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WATER SECURITY

The complex challenge of a water-secure world for all

This year, water crises – caused by declining quality and quantity and increased competition – have been identified by the World Economic Forum as the third greatest global risk, hot on the heels of fiscal crises in key economies and high unemployment. The greater incidence of extreme weather events, including floods and storms, also features in the top ten.

To reduce and ultimately avert further water crises, our aim must be a water-secure world for all. But even agreeing on what that entails is a challenge in itself. There are multiple definitions of water security, each dependent on the definition of need, be it for health, livelihoods or agricultural and industrial production. And within these needs there are yet further pieces of the complex puzzle to consider. Not simply ensuring adequate water quality and quantity, but also safeguarding the reliability and accessibility of supply – geographically, economically and politically.

However, there is one thing of which we can be sure – achieving a water-secure world requires a delicate balance of all these needs, since what can be a benefit for one, can almost certainly be detrimental for another. But of course the issue of water cannot be considered in isolation. Water security is a systemic global risk, inextricably linked to both food security and energy security, all of which are further affected by the risk multiplier that is climate change.

The articles in this issue of the environmental SCIENTIST provide insights into the many complex challenges and considerations that need to be addressed if we are to achieve global water security – from the impacts of waste disposal and abstraction on water quality and quantity, to the inherent difficulties and limitations of measuring water security and predicting future development paths and challenges. These articles present the case for a move from silo thinking towards a long-term and collective systems or nexus approach, integrating management and governance for success.

I hope that this issue will highlight both the scale and complexity of the challenge presented and provide a call to action for us all to work together to achieve a truly global answer for a water-secure world.

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CONTENTS

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Water security for nature and people

Mark Everard proposes that 'natural infrastructure' is essential for the long-term resilience of ecosystems, and that the multiple values provided by nature should be integrated into regulation, subsidy, planning and governance systems.

Water pervades the natural world, interacting with and transformed by its living and non-living elements. Talling and Lemoalle[1] observed that ecosystems and the human needs they support are driven by a cascade from physical processes (climate and topography), subsequently coloured by chemical processes (rocks, soil and their uses) and then biological processes. This same analysis applies to the character and functions of all ecosystems, shaped as they are by fluxes of water and the energy, chemical, sediment, biological and other loads it carries.

Consequently, all influences on the quantity, quality, timing, physical and chemical constituents, and residence time of water in habitats, at all scales, have major implications for the habitats' character and functioning, the human uses they can sustain, and adjacent ecosystems. This occurs from continental scale (orographic effect and run-off) to microscopic scale (localisation of nitrification and denitrification processes in adjacent aerobic and anaerobic layers of suspended particulate matter).

Water, then, plays a key connecting role in environmental resilience and production of ecosystem services. Historic emphasis on the discrete study of physical, chemical, ecological, biological, economic and social dimensions in education and research overlooks the fact that all elements are interconnected, as water flows permeate and link whole socio-ecological systems from the microscopic to the biospheric.

▲ Giant's castle from misty dam #04 (Water pervades and connected whole socio-ecological landscapes)

▲ **Rietvlei wetland and dam near Pretoria SA. (© Mark Everard)**

CONFLICT AND SOLUTION

The UN Millennium Ecosystem Assessment[2] and the UK National Ecosystem Assessment[3] summarise at global and national scales respectively how multiple dimensions of human well-being depend upon the services of nature. Human security is indivisible from environmental security. If water becomes scarce or more episodic, environmental assets decline and resource conflicts become more probable due to the central importance of water for basic biophysical needs, cooling, transport and irrigation, recreation, aesthetics and diverse dimensions of quality of life.

The often-repeated prediction by former World Bank Vice President Ismail Serageldin that "wars of the 21st century will be over water unless we change the way we manage water"[4] overlooks how competition for scarce water resources has sparked conflicts since the rise of hydraulic civilisations (societies managing water through technology rather than local access[5]). In 1967, the Six-Day War had competition for water and catchment lands at its heart. Deliberate flooding was the intent of the 'Dam Busters' missions of the Second World War, while draining the marshes of southern Iraq constituted a weapon of war for Saddam Hussein.

In southern England, post-medieval manorial court records catalogue rich case law relating to conflicts over water use for milling, water meadow, fishery and navigation. However, co-management of water systems has conversely frequently served as a basis for co-operation, innovation and even peace-making between and within nations[6–8].

Livelihood security is intimately related to water availability, including how it is shared and co-managed. This can be central in community-building, such as where co-operative water-sharing underpins centuries-old terraced paddy systems across the tropical world. Insightfully, Nelson Mandela perceived sharing of water and other environmental assets in the water-scarce nation of South Africa as fundamental to longer-term realisation of democracy, just as annexation of water was instrumental in entrenching privilege under apartheid.

ENVIRONMENTAL NEEDS VERSUS HUMAN NEEDS

Conceptual conflicts remain in allocating water to sustain the natural environment. In South Africa, there remains debate about balancing nature's needs with those of people. Under the National Water Act 1998, an 'Environmental Reserve' set by the State reflects the portion of water reserved in catchments to maintain ecosystems, natural processes and strategic needs. Remaining water is then available for allocation to different human users through democratically constituted bodies. This has led to debate about whether nature should be favoured above human needs.

From the perspective of more environmentally educated countries, the need to reserve resources for sustaining nature may seem self-evident. However, perceptions of conservation are culturally subjective. The views of some sectors of South African society are clouded by a history of 'environmental racism' as, in common with the USA, the historic preferences of a ruling elite for establishing reserves for hunting or nature sanctuaries led to displacement and disenfranchisement of marginalised communities.

So the debate about balancing the needs of nature with those of people is often contested. Emerging ecosystems science proves useful in exposing the myopia of the underlying assumption, also commonly seen where business pressures work against conservation needs.

In reality, the needs of people and nature do not compete, as may appear from a utilitarian world view. Rather, the processes of nature support our ability to feed, clean and clothe ourselves; extract and dispose of economic resources; and weather extremes of flood, drought and temperature. If nature's services are lost or degraded, so too is its capacity to enable people to live safe, wealthy, conflict-free and fulfilled lives.

Water security for the environment is then itself a myopic concept; the security of nature is indivisible from the security of people, including the economy. What people do has profound impacts on water flows and the natural environment, including its capacity to sustain human well-being. The core underpinning asset of nature, including water security, underwrites humanity's options and future opportunities, even if legacy market forces, management paradigms and resource-flow assumptions driving much political and business decision-making do not yet reflect this reality.

WHAT LIES BENEATH?

Ecosystem services have gained accelerating acceptance into pedagogy and policy over recent years, particularly since publication of the Millennium Ecosystem Assessment[2]. This has expanded understanding of the multiple values provided by water systems, biota and other elements of the natural world, over and above narrow utilitarian exploitation. Today, we see increasing emphasis on natural flood management, sustainable drainage and other urban green infrastructure, and emergence of economic tools such as payments for ecosystem services to bring formerly neglected services into decision-making.

Slower progress is occurring in recognising systemic context, and ascribing non-financial as well as financial values, to address all ecosystem services (provisioning, regulatory, cultural and supporting) defined by the Millennium Ecosystem Assessment[2]. Of these categories, supporting services remain the least readily quantifiable and hence the most overlooked. Many purported ecosystem service studies focus on more readily monetised services, either overlooking other services or assuming their values are internalised in quantified services; this focus on services already close to the market system that is the principal architect of ecosystem degradation undermines claims of systemic analysis.

Serious consideration of environmental security relates to system resilience, to which services that are hard to value (particularly supporting services such as soil formation, water cycling, habitat for wildlife and so forth) and regulatory services play a disproportionately significant role.

Climate instability and the demands of a growing global population highlight that it is not merely human-made water infrastructure that matters. 'Natural infrastructure', significantly including natural water storage and purification systems that add value to technological systems, represents a more fundamental resource securing human well-being[9]. Natural infrastructure is essential for the long-term integrity and resilience of the ecosystems that underpin continuing human well-being, and that society must therefore progressively internalise into statute, markets and corporate governance.

UNDERSTANDING THE SYSTEM

Control of water underpinned the founding of the first recorded global civilisation in Mesopotamia, allowing people to escape day-to-day subsistence, thus enabling settlement and societal differentiation. Innovations to increase security and productivity through water management, both technological and institutional, have underlain subsequent civilisations.

Mismanagement of water systems has also underlain the demise of many civilisations, such as the incremental effects of soil salinisation and nutrient depletion in Mesopotamia and progressive lead poisoning from plumbing systems in ancient Rome.

RECONNECTING SOCIAL AND ENVIRONMENTAL SECURITY

Developed world perspectives have tended to regard water security as a technical issue, managing supply through predominantly technocentric solutions. Dramatic successes have been achieved. For example, virtually all the water needs of the province of Gauteng, the economic and industrial heartland of South Africa encompassing Johannesburg and Pretoria, are provided by massive dam and transfer schemes from catchments outside Gauteng and even outside South Africa (such as the Lesotho Highlands Project).

However, water is more than a commodity, playing many wider roles in ecosystems, such as soil formation and fertilisation; supporting biodiversity, fisheries and ecotourism resources; regional aesthetic and spiritual value; crop production and grazing. This all contributes to overall resilience, livelihood support and diverse cultural value systems. Overlooking these wider services is inequitable and economically inefficient, and also erodes the capacities of the environment to secure future human well-being.

Water also has an important social context. Centralisation of water management in post-independence India led people in arid rural Rajasthan to abandon village-scale water management and natural-resource stewardship practices, leading to progressive ecological degradation, human hardships and village abandonment. Since 1987, the Ghandian-based NGO Tarun Bharat Sangh[10] has promoted reinstatement of village-scale governance, leading to re-establishment of community-based groundwater recharge techniques, increasing water availability and soil moisture between monsoons, uplifting food and economic security, freeing women from water-carrying, and bringing about repopulation of villages.

Only when ecosystems and human livelihood needs are integrated will serious progress be achieved towards sustainable management of the contiguous socio-ecological system. This entails integrating the multiple values provided by nature – monetary, cultural, inherent and other value systems held by people sharing the resource – into regulation, subsidy, planning and governance systems at all scales.

This integration is implicit in the Convention on Biological Diversity's Ecosystem Approach, to which the UK signed up in 1995. It is an ever more pressing need with rising human numbers and demands for food, water and energy, compounded by climate change and urbanisation.

Reintegration of nature into society is seen in SuDS (sustainable drainage systems) and 'green infrastructure' in urban settings, natural flood management and catchment-based water quality protection measures at landscape scale, and a shift back towards community-centred management. Further knowledge transfer is essential across all policy areas, recognising the central significance of water in securing environmental health and its capacities to support human well-being.

SECURING THE FUTURE

This brings us back to the importance of the security of water and other environmental resources for the human 'securitisation' agenda, connections not lost on the defence community. The Development Concepts and Doctrine Centre (DCDC) of the UK's Ministry of Defence takes a strong interest in resource security as a means to avert conflict and to secure enduring peace post-conflict, with natural resource stewardship and security featuring prominently and frequently throughout DCDC's *Global Strategic Trends – Out to 2040* review[11].

For the pacifist, the convergence of military thinking with an ecosystems ethos may seem bizarre, perhaps suspicious. However, it indicates an embedded understanding of human dependency on water systems and other natural infrastructure, and how collaborative stewardship can lead to positive-sum beneficial outcomes and improved security not only for the environment but for all who depend upon it now and into the future. ES

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Water security: A complex systems and governance perspective

▲ **Figure 1. Impounding the Pongola River has increased the vulnerability of traditional fisherfolk living downstream. (Source: Kevin Rogers)**

Charles Breen, Bimo Nkhata and **Duncan Hay** argue that improving water security will depend on developing appreciation for the complexity of social—ecological systems and our ability to sustain collective management.

"The Global Agenda Council on Water Security believes that only far-sighted and collective action can avert future water crises and ensure water security for communities, businesses and countries. This collective action, however, will be more successful if the diverse social and economic values that different groups attribute to water and its use are respected and reflected in their actions." (World Economic forum[1])

The quote reminds us that water security is embedded in a complex system characterised by multiple, dynamic interdependencies among resource users, and with a resource that is itself complex. If we are to become far-sighted and act collectively we must find ways of living with complexity while acting in ways that respect the diverse social and economic values the different groups attribute to aquatic resources. How might we do this?

COMPLEXITY OF AQUATIC AND SOCIAL SYSTEMS

Aquatic systems, particularly rivers, lakes and wetlands, provide a variety of ecosystem services that change across the landscape, creating a template of opportunities for people to engage in and benefit from. As people exercise their choices of which benefits to access, and where and when to do so, a complex pattern emerges among the beneficiaries. The social pattern mirrors the ecological template. It is just as heterogeneous and dynamic because not only must it adapt to the variability in the supply of ecosystem services, it is also being shaped by changing preferences and demand.

The ecological and social systems are coupled, each affecting the other, while at the same time being influenced by common factors such as climate change. In complex social–ecological systems of this nature there are so many pathways through which a disturbance may be propagated that the relationship between cause and effect can be difficult to discern, particularly when change may be suppressed in one pathway and multiplied in another, and take many years to become evident[2].

The ways in which individuals and society as a whole choose to access the benefits of aquatic systems can alter the pattern of availability of benefits such that one person's use can subtract from the opportunity others may have to access benefits. For example, choosing to store or abstract water alters the pattern of river flow, forcing change in downstream ecological systems that deliver services and the social systems that benefit from them.

EXPERIENCE OF RISK

As the social system adjusts, beneficiaries experience risk differently. Risk may be increased for a subsistence farmer who depends on annual floods to regenerate grazing for livestock, whereas an irrigation farmer may experience less risk as water availability becomes more predictable.

The spatial and temporal pattern of risk adjusts to reflect changes in the ecological and social systems. As this happens it affects the choices made, and the consequences are propagated through both the ecological and social systems to emerge later, sometimes with quite unexpected and undesirable outcomes.

This is illustrated on the Pongola River in South Africa where the floodplain provides poor households with a diversity of food and income sources, making them less vulnerable to economic and climatic shocks.

Impounding the river to support commercial agriculture, and consequent flow regulation, has led to a trend towards intensive agriculture along the floodplain, favouring some over others. While this may deliver higher returns to those who can farm, it comes with greater costs and increased vulnerability of both the ecological and social system[3] (see **Figure 1**).

The Pongola case should not be viewed as exceptional. South Africa shares its major rivers with other countries (see **Figure 2**) and water shortages already extend beyond the driest months of the year and become worse during prolonged periods of low rainfall and river flows. Social groupings – such as the under-serviced rural communities that depend on river flow for well-being – can be envisaged as going through a downward trend of resilience, where each recovery (adaptive renewal) is weaker, until a threshold is reached where government has to engage crisis management[4].

Such social–ecological systems are never stable; they are constantly adjusting to both immediate and past disturbances, some of which may take years to become evident. For management to be effective it should take account of this complexity and the associated uncertainty and be adaptive – acting, reflecting, learning, refining. It should be viewed as a way of testing understanding rather than providing definitive solutions.

The term security conveys a sense of being safe. It is an indication of how secure people feel with prospects for access to and equitable distribution of the benefits of aquatic systems. To feel secure a resource user would need to know that other resource users acknowledge his or her rights to use the resource and will defend this right if it was abused by others.

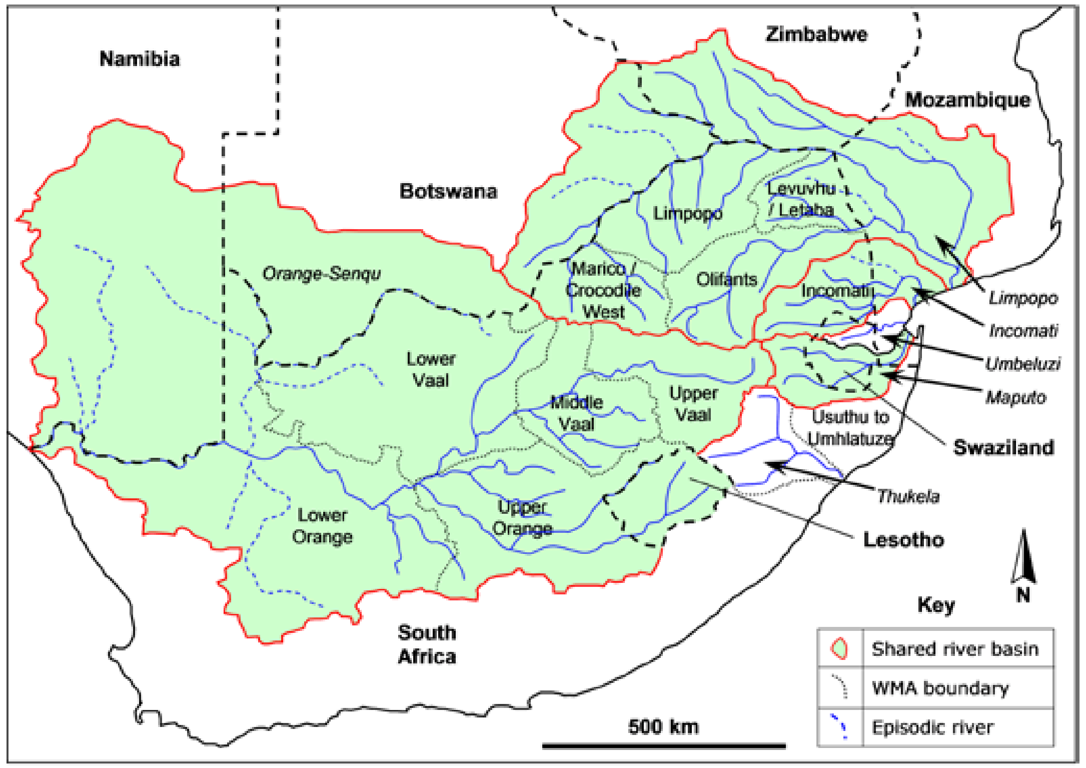
COMMON POOL RESOURCES

Because all beneficiaries are connected and need to defend rights to use and sanction abuse, they should identify with the system as a whole (the resource and resource users) and not only the benefit(s) they derive. And they should commit to sustaining a pattern of risk that is socially and environmentally just. When this happens the resource can be conceived of as being common to all, as a common pool resource.

The collective identity and social cohesion (social capital) built through the processes of identifying with the system and developing commitment provides a foundation for collective action that is necessary for managing use of common pool resources. This was particularly evident on the Rovuma River that separates Mozambique and Tanzania[5], where decreased social capital lowered the effectiveness of property rights and allowed individualistic behaviours, where it was no longer possible to exclude someone from access to the resource, and neither the methods of fishing nor the catch size were controlled. The governance system, characterised by low social capital, weak community-based governance and an open-access fishery, was not able to maintain those properties that would confer resilience.

▼ **Table 1. Bundles of rights associated with positions (extracted from Schlager and Ostrom[6]).**

Rights	Owner	Proprietor	Claimant	Authorised user	Authorised entrant
Access	x	x	x	x	x
Withdrawal	x	x	x	x	
Management	x	x	x	x	
Exclusion	x	x			
Alienation	x				



▲ **Figure 2. Map of southern Africa, showing the six river basins that South Africa shares, their South African Water Management Areas, and the main rivers and tributaries in each basin. The four shared basins examined in this study are shaded[4].**

PROPERTY RIGHTS REGIME

A defined property rights regime is necessary to provide the means for social coordination and ordered rule in the delivery of aquatic ecosystem services. It is needed to provide direction and to guide the energies of society members towards the common good. It provides the means for negotiating, constructing and ultimately defining the common good which the state must then secure. It also provides the means of resolving trade-offs in order to establish the common good.

Clearly defined property rights are used by society to guide the relationships among users, managers and policymakers as they go about articulating their interests, meeting their social obligations, and mediating their differences. In this way, they evince the nature and substance of the interactions among social actors in the delivery of aquatic ecosystem services

ESTABLISHING EFFECTIVE PROPERTY RIGHTS REGIMES

Although all common pool resource systems have the same generic properties, each is unique in its attributes of supply and demand for ecological services. At the scale of nations the attributes of supply and demand are quite different from those at the scale of floodplain such as the Pongola or Rovuma considered above. So, while we can establish general principles to guide us, application must be customised to service the particular situation and be responsive to emergent conditions. Schlager and Ostrom[6] suggested seven general guiding principles:

- the boundaries of the system (linked social and ecological system) should be clearly defined – in terms of the resource and who has legitimate rights to access, use and participate in management;
- there should be proportional equivalence between benefits and costs associated with accessing ecosystem services – costs associated with use should be internalised, and return must make it worthwhile to invest in sustainable use;
- those affected by the rules that regulate use should be included in the process of establishing the rules – governance should be inclusive and participatory;
- resource use, user behaviour and its consequences should be monitored – monitors (including government) should be accountable to the users or be the users themselves;
- graduated sanction should be imposed – there must be effective means to sanction those who abuse the rules governing access and use;
- there should be dispute resolution – this should be convenient, affordable and efficient; and
- rights to self-organise should be recognised – resource users should have the right to devise their own institutions with minimal interference.

We can see that these principles are generic and can be applied at all scales from international to local.

Property rights regimes can be characterised by the rights holders and their rights (see **Table 1**). We can illustrate this with a public impoundment. Government, as the owner, would have a bundle of rights such that it can control access, withdraw rights allocated to others, make and implement management decisions, exclude users, and alienate the resource for particular purposes. By contrast a fishing club that has been granted the rights of fishing would be able to control access to fish, withdraw rights from those who abuse the right to fish, manage the fishery, and exclude those considered to be undesirable. A visitor who is granted access has no authority to withdraw right, make management decisions, or alienate the resource for other purposes.

COLLECTIVE MANAGEMENT

The rights regime brings order and incentive for collective management. When there is no mechanism to regulate who has rights and what those rights are, it opens opportunity for individuals to take advantage, leading to use that is not sustainable, as shown for the Rovuma River. And, when we are unaware of rights that users may have, sometimes established over generations, we make decisions that can have unintentional consequences that are of considerable significance, as illustrated (see **Figure 2**) for the rivers South Africa shares with its neighbours.

Managing the use of common pool resources requires that all resource users understand, agree to and support the apportionment of rights to access and use ecosystem services. In other words, agencies have to implement a property rights regime in which users are granted rights and responsibilities that encourage self-regulation within the parameters set by the government that owns the resource on behalf of the people. It is government's responsibility to establish the formal institutional arrangements for governance, while the various user sectors are responsible for establishing the informal institutional arrangements necessary for self-regulation. The success of formal institutions such as national policy and regulation is strongly dependent on how effective informal institutions are in ensuring compliance.

This understanding encourages us to appreciate that natural resources, especially common pool resources such as water, are situated in complex social–ecological systems. Exposing the feed forward and backward loops and emergent properties enables learning about likely consequences of allocation decisions for system resilience. It also encourages us to seek fundamental solutions while addressing the increasingly urgent symptoms. Importantly, exposing the dynamic connectedness between the subsystems encourages appreciation that resilience can be achieved only when we incorporate robust, informed dialogue in governance, directed at trade-offs in access to and use of our increasingly scarce natural resources[4]. **ES**

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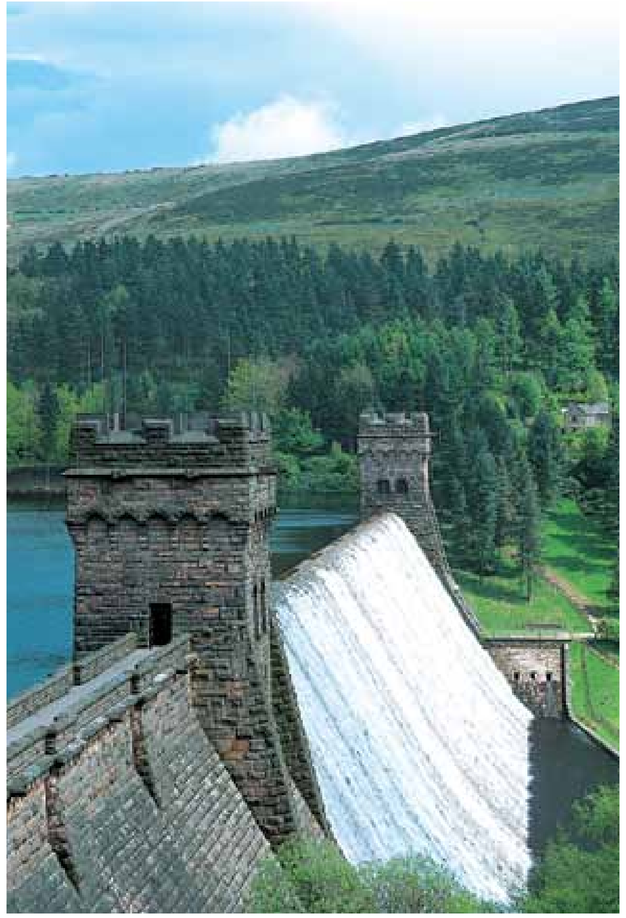
Urban water security as a function of the 'urban hydrosocial transition'

Chad Staddon and **Sean Langberg** introduce the concept of urban hydrosocial transition as a way of thinking about the complex and changing relationship between cities and water services, and present a brief case study of Bristol, UK, to illustrate the concept.



▲ **Figure 1. Ladybower Reservoir: early hydromodernity in England's Peak District. (© Severn Trent Water, used with permission)**

The development and extension of water services infrastructure has been a key foundational element of industrialisation and urbanisation since at least the 'Great Sanitary Awakening' of the mid-19th century. As urban areas became both larger and more densely inhabited, the collective need for better water services (drinking water and sanitation in particular) became overwhelming. Cities simply could not grow beyond a certain relatively modest size without the simultaneous articulation of an integrated water services infrastructure to replace the piecemeal local arrangements then in place, a reality amply demonstrated by Dr John Snow's intervention during the 1854 cholera epidemic in London. The mid-20th century completion (in Europe, North America and parts of Australasia) of the resulting project of mass provision of standardised water supply and sanitation services, elsewhere called 'hydromodernism'[1], was then followed by several waves of restructuring in the water-services value chain, based particularly on new ideas about the respective roles of the public and private sectors, new technologies and the water needs of the natural environment.

