Geovation Water Challenge

November 2015 sees the launch of Geovation's 9th Challenge focussed on the global water crisis - geovation.uk. Gauri Kangai writes.

A water crisis that is fuelled by ever increasing challenges from the effects of climate change and phenomenally growing societies. A crisis of resilience and sustainability: particularly water availability (too much and too little), poor water quality, ageing infrastructure, and behaviour (both in management and consumption; from utilities to domestic individuals). These water crises are recognised in the global development agenda, with issues from climate change drought and flooding to water quality, safe sanitation and sustainable management of water resources placed as priority challenges under the new 2030 United Nations Sustainable Development Goals.

The role of Geovation is to stimulate local solutions to these wide challenges – using the powerful tools of geographical thinking and geographic information, along with design thinking and technology – which scaled up, could impact sustainable change for the global too. Geovation focusses its Water Challenge on water problems experienced cross-sector and cross-regional in Britain. With underpinning the importance of geography, the global to local contexts are now explored to help pinpoint and inspire the greatest water problems in need of solving, first at home, in Britain.

Introduction:

THE GLOBAL WATER CRISIS

On the frontier of global water, did you know we are expecting a grave shortage of as much as 40% by as soon as 2030[1] (2030 Water Resources Group 2009)? That is, if we continue our daily business under current linear economical and consumption models of 'take, make, dispose'[2] (Ellen MacArthur Foundation 2014): abstracting as much water as we currently need without serious regard for the long-term future, including taking for granted the ability to treat any polluted water, and wastewater deemed negligible as if an infinitely abstractable resource.

Danger of this complacency is exacerbated by our continually rising population – which is projected to grow to 10 billion in 2050 from our current 7.3 billion[3] (United Nations 2015) – and we will therefore demand even more from already diminishing resources.

Why a crisis?

CLIMATE CHANGE

Climate change is a significant underlying influencer. Impacts of climate change are occurring today, close to home, already; in the UK alone, 2012 saw a remarkable 1 in 4 days in drought[4] (London Wildlife Trusts 2014). Impacts are projected to continue throughout the 21st century even if evidenced human-inducing activities (such as emitting extra greenhouse gases into the atmosphere) were to stop today, according to the board of international scientists of the Intergovernmental Panel on Climate Change (Collins *et al.*, 2013)[5].

Impacts on our water from climate change, as highlighted by the most recent UK Climate Change Assessment[6] (Defra 2012) include:

- Higher temperatures, causing faster evaporation of water;
- Increased intensity and frequency of rainfall events.

Consequences of these conditions include:

- Decreased water availability by drought;
- Greater risks of flooding by more intense and frequent rainfall;
- Distorted distribution of water overall by slower water flows from increased evaporation.

These consequences vary from place to place, depending on differing characteristics that naturally come with place – whether geological, atmospherical, or other – and as such, this is how *geographical* place-specific understanding in all these matters becomes fundamentally important.

HUMANS AND URBANISATION

Human influences additionally strain these situations, and will increasingly do so as our population and consumption demands increase in future. For example, urbanisation is a high contributing factor in affecting natural drainage processes, with reduced green space that would otherwise help to better prevent flooding and distribute water through ground filtering and vegetation uptake[4]. Population growth is disproportionately greater in urban areas, with the global urban population set to increase from 3.9 billion (in 2014) to over 6 billion by 2050, and to rise by 10 million here nationally[3]. In London alone, did you know that each year an area twice the size of Hyde Park is lost to impermeable surfacing[7] (Thames Water 2012)? We therefore face a real challenge to our water infrastructures (such as drainage, sewerage networks and impermeable surfaces). Examples include:

- Concentration of dark surfaces and buildings absorbing and transferring extra heat to the air, creating an 'urban heat island effect' of generally 8-10 degrees Celsius warmer than surrounding areas, further driving water demand (e.g. for cooling);
- Impermeable surfaces inducing surface run-off and affecting natural absorption rates, triggering greater flood risk[4].

