# Hydro-Urbanism:
# Reconfiguring the Urban Water-cycle in the Lower Lea River Basin, London

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# DECLARATION OF AUTHORSHIP

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I, Tse-Hui Teh confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

# ABSTRACT

This thesis explores how water infrastructures can be reconfigured in the urban environment to the advantage of human society in the future. It found actor-network theory co-evolutionary pathways between current material configurations and social practices for these reconfigurations. Material configurations include infrastructures, urban form, fixtures, fittings, and water types. Social practices, include existing behaviours, imagined behaviours, desires, and aspirations.

This is an important question to answer because there are many places around the world, both in developed and developing countries that currently face inadequate water supplies to serve the needs of their ever growing populations, or conversely flooding due to extreme precipitation or sea level rise. The lower Lea river basin in London is one such area. The large scale engineering solutions of pipes and pumps to control water that have been the typical solution are reaching their limits therefore it is imperative to find other means to manage water in urban environments.

This research used an actor-network theory co-evolution framework to understand the existing urban water-cycle, and to find areas of transformation in order to develop actor-network co-evolutionary pathways for change. Interviews, group discussions and water diaries were used to investigate the existing conditions and anticipated future changes of both private citizens and water professionals. An iterative process of design synthesis and discussions were repeated twice to test and define the actor-network theory co-evolutionary pathways.

This research stretches actor-network theory from its ethnographic beginnings into the realm of the future through design propositions. It found that there were two strongly favoured actor-network theory co-evolutionary pathways for reconfiguring the urban water-cycle in the lower Lea river basin. These were increasing freshwater productivity and transforming waste to resource. These create new water-cycle assemblages that offer advantages to people who face many, yet uncertain, types of water stress in the future.

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# ABBREVIATIONS

| | |
|---|---|
| ANT | Actor-Network Theory |
| BAP | Biodiversity Action Plan |
| BMP | Best Management Practices |
| CAMS | Catchment Area Management Strategy |
| CCW | Consumer Council for Water |
| CIRIA | Construction Industry Research and Information Association |
| CSO | Combined Sewer Overflow/Outlet |
| DWI | Drinking Water Inspectorate |
| EA | Environment Agency |
| EEA | European Environment Agency |
| EPA | Environmental Protection Agency |
| EU | European Union |
| GARDIT | General Aquifer Research Development and Investigation Team |
| GLA | Greater London Authority |
| ICE | Institute of Chartered Engineers |
| IPCC | Intergovernmental Panel on Climate Change |
| ISO | International Organization for Standardization |
| IWA | International Water Association |
| IWM | Integrated Water Management |
| IWRM | Integrated Water Resource Management |
| LDA | London Development Authority |
| LID | Low Impact Development |
| LVRPA | Lea Valley Regional Park Authority |
| NSW | New South Wales |
| Ofwat | Water Services Regulation Authority |
| OMA | Office of Metropolitan Architecture |
| PPS25 | Planning Policy Statement 25: Development and flood risk |
| RIBA | Royal Institute of British Architects |
| SSSI | Site of Special Scientific Interest |
| STS | Science and Technology Studies |
| SUDS | Sustainable Urban Drainage Systems |
| UK | United Kingdom |
| UN | United Nations |
| UN-HABITAT | United Nations Human Settlements Programme |
| US | United States |
| USA | United States of America |
| WRAP | Water and Resources Action Program |
| WSUD | Water Sensitive Urban Design |
| WWF | Worldwide Fund for Nature |
| WWII | World War Two |

**Chapter One**

# INTRODUCTION

Water has always been a key component to human settlements because it is essential to life, and an advantage for trade, agriculture, industry, and social stability (Barlow and Clarke 2002; Fagan 2009; Feyen, Shannon, and Neville 2009; Gleick et al. 2006; Tvedt, Coopey, and Oestigaard 2006). In the modern cities where I have lived: Wellington, Sydney, New York and now London, water has been made to seem benign, an unproblematic background feature to everyday life. I and every other citizen have had piped drinking-water and drainage to and from my home and every other building I use. Even more conveniently, it is piped and drained from the locations I need it: the bathroom, the kitchen, and the garden. We have been protected from floods by constructed barriers against rivers and oceans, and pipes that drain surface-water. The expectation is that we have control over water. There, exactly where and when we need it; gone, as soon as we don't. Rain is an inconvenience, hose pipe bans infrequent, and flooding seems to be a fantastical rather than a real threat. I, and every other citizen, am completely divorced from the consequences of the water that flows through and around my life. It conveniently appears and disappears, never causing more than a ripple on the fringes of our consciousness.

Water has not always been so hidden in the urban environment. Many ancient cities celebrated the water that helped the citizens of the cities thrive with fanfare and mythology. Rome had magnificent aqueducts that fed water to resplendent fountains that provided water for its populace (Chant 1999). Hangzhou and Suzhou are two famed water towns with canals and lakes that continue to be regaled as paradise on earth by the common saying "Just as there is *paradise* in heaven, there are *Suzhou* and *Hangzhou* on earth". Mexico City was built in the middle of a great lake (Chant 1999). Angkor's temple complexes were built around canals and water reservoirs (Rigg 1992). In London, "The vital importance of water in the everyday life of the City was reflected in the form and siting of the

Conduits constructed as the public supply points on the various pipelines bringing water in from the north and west. These were impressive structures, large and highly decorated, often sited in the middle of major thoroughfares" (Flaxman and Jackson 2004, 27). Each of these waters was both a necessary infrastructure, a connection to water availability and a source of pleasure for the populace. These infrastructures were a celebration of water that encompassed both the natural water features on which the city was founded and the human ingenuity that transformed natural water sources into a resource for the citizens.

Even though water is not a celebrated part of modern urban settlements now as it was in the past, we are still reliant on its constant supply and convenient presence to achieve our everyday lives. It is typically one of our first wakeful interactions with the world, whether we get up and drink the glass of water by our bedside, or rush off to the toilet and one of our last interactions before we go to sleep when we brush our teeth, or use the toilet. We are constantly affecting the quantity, quality and location of water throughout our daily lives. This control of water undoubtedly makes life easier to lead and is consistently seen as one of the characteristics and symbols of a modern city (Gandy 2003; Gandy 2004; Kaika 2005; Melosi 2000; Swyngedouw 2004). It is the infrastructural aspiration globally of people living in developing countries, where drinking-water, sanitation, and protection from flooding are not on the unconscious fringe of life, but a central concern (United Nations Human Settlements Programme 2003). But is this infrastructure, which obscures from people the environmental effects of their water use and fails to acknowledge the importance of water to human life, an appropriate paradigm to aspire to?

Water scarcity in London and Sydney are both harbingers that indicate this system has limits (EA 2006; EA 2008; NSW Office of Water 2010). This centralised infrastructure encourages the unconscious wasteful use of water because it continually flows from the source points to our places of habitation, and conceals from us the water sources, receiving waters for discharge and the consequent environmental impact on aquatic environments. This has led to a trend of increasing consumption (Butler and Memon 2006; EA 2010), which has led to a never ending chase to find more water resources (Butler and Memon 2006), which has now eventuated to the energy intensive solution of desalination for those countries who can afford it (NSW Office of Water 2010; Thames Water 2007). Desalination causes more environmental degradation from the discharge of super saline water (Roberts, Johnston, and Knott 2010). Continued over abstraction from the environment causes liminal land to dry out, which makes settlement on these low lands possible (Acreman 2000), these settlements are then susceptible to flooding because not only are they built on lowlands but also the former marshlands. Therefore they lack this liminal land that retains and absorb volumes of water from a deluge of rain or a high tide (Acreman 2000). Aquatic food stocks are also affected by the over abstraction of freshwater from the environment and the discharge of nutrient laden water into the environment, both of which cause the degradation of aquatic ecologies that are essential for the ongoing viability of habitats for fish and aquatic invertebrates (Kosmala et al. 1999), which are essentials to our food stocks (Newson 2007).

Despite the fact that our actions with water do not ripple our conscious minds, they are definitely still deliberate. Our partnership with this infrastructure forms part of the water-cycle moving and diverting vast quantities of water from rivers or aquifers through our settlements and then back to the aquatic environment. This is not a benign change to the water-cycle. Every point of human intervention causes degradation to environments that are detrimental rather than helpful to the long term continuity of human life (Newson 2007). It is easy to believe in the efficacy of these big engineering solutions because they do directly solve the concerns of drinking-water distribution, sanitation, and flood protection. However it is a solution that only works for a short timeframe within a limited space. The ongoing expansion of these solutions to more areas affects greater quantities of water, which escalates deterioration of our surroundings. Here lie the limits to this paradigm. However these boundaries can be stretched through understanding and adapting the interactions between people, water, infrastructure, technologies, and the urban landscape, to ensure the continuation of healthy environments that can support stable human civilizations. These adaptations will necessarily alter our everyday lives, our appreciation of water, and the urban landscape.

**Water Disappears**

Historically, water has been one of the founding factors of human settlement (Chant 1999; Spirn 1984; Vitruvius 1914). Without reliable sources of water, people would not thrive. Furthermore, different types of water had different advantages to offer a settlement. A river offered opportunities of faster transportation, trade, and additional food sources. An aquifer offered areas of settlement that were not dependent on the limitations of surface water supplies. Running water offered an opportunity to transform this energy to do work that would otherwise need to done manually. Rainwater provided irrigation for agriculture and water bodies could be incorporated into a defence system (Ackroyd 2000; Ackroyd 2008; Tvedt, Coopey, and Oestigaard 2006). Given the importance of water to human physiology and historic settlement patterns, it is surprising that water infrastructures could have disappeared as a primary ongoing concern of urban design and planning in the past century. It is only now re-emerging with urgency as more people are affected by water scarcity.

The re-emergence of water as a concern of urban design and planning is propelled by a growing understanding of the limits of the engineering solutions developed in the $19^{th}$ and $20^{th}$ centuries. During the late $19^{th}$ to the early $20^{th}$ centuries, urban design, urban planning and engineering were beginning to form as separate professions (Hall 2002; Schultz and McShane 1978). These professions formed in association with the ideas of centralised water distribution and sanitation drainage in underground pipes that aimed to rid cities of disease and improve public health. These were designed and implemented by engineers and despite some competing ideas, were largely constructed with great success in the then large and influential metropolises of Paris and London (Melosi 2000). It established engineers as the key profession who designed and implemented these new technologies which were then replicated in other modernising cities around the world. Moreover these were accepted to be the state of the art infrastructures, thus were then used for extensions to existing urban areas and new towns (Abercrombie 1998). These drinking and waste water infrastructures were mostly hidden underground and hence did not seem to have an impact on the form of the development of urban areas above ground. Water physically disappeared from the visible urban environment and in the discourse of urban designers and planners. There have not been many reasons to question the continuing viability of these infrastructures until the last 30-40 years, when their limits have become apparent to water resource planners, ecologists, geographers and sociologists (Alberti 2008; Butler and Memon 2006; Newson 2007; Shove 2004).

Since the implementation of piped drinking water supply there has been an increase of per capita domestic water consumption (Butler and Memon 2006; Gandy 2006a; Geels 2005; Shove 2004). In London the Metropolitan Water Board noted with some consternation that "Ever since the Board came into existence the demand for water has been increasing so that it is now half as much again as it was 50 or so years ago." (1961, 43). This was an outcome from the ease of supply leading onto greater desires of cleanliness and the consequential development of new technologies to facilitate the achievement of this desire that also increased water consumption. This has occurred in a seemingly ceaseless loop of ever increasing water consumption. It has led engineers in a chase to find and harness greater amounts of water from the environment to feed into the piped water supply system. But renewable water resources, whether from surface-water or aquifers are determined by the local water-cycle of rainfall in order to recharge water sources, as well as the space in which to store it. The limits of these available surface and ground water resources have been further emphasised by climate change projections that indicate greater rainfall variability and therefore more uncertain water supplies (IPCC 2007a).

This has pushed engineers to look at the other end of the pipe and attempt to control water demand through new water saving technologies with entreaties to citizens to consume less water (Butler and Memon 2006). However the amount of water consumed also depends on the types of acceptable social expectations that citizens aim to fulfil and their level of infrastructure dependency (Van Vliet, Chappells, and Shove 2005), which means that entreaties to individual citizens alone will not have much effect, social expectations must also generally change. At present urban design and urban planning have joined the chorus of voices appealing to the public to consume less water (Landry 2006; Register 2002), but themselves have not engaged with ways in which urban design and planning could enable this change. My research has begun to probe ways in which urban forms could alter the relationship between water and people to modify the way water is now consumed.

The centralised surface and wastewater drainage systems developed by engineers have increased the speed of water flow into water courses by diverting water that would otherwise slowly flow through aquifers, springs, streams, rivers, wetlands, estuaries and oceans. This reduces the residence time of water on terrestrial land subsequently causing ecological damage to water courses (Alberti 2008; Calder 2005; Newson 2007; Paul and Meyer 2008). The change in hydrological regime is also influenced by a value change of these waters by people living in urban areas.

Piped drinking water is generally regarded as the healthiest source of water for most citizens served by this infrastructure; therefore other types of water are less appreciated. Small water courses such as brooks and streams as well as temporary ponds, puddles and pools are regarded as inconveniences to transportation or as health hazards in built-up areas, rather than as a source of delight, or a connection to other ecologies, or a recharge to ground water, or as a valuable water resource. Accordingly these waters have been drained, sealed over with impermeable surfaces such as bitumen and paving. These have been constructed to ensure that water disappears quickly into the drainage infrastructure. This infrastructure then discharges a point load of this surface-water into water courses causing a surge in water levels which scours to the river banks and beds, disturbing and destroying aquatic habitats, and increasing flash floods in the vicinity (Alberti 2008; Calder 2005; Newson 2007; Paul and Meyer 2008). This degradation of aquatic ecologies is amplified because during dry weather conditions, water flow was lowered because water has been abstracted as a source of drinking-water.