Of course, in much of the developing world, even hydromodernism is as yet unattained and perhaps unattainable. In addition, rapid urbanisation in many developing nations has gone hand in hand with the growth of what are called peri-urban areas that combine urban and rural characteristics and present new challenges to water (and other) services provision[2,3]. Despite concerted international efforts in recent decades, there are still at least a *billion* people in the developing world without adequate access to basic water services. A typical pattern, exemplified by Kampala, Uganda, involves a very limited extent of piped drinking water and sewerage interconnection to urban households (hydromodernism), with the vast majority depending on expensive private water sellers, local water collection (often undertaken by children), and defecation in pit latrines or in the open. Dr Snow would be horrified by the high level of water services insecurity prevailing in many 21st-century cities.

Fortunately there is a way of easily presenting the historical progression from a low level of water services to a higher level. Cities around the world can be understood from the point of view of their location within the 'urban hydrosocial transition' (UHT), a historical geographical framework that sees cities as manifestations of successive 'hydrosocial contracts' between agents of economic, political, cultural and technological change. This concept builds on work undertaken by Brown and Morrison[4] on 'water-sensitive cities', Lundquist *et al.*[5] on the 'hydrosocial contract', Swyngedouw[6] (2005) on 'urban metabolism' and Thapa *et al.*[7] on 'water security indices'. A key innovation offered here is the simplified three-part historical geographical schema based on a limited number of readily available key indicators.

Here the UHT is introduced as a way of thinking about the complex and changing relationship between cities and water services. In addition to permitting observers to place any given city on a comparative continuum of hydrosocial development, the concept also suggests likely hydrosocial development futures. The salience of the UHT concept is illustrated through a brief case study of Bristol, a middle-sized city.

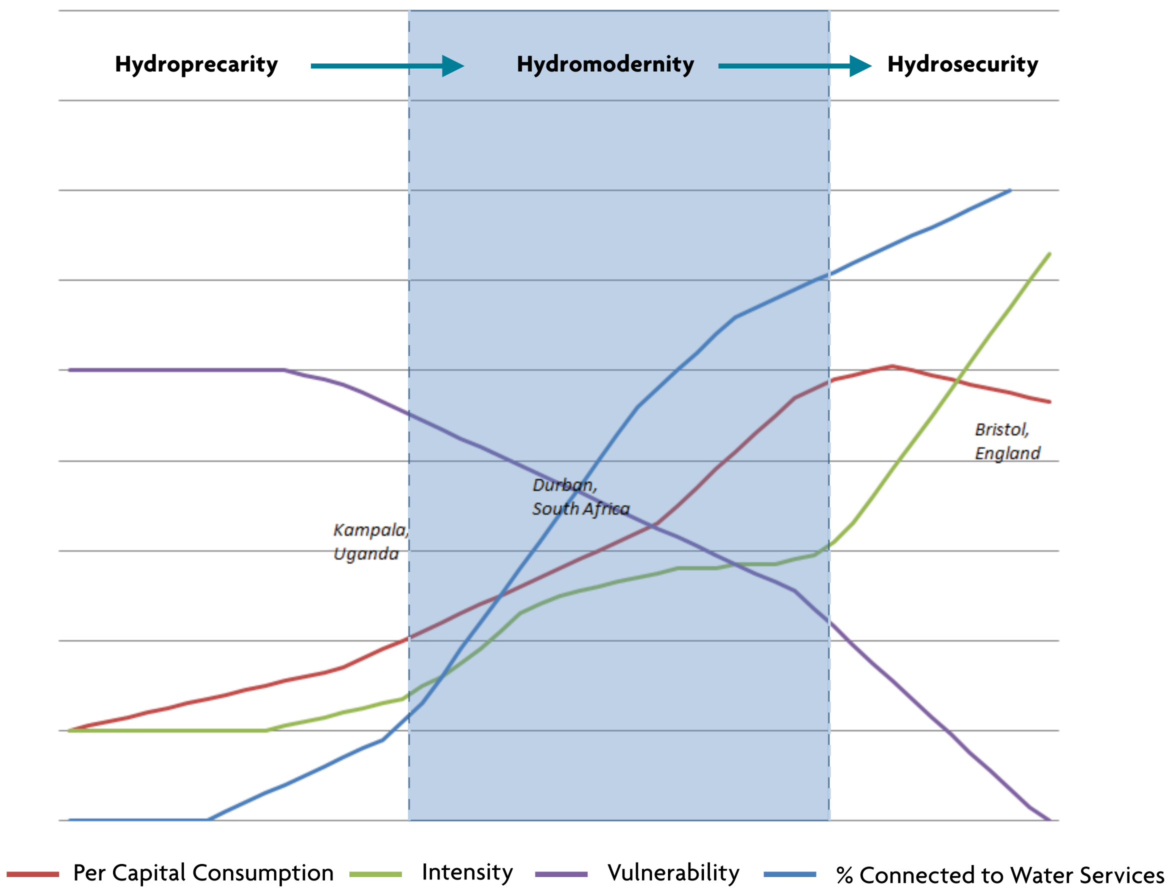
THE URBAN HYDROSOCIAL TRANSITION

We are used to the basic idea that different sorts of services or conditions go through stages and this is essentially what the UHT model proposes. It postulates that all cities can be located within a three-stage broadly historical transition from an early phase, called 'hydroprecarity', through a middle phase – hydromodernity, towards a contemporary phase, called 'hydrosecurity'. This is not to say that cities must move through these phases at the same rate, or even that they cannot evoke characteristics of multiple stages – indeed a certain hydrosocial hybridity definitely characterises many developing world cities.

Without sufficient space here to explore underlying drivers of hydrosocial transition (something we are currently working on), we must restrict our attention to empirical description of the model. There is a useful synergy here with Thapa *et al.*'s[7] contribution to this issue on water security indices, inasmuch as they may offer one concrete way of characterising numerically the different phases of the UHT. They focus on four key performance indicators: percentage served by piped water supply, percentage served by wastewater systems, annual damage due to flooding (an indicator of poor drainage) and measure of urban environmental quality. To these we propose adding the following indicators:

- daily per-capita water consumption; and
- a measure of capital intensity in water services provision.

The first of these measures relates to the fact that the transition from Phase 1 to Phase 2, hydromodernism, meant that householders could start to develop new uses for piped water, such as more fixtures and fittings, dish and clothes washers, and a taste for more water-intensive landscaping. **Figure 1** shows the sorts of large-scale infrastructure associated with hydromodernism. Such uses go well beyond merely providing personal hygiene and hydration, accounting for perhaps 40–50 per cent of current per-capita per-day domestic consumption.



▲ **Figure 2. The urban hydrosocial transition.**

By Phase 3 per-capita daily consumption starts to reduce as a function of growing conservationist views, both on the part of householders (who change water behaviours) and their governments (who bring in new rules to regulate for water efficiency in the built environment), and a shift towards water efficiency, particularly with respect to pressurised and hot water use (as these both require additional energy which is disproportionately expensive). Capital intensity in water services has been growing since we stopped just collecting water from open water sources and looks set to continue to grow, with the recent implementation in the UK of expensive UV treatment, ozonation, and granular activated carbon treatment to provide for only modest increases in water quality security. In Phase 3, water intensity in both the productive and domestic spheres also rises, partly as a function of an emergent biocentric conservation ethic, but also because regulation of abstractions and discharges (see this issue) becomes progressively tighter and the energy needed to move, pressurise, treat and heat water is rising disproportionately.

On our reading, Thapa *et al.*'s variable 'damage due to flooding' could usefully be recast as an indicator relating to overall resilience of the water services network to all sorts of challenge, including drought as well as flooding.

Figure 2 brings several of these variables together into a pictorial representation of the three phases of the UHT. It shows that Phase 1, hydroprecarity, is characterised by a low, but rising, proportion of the population covered by piped water supply and sewerage and the concomitant rise in both absolute as well as per-capita consumption. As urbanisation increases, a point is reached where absolute consumption begins to accelerate faster than per-capita consumption, largely due to the ways in which we conceive, build and maintain urban environments during the second, hydromodernist, phase. Moreover, there is an inevitable lag between the technical and administrative possibility of greater domestic water use and its reality, linked to the slow progress of replacing pre-existing urban fabric.

Put another way, in the UK, replacing crowded urban dwellings of the late 19th and early 20th centuries with the larger, more suburban dwellings of the mid and late 20th centuries takes considerable time. By contrast, in the USA and Canada, where many cities were urbanising 'from scratch', and space was less constrained, this process was much quicker. In all cases, however, a point is eventually reached where both per-capita and absolute water consumption actually start to decrease and water intensity, at home and in the economy, continues to rise. Simultaneously the capital intensity in water services undergoes a rapid acceleration, largely as a function of the need to guarantee the continued operation of the system in any context or weather. This heralds the arrival of Phase 3, hydrosecurity.

The UHT model is intended first and foremost as a descriptive model, allowing urban water services managers, planners and scholars to see where, on the general historical geographical development path, a given city or urban region may be located. This knowledge can then be used to predict future development paths and challenges, subject to two conditions.

First, it is likely that, as with other forms of urban infrastructure, urban hydrosocial systems not yet in Phase 3 could accelerate their arrival through state policy and massive infrastructural investment. There is even the possibility of stage jumping, again if there is the right combination of state policy and capital investment. Several cities in the Persian Gulf region have done exactly this, moving from Phase 1 to Phase 3 in little more than a generation.

Second, we do not suggest that the UHT model describes all possible variables of interest to the story of urban water services provision. Rather, we have designed the model with a view to incorporating quantitative variables that should be relatively easy to acquire in most jurisdictions. The following case study should highlight empirically the key features and insights offered by the UHT model.

THE URBAN HYDROSOCIAL TRANSITION IN BRISTOL

▲ **Figure 3. St. Mary Redcliffe church (© Lukas Blazek)**

Prior to the attempt to create a mass water services system from the mid-19th century onwards, the only water supply for which Bristol civic leaders took responsibility was the pipe from Knowle to St Mary Redcliffe church, (see **Figure 3**) which had been originally installed by Robert de Berkeley in the 12th century.

FEATURE

FEATURE

Some neighbourhoods had developed their own very local systems, but as late as the early 19th century there was neither a public commitment nor the necessary technical infrastructure to create a comprehensive water supply and sewerage system. This systematic water services infrastructure was initiated in 1846 when the Bristol Waterworks Company (now Bristol Water) was created to develop and manage a uniform public drinking water supply network for the burgeoning city.

Currently Bristol Water supplies customers with approximately 300 megalitres (ML) of drinking water per day, drawn largely from two sources: the Sharpness Canal, and the Chew Valley and Cheddar Reservoirs to the north and south of the city respectively. The main Bristol sewage treatment plant, located at Avonmouth and operated by Wessex Water (see **Figure 4**), treats most of the sewage generated by the city of Bristol, approximately 210 ML of it each day. Plant upgrades and sustainability-orientated changes to the treatment process mean that it now transforms that sewage into its own power (through biogas recovery), agricultural fertiliser (which is given away virtually free of charge) and clean water for release back into the natural environment according to the terms of its licences with the Environment Agency.

From the point of view of the UHT the key things to notice are as follows. The shift from Phase 1 to Phase 2 was largely completed by 1900, when virtually 100 per cent of the urban population had some form of reliable water supply, sanitation was considerably improved and water services companies had become vertically integrated entities. Both direct measures (percentage population served) and indirect measures (health outcomes and disabilty-adjusted life years) bear this out. The transition from Phase 2 to Phase 3 was manifest in the 1990s when the emphasis began to clearly shift from 'more water from further' (to use Barraqué's[8] felicitous phrase) and 'more hard engineering' to more attention to behaviour change, efficiency and the environment.

The key drivers of business strategy for both water services companies are now firmly linked to environmental sustainability, horizontal integration with other synergistic services sectors, and water demand management. Strikingly both companies are now far more interested in encouraging consumers to use less of their services than they are in simply building more capacity to accommodate increasing demand. We are a long way from the 'more water from further' approach characterising the first phase of the UHT. Wessex Water, which provides sewerage services to Bristol and both water supply and sewerage to much of Bristol's hinterland, has trialled various smart metering and differential water tariff programmes with customers in its service area to see if they can realise cost-effective demand reductions. Both companies have invested heavily in improving infrastructure resilience to handle extremes of both flood and drought, which seem to be occurring with greater frequency than in the past.

CONCLUDING COMMENTS

In retrospect it is perhaps unsurprising that urban water services manifest common and predictable historical geographical development trends. It would perhaps be stranger if it were not the case. After all, technological innovations in, for example, wastewater treatment are transmitted through professional networks with ever-increasing speed, and, as we have seen, the hydrosocial contract has evolved slowly from an initial inkling that there was a role for the public sector in addressing water-related illnesses such as cholera in the 19th century through a period of industrial massification of water services towards the current phase of both greater democratic localism and environmental sensitivity.

The UHT is, however, not temporally lock-step or completely uniform; different places have experienced their own versions of each of these three phases at somewhat different times. The extent to which any particular local expression of one of its phases marks an improvement in water security depends upon, as Breen *et al.*[9] put it in their contribution to this issue, "how secure people feel with prospects for access to and equitable distribution of the benefits of aquatic systems". Further, as Breen *et al.* show us within this issue, such systems may provide more than drinking water and sanitation services; food, irrigation, transport, recreation and even spiritual reward may also be possible. ES

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▼ **Figure 3. Avonmouth Wastewater Treatment Works: beyond the 'engineering paradigm'. (© Chad Staddon)**

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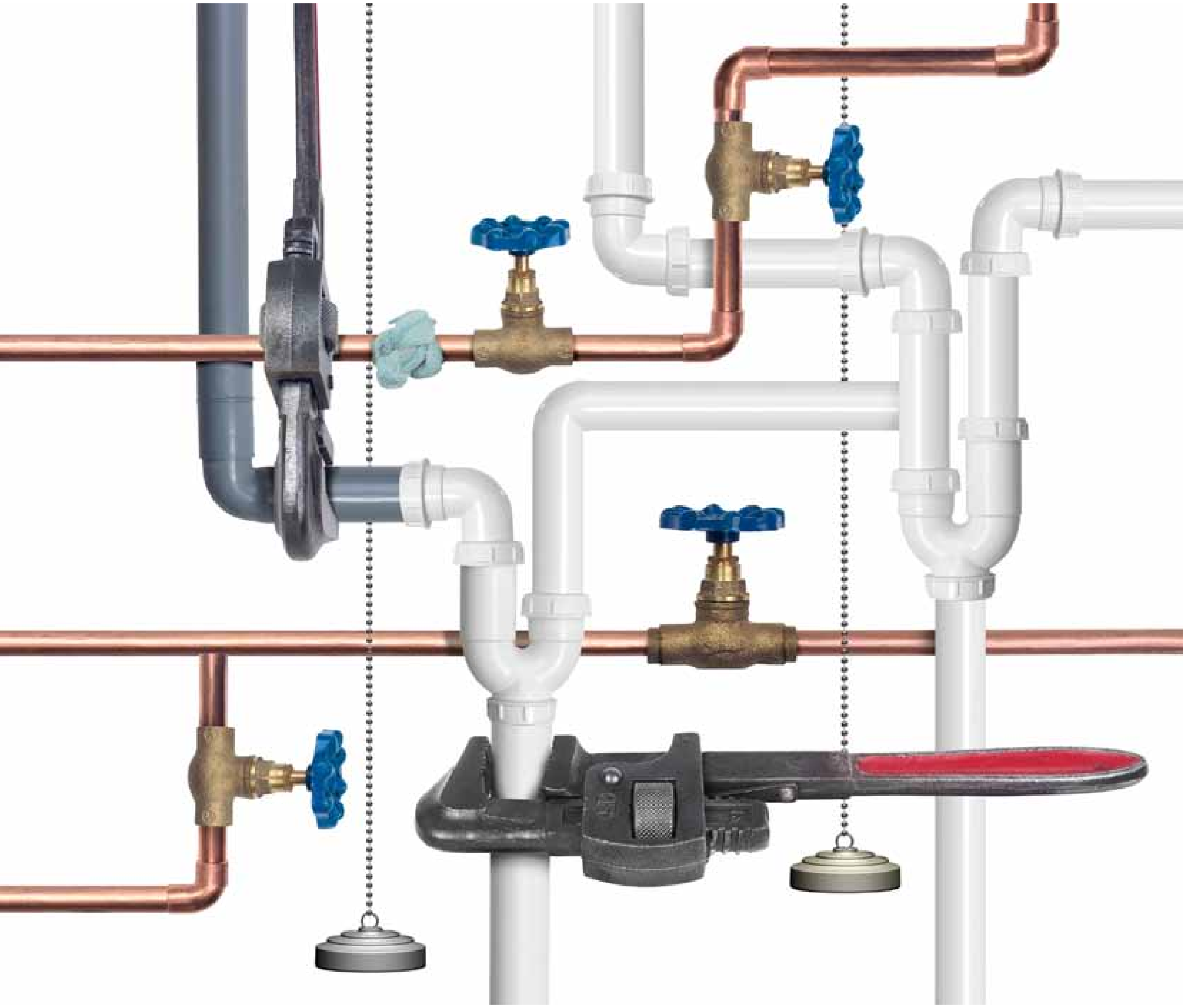
Urban Water Security: LCA and Sanitary Waste Management

Hazem Gouda describes a case study that aimed to reduce sanitary waste disposal via WCs and used life cycle assessment to assess the various reduction strategy options.



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CASE STUDY

A water-secure world is one where everyone has access to safe, affordable water, protected from floods, droughts and water-borne diseases. Urban water security means that urban water systems should not have negative environmental effects, even over a long time perspective, while providing required services, protecting human health and the environment, and minimising the use of scarce resources.

FLUSHING OF SANITARY WASTE PRODUCTS

The flushing of sanitary waste (SW) items via water closets (WCs) has undermined urban water security in a number of developed countries. The presence of WCs and fully sewered systems has eased the disposal of a range of items, with the WC being used as a 'rubbish bin'. Sanitary waste items disposed of via the WC comprise female sanitary items including sanitary towels, panty liners, tampons and applicators, and general bathroom refuse such as cotton buds, baby wipes and condoms.

An investigation of people's opinion about the disposal of SW items has shown that the practice of flushing is due to convenience and perceived hygiene. In the UK it is estimated that about 700,000 panty liners, 2.5 million tampons and 1.4 million sanitary towels are flushed via the WC every day. The total contribution of SW to total sewer solids load varies and depends on water supply, cultural habits, way of life and level of development.

SW causes technical problems for the sewer network (e.g. deposition and blockage) and aesthetic problems when the waste finds its way through the combined sewer overflows (CSOs) in combined sewer systems. The CSOs normally operate when the sewer system is running under full capacity during heavy rainfall storms; then the wastewater will be released to the aquatic environment. In the UK about 70 per cent by total length of sewerage systems are combined, and these systems typically have CSOs.

CASE STUDY: LIFE CYCLE ASSESSMENT AND SW MANAGEMENT

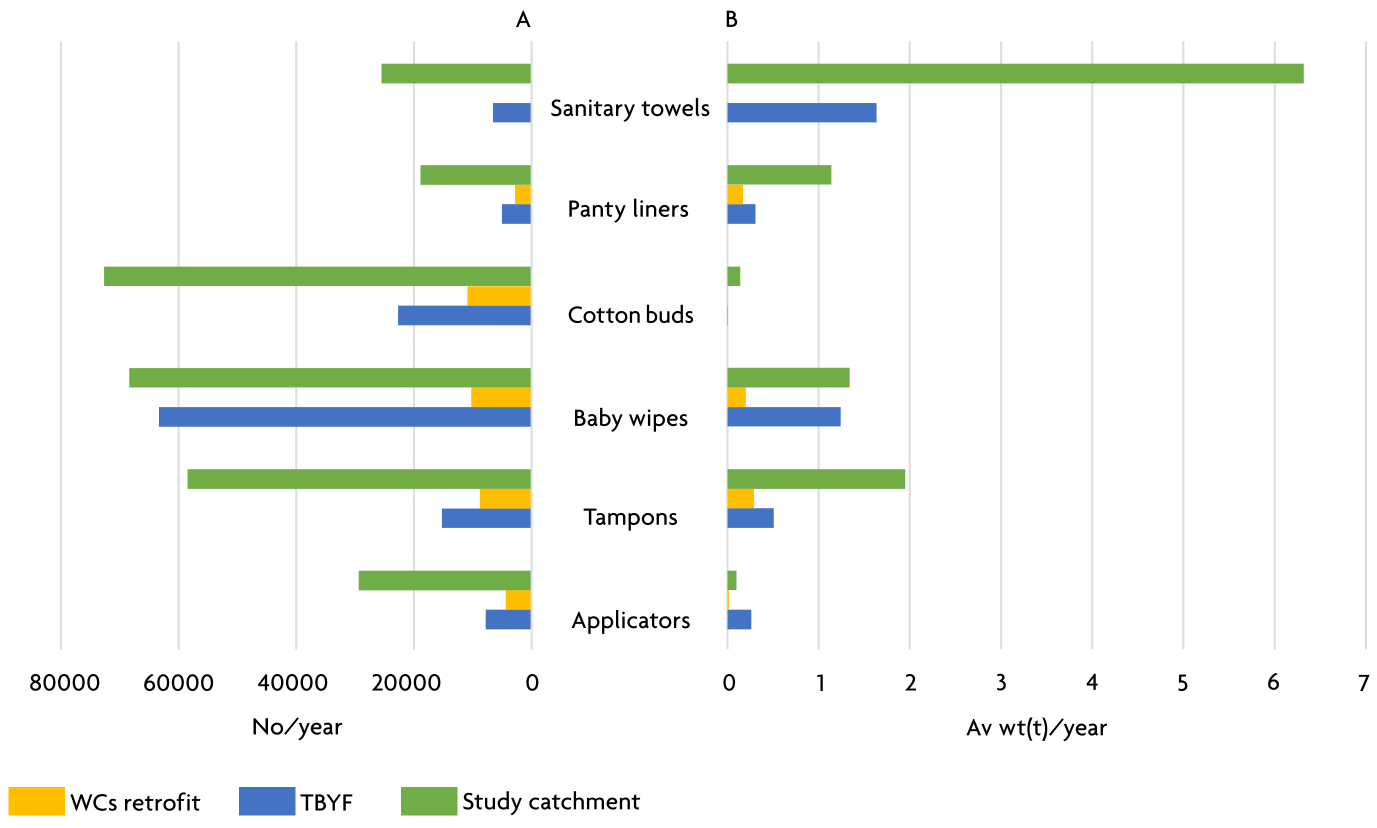
The case study presented in this article addresses SW management and actively presents solutions that address the challenges to urban water security. The case study has been carried out under the SWARD (Sustainable Water industry Asset Resource Decision) project funded by the UK Government and the UK water industry. The case study demonstrates a wide variety of efficient and effective strategies for reducing SW disposal via WCs.

The study has estimated the amount of SW that enters the sewer systems for a catchment in Scotland. A detailed hydraulic model was used to simulate the flow in the sewer system and estimate the annual amount of SW escape to the aquatic environment from CSOs and sewer overflows (SOs) during heavy rainfall storms.

The data from the hydraulic model are needed for the life cycle assessment (LCA) component of the study. LCA is a technique that can be employed to determine energy, mass flows and environmental burdens for a number of sewer-related options for handling SW. LCA can help to direct decision-makers

▼ **Table 1. Options for the management of sanitary solids**

Option	Measure	Primary objective
1	Install 6 mm screens on storm overflow at WTP	To screen storm overflows to constrain solids larger than 6 mm or equivalent to comply with minimum aesthetic pollution requirements for discharges
2	'Think before you flush' campaigns	To encourage a change in domestic disposal habits to dispose of sanitary solids via the bin rather than the WC
3	Install flow storage	To reduce the frequency and volume of overflow spills, thus reducing the number of SW items discharged to the environment
4	Retrofit stormwater source control	To reduce stormwater entry to the sewer system, thus reducing the frequency and volume of overflow spills
5	Sewer rehabilitation	To limit infiltration to the sewer system, thus reducing overflow spill frequency and volume
6	Retrofit outlet chokes on existing WCs and introduce these to new building developments	To force a change in disposal habits from using the WC to using the bin through the increased possibility of WC blockage in the home



▲ **Figure 1. Fushing profiles for study catchment, think before you flush (TBYF) campaign and retrofit campaign showing (A) Number flushed/year (B) Average weight (t)/year of sanitary waste.**

towards the more sustainable/preferred investment solution, and the transparency of the process can help demonstrate to stakeholders that decisions made are as environmentally sound as possible. LCA is one of the tools commonly in use for products and services to assess the environmental impacts on *environmental* systems and/or compare energy use, pollutant emissions and impacts between proposed alternatives.

CATCHMENT DESCRIPTION AND MANAGEMENT OPTIONS

The case study presented here was conducted as part of a EPSRC-funded project that developed a decision support system to assist water service providers to include sustainability in their asset management planning processes. Six proposed options used in the case study for the management of SW are presented in **Table 1**.

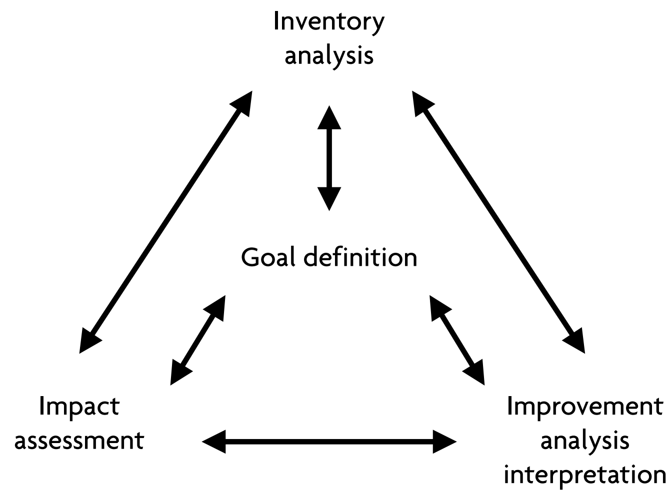
The catchment is located on the coast of Scotland and has 626 domestic properties with a population of about 1,500. The 'system' is formed by the sewerage system from the household WC to the wastewater treatment plant (WTP) and its outfalls. The catchment isserved by 80 per cent combined sewers and 20 per cent surface water sewers. The network has an internal CSO, a storm outfall at the treatment plant and an emergency outfall.

