Future Water Association

Informing, Innovating, Influencing

Systems Thinking for Intelligent Water Management

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Introduction

Growing demands on water usage and the sewerage infrastructure are putting severe restrictions on urban growth in many areas. Some areas of the UK are classified as water stressed with abstraction licenses reduced to protect habitats and the water environment. If water supply is restricted, what can we do to balance the demand side of the equation?

Perversely, in the UK we often have too much water, or at least too much in the wrong place at the wrong time. Increased efforts to mitigate flood risk now include restricting the surface water discharge from developments by the use of Sustainable Drainage Systems (SuDS) which can include improving amenity and biodiversity along with the control of water quantity and quality.

There are many different stakeholders involved when we look at the total water cycle, each bringing a specific focus to particular elements. It is to be expected that there will be unexploited overlaps and gaps between them. This discussion (?) paper proposes applying elements of systems thinking to water supply and demand, to develop an *Intelligent Water Management* approach. This approach will become more relevant as urban water deficits widen due to higher demand (population growth, agricultural and industrial requirements) and lower supply (depletion of natural resources, climate change).

The Big Picture?

The tension between water scarcity and increasing demand is not new and has led to the development of Integrated Water Resources Management (IWRM), defined by the Global Water Partnership (GWP) as "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems".[i]

In England & Wales, delivering a potable water supply and removing wastewater and surface water has been the remit of the water and sewerage sector companies. The normal response to increased demand has been to rely on the water companies to increase infrastructure and maximise water resources, particularly in water stressed areas.

Against this there is growing concern that increased abstraction will lead to degradation in England's rivers. At the time of water privatisation, responsibility for water resources management was separated and retained by the public sector: licensing of water abstraction of groundwater and surface water is now managed by the Environment Agency. Already a third of catchments are considered over-abstracted or over-licensed, new abstraction licences are not permitted in two thirds of catchments, and seasonal restrictions on volume abstracted can be applied. 'Untapped Potential'[ii], a 2011 study from the Policy Exchange, developed the concept of abstraction charges reflecting the scarcity of water in particular areas contained in the 2009 Cave Report[iii], to be more dynamic and potentially seasonally affected. This approach is becoming more viable with the development of 'Natural Capital' accounting to determine environmental benefits and costs (see the work of the Government's advisory National Capital Committee[iv]).

At the other end of the system there are issues dealing with the increase in wastewater, particularly surface water run-off. SuDS (Sustainable Drainage Systems) are part of the solution by controlling the volume and flow rate of surface water to mitigate effects downstream. An adjunct to this is

Water Sensitive Urban Design - "an opportunity to create beautiful, successful and resilient places" (CIRIA[v]).

Between the incoming water supply and outgoing wastewater there is demand management, which mainly relies on improved water efficiency to reduce water usage both domestically and in commercial and industrial establishments. This can be by targeting leakage from pipes and wastage in domestic water supply and in irrigation along with the promotion of water efficient domestic appliances and fixtures. In the UK much of the latter is being led by Waterwise[vi], although the water efficiency components of the BREEAM scheme[vii] and the Home Quality Mark[viii], along with the European Water Label[ix] are also noted.

Demand management should also consider the major benefits to be gained from water reuse (rainwater and greywater recycling).

Why Use Systems Thinking?

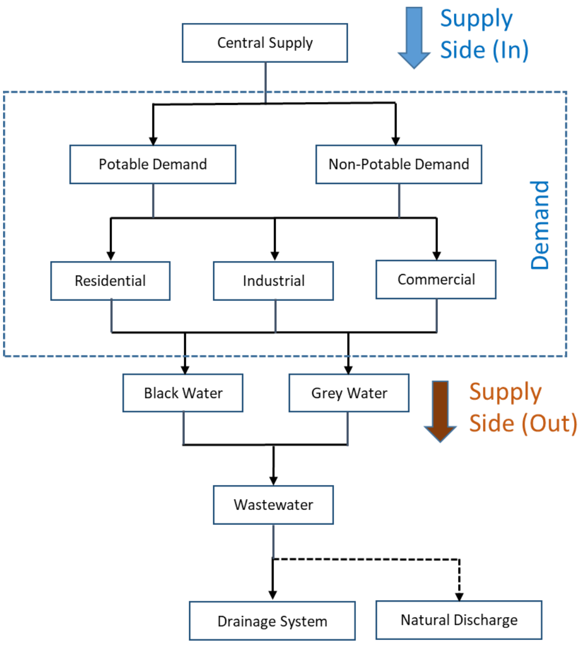
According to systems thinking[x], problems that are ideal for a systems thinking intervention have the following characteristics:

- The issue is important.
- The problem is chronic, not a one-time event.
- The problem is familiar and has a known history.
- People have unsuccessfully tried to solve the problem before.

With the possible exception of the last, we can see that the characteristics are met: there is an existing and increasing imbalance in the supply and use of water resulting from legacy issues, requiring cross-functional thinking.