Again, impacts toward water caused by human factors are geography-dependent, as a water challenge will change and occur to differing degrees also depending on social characteristics that come with place: such as infrastructure, political governance, and overall knowledge, expertise and even socio-economic conditions that influence management (including climate change management as well as direct water management) and user behaviour (for example, the Kuznet Curve model of attitude to environmentalism dependant on economic prosperity; Stern 2003[8]).

Priority problem areas:

TOO MUCH WATER

Distortion of changing and uneven water distribution is demonstrated by the simultaneity we are experiencing of mass flood events in some places whilst a spread of drought in others; both too much and too little. We know flooding is a critical problem as it has occurred already, on mass scales. At home in the UK for example, the rampaging floods we experienced of summer 2007 in Gloucestershire, England, brought to our awareness the crude reality of much hypothesised flood risk: being the wettest summer recorded nationally, globally it was the most expensive flood that year among an approximate total of 200 major floods[9] (Pitt 2008). Currently over 5 million properties in UK are at risk of flooding[4], and worldwide the number of homes affected by flooding will double within 70 years[10] (Sheffield Water Centre 2014).

TOO LITTLE WATER

Equally, too little water is a critical issue. Beyond the predicted 40% shortage by 2030[1], water shortages will impact us in areas where we may not be expect it. One of the simplest cases is water in our food. Agriculture is the largest consumer of water, taking on average 70% of all freshwater withdrawals[11] (Pimental *et al.*, Oxford University, 2004), with our universal staples needing large volumes of water to produce. For example, 2 tonnes is required to produce every 1 kilo of cereal[12] (FAO); a typical water to crop ratio of 2000:1. Due to greater demand for food from a growing population, agricultural water consumption is set to increase by 20% by 2050[13] (UNESCO-WWAP, 2012). In the midst of this challenge, there is an additional problem of agriculture not necessarily being possible in the areas where it is needed due to distortions in water distribution.

Adding salt to the wound, inequalities in water availability have potential to spur political tensions and even possible 'water wars' (as stated by "Waterman of India", Rajendra Singh, 2015 Nobel Prize for Water laureate; Stockholm International Water Institute 2015[14]), especially where transboundary issues come into play. As such, unsustainable local water systems will – and already do – produce reliance on (virtual) water imports. This in turn undermines livelihoods in others ways, such as the cycle of farmers providing food for exports rather than for domestic subsistence, consequently inducing a self-imposed shortage of food and reciprocal import issues leading to food dependency. This case is already being experienced the world over, particularly across sub-Saharan African countries such as Burundi, Cap Verde, Central African Republic, Eritrea, Gambia and Somalia[15] (Rakotoarisoa *et al*, FAO 2011). Essentially, a crisis of food can be seen as really a crisis of water, which fundamentally needs the context of geography to understand where its sore points are and why.

Every commodity, good or service we have has water present or connected to it, too: whether used to create a product literally (such as beverages, materials, including fabrics for our clothes), or indirectly through manufacturing processes (such as water used for kinetic energy). On top of water we may be aware of in our food, there is also water used for cooking this food; or cleaning and washing our products. From a national perspective, approximately 30% of imports to Britain are threatened by water shortage somewhere in their supply chain[16] (Green Futures 2011). There is currently less water per capita in London than in Sudan or Syria[4].

