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Coevolving Water Sustainability in London

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Abstract

London's water infrastructure has been developed over many centuries. It is a system of centralised water distribution and drainage that has formed the model for water infrastructure systems in cities around the world. However, this system is unsustainable: its incapacity to respond to the growth of populations and increasing water consumption per capita has led to the degradation of aquatic environments. A fresh approach is needed in order to identify urban water cycle solutions that can address these problems. This paper outlines an amalgamated theoretical framework – coevolutionary actor–network theory – and its use by the author to develop a methodology capable of formulating how London's urban water cycle might coevolve towards sustainability in the future. This framework allows the tracing of relationships between human and nonhuman influences and environments that coalesce into large infrastructural systems. Two coevolutionary possibilities towards water sustainability were identified. One lay in diversifying types of water reuse; the other in multifarious forms of waste harvesting. The paper further contends that this theoretical approach and set of methods could also be applied to other infrastructure systems such as energy, waste, and air pollution.

Introduction

To most people, the current water infrastructure in London is unproblematic. A twist of a tap or flick of a lever usually results in a stream of clean drinking water. Habituation to the accessibility of potable water gives most people little cause to consider where the water originates and the means by which it is piped to municipal areas. Questions arise as to the extent to which the current system of water delivery damages the environment and retains the capacity for sufficient future provision. These are issues that preoccupy specialists concerned with sustainable water use: how can we change the existing infrastructure to ensure water sufficiency for people and preserve the environment?

The official monitor of United Kingdom ecologies, the United Kingdom Environment Agency, has determined that the nation's existing water infrastructure causes damage to aquatic environments. The majority of London's water derives from nearby rivers, which constitute an over-abstracted water source (Environment Agency, 2006). Over-abstraction is when the amount of water removed from the environment for human use damages ecologies that also depend on this water source. These unsustainable levels of water abstraction are projected to increase due to population growth (Greater London Authority, 2009) and altered rainfall patterns caused by climate change (Environment Agency, 2009; World Wildlife Fund -UK, 2009), causing more damaging effects in the future.

It is imperative to investigate how this infrastructure can be altered in order to form sustainable urban water cycles – cycles that enable greater water availability for the environment as well as for human consumers. To explore these possibilities, this paper proposes a set of methods developed from the novel theoretical approach of coevolutionary actor–network theory in order to link everyday actions with broad infrastructural change.

The paper first describes this new method of research and why it is necessary in resolving problems of sustainability and capacity. It then summarises the methods and the process of applying these methods to a research case study conducted in the lower Lea River Basin in east London during 2009–12, before outlining the major findings. It concludes with reflections concerning the use of this theoretical framework to explore other types of infrastructural change.

Limits to Centralised Large Scale Water Infrastructure

For most people the paradigmatic model of water infrastructure is a centralised large scale, pressurized pipe network of water distribution and a gravity pipe network of drainage designed by engineers. It is comprised of municipal reservoirs, water treatment, distributed through pressurized pipes and pumps with the purpose of standardising water quality and pressure. Used water is discharged into another network of pipes that aim to drain water away rapidly. This model was developed mainly in the nineteenth century (Goubert, 1986; Jones, 2013). The underlying presumption is that the ideal form of this water infrastructure provides the same access to the same type of water to all people at all times. This is the type of infrastructure that currently serves the inhabitants of London (Thames Water, 2007).

Centralised large scale water infrastructure has been critiqued by a range of disciplines, including engineering, ecology, geography and sociology, because while it appears reasonable to expect the uninterrupted provision of water to all people, the enduring difficulty lies in sourcing sufficient volumes of water in changing rainfall conditions, fluctuating groundwater tables, growing populations, increasing per capita water use, and degrading ecological health. Local environments may at first maintain an adequate amount of water for the population, but as a population or per capita water consumption increases, then local aquatic ecosystems are damaged by over-abstraction. This is the current situation in London (Environment Agency, 2006) and many other places in the world (Barlow and Clarke, 2002; Gleick *et al*., 2006; UNEP, 2007). The attempt to maintain the ideal of uninterrupted water supply in the context of increasing water usage creates an ongoing need to identify and exploit new water sources. By abstracting water from farther afield or by using more energy intensive, water polluting operations such as desalination technology, this search vastly expands the scope of environmental damage. A further limit to large scale centralised water infrastructure is imposed by the material resources needed to implement the pipes, pumps and reservoirs that create the water infrastructure and the energy to keep the systems functioning. The recent critiques are unusual because they all move beyond their disciplinary foci to show that water infrastructures are an entanglement between both human and nonhuman elements.

