Crossness is almost all the length of the Tideway affected by CSOs.

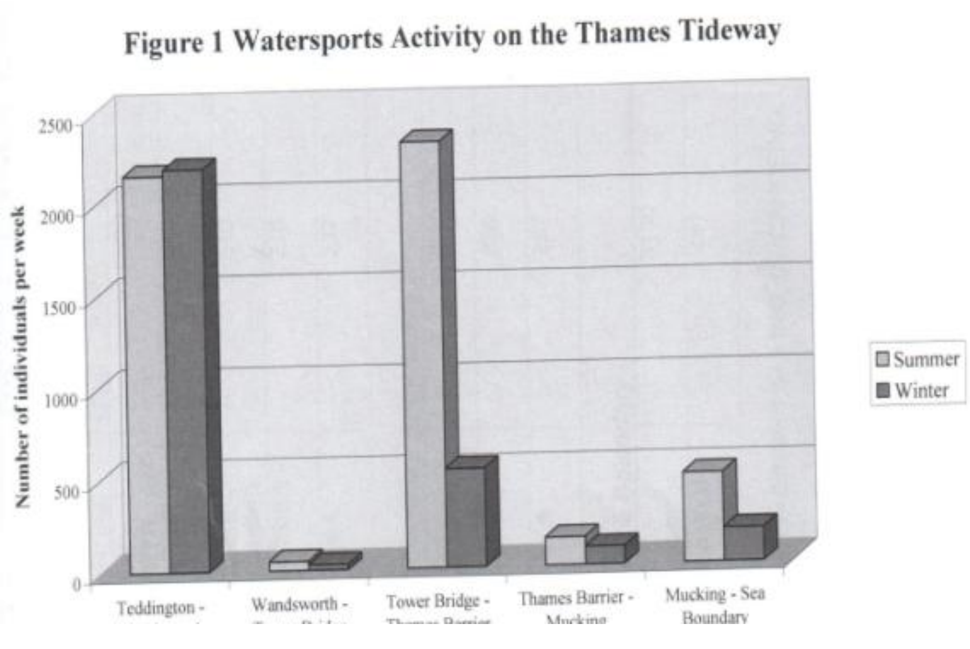
There is a quote about a swimmer having to have "*the event carefully planned and managed with safety boats in attendance at all times."* Presumably the event would be managed to be several days after a significant CSO spill so water quality conditions would be improved.

In any case none of the Tideway is designated as a bathing water under the Bathing Water Directive and so there is no statutory designation to be met. Thus the micro-biological standards are not directly relevant.

Identification of other recreation

The number of recreationalists was surveyed and the numbers reported in the document "Recreational Use of the Thames estuary."

The numbers found in each reach is shown on the histogram below.



This shows that the two most important recreational areas are the Hammersmith area, mostly rowers, and those in the general area of the London Docks. The study stated, page 53 that *"recreational users of the Thames tideway are predominantly rowers, canoeists, sailors and anglers and include very few bathers*."

Rowers in the Hammersmith area.

The Health Protection Agency (HPA) report The Thames Recreational Users Study 2007, states on page 1 "*there is little evidence to link the presence of high levels of bacterial indicators of faecal pollution to the level of risk to human health."*

page 48 "*The 95 percentile of indicator organisms in the upper tideway permanently remain above the WHO microbiological standards for recreational water and this represents a potential health risk to recreational users*." Thus there is a background health risk in the Tideway irrespective of the CSOs.

However the "*WHO guidance is only aimed at bathers*" total immersion and risk of ingestion " *and as such is not necessarily indictors of risk to other recreational use such as rowers, sailing etc..."* HPA page 8.

"*There is evidence to suggest that the influence of secondary treated effluent from Mogden sewage treatment works is as great as that of the less frequent but common CSO discharges."* HPA 2007 page 54.

Since then improvements are being made to Mogden STW including much increasing the flow to full treatment, improving the normal discharge quality, and greatly reducing the storm overflows. Following the storm of 2011 which killed many fish in the Chiswick area, Thames said " *I do need to assure you that once the extension is completed in March 2013 the works will be able to handle a similar situation without even using its storm tanks, let alone discharging to the river."*

The key information from a major study of health risks to recreational users in the upper part of the Thames (upstream from Putney Bridge) is summarised in the TW 2010 Needs report:

"*An assessment of health impacts upon recreational users of the River Thames was conducted and reported by the Health Protection Agency in 2007. This report, which quoted an EA estimate of between 3,000 and 5,000 recreational users of the tidal Thames... While there was evidence of an elevated health risk (gastric infection) to recreational users in the upper Tideway two to four days after a CSO spill event, the rate of gastric infection among recreational users was very low (12.8/1000/year) compared to the general population (190/1000/year). This may be due to the relative good health and fitness of recreational users, a greater awareness of hygiene and health and safety issues, and a developed immune response to infection from repeated exposure, which results in asymptomatic infection*."

The fact that gastric infection rates among recreational users in the upper Tideway are less than one tenth of the incidence level in the population as a whole, is a fair indication that the Thames health baseline, and the possible impact of the intervention, are not significant on a national scale in terms of the potential health impact.

In any case the improvements at the Mogden STW will significantly improve the water quality in the Chiswick/ Hammersmith/Putney area, one of the main areas for rowers.

The HPA study and the PLA announcement were done after the EA assessment. Thus the Environment Agency assessment should be reconsidered, taking on board the evidence from the HPA study and the PLA restriction. It is likely that this would then much reduce the assessed health impact from the upper Tideway CSOs.

Predictive spill timing

The HPA study states on page 58 that "*Predictive models of microbiological parameters... indicate that levels of these indicators can be predicted with reasonable accuracy given timely information about discharge events.*" I understand that since then Thames water has implemented a monitoring system at each overflow so it is likely that such information could be provided, especially if linked to the water quality model. *"The simplest and possibly most cost effective manner of making this information available to the recreational public would be through existing internet facilities." " A simple "traffic light" system could be used."* Thus the interim measures could include the provision of such information. It should be noted that the latest revision of the Bathing Water Directive allows predictive warnings of poor water quality to bathers and rather more events of water quality failure, reflecting the recognition that delivering high quality bathing waters during storm events is not always economically realistic.

Since the Mogden STW improvements have been commissioned I have seen notification to the rowing community as to when the Mogden system is likely to overflow. Thus notification of a spill is already operated by Thames Water.

Thus a further interim measure, in addition to the upgrading of Mogden STW, could be the development of the microbiological model and the running of it to provide the traffic light system. A budget cost estimate for this could be about £100,000, within the accuracy of the overall cost estimates.

Recreation in the London Docks

From the histogram above one can see that the other major area of recreational use is in the Tower Bridge to Thames Barrier reach. Looking at the details in the Recreational Use of the Thames Estuary report these are very largely dinghy sailors and water skiers in the London Docks. These are discrete non-tidal bodies of water where the only contact with the River Thames water is the abstraction of a small amount of waterto top up the docks following loss from evaporation or leakage.

Assuming that the evaporation per year is about 600mm and that this occurs over a period of 200 days then the evaporation rate would be about 3mm/day. Allow a similar amount for seepage making a total of 6mm/day. Taking the areas of the Royal Docks as about 84ha, then the top up rate would be about 5Ml/d. A similar calculation for the West India Docks gives about 2Ml/d.

Whilst Thames Water is not responsible for the quality of the water in the docks, by their STW discharges and CSO spills, they do influence its water quality. Should the water quality in the docks used for recreation not be sufficient, and the quality of the Tideway water be an issue, then, as part of the interim scheme it is suggested that water treatment be provided to the top up water. These would have to cope with significant turbidity at times. One method that could be considered would be some form of moving bed sand filter to remove solids and disinfection using hypochlorite. Such a scheme might well also provide some long term benefit and could continue as an element of the permanent scheme.

Cost estimate.

A broad brush estimate of cost for the traffic light scheme and the two small water treatment plants is, I am advised, about £2million for the Royal Docks and about £1m for the West India Docks, a total of about £3 million. Such a system should be implementable within two years.

10. Comparison with the TTSS objectives.

The objective of the Urban Waste Water Treatment Directive is *"to protect the environment from the adverse effects of ...waste water discharges."* There are no specific numeric criteria in the UWWTD. The TTSS over a period of 5 years considered all the constraints on the Tideway. The TTSS decided it would be much more appropriate to come up with specific objectives for the Thames Tideway. The broad aspirational aim was "*To reduce the impact of intermittent discharges and to further improve water quality in the Thames Tideway to benefit the ecosystem and facilitate use and enjoyment of the river"*, see TTSS Summary report 2005.

Further, the TTSS came up with three specific objectives. These are considered below with the summary of whether the current works plus the so-called Combined Interim Measures could meet the objectives.

General methods of reducing CSO spills

The Lee tunnel will reduce the average annual spill from 39 Mm3 to some 18Mm3. The upgrades to the sewage treatment works will also improve the quality of the discharged treated effluent as well as reduce the storm overflows, particularly from Mogden STW into the upper Tideway.

The analysis of spill volume by Thames Water assumes sewer flows increasing in line with population increase. Their own dWRMP shows a decline in water delivered and in leakage, thus normal sewer flows will decrease not increase, thus reducing spills somewhat.

The normal flow in the sewers would be reduced by reducing water delivered to households by further demand management including metering a greater percentage of households, by reducing leakage and by diverting parts of the sewerage system to other STWs. This would provide more capacity in the interceptors for storm flows.

The flow from storms would be reduced by utilising widespread SuDs and blue-green infrastructure to reduce storm runoff into the sewerage system.

The flows spilling from the sewerage system would be reduced by the elimination of bottlenecks, the provision of detention tanks, and by real time control of the sewer system, and by vortices to concentrate debris in the pass forward flow.

Aesthetic impact

Objective "*To reduce the frequency of those discharges that cause significant aesthetic pollution, or to limit the pollution caused, to the point where they cease to have a significant adverse impact."*

Currently sewage debris is only 10% of total litter. Jacobs Babtie concluded that what sewage litter there is appears to be invisible much of the time and concluded that any impact of the Tideway options, ie tunnel, on property prices is likely to be minor.

The EA has confirmed that the number of formal complaints regarding sewage debris is relatively few.

Since the TTSS report was written two litter collection vessels have been constructed and they have been successful in reducing the aesthetic impact further.

In addition to the methods above, the aesthetic impact would be reduced further by the provision of booms around most of the polluting CSOs and vessels to collect and remove the debris retained. More litter collection vessels would be provided, focusing on those CSO where it may not be feasible to provide booms.

It would be expected that these measures would meet the TTSS objective of "*ceasing to have a significant adverse impact."*

Ecological Objective

Objective "*to limit ecological damage by complying with the dissolved oxygen standards specified in table 1"*

"*since it is generally recognised that fish are the most sensitive indicator of ecological quality, the decision was taken to derive standards that are protective of relevant fish species."*

Fish can withstand a certain amount of mortality and still be sustainable. A fish risk model was developed by Dr Turnpenny for the situation post STW upgrade and Lee tunnel construction. There is only one failure of sustainability shown. This is based on a 69% risk for salmon. However salmon are a migratory species only spending a limited time in the Tideway. Once this error is adjusted then all the representative fish species would become sustainable.

