It was good enough for the Victorians: We know it works

Professor Richard Ashley 1st September 2014

'We know it works' is the response of many civil engineers when challenged about Thames Water's supersewer in London. How ironic that the 19th century civil engineers tried to stop Edwin Chadwick's sanitary revolution, preferring to maintain the status quo at the time, as 'we-know-it-works'[1].

There is much evidence that big sewers work; they collect and store excessive flows of water, much of it surface or stormwater mixed with sanitary or foul sewage collected in combined sewer systems. In the UK we have £bns of valuable existing sewerage assets built during the Victorian era when the UK had lots of money from the British Empire. The need to separate storm and sanitary sewage has been known about at least since the end of the 19th Century[2]. Yet, even where sewers are separated in the UK, they invariably recombine before the combined flow is dealt with for example, at a treatment works, with excesses discharged from sewer overflows (CSOs).

In the 20th century an understanding grew, firstly about the impact of all discharges into natural water bodies from drainage systems, as even those separated were found to cause environmental damage[3]. At the same time, there was growing evidence that: (a) all forms of water are in fact potential resources, not necessarily problems; (b) that piped drainage systems (known as 'big-pipe-in'[4]) were wasteful of resources, expensive and unnecessary on the scale they had been used in the past; i.e. unsustainable

Much of the evidence was collected in the State of Victoria in Australia, where ten years of drought meant that they had to develop ways to utilise all forms of water, including stormwater and sanitary sewage as opportunities to provide

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[1] Hamlin C. (1992). Edwin Chadwick and the Engineers, 1842-1854: Systems and Antisystems in the pipe-and-brick sewers war. Technology & Culture, Vol. 33, No. 4 Oct. pp 680-709.
[2] Staley, C., & Pierson, G S. (1899). The Separate System of Sewerage, Its Theory and Construction. New York: Van Nostrand.
[3] Novotny V., Brown P. (2007) (Eds.) Cities of the Future. IWA Publishing. ISBN 1843391368.
[4] Newman P., Kenworthy J R. (1999). Sustainability and cities: overcoming automobile dependence. Washington: Island Press.

both supply water and support ecosystems (in different classes)[5]. Ironically the 'we-know-it-works' desalination movement, fronted by the energy providers in Australia, displaced this world-leading research[6]. Now the Victorians have to pay high prices to keep their brand new desalination plant mothballed as the drought has broken there and it is much cheaper to abstract and treat water conventionally.

The Victorians (in England) in the 19th century did not realise that problems (and opportunities) are best addressed at or near source, ie. with demand management, stormwater harvesting etc. (learning from the waste management hierarchy)[7]. Today's Victorians and contemporary private water companies are well aware of the hierarchy, yet choose not to follow it as being 'too difficult' and we cannot be 'sure-that-it-works'.

Although Australia has spearheaded much of the water sensitive urban design (WSUD) philosophy and details of application[8], other parts of the world including the UK, have been developing sustainable drainage systems (SuDS)[9], which are the drainage components of the sustainable urban water management approach that WSUD brings together[10]. As part of the SuDS approach, there is increasing interest in the green infrastructure opportunities and the multi-benefit, multi-functional infrastructure vision that is now bringing together stormwater with ecological enhancements and ecosystem services[11]. New projects are variously providing guidance as to how to deliver 'blue-green'

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[5] Centre for Water Sensitive Cities (2011) Cities as Water Supply Catchments. Executive summary – literature review and practice summary. January.
[6] Head B W (2014). Managing urban water crises: adaptive policy responses to drought and flood in Southeast Queensland, Australia. Ecology and Society 19(2): 33. http://dx.doi.org/10.5751/ES-06414-190233
[7] Allen M. (2008) Cleansing the city. Ohio University Press. Athens Ohio. ISBN 10:0-8214-1771-1
[8] Fletcher T D., Shuster W., Hunt W F., et al (2014): SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. Urban Water Journal.
[9] Ashley R M., Lundy L., Ward S., Shaffer P., Walker L., Morgan C., Saul A., Wong T., Moore S. (2013). Water-sensitive urban design: opportunities for the UK. Proceedings of the Institution of Civil Engineers. Municipal Engineer 166 June. Issue ME2. Pages 65–76 Paper 120004
[10] CIRIA (2013). Creating Water Sensitive Places: Scoping the potential for Water Sensitive Urban Design in the UK. Report C724.
[11] CIRIA (2011) Delivering biodiversity benefits through green infrastructure. Report C711.

infrastructure[12,13]; monetised benefits assessment for using SuDS with GI[14]; and in revising the CIRIA SuDS Manual[15]. These are drawing on the clear, well detailed and case histories of how to deliver best value to society and to ecosystems and services from around the world[16].