Engineers initially approached the limits of water to serve this infrastructure by developing more water sources. As these water sources became exhausted or too costly to procure, engineers shifted from the search for new water sources and the consequential environmental damage to advocating water demand management (Butler and Memon, 2006). The engineering approach to including people typically concentrates on creating technologies to restrict water use: low-flow shower heads, low-flush toilets, flow-restricted faucets, and so on. While this helps to reduce water consumption, it does not fundamentally shift the expectation of people for endless supplies of potable water.

The limits of large scale water infrastructures were broached by ecologists because of the damage caused to aquatic ecologies. The different types of damage required the inclusion of humans and the implications of their cultural uses of water to be considered part of the ecosystem (Alberti, 2008; Marzluff *et al*., 2008; Pickett *et al*., 2001; Robbins and Sharp, 2008). While these studies include humans as a major factor in ecosystems, ecologists frequently allow the assumption that pre-urban conditions are more ecologically sound than urban conditions to determine research approaches, thereby discounting the need to conceive of urban water cycles that could avoid environmental damage.

Human geographers traditionally developed an urban political ecology approach as a means of interpreting the relationship between different types of water provision and their distribution (Graham and Marvin, 2001; Heynen, Kaika, and Swyngedouw, 2006). This approach relies mainly on David Harvey's Marxist interpretation of how capitalism influences the organisation of political power and urban space (Harvey, 1989; 2006) to explain the inequality of water distribution seen most starkly in the global south. This approach concentrates on the structure of social organisation as a means of considering inequality; as such the impact of ecological and infrastructural systems are normally only regarded as a passive background to the function of social and political systems. This approach does not challenge the assumption that the fairest water infrastructure is a monolithic system that serves every person in the same way, as its anthropocentrism disregards the extent to which local ecological and material limits influence sustainable models of water distribution.

Innovations in human geography have involved attempts to develop new conceptualisations of the link between nature and humans in urban water cycles. Swyngedouw (1999; 2004) uses the ecological metaphor of metabolism to conceive of water as alternately natural prior to abstraction, social as it is used by people, and again natural when it is discarded. This idea begins to articulate the relationship between people and ecologies. Also emphasising the links between people and nature, Gandy (2005) invokes the metaphor of the cyborg – an organism composed of both natural and synthetic elements – to illuminate the symbiotic relationships of humans and nature through resource use by industrial mechanisms such as pipes and pumps. These new conceptualisations show the importance of identifying these relationsips to explain how and why particular types of water infrastructures exist, but humans remain dominant over water and technologies. These metaphors also lack specificity in relating particular water ecologies with water technologies and practices.

The specificities of the relationships between technologies and practices of water use in centralised large scale water infrastructures have been better analysed by sociologists researching their subject in terms of socio-technical systems (Geels, 2005; Shove, 2004; Allon and Sofoulis, 2006).They determined that the cultural practices of water usage are dependent on particular forms of infrastructure and technology. In other words, sociologists have revealed that the type and extent of technology incorporation in a given society is significant in determining how and why water is used in particular ways. Furthermore, culturally specific conceptions of water, water practices and water technologies coevolved over long periods of time, such that it is extremely difficult to ascertain which factor is causative of changes to a water system, with the function of each factor dependent on many others. Although challenging, this approach nonetheless opens the possibility of identifying shifts within the relationships that create the current urban water cycle – shifts that may result in the overall alteration of a given water system. The set of relationships included in socio-technical systems by definition excludes the effects beyond these two elements. The ecological effects, or the equity of water distribution are not addressed within this framework.