At the start of the TTSS study there had generally been good salmon returns. As can be seen from the bar charts of fish sensitivity, the numbers in Table 1 are based on surrogate salmon. Over the last decade the average number of salmon caught in the salmon nets at Molesey Weir is less than 10 and sea trout have been not dissimilar. In addition the EA have stated that salmon are not sustainable in the short to medium term. In the long term Fredericks model shows that salmon would not be sustainable in the Thames both for river temperature reasons and marine conditions. Whilst there could be another fish species with similar sensitivity as salmon/sea trout, none have been identified. Thus it is challengeable that the use of surrogate salmon to set the numbers in Table 1 is unnecessarily stringent.

The ecological objective is really to achieve fish sustainability, thus, with the current works, the Tideway would meet the ecological objective.

Thus, taking account of the benefit of the current works, fish would be sustainable. Further, the Interim Measures of injecting air/oxygen into the Tideway could be implemented as well, thus enhancing dissolved oxygen levels as required.

Health risk objective

Objective "To help protect river users by substantially reducing the number of "elevated health risk " days following CSO discharges."

Since the objective was set by the TTSS, the PLA has banned swimming between Putney and Crossness, virtually all the Tideway. In any case the Tideway is not designated as a bathing water so is not subject to the Bathing Water Directive.

The Recreational Users study has shown that the users are primarily rowers in the upper Tideway and sailors, particularly beginners) in some of the London docks.

The HPA has done a study of the health of the rowers. This found that, prior to the improvements at Mogden STW, the rowers suffered from gastric infection rate of about 13/1,000/year compared with the general population rate of 190/1,000/year. Thus rowers do not appear to have "elevated health risks".

The HPA analysis considered that "*the influence of Mogden STW effluent is as great as that of CSO discharges*". As part of the post TTSS work, Mogden STW effluent quality has been much improved and its overflows very much reduced, thus much reducing its impact.

Booms would be put round most of the CSOs, the existing litter collectors retained and new oil skimmers provided to collect and remove floatables and oily deposits.

The Interim Measures include a traffic light system to warn rowers and other users of potential CSO spills into the river. In addition it is proposed to install water treatment on the river water used to top up the London Docks where dinghy sailing and water skiing occur.

Thus it is likely that, with all these measures, the health objective of substantially reducing elevated health risk would be met.

Summary

Thus it would appear that the Combined Interim Measures could well meet the TTSS objectives based on the UWWTD.

Programme

These interim works should be implementable within two to three years.

Cost of measures

The cost is estimated/budgeted to be

Flow diversion, in-sewer measures, RTC, etc	£ 7m
Vortices (or as early part of long term measure)	£ 3m
Booms around CSOs	£ 2m
Workboat to collect boom debris	£ 1m
Oil and fine litter skimmer	£2m
Fixed diffuser system and monitoring	£ 12m
Docks water treatment and warning system	£ 3m

Total about £ 30 million.

These estimated costs do not include the costs of the progressive Suds and BGI initiative.

However these costs estimates are at concept stage. Proper feasibility study and costing is required to identify what is feasible, with what benefit. As has been shown by ofwat, water companies have a bias towards large capital schemes as in that way they are allowed to charge their customers more and increase profit for their shareholders, called capex bias. Thus, in my opinion, such study work would need to be carried out independently of Thames Water, albeit probably using the TW sewer models.

I recommend that such Combined Interim Measures be studied, and, if found to be appropriate, discussed with the European Commission.

Excessive/disproportionate cost

The UWWTD, Annex 1A states that "*The design, construction, and maintenance of collecting systems shall be undertaken in accordance with the best technical knowledge not entailing excessive cost, notably regarding limitation of pollution of receiving waters due to storm water overflows."* (BATNEEC). This requires that a solution be adopted but that it should not be an excessive cost. The defra working paper submitted to the TTSs state in section 28 concerning the collecting systems "*For those operating in conditions less severe than storm or unusually heavy rainfall, the appropriate solution must stop the discharges from occurring in such conditions unless they are not having an adverse effect on the Tideway."*

With the comparison of about £30m for the so called Interim Measures, compared with £4,200 million for the Tideway tunnel, then, provided the Interim Measures can perform as expected, Tideway tunnel must be considered excessive cost.

The Water Framework Directive also includes a clause that measures should be the most cost effective, and another that cost should not be disproportionate.

Conclusion

Thus, looking at the analysis above, there seems every likelihood that the Interim measures would meet the objective of the UWWTD to protect the environment from the adverse effects of the waste water (in this case predominately storm water) discharges.

Thus, in my opinion, the Combined Interim Measures, including widespread SuDs and Blue Green Infrastructure, should be investigated, and where found beneficial, implemented.

10. Judgment of the European Court.

The UK was taken to the European Court by the European Commission for failing to implement the UWWTD, 97/271/EEC.

The case involved the inadequacy of the sewage treatment works at Beckton, Crossness and Mogden. The relevant works are now under construction or complete.

The case also involved the adequacy of the collecting system in London in that the TTSS 2005 report showed that it spilled about 50 times a year which is more often than the unusually rainfall events in the footnote to Annex 1A of the UWWTD.

"*The Commission ... does not propose a strict 20 spill rule but points out that the more an overflow spills, particularly during periods when there is only moderate rainfall, the more likely it is that the overflow's operation is not in compliance with Directive 91/271."* Para 28.

The UK argued that "*To evaluate whether collecting systems or treatment plants conform with Directive 97/271, a detailed assessment of the performance of the collecting system or the treatment plant must be carried out by reference to the environmental impact of the discharges on receiving waters."* That would be entirely logical and what is demonstrated in the earlier part of this report.

The Commission alleged that "*the frequency and quantity of discharges of untreated waste water from the Beckton and Crossness collecting systems are of such a magnitude as to constitute a breach of Annex 1(A) to directive 97/271, in particular given that those spills occur even during times of moderate rainfall.*" Para 43.

The Court held "*the word ' unusually' clearly indicates that failure to collect or treat waste water cannot occur in normal circumstances*" para 58. *"The United Kingdom's line of argument seeking acceptance that discharges might take place even outside exceptional*" should have said unusual" *situations cannot therefore be upheld*." para 59.

Since the objective of the directive 97/271 is "*to protect the environment from the adverse effects of waste water discharges,*" it does seem illogical not to consider what those impacts are or would be, and to stick rigidly to a footnote whatever the environmental impact of the spills. However the Court judgment rules.

The Court then considered BTKNEEC. "*The concept of BTKNEEC thus enables compliance with the obligations of Directive 97/271 to be secured without imposing upon the member States obligations which they might be able to fulfil only at disproportionate cost."* Para 64. I believe the words should have been "excessive cost".

"*However, in order not to undermine the principle set out in para 53 of the present judgement that all waste water must be collected and treated, the Member States must invoke disproportionate costs of that kind by way of exception only."*

"*it will be for the Member State concerned to demonstrate that the conditions for applying BTKNEEC are met*." Para 69

"*Thus , technological solutions to the problem of the collecting system for London exist and their costs cannot be regarded as disproportionate"* excessive" *given that the United Kingdom has already taken the decision to implement them*." Para 90. The original decision by the Minister was taken in 2007 when the estimated cost was £2bn. However, I understand that the decision has been ratified by Ministers when the cost of the Thames tunnel had escalated to £4.2bn. If the cost were to rise again, would that mean the minister could say it is now excessive/disproportionate and return to the Commission with that argument?

"*Accordingly, the Commission was right in finding that the collecting system put in place in London (Beckton and Crossness) does not meet the obligations laid down in Article 3 of, and Annex 1(A) to , Directive 91/271 and that...the United kingdom has failed to fulfil its obligations under the directive*."

11. Conclusions.

Central London has a **combined sewer system** which, in 2000, had 57 overflows which spilled into the Thames up to 50 times a year causing aesthetic, environmental and health impacts.

The Tideway was required to meet the **Urban Waste Water Treatment Directive** by 2000. The aim of the Directive is to protect the environment from the adverse effects of waste water discharges.

The European Commission has taken the United Kingdom to **European Court** as it considered that the collecting systems spilled more often than "unusual conditions" as set out in Annex 1(A) of the Directive 97/271 (UWWTD). The Court ruled in October 2012 that this was so, and that the UK had not established disproportionate (excessive) cost as it had decided to implement the tunnel, and thus that the United Kingdom had failed to fulfil its obligations under the directive. During the infraction proceedings the European Commission and the Advocate general indicated that a spill frequency of 20 spills a year would be acceptable.

The **Thames Tideway Strategy Steering Group** studied the Tideway from 2000 to 2005. There are no specific numeric standards in the UWWTD so the TTSS came up with three objectives specifically focussed on the Tideway covering aesthetics, environment and health. Based on the information available then, the TTSS proposed that, to meet these objectives, three sewage treatment works be upgraded and a storage/conveyance tunnel be constructed from Hammersmith to Beckton STW at a cost of £1.7bn for the tunnel. The total cost of the tunnels has now risen to a total of about £4.8bn.

At that time, 2005, there was limited information about **sustainable urban drainage systems** and there was very limited experience of how well they worked. Thus the TTSS was unable to recommend them as a viable solution to meet a European Directive.

The **current works of upgrades** to the Tideway sewage treatment works and the Lee tunnel, will reduce the volume of spill from the current about 39 Mm3/year to about 18 Mm3/year, much reduce the number of dissolved oxygen failures, and much reduce the spills from Mogden STW which was primarily responsible for the fish kills in 2004 and 2011 in the Kew/Chiswick area..

CSO spill volumes and spill frequency, were calculated by Thames Water using their **sewer model**. This showed Hammersmith Pumping Station spilling about 50 times a year on average. Since then TW have provided their Sewage Discharge Notifications. This shows Hammersmith Pumping Station spilling about 25 spills a year. Thus the model would appear to appreciably over estimate spill frequency. It needs re-calibration against actual spill frequencies.

TW assumed that **sewer flows would increase** with increasing population and constant per capita demand. The increase by 2021 is some 2.6m3/sec, some 13% of the current 20m3/sec STW flow. The TW sewer calculations also assumed constant sewer infiltration. In reality Thames WRMPs show for the future reducing water delivered and decreasing water main leakage, and hence decreasing sewer infiltration. Together these reduce projected sewer flow by 2024 by about 2m3/sec, about 10%. Thus TW sewer analysis has overestimated future sewer flows by about 23%. This has resulted in a significant overestimate in future years of both the frequency of spills and the volume of spills.

Flow in the sewer interceptors could be reduced further by reducing the amount of **water entering the sewers** by connecting part of the sewerage system to another STW, Mogden or Hogsmill, or to the existing Thames/Lee water transfer tunnel.

The implementation of widespread **SuDs and BGI** would also increasingly reduce storm flows from entering the sewers. During the infraction proceedings, the European Commission proposed that 20 spills a year should be the limit. Appendix E of the needs report of 2010 showed that, if 50% of the impermeable area were removed, then the number of CSOs failing this limit would be 12. However, more recent analysis, and one relatively minor work, showed this would reduce to 6 failing CSOs. Recalibrating the sewer model to match actual spill records, revising the sewer flows to match the TW WRMP water supply projections, and other works might well eliminate such excessive spills entirely.