INFRASTRUCTURE

Many of our 'too little' and 'too much' problems are related to our infrastructures: firstly putting water in the right place, and then managing it effectively where it is. In the decade up to the new millennium, there were 2,500 natural disasters, of which 90% were water-related and killing approximately half a billion people[17] (Adikari *et al.*, International Centre for Water and Risk Management 2008). In the UK, infrastructure for surface water flooding and efficient drainage has been identified as a particular challenge, with inadequate infrastructure our greatest flood risk: a third of our flooding is attributed to direct river flooding and surface water, but two thirds is an exacerbation due to incompetent surface water drainage systems. The consequences of flooding are real and damaging, as brought home by the 2007 summer floods in Gloucestershire: for example, homelessness still a year on from the event; hefty insurance and repair costs; further loss of economy and livelihood due to impacted businesses; and health issues from flood water[8]. 1998 and 2010 have so far been among the highest years of flooding globally and these events totalled financial costs of over $40 billion[18] (Jha *et al., The* World Bank 2012); over three times that of the colossal 2004 Indian Ocean tsunami disaster[19] (Cosgrove, Tsunami Evaluation Coalition 2007). Likeliness of flood events is widespread globally, as occurrence is driven not only by climate change – of more frequent and intense rainfall or sea level rise, for example – but also by greater surface run-off in non-flood plains due to increasing urbanisation. In the UK it is estimated that for every extra £1 we were to spend on flood protection, this would save £8 in flood damage repair[20] (Committee on Climate Change 2014).

As already highlighted, urbanisation is reducing natural drainage by surfaces that are less permeable than soil and vegetation to absorb water into the ground, therefore creating more surface run-off. Further to surface flooding, this also catalyses run-off water into sewer systems designed for smaller capacities that consequently overflow [4 5]. This is a particularly universal threat given that many of the world's largest cities are coastal, built on swamps that pose extra risk to flooding[21] (UNEP and UN-HABITAT 2005). In the UK, even 2 mm of rainfall can cause sewer overflow, with an underlying issue of the outdated capacity of our sewer systems. A prime example is London, whose large and ever expanding city is built on swamp land in an estuary with sewers that were originally built for a Victorian population density of less than 7,000 per square kilometre, yet today have to serve a density of over 18,000 people per square kilometre. As a result, public sewer discharge is triggered into the River Thames at a staggering frequency of once or more a week on average[7]. This not only poses enormous health risks to wildlife and humans, but also increased risk of logistical problems like toilet backflow[4]. On a more domestic scale, property leakage is another pressing infrastructural challenge: a home in UK on average leaks 133 litres per day, almost on par with what is actually consumed per person per day[22] (Greater London Authority *et al.* 2011).

By 2030, the majority of urban dwellers in the world are expected to live in towns with infrastructure unlikely to cope with these great water challenges, predominantly flooding (WHO and UN-HABITAT 2010)[23]. If smarter water solutions were created, it is estimated for UK nationally, this could save utilities between £4-7.8 billion per year[24] (Department for Business, Innovation and Skills 2013).

Examples of innovative solutions already to infrastructural water management, using geography, can be seen with rainwater harvesting and smart water sensoring in Singapore[25]

(UNEP 2002). As a megacity, dense with high buildings, the roofs of both private domestic and public facility buildings are used as reservoirs for collecting rainwater. Water is stored in basement tanks, then reusable for toilet flushing, gardening, firefighting, and even drinking in emergencies. Rainwater harvesting here capitalises on its landscape of skyscrapers as a tool for rainwater capture in place of conventional drains or non-existent green space. Groundwater stores are conserved and pollution is controlled that would otherwise commonly occur by discharged sewerage systems during stormflows. Furthermore, the cost of rainwater utilisation becomes cheaper per cubic metre than if pumped from the ground. In Singapore a third of water use is from this harvested source, and 20% cheaper. Rainwater harvesting is a successfully advanced method used in other cities exploiting their skyscraper resource too, such as Berlin and Tokyo. Sensors are also used for a 'smart water grid' within Singapore, enabling real time monitoring of drainage and sewerage network systems for intelligent hydraulics-based analytics. For example, analytics on rainfall volumes, flow rates, and detecting (when and what), localising (where) and then importantly acting (how) on events like pipe leaks (wastewater), nearing capacity strains (flooding) and long-term trend changes (local water availability)[26] (Allen *et al.*, Massachusetts Institute of Technology 2012).