Attempts to ameliorate the resulting damage to ecosystems have been developed by engineers, ecologists, landscape architects, and urban designers, who looked to modify the centralised piped drainage system by adding devices to attenuate water. These proposals are typically for new urban developments and include the use of combinations of water holding techniques: rainwater harvesting, green roofs, detention basins, ponds, swales, trenches, and permeable paving. These systems of water management are known by different names around the world: sustainable urban drainage systems (SUDS) (Woods Ballard, Kellagher, Martin, Jefferies, Bray, and Shaffer 2007a), water sensitive urban design (WSUD) (France 2002; Wong 2007), and low impact development (LID) (Prince George's County 1999). Climate change has also accentuated the urgency for these water retaining landscapes because more extreme rainfall will increase the likelihood of flash floods causing greater environmental damage and over burden the finite capacity of centralised drainage systems. This has brought surface-water into the minds of some urban designers and planners (Busquets and Correa 2006; Schafer 2009), however it is not universally seen as instrumental to the structuring of future city design where water is still often conspicuously missing (Landry 2006; Moor and Rowland 2007; Plunz and Sutto 2008; Read, Rosemann, and van Eldijk 2005; Register 2002).

Urban designers and planners most often only consider the ornamental aspects of water that add pleasure to the lives of citizens by the use of fountains, pools, river walks, and water front attractions (Alexander, Ishikawa, and Silverstein 1977; Malone 1996). Where water is "a decoration in the townscape, a pleasant toy for artists and architects, but a superfluous one…[while] all the essential water management in the town ...rainwater removal, drinking water provision and sewage disposal, is dealt with...scarcely visibly and without any aesthetic sense as part of the engineers' domain" (Dreiseitl and Grau 2005, 9). Neither the architects, urban designers, urban planners, or engineers considered how this late 19C engineering solution of the piped paradigm of centralised water distribution and sanitation drainage in underground pipes influences urban form. The effects of this system have been of interest to urban geographers. They have described how these water infrastructures have created the idea of the modern city (Kaika 2005; Farias and Bender 2010), changed the social relation with nature (Gandy 2003; Heynen, Kaika, and Swyngedouw 2006), changed the use of public and private space (Gandy 2004), and the inequalities formed by unequal access to the distribution of water resources (Graham and Marvin 2001).

While water has literally disappeared from the ground surface of modern cities into underground pipes, it still has an effect on urban form. The urban design and planning discourses since the turn of the 20$^{th}$ century have under represented the multiple roles water plays in shaping the urban environment and how it can be used to structure urban form. Insights from the related disciplines of engineering, geography, ecology, sociology, and science and technology studies inform this research.

**Theoretical Framework**

The long term effects of the comprehensive piped water network are the consequence of many interrelated elements, which include social values, environmental values, infrastructure, technology, urban form, and ecological understanding. Each of which have effects on one another. Each of these elements could and indeed have been studied in isolation. Water infrastructures and technologies have been the domain of engineers (Al Naib 1997; Butler and Davies 2004; Chen and Liew 2003; Droste 1997); social values of water by sociologists, geographers and historians (Geels 2005; Hand, Shove, and Southerton 2005; Gandy 2003; Graham and Marvin 2001; Kaika 2005; Shove 2004; Sofoulis 2005; Swyngedouw 2004); ecological values by ecologists (Alberti 2008; Marzluff et al. 2008; Sukopp, Hejny, and Kowarik 1990), and urban form by geographers, urban designers, and urban planners (Abercrombie 1998; Alexander, Ishikawa, and Silverstein 1977; Hall 2002; Harvey 1989; Landry 2006; Moor and Rowland 2007; Shane 2005; Waldheim 2006). Each of these disciplines brings insight to specific areas of the water-cycle, but their isolation inhibits an understanding of how water, people and the urban environment interact to form the urban water-cycle, nor does it lead to answers of how the long term effects of large engineering solutions can be mitigated and new beneficial changes be implemented.

In order to combine these different understandings to formulate possible answers to this matter of concern, I have used an actor-network theory (ANT) framework. This creates my ontology, where all things in the world are made equally of human and nonhuman influences; and my epistemology, where I seek to explore the intertwined relations between human and nonhuman elements, both of which are known as actants in ANT (Latour 2005). I have joined this understanding of the world with a socio-technical co-evolutionary perspective, which is complementary to ANT and gives insight particularly to the everyday nature of water use (Shove 2004; Allon and Sofoulis 2006).

I used actor-network theory as the overarching framework because it includes all things in the world, such as water, vegetation and taps as part of a network of influences. The socio-technical co-evolutionary perspective focuses on change between social values and technologies, which is a preconceived narrowing of what composes a valuable network to investigate. However the socio-technical co-evolutionary perspective gives insight into the way things change over long periods of time which is overlooked by actor-network theory which describes different ways knowledge is made in a short time span. I have used these two views to extend the one another, (1) actor-network theory to examine a wider range of actants beyond the human and the technological (2) the socio-technical co-evolutionary perspective to examine the longer time scale and the open-ended ability of actants to continue shaping properties of one another.

**Research Questions**

Through this framework my research aims to address how the interactions between people, water, infrastructure, technologies, and the urban landscape can co-evolve in the case study area of the lower Lea river basin in east London. This is an area served by big engineering water infrastructures for drinking-water provision, wastewater collection, and flood protection. It provides a platform to define how these water infrastructures influence the water-cycle and to devise means by which it can be reconfigured. The overarching question of this research is:

**Using an actor-network theory co-evolutionary perspective, how can the urban water-cycle in the lower Lea river basin be reconfigured to ensure its ongoing ability to provide water that humans and other biota require for the flourishing of human life?**

This question is supported by four main research questions:

1) How are the water-cycles in the lower Lea river basin assembled today?

The theoretical framework is applied to understand the things that influence the water-cycle today. It also aims to find variations in different people's water-cycle assemblages that constitute co-evolving network formations. It examines how these occur in order to expand on these practices with design propositions that reconfigure the urban water-cycle to create greater freshwater availability for humans and other biota.

2) How do people imagine changing their interactions in different water-cycle circumstances?

This question applies the theoretical framework to understand the different relative stabilities of influence humans and nonhumans have on each other in this water-cycle. This finds the weaker, more fragile networks which are more susceptible to change. It also investigates the affordances existing nonhumans have for new human interactions. These answers will determine the sorts of change that could happen to the water-cycle in the future and the type of necessary actant alteration for these changes to occur.

3) What are the design adaptations that can be made to the existing infrastructure?

This question is answered by synthesizing the co-evolved reconfigurations in both the unique water-cycles and those that would alter in times of water scarcity or flooding into design propositions that mitigate the long term effects of the water infrastructure that currently operates in the lower Lea river basin.

4) What value does the actor-network theory co-evolutionary perspective have to design practice and design practice to actor-network theory?

This question critiques the value of using the actor-network theory co-evolutionary theoretical framework in developing design changes to the existing water-cycle. It also investigates whether design can be used to extend actor-network theory from a theory which is analytical from a historical and contemporary perspective, to a theory that can also be projective.

This thesis contributes an actor-network theory understanding of the water-cycle in the lower Lea river basin.  It extends actor-network theory with the socio-technical concept of co-evolution and a design research method that uses an iterative process of design propositions to give projective accounts of possible reconfigurations to the urban water-cycle of the lower Lea river basin. Finally it reflects on the value actor-network theory and design methods have to each other.

**Research Methods**

This research is based on a case study in the lower Lea river basin in London, United Kingdom, which uses a combination of qualitative and design methods with an actor-network theory co-evolution framework to answer the questions outlined above. The case study approach is used to concentrate on understanding the specific interrelations between things and people using the combined actor-network theory and socio-technical co-evolution frameworks. The case study method also investigates how water can be reconfigured in the particular urban landscape of the lower Lea basin. The case study area is defined by the topographical boundary of a river basin (also known as a watershed or catchment) in which all the water on the ground surface flows towards the river. Each tributary of a river can be used to identify a watershed, thus smaller catchments are nested within larger ones. The lower Lea river basin in east London was selected because it is representative of many urbanised areas served by piped water supply and drainage. It also contains some strategic infrastructural nodes for London's water supply and drainage infrastructure.

Qualitative research in the form of semi-structured interviews, group discussions and diaries was used to formulate an actor-network theory co-evolution account of its current water-cycle and areas of personal change to these assemblages. A design method was used to synthesize these changes into propositions of new actants that reconfigure the existing water-cycle. These new actants were then introduced to existing networks through the qualitative methods of semi-structured interviews and group discussions which were used to describe new actant formation and further actant changes. The actants that produced the most possibility of new network relations from the participant responses were tested again through developing the designs and finding or producing physical prototypes. The qualitative method of group discussions was then used as a final iteration of this research, which introduced new people to these actants, to explore if these changes had stability as possible co-evolutionary pathways.

**Lower Lea River Basin Case Study**

The lower Lea (also spelt Lee) river basin is located in east London in the United Kingdom and is the largest tributary on the north bank of the river Thames (Encarta 2009). It is the most significant tributary of the Thames (Water Resources Board 1972), which is the bigger river basin within which the Lea river basin is nested. The definition of the lower Lea river basin used is defined by the Environment Agency (EA 2006). The majority of this watershed is within the Greater London Authority and crosses through eight different boroughs of London: Tower Hamlets, Newham, Islington, Hackney, Waltham Forest, Haringey, Barnet and Enfield, in addition there is one small corner to the north east in Epping Forest.

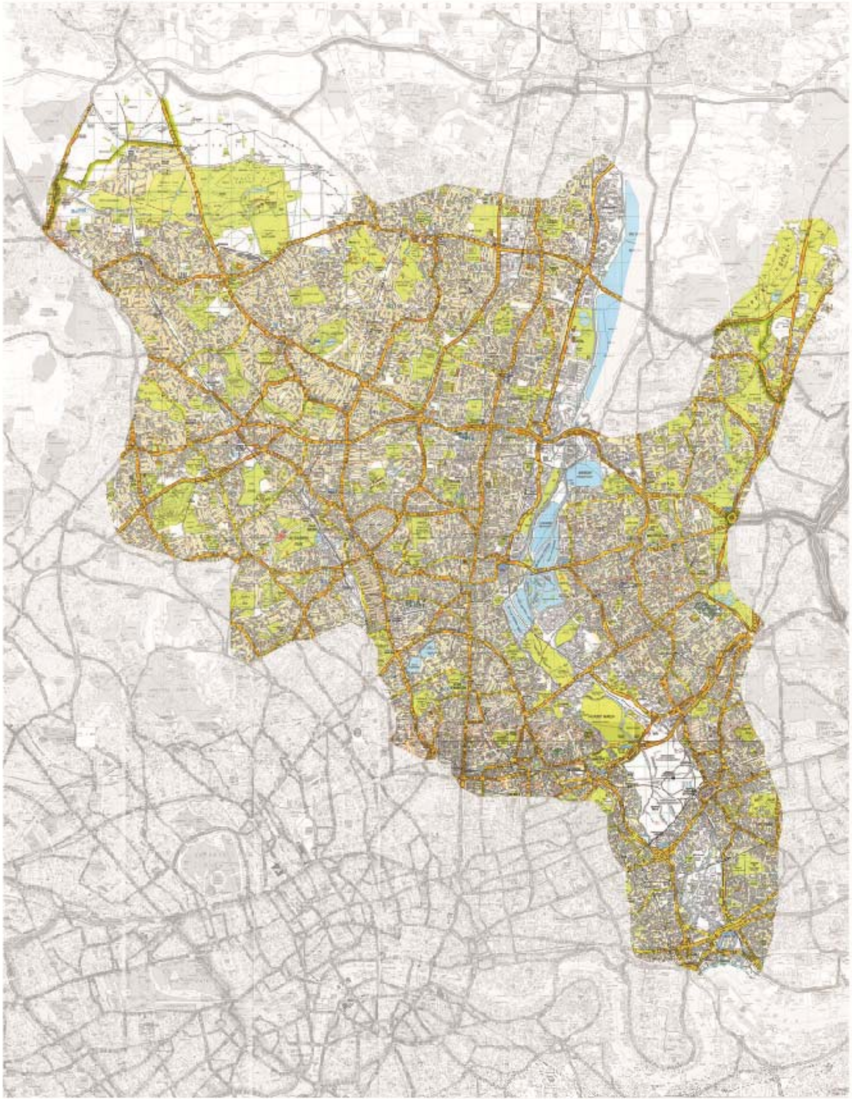


**Figure 1.1 Map of lower Lea watershed**
Based on 2008 London A-Z Map and Environment Agency watershed boundary

The southern end of the lower Lea river basin, where the Lea river meets the Thames, is densely urbanised with a majority of residential buildings comprised of two and three storey attached houses and midrise flats. Along the banks of the river are declining light industrial uses interspersed with recently built high-end midrise apartments. This lower portion of the Lea river is undergoing a planned property and socio-economic transformation that has been spurred by the London 2012 Olympic Games whose main site is located within the braids, canals and locks of this river (GLA 2009). This area is part of the London Thames Gateway regeneration plan in which it is intended to construct 91,000 new homes and supporting services by 2016 (New London Architecture 2006). In contrast, the northern portion of the watershed has a suburban character with larger building lots and a greater proportion of single family dwellings.