SW ENTERING THE SEWER SYSTEM

The amount of SW that enters the sewer system was estimated based on population, number of women and their age, and number of babies in the town. Data regarding the average number of items used per person per day were available from the surveys conducted prior to the 'think before you flush' (TBYF) campaign.

▼ **Table 2. Population data**

	Women aged 18–59	Women aged 12–17	Children 0–4	Total population
Total No.	426	35	69	1516



▲ **Figure 2. Interactions between LCA stages.**

The population data presented in **Table 2** were obtained from the census that represents the catchment at the time of the study. The profile of the SW entering the system for the study catchment is shown in **Figure 1**.

THINK BEFORE YOU FLUSH CAMPAIGN

The TBYF campaign was run in the catchment along with collection of social survey data. The survey data from running the campaign (option 2) shows a reduction of 65–70 per cent in the total amount of SW entering the system. The SW input data from the TBYF campaign, shown in **Figure 1**, has been used for this option or when it is combined with any other option.

RETROFITTING TO CONSTRICT WC OUTLETS

For the retrofit option (6) it is assumed that, although sanitary towels will not be flushed, 15 per cent of certain other SW items will still be flushed, resulting in 681.435 kg of SW entering the system per year, as shown in **Figure 1**.

The SW profile data for each option was used along with the detailed hydraulic model to estimate the total weight of SW escape from the sewer system to the aquatic environment via CSO/SO.

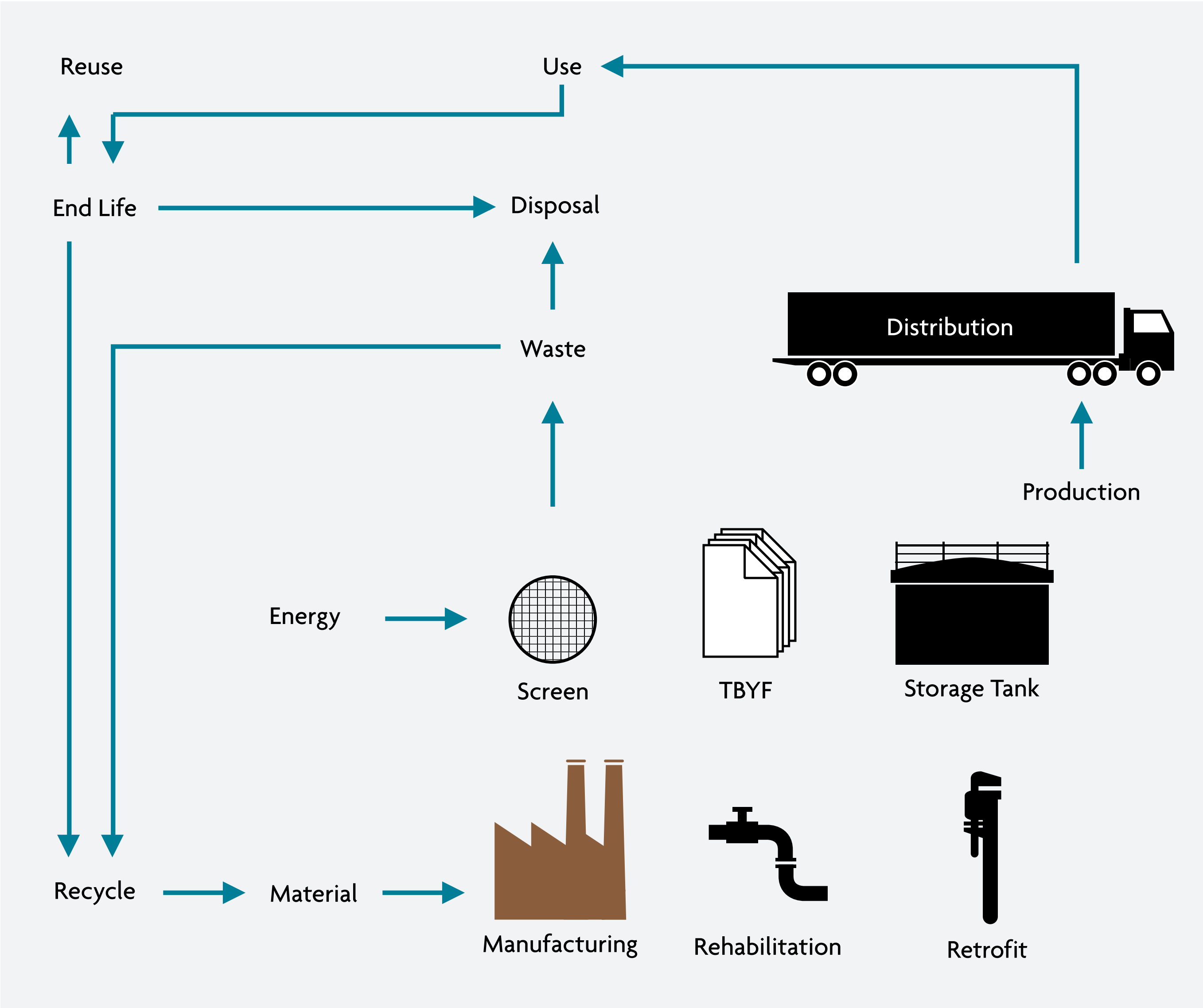
LIFE CYCLE ASSESSMENT

LCA is a technique involving cradle-to-grave analyses of production systems or services and provides comprehensive evaluations of all upstream and downstream energy inputs and multimedia environmental emissions. The International Organization for Standardization outlined the methodological framework for conducting LCA in four phases: goal and scope definition, inventory analysis, impact assessment, and improvement analysis and interpretation. The interactions of the four main LCA phases are represented diagrammatically in **Figure 2**. The study has been carried out in order to evaluate the environmental consequences of six different alternatives for SW management for a particular catchment. The goal of the study was to evaluate the resource consumption, pollutant emissions and the consequential environmental impacts of alternative SW management options and scenarios during their operation period, in a European context. The boundaries that are set for the options must be identical if a comparison is to be considered. In this study the materials, energy, natural resources, transportation, use and disposal were analysed.

Table 3 gives an overview of the material used for the SW management options. Data from specific manufacturers of the products implemented for each option and data from the SimaPro database were utilised where data for the specific process were not available. Waste streams are generated at each phase of the life cycle and waste management, including the mechanisms for treating, handling and transport of waste prior to release into the environment. Sensitivity analysis was carried out for the waste scenario for the different options. The main life cycle stages include three phases and their related boundaries are shown in **Figure 3**.

LCA RESULTS

The environmental indicators selected for this case study included carbon dioxide (CO_2), sulphate (SO_4), nitrogen oxides (NO_x) and sulphur dioxide (SO_2) emissions and energy use. The results are presented in this section according to the functional unit, which is emissions per kilogram of gross solids reduction



▲ **Figure 3. The elements of life cycle inventory analysis for proposed options.**

▼ **Table 3. The material components used for each of the options.**

Option	Component
1. Screen	6 mm rotary drum screen at storm outfall made of stainless steel.
2. TBYF	Paper leaflets, questionnaire and posters.
3. Storage tank	Concrete tank to store 1100m3 of water.
4. Rainwater barrel	Plastic barrels: total of 219 barrels made of polythylene.
5. Rehabilitation	Replace 300 mm, 450 mm and 600 mm concrete pipes. Total pipe length 87m.
6. Constricting toilets (WC)	Replacing toilet outlet connection with smaller plastic pipes (75 mm dia.) and cistern-flushing valve to 3 L/flush.

▼ **Table 4. Emissions values per kg gross solids reduction for proposed options**

	Option	SW Escape reduction	Greenhouse gas kg CO_2 equ.	Acidification kg SO_4 + equ.	NO_x kg	SO_2 kg	Energy MJ
1	Screen	95%	8	0.2067	0.0092	0.1764	127.07
2	TBYF	66%	0.56	0.0026	0	0	11.79
3	Storage tank	51%	136	1.7188	1.7097	0.3155	1282.27
4	Rainwater barrel 35% roof surface control)	17%	16	0.0972	0.0080	0.0136	471.32
5	Rehabilitation (infiltration reduction 42%)	35%	4	0.0200	0.0106	0.00098	53.10
6	Retrofit	94%	2.3	0.0296	0.0153	0.00322	73.16

for the proposed options. **Table 7** illustrates the SW results from the hydraulic model for each option and the relevant environmental emissions per kilogram of SW prevented from escaping to the environment during its life cycle.

The results show that the storage tank has the highest environmental emissions and energy use among all studied options per kilogram of SW prevented from escaping to the environment. The TBYF option gives the lowest energy use and environmental effect as it has the lowest score among all studied options, followed by rehabilitation and retrofit constricting of WC respectively.

CONCLUSION

LCA has been used to suggest improvements to the way in which SW is managed in urban drainage systems and addresses the challenges to our urban water security. The results from the SW case study have indicated that the option of changing user habit can significantly reduce the items flushed down WCs and hence reduce the total amount of SW entering the system.

The LCA results show that the TBYF campaign option, which is related to habit change, has the lowest environmental impact per kilogram of SW prevented from entering the sewerage system. However, one of the critical aspects is the lifecycle of the sanitary product itself. It should be possible to design products which have a strong likelihood of being disposed of via a WC in such a way that they degrade appropriately and can be appropriately dealt with by the sewage undertaker.

This involves the designers of sanitary products liaising closely with sewage undertakers in the design and procurement phase of their products. Hence, the way forward towards a secure urban water system is to manage SW in a sustainable way by encouraging behavioural change to stop the flushing of such items and design degradable products. ES

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▲ Figure 1. View from Avonmouth dock. (©Thomas Appleby).

Return to Eden: management of an inshore and intertidal marine environment

Tom Appleby examines the consenting regime for The Bristol Port Company's proposed container port extension.

The United Nations definition of water security sets out its broad ambit:

"the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability"[1]

Realising water security therefore requires a range of legislative tools and, given the Water Framework Directive's coverage to one nautical mile seaward, covers a wide variety of aquatic environments. This work examines the effectiveness of the Habitats Directive at preserving aquatic and intertidal ecosystems in the face of a major infrastructure project.

In 2008 The Bristol Port Company (TBPC) submitted ambitious proposals for a deep-sea container terminal at Avonmouth to berth ultra-large container ships (see **Figure 2**). The proposal included the loss of a small area of intertidal habitat from within Natura 2000 sites protected under the Habitats Directive[2], the alteration of approximately 80 hectares of intertidal mudflat, which would affect seabed dwelling communities and the (potentially temporary) loss of 60 hectares of intertidal area to waders and waterfowl[3].

In his Autumn Statement of 2011 the UK Chancellor of the Exchequer George Osborne announced: "We will make sure that gold-plating of EU rules on things like habitats aren't placing ridiculous costs on British businesses"[4]. But when Defra reviewed the application of the Habitats Directive in 2012 it found "that in the large majority of cases the implementation of the Directive[s] is working well"[5]. The TBPC application was reviewed as part of that process, and as an influential project it is worth further exploration. (For another case study in the application of the Habitats Directive, see Barham (2003)[6].

BACKGROUND

The Habitats Directive is certainly one of the most powerful pieces of environmental law currently on the statute books. Its core aims are exceptionally high. Though there are nuances, in lay terms sites protected by the Habitats Directive may not be developed if there is an adverse impact on the site's conservation objectives unless there are imperative reasons of overriding public interest (IROPI), there is no alternative and there is compensatory habitat created as part of the development (see article 6 of the Habitats Directive).[7]

IROPI is only generally available if there are no priority habitats or species (though even then IROPI may still then be claimed for human health or public safety). Also, technically, the IROPI statement needs approving before a move for compensatory measures can be made. In reality they are usually done together but compensatory measures cannot be agreed until the IROPI has been approved. The exact nature of the compensatory measures, given the geographical conditions of an area, can also be an important area of discussion. There are 1,161 Natura 2000 sites in the UK, and marine sites cover an area of nearly 74,000 km^2, just under 10 per cent of the UK's exclusive economic zone. Many of these sites are in the inshore marine, estuarine and intertidal areas.

THE TBPC APPLICATION

On 22 July 2008, First Corporate Shipping Limited (the holding company for TBPC) submitted a formal application to the Department for Transport for a Harbour Revision Order to permit the creation of a deep-water container terminal at Avonmouth on the River Severn under the Harbours Act 1964. The Harbours Act requires compliance with the Environmental Impact Assessment Directive[8] and the provision of environmental statements. In addition to environmental statements the Secretary of State for Transport, having decided that the project would have a significant effect on the Severn Estuary Special Area of Conservation (SAC) and Special Protection Area (SPA), also submitted the project for appropriate assessment[9] in compliance with

▲ Figure 2. Existing foreshore at Bristol & the proposed terminal. (© The Bristol Port Company)

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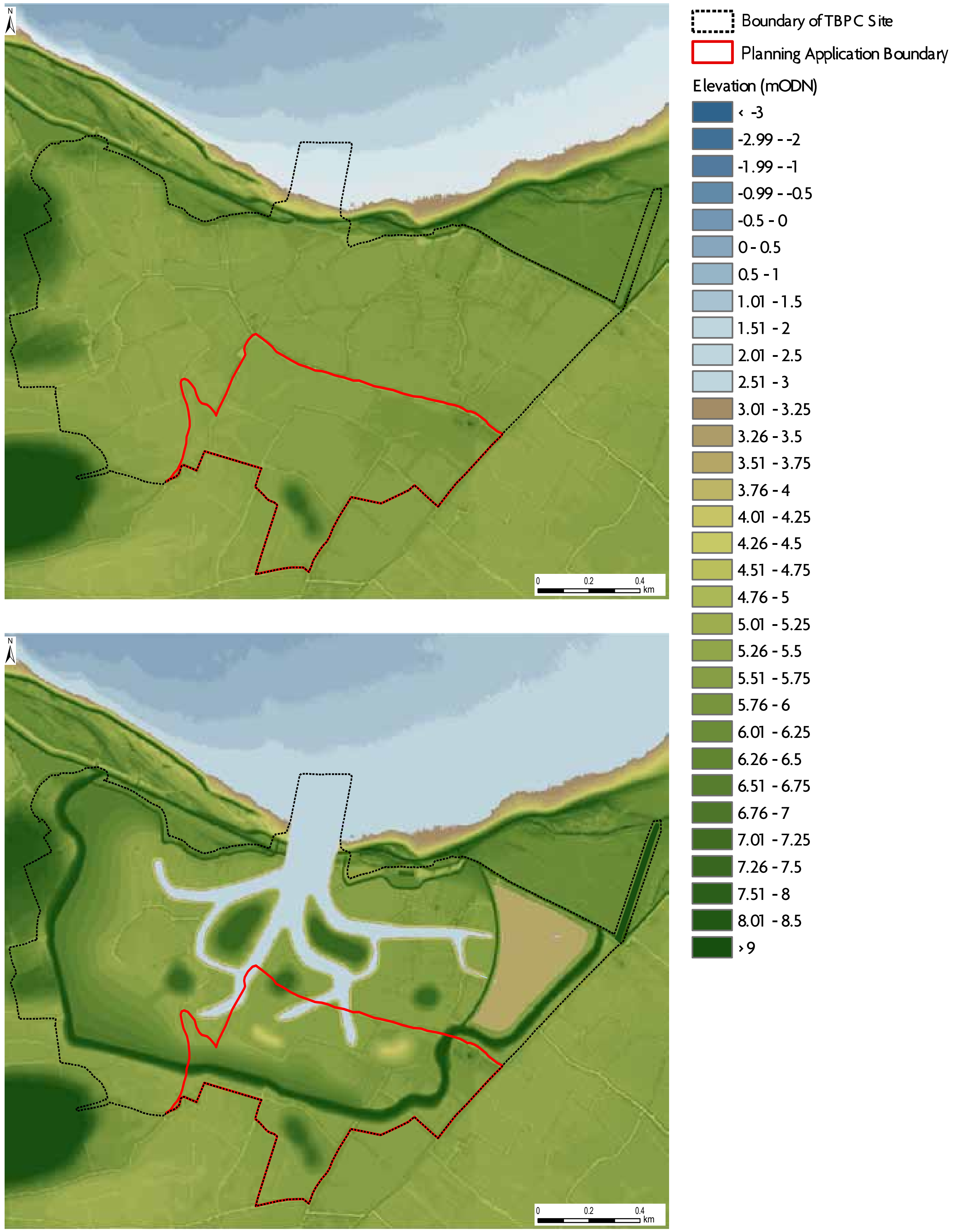

▲ **Figure 3. 3a Current topography of the TBPC Steart Habitat creation site 3b Future topography of the TBPC Steart Habitat creation scheme. (©ABPmer)**

the Habitats Regulations[10]. On the advice of both Natural England and the Countryside Council for Wales (since the potential impact was cross border) the Secretary of State found that it "cannot be ascertained that the project would not"[11] adversely impact on the integrity of the Severn Estuary Natura 2000 sites; and consequently noted the following potential impacts:

- permanent loss of a small area of intertidal habitat from within the SPA and SAC;
- the alteration of conditions that support seabed-dwelling animal communities within an area of approximately 80 hectares of intertidal mudflat due to increased accretion; and
- a resultant reduction, that could be temporary, in available feeding resources for waterfowl and waders, within the above intertidal area, of approximately 60 hectares of intertidal area due to potential changes in seabed life.

The Secretary of State was satisfied that there were overriding reasons of public interest to justify the port development going ahead, and this included looking at alternatives and commenting on the national provision of and demand for port infrastructure, and in particular that an agreement between TBPC, the Royal Society for the Protection of Birds (RSPB), the Environment Agency and Natural England was sufficient to ensure the production of compensatory habitat.

THE AGREEMENT OVER COMPENSATORY HABITAT

The agreement over compensatory habitat between TBPC, a national environmental charity and two non-departmental public bodies in advance of the application under the Harbours Act shows how effective early and thorough engagement with regulators and potential opponents to a scheme can be. UK legal processes are too often characterised by their adversarial nature, and this can lead to a trap where the enmities developed by the process overshadow the intended spirit of the legislation. In this case the benefit brought to TBPC was that the company avoided an expensive public inquiry[12] (something very rare for port developments) and, by directly working with organisations that might have objected to their proposals, came to a mutually satisfactory scheme on 22 December 2008; doubt was removed from the process.

ACCEPTANCE OF IROPI AND COMPENSATORY MEASURES

Multiparty agreements on poorly defined substance can be difficult to draft; for various complex reasons of contract law it is hard for lawyers to include areas within agreements that remain to be resolved (but courts' attitudes in the area are softening – see *MRI Trading* AG v *Erdenet MiningCorp*[13]). However, the 2008 agreement provided that TBPC would seek out a satisfactory scheme, and obtain the necessary land ownerships and regulatory consents before commencing works on the main scheme. **Figure 3** shows the Steart Compensation Scheme proposed by TBPC.

The scheme involves purchasing low-lying farmland in the Steart Peninsula, building new sea defences around the periphery of the site, creating a breach in the existing sea defences and creating an area of at least 120 hectares of intertidal estuarine environment on the site. TBPC used a partnership approach with the environmental NGO, the RSPB, in developing the design, delivery and future management of the site. This brought additional expertise to the scheme both in terms of protection of biodiversity and in ameliorating local concerns. TBPC also worked closely with the Environment Agency, which was undertaking a neighbouring wetland creation project as compensation for flood defence works[14].

Key to the compensation requirements was that the new intertidal habitat must be created and functioning prior to adverse impacts occurring at the Avonmouth container terminal site. This was an expensive and contentious issue; the timing of the completion of the compensatory package in the scheme of works could pose real financial constraints on the project, and there is a commercial risk that, in conceding the necessity for a functioning compensatory package prior to the main development, TBPC have set a very high standard for other developments in the UK. The Defra guidance on this issue states that "where possible, compensation measures should be complete before the adverse effect on the European site occurs"[15]. So the issue would not appear to have been settled.

IMPLEMENTING THE STEART SCHEME

In some sense, though, the creation of the obligation merely replaced one set of applications with another. Indeed, perversely, in many aspects the Steart scheme involves a more complex legal process than that of the container terminal project. With the container terminal the areas of land that are not within the ownership of TBPC belong to either the Crown Estate or the Swangrove Estate and thus any land ownership issues involve few participants.

For a compensatory package, finding the right land parcel in single ownership is likely to be impossible; so purchase, rental agreements, or options need to be drawn up with all the individual land owners and their legal representatives. If any of the land owners are difficult to persuade (and it only takes one to hold up the process) there are provisions for compulsory purchase within the Harbours Act, but compulsory purchase under English law is notoriously slow and complicated, and could ultimately involve revisiting the Harbour Revision Order process itself and a public inquiry.

FEATURE

Furthermore, whereas the Harbour Revision Order took place before the implementation of the Marine and Coastal Access Act 2009 (MACA), the application for consent at the Steart Scheme did not. MACA changed the marine licensing regime. On the face of it the abolition of the need for Food and Environmental Protection Act licensing and Coastal Protection Act licensing should have made the process simpler; there would need to be only a single marine licence rather than two, but marine licensing under MACA has a far wider remit, so in practice it is more complex.

Additionally, because marine licensing applies to the high-water mark and planning in England and Wales to the low-water mark, for the intertidal area there is double licensing. Under the Town and Country Planning Acts planning permission was required from the local authority (in this case two, since the Steart unfortunately straddles a local authority boundary), and a marine licence was required from the Marine Management Organisation under the MACA. This led to three very similar applications to differing public authorities (with the associated duplication of effort and administrative burden for the developer and statutory consultees). These rank as new applications and need to stand or fall on their own merits, regardless that they are in fact environmental compensatory packages for an already approved scheme.

This has two interesting consequences. Firstly the compensatory package itself required environmental impact assessment under the EIA Directive and secondly planning permissions involved further considerations removed from the main application.

SECOND ENVIRONMENTAL IMPACT STATEMENT

Because the Steart proposals involved significant change in land use and alterations to the line of the foreshore, the local authorities insisted on the preparation of an environmental statement. The site is close to a number of SPAs and SACs so this led to a further appropriate assessment for the compensatory scheme under the Habitats Directive. As a matter of fact, with the incorporation of mitigation measures, the Steart proposal was deemed to have no adverse impact on the integrity of the affected sites so was allowed to proceed, but it did raise the spectre of the requirement of a further compensatory package to compensate for the compensatory package. This also showed one of the key shortcomings in the current approach: an application to a local authority for a nature reserve operates at a different scale and speed to a major infrastructure development, and yet the whole port development miles up the coast is in fact tied to the speed of the paperwork of this related application.

PLANNING CONDITIONS

Because creation of the reserve on the Steart Penisula was treated by the local authorities as a new application, inevitably a further suite of considerations and obligations crept in. In this case both local authorities were keen to create car parking and a visitor centre[16]. In some sense this could be detrimental to the very success of the compensatory package in supporting estuarine birds; encouraging large numbers of people to the site is likely to cause disturbance and interfere rather than enhance the environmental side of the scheme.

FURTHER LICENCES AND CONSENTS

As well as planning and the marine licence for the compensation scheme, TBPC have to obtain:

- consents for the creation of the breach, contamination released during the breaching work and the disposal of any waste material arising from the site;
- Footpath Closure/Diversion Order – for changes to the coastal footpath;
- protected species licence – for moving badgers, newts and other species affected by the works; and
- common land consent – to alter access and undertake works on common land.

In short, the environmental compensation scheme is likely to require more consents than the major port redevelopment work itself. TBPC have not yet completed this process and it remains to be seen how difficult in practice these licences are to obtain, but the sheer number of consents is an issue for the effectiveness of the compensatory scheme. Some of the consents are routine, but a contentious application to move a public footpath, for instance, can be a time-consuming process.

CONCLUSIONS

The partnership approach between the RSPB, the government's statutory nature conservation advisor and the applicant was an excellent way of approaching this application; it ensured that the scheme met the stringent environmental requirements, and removed doubt from the process. In this case it even had the benefit of avoiding a public inquiry that could have been drawn out and costly. But the application of the Habitats Directive is still exceptionally complex, not because of the environmental regulation but because of three key latent issues within UK governance generally:

- the sheer number of consenting requirements left the scheme vulnerable to government and regulatory reorganisations (whether they are because of devolution, new legislation or budget cuts);
- there is a duplication of regulation in the intertidal area; and
- the strength in the UK of private property rights and the lack of clear compulsory acquisition powers associated with the directive make the assemblage of land for the environmental compensation scheme a very difficult task.

TBPC have managed to overcome these obstacles by working in partnership with the local authorities, the statutory nature conservation bodies and the RSPB, and this has enabled them (at least to date) to navigate their way through the complexity of the regulation. However the development remains to be completed, and lack of consistency in government remains one of the key obstacles. The Major Infrastructure Environment Unit[17] may alleviate some of these issues, as will the coastal concordat[18] between differing English public bodies, but major issues still exist for developments that straddle public authorities' boundaries, and national boundaries.

It is a relief that the Habitats Directive did not receive significant criticism from Defra's review. The directive is one of the first pieces of legislation that protects large parts of the environment for its own sake. It marks a fundamental shift in human relations with the environment. The acceptance by corporations that this reflects the social norm of our times is something of which our generation should be proud. When asked about the process in August 2014, Sue Turner, communications director of TBPC, commented:

> **"We support the principle of the Habitats Directive and are committed to promoting the sustainable growth of Bristol Port, but there needs to be a level playing field between us and our competitors and the rules need to be applied in the same way for all European developments."**

It is this shift in attitude to the environment in general that underpins a moral acceptance of the need for water security.

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The water–energy–food nexus–balancing our (in)securities

Enda Hayes and **Damian Crilly** describe the concept of the water–energy–food nexus, which has been identified as a key area of importance in a world of increasing demand for resources, and discuss its application in a case study of the Severn River Basin, UK.