Remaining **spills from the sewers** into the Tideway could be reduced further by adjusting the CSO weir levels, removing restrictions in the sewer system, and by implementing detention tanks, vortex separators, and real time controls. Studies would need to be carried out to assess the scope and cost of such measures.

The TTSS **aesthetic objective** is to limit the pollution caused to the point where it ceases to have a significant adverse impact. The EA reported that there were few formal complaints from the public about adverse impact. In addition to reducing the storm discharges by the methods above, discharge of sewage debris in the river could be reduced by installing booms around most of the CSO outlets covering some ¾ of the spill volume. The retained debris can be collected. The existing skimmers and new oil skimmers could be used in the river to collect that which escapes or where booms cannot be fitted.

The TTSS **ecological objective** is to have a sustainable fish population. Fish are considered the most sensitive ecological species and dissolved oxygen (DO) standards have been set, based on fish trials. The current works of the improvements to the sewage treatment works, particularly Mogden STW and the Lee tunnel, go a long way towards reaching the DO standards. The post upgrade Tideway Fish Risk Model has only one failure but this seems based on the assumption that salmon who migrate through the tideway are resident most of the time. Were that anomaly to be revised then the fish suite would be sustainable. The most sensitive species in the fish suite are salmon who are now deemed as unsustainable in the short, medium and long term. No other relevant similarly sensitive fish species was identified.

In addition a fine grained **diffuser system** using compressed air or oxygen would be able to raise the dissolved oxygen levels further and provide fish refuges as has been done in the River Seine downstream of Paris and presumably approved by the EC. The existing mobile bubbler boats would supplement the fixed system and would be flexible to reach where the monitoring system showed they were required.

The Tideway is used by rowers and sailors for **recreation**. The TTSS recreation objective is to substantially reduce the number of elevated health risk days. The Tideway is not a designated bathing water and is not subject to the Bathing Water Directive. For navigation reasons, the PLA has recently banned bathing in the Tideway except with a special licence. Health impact of those in the London Docks can be mitigated by putting in water treatment of the relatively small quantities of top up water pumped into the docks. Improvements to Mogden STW will much improve water quality in the Mogden/Hammersmith stretch of the Tideway where there are many rowers. A warning system has been provided to warn rowers in the Upper Tideway when CSO spills occur, similar to the approach now permitted under the Bathing Water Directive. The rowers in the Hammersmith area are already nearly ten times less susceptible to gastric infections than the general public.

Thus it would appear that the **Combined Interim Measures** may well be able to meet the TTSS objectives set to meet the UWWTD. These works should be implementable within about two to three years. Thus a major benefit to the River Thames and Londoners would be that the river would improve, and probably meet the TTSS objectives, in 2 to 3 years, as opposed to the Tideway Tunnel which would not improve the Tideway until it is completed, press reports now giving that as 2026, 13 years away. This earlier benefit would be an appreciable benefit to the rowers and sailors.

Compared to budget **costs** of the Combine Interim Measures of about £30million, the tunnel at £4,200 million would appear to be excessive/disproportionate cost under the UWWTD BTKNEEC clause. However the costs of the Combined Interim Measures are at concept stage.

However the Court did not rule that the tunnel solution be adopted, merely that a **solution** be adopted. To meet the European Court ruling that discharge should only occur as a result of such unusual rainfall, suggested as 20 spills a year, then the sewer model would need recalibration to align with actual spill frequencies found, and, in addition to the Combined Interim Measures, there would need to be an extensive programme of Suds and BGI.

Whatever, if the measures were viable but not able to reduce the spill frequency sufficiently, then the Combined Interim Measures should still proceed and reduce the environmental impact of waste water discharges during the period the **tunnel would be under construction**.

Proper **feasibility study** and costing would be required to identify what would be feasible, and with what benefit. As has been shown by ofwat, water companies have a bias towards large capital schemes as in that way they are allowed to charge their customers more and increase profit for their shareholders, called capex bias. Thus, in my opinion, such study work would need to be carried out independently of Thames Water, albeit probably using the TW sewer models.

The Commission has since stressed in its policy **Communication** the importance of Suds and Green Infrastructure. One approach would be to adopt this plus the Combined Interim Measures. It would be open for the UK government to discuss such an approach for London with the Commission.

I recommend that such **Combined Interim Measures, along with Suds and BGI**, be studied fully, and, if found to be appropriate, discussed with the European Commission with a view to being implemented. This could result in a major reduction in expenditure at a time of difficult economic circumstances.

Professor Chris Binnie, MA, DIC, Hon D Eng, FREng, FICE, FCIWEM.

22nd October 2013.

Appendix A modelling of the river conditions and Table of performance.

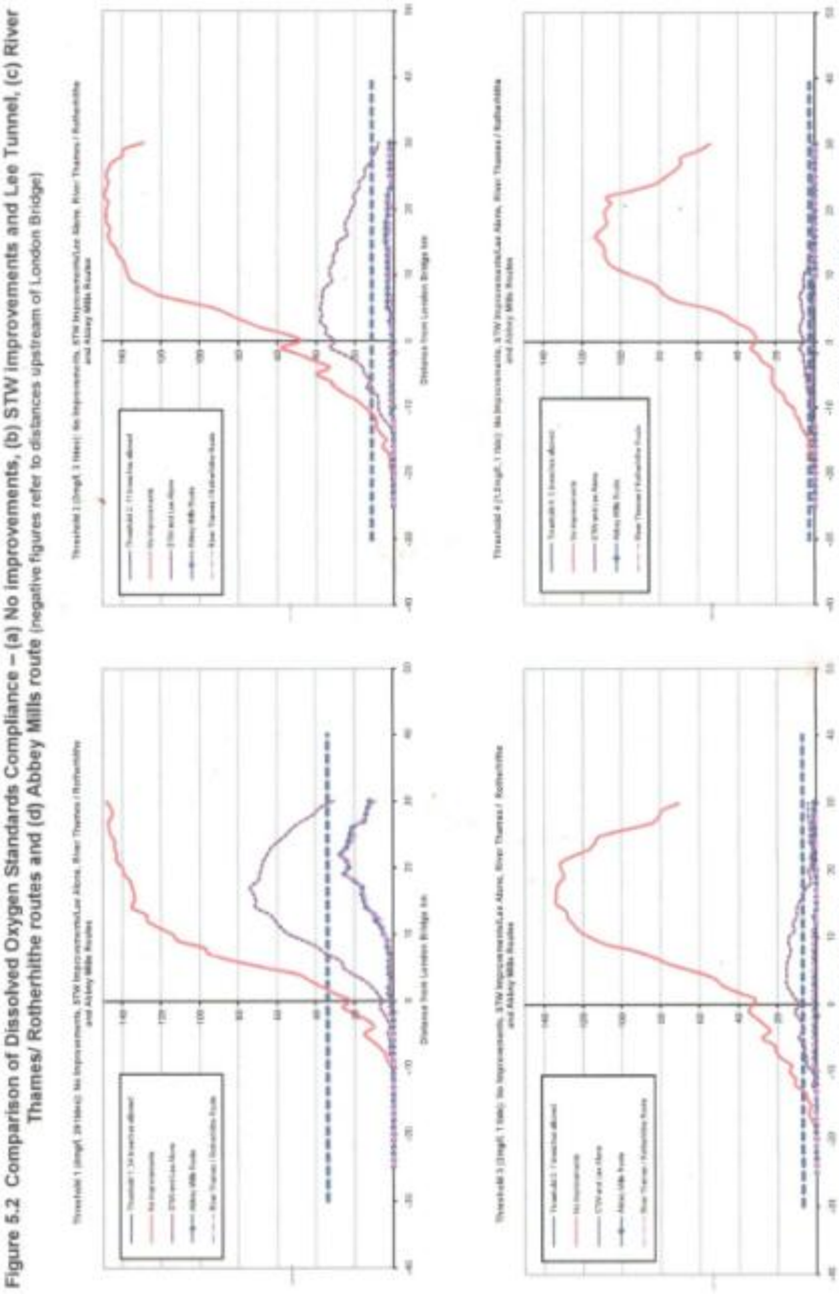


Figure 5.2 Comparison of Dissolved Oxygen Standards Compliance – (a) No improvements, (b) STW improvements and Lee Tunnel, (c) River Thames/ Rotherhithe routes and (d) Abbey Mills route (negative figures refer to distances upstream of London Bridge)