In approaches to handling too much water, the Netherlands is exemplar in its flood management[27] (Xianli *et al.*, UNEP 2010). Almost two thirds of the land is severely susceptible to flooding, yet with their underlying principle that this risk has to be lived with rather than denied, many different solutions have been adopted to creatively adapt to the differing locations and flood risk scenarios of the country[28] (Schultz, UNESCO-IHE 2008). For example, great investment is put into strong defences built to withstand extraordinary 1 in 10,000 year events, as opposed to 1 in 20 year events as is the common standard in UK[9], through a trial of diverse techniques. These include river channel widening to be able to better cope with excess water; dykes and sand dunes for coastal regions; and even inversely preparing for failure, by lowering some flood plains to purposefully allow certain areas to flood in order to save others[25]. Effective response to flooding is also prepared by using high accuracy and real-time weather forecasting and flood risk maps, and importantly cooperation between forecasters, hydrological centres, emergency services and public media (Slomp, Netherlands' Ministry for Infrastructure and the Environment 2012)[29].

Fundamentally, some places are more at risk than others to certain water challenges. There is even great differentiation between supposedly similar megacities. Therefore, geography is key. Geographic information, through mapping of drainage and sewerage networks, urban infrastructures (such as buildings and roads), populations (for customer demand, people and their properties who can be potentially at risk), rainfall patterns, wind directions (high rainfall or flood risk areas) and even geomorphology for example, can critically help to calculate place-specific system strains and influential factors in context.

WATER QUALITY

Water quality – both its natural quality as a result of natural chemical, physical and biological properties; and human influenced quality of polluted and treated water – is another great challenge of concern. In the world today, 650 million people do not have access to safe drinking water (UNICEF and WHO 2015)[30] and over half a billion children die each year – 1,400 children per day – from diarrhoea by consumption of contaminated water (UNICEF 2014)[31]. Whilst some problems may be already internationally recognised and highlighted for action, such as the 2015 Millennium Development Goal to 'halve the proportion of people without sustainable access to safe drinking water' (UN 2000)[32], these real life problems still persist every day. With much media attention, such as development aid campaigns, water quality is perhaps an issue easier realised on the global scale. However, challenges are also there on our doorstep.

Here, only a quarter (24%) of England and Wales' surface water bodies meet "good ecological status" (Water Framework Directive, Environment Agency 2013)[33]. Improvement in quality is not always the case, with some river basins, particularly the South East and Thames district, in decline. Moreover, 'quality' of water is generally measured by 'ecological status' – biological community, and the chemical and physical characteristics such as pH, cloudiness, bacteria (EU Water Framework Directive, European Commission 2015)[34] – meanwhile, other contaminants of quality can be bypassed, especially if not identified in official standards. For example, British public water supplies are usually recycled through human consumers several times; up to seven times in London for example. Consequently hormones (for example, oestrogen), and even drug traces (with London having the highest amounts of cocaine found in its wastewater in Europe), may be shared in the water supply where unregulated, and can subsequently become present in drinking water (Bevan *et al.*, Cranfield University Institute of Environment and Health 2012)[35]. There are commonly known water pollutants, such as carbon and nitrate contaminants from fertiliser and pesticide use that run off farms or from stock access to water courses, but water is most often a flowing resource which makes tracing the point sources of this diffused pollution another challenge in itself[4]; both practically, and due to a research gap.

Urbanisation is again a complex contributing factor to water quality – specifically, pollution. More impermeable surfaces increase pollutants that enter water courses due to surface run-off, especially during rainfall events, and lack of green space to clean this water through filtering. Slower water flows by greater evaporation from higher temperatures also enhance diffuse pollution rates[4]. Sewage discharge into public waters – which can often occur during high rainfall by overflowing drains and sewers – create inhospitable conditions for aquatic life, by bacteria having to use up oxygen in the water to break down the carbohydrate and protein compounds in sewage[36] (Defra 2002). Both because of macro climate change and the micro climate of cities' 'urban heat island effect', higher temperatures cause warmer waters that can hold less oxygen, making aquatic life more sensitive to subsequent pollution.