Although the global population growth rate is declining, the global population count is continuing to increase and is expected to reach 9.6 billion by 2050, with an estimated 70 per cent living in towns and cities[1]. The global trends of population growth, rapid urbanisation and rising living standards are placing increasingly competitive demands upon finite natural resources for agriculture, energy and industrial production. If these trends continue, by 2050 water demand is projected to increase by 55 per cent, energy demand is projected to increase by 80 per cent and food demand is projected to increase by 60 per cent[2].

These resource-demand challenges will be primarily experienced in cities where the growing middle classes will be the main consumers of electricity, oil, food beverages, household appliances, cars and other goods and services[3]. The question is: how do we provide energy, water and food security for a growing population now and in a future that needs flexibility to adapt to a challenging and changing climate? And once we have figured out the answer to this, how do we balance these securities to ensure that we are not achieving one at the expense of another?

WHAT IS THE WATER–ENERGY–FOOD NEXUS?

The nexus concept is not new. Environmental scientists and practitioners have been talking about this for years but using different terminology such as 'integrated resource management', or 'systems thinking'. The nexus concept sits within very obvious day-to-day issues where we have numerous interdependent relationships such as:

- water for energy (e.g. thermal electric cooling and hydropower generation);
- energy for water (e.g. treatment and distribution of water);
- water for food (e.g. irrigation of crops);
- energy for food (e.g. processing, transportation, sanitation); and
- 'food' for energy (e.g. biofuels).

Ecosystems are critical to the nexus, and ecosystems services (natural infrastructure) underpin each of the three nexus strands. Without healthy ecosystems in well-functioning watersheds, the infrastructure built for irrigation, hydropower or municipal water supply does not function sustainably, and is unlikely to achieve the economic returns necessary to justify investments[4].

Natural infrastructure does not replace the need for built infrastructure, and natural infrastructure can complement built infrastructure. For example, dams benefit from forests that stabilise soils and hold back erosion upstream. Lakes and wetlands provide water storage and therefore reduce the reservoir volume needed and thus the cost of built water storage.

The challenge of the nexus is not just about the interdependent relationships between water–energy–food but also involves the complex planetary drivers, pressures and challenges that influence these resources on different geographical scales (local, national, global), temporal scales (historical, current, future) and experiencing differing risks (political, economic, environmental).

The UK Climate Change Act (2008) places a commitment to achieve an 80 per cent reduction of greenhouse gases by 2050 based on 1990 levels. The UK Carbon Plan states that a major component of achieving this reduction will be "to make a transition to a low carbon economy while maintaining energy security" and "less reliance on imported fossil fuels and less exposure to higher and more volatile energy prices".

Whereas the Carbon Plan is focused on mitigation, there is a noticeable lack of considered integration of climate adaptation, which will primarily have an impact on water and food. This document alone is a perfect example of a lack of nexus thinking and illustrates the fact that having water–energy–food as shared priorities does not mean that they will be equal priorities. Many practitioners view water security as the key component to the nexus and the focal point that will bring together the global challenges that the world economy will face in the coming decades.

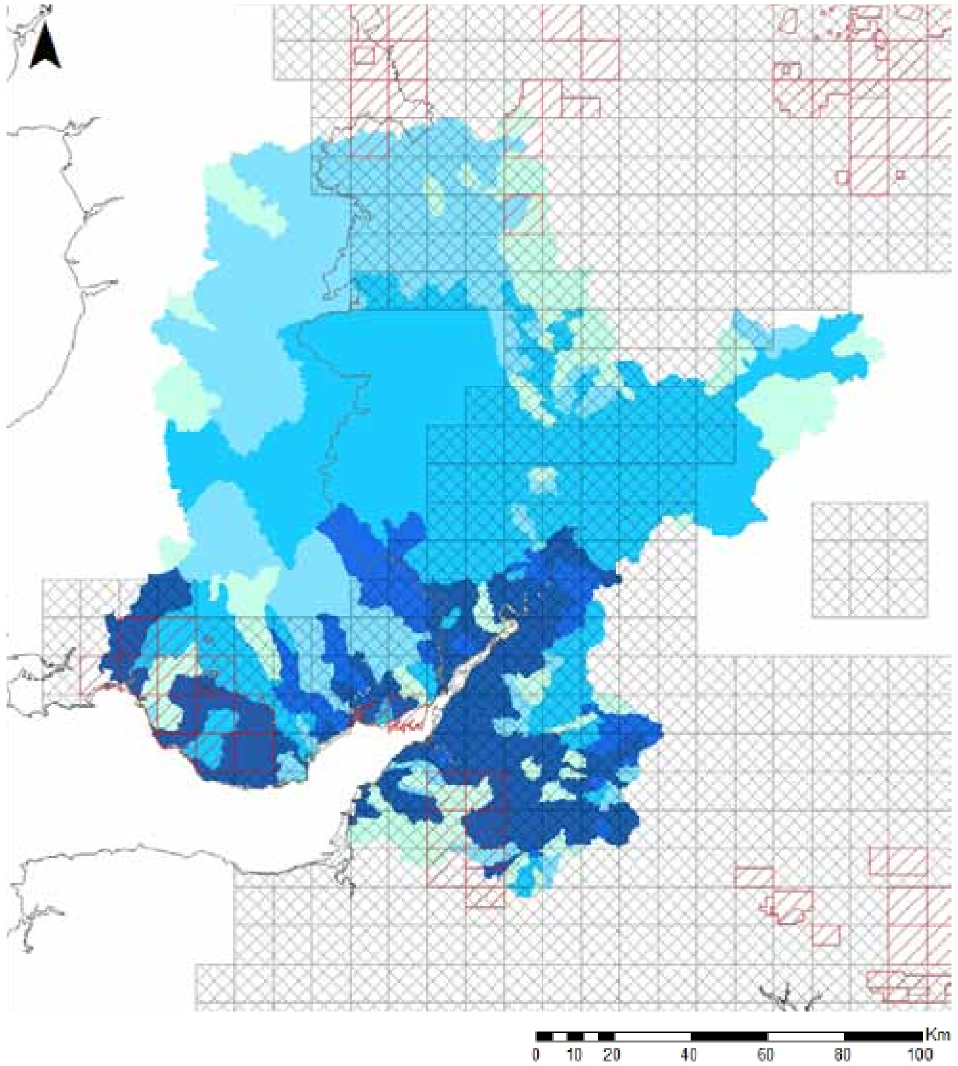
THE NEXUS IN ACTION (OR INACTION) – SEVERN RIVER BASIN

The Severn is the longest river and third-largest basin in the UK, supporting 5 million people including the major urban conurbations of Coventry, Cardiff and Bristol. It supplies water to approximately 2 million households and 193,000 commercial operations and currently operates at 94 per cent of its abstraction potential. Recent projections suggest that this basin is going to experience substantial pressures in the coming years. For example a projected 20.1 per cent population growth in the UK by 2050 [5] would see an intensification of agriculture in the Severn River Basin region accompanied by an increased water demand and abstraction uncertainty. Additionally, the river basin is no stranger to major flooding events as experienced in Gloucestershire in 2007 and more recently in Gloucestershire and Somerset in 2014.

The basin is of strategic importance to the UK's energy security plans and low-carbon agenda as it has the potential for the generation of approximately 10–20 GW of electricity through projects such as the Severn Barrage and Hinckley Point C nuclear power plant, plus a possible 6–7 years of natural gas through shale gas exploitation[6].

However, to achieve this target the underlying fundamental is water resource availability and in some instances this will require compromises. Data from the UK Catchment Abstraction Management Strategies indicate that large regions of the country have sufficient water resource availability less than 50 per cent of the time[9]. The overseas trade statistics show that over 50 per cent of the UK's food is imported and in many cases from locations that will be vulnerable to climate change[7]. Additionally, the Department of Energy & Climate Change advise that the UK energy mix is going to be reliant on nuclear energy, renewables and natural gas in the future and arguably some of that natural gas may come from the UK's own shale gas reserves.

- **Shale gas:** extrapolating from published estimated shale gas reserves in the Bowland Hodder, there may be potential technically recoverable reserves of 578 bcm (billion cubic metres) within the Severn River Basin geographical area (see **Figure 1**). At the current UK rate of 85 bcm of natural gas usage per annum the approximated Severn shale gas would provide 6.8 years of natural gas. Yet to access this gas, assuming that we were able to exploit 20 per cent over the next 20 years, the estimated water withdrawn would be 270 ML per annum (equivalent to the water use of approximately 5,000 people per annum). However, between 20 and 80 per cent of this water withdrawn would be permanently consumed (i.e. would be trapped in the shale rock due to the hydraulic fracturing process) and therefore permanently lost to the immediate water environment and the hydro-geological cycle;
- **Nuclear power:** the UK nuclear programme is to have 16 GW operational by 2030. Hinckley Point C will provide 3.26 GW and will be the first of the new generation of nuclear power plants to be operational by 2023. Located in West Somerset, the power plant will draw water from the Severn



▲ **Figure 1. Water resource availability (per cent of time) and possible shale gas development within the Severn catchment. Data sources: Department for Energy and Climate Change[7,8], Environment Agency (© University of West of England).**

Estuary and will build cooling water tunnels and other infrastructure out into the estuary. Unlike the shale gas example, the key issues for this project are the potential impact that the power station will have on estuary habitats, through issues such as suspended sediment, variation to the estuary-water chemical quality and thermal regime, and the impact that the land infrastructure will have on groundwater levels, rather than sufficient water supply for cooling. Additionally, the Hinckley Point location is at high risk of flooding by 2080 and erosion. Given the power station's location beside the Somerset flood plains, there has to be the additional requirement for elevated flood defences including the requirement for a 66 million gallon water lagoon (the annual water needs of approximately 5,500 people per annum).

- **Tidal energy:** Numerous schemes have been examined in recent years in the Severn Estuary and the pros and cons of lagoon schemes versus barrage schemes have been well documented. Primary concerns cited include issues surrounding the cost associated with the schemes, the scale of the infrastructure required, and the associated environmental and economic risks. Therefore the Severn tidal energy agenda has remained relatively quiet since 2009. From a nexus perspective the key risks included environmental impacts on fisheries and the estuary ecosystem and accessibility to Bristol Port.

These three different low-carbon projects each bring their own nexus risks whether they are potential water loss from shale gas exploration or impact on estuary habitats and fisheries from nuclear and tidal schemes. The challenge is how to weigh and balance these issues to ensure that we are not trading off one security for another insecurity. The water and food strands of the nexus are inherently linked and have a long-standing record of co-dependency, resulting in co-operation but it is in the energy strand where the challenges for the UK and the balance for the nexus are going to be under most scrutiny.

THE NEXUS RISK TRILEMMA

So how can we provide (a) security of supply, (b) equitable supply and (c) environmental protection for the various complex strands of the nexus (i.e. the nexus risk trilemma?) There is no single solution to the issues inherent in the complex nexus web of relationships, but from a UK perspective here are some of the key challenges that must be addressed.

- **Spheres and silos:** although the need for integration is well acknowledged, many institutions are divided into 'spheres' and 'silos' often from the top down. The silo approach is no longer fit for purpose in a VUCA (volatile, uncertain, complex and ambiguous) world. The old adage of getting levels of government and government departments to share and more importantly act on nexus information is an ongoing difficulty;

- **Planning:** most planning projects are examined on their own individual merits, but what is the cumulative impact of numerous projects over different geographical scales and time on the nexus balance? What would (will) the Severn catchment look like in 2030–50 with widespread shale exploration, tidal projects, nuclear power demands, intensification of agriculture, a growing population and urban footprint, and the impact of climate change? How will we plan for the cumulative and competing resource demands?

- **Education and awareness:** education is required, but not for people in the water, food and to a lesser extent the energy sector but for planners, finance and the public. Additionally, we must manage our expectation of what resources our stressed global ecosystem can provide in the future; and

- **Policy balance:** it could be argued that the energy agenda carries much more weight in the UK than the food or water agendas and this policy imbalance needs to be addressed.

THE FUTURE OF THE NEXUS

There is no quick-fix solution; rather what is required is the rapid uptake of a way of thinking, nexus/systems thinking, which demands that our current and future societal needs are met. There is never likely to be a single suitable target or optimal solution and we need to consider multiple benefits. We need to start thinking outside of our silos not just about a low-carbon future but a nexus-friendly future, a future with shared ownership not only of nexus security challenges but, more importantly, the solutions.

The perfect nexus solution does not exist, there will always be some element of trade-off required, but a number of good, no-regret solutions that allow for benefit-sharing may be good enough. However, until we start to think 'nexus', society will continue to be stuck in a securities (insecurities) trilemma. ES

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IES: new members and re-grades

Fellow — is for esteemed individuals in environmental science and sustainability who are held in high regard by their peers

Member — is for those individuals who have substantial academic and work experience within environmental science.

Associate — is for individuals beginning their environmental career or those working on the periphery of environmental science.

Affiliate — is for individuals with an interest in environmental issues but don't work in the field, or for students on non-accredited programs.

Members	Occupation
Dominic Adams	Environmental Group Lead
Declan Alder	Air Quality Consultant
Yoseph Araya	Lecturer in Environmental
Jennifer Best	Principal Specialist Scientist
Alexander Bull	Senior Engineer
Mark Churchill	Senior Environmental Consultant
Feliciano Cirimele	Environmental Protection Officer
Ian Clarke	Senior Enviornmental Technician
Carol Connery	Associate (Waste, Energy & Environment)
Jill Cottrell	Environmental Consultant
Anne Danskin	Principal Consultant
Selin Demirkanli	Senior Environmental Consultant
Aniko Dobi-Rozsa	Science and Technology Attaché
Daniel Doran	Senior Consultant (Life Cycle Assessment)
Matthew Edwards	Senior Air Quality
Etiese Etuk	Base Superintendent
Wendy Fail	Sustainable Tourism Assessor
Andrew Fawcett	Geotechnical Engineer
Andrew Fellows	Environmental Scientist
Alexandra Gilbert	Sustainability Specialist
Lesley Goodall	Director - Air
Michael Goodfellow	Environmental Health Officer
Charlotte Goodman	Air Quality Consultant
Sally Hare	Environmental Consultant
Colm Harkin	Senior Environmental Advisor
Michael Harper	Environmental Consultant
Kristina Himmler	Principal Environmental Scientist
David Hooton	Principal Geo-environmental Engineer
Tanya Howard	Senior Environmental Consultant
James Jenkins	Senior Lecturer in Environmental Management
Noel John	Signalling Verification & Validator Engineer
David Jones	Geoenvironmental Engineer
Emma Jones	Pollution Control Officer
Patrick Kirkby	Environmental Manager
Adam Lilley	Higher Research Scientist
Christine Loney	Environmental Consultant
Kate Lowe	Senior Environmental Consultant
Andrew Lowe	Senior Energy Consultant
Michael Lynch	Senior Environmental Engineer
Helen Matheson	Project Manager
Rachel McEvan	Principal Environmental Consultant
Paul McGimpsey	Senior Environmental Consultant
Amit Mhalas	Lead Environmental Engineer
Karunakar Nagula	Senior Air Quality Consultant
Christopher Netherton	Managing Director
John Nicklin	Senior Pollution Officer
Adam Pawson	Regulatory Officer
Gareth Payne	Field Chemist
Rachel Perryman	Environmental Scientist
Natalie Rees	Project Coordinator
Nikki Robinson	Director & Principal Consultant
Enrico Salvagni	Consulting Engineer
Victoria Seller	Pollution Control Officer
Adam Shelton	Environmental Consultant
Diana Silva	Assistant Consultant
Mark Silverton	Principal Environmental Consultant
Darien Simon	Research Associate
Josep Simona	Senior Acoustic Engineer
Alexander Smith	Senior Consultant
Emily Spencer	Geo-Environmental Consultant
Lisa Statham	Environmental Scientist
Lesley-Anne Stone	Environmental Scientist
Nicholas Struggles	Principal Geo-environmental Engineer
Peter Swettenham	Freelance Environmental Scientist
Simon Tagg-Wilkinson	CEO
Harsh Thapar	Associate Environmental Design Analyst
Alice Thomas	Engineer
David Trew	Senior Environmental Protection Officer
Peter Watson	Owner
Jenna Webster	Senior Consultant
Jamie Williams	Senior Environmental GIS Consultant
Andrew Williams	Senior Scientific Officer

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Lovemore Amidu	Graduate
Francis Atta-Agyem	Operation Manager
Paul Bentley	Environmental Consultant
Sarah-Jane Blackburn	Project Management Assistant
Ciaran Brady	Graduate
Jamie Brown	Graduate
Lewis Carter	Graduate
Alan Cawley	Environmental Advisor
Roberta Clarke	Graduate
Gillian Clayton	Graduate
Cameron Clow	Risk Analyst
David Costello	Environmental Consultant
Adam Cross	Graduate
Rory Daines	Quality & Environmental Advisor
Luke Farrugia	Air Quality Specialist
Jason Fitzgerald	Environmental Consultant
Ricky Gellatly	Air Quality Consultant
Joanne Grantham	Assistant Environmental Scientist
Jonathan Griffiths	Master Student
Ryan Hall	Graduate
Colman Hands	Group Environmental Adviser
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Richard Jones	Graduate
Sian Jones	Graduate
Richard Lane	Environmental Scientist
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Nathan MacDonald	Graduate
Thomas Marker	Graduate
Mauricia Sánchez	Customer Care Assistant
Bernard Mbogoh	Postgraduate student
Laura McGoohan	Graduate
Daniel Mullick	Junior Environmental Consultant (Air Quality)
Lee Mundy-Steel	Scientific Officer
Michael Page	Graduate
Maiga Reinharde	Graduate
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Eleanor Smith	Graduate
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Measuring water security: an assessment of the 2013 *Asian Development Bank Outlook* National Water Security Index

Bhuwan Thapa, Robert Varady and **Christopher Scott** evaluate the methodology and indicators used in formulation of the National Water Security Index, and assess its ability to quantify water security in the context of analogous indices.

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ANALYSIS

Water security is an inclusive concept that focuses on fulfilling human needs while addressing competing water demands, water pollution, environmental needs, and disaster risk management. UN-Water, the United Nations' inter-agency coordination mechanism for freshwater-and sanitation-related matters, defines water security as :

"the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability" (United Nations University, 2013, p.vi)[1].

A more succinct working definition is "the sustainable availability of adequate quantities and qualities of water for resilient societies and ecosystems in the face of uncertain global change"[2].

The multi-faceted definitions of water security complicate attempts to measure the concept. Most such attempts have taken the form of indices. An example is the National Water Security Index (NWSI) developed by the Asia-Pacific Water Forum and the Asian Development Bank[3]. The index measures water security via five dimensions (see **Figure 1**): household, economic, urban, environmental, and resilience to water-related disasters.

MEASURING WATER SECURITY

Water security is an emerging and complex term for which few quantitative matrices have been developed to date. The notion originated in the 1990s in the academic community as a corollary to such paradigms as sustainable development, integrated water resources management, and adaptive capacity. Since the mid-2000s the term has gained prominence among policy-makers and practitioners in national and international organisations, including the World Economic Forum, Global Water Partnership, World Bank, Asian Development Bank, North Atlantic Treaty Organization, G8, and United Nations[3,4].

The difficulty inherent in measuring the degree to which a society is 'water-secure' is mainly due to its hydra-like nature. An effective metric not only must factor in meeting basic human needs, but should address competing water demands, efforts to control water pollution, environmental needs, potential disaster impacts, and water-induced conflicts. Several quantitative indices exist that measure one or more aspects of water security. In all such indices, the inclusion of indicators depends upon the purpose behind the instruments' development as well as on the needs of end users.

WATER SECURITY RISK INDEX

Maplecroft, a firm specialising in business-risk forecasting, has developed a Water Security Risk Index (WSRI). It assesses the risk to economic and societal functions due to limited availability of water. The WSRI is tailored toward business investment risks, and accordingly it measures water security using countries' water stress, population rates, reliance on external water supplies, sustainability of water use, intensity of water use in the economy, government effectiveness, and virtual water use[5].

WATER POVERTY INDEX

The Water Poverty Index (WPI), whose development dates to the late 1990s, focuses on water scarcity using biophysical and socioeconomic variables, mainly resources availability and reliability, access to water and sanitation, socio-economic capacity, different water uses, and environmental impacts of water use[6]. Though it captures socio-economic dimensions of water-resources management, the WPI is primarily geared towards measuring *water scarcity* and not *water security.*

WATERSHED SUSTAINABILITY INDEX

Chaves and Alipaz's Watershed Sustainability Index (WSI), developed using the UNESCO International Hydrologic Program's HELP (Hydrology for the Environment, Life and Policy) framework to assess basin sustainability, measures pressures and policy responses to manage watersheds in four dimensions: hydrology, environment, life and policy[7]. These dimensions incorporate variables to measure water resources, environmental pressure on vegetation, socio-economic conditions of people's lives, and water governance and institutional capacity.

One of the innovations of the WSI is that it uses the pressure–state–response framework to develop indicators. The framework helps to identify the cause–effect relationship between pressures on a watershed and responses by society to address these pressures. While the WSI measures human and environmental water demands and environmental pollution at watershed level, it does not directly measure the disaster risk, nor water related conflict and co-operation, which are equally important dimensions of water security.

NATIONAL WATER SECURITY INDEX

The NWSI was developed jointly by the Asia-Pacific Water Forum and the Asian Development Bank and was published in *Asian Development Bank Outlook*[3] (ADBO) of 2013 — hereafter referred to as the ADBO study. The index aims to yield an inclusive matrix for water security in order to inform government leaders and policy-makers about threats due to water insecurity.

The index is based on a lofty premise that societies can enjoy water security when they successfully manage their water resources and services to:

(i) satisfy household water and sanitation needs in all communities;

(ii) support productive economies in agriculture, industry, and energy;

(iii) develop vibrant, liveable cities and towns;

(iv) restore healthy rivers and ecosystems; and

(v) build resilient communities that can adapt to change[3].

Based on this comprehensive definition, water security is measured in five key dimensions: household, economic, urban, environmental, and resilience to water-related disasters. The NWSI measures security on a national scale, with an aggregate score for a given country. The index assigns each country a score of 1 to 5, where 5 represent a water-secure country (which is a model in terms of water-resources management) and 1 represents a country with a hazardous status[3].

▲ **Figure 1. Five dimensions of Asian Development Bank Outlook (ADBO) National Water Security Index.**

▼ **Table 1: Indicators used in assessment of five dimensions of ADBO National Water Security Index.**

NATIONAL WATER SECURITY INDEX

Composite score (1 to 5) based on the five sub-security indices: household, economic, urban, environmental and resilience to water-related disasters

HOUSEHOLD WATER SECURITY

1. Access to piped water supply
2. Access to improved sanitation
3. Hygiene (age-standardised disability-adjusted life years per 100,000 people for the incidence of diarrhoea)

ECONOMIC WATER SECURITY

Agricultural water security sub-index
4. Productivity of irrigated agriculture
5. Independence of imported water and goods
6. Resilience (percentage of renewable water resources stored in large dams)
Industrial water security sub-index
7. Productivity (financial value of industrial goods relative to industrial water withdrawal)
8. Consumption rate (net virtual water consumed relative to water withdrawn for industry)
Energy water security sub-index
9. Utilization of total hydropower capacity
10. Ratio of hydropower to total energy supply
Resilience (see below)

URBAN WATER SECURITY

11. Water supply
12. Wastewater treatment
13. Drainage (measured as the extent of economic damage caused by floods and storms)
14. Adjustment factors for urban growth rate and river health

ENVIRONMENTAL WATER SECURITY

Watershed disturbance	*Water resource development*
15. Cropland	28. Dam density
16. Imperviousness	29. River network fragmentation
17. Livestock density	30. Relative water consumption compared to supply
18. Wetland disconnection	31. Agriculture sector water stress
Pollution	32. Residency time change downstream from dams
19. Soil salinisation	*Biotic factors*
20. Nitrogen	33. Non—native species
21. Phosphorous	34. Non—native species richness
22. Mercury	35. Catch pressure
23. Pesticides	36. Aquaculture
24. Total suspended Solids	
25. Organic loads	
26. Potential acidification	
27. Thermal impacts from power plant cooling	

RESILIENCE TO WATER-RELATED DISASTERS

37. Exposure (e.g. population density, growth rate)
38. Basic population vulnerability (e.g. poverty rate, land use)
39. Hard coping capacities (e.g. telecommunication development)
40. Soft coping capacities (e.g. literacy rate)

CALCULATING THE NATIONAL WATER SECURITY INDEX

The NWSI is developed using a quantitative rating method carried out in two steps. First, selected indicators are chosen for each of five dimensions and given a rating between 1 and 5. Indicators selected for each dimension are provided in **Table 1**. Weighting can be used but in the simplest NWSI method, the ratings for the variables are added and re-rated (normalised) between 1 and 5 to generate a single index for each of the five dimensions. Second, to calculate the national water security index, the ratings of five dimensions are added together and re-rated between 1 and 5 to produce a single value of the national water security index.

COMPONENTS OF THE NATIONAL WATER SECURITY INDEX

NWSI is a composite score of water security on five dimensions (see **Figure 1**).

- Household water security is the foundation and cornerstone of water security. It measures the extent to which countries are satisfying their household water and sanitation needs and improvement in hygiene for public health. While water and sanitation are measured using a standard indicator of access to piped water supply (per cent) and access to improved sanitation (per cent), the hygiene status is measured using the age-standardised disability-adjusted life years (DALYs) index developed by the World Health Organization. DALY is a measure proportional to the diarrhoeal incidence per 100,000 people[3].

- Economic water security is measured in terms of the productive use of water in the agricultural, industrial, and energy sectors of the economy[3]. Sub-indices are generated for each of the three sub-sectors. The sub-indices are summated and rated between 1 and 5 to produce a single economic water security index. Economic water security addresses the interdependency between water-consuming sectors. One of the challenges of economic water security is that, since it focuses on measuring sectoral productivity and dependency on water resources, it does not account for actual degradation of the resource base. For example, the agricultural sub-index is a composite score of the productivity of irrigated agriculture, independence of imported water and goods, and resilience in terms of percentage of renewable water resources stored in large dams. The current index does not account for depletion of the groundwater table that can occur as a result of extensive agriculture, mainly because of lack of comparable datasets[3].