'We-know-it-works': yes, WSUD, SuDS, green infrastructure and multi-valued, multiply beneficial, multi-functional land use in urban areas increases sustainability, liveability, amenity and biodiversity. A major benefit of these systems is their flexibility and adaptability in regard to uncertain futures. This flexibility is recognised in the way in which natural systems and ecosystem services are promoted by and accepted in economic analysis for flood-defence-grant-in-aid[17]. And the use of 'real-options' analysis by both the Environment Agency and Defra, as promoted by HM Treasury[18]. So far, none of these approaches has even been considered by EA/Defra for stormwater management using SuDS, despite recent guidance[19].

The supersewer provides a single outcome: reducing the number and volume of combined sewer overflows to the river. It adds nothing to flood security to London, is inflexible to future uncertainty and provides no ecological benefits other than to reduce the impacts from spills on the river. The standards by which the spill reductions have been set are internally defined by the Environment Agency based on computer models that at best are +/- 100%s in accuracy[20]. Yet no benefit cost assessments have been made that consider the risks against costs

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[12] Blue Green Cities (2013). Delivering and Evaluating Multiple Flood Risk Benefits in Blue-Green Cities. Inception report. EPSRC Project EP/K013661/1.
[13] RSA/WWF (undated) Dealing with the Deluge: Urban Water management in a changing climate.
[14] CIRIA (2014). Demonstrating the multiple benefits of SuDS - a business case. Phase 2. Project RP993.
[15] CIRIA (2014). Update of the SuDS manual. Project RP992.
[16] e.g. USEPA (2013) Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs. U.S. Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds, Nonpoint Source Control Branch (4503T). Washington, DC 20460. EPA 841-R-13-004. August.
[17] Brouwer R., Ozdemiroglu E., Provins A. et al (2010) Flood and coastal erosion risk management: Economic Valuation of Environmental Effects. Handbook. Eftec. Mortimer Street, London.
[18] Defra (2009) Accounting for the effects of climate change. June 2009—Supplementary Green Book Guidance
[19] CIRIA (2012). Retrofitting to manage surface water. Report C713.
[20] Schellart A., Tait S J., Ashley R M. (2010). Towards quantification of uncertainty in predicting water quality failures in integrated catchment model studies. Water Research 44. 3893 - 3904.

that these uncertainties bring. In terms of value for money, the supersewer cannot be justified with any confidence, compared with taking a WSUD/SuDS/GI approach. In parts of the world, life cycle analyses have shown that the 'big-pipe-in' way of managing combined sewer overflow spills has a net damaging overall effect on environmental systems due to resource use, energy consumption and greenhouse gas emissions[21]. The need for some 15,000,000 kWh of pumping to empty a tunnel that will have recurrent problems with sediment deposition each and every time it is used[22], at a time when energy use is clearly to be minimised is astounding.

With the Lee tunnel completed, many of the original problems defined in the early tideway studies have already been dealt with, as illustrated by the results from the original computer models used by the Water Research centre.[23]

Sadly, despite the invective from the Mayor of London that he wishes the City to be the greenest in the world[24], he fails to understand that stormwater is a resource and an opportunity to irrigate the new green infrastructure and offset London's demand for water. Thames Water's approach to the shortage of potable water in London and water stress in the south east is, just like the Victorian's (State), to build desalination plants; in the face of an adequate amount of rainfall per year, to rely on expensive energy consumptive technology.

In conclusion it is evident that the approach to the handling of excess stormwater in London is resource consumptive, inflexible, lacking in promotion of biodiversity and amenity (it focuses on one component of this alone, see Table 2 at the end of this note for liveability and amenity provided by WSUD) and in short, unsustainable. The supersewer will rapidly become a 'stranded-asset', which given the funding model, will mean that just like (the State of) Victoria, Londoners will be paying for something that will not be being used just to satisfy the investors. The missed opportunity is colossal especially for the amenity and

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[21] De Sousa M R C., Montalto F A., Spatari S. (2013). Using Life Cycle Assessment to Evaluate Green and Grey Combined Sewer Overflow Control Strategies. Journal of Industrial Ecology. Volume 16, Number 6. 901-913.

[22] The equivalent combined sewage storage systems in Brussels constructed in the 1990s had to be abandoned due to sedimentation each and every time it was used.

[23] Martin N., Dempsey P. (2004). Thames Tideway Project – Integrated Wastewater and Estuary modelling for Water Quality Compliance Assessment. WaPUG conference, Blackpool, November.

[24] Mayor of London (2012). green infrastructure and open environments: the all London green grid - supplementary planning guidance

biodiversity that could be created all over London by spending and doing it differently. Gradually, all combined sewage overflows would cease, if we do it this way, unlike for the tunnel where overflows will continue especially as climate changes mean that the capacity of the supersewer becomes inadequate.