Regarding serious health impact to humans by poor water quality, globally did you know there are 4 billion – over half of our entire population – cases of water-borne diseases per year by consumption of polluted drinking water[37] (UNICEF 2003)? Even locally, in summer of this year (August 2015), there was a serious incident of a dangerous parasite, cryptosporidium, entering Lancashire's tap water supply[38] (BBC 2015): affecting the entire county, 300,000 households were exposed to this outbreak, critically risking the health of 80,000 people[39] (The Telegraph 2015). For over two weeks precautionary consumer action of having to boil tap water and use bottled water persisted before the source problem was solved. Cumulatively, immediate investigation and treatment works as well as compensation to households cost the water provider company around an unprecedented £15 million[40] (Davies and Brignall, Guardian 2015). Such an incident is on top of other water quality issues less visible to public eyes. This prompts awareness that our national water works are not as entirely free of contamination problems like those experienced elsewhere in the world – despite enormous progress since the days of open sewers and the 'Great Stink'[41] (Halliday 1999) of our early nineteenth century.

On the flip side, there is a challenge with water treatment itself. Polluted abstracted water requires more intense treatment, and treatment of wastewater is expected to demand an increase in energy of over 40% by 2030[13] (UNESCO-WWAP 2012). Yet, in spite of much talk about water treatment and shortage, over 80% of water is neither collected nor treated, and almost 1 billion people rely on unimproved drinking water[13]. Despite perhaps wide awareness of the global problem of access to clean water by popular development campaigns, only 6% of international aid is actually given toward the water sector[42] (World Water Assessment Programme 2009).

A classic but timeless example of how geography-based thinking has helped solve a water quality problem is the case of nineteenth century scientist John Snow in his deduction of how cholera was caused in a mass outbreak in central London, 1854. By correlating disease cases with close proximity to a certain water pump in Broad Street, Soho, conclusion was made that the disease was spread by water transmission, and then identified as borne from sewage contamination in the supply. Before this the 'germ theory of disease' had not yet been established and this health geography investigation laid the fundamental development for the science of epidemiology, helping solutions for disease prevention to this day[43] (Cameron and Jones 1983).

Geography-based innovation in tackling water quality problems still continues today. A prime recent example is the "drinkable book", which is aimed at over half a billion people worldwide who daily do not have access to safe, clean drinking water as an easier mode of point-of-use water treatment. The simple idea but sophisticated creation is a book firstly explaining how water can be treated and why, and then sheets of the book itself can be used as a filter dipped into water to purify it, containing silver nanoparticles and other elements that combat microbes and bacteria to a state safe for drinking[44] [45] (Drinkable Book 2015;

American Chemical Society 2015). This effective invention exemplifies the amalgamation of science with service design to provide simplicity for the user, and place-specific understanding of geography to realise the importance of a more efficient mode of water improvement for those people in developing regions who have limited access to larger scale, infrastructural and procedural water treatment services.

BEHAVIOUR

Finally; last but not least, people behaviour is a significant influencer underlying all these challenges: behaviour both from the individual domestic consumers to the utilities and wider authorities. Following the premise of the 'circular economy'[2], all systems are interconnected – 'systems of systems' – for example, all water, power, housing, food supply, product supply, and even education and wellbeing connect to each other in some way. Failures in one affect the others, calling us to make holistic not siloed approaches if we are to achieve better universal success[46] (Meacham and Benton, Global Food Security Programme 2015).