Water Supply and Demand

In the UK, since the provision of public potable water supply and sanitation, the received wisdom has been that the supply side, both incoming centralised supply of potable water and outgoing infrastructure required for the wastewater, has flexed to match the demand from the building, commercial site or residential development. Of course, there are some variations to this: borehole and water course abstraction by some heavy water users and some direct discharge of grey water to water courses, but the general model is a useful one. A simplified representation (adapted from an AECOM study for an IWM strategy for the Old Oak Common and Park Royal development in London.[xi]) is given in the figure below.



The difficulty with the traditional model is the assumption that the supply side (in and out) can expand indefinitely to meet continued growth. However, even if the water is available upstream, the existing infrastructure may be at, or near, capacity. Further increase in supply may therefore necessitate replacing or duplicating existing water and sewer networks, and even building additional water or sewage treatment plants. The cost-benefit analysis (particularly if Natural Capital and Social Capital is factored in) may not support the increase in supply.

In addition, there is an implicit expectation that the availability of water is infinite. This is clearly not the case and some areas of the UK, particularly the South East and parts of East Anglia, are already designated as water stressed[xii]. There have been reductions in the volumes of water that can be abstracted from most boreholes and water courses, to meet the requirements of the Habitats Directive[xiii] and proposals to build more reservoir capacity are not received favourably by the regulator, Ofwat, and are often resisted by the public, mainly on 'environmental grounds' .

The recent National Infrastructure Commission report 'Preparing for a drier future'[xiv] recommends that government ensures plans are in place to deliver additional supply and demand reduction of at least 4,000 Ml/d in the period up to 2050. This would be achieved by a combination of reducing leakage, additional supply infrastructure / national transfer network and compulsory, even smart, metering to improve water efficiency.

In short, though we are not yet in the Cape Town 'Day Zero' scenario of running out of water we are in a position where continuing increase in demand cannot (should not?) be met by increased supply.

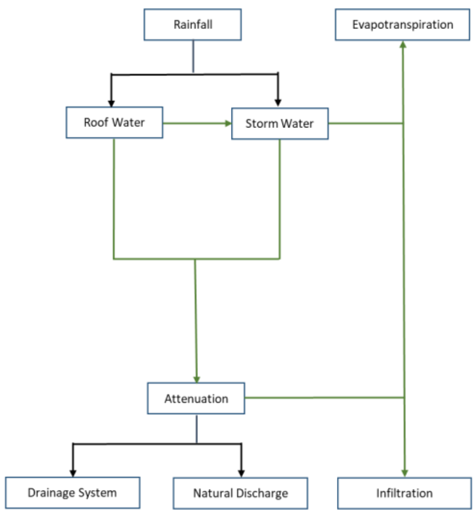
Almost in parallel to this, and often considered separately at the design stage, is what we do with rainwater falling on impermeable surfaces such as roofs, roads and car parks, and public spaces with hard landscaping. Traditionally this has been handled by collecting it from the surface and sending it underground as quickly as possible into pipes which connect into either a dedicated surface water sewer or, commonly in the UK, a combined sewer.

With growing urbanisation comes an increase in drained surface and, coupled with more intense rainfall events due to climate change, means higher volumes of surface water and, very importantly, higher flow rates at the discharge point, since water travels faster over impermeable surfaces. Such volumes can overload the existing sewers, either at the site point of discharge or further downstream. Surcharged sewers cause flooding, which can include sewage in the case of a combined system failing.

Should an individual development have the 'right' to connect to a public sewer and effectively take up capacity that is already needed by existing sites downstream? Although the subject of debate, the 'right to connect' was enshrined in the Water Industry Act 1991. However the sewerage undertaking, at the planning stage, can require evidence to prove that all surface water disposal routes have been explored.

SuDS (Sustainable Drainage Systems) is a means of mitigating the downstream effects of surface water. Where feasible, SuDS can also improve the biodiversity and 'liveability' in urban areas but, at the very least, they must be designed to control the volume and flow rate of water being discharged from a site and not adversely affect the quality of any receiving water body.