All of the abovementioned innovative approaches demonstrate the efficacy of moving beyond core disciplinary boundaries in order to include previously unconsidered factors. However, due to the epistemic dominance of each discipline’s core concern, each approach has been predisposed to prioritising either human or nonhuman issues. The way each aspect can be considered primary by different disciplines implies that they can be considered to have equal importance. An epistemology is needed that incorporates an extra-disciplinary perspective and is also successful in amalgamating societal and natural concerns in order to understand how these phenomena are related to each other to form the urban water cycle. This will enable researchers to identify a process of change that could lead to an equitable distribution of water to humans and nonhumans throughout both natural and constructed environments.

A Coevolutionary Actor–Network Theory Framework

Actor–network theory has as its primary idea that all phenomena are constituted through a symmetrical relationship between human and nonhuman elements (Latour, 2005; Law, 2004). This creates a flat ontology in which humans and nonhumans relate to each other equally, which enables the combination of all the different insights about water infrastructure and the urban water cycle while attentively circumventing disciplinary preoccupations favouring either humans or nonhumans. Sociological adaptation of the biological model of coevolution introduces the concept that trajectories of change commonly arise from existing network relations. By combining actor–network theory with coevolutionary theory, water infrastructure research is able to develop by investigating existing network relations that create urban water cycles and ascertaining how these may change in the future.

Actor–network theory has been developing for over thirty years, originating in Science and Technology Studies, where it was first used to understand how scientific knowledge was formed and technological innovations invented (Callon, 1986; Latour, 1987; Law and Callon, 1988). It is a relational theory in which all objects in the world are composed symmetrically of human and nonhuman relations; our perception of things in the world is limited to those that we have found ways to recognise, and this recognition requires both a world out there to perceive and a human to perceive it. This ontology results in an epistemological stance that concentrates on investigating the relationships between humans and nonhumans that brings phenomena into being. This emphasises that all knowledge is anthropocentric, but equally that the cultural structure of knowledge is formed from the material world surrounding humankind (Latour, 1993; Latour, 2005; Law and Hassard, 1999). Power is regarded as a function of relations distributed throughout the network, whereby network-created phenomena can be affected by any actant; that is, any entity, cognisant or otherwise, has the capacity to affect the relational network, causing it to alter (Callon, 1986; Law and Callon, 1988).

The actor–network theory (ANT) approach has been used to understand many different water infrastructures – from the large-scale systems of water provision in Paris and Istanbul (Dinckal, 2008; Latour and Hermant, 2006), to the bush pumps of Zimbabwe (de Laet and Mol, 2000) and the taming of the Rhine river for navigation and trade (Disco, 2008). ANT analyses of these phenomena are snapshots of the relationships between people and objects that make up water infrastructure. Sometimes an actor-network approach describes the relations of the system as it presently exists (Latour and Hermant, 2006); in other instances it describes a change in technology, for example the spreading of water pump technology (de Laet and Mol, 2000), or the control of an urbanising water navigation system (Disco, 2008).

New technologies are examples of intense changes in network relations. Intense changes can be characterised by five distinctive stages: problematisation, interessement, enrolment, mobilisation, and stabilisation (Callon, 1986; Latour, 2004). Problematisation is when an actant (a human or nonhuman agent) decides to effect a specific change in the world. Interessement occurs when an actant begins to probe the relationships between things to determine whether other actants would be willing to make this type of a change in the world. Enrolment is when the actant gathers other relevant actants to make this change. Mobilisation takes place when the actant affects all the other actants and makes the desired change in the world. Finally, stabilisation occurs when all the actant relations are continually mobilised and no longer questioned. This way of looking at change in network relations is useful because its emphasis on relational processes overcomes conventional disciplinary limitations of perspective, which – as discussed earlier – frequently prioritise either human or nonhuman factors. However, it nonetheless fails to probe the question of how new problematisations – decisions to effect change – arise.

The socio-technical approach to understanding water infrastructures and cultures of practice has shown that changes in network relations are caused by problematisations that develop from tensions in the existing network relations between people and technologies – that is, a coevolution of relations (Geels, 2005; Shove, 2004). To the extent that new relations arise from pre-existing relationships between things, a trajectory of change is formed by existing relations (Geels, 2010). These covolutionary changes can occur gradually, through many tiny changes over a long timeframe.