A prime example for 'circular' water management is the importance of managing water according to their natural *catchment* areas rather than administrative boundaries we prescribe to them[47] (Defra 2013). Water is most definitely not restricted to political borders – worldwide there are 286 transboundary river basins[48] (Transboundary Waters Assessment Programme 2015); the Russian Federation shares as many as 30 river basins with other countries[49] (Wolf *et al.* 1999), whilst the one Danube river basin in Europe stretches across 19 nations[50] (International Commission for the Protection of the Danube River 2011); including an even greater number of actual catchment areas within. Catchments are natural units which inside them encompass a complex, but whole, interconnected system: a nexus that provides a range of ecosystem services beyond simply water and food, for example land management for flood prevention, habitats for biodiversity that also influence water quality, and recreation[51] (Ofwat 2011). As such, a 'catchment based approach' would involve partnership working, with less controversial emphasis on who's responsibility is what, and rather on understanding the roles that can be played: that is, a more open, sustainable solution to water management[52] (UK Water Partnership 2015). Geography is key to this management approach, as educating and focussing on properties, activities and individuals within critical drainage areas who can all have roles affecting water quality, availability and waste *etc*., will require physical geographical analysis as well as a human geography understanding (where, what and how) of people and organisations' activities, behaviours and cultural lifestyles *etc.* that will significantly interplay.

On the local home level, our individual consumer actions also scale up to contribute to overall water management, even to the global level. Households in the UK are using almost 50% more water today than 25 years ago[4] – for example, through increase of power showers and household appliances. Typical household water use is 32% towards bathing and showering; 22% for toilet flushing; 17% for kitchen activities including cooking and drinking;

another 12% for clothes washing, and 17% for other[53] (Affinity Water 2015). Average water usage per person per day in the UK is approximately 150 litres[54] (Waterwise 2012), whilst in the US this is over 500 litres per day, and 90 litres on average in China[55] (Amarasinghe and Sharma, International Water Management Institute 2008), highlighting how individual consumption can markedly affect water use at the national and global level.

Following 'zero carbon' and sanitation initiatives, a brilliant example of innovation reducing water use to zero in a typical water-intensive appliance is the "waterless toilet"[56] (Cranfield University 2012). A third of our world's population do not have access to sanitation[30], and far from being an assumed essential, did you know more people own mobile phones than have access to a flushing toilet?[57] (UN 2012). The "waterless toilet", initiated under open innovation in the 2011 'Reinvent the Toilet' Challenge by Bill and Melinda Gates Foundation[58] (2012), developed by Cranfield University, is similar to the inter-disciplinary thinking behind the "drinkable book". Using advanced water treatment and nano technologies with specialist service design, together with contextual understanding of the importance of on-site treatment where it is needed among non-sewered societies, the toilet ensures human waste becomes treated there and then without external energy or water needs; by technology that evaporates water from the waste and uses nanoparticles to treat the residue. As a result the waste can then be safely transported away and even potentially reused[56] – addressing water quality, water shortage and the infrastructural context of non-sewered sanitation.

Behaviour beyond simply volume of water usage however is a relevant concerning factor. Many problems incurred by water utilities also result from sewer blockages from homes due to misuse of toilets for unflushable items[59] (United Utilities 2013). Did you know, per year there are around 200,000 sewer blockages across the UK, predominantly caused by fat, oil and grease down drains and items like wet wipes down toilets? This costs utilities an excess of £15 million and causes flooding of over 3,000 homes, annually[60] (Water UK 2015).

Through a more holistic management approach, including people engagement, all these issues could be addressed simultaneously, with people and their communities becoming active stakeholders. For example, using green infrastructure (such as green roofs) to decrease flood risk and harvest water, whilst increasing water quality, air quality and biodiversity; and locals to be agent 'citizen scientists' of information capturing, evaluation and communication.

How do you solve a problem like Water?

These problems of water – too little, too much, poor quality, ageing infrastructure, and user and management behaviour – highlight water crises experienced from the local to the global scale, but are no means them all.

The new 2030 Sustainable Development Goals recognise the importance of solving these water challenges, and have recognised too the indirect and interdependent links that play in the entire water cycle: from the need of resilient infrastructure, to conservation of terrestrial ecosystems, and attention to sustainable use of the further marine environment for development too[61].

As part of contributing to solutions, the 9th Geovation Challenge invites open innovation and collaboration, using the powerful tools of geographic information, design thinking and technology, to develop a local innovative solution, which scaled up, could achieve sustainable change at the global scale too.

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