Table of performance

LTT ID	EA Cat	CSO Name	Existing System & Existing STW 2006 (June 2011) Total Volume (m^3) [a]	Existing System & Existing STW 2006 (June 2011) No. of Spills [a]	Existing System & Existing STW 2006 (June 2011) Spill Duration (hrs) [a]	STW Improvements and Lee Tunnel 2021 (June 2011) Total Volume (m^3) [a]	STW Improvements and Lee Tunnel 2021 (June 2011) No. of Spills [a]	STW Improvements and Lee Tunnel 2021 (June 2011) Spill Duration (hrs) [a]	Recommended Phase 2 Consultation Scheme 2021 (June 2011) Total Volume (m^3) [a]	Recommended Phase 2 Consultation Scheme 2021 (June 2011) No. of Spills [a]	Recommended Phase 2 Consultation Scheme 2021 (June 2011) Spill Duration (hrs) [a]
CS01X	Cat 1	Acton Storm Relief	312,000	29	152	325,800	30	163	0	0	0
CS02X	Cat 2	Stamford Brook Storm Relief	500	2	2	500	2	2	400	2	2
CS05X	Cat 1	West Putney Storm Relief	34,300	26	113	36,400	28	119	1,500	1	4
CS37X	Cat 3	LL1 Brook Green	0	0	0	0	0	0	0	0	0
CS03X	Cat 2	North West Storm Relief	2,800	1	1	4,100	1	1	700	1	1
CS04X	Cat 1	Hammersmith Pumping Stn	2,208,000	50	648	2,362,100	51	690	103,600	1-3	16
CS06X	Cat 1	Putney Bridge	68,100	33	107	70,800	33	111	1,600	1	3
		Upstream Putney Bridge Total / Maximum [b]	**2,626,000**	**50**	**1,023**	**2,800,000**	**51**	**1,086**	**108,000**	**3**	**26**
CS07A	Cat 1	Frogmore SR - Bell Lane	17,300	26	124	18,100	27	130	500	1	4
CS07B	Cat 1	Frogmore SR - Buckhold Road	85,600	19	68	88,600	21	72	1,500	1	3
CS08A	Cat 1	Jews Row - Wandle Valley SR	300	1	2	2,900	1	5	0	0	0
CS08B	Cat 3	Jews Row - Falcon Brook SR	7,400	2	7	7,500	2	7	7,500	2	7
CS09X	Cat 1	Falcon Brook Pumping Stn	708,900	40	263	779,300	42	291	56,200	4	26
CS10X	Cat 1	Lots Rd Pumping Stn	1,135,000	38	346	1,263,000	42	410	91,600	4	31
CS11X	Cat 2	Church Street	0	0	0	0	0	0	0	0	0
CS12X	Cat 2	Queen Street	0	0	0	0	0	0	0	0	0
CS13A	Cat 2	Smith Street Main Line	1,400	4	8	1,500	4	8	1,500	4	8
CS13B	Cat 2	Smith Street Relief	0	0	0	0	0	0	0	0	0
CS14X	Cat 1	Ranelagh	283,000	26	142	305,700	27	153	18,500	2	10
CS15X	Cat 1	Western Pumping Stn	2,046,200	37	200	2,323,900	41	228	244,500	4	24
CS17X	Cat 1	South West Storm Relief	227,900	12	38	238,400	13	40	3,900	1	3
CS16X	Cat 1	Heathwall Pumping Stn	654,900	34	200	748,300	38	246	62,500	4	26
CS18X	Cat 2	Kings Scholars Pond Storm Relief	1,400	2	4	1,800	3	5	500	1	2
CS19X	Cat 1	Clapham Storm Relief	12,700	5	12	14,400	6	15	7,900	1	5
CS20X	Cat 1	Brixton Storm Relief	264,600	28	131	278,600	29	137	5,700	1	4
CS21X	Cat 2	Grosvenor Ditch	2,600	3	7	3,000	4	9	500	1	3
CS39X	Cat 3	Horseferry	3,400	3	7	3,800	3	7	300	1	2
CS40X	Cat 3	Wood Street	0	0	0	0	0	0	0	0	0
CS22X	Cat 1	Regent Street	22,200	4	12	25,700	8	19	0	0	0
CS23X	Cat 1	Northumberland Street	71,500	13	34	88,400	14	43	300	1	2
CS24X	Cat 2	Savoy Street	8,400	18	47	8,500	18	4	1,400	4	7
CS25X	Cat 2	Norfolk Street	0	0	0	0	0	0	0	0	0
CS26X	Cat 2	Essex Street	2,100	3	6	2,300	3	6	0	0	0
CS27X	Cat 1	Fleet Main	521,100	20	73	571,200	23	8	36,80	4	14
CS42X	Cat 3	Pauls Pier	0	0	0	0	0	0	0	0	0
CS55X	Cat 4	London Bridge	8,300	7	14	8,900	7	1	4,300	5	10
		Downstream Putney Bridge to London Bridge Total / Maximum [b]	**6,086,000**	**40**	**1,74**	**6,784,000**	**42**	**1,975**	**546,000**	**5**	**191**
CS28X	Cat 1	Shad Thames Pumping Stn	91,900	15	70	100,400	15	69	71,300	4	14
CS43X	Cat 3	Battle Bridge	0	0	0	0	0	0	0	0	0
CS44X	Cat 3	Beer Lane	0	0	0	0	0	0	0	0	0
CS45X	Cat 3	Iron Gate	200	1	2	200	1	2	300	1	2
CS46X	Cat 3	Nightingale Lane	0	0	0	0	0	0	0	0	0
CS49X	Cat 3	Cole Stairs	0	0	0	0	0	0	0	0	0
CS50X	Cat 3	Bell Wharf	0	0	0	0	0	0	0	0	0
CS29X	Cat 1	North East Storm Relief	782,400	31	286	847,400	31	303	84,300	4	32
CS51X	Cat 3	Ratcliffe	0	0	0	0	0	0	0	0	0
CS31X	Cat 1	Earl Pumping Stn	539,000	26	184	593,900	30	207	50,500	4	26
CS30X	Cat 1	Holloway Storm Relief	7,800	8	18	8,400	9	23	7,000	2	9
CS52X	Cat 3	Blackwall Sewer	0	0	0	0	0	0	0	0	0
CS36X	Cat 2	Wick Lane	0	0	0	0	0	0	0	0	0
CS32X	Cat 1	Deptford Storm Relief	1,471,500	36	252	1,976,000	39	343	161,300	4	29
CS33X	Cat 1	Greenwich Pumping Stn	8,322,500	51	672	3,940,100	28	240	571,500	4	35
		Downstream London Bridge to Greenwich Total / Maximum [b]	**11,215,000**	**51**	**1,484**	**7,466,000**	**39**	**1,187**	**946,000**	**4**	**147**
CS56X	Cat 4	Isle of dogs Pumping Stn (Foul only)	12,900	6	9	13,100	6	10	13,100	6	10
CS35X	Cat 1	Abbey Mills Pumping Station from STATION F	15,319,000	56	873	0	0	0	0	0	0
CS35X	Cat 1	Abbey Mills Pumping Station from STATION A	4,099,800	45	403	0	0	0	0	0	0
CS57X	Cat 4	Canning Town Pumping Stn	0	0	0	0	0	0	0	0	0
CS34X	Cat 1	Charlton Storm Relief	600	2	3	900	2	3	900	2	3
CS53X	Cat 3	Henley Road	0	0	0	0	0	0	0	0	0
		Downstream Greenwich to Henley Road Total / Maximum [b]	**19,432,000**	**56**	**1,288**	**14,000**	**6**	**13**	**14,000**	**6**	**13**
		Crossness STW Storm Tanks	308,300	5	27	50,200	3	8	50,600	3	9
		Tideway CSO				609,100	3	19	698,300	3	22
		Total / Maximum [b] to the River (CSO + Tunnel Overflow)	**39,667,000**	**56**	**5,567**	**17,723,000**	**51**	**4,288**	**2,363,000**	**6**	**408**
Sewarage Treatment Works [c]		Beckton Catchment	444,610,000		8784	508,290,000		8784	508,240,000		8784
		Tunnel Pump Out	n/a		n/a	6,201,000		791	22,128,000		1551
		Beckton STW (Catchment + Tunnel Pump Out)	444,610,000		8784	514,490,000		8784	530,370,000		8784
		Crossness STW	200,560,000		8784	230,940,000		8784	230,280,000		8784

Notes

a. All CSO spills less than 100m3 have been removed. Volume, number and duration of spills have been adjusted accordingly.

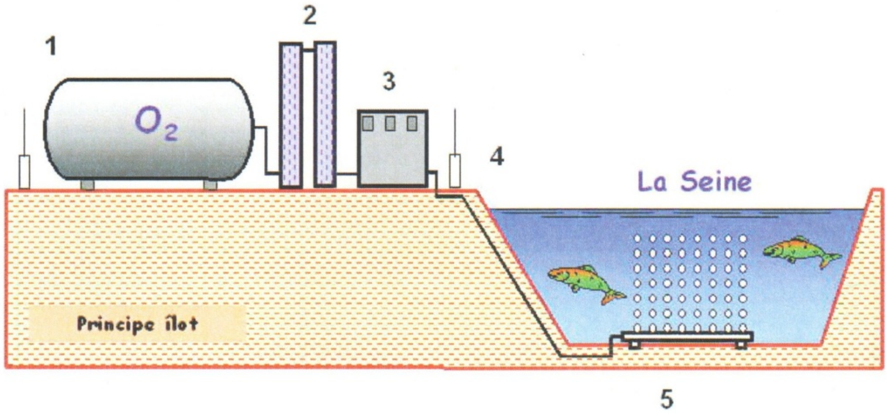
b. For Volume and Duration, the sum of all CSO spills in the reach is reported. For Number of Spills, the maximum number of spills in the reach is reported.

c. Typical Year Model simulation is only for 270 days. The table includes infilling the remaining days with average daily DWF for Beckton and Crossness STW.

Appendix B Information about the Seine system

The Seine at Paris is a large river and Paris is a smaller city than London. The Seine at Paris also well upstream of the tdal limit, thus te river continues to flow seawards. As I understand it, there are five oxygen injection stations in the Sene immediatly downsteam of Paris. These are able to inject liquid oxygen into the Seine.

Schéma de principe

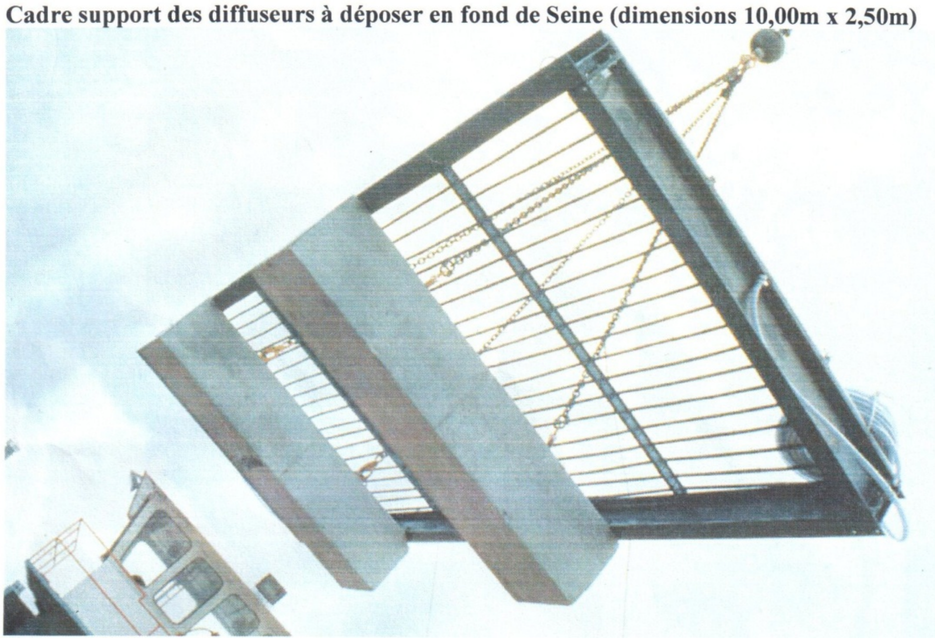


1 - Stockage d'oxygène liquide
2- Vaporiseurs de remise en pression
3- Armoire de régulation
4- Tubes d'alimentation en oxygène gazeux
5 - dispositif d'insufflation d'oxygène

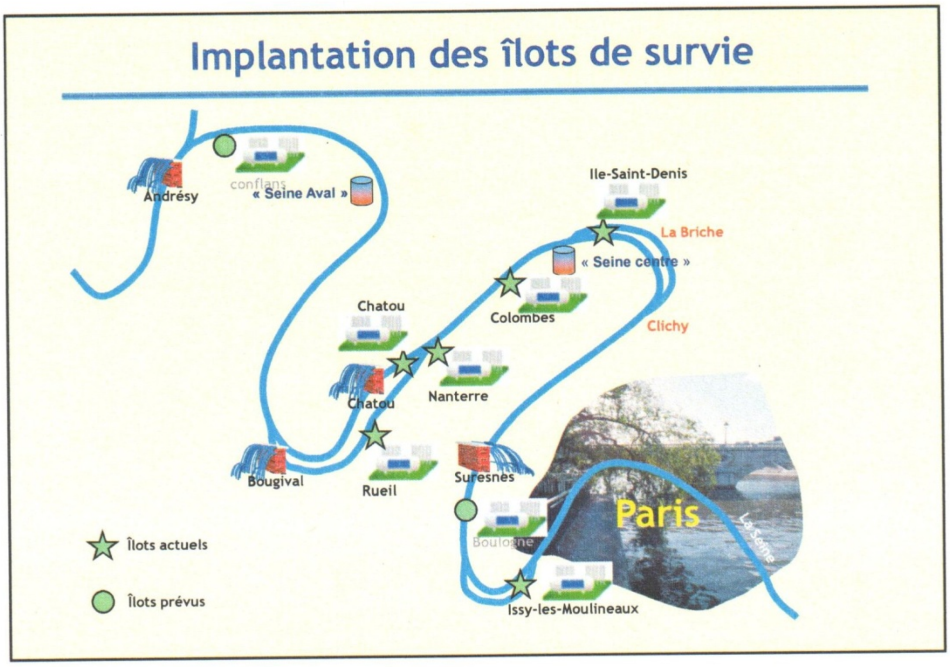
A picture of the diffusers is shown below.