The lower Lea river basin plays a key role in both the drinking and wastewater infrastructure of London. The upper and middle portion of the river is abstracted for drinking-water, and the middle and lower river receives effluent discharge (treated wastewater) from wastewater treatment plants and untreated wastewater from combined sewer overflows. The water from the river is also a location of indirect potable reuse as the middle river is also abstracted for drinking water.

**Lower Lea River Basin Water Conditions in 2011**

The Lea river begins from a natural spring that is fed by ground-water from a chalk aquifer, which forms part of the water flow in this river. The chalk aquifer is recharged by rainfall that seeps through the space in the soil matrix into the pores and fissures of the chalk. Another source of water for the Lea is surface-water that drains from the ground into the river from rainfall. The lower Lea river basin experiences a relatively low rainfall with an annual average of 640mm (EA 2006). The ground surfaces of the lower Lea river basin are highly modified urban areas so little of this rainfall drains into the Lea river. The majority has been made impervious to water infiltration by either buildings or hard paving that drain into the sewer system rather than the river (European Environment Agency 2011). These impervious surfaces also decrease the residence time of water in this river basin by shedding water quickly preventing a slow flow of water absorbed through soil and vegetation. Moreover the paved surfaces directs the surface-water into the sewer system which transports it to a wastewater treatment plant that discharges into the river Thames which means that a much smaller quantity of the surface-water now drains into the Lea river. A smaller portion of its ground surfaces are wetlands, grasslands, forests, parks or gardens with soils and vegetation that retain water. Landholders and local council authorities are responsible for the different types of ground cover. Another source of water for the Lea is from stormwater pipes that drain surface-water, and combined sewer overflows that drain a combination of sewage and surface-water. The final source of water flow in the Lea river is from effluent discharge from wastewater treatment works, which can make up the majority of the water flow during prolonged dry weather conditions (WWF-UK 2009).

The subsidiary water courses that once fed into lower Lea river are highly modified, the majority of which have been subsumed into the sewer system (Barton 1962). The Lea river itself has been canalised, straightened, abstracted and dredged. Humans have modified and managed every aspect of the water in this river basin, either through deliberate action to control water, or as a consequence of achieving other needs.

Thames Water Utilities provides this urban area both its drinking-water treatment and distribution; and wastewater collection, treatment and discharge. Thames Water Utilities is a solely private water and wastewater company that is regulated by the government through the Environment Agency (EA), Water Service Regulation Authority (Ofwat), Drinking Water Inspectorate (DWI), and Consumer Council for Water (CCW). The Environment Agency regulates allowable water abstractions, which includes ground-water and river-water. It also regulates the quality of water discharge and the quality of river waters. Ofwat regulates the cost of water and sewerage services to the consumer in relation to all other water and sewerage companies in the United Kingdom (UK) and Wales. This is a mechanism to ensure competition between the privatised water companies in England and Wales who operate in natural monopolies. The regulation of cost means that Ofwat effectively decides on the budget of capital expenditure for each water and wastewater company and the price that each water and wastewater company can levy for water provision and discharge. As its name describes, the DWI ensures that all the water companies in England and Wales meet an expected standard of drinking-water quality, which includes indices of acceptable levels of bacteria, chemical composition, clarity, and smell. The CCW advocates for consumer concerns about drinking-water quality. The majority of these regulators are purveyors of drinking-water quality, not about protecting environmental qualities to places of water abstraction or discharge.

A number of nongovernment organisations also contribute to the water-cycle in the lower Lea river basin. Waterwise is a nongovernment organisation funded by the UK water industry and private consultation fees to advance and build knowledge about reducing household water consumption. The government also supports a Waste and Resources Action Programme (WRAP/Envirowise) that deals in similar types of support and information to businesses. The UK water industry also funds a nongovernment organisation, UK Water, to represent their interests to the national and international governments. British Water is supported by and advocates for other businesses that supply technologies and expertise to the water industry.

To provide drinking-water for London, Thames Water abstracts water from the upper Lea river at Luton, and the middle Lea river at Waltham Cross amongst other sources. The reservoirs in the Lea river basin store the greatest volume of water in London (Encarta 2009). The Lea river has a status beyond over-abstracted from the Environment Agency which means it needs additional volumes of water flow to achieve an over-abstracted status (EA 2006). The water abstracted from the upper Lea is transported via a ground level open aqueduct known as the New River that opened in 1613. This raw freshwater is then treated at Coppermills water treatment plant to a drinking-water standard before entering the general distribution of drinking-water in London.

Thames Water is also responsible for the surface and wastewater collection and treatment in London. Surface and wastewater is transferred in a combined sewer system. Deephams wastewater treatment plant discharges its effluent into the lower Lea river. Abbey Mills Pumping Station which lifts wastewater from the northern intercepting sewers of London is also located along the banks of the lower Lea river. This sewer system has combined sewer overflows which release untreated wastewater into the lower Lea river in times of high volume (approximately fifty times a year (Thames Water c2008)). Without these overflows the mixture of untreated surface and wastewater contained in the piped network would back up into streets and buildings. This combined sewer overflow system is being upgraded with the Lee Tunnel project by Thames Water, which intercepts all the points of overflow along the Lea river and diverts them into the Lee Tunnel for storage and transfer to Beckton wastewater treatment works. This tunnel is due for completion in 2014.

Another recent modification to water in the Lea river is Three Mills Lock (previously known as the Prescott Lock) on Prescott Channel, part of the Lee Navigation canal. This lock was completed by British Waterways in 2009 and makes the channel navigable for barges that transport construction materials and waste from the building of the Olympic Games venues and other constructions from residential regeneration projects associated with the Olympic Games. This new control also increases the property value of land adjacent to the waterfront because of the landscape feature; the high water also provides a prettier backdrop to the main Olympic games venue and prevents it from smelling of tidal mudflats during low tide. British Waterways and the Environment Agency also collaborated to dredge approximately 7km of the Lea Navigation canal in 2009 from Tottenham Lock to Old Ford Lock to remove contaminated silt and thus improve the water quality. There are also two other nongovernment organisations overlooking the quality of water in the Lea river and navigation canal. These are Thames 21 and the Thames Estuary Partnership.

Walthamstow Marshes and Reservoirs within the lower Lea river basin have a statutory designation as Sites of Special Scientific Interest (SSSI) indicating that they are amongst the United Kingdom's best wildlife sites. Both these habitats are water dependent. The Lea Valley Regional Park Authority is responsible for the management of these habitats.

Some low lying areas of the Lea river basin are susceptible to fluvial (river) floods, from the Lea river and its tributaries. Other areas have flooded in the past due to a lack of sewer capacity and there have been some cases of groundwater flooding in basements of buildings. The most recent flood event was in 2000 and was a fluvial flood (Bakewell 2008). The Environment Agency and

British Waterways are responsible to prevent damage and loss of life from fluvial floods. Pluvial (rainwater) floods are surface-water floods and are caused by a lack of drainage from insufficient permeable areas of ground for water infiltration or an inadequate provision of pipes. Thames Water Utilities and local councils are responsible to prevent surface-water floods. Thames Water for the provision and maintenance of the sewers and local councils for street cleaning and clearing drains that transport surface-water to the sewer system. While these responsibilities might sound well demarcated, the reality is that the same water moves from one responsible authority to another without boundary. Pluvial floods can become fluvial floods as sewers overflow into river courses.

The geology of the river basin is mostly London Clay over a sequence of Lower London Tertiaries, in this case the Lambeth Group and Basal Sands, under which there is the Chalk aquifer. The London Clay forms the confining layer to the Chalk aquifer. The Basal Sands forms a minor aquifer that is in hydraulic continuity with the Chalk aquifer. There is a wide band of water retaining alluvium and river gravel deposits that run on either side of the course of the Lea river and overlie the clay. There are also two areas, one close to and the other on, the river Lea where there are outcrops of the Lower London Tertiaries which are unconfined by the London Clay and are windows to the major Chalk aquifer below (Water Resources Board 1972). At these points in Hackney and Enfield, Thames Water has two experimental wells for artificial recharge of the Chalk aquifer to store water (EA 1997).

The Lea river begins in the unconfined Chalk aquifer in the Chiltern Hills, which is one area of natural recharge to the confined Chalk aquifer which lies under London. The water levels of this aquifer are managed and monitored by the General Aquifer Research Development and Investigation Team (GARDIT) Strategy. This strategy is a collaborative effort by Thames Water, the EA, and London Underground with support from Corporation of London, Envirologic, the Association of British Insurers and British Telecom (Jones 2007).

There are many different types of water and numerous authorities responsible for the quality, quantity and location of these waters in the lower Lea river basin. Water types have included rainwater, surface-water, drinking-water, wastewater, groundwater, river-water and flood-water. The people responsible for the quality, quantity and location of this water have been landholders, local councils, Thames Water Utilities, the Environment Agency, Ofwat, the Drinking Water Inspectorate, the Consumer Council for Water, British Waterways, Lea Valley Regional Park Authority, London Underground Waterwise, WRAP, Thames 21, and Thames Estuary Partnership.

**History of the Lea River**

The Lea river has been of historical importance to the growth of London as an urban metropolis. During the industrial revolution it was used for the transportation of goods, an energy source, for food, for materials, and finally for drinking-water. Its location was at first far from the city, but the marshlands surrounding it were gradually urbanised from the late nineteenth century onwards.

From medieval times the river Lea was used for transporting grain, meal and malt to London. The Limehouse Cut was built in 1767 to shorten the route to transport goods between the Lea river and the city (Fairclough 1986). The running water of the Lea was harnessed for energy, The Domesday Book of 1086 records eight mills along the Lea river (Lewis 1999) and the Wallis's Plan of the Cities of London in 1804 shows three mills along its banks: Abbey Mills, Three Mills and Four Mills. These mills provided flour for the bakeries of London. During this time it was also used as a source of aquatic food and fisheries and fish weirs were developed along its banks (Fairclough 1986). The vegetation along the banks was used as a source of osiers for basket weavers (Fairclough 1986). By 1823 reservoirs were built along its banks and it was being used as a source of clean drinking-water for the city (Thompson 1824).

In the 1860's the marshlands of the lower Lea river were developed as market gardens that provided food for the city. By the 1960's these market gardens had moved to the upper Lea where in the 1970's one third of Britain's cucumbers were being grown (Lewis 1999).

The Lea river with its water transportation, flowing water conducive to the easy disposal of wastes and open land from its use as market gardens had many advantages that made it an attractive place to build industries from about the 1880's onwards. It was the place where many technological innovations were made that changed the lives of countless people. Some of these innovations are the incandescent lamp, glass house technologies, the thermos flask, petrol, the carburettor and other electronic household equipment (Lewis 1999). Also manufactured here were iron clad warships, boats, gunpowder, armaments, matches, furniture, dye, and porcelain amongst other things.

The upper reaches of the Lea river are still used as a source of raw-water for London's drinking-water supply, and its lower reaches receive London's treated wastewater. This river has had centuries of human modification to become more convenient for transportation, food harvesting, mill running and the transport of effluent. Its banks have consequently been made from soft indeterminate edges, to hard solid boundaries so that buildings can be built closer to the flowing water; various channels and rills have been formalised into canals to manage the water level; and the meandering curves have been straightened to make waterborne transportation more efficient. In the Greater London Plan (Abercrombie 1945), Patrick Abercrombie gave this watercourse another strategic importance by identifying it as the 'green lung' of London to be preserved for the health of the city.

The water of the Lea river facilitated the conditions that allowed the city to grow and industrial innovations to flourish. However today the ecologies of the river are compromised, in the summer its water flow comprises of 80-90% effluent (Rudd 2009). It takes 50% of all of London's combined sewer overflows (Thames Water c2008). The EA regards the flow of the river-water so reduced from an estimated natural level that the target to improve to the river-water is to achieve an over abstracted status. The Lea river continues to be reconfigured.

**London's Water Projections**

South-east England, where London is located is currently designated "water stressed" for drinking-water supply by the Environment Agency (EA 2006) and is projected to become more so in the future. The prediction of increased water stress lies in three factors: population growth, increased water consumption, and rainfall variation due to climate change.

There is an anticipated continued growth in the population in London (GLA 2009), which will require additional water resources from a water supply limited by rainfall, environmental regulations, and water treatment and water reservoir capacities (Thames Water 2007). The majority of the increase in population is anticipated to settle in the east of London, north of the Thames river, some of which is within the lower Lea river catchment.

Of the existing population, there is also an uncertain trend in level of per capita water consumption, which had steadily grown over the last 30 years (Butler and Memon 2006; EA 2008), but has shown a slight decrease of 2L per day, over a four year average from 2004/5-2008/9 in comparison with 2003/4 – 2007/8 (EA 2010). The Environment Agency expects per capita consumption to decrease due to increased water metering and the reduction of leakage, but this decreasing trend is only expected to continue until 2018, when water consumption is expected to rise again (EA 2010).

More extreme weather conditions are projected in the UK due to climate change, in the south east of England, this means wetter winters and hotter drier summers (Jenkins, Perry, and Prior 2009). This could result in a net rainfall that might remain approximately the same over the annual average, but the rainfall season will be concentrated in the winter months rather than spread more evenly over the year. This has an impact on water supply and the quality of aquatic ecologies over the drier summer months. Typically, water demand is higher in the summer, when people bathe and water their gardens more often (Thames Water 2007), if there is less rainfall in the summer, this demand will be difficult to meet. Aquatic ecologies would then suffer from both a maximum abstraction and higher temperatures, leading to a more likely state of eutrophication because of higher biological activity triggered by the warm weather and a higher concentration of nutrient in the water because of the reduced water volume (WWF-UK 2009). Thames Water has responded to this possible shortfall in supply with the construction of a desalination plant at Beckton.