- Urban water security measures urban water services in terms of improved drinking water supply, wastewater treatment coverage, and effective drainage system. A proxy indicator of economic damage caused by floods and storms is used to measure effective drainage system. The index adjusts for urban growth rates and river basin health.

- Environmental water security assesses the health of rivers and measures progress towards restoring rivers and ecosystems at the basin scale within countries[3]. River health is measured in terms of watershed disturbance, pollution, water resource development, and biotic factors. Each parameter is measured using multiple variables. The ADBO study found that water resource development and pollution were two major causes of deteriorated river health[3]. Currently the index does not include aquifer health.

- Resilience to water-related disasters measures the flexibility of communities to reduce risk from natural disasters. Here resilience is defined as the country's exposure to disaster-related risks and its ability to overcome such disasters. Resilience is a function of exposure, vulnerability, and adaptive/coping capacity. In terms of coping capacity, both soft measures (land-use planning, control of development in exposed lands) and hard measures (flood embankments and levees, seawalls, and early warning systems) are included[3]. The ADBO study found that water-related vulnerability is strongly correlated with socio-economic development, which increases the coping capacity.

When the ADBO study calculated the NWSI for 49 countries in the Asia and Pacific regions, 39 scored a low rating of 1 or 2. These are mostly the developing countries facing water insecurity from multiple dimensions. Countries, such as India, Bangladesh, and Nepal, that have low scores of one or two, are insecure due to lack of access to water and sanitation, polluted rivers, insufficient wastewater treatment, or poor urban drainage systems. Australia and New Zealand are the only countries that have the NWSI of 4. Japan and Singapore have an NWSI score of 3; they have high water security at household and economic levels but relatively lower values in environmental and urban water securities.

DISCUSSION

We assess the usefulness of the NWSI based on eight general criteria that have been used in UNESCO HELP-related assessments of indicators[7]. These criteria are relevance and representativeness, simplicity, transparency and accuracy, credibility, appropriate scale and context, stakeholder engagement, data availability, and end-user focus. Four of these criteria are discussed below, with transparency and accuracy, credibility, and data availability subsumed under simplicity. Similarly, end-user focus is referred to in our comments on stakeholder engagement.

Relevance and representativeness. A useful indicator should be relevant and should provide a representative picture of the state of water security in a fashion that is simple and easy to interpret. From the UN-Water definition of water security provided above, we suggest that a representative index should incorporate these five dimensions: (i) human needs for water, sanitation and livelihood; (ii) competing water demands for economic sectors; (iii) water pollution and environmental needs; (iv) water-induced disaster risk; and (v) water-induced conflict and co-operation.

▲ **Figure 2. River at Taroko. (© Tuomaslehtinen)**

The NWSI is the first index of its kind that captures four of the five dimensions of water security. Though water-induced conflict and co-operation, the last of the five, is not directly measured by the index, the variables used in assessing resilience to water-induced disaster risk can be used as proxy indicators for this dimension.

Simplicity. Simplicity comes when the methods and indicators used are few, simple and easy to understand. The NWSI uses more than 40 indicators covering biophysical and socio-economic variables. In an attempt to incorporate diverse nuances of water security, the index uses redundant variables and a complex methodology in some cases.

For example, nine variables are used to derive a pollution sub-index within the environmental security index. Similarly, a basin-level GIS-based method is used to calculate the environmental security index, which can be hard for stakeholders to follow. This problem is commonly called the 'black-box syndrome' in which stakeholders and end users have difficulty understanding the methodology of deriving the index and hence are reluctant to believe in it.

Appropriate scale and context. The NWSI is a national index that uses nationally available secondary data sources. The national level index can still be a coarse indicator to represent the geographic and socio-economic variations in water security status within the country. Except for the environmental security index, which is developed at a basin level, the other four dimensions use national level datasets. Similarly, since water security is more relevant at a basin level, the national-level index may miss the local context of specific basins or regions.

Stakeholder engagement. Recently, there has been greater emphasis on stakeholder-driven research, where decision-makers are engaged from early stages in applied research (see Scott *et al*.[2]). Engaging relevant stakeholders in the formulation of a water security index can enrich discussion of the selection of appropriate indicators, and support information and data provision as well as adoption of indices. The NWSI has been developed in consultation with 10 of the leading water knowledge organisations in Asia, including the International Water Management Institute, Food and Agriculture Organization, International Water Centre, and United Nations Economic and Social Commission for Asia and the Pacific. These organisations have been engaged in the development of some sub-indices. Nonetheless, it is unclear whether other related stakeholders are engaged in the process of formulation of the index.

A notable limitation of the NWSI is that, although the ADBO highlights the importance of good governance in determining the extent of water security, none of the indicators capture the governance aspect of water security. Currently, NWSI only measures the outcomes and not the processes that can effectively assess governance parameters. The governance dimension can be built upon the existing works of Araral and Yu[8], Engle and Lemos[9], and Gupta *et al*.[10].

While the NWSI already uses about 40 indicators to assess water security, the inclusion of a few additional variables can further strengthen the index. These variables can include water-induced conflict and co-operation (perhaps adapted from the NWSI's disaster risk component), a sustainability indicator of groundwater, a water-reuse measure, and a climate-adaptation measure (in order to minimise the tendency to increase water security through maladaptive practices, e.g. by greatly increasing energy consumption or irreversibly reducing the viability of key ecosystem processes).

A conflict-related indicator can shed light on water-security and governance implications for national security. Similarly, including sustainability and water-reuse data can guide users of the index on the health of natural capital and the degree of water efficiency. It is also acknowledged that the inclusion of additional variables will depend upon the availability of comparable datasets while reducing redundancy of the composite water security index.

A homogenised value at a national level ignores regional geographical and cultural variations. Also the index suffers from redundant variables and a complex methodology in some cases, in particular the environmental water security index. Whereas most of the indicators are related to the social and environmental outcomes of water security, the index could be further improved by bringing in process-based indicators like water governance, which is central to achieving water security.

Even though water security is a multi-faceted concept, ADBO's NWSI is a notable first step towards a systematic approach that quantifies national, basin, and city water security by bringing together a wide array of data to assess progress toward water security using standardised indices. ES

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Improving water quality security through self-governance

Bimo Nkhata, Charles Breen and **Duncan Hay** propose a conceptual model that represents the factors that have an effect on water quality security.

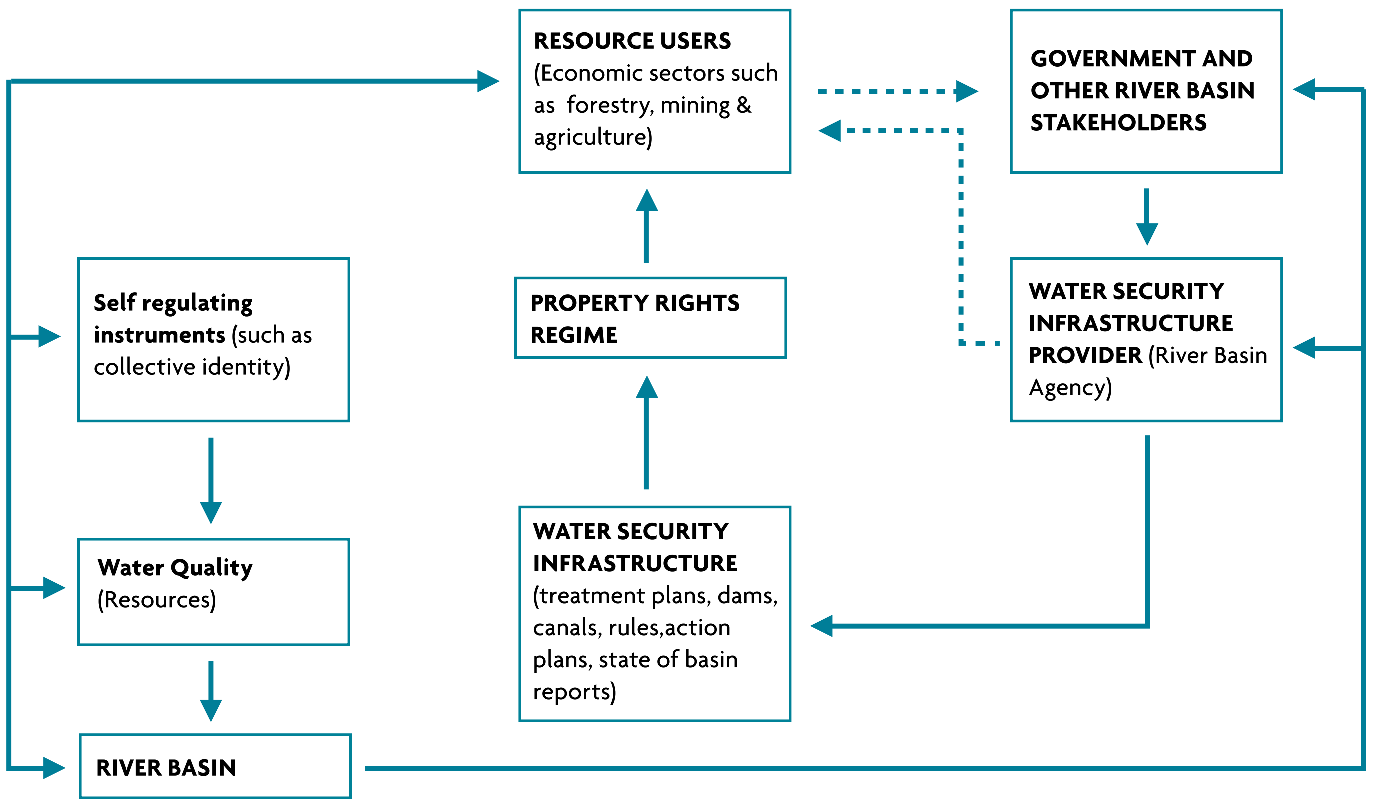
The continued deterioration of water quality is a major challenge for most societies in the world. The poor quality of water in river basins, lakes, wetlands and estuaries continues to place human livelihoods, health, economic production and ecosystems at great risk. Increasingly, water engineers are asked to address the problem of poor water quality. However, it is doubtful whether water engineers on their own are capable of grasping the full implications of poor water quality.

Most of the technical protocols and procedures applied by water engineers are not sufficient for understanding and dealing with complex water quality problems. In fact, some argue that most water quality problems are not even amenable to technical solutions. Concerted efforts by water engineers and other scientists from various disciplines are required to understand these implications and to begin to design appropriate solutions.

Water quality essentially refers to the chemical, physical and biological characteristics of water. While these characteristics are directly influenced by substances that are either dissolved or suspended in water, the actual extent of water quality clearly shows a strong dependence on socio-political and economic factors.

WATER QUALITY SECURITY

The ways in which societies are structured and organised have a major bearing on the full extent of water quality. Investments in both physical infrastructure and human institutions are almost always needed to secure the quality of water. Importantly, societies need to invest in the capacity of people to safeguard access to a desirable quality of water. We refer to this capacity as water quality security. Water quality security is primarily concerned with the management of societal risks associated with the quality of water.



▲ **Figure. 1: A conceptual model for understanding the self-governance of water quality security (adapted from Anderies *et al*[1], © International water Security Network)**

In this article, we propose a conceptual model as a starting point to understanding and dealing with the broad implications of poor water quality. The conceptual model is a representation of the factors that affect water quality security and the implications thereof.

We use the conceptual model to illustrate real-world situations that involve the apportionment of risks among social actors who are affected by or directly dependent on the quality of water. We demonstrate how the establishment and maintenance of a water quality security system take place in a complex social environment.

The essence of the conceptual model is to facilitate understanding and building of a robust water quality security system for tackling the risks associated with poor water quality. More specifically, our goal is to contribute to the understanding of how the concept of self-governance can lead to improvements in water quality security.

UNDERSTANDING A WATER QUALITY SECURITY SYSTEM

Why do some water quality security systems perform better than others in varying social environments? Why do some systems survive over time and other s collapse? How do institutional arrangements affect both the performance and the survival of water quality security systems? To answer these questions, we propose a conceptual model that links water quality as a resource, resource users, water security infrastructure, and water security infrastructure providers (see **Figure 1**).

As depicted in **Figure 1**, the functioning of a water quality security system revolves around a resource (water quality) that is used or abused by multiple resource users (e.g. economic actors in sectors such as forestry, mining, agriculture and manufacturing). Alongside this, the water security infrastructure facilitates use/abuse and control.

The water security infrastructure providers, such as river basin agencies, provide the water security infrastructure that essentially comprises both human-made physical and social capital. Whereas the human-made physical capital denotes engineered works including treatment plants, dams and canals, the social capital includes formal and informal rules such as government policies, laws and statutory regulations that are promulgated and/or enforced by river basin agencies.

LINKS BETWEEN COMPONENTS OF A WATER SECURITY SYSTEM

Table 1 shows examples of links between the components of a water security system. These links sustain the robustness of a water quality security system and ultimately affect its performance. Depending on how the system is configured, the links may be a source of stimuli with the capacity to trigger major problems in the system.

A typical link would be between water quality and economic actors that either use or abuse water quality. The desirability of water quality at a particular point of time would in this case be a key mediating variable in this link. A potential problem associated with this link includes poor water quality that is not fit for use by a particular economic actor such as a domestic water user.

Furthermore, the links between users and infrastructure providers, infrastructure providers and the infrastructure, and water quality and infrastructure are also sources of fluctuations that may challenge the robustness of the system at any particular point in time. The system is never stable as it has to adjust to short- and long-term disturbances. Given the inherent delays within the system, some consequences may take time to become evident. The implication is that management has to be able to adjust to emergent conditions.

Similarly, the external environment of a water security system may be a source of external stimuli with the capacity to trigger major changes in the system. Political transformation within a country can lead to great uncertainty and even conflict. For example, the major socio-political transformation of 1994 in South Africa led to significant changes in the management of water quality. This transformation saw the revocation of over 200 pieces of legislation related to the management of water quality, thereby generating great uncertainty among resource users. Clearly, the above description of a water quality security system provides a more complete understanding of the dynamics that underlie its structure and processes. This has vital implications for the management of water quality, be it at a national or basin scale. One such implication is that pollution incidents should not be managed as one-off events, but as part of processes and interconnections between the components that make up a water quality security system.

USING SELF-GOVERNANCE TO IMPROVE SECURITY

Improving water quality security requires that the links between the components of the system are well coordinated and harmonised. The coordination and harmonisation of these links is called governance. Governance is about who decides, and how and when.

▼ **Table 1. Examples of links involved in a water quality security system and potential problems.**

Link	Examples	Potential problems
Between water quality and users of water quality as a resource	The desirability of water quality at time of need	Undesirable quality of water; water quality not fit for use
Between users and water security infrastructure providers	Election or appointment of providers Designing or recommending policies	Apathy by users Predatory tendencies by appointing authority
Between public infrastructure providers and public infrastructure	Inventories Building initial structures Regular maintenance Monitoring and enforcing rules	Overcapitalisation or undercapitalisation Shirking disrupting patterns of use High costs Corruption
Between public infrastructure and resource	Effects of infrastructure on the quality of water	Malfunction
Between resource users and public infrastructure	Joint construction Maintenance of works Monitoring and sanctioning	No incentives Free riding
External forces on resource and infrastructure	Nonpoint-source pollution Severe weather, earthquake Alternative sinks	Destroys resource and infrastructure
External forces on economic actors	Political transformation Demographic changes Market dynamics	Conflict, uncertainty Migration Growing demand

Although there are different forms of governance, here we focus on self-governance, which refers to situations where the resource users, who are directly affected or dependent on the quality of water, are involved in making rules regarding water quality. While we acknowledge that in modern societies it may not be possible to have absolute self-governance, we espouse a self-governed system in which resource users make most of the rules that affect the quality of water within the broader ambit of societal priorities.

Not many examples have been documented that illustrate how self-governance can be used to improve water quality security. With the exception of a few related stories such as the management of water quality in Lake Tahoe Basin on the California–Nevada border in the USA[3], much of the focus insofar as self-governance is concerned has been on water quantity security. To help us better understand self-governance and its influences on water security in general, we draw on the classic story about self-governance and lobster fishing in the state of Maine in the USA, as narrated by Schlager and Ostrom[4].

GOVERNANCE APPLIED TO LOBSTER FISHING IN MAINE, USA

Before 1920, the lobster grounds off the coast of Maine were self-governed by the local lobstermen. The coast was separated into zones that allowed lobstermen from each harbour to fish only from grounds that were associated with particular harbours. Permissions to enter and fish from particular grounds were sought from and made by the lobstermen themselves, who could also determine how the grounds were used and what fishing technologies were employed.

The lobstermen carried out the enforcement of rules and rights to access and use. Enforcement was usually accompanied by sanctions tailored for specific violations. For example, they used gear destruction to deter and exclude anyone who violated group rules. Such destruction involved the cutting of large wooden traps that are set on the ocean floor to catch lobsters.

The period in which lobstermen self-governed the grounds and were able to enforce rules and rights is generally associated with stable and sustainable outcomes.

After 1920, the situation in Maine began to change, particularly in the northern areas. The state of Maine took over governance of the lobster grounds and new fishing technologies began to emerge. The *de facto* system of self-governance transformed into a *de jure* system of state governance. The beginning of state governance saw the introduction of a licensing system and the breakdown of the informal zoning system.

Lobstermen also began to install motors on their boats. The introduction of motors had a great impact on the lobster fishery by increasing the range and extent in which fishing was conducted. Before 1920, fishing was conducted only during summer time in the bays, which

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were preferred by the lobsters for their warm waters. With the introduction of motor boats, lobstermen could go beyond the bays and gain access to open water grounds that were previously inaccessible.

The changes in the systems of governance and technological capabilities brought about a period associated with greater uncertainty and unsustainable outcomes. Without the zoning system, the prevailing rules and rights made it virtually impossible for the lobstermen to self-govern.

The major thrust of this story is that the nature and context of governance matter in determining the outcomes of a water security system. The story clearly illustrates that there are many combinations of forms of governance that can be used to improve water security in general. By examining the institutions and actors that governed the Maine lobster fishery, Schlager and Ostrom[4] were able, through their narrative, to illustrate the importance of explicitly defining and categorising the range of governance mechanisms.

CONCEPTS AND TOOLS OF SELF-GOVERNANCE

This narrative helps us to begin to understand the main concepts and tools of self-governance, which are central to improving water quality security. We can safely affirm here that the attributes of the lobster fishery, when sustainably used, included enforceable authority over rights of use, rules that authorised and regulated use, and an institutional arrangement necessary to regulate use. A weakening of the institutional arrangement led to overfishing, and thus deterioration in water security in general.

The foregoing story suggests that a self-governed system is critical in enhancing co-operation and establishing accountability when dealing with persistent complex water quality problems. Under appropriate conditions, a self-governed system has the advantage of functioning through social rather than legal enforcement and sanctions[5]. It helps in promoting and upholding collective action among resource users.

It is also important in enhancing essential social attributes such as collective identity and mutual reciprocities, rather than bureaucratic prescriptions[6]. Thus, within a self-governed system, compliance with societal and group norms is largely advanced through peer pressure.

CONCLUSION

Given that water quality security is associated with multiple resource users, and therefore multiple benefits and multiple relationships, it could be argued that managers in a self-governed system deal with a common pool resource when managing water quality. To self-governance a common pool resource such as water quality requires that managers are able to establish who has legitimate claims to benefit from such management. In other words, managers have to implement an appropriate governance regime in which users are granted rights and responsibilities. Such a regime would encourage self-governance within the parameters set by the government that owns the resource on behalf of the people.

While the various user sectors may be responsible for establishing the informal institutional arrangements necessary for self-governance[7], it is the government's responsibility to establish the formal institutional arrangements for broader governance. However, the success of formal institutions such as national policy and regulation is strongly dependent on how effective informal institutions are in establishing and promoting the roles of non-state actors. ES

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Water security and shale gas exploration in the UK

Jenna Brown, Chad Staddon and **Enda Hayes** outline the water requirements of shale gas extraction and discuss the implications for UK water security.

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A GLOBAL ENERGY CHALLENGE

A global challenge has been set: how to meet a growing population's energy needs while reducing carbon emissions to *mitigate* climate change. Natural gas has been purported as a 'transition fuel', as the energy mix moves towards reduction targets set out in the Climate Change Act (2008). There is, however, the complication that at least 50 per cent of the 85 billion cubic metres (bcm) we consume annually in the UK has been imported since 2011. Owing to increased gas prices, shale gas has received interest as a resource, as the UK seeks to emulate the success of the USA in shale gas extraction and in doing so improve natural gas security of supply.

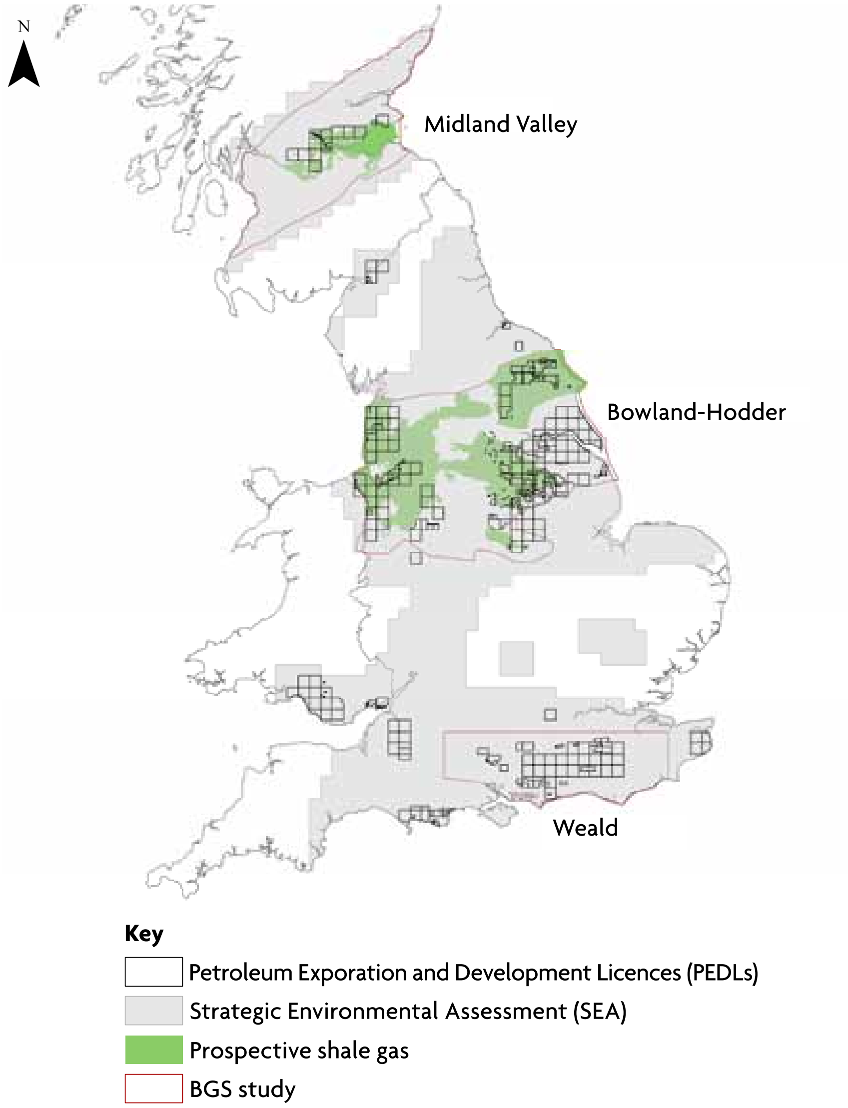
There is also a second parallel global challenge: how to produce energy to meet growing demand while *adapting* to climate change. Shale gas extraction is a water-intensive industry. In the UK alone we have seen the floods of 2007, followed by the environmental drought of 2012 and again the floods of winter 2013–2014. Climate change can influence our water security and, as population increases, finite freshwater resources per capita can only reduce. Are we therefore risking a trade-off of low-carbon energy security in shale gas for water security?

WHAT IS SHALE GAS?

There are three key differences between conventional (e.g. the North Sea) and shale gas: the geological location, the process of extraction and the well intensity.

In conventional gas extraction, a pocket of gas capped by an impermeable rock is located. A single well is drilled vertically into the pocket with the difference in pressures forcing the predominant volume of gas to the surface. Although the pockets of gas are dispersed, once one has been located and developed it can produce gas for around 30 years.

In unconventional gas such as shale, the volume of gas *in situ* is greater than for conventional gas, but the concentration and permeability is reduced. Shale therefore requires stimulation for the gas to be released. This is accomplished by a process known as hydraulic fracturing or 'fracking'. Following the drilling of a vertical well into the shale (at a depth greater than 2,900 m), a water-based fluid is pumped into a designated section of a horizontal well at pressures greater than the geology causing it to fracture; a proppant (sand) is pumped into the well to hold open the fractures, enabling the gas to be released. The volume of water and pressure required are a function of the geology and depth of the well, varying on a site-by-site basis. The 'reach' of the stimulation is in the order of 300 m from the horizontal well; therefore to increase economic output, multiple wells may be developed form a single site creating a 'well pad'. As the shale in the UK is over 1,000 m deeper than in the USA, the geology lends itself to multiple wells. The design reduces the surface footprint of development, but in doing so increases the resources required per site.



▲**Figure 1. Prospective shale basins in the UK**
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Box 1. Shale gas resources versus reserves (Source: DECC[6])	
Resources	**Reserves**
An estimate of the amounts of oil and gas that are believed to be physically contained in the source rock. Gas in place (GIP) is an estimate of the total amount of gas that is trapped within the shale rock. Because of measurement uncertainty, the DECC report provides a range of values for GIP rather than a single value. There is an 80 per cent chance that the true GIP value lies within this range, a 10 per cent chance that it lies below and a 10 per cent chance that it lies above.	An estimate of the amount of gas that is technically and economically viable to be extracted from a geological formation. DECC does not consider that there is sufficient understanding of the geology, or experience of the engineering or costs of production to make a reliable estimate of shale gas reserves at this stage. Estimates of reserves will develop and improve with increasing exploration drilling in the years ahead.