Diffuseurs utilisés

Cadre support des diffuseurs à déposer en fond de Seine (dimensions 10,00m x 2,50m)

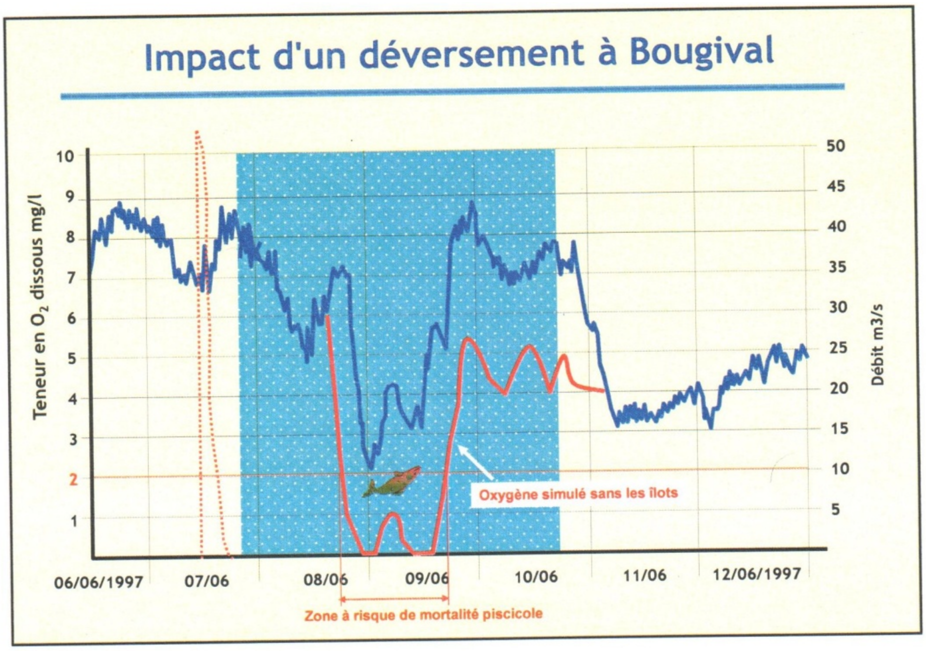


There are six such installations just downstream of Paris.



The picture below shows the size of the Seine and the diffusers in operation.

There is one plot of the benefit they have brought, as shown in the plot below for Bougival. This shows the dissolved oxygen content of the river following a storm on 7th june. The blue shaded area is when the diffusers were operating. The red line is what the water quality model of the river prdicted would have happened. As can be seen for a day the dissolved oxygen content would have been between zero dissolved oxygen and 1mg/l. This would have resusIted in severe fish mortality.The blue line is what the diffusers wer actually able to acheive. At no time did the dissolved oxygen drop below 2mg/l and the drop below 3mg/l was only about 4 hours. Based on the Tideway fish trials suite of fish only salmon would have been significantly affected. This shows the substantial benefit that such dosing can bring.



Elsewher in the presentation it implies that the river flow at the time was some 200m3/sec.

This demonstrates the gret benefit that can be obtained by installing diffusers and injecting air/oxygen into the river water.

.Appendix C Description of the Cardiff Harbour bubbler scheme.

Introduction

In the 1970s Cardiff Harbour was a rundown area with a poor environment. "*A neglected wasteland of derelict docks and mudflats...incapable of supporting most aquatic life.*" WEM Nov 2011 page 27. In the 1990s it was decided to impound the harbour and a barrage was installed across its mouth. The harbour area had a number of sewage and CSO discharges into it. The scheme is described in the Special issue of Water and Maritime Engineering June 2002 and illustrations have been kindly provided by the Cardiff harbour Authority.

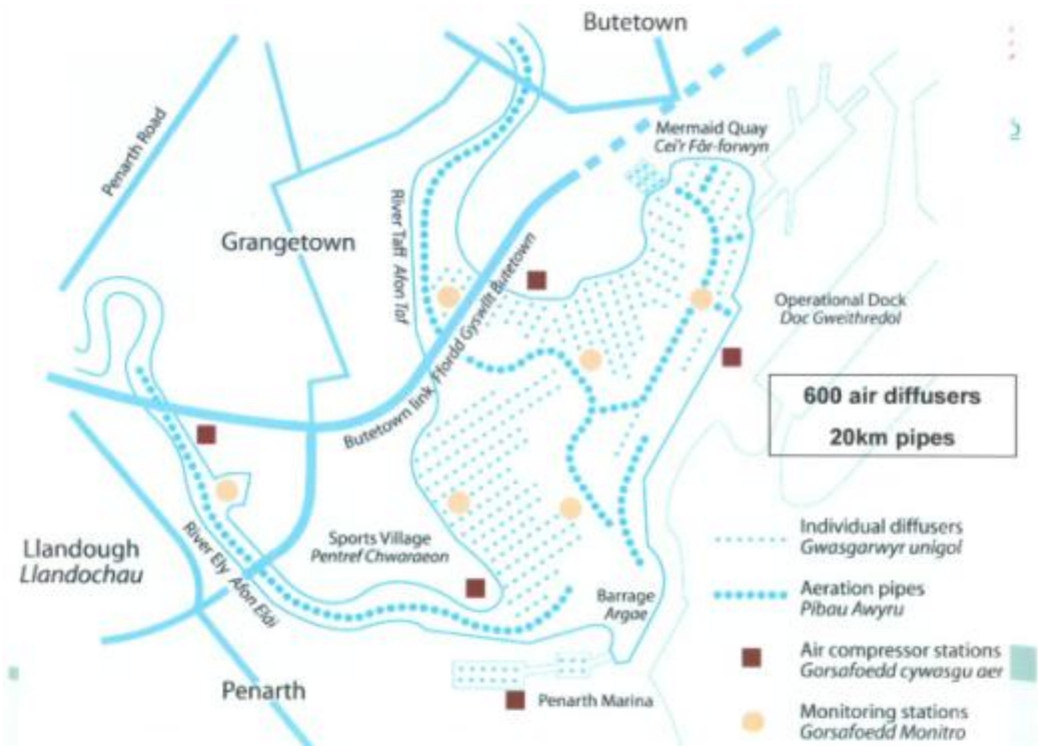
Scheme description

Page 84 "*Sixteen major sewers have been diverted from the bay prior to impoundment.*"

Page 131 "*Althugh major sewage and other outfalls have been diverted from discharging into the impounded water, there are still some inputs of sewage, industrial effluent, and diffuse inputs from the river catchments and discharges from combined sewer overflows (CSOs) during high rainfall events....Combined sewer overflows contribute high waste loads...the discarges were located in the rivers Taff and Ely*" I am informed that there are still frequent CSO discharges.

Fixed and mobile bubbler system for dissolved oxygen content

Page 84 "*The original concept for dealing with low oxygen levels was the provision of direct injection by Vitox units at a number of points around the perimeter of the bay...In practice a system of aerators has been installed in the bay with the agreement of the Environment Agency. The aerators inject air into the water body rather than oxygen, and are designed to operate continuously during the period from March until September each year.*"



The 600 coarse bubble diffusers are connected to air delivery pipes from the compressor stations on the shore. Thus this installation show that it is feasible to lay pipes on the bed of a water body and bubble air through them. The object is not to increase the dissolved oxygen content of the water but to turn over the water such that the surface water and the low oxygen bottom water are turned over, thereby eliminating stratification and raising the dissolved oxygen content of the water body.

A mobile bubbler is used should such action be required.

Monitoring system

The monitoring system consists of sensors hanging from the 9 buoys providing water quality data every 15 minutes.

Water Quality Monitoring Buoy

The data is relayed and displayed both in the Cardiff Harbour Authority (CHA) and EA offices and live on the web so anyone can view it in near real time. In addition the historical data can also be interogated on the web. Below is a sample I downloaded from the web showing the readings every 15 minutes, in near real time mode for one of the sampling points.