The higher rainfall in the winter months could also cause flooding (pluvial or fluvial) from several sources. This is problematic for aquatic ecologies because the combined sewer overflow relief valve for the centralised wastewater and storm-water drainage system will release a surge of untreated water into the river system.

The climate change projections clearly magnify the problems of the existing urban water-cycle of London. These are matters of concern that require attention. The problems, water shortages, flooding, population growth, increasing water consumption and degradation of water ecologies are not unique to London. Many urban areas around the world contend with similar problems, with or without a projected change in climate (Barlow and Clarke 2002; Gleick et al. 2006; UNEP 2007). The results of this case study will have relevance to those places that face comparable water stressed characteristics. Some of these cities share similar modern infrastructures of reservoirs to store water and treat water, piped drinking-water distribution networks, piped drainage, walls and barriers to protect against river or sea-water floods. Others do not. Regardless, these questions of water control and distribution are pertinent to them all in order to continue to achieve the wellbeing of citizens and the global ecological environment we rely on. Though the material legacies in the lower Lea river basin offer specific opportunities, water control and distribution for human settlements is a recurring matter of concern. Any solution is necessarily time limited for it simultaneously changes the water-cycle and cannot be replicated without considering the new material and social relations. The urban forms that create human settlements will need to constantly adapt to ensure that the water-cycle changes continue to sustain the environments that support human life.

**Conclusion**

This research uses a case study of the water stressed area of the lower Lea river basin in east London to explore ways in which the urban water-cycle could be reconfigured in the future. This is an area that is served by the typical water infrastructures of London, but is also strategically important water infrastructures of London. The research investigates the ways in which the urban water-cycle can be reconfigured through a research framework of actor-network theory co-evolution. The methods employed have combined qualitative and design research methods to investigate the human and nonhuman relations that create the co-evolving water-cycle that occurs in this catchment area. The original contributions of this research have varied relevance for different readers and range from the empirical data gathered, design propositions, design research methods, and the development of the actor-network theory co-evolutionary framework.

The survey of current daily water practices is of relevance to people and policy makers who want to understand contemporary water usage and how these patterns vary amongst the environmentally committed citizens. These water practices have become historical almost as soon as they are written because people are constantly changing their practices and making new material configurations to fit their aspirations and moral values.

The design syntheses are unique propositions generated by myself. While they are tied to this locale and these particular human and nonhuman interrelations, they provide a source of ideas for further urban design proposals in other places. These propositions are sketches and require much further work with many different actants to become a reality. As such, they have time limited validity as they will soon be overtaken by built projects and thus the network relations will change, giving rise to other new propositions.

The use of design as part of the research method is a contribution to extending design research. Design in this case has been used to probe existing and forming network relations of personal practice, materials, and people. This differs from the typical use of design would have sought to find a single material solution to a singular problem.

This use of design as a method of investigation was made possible due to the use of actor-network theory socio-technical co-evolution research framework. At the same time, the use of design as a method of research shifted the research frameworks from a historic and ethnographic observational case study approach to one that operationalizes these observations to investigate the possibilities of new network formations. This adds a new interpretation to these theories and stretches it beyond its current applications.

For urban design and planning this research brings a new application of a theory that was developed in Science and Technology Studies and has recently begun to be applied to the urban environment. Actor-network theory brings a way the social and material dimensions of urban design and planning can be brought to bear on each other equally, which paves a pathway for these professional disciplines to enfold ecological matters of concern as part of the structure of urban settlements. These ecological matters of concern bring essential resources to our lives, which can be traced and highlighted using actor-network theory. Actor-network theory co-evolution offers ways in which these relations could be altered to continue to favour human life in the future.

The next chapter reviews literature that explores the different ways water in the urban environment has been managed and interpreted. This literature comes from the disciplines of urban design, urban planning, engineering, geography, sociology, and science and technology studies. The chapter following gives an overview of the actor-network theory co-evolutionary theoretical framework that has been used in this research. Chapter 4 describes the relationship between the theoretical framework and the methods that were used to trace the network relations between humans and nonhumans in this research and how these were extended to follow co-evolutionary trajectories using a design method.

The following four chapters: 5, 6, 7 and 8, document the empirical findings of this research. Chapters 5 and 6 look at the existing assemblages of water-cycles in the lower Lea river basin in 2009 and how these could be imagined to be altered during times of extreme water scarcity and regular flooding. These assemblages could be divided into two major categories: water-cycles for others and water-cycles for self. Chapter 5 looks at water-cycles for others which were only created by water professionals. Chapter 6 gives an account of the personal, domestic influences of water-cycles for self which were created by everyone. These accounts of water-cycle for self were characterised by differences in water-cycle assemblages that depended on whether people took it as a matter of fact that they lived in a water scarce world or a water plenty world. The water scarce water-cycle assemblages show areas where water plenty water-cycle assemblages are unstable. These instabilities are areas where actor-network theory co-evolution pathways are developing.

Chapters 7 and 8 look at two different and strongly favoured actor-network theory co-evolution reconfigurations of the urban water-cycle in the lower Lea river basin in 2009-2010. Chapter 7 looks at reusing the freshwater resources such that not only is the water reused, but that the nutrient and energy inputs are also harvested for produce and products to improve human life. Chapter 8 looks at improving the quantity of water available for ecological purposes by reducing the total quantity of water abstracted through reconfiguring toilet flushing systems to dry sanitation with waste recovery for fertilizer and energy.

Chapter 9 is the final concluding chapter that draws together the answers to my research questions from the empirical findings.

## Chapter Two

# WATER AND URBANISM

The urban environment is a place of concentrated human habitation that is created through the collective relations between people and the material world. Its form is emergent from the resolution of multiple interactions between local geography, endemic ecology, material legacies, material possibilities, people's physiological needs, people's differing viewpoints, and people's conflicting future desires, to name but a few of the major influences. These influences can be in conflict with one another or completely alter their state, hence changing the types of influence exerted. Therefore urban form can never be a static artefact, but is a constantly changing material configuration that is always being transformed and negotiated. Water is one such material influence on urban form. It affects human physiology, endemic ecology, local geography and geology. Its influence has been studied from multiple disciplinary perspectives that have often had to expand beyond their core concerns in order to adequately describe and explain the water phenomena that are found in the urban environment because the effects of water are so numerous.

The control and distribution of the quantity, quality and location of water are influential to urban form because water is both a fundamental necessity and a threat to human life. Water management is necessary to ensure human health therefore it has had and will continue to have an effect on the places of human habitation. The fair distribution of water resources to people increases social cohesion and promotes productivity (Ostrom 1990; Trawick 2006; UNDP 2006). Furthermore water management can also increase irrigation capacity for agriculture, allocate water for industrial production, create water based transportation systems, move waste, and create pleasurable landscapes, all of which enables an expanded quality of life to the citizens living in this area (Ackroyd 2008; Halliday 2004; UNDP 2006).

Post WWII, the impact of water on urban form has largely been ignored within the discourse of urban designers and planners, two disciplines that are primarily concerned with altering existing and imagining new urban forms (LeGates and Stout 1998; Ockman 1993; Smithson 1967). Urban planners and designers in earlier eras had included drinking, waste and energy generating water in their concerns, but this interest waned with the widespread adoption of centralised piped drinking and wastewater infrastructure solutions that were designed, implemented, maintained and expanded by engineers (Melosi 2000).

Over the past two hundred years or so, the water management of modern urban environments has been increasingly dominated by engineers who have created many technologies to ensure water is where it is needed when it is needed (Goubert 1986). These solutions have shaped an understanding and expectation of what a modern city is (Gandy 2003; Hard and Misa 2008; Kaika 2005; Swyngedouw 2004), but these solutions are not without their consequences, they have changed ecologies, social structures, and water consumption patterns. These effects have been studied by urban ecologists, urban geographers, and sociologists.

This chapter first looks at how urban designers and planners have considered water infrastructure and urban form from the early planning ideas through till today. This interest rises and then falls post WWII when piped systems become the standard solution. Today the idea of including water and wastewater infrastructures into the concerns of urban design is growing. The chapter then explores urban ecology and urban political ecology approaches that show how water infrastructures interact with the water-cycle, urban form and social structures. It also reviews how some of these insights from urban ecology have been translated into the current best practices of engineering for water management. Finally, engineering solutions sometimes have unexpected consequences, some of which can be solved by more engineering solutions, but at other times require insights from other perspectives. The last section of this chapter explores the socio-technical perspective developed by sociologists which offers an explanation for the continually rising water consumption in areas served by the engineering solution of piped water. This rise in consumption could not be explained or solved in engineering terms, nor could it be explained or solved in purely sociological terms. Instead it has required a socio-technical approach, which describes how technology and social practices engender change in one another. These different approaches to understand water in the urban environment build a picture of the different ways these relations can be conceptualised and how water and the urban environment are mutually shaped by each other and many other influences to give rise to particular urban forms.

**Urban Designed and Planned Water**

Urban design and urban planning were two disciplines that grew out of a desire to solve the ills of the 19th century industrialised city where many people were living in abject poverty in great densities with poor sanitation; little access to light, air and space; suffering alienation from other people and nature; and the distress of urban ugliness, moral depravity, and environmental degradation (LeGates and Stout 1998). Of course some practices now identified as urban design and planning existed prior to the nineteenth century (Chant 1999; LeGates and Stout 1998), but these were not identified as discrete professions until this era (Hall 2002; Schultz and McShane 1978).

Contemporary urban design and planning professionals come from a range of disciplinary backgrounds, typically: architecture, town and country planning, landscape architecture, and engineering. They often continue to practice these other disciplines concurrently with urban design and planning. Consequently different strands of urban design and planning literature reflect these different professional starting points. In the early nineteenth century when urban design and planning were emerging, the professional backgrounds are even more varied. The common thread is a mutual concern to debate and create material change of the urban environment in the future.

Urban design and planning in the nineteenth century included ideas such as the garden city by Ebenezer Howard (Hall 2002; Howard 1998) which dispersed the population into the countryside to solve the ills of an overcrowded London; and the city beautiful, with grand sweeping tree lined boulevards by Georges-Eugene Haussmann (Hall 2002; Gandy 1999; Tatom 2006) that opened up the medieval street configuration of the Paris city centre to more light and air, easier vehicular mobility and a clear passage for a centralised sewer system. These ideas began to establish urban design and planning as a profession.

Simultaneous to the development of these ideas, that solved light, space, air and a connection to nature, were those to solve the problem of overflowing wastewaters that came about because of the dense urban population with insufficient water permeable areas, the common practice of throwing wastewater into the street and inadequate cesspits (Allen 2008). It was thought that this foul smelling water created miasmas of disease, therefore ridding the urban area of this water would also eliminate the blight of disease (Halliday 1999; Molella and Bedi 2003). The solution of an underground network of sewers was proposed by the then emerging field of engineers to collect wastewater within the city and dispose of it far afield (Melosi 2000; Molella and Bedi 2003; Schultz and McShane 1978). This solution was an expansion of existing practices of using natural watercourses to rid waste (Ackroyd 2000; Halliday 1999; Melosi 2000; Teh 2009; Schofield 1987).

This was not the only solution (Allen 2008; Halliday 1999; Waring 1869), but it was the solution that both Paris and London implemented to great success.

While the miasmic theory of disease transmission was shown to be incorrect, the solution of removing foul waters was successful in lowering mortality from these diseases (Molella and Bedi 2003). Hence this was the solution emulated as the paradigm by other urban areas all around the world that wanted to achieve this success and become a similar "center of all that is best in art, literature, science and architecture…[in which] sewers took at least a leading part, for we only [need] to look at conditions existing prior to their construction to see that such a realization would have been impossible before their existence" (Schultz and McShane 1978, 389).

These underground sewer works were also combined with the other urban concerns of providing the city dwellers better access to light, air, space, and improved vehicular transportation to relieve congestion. The Haussmann boulevards are famed for solving many problems at once: light, air, and vehicular circulation above ground and waste circulation below (Gandy 1999). Similarly Joseph Bazalgette's intercepting sewer system to cleanse London of its wastewater was also associated with the public boulevards of the Embankment along the north banks of the Thames, which also provided space for the Metropolitan railway line (Halliday 1999). Thus, these piped networks of wastewater conveyance were developed as the state of the art technology by engineers, incorporating the ideas of urban improvement that concerned urban designers and planners.

In London piped networks for the distribution of drinking-water had many centuries of development from medieval times (Magnusson 2001), however their widespread use came into effect in the early 1800s, when there was a dramatic increase in water consumption due to industrial uses and the explosion of the urban population due to industrialisation (Graham-Leigh 2000; Melosi 2000). Prior to the widespread piped network of drinking-water, London was served by multiple systems of water supply. There were the rivers and streams, water conduits, water bearers, private wells, and public standpipes. The increase in water consumption caused a fall in the water levels of the shallow and deep aquifers below London (Buchan 1938). Simultaneously there was a drop in water quality from the wells due to the seepage of contaminants into the aquifers. At the same time technologies for cleaning surface-water to a regular drinking quality were developed. This meant that eventually the multiple systems of water supply were replaced by the single system of pressurized pipes and people came to see piped water as a purer, more consistent and convenient source of water (Flaxman and Jackson 2004; Graham-Leigh 2000; Metropolitan Water Board 1961). From the 1920s most new suburban developments were equipped with pressurized drinking-water, by the 1930s most middle class houses, and by the 1950s most working class houses (Hand, Shove, and Southerton 2005).