▼**Table 1. Water use of shale gas extraction (adapted from CIWEM, 2013).**

			Water use per well pad		
Process	**Duration**	**Per well**	**4 wells**	**8 wells**	**12 wells**
Drilling **	2 – 8 weeks	1 – 2ML	4 – 8ML	8 – 16ML	12 – 24ML
Hydraulic Fracturing ***	5 – 7 weeks	10-20ML	40 – 80ML	80 – 160ML	120 – 240ML
Production	5 – 20 years	0ML	0	0	0
Total		11 – 22ML	44 – 88ML	88 – 176ML	132 – 264ML

* The potential exists for some of the water returned to the surface to be re-used following treatment.
** Drilling includes both the initial vertical well and horizontal, therefore for an additional well the water use will be reduced.
*** A well may be fractured more than once.

SHALE GAS IN THE UK

The rights to natural gas are vested with the Queen and are managed by the Department of Energy and Climate Change (DECC), who has commissioned the British Geological Society (BGS) to advise DECC on resource estimates. Operators purchase the right to extract gas through licences – petroleum exploration and development licences (PEDLs). Purchased licences are displayed in **Figure 1**. Of the many companies that have already purchased licences, Cuadrilla, based in Lancashire, is the only company to have drilled and fractured a well.

In 2013 DECC commissioned a strategic environmental assessment for conventional and unconventional onshore oil and gas development in the UK with the purpose of identifying and quantifying potential environmental impacts, and identifying measures for mitigation[1]. This permitted 57 per cent of England and Wales to be made available to offers for additional PEDLs from July of this year, although this is not a guarantee that shale gas resources exist within the PEDLs nor that they will be developed[2].

There are three basins of shale in the UK that have been explored by the BGS, with prospective areas shown in **Figure 1**: the Bowland-Hodder in the north of England, containing 37,633 bcm[3], the Weald, located in the south-east, which has since been reported as containing shale oil for extraction[4]; and the Midland Valley in Scotland, containing a comparatively modest 2,265 bcm[5] of 'gas in place' (see **Box 1**).

As the UK geology is favourable to shale gas extraction, it is thought that a shale gas well would produce up to 85 million cubic metres (mcm) of gas in its lifetime compared to less than 74 mcm per well in the USA[7]. However, due to the short lifespan of a well, a cumulative number of wells must be developed. Based on the production profile of the Barnett shale in the USA, providing 10 per cent of natural gas demand in the UK would require 300 wells to be drilled annually[8], with the strategic environmental assessment consider the environmental impact of between 30 and 120 pads being developed (each having between 6-24 wells)[1].

WATER DEMAND OF SHALE GAS

The water demand of shale gas extraction has been reported, notably by the Chartered Institute of Water and Environmental Management[9] (CIWEM) in late 2013. They estimated that to drill and fracture a single well would use 11–22 ML (1 ML = 1,000 m^3), the equivalent of 4–9 Olympic swimming pools (**Table 1**). However, CIWEM base their figures on the assumption that a well will be fractured only once, whereas it is possible to refracture a well to increase productivity, thereby increasing the water use.

It is unlikely that a single well will be drilled per site, a well pad being developed instead with a minimum of four wells per pad. Using the CIWEM per-well estimates, a four-well pad would use 44–88 ML (the equivalent of up to 35 Olympic swimming pools) of water. The environmental statement for Cuadrilla's Preston Road and Roseacre Wood developments in

FEATURE

Box 2. What options exist for water re-cycling?

Water returning to the surface following fracturing, flowback, contains the same chemical additives as the water-based fluid used to fracture the shale in addition to sediment and low-level naturally occurring radioactive material. It is not suitable for re-use without prior treatment with two options available: thermal distillation and membrane filtration. Treatment research and development is continuing in the USA where shale gas extraction is advanced, but treatment is not yet common practice at each site with a wide range of 5–80 per cent of produced water being re-cycled (Nicot and Scanlon).[11]

Lancashire each include four wells per well pad with the estimated water use (provided by mains water) being 97.25 ML for drilling and fracturing the four wells[10]. This is nearly 10 ML above the CIWEM upper estimate and includes water recycling (options for water recycling are given in **Box 2**).

It is therefore important to consider that local geology, vertical well depth, and horizontal well length and density will influence water usage. Should a well pad increase to 12 wells per pad (as considered in the strategic environmental assessment[1]), the water use will therefore increase to 132–264 ML, the equivalent of over 100 Olympic pools.

The CIWEM estimate that to meet 10 per cent of the UK gas demand from shale gas over 20 years, the water demand of extraction would be in the order of 1.2–1.6 million m^3 per year, the equivalent of 480 –640 Olympic swimming pools. This would be less than 0.1 per cent of total abstraction for industry and agriculture when compared to annual licensed water abstraction in England and Wales. Nonetheless, in consideration of development density, the stress placed upon water resources would be concentrated. Industry analysts have often suggested that shale gas has a relatively high water efficiency compared to other fossil fuels and also biofuels such as ethanol[12]– a single well producing 85 mcm[5] requiring 23 ML of water produces over 3,696 m^3 of natural gas per m^3 of water.

However, this representation makes the fundamental error of neglecting to distinguish between water withdrawal defined as "water diverted or *withdrawn* from a surface water or groundwater source" and water *consumed*, "water use that permanently withdraws water from its source … or [is] otherwise removed from the immediate water environment"[13].

Between 20 and 80 per cent of the water used is retained by the shale this translates as up to 80 per cent of the water withdrawn for the use of hydraulic fracturing could be consumed, removed from the immediate water environment and the hydrogeological cycle. In light of climate change and a reducing freshwater resource per capita, is this an appropriate use of water?

POTENTIAL FOR WATER STRESS

Concerns for water resources generally include the adequacy of water for human and industrial uses beyond environmental need, particularly in areas already susceptible to drought or a history of water stress, with the impact on ecosystems a major concern. The amount of water required for shale gas development is of particular concern to communities due to the geographical variability of water resources. This is particularly true in England and Wales, as shown in **Figure 2**, the lighter areas representing a reduced ability to meet water resource demands[14].

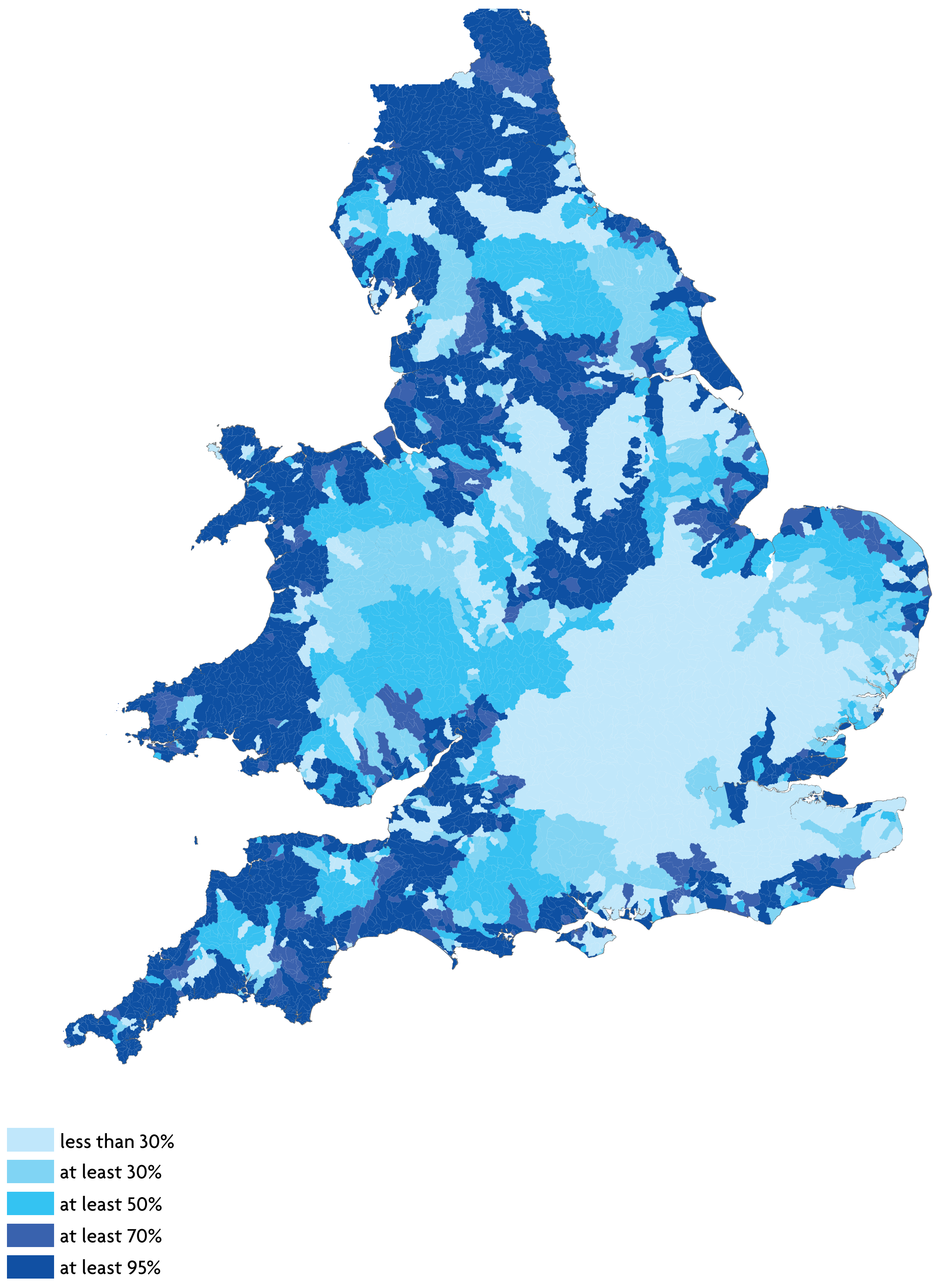
For inland England, Cambridgeshire to Gloucester and to Surrey in the south, water resources for new abstraction licences will only be available 30 per cent of the time, while the west's coastal boundaries have greater water resource availability. Shale gas distribution, however, does not follow postcodes.

The increased landward acreage of the offered PEDLs increases the likelihood that they will be located in within areas of low water resource availability: 30 per cent of land offered for PEDLs reside in catchments with water resource availability less than 30 per cent of the time and 14 per cent of land in catchments with water resource availability less than 50 per cent of the time. The potential therefore exists for shale gas water requirements to exacerbate local or regional water shortage areas of existing over-abstracted parts of the country (see **Figure 3**).

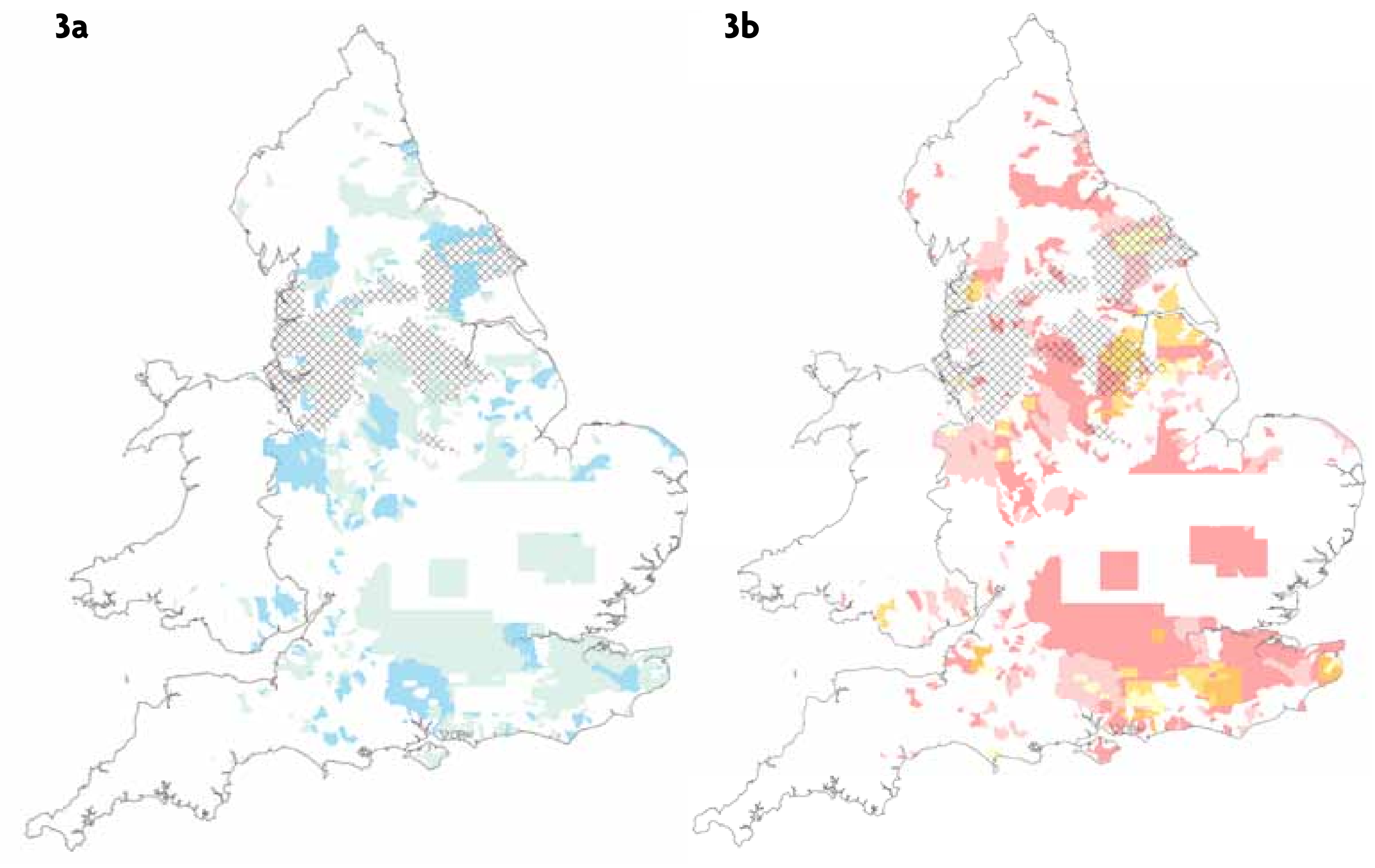
An area spanning western Buckinghamshire and Oxfordshire, and a second within Cambridgeshire and Essex, are centrally located within an area of low resource availability. In addition, the high concentration of PEDLs on the eastern side of the Bowland-Hodder is a cause for concern, falling within an area of low water availability.

RESOURCE PROVISION AND IMPACT

In the UK, rights to water do not follow land ownership – just as neither do mineral and gas rights. Abstraction is included in the planning process on a well-by-well basis: the operator applies for a permit from the Environment Agency, who has the power



▲ **Figure 2. Water resource availability in England and Wales (percentage of time). (Environment Agency)**



Key

- Shale Gas England and Wales SEA
- DECC Existing Onshore PEDLs
- Bowland-Hodder
- Water Resource Availability ‹30% of time
- Water Resource Availability ‹50% of time

Water availability for new water abstraction licences (% of time)

- ‹30% within purchased PEDLs
- ‹50% within purchased PEDLs
- ‹30% within offered PEDLs
- ‹50% within offered PEDLs
- Prospective Shale Gas

▲ **Figure 3. 3a Water availabilty for new water abstraction licences (% of time) 3b Water availability for new water abstraction for purchased and offered Petroleum Exploration and development licenses (% of time)**

to issue a permit for a fixed period. Work done by the Environment Agency through its Catchment Abstraction Management Scheme and Restoring Sustainable Abstraction programmes shows that most catchments in the country are already at or near maximum sustainable abstraction.

The UK government has delayed reform of the abstraction licensing system, but any new abstraction management system is likely to include mechanisms for reducing, rather than increasing, the amount of water available to existing or new abstractors. In general, shale-related water withdrawals are small with respect to irrigation of agriculture and cooling associated with electricity production. It is the timing, location and concentration of shale-associated water withdrawals that have the potential to create water adequacy issues.

In the Barnett shale, operators rely upon groundwater for 45–100 per cent of their water needs placing additional stress on aquifer systems, which are already stressed from rural and municipal pumping[10].

When the consumptive proportion is considered (in addition to the water security threat associated with climate change and the increase in extreme weather conditions), it is clear that the potential exists for shale gas development to induce water scarcity on a local scale. A report by Ceres[15] recorded that, of the nearly 40,000 oil and gas wells (conventional and unconventional) drilled since 2011 in the USA, three-quarters were located in areas where water is already scarce, and 55 per cent were in areas already experiencing drought.

In a bid to mitigate climate change by shale gas extraction, attention needs to be given to the cumulative effects of significant fracking operations on county and even national water balance assessments as water resource are influenced by the effects of climate change. There exists a key policy disconnect that needs to be addressed if a well-regulated shale industry, one that learns from experience in the USA, is to be developed. It is crucial that water withdrawals should be monitored and coordinated so that they are sustainable, with the cumulative effect of developed wells considered by catchment and not on a site-by-site basis. **ES**

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Water security through integrated local delivery

Lorraine De Souza Jenny Phelps and **Chris Short** explains the concept of integrated local delivery and describes its application in the Upper Thames catchment area.

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There is widespread recognition that there have been dramatic changes across UK rural policy over the past 70 years. For much of this period, environmental initiatives covering both land and water have tended to be top-down issues driven by national legislation, policy obligations and international directives and conventions.

Local communities, who may feel protective of the natural assets within their vicinity (which may also contribute to a local sense of identity), can feel alienated by the imposition of targets relating to these same natural assets, from whose formulation they have been excluded. However, such communities frequently have essential knowledge, experience, a sense of pride and a commitment to the future survival of such areas. Complex sites with a combination of land and water issues will have a wide range of legal obligations and interests. In such multi-objective areas there is a real need for greater connectivity at all levels - local, regional and national - to enable a synergy to be possible on the ground. The lack of co-ordination, coherence and integration at the national (and even regional) level results in a series of confusing, disjointed and contradictory signals and mechanisms for those who live and work close to these areas.

A move towards a territorial or systems approach brings land and water together and has the capacity to assist in both management and governance. While it is possible to see how these tensions have developed, largely through the shift in power away from productivist agriculture and towards measures aimed at halting issues linked with environmental decline, the need to embrace a holistic multi-objective approach that inspires and enables land managers and local communities is pressing. The perception that external goals, however worthy and legally upheld, are being imposed by national or international institutions without the engagement of local people, who feel distanced and even disenfranchised from their own land as a result, undermines the environmental imperative.

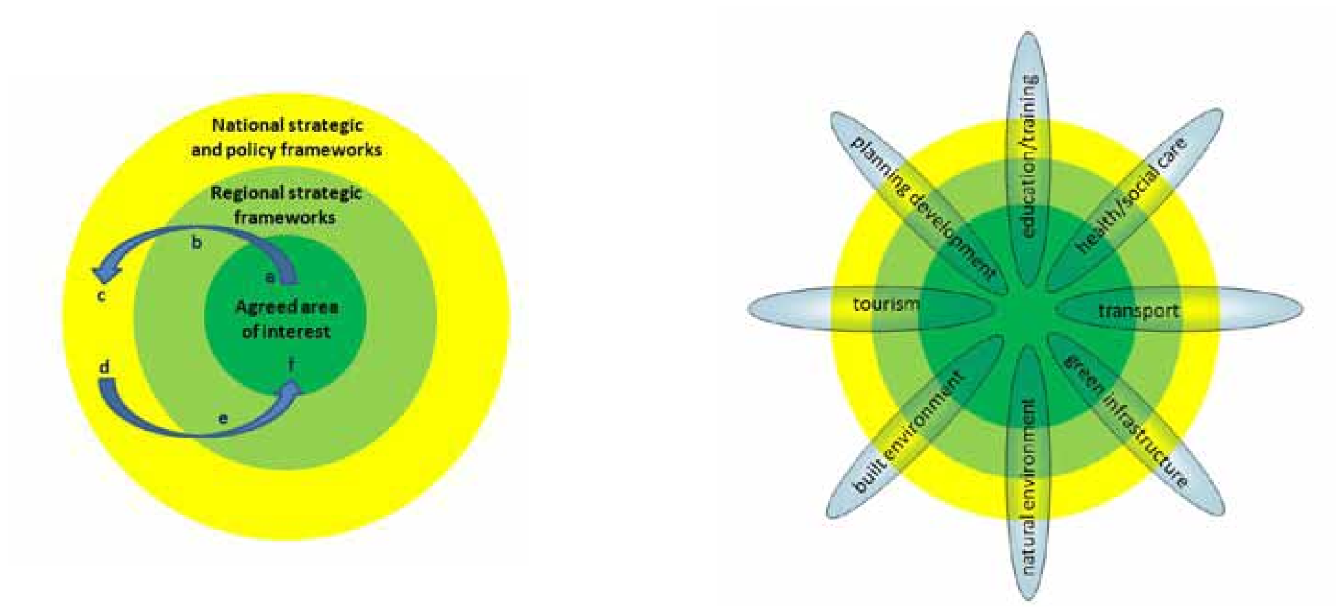
Within Gloucestershire, the Farming and Wildlife Advisory Group (FWAG) and the Countryside and Community Research Institute (CCRI) at the University of Gloucestershire have developed an integrated local delivery (ILD) framework, implemented in a range of situations, that enables those with local skills and environmental land management knowledge to contribute to the management of sensitive and key environmental sites. The first project to be delivered using the ILD framework was in the parish of Uley, Gloucestershire, where the objective was to support the village and local farmers in the restoration and long-term protection of Uley Bury Hill Fort and surrounding grassland.

THE INTEGRATED LOCAL DELIVERY FRAMEWORK

The ILD framework was developed in 2004 from a landscape-scale project that outlined the urgent need for a simple mechanism that valued local knowledge and connected this knowledge and all levels of strategy to delivery by providing local relevance through a simple transferable process. The concept of ILD is that each community could be inspired and enabled to look after its piece of the global jigsaw to deliver multi-strategy objectives at a local level. The ILD approach has been so successfully used in Gloucestershire for over 10 years, to restore key environmental protected sites, that the approach is now being applied to deliver water security through integrated catchment management.

The first part of the scoping phase is to gather information on the key natural assets and characteristics within the inner circle (a), the agreed area of interest. Next move to the middle circle (b), and record all the regional strategic frameworks that could be delivered within the defined central area. Finally move to the outer circle (c), this represents the national and in some respects international strategic and policy frameworks that have a direct relationship to the inner circle (a). This should provide you with a good grasp of the range of physical assets and the associated frameworks at the local, regional and national level.

The next part of the scoping is to identify the contacts responsible for the delivery of these frameworks. This is done in reverse order (d to f), because a secondary aim here is to make the connections from the national and regional to the local level. So the aim at the national level (outer circle) is to identify the person (d) with responsibility for delivering the legal obligation associated with a designation or policy objective (c). When completed for each asset it provides you with a number of circular connections, much like the petals of a flower.



▲ **Figure 1. National, regional and local frameworks within ILD (Source: Defra[3]).**

Step 1

Begin initial scoping to determine the area; individuals and statutory frameworks involved.

Step 2

Map the management tasks and verify these in an inclusive and open format.

Step 3

Develop a management group around key local and statutory stakeholders.

Step 4

Encourage linkages and opportunities for local contribution and adoption of responsibilities.

Step 5

Establish capacity and role of local management group; identify and prioritise tasks.

Step 6

Implement proposals and embed management group and support..

▲ **Figure 2. Interlinked steps of the ILD framework. (Source: Short *et al.*[1])**

The eight themes used to develop the ILD framework (adapted from Short *et al.*[1], CCRI[2]) are:

- **local level:** works within the lowest appropriate national and European administrative structure (for example parish or ward, town, county, district, region, country) (see **Figure 1**);
- **connect objectives:** seeks to deliver a wide range of strategic objectives within the defined area in order to maximise the effective use of public funds and resources;
- **stakeholders:** identifies statutory and non-statutory stakeholders with an interest in the area so that their involvement and strategic aims can be delivered within the administrative area in partnership;
- **local knowledge:** seeks to strongly support and value the role and knowledge of the farming and local community and inspire them to lead the protection of their own local environment;
- **facilitation:** promotes the use of facilitation through an independent third party to develop or support an existing local management group that acts as the collective discussion forum for the area, with clear lines of communication to public agencies with legal responsibilities;
- **local governance:** incorporates the parish council (or relevant local government framework) into the communication structure of the local management group to ensure continuity beyond project timescales and embed information;
- **communication:** provides a forum for identified partners and stakeholders within the defined area to take action and offer knowledge and resources for a multi-objective benefit; and
- **funding:** identifies funding and resource opportunities for further development and delivery of the locally identified actions.

THE ILD FRAMEWORK STEP-BY-STEP PROCESS

The ILD framework is delivered through a process of highly skilled facilitation, shown in **Figure 2**.