Socio-technical coevolution related to water infrastructures has been studied by Geels and Shove. Geels (2005) demonstrates how piped drinking-water infrastructure has been simultaneously driven by and determinative of the Dutch people's ideas of hygiene. Shove (2004) similarly illustrates how British people's notions of cleanliness are affected by the washing machine as both an agent and an object of change. Both these studies illustrate their examples with over fifty years of incremental change. However, the use of the socio-technical approach focuses on the relationship between technologies and people, largely excluding factors such as ecologies, chemicals, biota, energy, and money, which are also significant components of the urban water cycle. In order to develop a more inclusive theory than socio-technical coevolution – one which takes account of these factors – it is necessary to supplement it with the concept of ANT, which admits the range of phenomenal relations – actants – into analysis of the urban water cycle.

My amalgamated coevolutionary actor–network framework adopts the ANT concept of a symmetrical interrelationship of influences between human and nonhuman elements, which are each defined by their inter-relational relevance in terms of actants and networks. ANT also contributes the concept of the process of new network formation and stabilisation. By conjoining ANT with the socio-technical understanding of network change, relations between humans and nonhumans are understood to be always in flux, continually remade and open to change. Such change is not random: it has a particular trajectory based upon pre-existing relations. This moves both theoretical frameworks from describing existing situations to being able to extrapolate conceivable future trajectories that exist within the tensions of current network relations.

Coevolutionary Actor-Network Theory Research Methods: Water Cycles in London

The coevolutionary ANT framework enables this research – the results of which are presented below – to focus on identifying the existing relationships between humans and nonhumans, to investigate their relative stabilities, and to postulate probable new relationships. The framework was used to identify methods to probe specific relationships comprising the urban water cycle in London in order to develop ideas for new types of water cycles allowing improved ecological sustainability and availability. A combination of methods was used for this research, including interviews, group discussions, photographic diaries and notebooks, design illustrations and models, and codesign games, whereby the researcher and participants mutually develop the research objective.

In order to understand the existing relations between actants that constitute the current stabilised water cycle, three methods were employed: interviews; group discussions; and photographic diaries, in combination with notebooks of water interactions. The interviews and group discussions form part of the understanding of how people interact with water on a daily basis in both personal and professional capacities. Fifty-three people took part in this stage, with 30 individual interviews, and 23 group discussants.

The other important element in this research was gained through a 27-exposure photographic diary and a notebook, which were used to log all the water interactions that each person had over a twenty-four hour period. If there was remaining film, then participants logged their periodic water interactions, such as clothes washing, and others that were meaningful, such as picnicking by a pond. Thirty-five diaries were returned. The combination of diarised entries and photography helped to trace the human–nonhuman relationships that create the extant urban water cycle. It also increased participants' awareness of their water use in order to facilitate a nuanced discussion of how this might alter if their access to water changed.

The interviews and group discussions investigated how people imagined their water interactions would alter if they were faced with an extreme water shortage or an extreme excess of water. In the case of extreme shortage, a scenario was posed in which direct water supply to the point of use ceased, and the only available water source was a standpipe about 750m from the front door of the home. In the case of extreme excess, participants considered the scenario of seasonal flooding to the property of approximately 30 centimetres deep, which occurred for about a fortnight annually. Respondents' conjectures about their behaviour in these hypothetical situations revealed which relations were more likely to be discontinued and which ones would be maintained. It also indicated the likelihood of such a strategy being adopted by the number of people who suggested the same behaviour.

Thematic analysis of the interviews, group discussion and diaries was conducted to gain an understanding of the existing, stable and fragile relationships that create the urban water cycle in London. From this analysis it was then possible to speculate on probable coevolution pathways that could form in the future through alteration of these relationships.

The problematisation – the decision to effect specific change – was identifying how to create increased sustainable water availability for people and ecologies in London. Interessement was created through two means: first, by using coevolution pathways to formulate design propositions, which reconfigured the quantity, quality and location of water. These design propositions were expressed in illustrations, models and verbal descriptions. Secondly, interessement was tested by employing these coevolution design propositions as the basis for further interviews and group discussions. Forty of the original 53 participants returned for the second stage of interview or group discussion.