By WWII, underground piped drinking-water supply and wastewater drainage networks had become the accepted state of the art technology that was designed by engineers (Melosi 2000). At this point in time urban planning and design had also become established professions that controlled the types of acceptable extensions to cities or the configuration of whole new towns (LeGates and Stout 1998; Melosi 2000). For the urban designer or planner, the drinking-water and wastewater infrastructures were of little concern because they were buried or concealed. It was an infrastructure that seemed to have little impact to the material form of the city thus it had a decreasing amount of interest for urban design and urban planning discourse post WWII, where it was presumed that drinking-water and wastewater would be provided by these now established engineering means. The pressing concern was for the rapid construction of buildings to replace those destroyed by the war (Hall 2002).

The early works of urban planning and urban design pre WWII do show an interest in water infrastructures. The main text of Ebenezer Howard's Garden City proposal concentrates on describing how the garden city provides better living conditions and its economic viability, it only lightly touches drinking-water supply and wastewater collection. However water has an entire appendix devoted to proposals on how water can be supplied, where reservoirs can be located, how reservoirs can be used for storing energy, how motor energy can be derived from water, how electricity can be generated by water driven turbines, and how nutrients can be recovered from wastewater for agriculture located on the outskirts of the garden city (Howard 1998).

Howard's Garden City proposal of 1898 contains three types of water. Drinking-water is provided for by deep wells and distributed via underground pipes. Wastewater is also conveyed by underground pipes to agricultural lands located nearby. Local rain and surface water is collected in canals and reservoirs and are described as "perfectly adapted for watering streets and gardens, for flushing sewers and drains, as well as for fountains" this water "would continuously fall from the high level reservoirs, either into the storage reservoir or the low level reservoir, motive power thus obtained being used for driving machinery and for generating electric light" (Howard 1998, 2:157). This water infrastructure serves multiple purposes as "a system of drainage, of irrigation, of transport, of motive power, of recreation, and of ornament" within the one material form (Howard 1998, 2:159). Howard does presume that the drinking and wastewater distribution will be in underground pipes, and all the water systems will be designed and implemented by engineers.

Patrick Abercrombie, who also wrote the first Greater London Plan (1945), is clearly concerned about the impact of water on the urban environment when he writes of "A certain maximum height above sea level may be taken as a datum line above which building is not to be encouraged, being above the water-supply level...Equally, a low level may be determined upon below which flood land occurs and a drainage system becomes unduly expensive." (Abercrombie 1998, 8:193). He also describes a special situation in Eastry, East Kent, which is located on an unconfined chalk aquifer. In this case, planning needed to be used to establish the appropriate urban forms for the new coal mining towns that would preserve the quality of the drinking-water that is drawn from this aquifer. A dispersed urbanisation would compromise the quality of drinking-water drawn from this aquifer therefore planning regulations were written to limited expansion of existing townships with four or five new towns to be built, each serving three or four mines. In this way, the quality of drinking-water from the chalk aquifer could be preserved (Abercrombie 1998, 8:205–7).

In the intervening 45 years between the publication of Howard's and Abercrombie's planning visions, the tide of interest of urban designers and planners in how water and the urban environment could structure each other was receding. Where Howard saw water as being important enough to warrant a detailed appendix of how different water types would integrate with his planned garden city, Abercrombie sees water in the general terms of flood and drinking-water protection. None of Abercrombie's comments relate to wastewater systems nor how water could be used for energy or other purposes. The first metropolitan plan of London (Abercrombie 1945) assumes centralised drinking and wastewater infrastructures to be provided by engineers and expansion to accommodate future growth is ensured within the plan.

This trend of diminishing interest in water within urban design and planning is continued in the subsequent writings, which either do not mention water at all (Ockman 1993; Smithson 1967), or limit discussion to water bodies that beautify the landscape or offer a scenic outlook and settings for buildings (Lynch 1984; Shane 2005). This concern with the beauty of a water landscape is still pervasive in influencing London's changing urban form. As noted in the "Waterfront London" exhibition "Today residential developers can expect a 10 per cent uplift on housing that overlooks water…" (New London Architecture 2008, 2), this monetary return encourages the continuing growth of urban development on the water's edge.

In the historical compendium "Cities of the Future" (Hall 2002) water is not described as an influence on urban form at all. The book concentrates on the social impacts caused by different types of planning approaches. Even though there is an entire chapter devoted to the Howard's Garden City, his proposals for water distribution, water for energy and the nutrient recycling of wastewater for agriculture are not mentioned.

Professional texts such as the "Land Development Handbook" (The Dewberry Companies 2002) which aims to give people developing new land a comprehensive checklist of design considerations and obtaining the correct approvals and permits, only gives the option of how to provide a schematic layout of piped drinking water. However it does give options other than centralised wastewater collection and treatment in the form of distributed wastewater treatment using septic tanks, and subsurface or mounded absorption beds.

The "Charter of the New Urbanism", which was written and compiled by an influential group of urban designers based in the United States of America barely mentions water. Again, like Abercrombie, they write of providing spaces to protect drinking-water supply for large centralised water supply systems and do not question the urban form, environmental or ecological outcomes of these infrastructural systems (Leccese and McCormick 2000). In "The Art of City Making" there is even less mention of water. Landry (2006) has a section that exhorts people not to waste drinking-water, but does not consider that water infrastructures could have a function in structuring the urban form of the city. These texts show a very limited concern with water infrastructures, even though others have noted that "Water and sewer systems were the city's lifelines" (Schultz and McShane 1978, 395).

Christopher Alexander's book "A Pattern Language" follows in much the same vein. Within the 253 patterns there are three patterns for water "Access to Water", "Pools and Streams" and "Still Water". These patterns all concentrate on the psychological value of water in the environment to humans. "People have a fundamental yearning for great bodies of water" (Alexander, Ishikawa, and Silverstein 1977, 136) "…as marvellous as the high technology of water treatment and distribution has become, it does not satisfy the emotional need to make contact with the local reservoirs, and to understand the cycle of water: its limits and its mystery" (Alexander, Ishikawa, and Silverstein 1977, 324). Interestingly, Alexander does consider alternatives to a centralised sewerage system for wastewater. Pattern 178 is for a composting toilet system, which like Ebenezer Howard's Garden City aims to input human waste as compost for the land around the buildings. The system he described is a dual chamber composting toilet, where one chamber is used over the course of one year, and then allowed to rest for one year to give time for the organic matter to become compost.

Alexander's pattern is for a single household and is not as sophisticated as the collective use of wastes for agricultural purposes presented in Howard's Garden City idea (Howard 1998).

More recent compilations of contemporary urban design and planning trajectories such as "Cities X Lines" (Busquets and Correa 2006) and "Future Cities" (Read, Rosemann, and van Eldijk 2005) also have few mentions of water. "Future Cities" concentrates on social issues, rights to the city, and ways to experience the city. There is no mention of water as an influence on "Future Cities" except as a caption on the side of one figure in an article about Duoala, Cameroon, where it is noted that the first well in Bessengue Akwa "serves as a source of drinking water, a place for small-scale commercial activities and a meeting place". This water infrastructure had an influence on the life and urban form in this area, but it was not the focus of this chapter (Simone 2005). "Cities X Lines" shows that there is a growing interest in water in the urban environment. The majority of this interest lies in waterfront development, recreational water landscapes and surface-water management. However one chapter contains an historical analysis about Bangalore's urban form, which shows how bunds and reservoir tanks for storing water structured the urban form of historic Bangalore. Water is clearly rising as a topic in current urban design and planning discourse and this historical study shows the potential of water infrastructure to generate urban forms that respond to local water resources, in this case, monsoonal wet and dry seasons.

Within the trajectory of declining interest in water in the urban environment, there is one re-emergence of water as a topic of interest in the late 1960s with the publication of "Design with Nature" by Ian McHarg(1995). At this point in time, there was a rising awareness of potential resource limits (Donella Meadows et al. 1972) and ecological crisis (Carson 1964). In this context, McHarg calls for an urbanism that is sensitive to the ecological resources that underpin the city. Notably it uses a watershed approach to manage land use, which is what is considered best practice by water managers today (Calder 2005; Newson 2007). This book remains influential to landscape architects (Spirn 1984) and a touchstone for people who practice and write about landscape urbanism (Waldheim 2006).

McHarg believed that "the most reasonable approach would be to investigate the tolerance or intolerance of the various environments to human use in general and to some particular uses" (McHarg 1995, 13). He used maps to describe and then overlay different types of geology, ecologies and surfaces in order to determine which areas were robust for human habitation. He does not go into the details of how water cycles through the urban environment, despite the fact he was quite clear about the process in that "the output of one creature, are the imports or inputs to the others.

The oxygen wastes of the plant were input to the man, the carbon dioxide of the man input to the plant; the substance of the plant input to the man, the wastes of man and plant input to the decomposers, the wastes of these input to the plant: and the water went round and round and round." (McHarg 1995, 45)

Likewise in the last two decades, the rise of the environmental movement has generated two converse concerns about the environment and resource scarcity. One concern has been the impact of urban areas on the environment and the other is the impact of the changing environment on urban areas. This has created a new generation of urban design and planning discourse that includes the influence of water on urban form. The first concern gives rise to ideas that follow along the vein of McHarg's work. Whereupon urban designers and planners attempt minimise, maintain or imitate as best as possible the pre-urban water environment conditions when designing a development. This leads to maximising infiltration of water into the ground and ensuring the quality of water discharges from sites (Dreiseitl and Grau 2005; Grau 2009; Moutaud 2009).

The second concern of the impact of the changing environment on urban areas looks at how the projected outcomes of global warming might affect urban areas. It is projected that there will be more extreme weather conditions on earth in the future as well as a rise in sea level due to global warming (IPCC 2007b). This has generated concerns about water resource scarcity, flooding from extreme storm events, flooding from sea level rise, and more catastrophic flooding from a combination of sea level rise, a high tide and an extreme storm event. The vast majority of projects are concerned with how to adapt urban areas to floods. These projects include planning areas to be flooded, including the demolition of existing urban form or building new barriers against the rising waters (de Meulder and Shannon 2009; Drake and Kim 2009; Nordenson, Seavitt, and Yarinsky 2010; Peel 2009; Reise 2009; Sijmons 2009).

The concern of resource scarcity has also led to investigations by urban designers to find precedents in how traditional communities have managed water resources. Hester's "Ecological Democracy" (2006) describes how the Orchard Island community had a settlement pattern that fitted local water resources. Each settlement of the community was developed within a single watershed. Each settlement limited their population size to suit the catchment area and further watersheds were developed when the population increased beyond the capacity of the existing developed watershed. Register's "Ecocities" (2002) describes the nomadic Kogi's management of water by shifting rocks to divert and dam water for agriculture. However, neither of these authors shows how these water management strategies could be applied to modern urban settings where people's interactions with water are mostly confined to centralised distribution and collection via underground pipes. These examples serve more as romantic anecdotes of how past civilisations seem to have lived within ecological limits.

Spurred by the desire to achieve sustainable development, there have been several conferences in the last 5 years to reconsider the efficacy of existing water infrastructure paradigms and share ideas about future directions of water management and design in urban developments. These conferences involved water professionals in engineering, water management, landscape architecture, planning, and urban design. Therefore these conferences were a mix of professional, commercial and academic interests and have been hosted by both professional bodies and academic institutions.

Hosted by professional bodies, was a Wingspread Workshop in July 2006, which then set the agenda for a conference series titled "Cities of the Future", the first of which was held in March 2010, with a further two conferences in May 2011 and September 2011. These "Cities of the Future" conferences concentrate heavily on cities in the developed world and on engineering technologies and concerns to create sustainable water systems (Novotny and Brown 2007). In September 2008 the Katholieke Universiteit Leuven hosted a similarly interdisciplinary conference titled "Water and Urban Development Paradigms" (Feyen, Shannon, and Neville 2009), which brought an expanded focus on urban design and the challenges of water in urban environments in developing cities. These conferences herald a renewed interest in how all types of water: surface, river, estuarine, sea, flood, drinking and waste, affect the form of the urban environment and vice versa, which is also reflected by Shane in his overview of "Urban Design Since 1945" (Shane 2011).

The renewed interest of water and the urban environment can also be seen in a comparison between the "Greater London Plan" of 1944 and the draft replacement of "The London Plan" of 2009. The 2009 plan has a vastly expanded interest in how water interacts with the urban environment in comparison to the 1944 plan. The 1944 plan, which was the first comprehensive plan for the London metropolitan region, only mentions the planning of water in the context of expanding and improving the piped infrastructures of drinking and wastewater, while the 2009 plan has an interest in a plethora of different types of water for different effects in the urban environment. The 2009 plan includes flood adaptations for climate change; reduction of stormwater flow through green roofs and sustainable urban drainage; improving the quality of water in rivers; realising the potential of cultural, economic, and environmental value added to local areas by open water bodies; the potential of passenger and freight waterborne transportation to reduce greenhouse gas emissions in comparison to land based transportation; and creating new developments within the existing drinking-water capacity, rather than expanding the capacity of the water infrastructure, so called water neutrality.

Even though the 2009 planning document demonstrates an enlarged interest in how water and the urban environment interact it performs more as a wish list of discrete water considerations. Unlike the recent water conferences, it still presumes the efficacy of the centralised piped drinking and wastewater infrastructures. It does not identify that these infrastructures are interconnected to the water concerns that have been listed as isolated issues. In fact it describes three recent expansions to these centralised piped networks: a desalination plant to increase drinking-water supply; the Thames Tideway Tunnels to increase wastewater storage capacity and decrease the overflow of raw sewage into the river system; and an associated extension to the Beckton wastewater treatment plant to treat the additional wastewater collected in the Thames Tideway Tunnels (GLA 2009). These works reinforce the dominance of the centralised piped system in London.