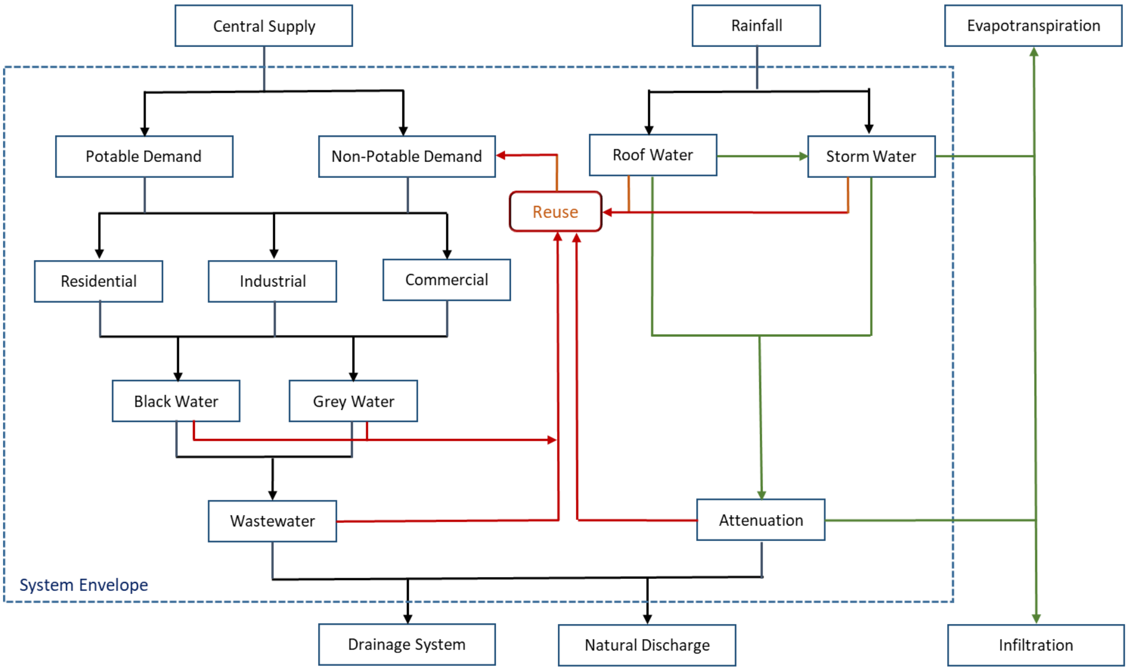
The steps for designing SuDS are eloquently captured in CIRIA C753 The SuDS Manual[xv] – regarded by most practitioners as the 'SuDS Bible' - but the basic principles are, where possible/feasible, use the water on-site (e.g. rainwater harvesting), lose volume through infiltration and evapotranspiration, hold the rest of the volume back (attenuation) and then control the discharge flow rate into a receiving water course, surface water drain or combined sewer (in that order of preference).



Intelligent Water Management

Integrating water reuse for non-potable demand brings together the two systems: water use and SuDS. This allows us to identify the reinforcing and balancing loops of the system. For example, higher occupancy leads to higher demand (reinforcing), whereas higher occupancy leads to more availability of grey water to reuse (balancing).

What are the limits of the system? Where there are external elements that change very slowly or over which we have little control, we can exclude them from consideration. In this case, we can exclude the centralised (potable) water supply and sewerage so avoiding trying to (directly) influence infrastructure elements over which we have no control, and natural physical factors (rainfall, evapotranspiration, infiltration) which are regarded as inputs into the water balance. The system envelope is therefore as shown in the figure below.



The key integrating element in the system is moving from single use water to reusing wastewater and surface water that would otherwise be wasted, thus reducing the demand on the potable water supply. The level of treatment required will depend on the source and the intended use (irrigation, toilet flushing, etc.). Thames Water have identified a looming water deficit in London (414 Ml/d by 2040) and published, in June 2017, 'Non-Potable Water Reuse as a Demand Management Option'[xvi] which assesses the various reuse technologies and their capability to reduce demand on both the potable water supply and the wastewater infrastructure. This report concludes that, though there are some barriers to implementation, non-potable water reuse is viable in larger developments and would make a significant impact on the predicted water deficit.

To take the concept of Intelligent Water Management forward we need to flesh out the elements and bring together different technologies. The following list of pertinent technologies may not be complete but would form a starting point for cross-functional collaboration and consideration of reinforcing and balancing loops.

- Demand Management:
  - Smart network technologies – remote, real time monitoring of water usage; smart meters.

  - Water efficient fixtures and fittings.
  - Micro-climate controlled irrigation.
- SuDS:
  - Green Roofs; bioretention and manufactured soils; tree Pits and rain gardens; below ground storage; crate systems; 'thirsty concrete'.
  - Downstream retention ponds or wetlands.
- Water reuse
  - Roof water recycling; grey water recycling; black water recycling.
  - Package wastewater treatment plants; electrocoagulation; organic food chain reactors.

By bringing cross-functional systems thinking to the design of Intelligent Water Management systems, particularly in new developments, we should be able to mitigate the problems of water scarcity and local flooding in a sustainable way, whilst improving the liveability of our urban environment.

How can we achieve this? We need to bring together stakeholders and providers of pertinent technologies. They will need to work together and override vested interests to create an enabling body that will produce guidelines for intelligent water management and, potentially, influence legislation and regulation.

References

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[vi] http://www.waterwise.org.uk/

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[xi] https://www.london.gov.uk/sites/default/files/iwms_new_cover_low_res.pdf

[xii] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/244333/water-stressed-classification-2013.pdf

[xiii] In UK law as The Conservation of Habitats and Species Regulations 2010, http://www.legislation.gov.uk/uksi/2010/490/contents/made

[xiv] https://www.nic.org.uk/wp-content/uploads/NIC-Preparing-for-a-Drier-Future-26-April-2018.pdf

[xv] https://www.ciria.org/Resources/Free_publications/SuDS_manual_C753.aspx

[xvi] https://corporate.thameswater.co.uk/-/media/Site-Content/Thames-Water/Corporate/AboutUs/Our-strategies-and-plans/Water-resources/Document-library/Past-meetings/19th-June-2017/Non-potable-water-reuse-Feasibility-Report-June-2017.pdf