When combined, the design propositions, the interviews and group discussions found the human and nonhuman relationships that were most likely to be mobilised in the future, and those that were least likely to occur due to an assessed lack of actantial support – that is, insufficient interessement. The result was the identification of two potential coevolution pathways for new water cycles in London. The interessement for these two coevolution pathways was retested for saturation through group discussions involving 15 original participants and 23 new people who had not participated in either of the first two stages.

One coevolution pathway, involving recycling human waste through a dry sanitation system, was further explored through codesign games. Rather than the researcher being the actant that develops the design actant for interessement, as was the case in the earlier stage of this methodology, the codesign games brought together 14 people – two having participated in the previous stages – to work together to formulate design propositions that respond to this coevolution pathway. Together they combined actants in a new set of relations, a new water cycle.

The codesign games presented an initial context in which a change in sanitation may or may not occur in the view of the participants for an existing area in London. People then worked in teams of three or four with paper, printers, video cameras, figurines, play dough and other found materials to develop the new nonhuman and human relationships that would need to occur to realise or impede the future adoption of dry sanitation infrastructure in London. These human and nonhuman relations included the designs of material configurations, behavioural characteristics, ways of governance, forms of management, and types of economies. These were expressed in three short videos explaining the new relations between given actants.[2]

Coevolution Pathways for New Urban Water Cycles in London

As mentioned earlier, this research process identified two distinct coevolutionary pathways that would create new water cycles which enabled increased water sustainability and availability for people and ecologies.[3] These were: polyculture water reuse communities; and a human waste harvesting system. These were interpreted as viable coevolutionary pathways because many people expressed the desire to mobilise these networks over the course of all the stages of the interviews and group discussions.

The coevolutionary pathway of polycultural water reuse communities was developed from existing and imagined water reuse projects that began with simply reusing water in the kitchen, escalated to piped bath and shower diversions to the garden, through to tanks to store water for future reuse, and finally to a complex network of ponds, wetlands and reservoirs from which food, energy and clean water could be generated.

This final proposal of polycultural water reuse communities would result in new forms of public space, infrastructure, products, markets, jobs, governance, management and ecologies. It would repurpose part of back garden areas to create the space for this infrastructure and connect it to nearby public and commercial buildings. This implies new types of social relationships between neighbouring properties and residents. The management of the infrastructure would constitute new employment roles, and the products that could be harvested from aquaculture would create new markets for food crops, animal feed, or biofuels.

The second coevolutionary pathway was the development of a human waste harvesting system by implementing a dry sanitation infrastructure system. Dry

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[2] The videos created are available via these links: "Silvia Makes a Poo": http://www.youtube.com/watch?v=r4_wQPn2FKY&feature=youtu.be
"McWorm": http://www.youtube.com/watch?v=0UZGnRjpi0s&feature=youtu.be
"Status Quo": http://www.youtube.com/watch?v=wCAtt6JueMM&feature=youtu.be

[3] For further details of the results, please see "Hydro-Urbanism: Reconfiguring the urban water-cycle in the lower Lea river basin, London", available at: http://discovery.ucl.ac.uk/1342812/

sanitation removes the need to flush the toilet, thereby diluting valuable fertilizer produced from human waste. This coevolutionary pathway arose from several participants' existing practices of not flushing the toilet after urination, reserving cistern water for defecation only. In times of water scarcity this "If it's yellow, let it mellow" practice has been an adaptive strategy used by many people with access to flush-cistern toilets. It was acknowledged by research participants that the social acceptability of this practice was not widespread, and also regarded as inefficient in comparison with the ideal of waterless alternatives, as cistern water would continue to be required. This tension led to the suggestion of dry sanitation, which gave rise to the prospect of waste harvesting as part of its treatment.

A dry sanitation, waste harvesting system would result in new infrastructure for the collection, treatment and reuse of human waste, as well as new products and job roles. Treatment could be undertaken on existing sites of wastewater treatment, or new sites could be developed in locations close to places of urban agriculture. The products from this system would be used for fertilizers and biofuels.