Over the course of the last one and a half centuries or so, since urban design and planning have become defined professions producing projects, books, articles, documents and policies concerning future urban formations, water has had a changing degree of articulation, from Howard's detailed appendix, to a side mention in a caption in "Future Cities". This changing degree of concern of water in the urban environment is a reflection of the complexity of interests that create the urban environment. It is impossible to be comprehensive of all the influences and therefore the concerns that are expressed are only those that seem most urgent and pressing. Abercrombie's example of using planning to protect drinking-water supplies; McHarg's ecological watershed development method; and the recent increase of conferences reconsidering centralised piped water infrastructures demonstrate that urban designers and planners raise an interest in water only when there could be a threat to drinking-water supply or a crisis arising from flood inundation. The lull in the engagement of water was reflective of a consensus by urban designers and planners that the essential concepts of the nineteenth century engineering solutions to control and distribute water were adequate.

Now that climate change, environmental degradation, and inadequate supplies for growing populations and rising water consumption have shown the limits of this system, there is once more a renewed engagement with water and the urban environment by urban designers and planners. However, the control and distribution of drinking, waste, and energy generating water is still mostly seen as the domain of the engineer. Urban design and planning's engagement with water is limited to allowing more space for surface and flood waters when imagining urban forms for the future, and not with using it as a structuring element of urban areas by an essential resource, as it was in the historic urban fabric of Bangalore or Howard's conceptual Garden City.

**Urban Ecological Water**

Even though these centralised piped drinking and wastewater infrastructure solutions have not been thought of as structuring urban areas by urban designers, planners, or engineers, it does not mean that they do not have this effect. What it does mean is that none of these effects have been designed, thus are unintended consequences of this form of infrastructure. These relationships between this infrastructure and urban form have not gone unnoticed by other disciplines. Urban ecology and urban political ecology are two fields that have emerged from the disciplines of ecology and human geography respectively, which have identified ways in which water has influenced urban form.

The convergence of term 'urban ecology' from ecology and human geography demonstrate how the core disciplinary concerns of each needed to be expanded in order to explain how water and urban form influenced each other. For the ecologists this has meant looking beyond nonhumans, such as plants, animals, nutrients and chemicals to include humans and their values, beliefs, organisations and institutions as factors that influence the ecology of urban areas (Alberti 2008; Botkin and Beveridge 1997; J. Morgan Grove and Burch 1997; Steward T. A. Pickett et al. 1997; Marzluff et al. 2008). For the human geographers this has meant including the material properties of nonhumans, such as water, pipes, plants and trees in producing urban social values, beliefs, organisations and institutions in particular places (Gandy 2005a; Gissen 2006; Graham and Marvin 2001; Heynen, Kaika, and Swyngedouw 2006; Kaika 2005; Swyngedouw and Heynen 2003).

While it could be expected that despite these different starting points, these two forms of urban ecology would begin to merge not only in name but also in concepts. For the majority of papers, this has not occurred. This is because urban ecologists from ecology have used scientific and experimental methods to frame and test hypotheses of the processes that they have observed. While urban political ecologists from human geography have used social and political theories with historic methods to frame and make reasoned arguments to answer the processes that they have observed. The ecological framing favours the observation of nonhumans while the human geography framing favours the observation of the humans hence there is little research that finds a way to bridge this divide. Nevertheless they both have insights about the effects of water on urban areas and vice versa.

One of the main concerns of both urban ecology and urban political ecology is the flow of water in an urban area. Urban ecology uses the concept of the water-cycle, whereupon the overall amount of water on earth remains more or less constant, but changes quantity, quality and location in a process driven by gravity and the sun which shifts the location of water and transforms it from liquid to gas to solid in a continual process (Alberti 2008; Vitousek et al. 2008). Urban political ecology looks at the process in which humans harness water for urban areas, this includes setting up new or altering old institutions of politics, finance, governance, and water practices, and changing conceptualisations of the relation between society and nature expressed by science, arts, technologies and practices (Heynen, Kaika, and Swyngedouw 2006).

From the ecological standpoint, the water-cycle in urban areas are very different from those in forested, grassland, or wetland areas, with a much higher water runoff rate and much lower shallow and deep infiltration of water, and lower evapotranspiration rates. They have identified that the cause of this change is the amount of impervious surface ground cover in urban areas. A 10-20% increase in impermeable surface cover in comparison to forested areas have been shown to cause channel enlargements with unstable banks, a decrease in fish, invertebrate, and insect diversity (Paul and Meyer 2008). The changes related to urbanised areas are the faster speed of water entering the river after a rain event, the more extreme temperature variation between the summer and winter months of water flowing in the river, the higher nutrient content of the water, and an altered chemical content that includes pesticides, metals, hydrocarbons, and suspended solids (Hengeveld, Vocht, and Bencko 1982; Paul and Meyer 2008). The human characteristic that Paul and Meyer attribute to these water changes is commerce which historically located "urban centres around rivers, which were the lifeblood of commerce. These commercial interests ignored and degraded the ecological services rivers provide, a phenomenon continuing today as urban sprawl accelerates." (Paul and Meyer 2008, 224).

Using the idea of commerce as the formation of human and water resource relations is a very simplified and cursory inclusion of the social within the natural. A much better example was the research conducted by Robbins and Sharp (Robbins and Sharp 2008a; Robbins and Sharp 2008b) looking at the effect on water through the use of chemicals on lawns in order to produce the perfect turf. This perfect turf was looked at as a moral signifier and participation in a neighbourly community; a capitalist economic need of the agrochemical industry to expand their market beyond agriculture as well as homeowners wanting to increase their property value; and how this market was produced by commercial interests who used advertisements in images and text to promote the use of the lawn as part of producing a happy, healthy, traditional family. It also showed how the increase in the use of agrochemicals to kill weeds that produced a perfect lawn also produced a predominantly turf ecology and decreased the quality of water through the use of specific herbicides and insecticides that inadvertently also killed birds, fish and insects.

These particular urban ecologists used a political economic framework to understand these human influences on the water and nutrient cycles within the urban ecosystem they were studying, but other frameworks have been developed by urban ecologists. One such is the human ecosystem framework, which characterises human impacts into several categories of interacting institutions, cycles, orders, cultures, and socio-economic systems (J. Morgan Grove and Burch 1997; Steward T. A. Pickett et al. 1997; S. T. A. Pickett et al. 2001). These appear to be fairly arbitrary categories under which are described some examples of what might belong here. For example 'Social Cycles' includes physiological, individual, environmental, organisational, institutional, or 'Cultural Resources' that includes organisations, beliefs, myth (Steward T. A. Pickett et al. 1997) (figure 2.1). The categories are both confused and confusing with multiple allocations where categories go from being headings to subcategories under other headings. This confusion is reflective of an erroneous application of an ecological framework of nested scales to social systems that do not necessarily fit this framework. The idea of nested scales is where small localised ecosystem patches, fit into larger regional systems, which fit into even larger areas, which then fit into the global system. The multiple allocations of social categories in different nested scale locations shows that this concept that predefines categories as global, regional, and local might not be a sufficient or useful way of integrating the human with the nonhuman.

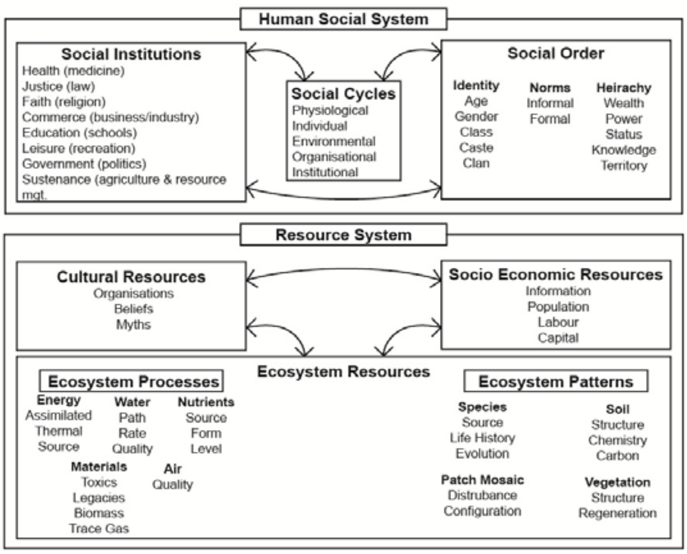



**Figure 2.1**
**Human Ecosystem Framework**
After Pickett etal 1997

The findings of water degradation from human water use by urban ecologists have also been translated into a change in practice of water management on a watershed scale. This is mainly known as Best Management Practices (BMP) (US EPA 1999) and Integrated Water Management (IWM)/Integrated Water Resource Management (IWRM) (Newson 2007), but can also be known as Integrated Land and Water Management (Calder 2005) or Catchment Management (Thomson 2003). These management frameworks are typically applied by government agencies worldwide for national water management, but are also used for transnational catchments (Howell and Allan 1994; Toope, Rainwater, and Allan 2003). The multiple names for these management strategies reflect the multiple locations in which similar ideas of water management were developed simultaneously from people facing similar problems due to the physical qualities of water flow.

This management of water takes into consideration that while people's water uses might be discrete, for example irrigation or drinking, the water itself flows in a cycle, so the water output of one user will affect the environment and the next water user. BMP, IWM, IWRM therefore advocates that water should be managed in an integrated way between users including the environment in order to negotiate, agree and produce adequate supplies of water quantity, quality and flow for each subsequent user. These management frameworks are primarily concerned with flowing water, thus promote the use of the river basin/catchment/watershed as the primary boundary within which water users need to be integrated. However this does not preclude the use of confined aquifer boundaries or other water boundaries to define a set of water users who affect each other. In practice, all these management frameworks have been difficult to achieve because of pre-existing governance frameworks and conflicting desires between users (Medema, McIntosh, and Jeffrey 2008).

The findings of damage to river systems by urban ecologists from the modification of pre-urban water-cycles have also been translated into a modification in the design of urban drainage by engineers, landscape architects, and urban designers. These professions have devised ways in which water flows can be retained on site and released at a similar rate and quality to the pre-urban water-cycle. Like BMP/IWM, these techniques of attenuating the net water flow from the site to the wider environment are known by several names around the world: Sustainable Urban Drainage Systems (SUDS), UK (Woods Ballard, Kellagher, Martin, Jefferies, Bray, and Shaffer 2007a; Woods Ballard, Kellagher, Martin, Jefferies, Bray, and Shaffer 2007b); Water Sensitive Urban Design (WSUD) Australia/USA (France 2002; R. Brown and Carke 2007; Waldock 1996; Wong 2007); and Low Impact Development (LID), USA (Prince George's County 1999). All these techniques recommend the use of devices that slow the speed of water and also often rid the water of contaminants such as heavy metals, organic pollutants, and sediments. These devices include rainwater harvesting, green roofs, detention and retention basins, ponds, rain gardens, gross pollutant traps, swales, trenches, permeable paving, and constructed wetlands. These devices can be installed in series, where the water flows from one device to another, which has the advantage of better water treatment, or in parallel to solve a specific water quality or quantity in one area, or if space is limited (France 2002; Kinkade-Levario 2007; Margolis and Robinson 2007; Woods Ballard, Kellagher, Martin, Jefferies, Bray, and Shaffer 2007a; Wong 2007). These devices start to form new ecologies within urban areas.

Urban ecologists have suggested that this could be taken one step further and have called for 'designed ecologies' whereupon ecologists and designers could work together to formulate new ecologies with the aim of achieving sustainable outcomes (Felson and Pickett 2005; Palmer 2010). One of step towards achieving this suggested by Felson and Pickett (2005) is to combine ecological experiments with urban design projects. This combination would give ecologists an expanded field of experimental sites that they would not ordinarily have access to in urban areas and allow urban designers to systematically investigate new forms of human dominated ecologies that are healthy for human systems.

Urban ecology has identified that the creation of urban areas by humans have influenced the quality, quantity and location of water because humans favour the creation of particular types of mono-cultural landscapes such as turf and paving. These mono-cultural landscapes have inadvertently damaged aquatic environments by poisoning native wildlife; and increasing the speed, nutrient content and temperature of water discharged into the aquatic environment. This has led to ecologists developing frameworks to include humans within ecosystems. These observed changes to the aquatic environment also led to the development of strategies to restore the water quality, quantity and location to pre-urban conditions by engineers, landscape architects, urban designers and planners.

**Urban Political Ecological Water**

Urban political ecologists from the discipline of human geography have been less concerned about the nonhuman ecologies that are created in urban areas and more concerned with the human ecologies of inequality that have been made by large centralised infrastructures (Graham and Marvin 2001; Heynen, Kaika, and Swyngedouw 2006). Many of the studies about water concentrate on drinking-water supply (Kaika 2005; Swyngedouw 2004), but some have also looked at the wastewater system (Gandy 1999; Gandy 2006a). These large centralised infrastructures include both institutions and the physical infrastructures that convey the materials required by the people who use the infrastructure.

Amongst these geographers the political framework used is Marxist and based on David Harvey's interpretation of how this manifests in the urban environment (Harvey 1989; Harvey 2006). Harvey was one of the first geographers to consistently apply Marx's theories of the way capitalism functions to show its spatial impacts on urbanisation. Harvey shows how capitalists require certain spatial configurations of places and material flows in order to maximise their profits. He then shows how capitalists engage politics, the state and other social and symbolic organisations in order to create these spatial changes, which the citizens of the city then have no choice but to occupy.