IMPLEMENTATION OF ILD IN THE UPPER THAMES

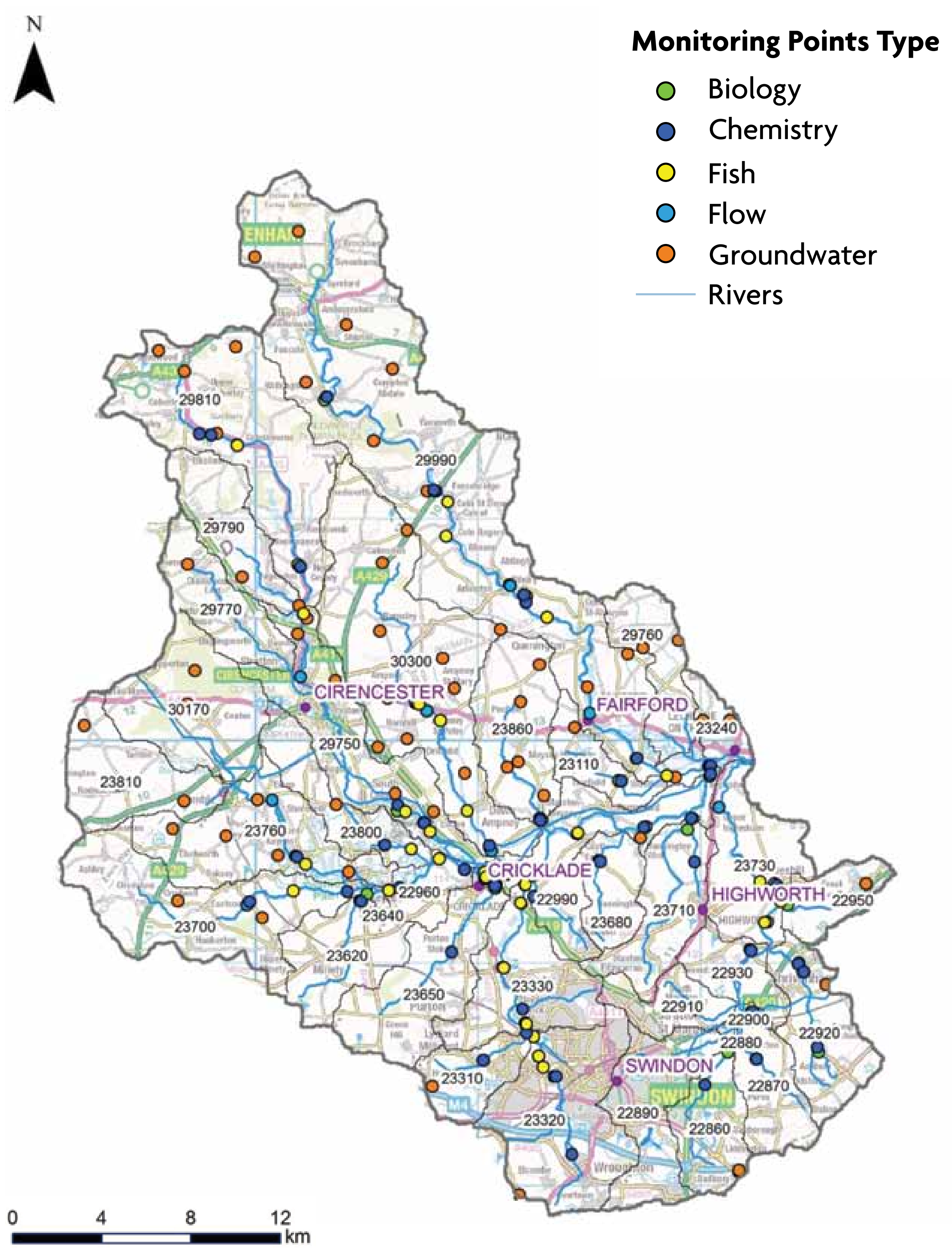
Government policy aims to secure multiple benefits from integrated approaches to improve water quality, supply water, and protect and enhance the natural environment. It aims to integrate programmes that address wider environmental issues with Water Framework Directive programmes at a catchment scale. For this to be achieved, a delivery framework is required that can locate and pull together the different strategic frameworks, and different stakeholders.

UPPER THAMES IMPLEMENTATION PLAN

The Upper Thames catchment covers approximately 30,000 hectres of the Cotswolds, an Area of Outstanding Natural Beauty in the UK, and is drained by the River Thames and its tributaries (see **Figure 3**). The catchment supports a wide range of economic activity in industries such as farming, recreational fishing, tourism and recreation and is a source of drinking water.

At first glance this attractive area would appear to be in perfect condition due to the wide range of wildlife it supports. However, monitoring and consultation suggest otherwise, for example:

- the ecological status of parts of the river system is not as healthy as it should be;



▲ Figure 3. The Upper Thames Catchment area (Source: Environment Agency).

▲ **Figure 4. Siddington Meadows taking water away from the village down the natural flood plain after four road under drains had been unblocked — a simple act by a landowner that helped to reduce flood risk to the village flooding and improved ecological status for both meadow and water quality. (© Jenny Phelps)**

- fish, invertebrate and macrophyte populations in some rivers are below what would be expected in a healthy river;
- non-native invasive plants grow within the catchment;
- there are issues with water quality and low flows on some of the rivers and groundwater bodies;
- some communities are at risk from flooding and the risk may increase if climate change predictions are realised; and
- long-term economic development of some areas is well advanced and spreading.

The Upper Thames Catchment Pilot is a pioneering initiative, supported by the Department for Environment, Food and Rural Affairs (Defra), set up to develop ways to achieve these aims. A number of key organisations, including public, private and third-sector organisations, have come together to develop ways of adapting, protecting and improving the quality of water, reducing flood risk, and protecting wildlife while benefiting the social and economic well-being of communities within the catchment.

There is now an established Upper Thames partnership that aims to work towards delivering a healthy, functioning water environment for people and wildlife across the catchment through a shared vision. The partnership is committed to identifying related actions, many of which are already in progress in the catchment, and linking them together through the steering group to deliver integrated management of land and water. The partnership used the ILD framework to embed this collaborative working both in the development of strategic priorities and on-the-ground delivery through a shared problem-solving approach.

▲ Upper Thames River. (© Simon Grieg)

THE WILD PROJECT

There was a particular desire to develop a project that implemented a partnership approach within the catchment-based approach, and an opportunity arose across 20 parishes within the Upper Thames catchment around the Cotswold Water Park, an area of many lakes created after gravel extraction. The aim was to demonstrate the benefits of linking together community, environmental and agricultural interests to provide a test bed for localised problem-solving and cost–benefit analysis using ILD.

The WILD project (Water with Integrated Local Delivery) was developed in partnership with four organisations working together to facilitate and improve the ecological status of the rivers and watercourses in the Cotswold Water Park. The WILD project partnership was established in January 2012 and is led by Gloucestershire FWAG and includes Gloucestershire Rural Community Council, Cotswold Water Park Trust and CCRI.

The WILD project has been engaging with local communities and landowners since May 2013 by encouraging them to get involved in understanding their local watercourses and the management of them. Through local community participation, delivery plans are being produced that will see enhancements over a three-year period.

The ILD framework has been used in the WILD project by discussing and mapping water-related issues in parishes/towns with both communities and landowners, including walk-over surveys of ecologically failing water bodies. This fundamental information is compiled together and used to generate improvement projects and recommendations that are then discussed and implemented by stakeholders, and embedded in local parish and neighbourhood plans.

An example of the WILD project has taken place in Siddlington parish in the Upper Thames Catchment. The parish did not experience flooding from the River Churn during the extreme weather during the 2013/14 winter because of a few key local actions identified through the ILD process: in September 2013 the local community and landowners unblocked silt from road drains and culverts, allowing the water to flow naturally in ditches and meadows (see **Figure 4**).

The River Churn that flows through Siddlington parish has been failing on its ecological status. By reconnecting the river to its natural flood plain (with the support of the farming community), the ecological status will be improved, together with the health of the farmland, and also flood risk within the community has been reduced. **ES**

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Helping improve community-led management of water resources in Uganda

Oscar McLaughlin, Francis Kazooba and **Alan Terry** outline the problems facing Water User Committees in Uganda and describe how participatory techniques helped to resolve them.

▲ Lake Bunyonyi, Uganda. (© Palenque)

The Millennium Development Goal (MDG) target on access to drinking water, to "halve, by 2015, the proportion of population with sustainable access to an improved water source, urban and rural" and the "proportion of urban population with access to improved sanitation", is now considered to have been achieved. However, 768 million people still lack access to potable water, and in sub-Saharan Africa the numbers without access to potable water actually increased by 63 million between 1990 and 2011[1].

As Skinner[2] points out, while progress has been made on access to water, definitions as to what that means are inconsistent. The apparent success in reaching the target fails to take into account factors such as whether the water source is still operational, whether the costs preclude the poor from accessing it, whether certain groups are denied access by others and whether marginalised groups who are not officially counted are included in the official statistics.

This vagueness results in Uganda claiming that it has achieved this part of the MDG despite the fact that, in a population of approximately 36 million, only 1.5 million have access to piped water.

THE POLICY CONTEXT: THE GLOBAL SOUTH

Since the 1990s, many governments in the Global South have decentralised the management of water resources. This process was driven initially by the fallout of the Third World debt crisis of the 1980s, in which governments were forced to adopt structural adjustment policies by the World Bank and International Monetary Fund in return for financial support to overcome indebtedness to the commercial banking system of the Global North. Like the countries affected by the 2007 – 2008 banking crisis in the Global North, indebted countries were required to cut back on government expenditure and encourage other stakeholders such as communities, non-governmental organisations (NGOs) and civil society groups to take responsibility for the running of public services.

This move to decentralisation coincided with a growing trend in development thinking that encouraged bottom-up development through participation with those groups in the Global South that had traditionally been omitted from decision-making, namely the economically and politically marginalised poor[3]. Participatory development and decentralisation of decision-making of services such as water simultaneously managed the rare feat of appealing to the political right through its transfer of resources from the public to the private sector and the replacement of big government by small government, and the political left, who were in favour of empowering the poor.

CASE STUDY

Within sub-Saharan Africa, Zimbabwe's 1998 Water Act, Uganda's 1999 Water Act, Kenya's 2002 Water Act and Malawi's 2003 National Water Act, among many others, all sought to a greater or lesser extent to decentralise water resources management to the user level and reduce the direct role of the state in their management. The expectations were that, once in place, decentralisation would deliver improved services. However, in the past decade, the performance of these newly created management systems has come under critical scrutiny[4].

A key criticism is that the newly created management groups, in Uganda called Water User Committees (WUCs), are unaware of the rights and responsibilities that have been transferred to them under the new regime. This is exacerbated by the fact that, in many rural and peri-urban communities, water has traditionally been managed by customary rights, many of which are based upon oral traditions or long-standing informal agreements that may or may not be compatible with the modern rights that are meant to have replaced them.

THE POLICY CONTEXT: THE 1999 UGANDA WATER ACT

In Uganda, the 1999 Water Act (hereafter referred to as the Act) is now the principle law that regulates the water sector. One of its objectives is "to promote the rational management and use of the waters of Uganda through use of appropriate standards, co-ordination of activities, allocation and delegation of responsibilities"[5].

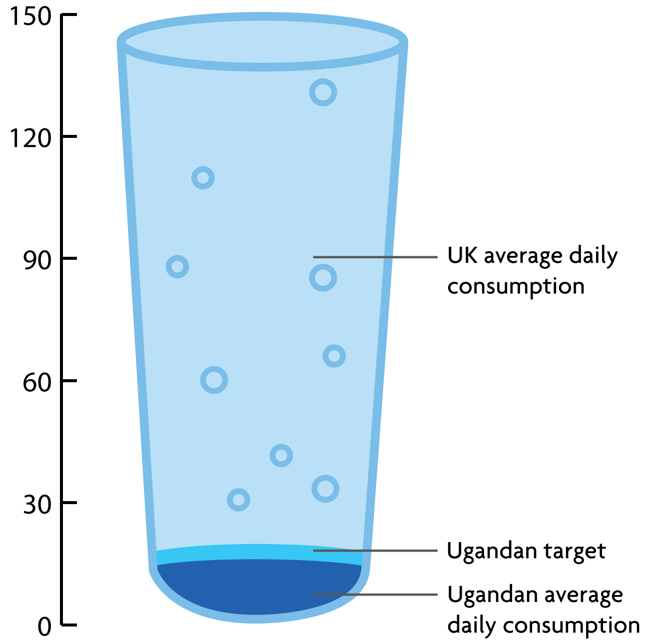
A key strategy is to enable the formation of WUCs, whose membership is drawn from the beneficiaries of the water supply, tasking them with ensuring the proper maintenance of the water system by collecting revenue from users. This demonstrates the move from a rights-based to a more market-based system of resource allocation. However, while handing over responsibility for day-to-day planning and running of water resources to WUCs, the Act also vests all water rights in the government, who has therefore become the owner of all water resources in Uganda.

Local authorities are required to organise the formation of WUCs within their area, although the responsibility for this task between the district, sub-county or parish is ambiguously drafted within the Act, which has added to the confusion. Once created, the WUC is responsible for planning and managing the point-source water supply (eg. boreholes and shallow wells) in the area. The unclear drafting of the Act is one factor that has made the implementation of better functioning local water supplies less successful than had been expected.

The Act defined the basic level of water supply (see **Figure 1**) from a public water point within a distance of 1.5 km of all households; this has since been updated to 1 km in line with international standards. Ugandan consumption averages 12–14 L/(person·day) in rural areas and less than 17 L/(person·day) in urban areas with a population greater than 5,000[6].

The Act also highlighted protected springs, hand pumps and gravity flow schemes as appropriate technology options for rural and sparsely populated peri-urban areas. Community contributions in the form of cash or kind should be made towards construction based on the technology choice; furthermore, operational and maintenance costs have to be fully paid for by the beneficiaries except in situations where the costs are beyond the capacity of the community.

This clause is also ambiguous in that it is difficult to identify when that point has been reached. The policy promotes *de facto* community ownership as a strategy for ensuring sustainability; therefore the users `own' all protected water sources or sources that have been constructed in their communities, though this clearly contradicts the clause that vests all ownership of water in central government.



▲ **Figure 1. Daily consumption (L/(person·day)) of fresh water in the UK compared to Ugandan 1999 Water Act target. (Source: Water Footprint Network[7])**

CREATING FUNCTIONING WUCS AND WIDER CIVIL ENGAGEMENT: IN THEORY

The community is required by law to form WUCs to manage, operate and maintain point water sources. The WUCs are set up by a mobiliser from either the district, sub-county or parish level. The approach is to make use of participatory tools to allow the community to identify and solve their own water and sanitation (WASH) problems, i.e. learning-by-doing through self-discovery. This strategy is based on the premise that people are the most valuable resource, that the process is about furthering human development, and that the fulfilment of human potential occurs as the working groups set up in the community are given more responsibilities.

The participatory tools are intended as a starter to a process that should encourage the community into continuous dialogue and that should be followed up with home visits by the newly empowered WUCs and district water officers.

The first activities involve the entire community, or as many people as are available, and revolve around mapping the current resources in their settlement and the identification of gaps in relation to water and sanitation provision, as a first step in enabling them to identify needs, thereby providing the community with data to apply to local government for help to fill these gaps in services. The next stage involves identifying various sanitation issues and best practices. The mobiliser enters into a discussion with the WUC. He or she should continue to train the WUCs individually then collectively on their roles and responsibilities such as promoting good sanitation practice, the operation and maintenance of the water source, gender inclusion, environmental maintenance, how to collect funds for the services, book-keeping and monitoring the facilities.

This strategy of placing responsibility on the WUCs to act as promoters and instigators of good sanitation and local environmental practices is conceptually sound. If done well, it empowers the community to act as a homogeneous self-governed group and reduces their reliance on the government for funds or services.

At the same time it helps to unlock the vast amount of water resources within Uganda by unlocking the potential energy and resourcefulness of local communities whose long-term livelihoods and health are dependent upon good management of those water resources.

THE PERFORMANCE OF WUCS IN PRACTICE

The Ugandan Ministry of Water and Environment (MWE) claims that 71 per cent of the 278 WUCs that it sampled were functional[8]. However, this figure seems to be significantly higher than the findings of this research project, which were that only 10 per cent of WUCs from the three districts that participated in the research met regularly, and a district deputy water officer stated that, from her experience throughout south and central Uganda, she did not think the MWE figures matched reality. Many WUCs that were visited during the research had met only once since they were established over a decade ago, with one sheet of paper displaying their very first meeting as the only record of any activity during that period.

▲ **Figure 2. A badly degraded 'protected' spring with low flow rates leading to long queues and poor access to the site, creating further hazards for women and children, the main water carriers. (© Alan Terry)**

CASE STUDY

▲ **Figure 3. Discussing issues with a WUC. (© Oscar McLaughlin)**

In the Mukono District, east of Kampala, WUCs were faced with abuse and physical attack from community members when attempting to collect funds, and the majority of community members refused to contribute. Accounts of the misuse of WUC rolling funds were common.

Typically, they were being used for home improvements, food, gambling and alcohol, creating an atmosphere of distrust and frustration. Poor management of the WUCs is caused by internal mismanagement and corruption and by external pressure from other community members who undermine well-meaning WUC officers in carrying out their duties.

THE CONSEQUENCES OF POOR MANAGEMENT ON WATER SUPPLY PROVISION

Access to an improved water source, defined by the MDGs as "reasonable access to an adequate amount of water from an improved source" such as the communal resources managed by WUCs, also includes household connections, public standpipes and rainwater collection. Unimproved sources include vendors, tanker trucks and unprotected wells and springs[8]. Reasonable access is internationally defined as 1 km in rural areas and 0.2 km in urban areas.

The national functionality of rural supplies, defined as producing water to a pre-set standard at time of visit, was recorded as 83 per cent in 2012, although according to MWE the research was underfunded and consequently the sample was not fully representative of the national situation. This figure has stagnated between 80 and 83 per cent over the past 9 years and is considerably lower than the sector target of 90 per cent.

As of June 2012 access to improved water within 1 km in rural areas was 64 per cent, a decline of 1 per cent compared to 2011. In urban areas access increased from 66 per cent in 2011 to 69 per cent in 2012. The post-1999 regime is therefore inconsistent in the outcomes with respect to functionality and access, and cannot be considered as having met the expectations of those who drafted the Act.

Functionality currently sits at 82–86 per cent for all technologies apart from shallow wells, which was 71 per cent in 2010–2011 and 74 per cent in 2011–2012. Wells have the lowest level of functionality and protected springs have the highest. An important factor in explaining the low functionality of wells is the lack of trained hand-pump mechanics[9].

Seventeen per cent of the sources are low yielding and 10 per cent are classed as vandalised. A further 8 per cent have limited functionality due to poor water quality. Technical breakdowns account for 43 per cent of non-functionality, with an inability to afford worn-out parts being a major factor. In such cases, government claims it would step in to finance the repair although in practice this is very rare.

Of the 66 per cent of the rural population with access to an improved water supply, 24 per cent have access to piped water (public outlets and private and institutional connections) and 76 per cent to point water sources (deep borehole, shallow well, protected spring, rainwater harvesting tank). In rural areas access to safe drinking water varies from a low of 20 per cent in Kaabong District to 93 per cent in Rukangiri District. Urban centres show similar fluctuations.

WATER QUALITY PROBLEMS

The quality of water is something not taken into account by the MDGs in terms of access to water. However, the MWE[10] states that water quality problems accounted for 8 per cent of non-functioning water sources, but national standards of water quality indicators fall well short of international indicators. For example, total iron content has a 79 per cent compliance rate with national guidelines but a 45 per cent rate with higher World Health Organization (WHO) guidelines. Similarly the *E.coli* compliance rate is 97 per cent, in agreement with national guideline, but only meets 63 per cent of WHO guidelines.

This questions what the country's access to improved water sources may actually be (further complicated by reports of water quality varying widely during the day depending on use), as well as the robustness of Uganda's water quality assessment, which the MWE has already stated is very under-funded[10].This indicates the range of highly technical issues that, in theory, WUCs need to have some knowledge of if they are to maintain and challenge the existing provision in order to facilitate improvements.

TRYING TO UNDERSTAND WHY WUCS UNDERPERFORM

As a consequence of the patchy performance of WUCs, between November 2012 and May 2013 a series of workshops were held to try to understand the causes and address the issues that were holding back their performance. The project was jointly run by a Ugandan NGO, the National Association of Professional Environmentalists (NAPE) and a geography student on placement from the University of the West of England.

It was important that WUCs and other members of the communities participated in the project so that those individuals responsible for maintaining the WASH systems could explain the circumstances in their local communities and in this way learn from each other. WUC members and people from the wider community from the Mukono, Nakawa and Luwero Districts were involved.

These are urban, peri-urban and rural districts in or near Kampala, with a high percentage of people living in informal settlements. They were selected because NAPE had worked in the districts for over a decade and had established good relationships with the district, sub-county and parish elected representatives and WUC members.

In addition to the WUCs, a range of stakeholders were also invited to participate, including civil servants, members of higher government and other civil society organisations such as WaterAid, Community Integrated Development Initiatives and the Uganda Rain Water Association. To provide a wider view, 10 unannounced visits were also undertaken to WUCs not represented at the workshops, to speak directly to community members and WUC members who had no previous contact with the researchers (see **Figure 3**).

This had the added benefit of increasing the number of women interviewed, who tended to be under-represented in the workshops despite their predominant role in collecting water.

WHAT WAS LEARNED?

A key factor that emerged during the participatory workshops was that the majority of poorly functioning WUCs and the wider communities in which they were located had very little understanding of their rights and responsibilities as set out in the 1999 Act. The principle output from the research was an illustrated bilingual (English and Luganda) handbook for WUCs[11] (see **Figure 4**).

The handbook aimed to educate and inform the WUC members about their roles and responsibilities, in order to allow them to understand their rights to water and sanitation and to provide them with some basic professional communication and conflict-resolution skills that would allow them to fulfil their roles as WUC members by having a more professional attitude. The five-page booklet, which doubles up to 10 when translated, is divided into a series of clearly defined sections.

The first is a summary of people's rights, as citizens of Uganda, to water and sanitation, with reference to the particular act, policy, statute or constitution that the rights apply, to give a higher level of authority. The aim of this part was to give the community a legal toolkit to either demand better services from the government or give them legal authority to function, as intended by the 1999 Act and other water-related acts. Subsequently, the handbook describes the roles and responsibilities of the community towards water and sanitation, such as keeping up good practices of sanitation.

It then provides each of the six members of the WUCs with a clear explanation of their individual roles and responsibilities and provides timetabled activities for certain members. It also provides a checklist for the WUC to check the sanitary state of the environment, as well as general tips for maintaining good levels of household and community sanitation and health.

The final section contains basic communication skills for dealing with members of the community. All of these sections are complemented with illustrations to help convey the message to those who cannot read.

Once the handbook had been produced, a final workshop was convened where its contents were explained to the participants and which served as an efficient method of distributing copies to those community members who would be most interested and influential within their communities. In addition, district officials, low-level government officials and high-ranking employees from the National Water and Sewerage Corporation provided another outlet for knowledge transfer and the distribution of the handbook.

SOME PRELIMINARY IMPACTS OF THE HANDBOOK

Since the distribution of the handbook in the Nakawa municipality in Kampala, three sub-counties of Luwero and 10 villages in Mukono town council in April 2013, it has been used by WUCs to educate communities in the management of water sources and to improve the functioning of the WUCs. Although there has as yet been no systematic follow-up research to evaluate its impact, informal reports from WUCs via NAPE describe significant improvements in the payment of water user fees. There have also been reports of improved hygiene and sanitation practices around water facilities.

▲ Figure 4. The front page of the handbook. (Source: NAPE[11])

WUCs who have received the handbook are now far more knowledgeable about their rights to water and sanitation. One example is in the Zirobwe Sub-County of Luwero District where one WUC used the handbook to demand their right to water in circumstances where an individual had recently bought and fenced off the land on which their community water source was placed. That individual was asked to remove the fence by the local government officers, who made use of the handbook to illustrate the illegality of the enclosure.

The community development officer within Zirobwe appreciates the impact the handbook has created. As well as the previous case, the reporting and fixing of non-functioning boreholes have improved compared to the time before the handbook was available.

WUCs from informal settlements within Nakawa Municipality, using their rights to water and sanitation, have petitioned the municipality to test water sources, having learned from the handbook that local government has a responsibility to undertake this essential testing. As a consequence spring wells were identified as contaminated and these wells have been closed, which should improve local health.

CONCLUSION

The water resource management reforms that have taken place in the Global South since the 1990s were based on redefining the role of the public sector in the management of resources. They focused on an institutionalised approach to managing communal resources to allow for management and use that would not degrade the quality of those resources.

The Ugandan 1999 Water Act was one of many community water management reforms to sweep across the Global South, concentrating on water provision from non-conventional sources such as boreholes and protected streams. In theory this is conceptually appropriate as it should help to empower the community, bestow a sense of ownership upon them and encourage a participatory grass-roots management system that in turn legitimises the process of decentralisation of power and reduces inappropriate government intervention.

However, this research has found that assumptions in the 1999 Water Act concerning the willingness and ability of communities and WUCs to undertake the often complex and at times highly politicised tasks assigned to them were based on over-simplistic and optimistic expectations, with the result that their functionality has been compromised. A key factor in undermining their functionality was a lack of knowledge of the rights and responsibilities within WUCs and the wider community.

The work undertaken in Mukono, Nakawa and Luwero Districts provides some preliminary evidence that the provision of a user-friendly handbook that enables literate and illiterate members of the community to learn about their rights may help to improve the functionality of WUCs and therefore the management of water supplies at a community level. However, more systematic research is required to fully test its effectiveness, although preliminary evidence seems to be positive. Nevertheless, even with the relatively small amount of evidence that exists, we believe that the findings may be of value to other countries that have followed the same path with respect to the decentralisation of water management. **ES**

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Abstraction reform and water security: the view from England and Wales

Chad Staddon summarises past and future law and practice for abstracting water.

We take water from the natural environment for all kinds of reasons: households, farms and industries all depend on water resources. The impacts of abstracting water directly from rivers or underground aquifers can be wide-ranging, including reduced water flow or quality leading to habitat loss or lack of availability for other human activities. Poorly managed abstraction systems can also result in water being used for irrational or suboptimal purposes. We already face challenges in water availability that put pressure on some of the existing 20,000+ abstraction licences currently in existence in England and Wales. Many catchments in the UK have no spare water that can be allocated for further abstraction and existing allocations are also under climate-change-related pressure.

Managing our available water resources is likely to become more of a challenge in the future with an increasingly varied climate and increased demand for water from a growing population. Yet water is vital to the economy to generate power, run industries and grow food. This is why water abstraction, in most countries, is monitored and licensed by national or regional agencies. Of course in some countries, for example the USA, legal principles such as riparianism (rights that come with ownership of land alongside a water course) and prior appropriation (rights that come with having been the first to abstract water historically) may mean that state agencies are very constrained in their ability to control abstraction[1]. In England and Wales water abstraction management is currently undergoing a significant rethink, which may result in a new system after 2015.