Of course, such dispersed green systems as are being constructed in Philadelphia[25], bringing $3m of added benefits to the City and in such a way that would also help with managing local flooding will be the responsibility of local communities and will not add to Thames' Water's asset base and hence profitability.

London has a population of 12,681 people per square mile as compared with Philadelphia's 11,379 per square mile, so of course, fitting and retrofitting new green areas that provide multiple benefits (see Table 1), will be harder (*really?).* Appendix E of the tideway tunnel study reports suggested that in many parts of London, this would be eminently feasible[26].

Table 1 Examples of benefits accruing from using SuDS for stormwater management in urban areas[14]

SuDS benefit category	Examples of SuDS contribution	SuDS group the example belongs to Quantity/quality/amenity/biodiversity
Air quality	Particulate filtering	Amenity
Amenity / Liveability	Visual enhancement	Amenity
Recreation	Quality of life	Amenity
Biodiversity (habitats)	Ecosystems	Biodiversity
Carbon	Sequestration	Amenity
Flood risk	Peak flow attenuation	Water quantity
Pollution (water bodies and groundwater)	Runoff treatment	Water quality, biodiversity
Reduced treatment / pumping	Runoff removal and interception	Water quantity & quality
Population growth / network capacity	Add buffering capacity for expansion	Water quantity & amenity
Air temperature	Green and blue areas lower	Amenity
Groundwater	Replenish / protect quality	Water quantity, quality, biodiversity

[25] Philadelphia Water Department, 2009, Philadelphia Combined Sewer Overflow - Long Term Control Plan Update - Supplemental Documentation Volume 2. Triple Bottom Line Analysis. Updated October 1st http://www.phillywatersheds.org/ltcpu/Vol02_TBL.pdf [accessed 10-01-11].
[26] Stovin V R., Moore S L., Wall M., Ashley R M. (2013). The potential to retrofit sustainable drainage systems to address combined sewer overflow discharges in the Thames Tideway catchment. Water and Environment Journal 27 (2013) 216–228

Health	Sports opportunities	Amenity
Water resource/ rainwater harvesting	Water storage	Water quantity
Crime	Reduced due to enhanced environment	Amenity
Economic growth	Inward investment attracted	Amenity
Education	Outdoor classroom facilities	Amenity
Flexible infrastructure / CCA	Easily adaptable	Amenity
Noise	Mitigate traffic noise	Amenity
PR – business / CSR	Demonstrate green credentials	Amenity
Tourism	Attractive places	Amenity
Traffic calming	Dual use of street rain gardens	Amenity

But, above all, it must be remembered: 'we/they know it works'!

Table 2. The liveability, amenity and other benefits associated with using Water Sensitive Urban Design (WSUD) for stormwater management

Liveability categories[27]	WSUD overall group contribution to liveability	Specific amenity provision categories	Category description	Explanation and examples
Human Existence needs [Sustenance, shelter, safety, livelihood, security]	Water resources (potable & non-potable); pollution control; health protection; flood protection; climate extreme buffering; crime reduction	Jobs & labour productivity	Employment is a key element that contributes to and impacts on all of the other human needs categories	Productivity is enhanced in attractive environments, such as business parks with green spaces, and includes a reduction in staff recruitment costs. Ponds, green and blue spaces provide job opportunities for maintenance lasting indefinitely, with additional jobs also being created by the added tourism from pleasant urban landscapes. In Philadelphia for example, it was estimated in 2009 that 170 permanent jobs would be created from 25% of the city being retrofitted with WSUD.
		Air quality	Health effects of poor air quality are important as are the aesthetic and ecological benefits	WSUD using blue and green areas, including grass and trees, provide significant air quality improvements by for example, trees 'scrubbing' fine particulates from urban streets. Toronto's urban forest comprising some 10 million trees, removes over 1,400 tonnes of air pollutants annually.
		Rainwater harvesting and urban agriculture opportunities	Productive landscapes are becoming more utilised in urban areas especially in horticulture and food production	Direct collection of rainwater to use for domestic and other purposes saves water, as well as potentially providing essential irrigation resources and long-term viability for urban plants and crops.
Human Relatedness needs [Interaction and social cohesion, ecological health, knowledge and beliefs, beauty and pleasure, comfort and convenience]	Water supported public domain, productivity and comfort; healthy ecosystems; enjoyment and accessibility of water; tranquillity; quality of places and landscape	Recreational opportunities	This adds to the physical and mental health and well being of individuals and communities and offsets medical costs.	Provided by a wide range of green and blue spaces that can be used, for example for walking, cycling, informal play or space for organised sports and games.
		Parks and other public spaces	As above and may not necessarily be for formal recreational purposes although ensure there is no overlap with aesthetics category	Provide park area opportunities that may overlap with recreation above but also provide pleasant and aesthetic places to be. Below-ground systems, such as infiltration basins or geocellular systems can keep spaces open, as these cannot be built over.
		Traffic calming/ parking opportunities	Restrictions on speeding traffic due to highway form and layout	SuDS, such as rain gardens and bioretention systems, can provide horizontal constraints in roads, discouraging driving at excess speeds.