This uneven distribution of resources in the city was further developed into a concept of "Splintering Urbanism" by Graham and Marvin (2001). Splintering urbanism describes the unequal distribution of resources that can develop around large scale infrastructures and the relative access and inaccessibility of the resources conveyed by the infrastructure to different groups of people. When they describe large scale, it is generally a network that covers a large area or traversing a long distance that is owned and managed by relatively few people given its spatial size. The examples they give are infrastructures such as a telecommunications network, special economic areas, water transfers, rail and highway systems. Splintering urbanism is explained by political power and economic gain by the few people who manage the infrastructure. That is, the infrastructure is located and created to best serve the economic needs of those who have the power to build, locate, and maintain its physical form.

The splintered urbanism of access to large scale water infrastructures can be seen most starkly in cities of the global south where wealthy people are served by large scale centralised water infrastructures comprised of reservoirs, water treatment plants, pipes and sewer systems similar to those of modernised cities. Meanwhile the poor people have no access to this infrastructure and use alternate systems of drinking-water sources such as tankard deliveries or self-collection from wells, ponds and rivers. The urban poor also have little or no access to sanitation systems (Gandy 2008; Gandy 2005b; Graham and Marvin 2001; Swyngedouw 2004; Swyngedouw and Heynen 2003). This splintered urbanism is not much different to the early days of the development of centralised drinking and wastewater infrastructure in modernising cities of the early nineteenth century (Dinckal 2008; Flaxman and Jackson 2004; Gandy 1999; Gandy 2003; Graham-Leigh 2000; Melosi 2000), except that there seems to be little effective effort to provide access to this mode of infrastructure service to poor people. In comparison, the urban areas of western Europe, north America and

Oceania now have close to 100% access of all properties to centralised drinking-water supply and wastewater sewers regardless of the level of wealth of the occupants (World Health Organization 2000).

A multitude of reasons can be given for the lack of universal service in the global south, the poor could be characterised as "traditional" with "indigenous social organisation" (Gandy 2006b) which was resistant to the "modern" and colonial social organisation. Or that the provision of universal service will be detrimental to the profit makers of the existing system, such as the water tanker consortiums (Gandy 2008; Swyngedouw 2004). Or that private capital investment will not supply poor areas because of loss of profit due to the long recovery time of the initial costs of supply (Gandy 2004; Swyngedouw and Kaika 2003). Or that the population is served by weak governments and public institutions that cannot organise the resources required to undertake the construction, maintenance and running of such an infrastructure (Gandy 2005b; Swyngedouw 2004).

More recently Hodson and Marvin (2010) have also applied a similar political economic analysis to the recent spread of urban design and planning projects for eco-towns-blocks-islands-regions. They argue that these are enclaves of privilege that are another form of splintered urbanism. These eco-towns-blocks-islands-regions are formulated in a conjunction between governments, new financial mechanisms and capital flow all hoping to be protected from the potential capital loss due to climate change. Many of these schemes include rainwater harvesting, water reuse, and low water consuming fittings. Some aim to be self-sufficient, though most are still reliant on extensions to centralised drinking and wastewater infrastructure. None of these eco-towns-blocks-islands-regions have suggested new forms of sanitation infrastructure technology.

However power to affect the form of the city and the water-cycle are not just manifested in these large scale infrastructures. Other human geographers Gandy (1999) and Kaika (2005) have also looked at how daily practices of water use shift and consequently also change these large scale infrastructures. Most notably have been the shifts in practices of personal hygiene. In medieval times bathing was a communal activity; by the seventeenth and eighteenth centuries there was very little bathing because of the common the belief that soaking in water was harmful to human health, while a layer of dirt protected humans from ailments; in the nineteenth century bathing became more common because the rising bourgeoisie and middle class began to find offence at the smells of dirt and the cause of disease was discovered to be bacteria that was present in the unwashed (Gandy 2006a; Geels 2005). This increase in the prevalence in bathing in the nineteenth century developed alongside an increase in the ease of accessibility of water by more people with the advent of piped water supply. These two factors fuelled each other and drove the widespread adoption of piped water, an increase in water use, the invention of new spaces within houses for bathing in private and a drainage system to remove the water (Gandy 2006a; Geels 2005). The ready availability of water piped to and from the house also led to an alteration to communal water practices such as fetching water, bathing and laundering into a private practice (Kaika 2005; Shove 2004). These altered practices and infrastructures changed urban form by enlarging the realm of the private (new spaces for washing) and reducing the realm of the public (water fetching, laundering and bathing) (Gandy 2006a; Kaika 2005; Shove 2004).

The change in urban form, water practices and infrastructure was also accompanied by a change in the relationship between nature and the human (Gandy 2003; Kaika 2005; Swyngedouw 2004). This can be seen by the change in the value given to human waste prior and post the widespread adoption of waterborne sanitation systems. Prior to the widespread use of waterborne sanitation human waste was also known as night soil and was used as fertilizer for agriculture. The change in name encapsulates the change in value of this commodity. Night soil describes a cyclical relationship with nature, whereupon people ate, defecated and returned the metabolised nutrients back to the soil to produce more food. The breaking of this cycle by the waterborne sanitation system was disturbing to early engineers who felt that it was immoral to squander this resource (Halliday 1999; Gandy 1999). Early systems suggested that the wastewater could be directed to the agricultural fields outside the city rather than to the river, lake or ocean (Gandy 1999; Halliday 1999; Howard 1998). This was not a system that was widely adopted and it was soon found that the fertilizer content of the wastewater was too low to warrant the energy to harvest the resource. Today the faecal content of wastewater is as low as 1% (Speers 2007) and many people served by this form of infrastructure no longer see its value as a fertilizer (Chapter 8). This is not the case in the rest of the world who value this human waste as fertilizer (Carr, Nortcliff, and Potter 2010; Chang et al. 2002; World Health Organization 2006).

This break with the cycle of growth, harvest, consumption, decay and growth could be viewed as part of the shift towards the modern worldview as described by Latour (1993). Latour has defined the modern world as one in which people try to divide what they see as society/culture/subjectivity/human from what they see as nature /science/objectivity/nonhuman. Latour calls this act of division the cutting of the Gordian knot and an act of purification. In his view this is a false division that means that hybrids, or quasi-objects and quasi-subjects proliferate in a collective unconscious while the moderns focus only on those things that they have cut from this mess and have defined as being in one category or the other.

Urban political ecologists like urban ecologists and Latour agree that the modern view that divides humans and nonhumans is false. Water and humans mutually affect each other. Swngedouw (Swyngedouw 1999; Swyngedouw 2004) has suggested that this transformation of water and other materials from the natural to the social and back to the natural is the metabolism of the city. This is an organic metaphor that attempts to tie nature more intimately with the social. However, the concept of metabolism belongs to a discrete body that consumes resources and excretes waste therefore a metabolic metaphor does not encapsulate the idea of the urban environment as integral to and interacting with the systems of nature. In fact in some ways it reproduces the dichotomy where being in the urban area is to be in the social organism, while being outside the urban area is to be in nature. While the vocabulary of the metaphor brings nature into the urban dialogue, the metaphor also reinforces the divide between nature and society by creating a boundary around urban areas in which the metabolic process happens.

These different perspectives from urban ecology and urban political ecology show how water and water infrastructures influence different types of urban form. Centralised infrastructures can cause splintered urbanism where capitalism prevails and there is no counter balancing impetus for social equity. It can also cause the degradation and devaluing of water courses and aquatic ecologies. Ecologists and human geographers looking at the urban environment found they had to invent new ways to incorporate humans and nonhumans into their frameworks of research. These different frameworks have proved only partially successful because they are difficult to achieve due to implicit disciplinary assumptions. The human ecosystem framework predefined social and ecological categories of relationships, but became confusing because social categories did not fit neatly into nested sets of interactions comparable to ecosystems (Steward T. A. Pickett et al. 1997). The metabolism of urban areas used an organic metaphor that inadvertently reinforced the concept of the division between the society and nature. This has shown the tensions of trying to understand how humans and nonhumans relate in a single framework for understanding the world. Even though there is ontological agreement that the relations between humans and nonhumans are necessary to understanding the effects of water in urban environments, inevitably disciplinary starting points, methods of research, epistemological frameworks tend to concentrate the focus on either the human or the nonhumans.

**Waters Engineered**

Engineers have created many technologies to manage the quantity, quality and location of water all for the purpose of human health and convenience. Engineers have designed dams, reservoirs, aqueducts, and pipes to ensure supply and distribution of drinking quality water (Chen and Liew 2003); sewers collect and discharge used water (Butler and Davies 2004); water treatment works to produce different chemical and bacterial qualities in water (Droste 1997); dykes, embankments and barriers to keep land dry; weirs and sluices to change the depth of water; canals to hasten routes of water transportation; locks for water transport to traverse changes in heights of a terrain; dams to drive turbines for energy and save water for future use; and ditches and drains to create dry land from wetlands (Al Naib 1997). All of these technologies address a particular matter of concern for human habitation. They also have a multitude of different influences on urban form, but this is not necessarily the interest of the engineer whose focus is on creating efficient technologies that directly address a single matter of concern for managing water for a specific human need.

The focus of engineering is the development of technologies as the primary means of finding solutions to water management has been shown to have limits that are caused by the continued replication of the same technological solution. The multiplication of the technology creates an expanded territory that has a magnitude of effects that are cumulative on ecologies (Alberti 2008; Hengeveld, Vocht, and Bencko 1982; Johnson and Hill 2002; Marzluff et al. 2008), societies and other technologies (Brand 2005; Shove 2004; Shove et al. 2008). These effects could not have been anticipated by the original design.

The expansion of the piped drinking-water supply network is one such example of a replicated technology that incrementally changes the magnitude of effects on ecology, society and other technologies. The convenience of this technology has the immediate effect of increasing water consumption when compared with people that previously had to haul water to the place of consumption (Gandy 2003; Geels 2005; Ensink et al. 2002). People served by this technology have also incrementally increased consumption due to changing water practices, the addition of new water consuming technologies that rely on piped water supply and little personal awareness of the environmental consequences of water use and hence no sense of responsibility towards these effects (Butler and Memon 2006). The increasing water demand has caused a continual search for new water sources, until finally engineers began to question the efficacy of simply meeting the ever increasing water demand of the population and have sought to manage this demand and suggest alternative water sources for water use that does not require drinking-water standards.

The alternative water sources suggested have been grey-water reuse and rainwater. Grey-water is water that might contain soaps and sediments, but does not contain any urine or faecal matter. Grey-water and rainwater can be used to water gardens, flush toilets and cleaning. These additional water sources critiques the use of drinking quality water for all water use, which is the typical practice of most people served by piped drinking-water supply.

Water demand management breaks with traditional engineering because it incorporates strategies that attempt to influence the behaviour of people and not just improve technologies. Water demand management strategies have included education campaigns to encourage people to use less water by turning off taps when the water is not being used; providing adaptive technologies that restrict water flow such as low flow showerheads and tap aeration inserts; providing adaptive technologies that reduce the quantity of water used such as push taps and water displacement devices in toilet cisterns; providing new more efficient technologies that consume less water such as washing machines and dishwashers; and water meters so that people are only charged for the quantity of water they have used (Butler and Memon 2006; Van Vliet, Chappells, and Shove 2005).

These strategies have had mixed degrees of success. There are many reasons for this, sometimes the adaptive water saving technologies have been incompatible with the pre-existing technologies, for example the tap aeration insert may not fit to the spout of the tap; or people's habits are hard to change, for example leaving the tap running while brushing teeth. Water demand management requires that both the technology and the person using the technology work in concert to achieve a reduction in water consumption, after all even if a tap was flow restricted with an aeration device, it would not give the reduction in water consumption if it was left running, in comparison to a non-restricted tap that was turned off. People cannot reduce their water demand unless both social expectations and physical infrastructures are changed. This interrelation between technology, social practices and values is beyond the scope of engineering which concentrates on material technologies to solve problems. However sociologists have been directed to this line of enquiry through the impossibility of technology alone to create sustainable systems.

### Socio-technical Co-evolutionary Water

Socio-technical accounts of water describe the interactions between technologies and people in creating patterns and practices of water usage. Most of these accounts concentrate on drinking-water supply within the household and do not look at the effects of drainage systems, or outside the domestic sphere. These socio-technical accounts of water consumption show that people do not consume water in the same way that they might consume products. Water is consumed in order to achieve certain standards of comfort and cleanliness that is judged to be necessary to conduct their daily lives amongst other people (Shove 2004). These standards have changed over time as have technologies in a process of co-evolution (Geels 2005; Shove 2004; Shove et al. 2008). When a technology changes, new possibilities for different standards present themselves; when new standards develop, technologies change to achieve these standards; and so on in a continual loop that gradually shifts both social standards and technologies as intertwined strands so that it is impossible to disentangle one from the other as both are necessary to explain the production of a particular water consumption pattern. What we consider 'normal' water practices today are a result of constantly circulating effects that have co-evolved over long periods of time (Geels 2005; Shove 2004; Shove et al. 2008). This is the cause of ongoing frustration to water providers that face water shortages, but are seemingly unable to stimulate change in either the technologies or the social practices (Allon and Sofoulis 2006; Sofoulis 2005).

These co-evolution changes in society and technology can happen rapidly or slowly over time. Rapid co-evolution occurs when a completely new technology replaces an old technology. Piped water replacing a standpipe or a well is an example of rapid change. Historical studies of the Netherlands and New York City reveals an immediate rise in consumption (Geels 2005; Gandy 2003) which is replicated in contemporary installations of piped domestic water supply (Ensink et al. 2002). The piped water supply allows new behaviour and practices to achieve new social values and desires that have the immediate effect of increasing water consumption.