A SHORT HISTORY OF ABSTRACTION MANAGEMENT

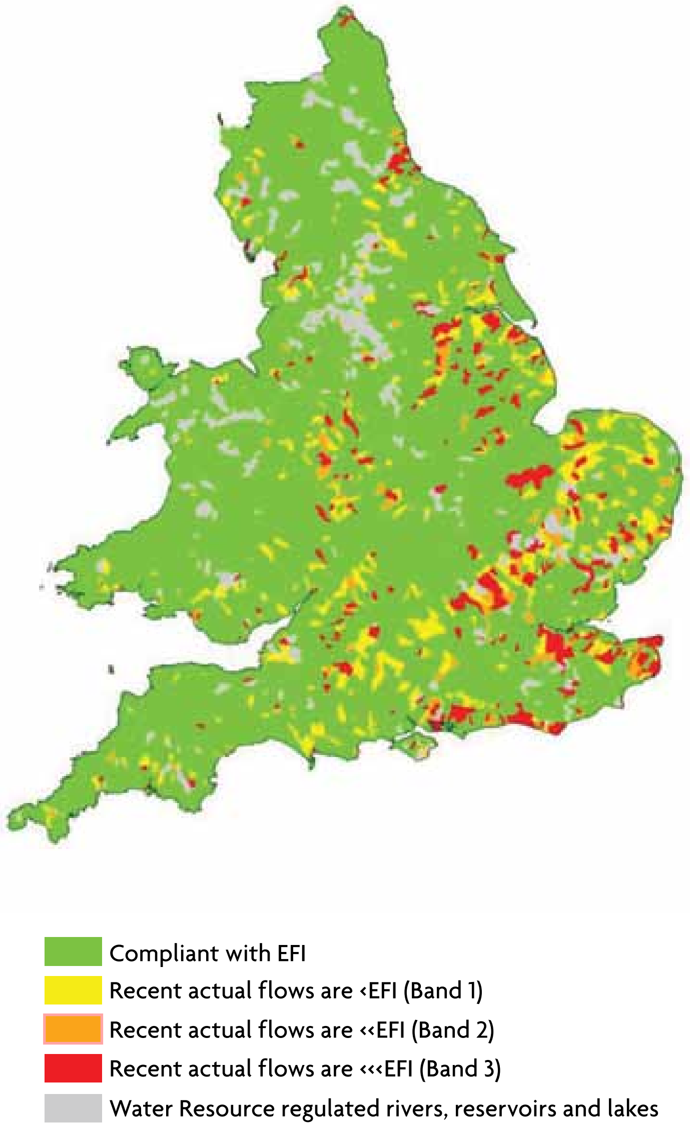
Prior to the passage of specific legislation covering abstraction, water users could only appeal to common law principles of riparianism and prior appropriation. The current system for managing abstraction of water from rivers and aquifers in England and Wales is a product of the Water Resources Act (1963) which gave most abstractors a licence to take a fixed volume of water, regardless of availability. Much of the water that is licensed in this way is not actually used, but the regulator cannot make it available to others who may need it – the licenced volumes are not flexible or easily transferrable.

A May 1997 Water Summit between water companies, the Environment Agency and key stakeholders led to an agreement that there should be a full review of the abstraction licensing system. This led the Government to order the Environment Agency to use its existing powers to change environmentally harmful licences and to prepare new legislation covering abstraction reform.

Following the 1997 Water Summit, the Environment Agency launched two processes for reviewing existing abstraction licences. Through the Restoring Sustainable Abstraction (RSA) and Catchment Abstraction Management System (CAMS), authorities in England and Wales have intensified their work to make abstraction sustainable by varying and removing abstraction licences. The RSA process looked particularly at water bodies located in or near sites that are affected by the EC Habitats Directive, Sites of Specific Scientific Interest (SSSIs) or other conservation areas. The CAMS process involved developing and implementing a consistent and structured approach to local water resources management, recognising the reasonable needs of abstractors and our growing knowledge about the needs of the environment.

CAMS are strategies for management of water resources at a local level and in particular for striking a better and more flexible balance between the needs of abstractors, other water users and the aquatic environment in consultation with the local community and interested parties. CAMS are also the mechanism for managing time-limited licences by determining whether they should be renewed and, if so, on what terms.

In this way the Environment Agency has already changed 77 licences in England since 2008, returning around 75 billion litres of water per year to the environment (the equivalent of more than 60,000 Wembley Stadiums or 100 Lake Windermeres). Similarly, in Wales, 44 abstraction



▲ **Figure 1. Recent actual complaince with environmental flow indicators (EFIs). (© Environment agency)**

licences have already been changed. Environment Agency statistics show that between 2002 and 2011 only an average of 45per cent of the annual total of water licensed for abstractions in England and Wales was actually abstracted. Unused abstractions can, where there are competing uses, mean that the economy or society suffer. Conversely if all this unused water was actually abstracted, there could be significant deterioration of the environment.

THE WATER ACT (2003)

The Water Act (2003) made specific provision for:

- time limits for all new abstraction licences;
- the facility to revoke abstraction licences causing serious environmental damage without compensation;
- greater flexibility to raise or lower licensing thresholds; small and environmentally insignificant abstractions (under 20 m^3/day) deregulated;
- licensing extended to abstractors of significant quantities presently outside the licensing system; and
- water company drought plans and water resource management plans became a statutory requirement (both were previously produced voluntarily).

These provisions strengthened the RSA process in particular. Investigations under the RSA programme have helped to identify improvements that will contribute to meeting the UK's objectives under the European Water Framework Directive (WFD). This came into force in December 2000 and became UK law in December 2003. CAMS data is also central to the preparation of River Basin Management Plans (RBMPs) under the WFD.

THE FUTURE OF LICENSING

Currently, abstractions over 20 m^3 (20,000 litres) per day require an abstraction licence. Applications are considered with reference to the local CAMS data and the current RBMP, as filed with the EC. New licences will generally be time limited and renewable according to the stipulations of the Water Act 2003. Time-limited licences will be replaced, providing:

- the abstraction is environmentally sustainable – investigations by the EA will identify where sustainability may be in question;
- there is continued justification of need – licence holders will need to demonstrate that they still have reasonable need for water, and whether the quantity is still justified; and
- water is being used efficiently – this means using the right quantity of water in the right place at the right time. The UK Government expects abstractors to use water in a responsible and efficient way, and will expect them to provide evidence of this when applying for a replacement licence.

REFORM OF ABSTRACTION MANAGEMENT FUTURE

Note that the EA is specifically empowered to make judgments about the rationality and efficiency of any given licence applicant's proposed use. The map indicates the areas (in orange and red) where licence renewal applications are likely to encounter difficulties related to insufficient environmental flow.

The UK Government committed to reform of the water abstraction management system in England in the Natural Environment White Paper, *The Natural Step*, in June 2011 and then set out the proposed direction, principles and process for reform in the Water White Paper, *Water for Life*, in December 2011. The reforms proposed by Defra in a consultation document published in December 2013, but not included in the recently passed Water Act 2014, would build on this action to tackle unsustainable abstraction and are designed to make the system more flexible and resilient to future pressures. Key intentions are to:

- increase the amount of water that can be used by systematically linking access to water to water availability;
- incentivise abstractors to manage water efficiently;
- help abstractors to trade available water effectively, ensuring that we get the most value out of our water and do not waste water that could be used;
- ensure we have a more effective process to review licences, striking the right balance between providing regulatory certainty for abstractors and managing environmental risk; and
- incentivise abstractors to manage risks from future pressures on water resources, increasing their own resilience and that of river catchments.

Fugure 2. The River Itchen, Winchester. (© Plinsworth96)

CURRENT SYSTEM PLUS AND WATER SHARES

Two main options for reform, labelled Current System Plus and Water Shares went out to public consultation in early 2014. Under Current System Plus, the regulator would continue to use the tools currently applied to some licences (under the powers granted in the Water Act 2003) to reduce or stop abstraction to leave enough water for the environment or other abstractors when flows are low.

These tools would be refined, strengthening the link between water availability and permitted abstraction to allow more water to be abstracted when more is available and improve environmental protection, particularly at very low flows – implying a dynamic system of abstraction licensing. Defra would also make it easier for abstractors to trade water with each other, by pre-approving temporary low-risk trades.

The Water Shares option would be a bigger change from the current system. Abstractors would be allocated a share in the available water resource, rather than an absolute amount, encouraging abstractors to take a shared responsibility for water resources in catchments. This option would allow for pre-approval of shorter-term trading between abstractors and of a wider range of trades. Lumbroso *et al.*'s (2014) report[2] on research with abstractors in eastern England showed that stakeholders were cautiously interested in the benefits offered by both methods, especially the ability to trade water at short notice.

Under either reform option the Government seeks to avoid the rigidities of the previous permitting regimes (such as seasonal licences that do not recognise seasonal variation in flow), arbitrary time spans (time-limited licences are currently generally renewable after 12 years) and disincentives for permit holders to trade amongst themselves to seek the highest and best use for water. The Government also seeks to introduce "fairer" and "more accurate" pricing for water through associated charging for abstraction licences, although there is little evidence worldwide for significant price sensitivity amongst water abstraction licencees[3].

CASE STUDY: THE RIVER ITCHEN IN WILTSHIRE AND DORSET

The Itchen (see **Figure 2**) is often thought of as the iconic chalk stream. Its crystal-clear waters spring from the chalk hills in the South Downs National Park before journeying for 30 miles or so down to join the sea at Southampton.

In total, 217 million litres per day (ML/d) are licensed for public supply in the Itchen catchment, although to date these licences have never been used to their maximum allowance. After it is used in public supply, the majority of the water is returned to the river at Chickenhall sewage works, close to the tidal limit. Public water supply represents 24 per cent of the total abstraction volume licensed within the catchment. Other main abstractors include watercress farming (licensed for 99 ML/d) and fish farming (licensed for 184 ML/d). While these sectors are high abstractors, in effect they have almost no impact on water quantity in the river as the water is returned to the river close to where it was abstracted.

Over-abstraction has long been noted as an issue affecting the lower stretch of the Itchen. The Environment Agency's CAMS (2013)[4] has designated the River Itchen as "over abstracted", particularly because of the impacts on the lower stretch of the river (albeit some of the upper reaches have "water available"). In the lower river, below Otterbourne, CAMS showed that during the lowest flow periods, historical abstraction was resulting in river flows at 21.8 ML/d less than the sustainable level. A low flow is generally accepted to be a flow that is exceeded 95 per cent of the time; this is called a Q95 flow. Average annual abstraction on the lower river is only about half that allowed by the current licences. If the full licence was taken, flows would not meet sustainable levels for much longer periods, and the deficit between environmental and actual flow levels during the lowest flow periods (Q95) would be much greater.

Thus under the RSA and CAMS processes, Defra has imposed abstraction licence reductions on the two largest abstractors, Southern Water and Portsmouth Water. Both companies have subsequently been required to develop new security-of-supply programmes to make up potential low-flow deficits, reflected in their water resource management plans.

"Parliament has signalled a direction of travel in these matters, but it is likely to be well after the spring 2015 general elections before we see new legislation."

CONCLUDING COMMENTS

An important by-product of a comprehensive abstraction licensing system such as the one operated in England and Wales is the need for ongoing monitoring of the licensed abstractions and their environmental impact. This can contribute to a fuller understanding of the finer mechanisms and processes impacting on the water environment and resultant adjustment of licences especially when linked to processes such as RSA and CAMS. As discussed above, however, the current system does require reform, not least in recognition of the much lower volumes of water available in many catchments of climate change and better environmental science.

One debate involves the role of other tiers of government in the abstraction licencing process. Adeloye and Low (1996) noted that in Germany and Switzerland abstraction licensing is operated at the Lander (county) level, in Luxembourg, by central government, in Switzerland, by the Canton and in Italy by the water service authority[5]. Cook *et al.* (2013) note that devolution of decision-making and involvement of non-governmental organisations (as mandated in the WFD, 2000) is also challenging the prevailing top-down models of abstraction decision-making in many developed economies around the world[6].

Other important drivers relate to rising concern about the links between water, food and energy, the so-called "water—food—energy security nexus". The UK will need to decide whether it wants to develop an abstraction management system based on the recognition that some uses of water – for food and energy – are more important than others. In the case of energy-water relations such considerations are further complicated by potential shale gas development in the UK as this energy extraction technology uses considerable volumes of water (an issue discussed in Brown's contribution to this).

Parliament has signalled a direction of travel in these matters, based on greater competition, but it is likely to be well after the spring 2015 general elections before we see new legislation. **ES**

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Sustainable drainage: overcoming the challenges to a more secure future

Wilhelmina Drayton outlines how the UK's drainage methods can exacerbate flooding mechanisms, and discusses the opportunities of, and barriers to, SuDS implementation.

▲ **Figure 1. When surface water sewers surcharge the results can sometimes be very dramatic! (© Gerrald Isaaman)**

FEATURE

▲ **Figure 2. Gullies frequently become overwhelmed, restricting any further water from entering the drainage system. (© Wilhelmina Drayton)**

The current interpretation of water security is heavily biased towards supply and quality. However, the discourse needs to be broadened to cover matters of flood risk and managing stormwater. Earlier this year the UK once again experienced devastating flooding, an occurrence we are facing with seemingly increasing frequency. This intensification is borne out by the data, with four of the five wettest years on record having occurred since 2000[1]. The Department for Environment, Food & Rural Affairs (Defra) has identified flooding as the most significant threat from climate change facing the UK[2].

INADEQUATE DRAINAGE CAPACITY

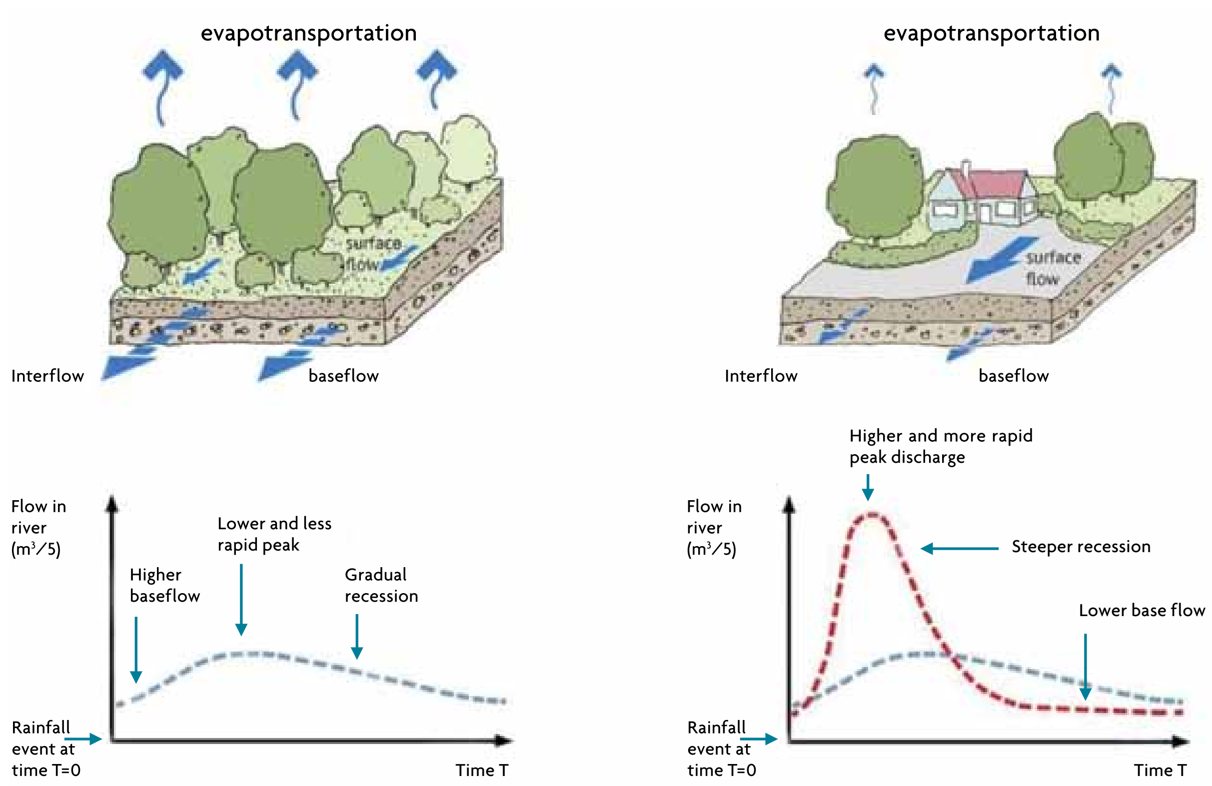
With a backdrop of wetter years and more intense rainfall events, the challenge of surface water management is compounded by traditional drainage infrastructure that is, in many cases, woefully inadequate. Surface water drainage systems in densely populated urban areas are increasingly having to handle volumes of water far in excess of what they were designed for. This can result in the system frequently becoming overwhelmed, and on occasion surcharging, as pipes running at full bore back up and excess overland flows are then prevented from entering the system (see **Figures 1** and **2**).

This capacity issue is responsible for creating low-level flooding and nuisance waters (which in turn causes damage to infrastructure, such as road surfacing) on a regular basis. During heavy rainfall events this can contribute to more serious flooding issues, even transferring flood waters and risk from one area to another. Many of these aging surface-water systems were designed for less intense rainfall events and for a built environment where much more surface water was allowed to infiltrate directly into the ground.

LOSS OF PERMEABLE SURFACES

Increased development and the proliferation of gardens that have been paved over have dramatically reduced the amount of permeable surfaces through which water can infiltrate. The impact on the water cycle is pronounced. When rainwater falls on undeveloped, more natural

▲ **Figure 3. Traditional drainage approaches can result in surface water from the entire catchment reaching the watercourse in very short time periods, leading to it becoming overwhelmed. (© Wilhelmina Drayton)**



▲ **Figure 4. The Impact of impermeability on the water cycle. (Source: susdrain[4]).**

ground a greater proportion of it will infiltrate, leaving some to become runoff. Runoff that is flowing over land coverings such as grass will travel considerably more slowly than that which falls on hard paved surfaces. This slower-moving (and already reduced in quantity) runoff therefore has more opportunity to infiltrate the ground. Some water that infiltrates will eventually become groundwater or baseflow how in local watercourses – an important resource in water security – and some will be used in the process of evapotranspiration.

In contrast, water falling on hard-surfaced areas will flow quickly into often undersized drainage pipes via gullies. In pipes it will flow at increased velocity to a discharge point (assuming there are no blockages or surcharging of the system on the way, which are likely to lead to flooding at some scale). Often these systems discharge into watercourses, resulting in high volumes of water entering the watercourse from the entire catchment in a very short time following the peak of the storm. This short lag period increases the likelihood of the river becoming overwhelmed, flowing out of bank and therefore flooding (see **Figures 3** and **4**).

In the case of combined sewers, where surface water and foul sewerage flow within a single system, there is also the increased threat of combined sewer overflows (CSOs) discharging untreated sewerage directly into watercourses when the CSOs become overwhelmed with surface water. This can have a dramatic impact on water quality and the ecology of the watercourse[3].

SUSTAINABLE DRAINAGE TECHNIQUES

The issue of overwhelmed, undersized drainage systems can be resolved in two ways: by increasing the capacity of the system, or by reducing the volume of water entering it. Laying larger pipes or installing offline storage involves considerable expense and disruption (road closures, etc.) and is likely to result in a greater volume of water being discharged into the receiving watercourse at the peak of the storm, further aggravating flood risk. In order to decrease the burden on the drainage system another solution has to be employed, providing rainwater with alternative routing and infiltration options before it can enter the system (see, for example, **Figure 5**).

By increasing permeable ground covering within urban areas, rainwater and overland flows will have greater opportunity to infiltrate into the ground, thereby reducing the burden on surface-water drainage systems, and allowing rainfall from the catchment to reach the receiving watercourse over a longer period. This will not only assist in reducing the likelihood of flooding, but will also offer other benefits.

More than half of all rainfall events produce rainfall of less than 5 mm[3], and these small frequent events

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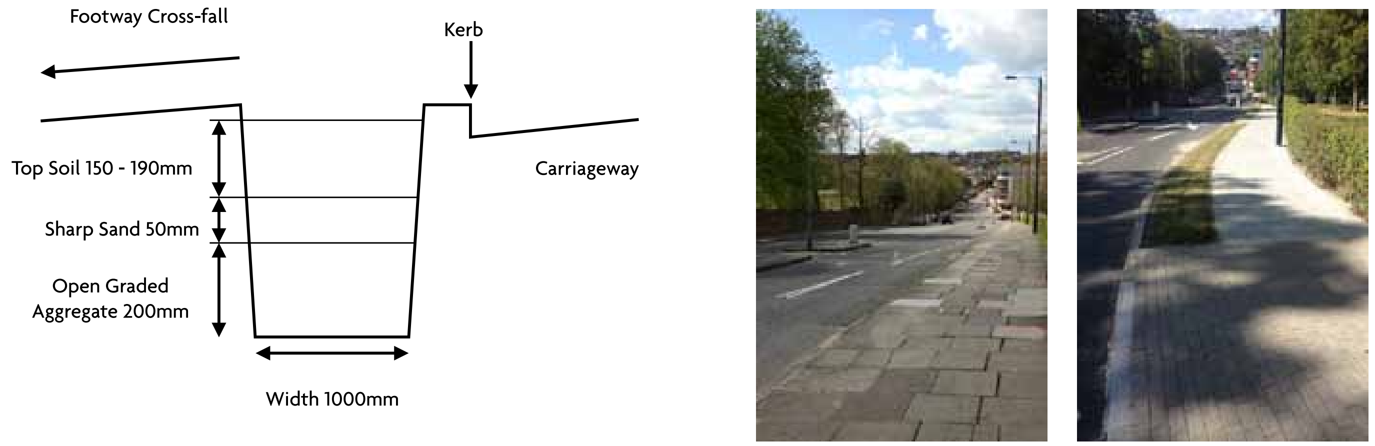

▲ **Figure 5. There are opportunities to increase infiltration everywhere. The introduction of this green verge, designed with additional storage in the subbase to allow more water to be accommodated, improves the urban environment, reduces diffuse pollution and reduces flood risk. (Source: from Owen Davies)**

also result in the most-polluted runoff, an occurrence known as first flush, where pollutants that have built up on impermeable surfaces during dry periods become entrained in the first flush of rainfall and are transported to sewers and watercourses. If the vast majority of runoff from small, frequent events were allowed to permeate into the ground, where natural processes could be employed to break down the pollutants, this would result in a substantial reduction in diffuse pollution, which in turn would have a significant positive impact on river water quality.

Selection of the most appropriate techniques and sustainable drainage systems (SuDS) is vital as they can also provide the opportunity to increase biodiversity by greening the urban environment, and, if the correct locations are selected and systems sympathetically designed, the amenity value of the land can also be increased[5]. Alongside this, some studies have shown that green urban areas have a beneficial effect on the mental well-being of people living within them[6], and can even reduce crime rates.

The reasons for increasing and promoting permeable ground coverings and sustainable drainage techniques are clear, but there is a challenge around the land take that may be required to fully realise their benefit. This is of particular concern in densely populated residential areas, as redevelopment of large areas of land, where

▲ **Figure 6. Streets with no green or permeable areas are an all-too-common sight. Water has no option but to pond until there is available capacity in the drainage system. (© Wilhelmina Drayton)**

▲ **Figure 7. Vehicles can still be parked on these very attractive front gardens, but they are permeable, reducing the burden on traditional drainage systems. (© Robert Smith)**

water-sensitive design can be employed, is infrequent. Within our towns and cities many front and indeed rear residential gardens have been paved over, often to create space for off-street parking or patios (see **Figure 6**). These choices have significantly contributed to the increase in surface water runoff.

While a change in permitted development rights in 2008 stated that driveways could only be installed without planning permission if they were permeable, or rainwater was directed to a lawn to drain naturally, enforcement is inconsistent and not retrospective. A study of London concluded that in the 10 years prior to 2008, the amount of hard surfacing in gardens had increased by 26 per cent, equating to a loss of vegetated garden land equivalent to two Hyde Parks every year[7].

To reduce the proportion of rainfall entering traditional piped systems, opportunities for 're-permeating' or 'de-paving' small plots of developed ground, such as gardens, must be sought (see, for examples, **Figure 7**). If large numbers of these small plots of land can be reclaimed to allow water to infiltrate and to slow the flow following a rainfall event, the aggregate effect will significantly reduce runoff. In turn this will decrease the volume of water entering the public sewerage system, along with reducing diffuse pollution, as water will be managed at source as opposed to flowing over surfaces, accumulating sediment and pollutants on its journey.

LEGAL BACKING FOR SUDS

Uptake of SuDS in England has been sporadic, and although there are some excellent case studies in the UK (susdrain[4] is a good source for examples and information on SuDS) these techniques are still not the first choice for too many developers, despite numerous case studies showing them to be less expensive than traditional drainage approaches. The Flood and Water Management Act 2010 gave some recognition to the significance of SuDS, with Schedule 3 of the Act creating a new SuDS approving body (SAB), responsible for approving the drainage plans of all developments and ensuring that drainage approaches are selected from a hierarchy, with SuDS as the first choice.

The adoption and future maintenance of most approved SuDS features also fall to the SAB, the first time that adoption has been legally set out. However, commencement of this vital part of the Act has been delayed by the Government time and time again. Expectations of an October 2014 commencement date were dashed in May 2014 when Defra issued a briefing detailing their concern that implementation of the legislation might have an adverse impact on development.

Given that the Act was brought in prior to the coalition Government coming to power, it now looks unlikely that Schedule 3 will commence before the next general election. In that time many opportunities for SuDS have been lost, and, where they have been realised, the issue of adoption and long-term suitable maintenance regimes cannot be assured, as legislation is not in place to guarantee it.

Living with the disruption and devastation of flooding is a reality for many people in this country, and that very real pain can go on for numerous months after the waters have receded. Giving rainwater places to go, that does not involve getting it into pipes as fast as possible, is an imperative step in managing and reducing the frequency and impact of floods. This needs to be realised and acted upon seriously by us all – individual house owners, developers, planners and Government. ES

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