[27] de Haan F., Ferguson B C., Adamowicz R C., et al (2014). The needs of society: A new understanding of transitions, sustainability and liveability. Technological Forecasting and Social Change. 85, 121-132.

			to protect public health and also discourage excess vehicular fuel consumption	Spaces between SuDS components or the components themselves can also provide parking spaces for cars and bicycles.
		Noise	Quietness, peace and tranquillity are valued by many	WSUD and associated trees and grassed areas can provide noise absorbent barriers and surfaces in noisy urban areas. Green roofs can also provide sound insulation within buildings.
		Community cohesion	Green spaces increase social ties and community strength	WSUD can help bring communities together. By increasing opportunities for human interaction and creating a more enjoyable environment, people are more likely to feel they belong to the community and take a greater pride in their neighbourhood. This is especially the case if the community has been involved in the design process and residents have ownership of the on-going maintenance (even if only in part).
		Energy use	This is in the entire supply chain and life cycle: resource extraction; manufacturing, transportation, construction and usage as well as decommissioning.	WSUD requires far less energy use in all stages of the supply chain and life cycle than conventional drainage and by harvesting water at source this also save energy. For example, De Sousa et al (2012) use Life Cycle Analysis to consider the relative merits of using porous pavements, trees and bioretention SuDS for CSO control in New York and concluded that there was a reduction of some 314 kWh/Megalitre in energy needs for the wastewater treated at the downstream plant by using WSUD compared with retaining the flows in the combined sewer network. De Sousa et al (2012) describe how in hot climates, trees in urban areas can reduce building energy needs by some 2.5% by shading and that the reductions in energy use in New York as a result are substantial.
		CO2 and other greenhouse gases	Managed by sequestration and storage and also by not using grey infrastructure (avoided infrastructure).	Plants and soils take in and store CO_2 and other greenhouse gases; hence where plants are used this potential can be exploited. For example, the Ripple Effect study in Coventry (UK) stated that 1.5 tonnes of carbon dioxide is sequestered for every hectare of trees. In the example above for New York, it was estimated that the use of WSUD resulted in net greenhouse gas emissions of only around 20% of those emitted from the construction and use of the equivalent CSO storage tanks. After the first 25 years of operation, the green infrastructure would have developed sufficiently to completely mitigate all of the greenhouse gas emissions in the construction and operation of the WSUD.
		Temperature extremes	Extremes occur especially in dense urban areas and are increasing	Green and blue infrastructure buffers and moderates temperatures which will become increasingly important as the climate changes and urban areas get hotter in future. For example, the use of WSUD in Australia as part of urban planning and design has been shown to reduce

				urban heat island temperatures by judicious location to maximise their effectiveness.
		Aesthetics and quality of places	Green and blue infrastructure add open space to urban areas and visual quality.	Provide aesthetic value, green/blue space and contribute to biodiversity, for example in the UK, the Landscape Institute & Institute of Environmental Management and Assessment provide guidance as to how best to provide this especially for large-scale developments.
		Investment	High quality places encourage inward investment and locational establishment of vibrant businesses	Using WSUD to collect surface water to irrigate green areas and creating attractive places encourages and supports inward investment and often attracts tourists.
		Biodiversity and ecology (ecosystem services)	Ecosystem services are the services provided by natural systems to humanity, defined as a range of benefits in four categories: Provisioning; Regulating; Habitat or supporting; and Cultural services	Green and blue WSUD help to support flora and fauna and here amenity and biodiversity value come together. See Ashley et al, 2011.
		Land and property values	A proxy measure for the relative prosperity and attractiveness of a community, neighbourhood or place and include a wide range of factors in which surface water is important	Green and blue WSUD add value to land and property nearby. For example, in a study in USA that looked at demand for local amenities, certain types of open space preservation have contributed to higher housing prices, in so doing, offsetting local demand for these natural amenities.
Human Growth needs [Culture and identity, equity and justice, purpose and expression, influence and respect, freedom and autonomy]	Water provision, culture and identity; independence, choice, freedom, autonomy and meaningful influence on water services; equity & justice; employment; education and communication	Public education	Engagement in the water cycle is important for education, public behavioural and valuing water systems and services	By using green and blue spaces as part of the management of the water cycle this provides many opportunities to support education both formally in schools and in communities as a whole.
		Tourism	Attractive and interesting places are appealing to non-residents and others	WSUD in themselves may provide interest for tourists especially where they are a novelty, as in Malmo in Sweden, but are most likely to be part of creating attractive places that will appeal to tourists.