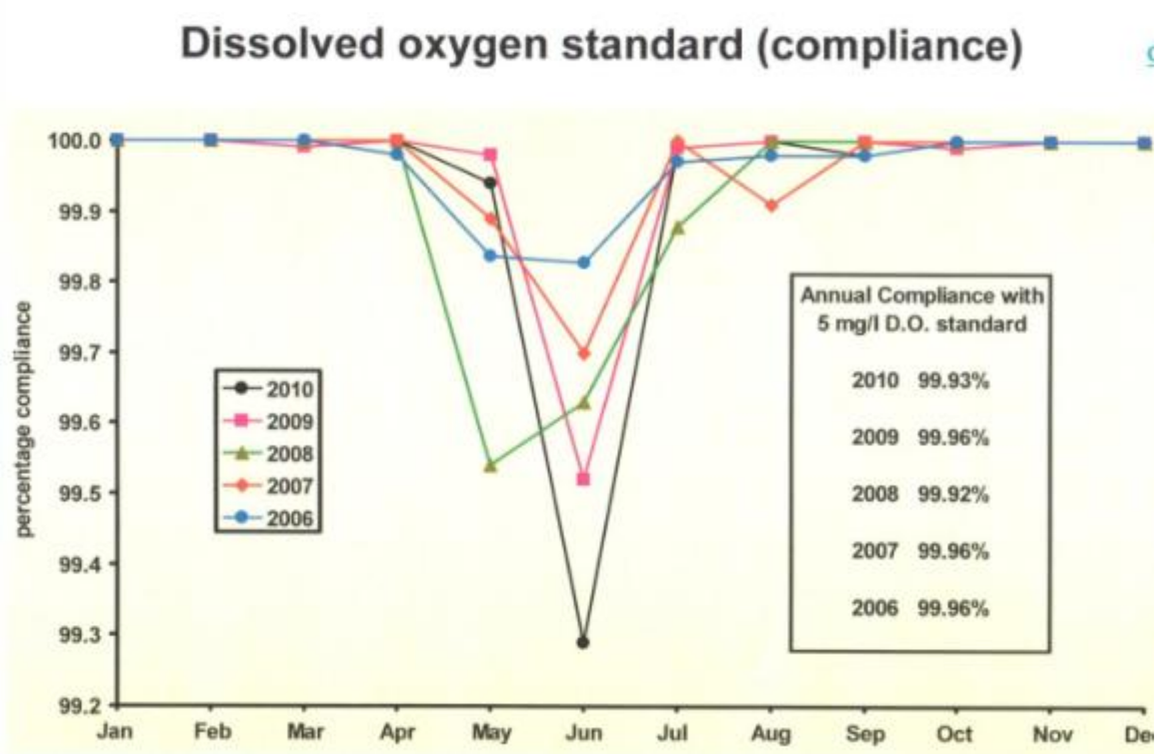
Site 5 Top & Bottom (all

	Min: 11.19 Max: 11.41 Mean: 11.29 Median: 11.29 St.dev: 0.04	Min: 93.0 Max: 96.4 Mean: 94.8 Median: 94.7 St.dev: 0.7	Min: Max: Mean: Median: St.dev:	Min: Max: Mean: Median: St.dev:	Min: 7.25 Max: 8.17 Mean: 7.74 Median: 7.73 St.dev: 0.22	Min: 305.0 Max: 338.0 Mean: 319.0 Median: 318.0 St.dev: 5.8	Min: 0.15 Max: 0.16 Mean: 0.15 Median: 0.15 St.dev: 0.00	Min: 1.001 Max: 1.190 Mean: 1.089 Median: 1.091 St.dev: 0.062	Min Ma Me Me St.c
Date/Time	**Site 2 S5 Bay 00010441 ODO Conc [mg/L]**	**Site 2 S5 Bay 00010441 ODO% [%]**	**Site 2 S5 Bay 00010441 DO Conc [mg/L]**	**Site 2 S5 Bay 00010441 DO% [%]**	**Site 2 S5 Bay 00010441 Temp [C]**	**Site 2 S5 Bay 00010441 SpCond [uS/cm]**	**Site 2 S5 Bay 00010441 Salinity [ppt]**	**Site 2 S5 Bay 00010441 Depth [m]**	**Site S5 000 OD [mg**
26/01/2012 00:00	11.33	96.1			8.17	311.0	0.15	1.010	
26/01/2012 00:15	11.33	96.1			8.15	319.0	0.15	1.014	
26/01/2012 00:30	11.33	96.0			8.13	321.0	0.15	1.013	
26/01/2012 00:45	11.35	96.3			8.16	315.0	0.15	1.012	
26/01/2012 01:00	11.36	96.4			8.16	314.0	0.15	1.007	
26/01/2012 01:15	11.34	96.3			8.16	317.0	0.15	1.010	
26/01/2012 01:30	11.34	96.2			8.16	317.0	0.15	1.008	
26/01/2012 01:45	11.32	96.0			8.14	316.0	0.15	1.005	
26/01/2012 02:00	11.30	95.8			8.13	316.0	0.15	1.011	
26/01/2012 02:15	11.35	96.2			8.12	314.0	0.15	1.009	
26/01/2012 02:30	11.34	96.1			8.12	318.0	0.15	1.007	
26/01/2012 02:45	11.35	96.1			8.10	315.0	0.15	1.008	
26/01/2012 03:00	11.30	95.7			8.09	316.0	0.15	1.008	
26/01/2012 03:15	11.30	95.7			8.07	330.0	0.16	1.006	
26/01/2012 03:30	11.26	95.2			8.05	317.0	0.15	1.007	
26/01/2012 03:45	11.23	95.0			8.03	319.0	0.15	1.008	

.

This network of sensors and near real time display enables any oxygen sag to be rapidly identified as it starts and rapid action to be taken at the relevant point in the harbour.

The aeration system has been operating since about 2001. During the early years there were problems with receiving near real time data from the monitoring buoys. However since 2005 the new arrangement now gives reliable near real time (15 minutes interval) readings for anyone connected to the web. This has enabled the scheme to meet its 5mg/l DO target reliably.



Thus such a scheme can be a very effective and reliable long term solution.

Booms and skimmers for litter collection

For litter collection the Cardiff scheme uses booms, and a litter collection and skimmer arrangement.

Cardiff harbour ,page 91, "*CHA has procured a purpose-built vessel and booms in order to deal with the considerable amount of debris that builds up in the bay following floods.*"

Conclusion

Thus the Cardiff harbour arrangment of fixed coarse grained diffusers and mobile bubblers, a near real time monitoirng system, and booms and mobile skimmers, has enabled the Cardiff Harbour to meet its dissolved oxygen and litter targets, and hence the UWWTD.

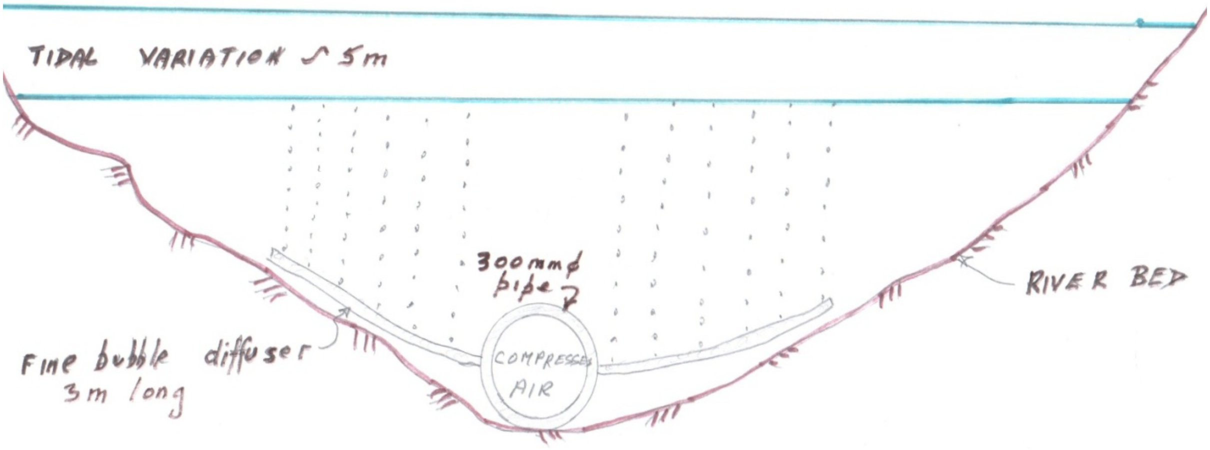
Appendix D Details of the in-river aeration system.

System

The diffusers proposed would not be the coarse discs used in Cardiff harbour and elsewhere to turn bodies of water over, but fine bubble air diffusers designed to increase the oxygen content of the water body. The large surface area of the fine bubbles aids oxygen transfer through the bubble water interface, but also because more water is moved there is also an increased transfer between the surface of the water and the air. Each diffuser is designed to input 1kg of oxygen from the air to the water each hour.

The diffusers are tubes, about 32mm diameter, made in lengths generally about 3m long and just negatively buoyant so they rest on the bottom of the terrain.

They would be attached to an air pipe. This would normally be HDPE and about 200mm diameter laid on the bed of the river.



CROSS SECTION OF RIVER

Considering the width of the river, it is suggested to have two air pipes, one on each side of the deep water section of the river. This would provide a greater width of aeration, and enable the pipe and diffusers on one side to be maintained or the channel dredged whilst the other system remained in operation.

For the Hammersmith section take the lowest dissolved oxygen level and the highest water flow assumed to be 200,000m3/hour, then the aeration system of 1km with two pipes and a diffuser every 10m on either side of each pipe equating to 400 diffusers, would input 400 kg of oxygen /hour into the water. In theory this would raise the dissolved oxygen content by 2mg/l. The actual transfer conditions would depend on the storm water CSO overflow volumes and BOD. To assess this the system needs to be modelled with the water quality model.

If a greater transfer rate were appropriate, then oxygen could be pumped through such a system, increasing the transfer rate by a factor of 3.

It is important to note that this is an interim system until the tunnel is operating sufficiently. Thus the object is to alleviate the dissolved oxygen sag. However it would be most helpful to know what the air system can achieve.

Location of installations.

A similar arrangment of diffusers has been installed in Cardiff harbour. This meets a need to turn over the static water in the harbour. This is a different aim than that proposed on the Tideway. However it does demonstrate the ability to install and operate such a system. Further information on the Cardiff arrangment is shown in Appendix C

The Environment Agency report Assessments of Thames Tideway Combined Sewer Overflows, Annex A shows that, downstream of Heathwall, only Deptford and Greenwich have an adverse effect on dissolved oxygen. Thus it would probably be appropriate to space the diffusers upstream and downstream of the identified CSOs, thus minimising cost. There would need to be a number of air compressor stations along the river bank.

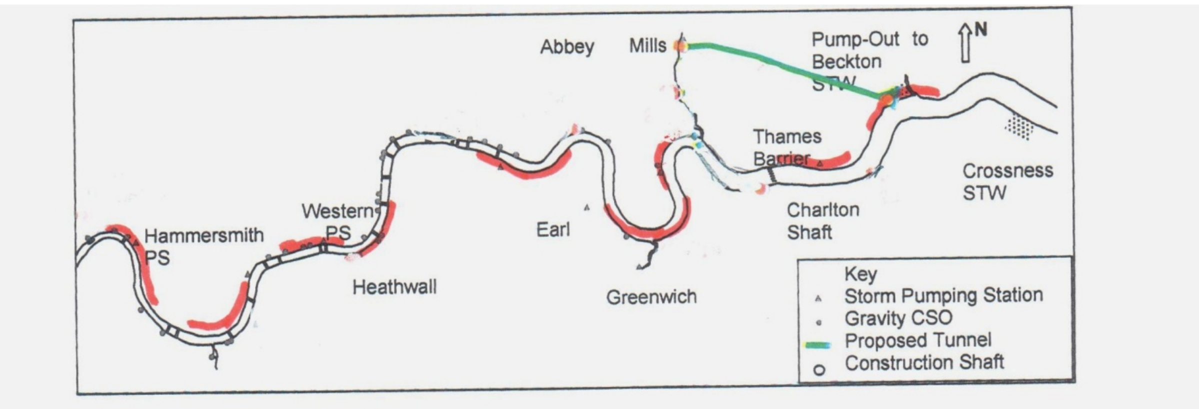
The lengths of diffusers would be in stretches, generally both upstream and downstream from an air /oxygen plant. In general the stretches would be up to 2 km in length.

Places where Thames Water own, or have access to, land such as at existing pumping stations, or land obtained for the tunnel construction sites, could be appropriate for on shore air blower or oxygen generation systems. Possible locations were identified as at the pumping stations at Hammersmith PS, Carnwath Road tunnel site, Falconbrook PS, Western PS, Heathwall PS, Shad PS, Chambers wharf, Earl PS , Greenwich PS, Isle of Dogs PS, Woolwich PS , and Becton STW. See plan below for the provisional sitting of the diffuser installations and the lengths covered.

Regarding the space needed I am informed by Dryden Aqua that "The two main air blowers, would measure about 2m x 2m as a foot print in their acoustic enclosures, then one would need at least 1m clearance. The oxygen generator will take up more room. There needs to be spece for the buffer tank and columns. However we can use the air blower to drive the VSA." On 10th December 2012 Dryden Aqua stated, "The sisze of the system (375 kg/hr) will have a footprint of 12.8 m x 7.3m x6.1m.