Beyond the interviews and group discussions that had reached a saturation point for both of these coevolutionary pathways, the codesign games further explicated the human and nonhuman mobilisations that people felt would be necessary to establish a functioning dry sanitation system in London. One video shows how the status quo of waterborne sanitation would remain due to health concerns and sunk investment in existing infrastructure. Another video shows a complete new economy based on recycling human waste through a neighbourhood vacuum flush, urine collection, and biodigester infrastructure system combined with a local farmers' market, fertilizer and food distribution system. The third video documents a system of treatment that ties in with potential shortages in the food supply chain for proteins and suggests vermiculture as a sustainable means of producing animal protein and replacing pastoralism.

Given the brevity of the research period and the expense of material alteration, it is not possible to explore the results of mobilisation and stabilisation of actants in a new water cycle. However, to the extent that codesign games and interview processes function as a demonstration of potential change, the participants in this research have collaboratively supported alternative water systems to the present infrastructure and have made various changes to their personal water cycles – that is, they have mobilised as actants in a changing network of human/ nonhuman relations. Their personally-instigated changes have included the creation of ponds, the installation of water meters, hand pumps, rainwater collection tanks, and drinking-water saving devices. One participant even documented a household decrease of water consumption from 70L/person/day to 52L/person/day between the first and the second interviews.

Reflections on the New Method

Using coevolutionary ANT as a theoretical framework with which to develop research results has enabled detailed investigation of the microcosm of people's individual material worlds, cultures, practices and ideas concerning water use. These ideas and practices might then be used to inform infrastructural, ecological, governance, market, and management changes. Coevolutionary ANT first uses ethnographic techniques to document – and make participants self-aware of – household water use. It then uses this self-awareness to speculate on how the current circumstances might be transformed in the future given a particular problematisation of their current water situation. The process of establishing self-aware and participatory engagement in this research project enabled two different proposals concerning current water usage; these proposals were investigated using design propositions to find if they would garner sufficient support (or *interessment*) with the research participants. Codesign game then developed the individual design proposals into collectively endorsed infrastructural models cognisant of the human and nonhuman relations that form existing and new water cycles in London.

This set of methods resulted in the identification of two coevolution pathways for water sustainability in London: polycultural water reuse communities, and the harvesting of human waste through dry sanitation. Both of these ideas can be seen as radical changes to the existing regime, which encourages people to flush and forget, yet they are both based on the micro-understanding of people's existing material worlds, practices, and ideas of the future.

Wider Applicability of Coevolutionary Actor–Network Theory

This research found two specific coevolution possibilities for new urban water cycles in London that were attuned to the local tensions within the existing network of the local urban water cycle. The theoretical basis and methods of this research have the capacity to be applied to water infrastructure scenarios further afield, allowing for an array of innovative water cycle models relevant to local water practices and sources. In so doing this could challenge the predominant paradigm of large-scale piped infrastructure for the distribution of water.

The availability of adequate potable water is a problem for people all over the world. Different places offer different types of fresh water (Gleick *et al*., 2006); one water infrastructure solution cannot possibly suit all situations. How we use water influences what we believe to be an adequate supply; but, equally, how we use water depends on numerous specific material relationships. By using a coevolutionary ANT approach it is possible to understand the existing water cycle and its innate tensions, and consequently to investigate these nascent coevolution pathways as a means of determining their applicability and appeal. By considering both applicability and the likelihood of support, this combined approach makes it possible to develop infrastructural transformation that is responsive to the unique water ecologies of the locality and to existing local water practices.

The coevolutionary ANT framework and the methods it applies form ways in which the micro infrastructures of people's everyday changing material practices and desires can be linked to macro changes in infrastructure, ecologies, governance, management, markets, culture and social relations. This framework is demonstrably of value in exploring new means of water sustainability in London, and would be valuable to other regions facing water stress. As a framework that joins the micro with the macro, people and things, its breadth of applicability to the many other problems that we face today – such as clean energy supply, air pollution, and spaces for wellbeing – is clearly evident.

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