I have site plans for almost all of these sites. Shad and Earl look congested so I have assumed that it may well be necessary to replace Shad with Chambers Wharf and have the Greenwich system going more upstream. I have asked for, but have yet to receive plans of the Woolwich site. Lots Road site itself appears too congested, although the adjacent site for the water screens of the defunct power station might be a possible site but it is not on land owned by TW. Falconbridge also looks too congested so this is replaced by Carnwath Road tunnel site. Thus it seems reasonable to assume at this stage that nine diffuser installations could be put in.

It was intended that Appendix D would show the actual proposed site areas for each installation but TW have put a confidentiality restriction on the plans of some of the sites. Whatever, I have now reappraised the information available to me and made the best judgement that I can on the available public domain information.



Several of these installations are set back from the river wall. However there are CSO conduits of appreciable size connecting these installations to the river and it should be possible to install the air pipes, about 200mm dia, in these conduits without measureable loss of overflow capacity. In general the length from the on-land installation is generally reasonable but the Greenwich installation is nearly 1km from the river.

The longest distance between these installations would appear to be 6.5km, from Heathwall PS to Shad PS. Here there would be a gap of some 4km. However, with a tidal excursion of some 14km, this should still be satisfactory. Thus there would be about 10 stretches of diffusers.

If necessary it would also be technically possible to mount the air compressors on a floating barge, connected to the shore by a flexible electric cable, and to the diffuser system by a flexible air pipe.

Depth of water

From the Admiralty charts, upstream of London Bridge the general charted depth in which the diffusers would be laid would be about 2m. Downstream of London Bridge the general charted depth would be about 5m.

At Tower Pier and Silverton, the predicted tidal heights from the PLA website for July to September, the most critical quarter, are a spring tide high water of about 7.4m. With the charted depth of about 5m then the water depth would be some 12.4m. With the pressure drop along the air pipe, then it is likely that a compressor pressure of at least 1.5 bar would be required.

With a predicted spring water low tide of about 0.2m, then the minimum water depth over the diffusers would be about the 5m chartered depth.

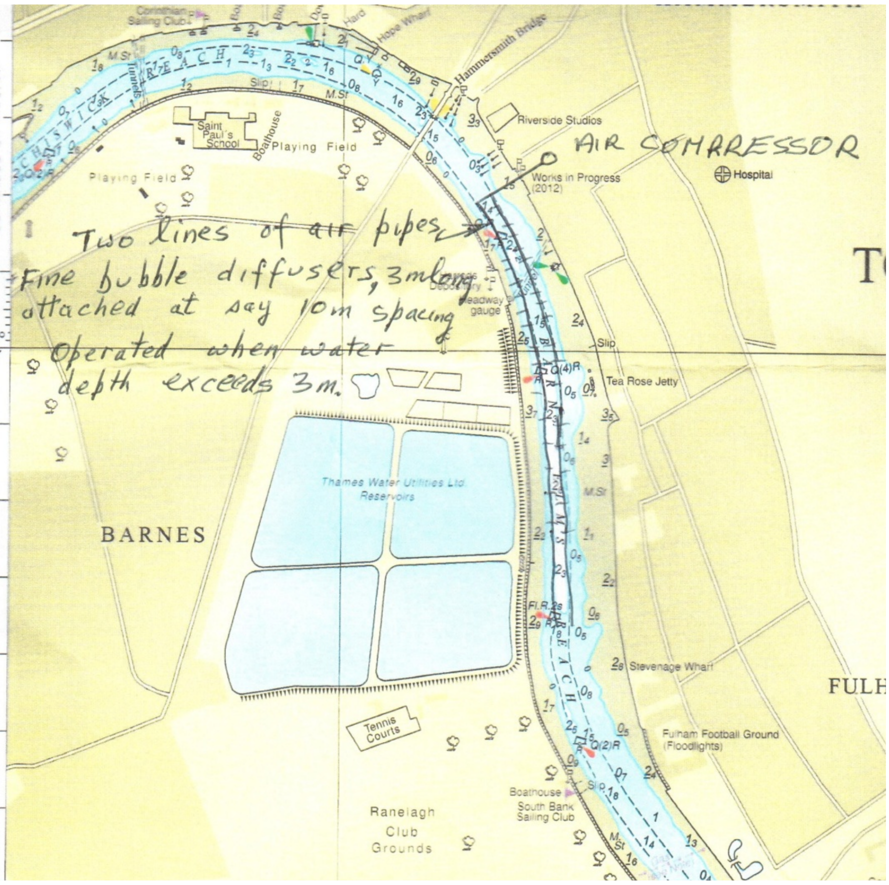
The average water depth over the diffusers here would be the charted depth of say 5m plus the mean tidal height of about 3.7m, a total of about 8.7m. It is proposed to have a screw compressors rated at 2.5bar which would cope with this sort of pressure variation.

In the Chelsea reach area, the predicted maximum tidal height is a spring tide of about 6.7m above chart datum giving a total water depth of about 8.7m.

With a low water of about chart datum the minimum water depth would be about 2m. A minimum depth of 2m is satisfactory when the tide is flowing as the rising bubbles are swept along with the tide. However around low tide when the water flow is slack, the bubbler system might have limited affect.

The average tidal height appears to be about 3m, giving an average depth of water of about 5m over the tidal cycle. This would be more than sufficient.

The plan below sets out a provisional layout of the most upstream diffuser length, that from Hammersmith pumping station. Being the most upstream this has the shallowest depth and the smallest tidal cubature.



Temperatures

The amount of oxygen in the water varies with the water temperature. There is data in the HPA report of the river water temperature in 2005 and 2006. This shows summer temperature of about 20C, with some readings of 22C and one of about 24C. There is also projected to be a temperature rise in the summer of about 1.4C by 2050 due to climate change.

Salinity conditions

The Environment Agency has shown a low flow profile of salinity with about 2,000mg/l at London Bridge, effectively fresh water, and up to about 6,000 mg/l at Becton STW, the most downstream installation.

Design conditions.

There is very little information on which to base the design of the system. However a few general considerations can be made. As can be seen from the FARL report, the cold conditions in winter do not give rise to a significant number of potential failures. As temperature rises then the saturation level of water reduces, meaning it can carry less oxygen. However the reduction in oxygen solubility with increasing temperature is not the main issue. When water temperature increases the biochemical activity of bacteria increase exponentially. The bacteria can then exert their BOD and reduce the oxygen content of the water.

Air diffusers have a greater effect the lower the oxygen content of the water. For instance at 2mg/l, the transfer is about 2kg of O2/diffuser/hour whereas at 4mg/l of O2, a diffuser will do some 0.5 to 1.0 kg of O2/hour/diffuser. Thus above 5mg/l of O2, the diffuser system would have reduced benefit.

Thus the air/oxygen diffuser system would be appropriate at below about 5 mg/l.

Assuming that the diffusers would be sized to raise the oxygen level by 1mg/l in one 12 hour tide, then this would require about 100,000 kgs of oxygen /day. The Dryden Aqua web site states that each diffuser diffusing 10 cu.m/hr of air will add " *at least 25kg/of oxygen*". Thus some 4,000 diffusers would be required.

Dryden have reviewed the limited amount of information available and believe that a diffuser system with two lengths of pipe averaging 1km each and a diffuser each side at 10m spacing would provide 400 diffusers and 10 such lengths would provide about 4,000 diffusers. With occasional use of oxygen, should be able to maintain a dissolved oxygen content in the river above 4mg/l., thus meeting the environmental target of 4mg/l.

What is needed to firm up the design is information about the BOD and COD of the river water and the CSO spills.

Potential negative issues

Frequency of operation

It had been suggested on the basis of the post Lee tunnel number of failures at standard 3, 20 failures of the dissolved oxygen (DO) standard in 40 years, that the diffuser system would not be worthwhile. Use once every two years might well be too small a benefit. However the reality is that the most frequent failure of the DO standards is standard 1. The plot in the TW Needs report,

Appendix A of this report, shows for standard 1, about 75 failures in what appears to be 34 years. That is already 2 ½ times a year. In addition there would be a number of "near misses" and the operators would need to operate the diffuser system to try an ensure that a failure did not occur. Because failure would be difficult to predict, there could well be another 3 to 6 times a year. Thus the diffuser scheme would be required to operate a sufficient number of times a year to warrant its installation.

Grounding.

In a note by Thames Water they state that "*any structure on the bed of the river would be very vulnerable, especially at low water when it is not uncommon for craft to ground*." First there is no evidence provided of how frequently craft ground. Below London Bridge the depth would be about 5m at spring low tide and significantly more at other times. There are very few ships of this size still using the river. Above London Bridge the minimum water depth for the diffusers is about 2m. Few private river craft draw this much. The tourist craft and the waste craft are under professional masters who seldom, if ever, run aground. In any case should a vessel run aground on top of the plastic pipes or diffusers, then they would be pushed into the underlying soft river sediments.

Silt.

"*The Thames is a very silty river and the system would require considerable maintenance*."The river is indeed a very silty river. However the air would be going out through the diffusers so would effectively clear off any silt lodged in the outer part of the diffusers. This could be planned as part of an ongoing maintenance programme. As shown below it would be quick and easy to raise the sections of the system for inspection and maintenance.

Dredging.

It is possible that the PLA would wish to dredge part of the channel. For this to happen, then the pipe and diffuser system would be made to float and recovered in sections, see the section on maintenance.

Buoyancy of small craft

Adding air to water reduces its buoyancy, which can theoretically be a problem with swimmers and small craft. However, given the depth of the water and the volume of air passed through the diffusers, the change in water density is so small as not to result in a problem. Such systems have been used previously in natural swimming areas.

Anchoring of other craft

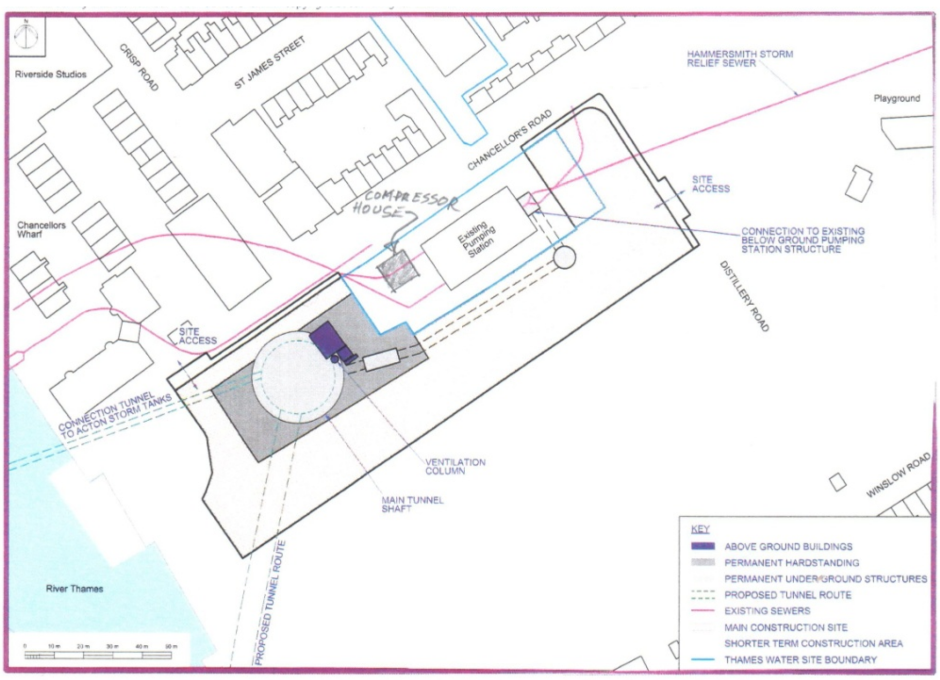
There would need to be a prohibition on anchoring in the vicinity of the system. This should not be a problem as few craft anchor in the Tideway, they either pick up a large buoy or go alongside. In any case the system would not cover the full length , there being gaps between the stretches where anchoring could take place. In any case the system would be requird to obtain the approval of the PLA.

Onshore installation

The onshore installation would consist of one or two air compressors within a sound proof structure. There would also need to be a power supply. Presumably, since most of the sites are current pumping stations, there would be sufficient spare capacity in the incoming power supply. However the appropriate switchgear would also need to be provided.

During peak times, it might be necessary to pump oxygen and air through the diffusers. What would be required to do that is a couple of Vacuum Pressure Swing Absorbers, effectively a couple of vertical tanks. These can be mounted above the air compressors.

From the plans of the installations found on the Thames Water Tunnel web site, it would appear that there may well be space for such an installation at the proposed sites.



Preferred site at Hammersmith Pumping Station – showing use during construction

Operation

The air system becomes much less effective when the dissolved oxygen content of the river exceeds about 5mg/l. This is because the oxygen transfer coefficient drops appreciably. Thus close monitoring would need to be provided using monitoring buoys and near real time readings. Thus, were there to be a plume of low dissolved oxygen water then, as it was carried back and forth by the tide, then the relevant diffuser stretches could be switched on and off automatically as necessary to oxygenate the water. This limited operational period would save in operational costs.

Maintenance

Dryden Aqua have developed a way of bringing the pipe and diffusers to the surface by attaching the air pipe to another pipe. Normally this second pipe sits on the bed of the river with water in it. When it is required to bring the diffusers to the surface for inspection or repair, the second pipe is filled with air and both pipes float to the surface, bringing the diffusers with it. To sink the system again, the second pipe is filled with water and the system sinks.

Benefits for fish

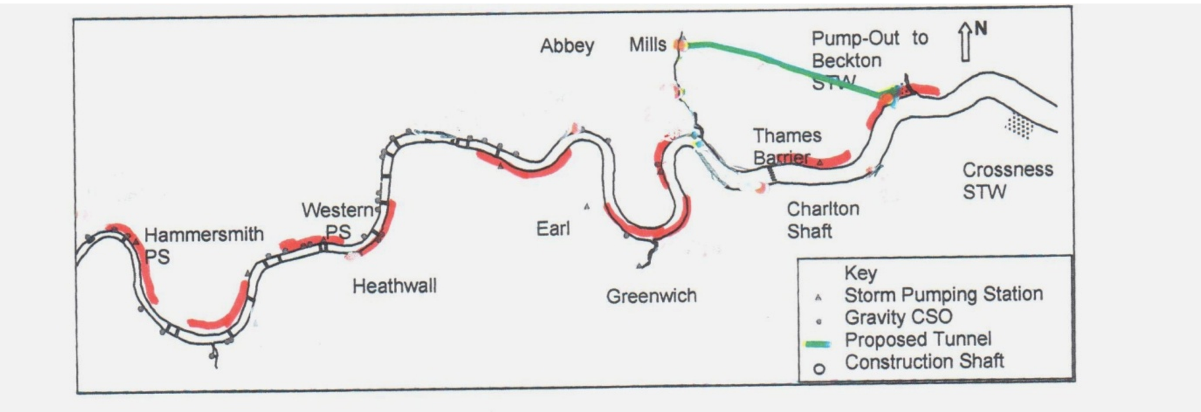
Dryden Aqua comment by email" *We went through a similar exercise for the Manchester ship canal, which is on the same scale... The diffusers will create a path for the migratory fish will follow. Also if the aeration system does not maintain a complete path, each air diffuser can act as a life support island of oxygen to support the fish. One diffuser can support around 1 tonne of fish, and will provide a safe zone during period of heavy pollution or during the DO drop that will occur at night."*

Appropriate modelling
In my view the only way of analysing the future conditions, and trying to see what the benefit of a normal rise of DO due to the proposed air diffuser system, say, to a 1mg/l rise, would be to put the various potential alleviation schemes into the TW water quality model, try various alternatives, and see what the benefit and outcome would be. That is the approach that I have proposed.

Location
It had been intended to include plans showing the loaction of the air diffusers/oxygen generators on each site. However, for security reasons, TW have required that the plans be considered confidential.

Locations proposed.

Hammersmith PS
Carnwarth Road tunnel site
Western PS
Heathwall PS
Chambers Wharf tunnel site
Greenwich PS
Isle of Dogs PS
Woolwich PS plan awaited
Beckton PS big site, presumed space somewhere



Appendix E Assessment of potential infraction fines

Infraction proceedings

The European Commission has taken out infraction proceedings against the UK. The Judgement of the Court, case C-301/10 dated 18th October 2012, states in para 95 "*Consequently, it must be held that, by failing to ensure: appropriate collection of the urban waste water of the agglomerations of London(Beckton and Crossness collecting systems)..the United Kingdom has failed to fulfil its obligations under that directive.*

Thus it is likely that infraction fines will be imposed, based partly on the period of non-compliance.

Period of non-compliance

The period of non compliance is from the deemed start of non compliance to deemed end. I examine both dates below.

Start of infraction period

The date for compliance specified in the Urban Waste Water Treatment Directive is 31st December 2000.

The Court in its judgement appear to consider that the appropriate date is "*the situation prevailing in that Member State at the end of the period laid down in the additional reasoned opinion."* Para 91. The additional reasoned opinion was sent on 1st December 2008. "*The additional reasoned opinion dated 1 December 2008 prescribed a period of two months from receipt thereof for the United Kingdom to comply with its obligations resulting from directive 91/271."* Para 75. This date would be 1st February 2009 or very shortly thereafter. It is noteworthy that this date is already some 8 years after the date for compliance in the Directive.

Date of completion

The question then is whether compliance will be deemed to be when the tunnel " begins" dealing with the problem or when the problem is fully addressed.

I understand that DEFRA takes the view that there will be no penalty proceedings brought against the UK because the Commission will treat compliance as the point at which the tunnel construction begins or is approved, rather than completed.

I understand that the Commission's view is that compliance is when the system is functioning in accordance with the UWWTD, which would be when the tunnel is completed and operating.

The Commission's view does seem the logical conclusion.

The Thames Water Stage 2 consultation states in the document Timing "*Subject to approval, our provisional start date for the construction period is 2016....(duration is expected to be six to seven years*." That would mean completion in about 2023.

This date compares with the completion date in the Thames Water report of December 2006 Vol 1 Tunnels and shafts page 14 of 2019. Thus the project has already slipped about four years.

The tunnel will be some 20km long. It could not become fully operational until the whole length had been completed. Thus any delays would compromise the scheme becoming fully operational.

Tunnelling is always at risk of unknown geological features. For instance the London Water Ring main tunnel constructed under London in the early 1990s, hit a water bearing fault which required ground freezing to be able to tunnel through it. This delayed the tunnel by several months. As the Tideway tunnel is mostly under the river access from the surface to any problems would be difficult and require special equipment.

Thus it is possible that the date for the tunnel becoming operational, about 2023, could slip further. This could increase the period of non-compliance and hence the infraction fines accordingly.

Thus the period of infraction could well be from the date in the reasoned opinion, 2009 to the date of completion 2023, a period of 14 years. The analysis below is based on the period from 2017 to 2023, a period of some 6 years.

Amount of the fines.

Only the court can hand down a fine on the Commission's application. The text below assumes that the period of non-compliance would start in 2017. However this could well be 1st February 2009, more than doubling the fines.

I have not been in touch with the Commission and do not have the relevant documents. However I have received an email from a lawyer who has. He states:

"My team and I have come up with the following estimate of the fine the UK can expect to be liable for in the event that it loses its case before the ECJ. It is EURO 891,845,800.

This breaks down as-

Lump sum: Euro 2500000 (aimed at punishment)

Daily penalty: Euro 395820 (or Euro 144m per year) (aimed at pressuring the UK into compliance)

The daily penalty is based on the following calculus which the Commission and the Court use:

600 (flat rate) x 10 (seriousness of infraction) x 3 (duration of infraction) x 21.99 (UK 'n' factor).

Say the ECJ hands down its decision in Summer 2012. By Summer 2015 the Commission will have brought enforcement proceedings asking the court to recognise that the 2012 judgment has not been complied with and to lay down a fine. By Summer 2017 the Court will have ruled on this application, awarding a lump sum and period penalty. The clock begins to tick on the daily penalty from 2017

If it is not until the Summer 2023 that the tunnel is opened, " six years*" the total liability will be Euro 866,845,800."*

"The seriousness coefficient contains a value of between 1 and 20. I have estimated 10.

Using the Commission's own published guidance and the case law...I have calculated this figure on the basis of the following analysis:

Member state conduct – 4 out of 5

Environmental impact of non-compliance – 2 out of 5

Impact on competition – 2 out of 5

Miscellaneous (e.g. size of population affected, importance of compliance with this specific law to the functioning of the EU) – 2 out of 5.

The estimates in all these headings are on the conservative side. For example, the Commission could easily press for the maximum on member state conduct... Regarding environmental impact, the Commission will probably view this as above rather than (as I have estimated) below average seriousness. Likewise the impact on competition, and in terms of population, London is one of Europe's most populous cities so, once again, there is real scope for uplift."

Based on the analysis above, it would be quite possible for the seriousness of infraction to be 15 rather than the 10 used in the analysis, increasing the infraction fine by about 50%. If so the fines could amount to about Euro 1.5bn.

However, were the Commission to assume that the date in the reasoned opinion were to be the date for completion, then the period of noncompliance would be 14 years. Thus the fines would amount to about E2bn. I have been informed that "*EU Water Commissioner's office spokesperson has said that they are seeking 2Bn Euro infraction fines to be applied to the UK*."

At a visit to the EC in February 2013, the EC representative said that, provide they could see a solution being progressed, the EC might well not take enforcement action. However this view could well change with change of policy or personnel, especially considering the long infraction period.

However the one criterion I will concentrate on in this report is the "*environmental impact of non-compliance*". This can vary between 1 and 5. Based on the calculation above, reducing the impact number by one point would reduce the fine by about 10%, ie by some Euro 200m, about £160m. The Commission might well take a more serious view of this and if so there would be greater scope for improving the environment and reducing the fine further. By showing early improvement in the environmental impact, the interim measures might also help on reducing the size of "*member state conduct."*

If so, then interim measures could reduce the extent of the environmental impact of non-compliance and also potentially reducing the size of the infraction fines.

An interim solution would not need to meet all the standards laid down but would need to reduce the environmental impact of non-compliance in a cheap way to a level where the fine would be lower and the net cost beneficial. They would also need to be implementable within two to three years. Such interim measures could also be beneficial in providing an environmental improvement when the tunnel is operating.