An example of slow co-evolution is the gradual 1% average increase in water consumption per annum over a time period of 30 years of people who have been continuously served by piped water (Butler and Memon 2006). This co-evolution comes about due to the addition of new technologies that are reliant on the piped water system, such as washing machines, dishwashers, ice makers, water fountains, showers, hoses and sprinklers. It also comes about due to changing perceptions of the ease of obtaining water. Piped water makes it possible to wash vegetables under a running tap, or take a slightly longer, more luxurious shower with a higher water pressure. These systems were developed by people to make life more convenient, clean and comfortable, making use of the opportunities of piped water supply and drainage (Shove 2004).

None of these technologies are immediately universally accepted. Shove (2004) documents the shifting changes of laundering practices that are at first resistant to the use of a machine to launder because of the belief that the only properly clean laundry were those washed by hand, boiled and wrung to the particular standards practiced by the launderer. These particular practices were then translated into the creation of machines that allowed a person laundering to set many combinations of temperature, soaking and washing duration, and wringing cycle. Today washing machines are trusted and wash cycles have been simplified to material type, colour, temperature and a long or quick wash, there are no longer any options to specify all the different steps within the process of laundering. This illustrates that slow co-evolution is in a constant state of change as humans and nonhumans affect one another.

The growing practice of showering and the decrease in bathing has changed in less than a generation in the UK (Hand, Shove, and Southerton 2005). This change has been studied in a similar way to the co-evolution of laundering practices. In this case the shower device has been available for about 1000 years since Greco-Roman times therefore the change has mostly occurred to other infrastructures that connect to the device and social values surrounding its use. The technological innovations that have helped drive the increase in showering practices are piped water supply and instantaneous hot water. The social values that have changed are the ideas that surround the body and its requirements to be clean in order to regenerate itself, create a respectable persona, and the site of personal re-invention through fitness, health, lifestyle and freshness that broadly fit within the consumer culture. Another social value that has altered is that of time. Speed and efficiency is what the contemporary person desires, and showering achieves this in a way bathing cannot.

The increase in showering is not dependent on any one of these elements, "current conventions seem to involve the *coalescence* of distinct sets of infrastructural provision, artefacts, discourses of cleanliness and spatial-temporal arrangements" (Hand, Southerton, and Shove 2003, 13), which are assembled by the practices of people showering. These relations are continuously being remade every time a person showers (Hand, Shove, and Southerton 2005). Each element presents obduracy to another element. For example, a person who would like to save water and energy to preserve the environment may be faced with breaking the social acceptability of body odours; challenging their own conceptions of dirt and hygiene; controlled by the volume of water consumption set by the showering device; and bounded by the level of energy consumption set by the water heater. The limits of change presented by infrastructures and technologies means that certain levels of consumption are 'baked in' (Sofoulis 2005) regardless of changes that might be desired by the person performing the water consuming practice. This is also an obduracy of the values of the people who first designed and implemented these material configurations.

At the same time the continual remaking of the showering practices means that people can also change the assembly of the elements. For example if a person wants to save water they could share a shower with another person saving on the volume of water used per person, a new water saving shower head could be bought or invented and inserted, or a new form of body cleaning could replace showering altogether. The driver for this change is the person desiring to save water perhaps because they value the health of the environment, but practices could change for other reasons, say a disruption to water supply or drainage, or a malfunctioning water heater or shower rose. If these disruptions were continual, showering practices would co-evolve to accommodate the altered behaviour of that element. Hand, Shove and Southerton suggest that "there are more points of leverage and more opportunities for intervention than is generally supposed", however "establishing and institutionalising the capacity to spot such opportunities and take advantage of them...is a particularly significant challenge" (2005, 6.9). Furthermore Shove has proposed that these openings present an opportunity to develop designs based on co-evolving practices, which is an area designers have yet to explore (Shove et al. 2008, 134).

These examples of co-evolution concentrate only on the interactions between the social and technical. They do not include other biota or abiota even though the aim of the investigation is to reduce, prevent or remediate environmental damage (Hand, Shove, and Southerton 2005; Shove 2004; Shove et al. 2008; Southerton, Chappells, and Van Vliet 2004; Van Vliet 2003). Other accounts of co-evolutionary change have identified that these same relations occur between the social and the environment (Gual and Norgaard 2008). This can be inadvertent due to humans causing a change in the environment that then favours certain species or variants within the species and viruses developing resistance to the systematic application of the same drugs to eradicate disease, or deliberate in the case of genetic manipulations due to breeding or genetic engineering.

Implicit to these studies is the idea of scale. In socio-technical co-evolution a group of people need to share similar assemblages in order to make practices 'normal'. The more people that share the same practices which have grown incrementally over time, the more likely it is to have an unplanned and potentially detrimental environmental impact. For example, high water consuming practices are only problematic when many people practice them in a place that does not have the quantity of water to serve this level of consumption, or a place that does not have adequate drainage to remove the used water. If only a few people had high water consuming practices, their impact on the environment would be minimal.

Van Vliet identifies four dimensions in which scale "can be distinguished: technical scale, scale of management, reach of a system, and whether technologies can be applied on a stand-alone or a grid-connection basis (Van Vliet 2004, 71). Scale can simply be the size of the device, a rainwater tank is a smaller scale than a water reservoir. It can be the size of the infrastructural network, centralized drinking water distribution is larger in scale than a neighbourhood rainwater distribution system. It can be the size of the managerial system involved in running the infrastructure, a multinational running several different water supply systems in many countries and cities is larger in scale than a local water supplier. It can be the infrastructural dependency of a technology, a rainwater butt that is connected to a proximate water capturing surface is small scale, but a washing machine connected to a centralised piped water source is large scale. These four dimensions focus only on the social and the technical, which are the limits of the socio-technical framework. However, these shifting relations between large and small holds true for socio-environmental co-evolution where genes and individuals, the small scale, and the biophysical environment, the large scale, mutually effect each other (Gual and Norgaard 2008). Furthermore, as Van Vliet points out, scale is a complex issue not just because of its relativeness, but also because small scale devices can require large scale management systems or infrastructures in order to operate or vice versa. Therefore scale shifts depending on the relation to what is included in the system.

This renders preconceptions of a particular scale of effects for technologies or social groups irrelevant. It would seem that there are four important aspects that define scale to relations between actants. One is its magnitude, how many times similar relations are enacted or assembled. The second is territory, how far it is distributed over space. The third is effect, to how many things is the actant related to and therefore effects a change in relation to it. The fourth aspect of scale is temporality (Geels 2005), how long the same relations persist over time and therefore the ongoing effect of those particular relations. Using these four aspects something large scale could be repeated many times over, or distributed over a large space, or effects many other actants, or persists for a very long time. Something small scale would be unique, or distributed in a local area, or not affect many other actants, or be of short duration. Large and small becomes relative to the other actants included within the network, and how far in history these relations are studied. It is not possible to define scales of effects without also knowing the specific relations to other actants.

The socio-technical co-evolutionary perspective gives valuable insights into how water technologies and practices have effected change in each other over long periods of time. Furthermore it indicates where design could contribute valuable knowledge in finding ways to consciously respond to and formulate new configurations of practice, material relations, infrastructures and values. Its limitations are its preconceived restrictions of examining only society and technology which renders the co-evolution with the environment invisible, even though environmental concerns are the impetus for examining socio-technical systems.

**Conclusion**

Water in the urban environment is a growing concern of urban designers and planners, however this concern has so far been restricted to the surface, flood and cultural aspects of water. There has been little discourse in how water structures urban environments because in modern cities these infrastructures are underground and at first glance seem to have little effect on urban form. However the urban ecological and urban political ecological studies have shown that this is not the case. These underground piped water infrastructures do have an effect on urban form, whether it be the paving over and subsequent degradation of water reliant environments, the unequal distribution of water resources creating a splintered urbanism, or the change in water use from a shared public life with associated public spaces to a private life and the expanded of spaces in the home. These were not effects that were intended by the engineers that have designed and maintained these water infrastructures since its successful inception in the nineteenth century.

Another unintended consequence has been the continuing rise in water consumption which has been caused in part by the magnitude of people who assemble their water practices with similar material configurations that are reliant on these centralised water infrastructures. This has caused socio-technical co-evolutionary effects where to date there has been ongoing change between values and technologies that has resulted in greater water consuming practices as people achieve greater comfort, cleanliness and convenience. Engineers have tried to manage this water demand by adapting existing fittings and education campaigns to exhort people to consume less water. These have had limited success. Socio-technical co-evolutionary studies offer an explanation of the limited success based upon the obduracy of the different elements that are related in creating different types of water consuming practices, these elements include habits, values, ideas, infrastructure types and technologies. The socio-technical co-evolutionary perspective of water practices has also identified that design has a role to play in formulating new material configurations based on the changing water practices that can enable the co-evolution of sustainable practices.

## Chapter Three

# ACTANTS AND CO-EVOLVING RELATIONS

It is evident from the research, theorisation and design knowledge about water in the urban environment that both water and the urban environment are formed by relations between the social and the natural, therefore it was necessary to use a theoretical framework that could bring both these elements to bear with equal importance. Actor-network theory (ANT) is a framework that assumes this symmetry of influence between the social (humans) and the natural (nonhumans) in all human experiences and knowledge of the world. This theoretical perspective opened this research to an undefined field of types of entities, such as water, people, technologies and biota that create the urban water-cycle.

This research also takes inspiration from the socio-technical research that observed a co-evolution of network relations between social practices and the technologies that were used to enable water practices. This adds to the ANT framework by noting that actants are predefined by their existing relations, these relations form a trajectory that defines new relations and that these are always contingent and change over time.

The use of actor-network theory accounts for more actants than socio-technical co-evolution because it does not presuppose that there are only technologies and people to be studied and allows the relational network to encompass any nonhuman, including those of the natural world. Socio-technical co-evolution complements ANT by extending the timeframe that relational networks are observed.

**Actor-Network Theory**

ANT has an ontological stance that assumes that there is symmetry between human and nonhuman influences that make all things in the world. Epistemologically this means that ANT focuses on understanding the relations and changing relations that occur between actants that form networks of knowledge, practices and things. However, this is a complicated entanglement because actants are both made of network relations and make network relations. The actants that exist within any research depend on its relation with the researcher, who themselves is a human actant whose relationship forms the actant(s) in question. This makes all things unique and unstable.

Due to the unique aspects of network relations, actor-network theorists tend to analyse case studies of actants at work within a short timeframe (Callon 1986; Farias and Bender 2010; Latour 1987; Law 2004a; Mol and Law 1994) within which a controversy occurs and a new relational outcome is stabilised. Initially, it was used to be reflective about the making of scientific knowledge in books by Latour such as "The Pastuerisation of France" (1988) and "Science in Action" (1987). Lately ANT has been applied to many other arenas such as economics (Callon 1998), law (Latour 2010), architecture (Yaneva 2009a; Yaneva 2009b), and is just beginning to be applied to the arena of urban studies, design and planning (Doak and Karadimitriou 2007; Hommels 2008).

Three main proponents, Bruno Latour, John Law, and Michel Callon have developed actor-network theory over the last thirty years. The framework had its beginnings in the field of Science and Technology Studies (STS) and is heavily influenced by anthropological methods. ANT describes the world in terms of material relationships between both humans and nonhumans. Things in the world are made up of material relations that require continued enactment to exist for people. This leads to a view of the world that is endlessly changing and translated, made of humans and nonhumans (Latour 2005; Law 2004a). This is one of the most challenging aspects to ANT compared to other frameworks in philosophy, social sciences or the natural sciences which generally concentrate on either the human or the nonhuman. ANT insists on the inclusion of nonhumans in the social arena and humans in the natural arena, thereby bypassing any essential divide between nature and culture (Latour 1999a).

It is important to ANT to bypass the divide between nature and culture because this divide is seen as the fallacy of purification made by modernism. The moderns, as argued by Latour (1993), are the people who believe that the natural should be understood excluding the social, and the social by excluding the natural. This blinds the moderns to the hybridity of the phenomena that they attempt to grasp because they look only for the human or nonhuman within phenomena that are comprised of both. The social is never enacted without material objects and what we know of nature is never without translation by particular human beings with particular interests. Whereupon Latour draws his conclusion that modern society 'has never been modern' rather, modern society simply operates with ontologies and epistemologies that divide studies of nature and culture into two types of knowledge that are incommensurate with the world. This means that in the modern world social/cultural/human elements of the world are considered separately from physical/natural/nonhuman aspects. Unlike the pre-modern world, these two entities are believed to not to have an effect on one another and thus must be constantly (but secretly) joined together by hybrid entities to be operational in the world we live (Latour 1993).

From this, comes the argument that if there is no real thing as modern because there can be no division between culture and nature without the mediating work of hybrid entities comprised of both human and nonhuman actants, the world must therefore be nonmodern (Latour 1993).

**Actor-Network Theory Vocabulary**

Actor-network theory not only offers a unique viewpoint on what there is to know in the world (matters of concern) and how we know it (the tracing of the configuration of effects between humans and nonhumans), it also offers a new vocabulary to describe these effects and their components. This vocabulary is also intended to moderate the humancentric vocabulary that is usually ascribed to effects or translations between things.

**Actant**

Latour (2005, 55) recommends using the word actant to describe both human and nonhuman actors. This intentionally dissolves the boundary that is created by the word "actor", which is automatically associated to humans by its common useage to describe a person who pretends to be someone or something other from what they are as part of a performance. This thesis has used this terminology.

Actants are defined in relation to each other by the actor-network of effects in which they are enrolled. In this thesis these actor-networks are also referred to as assemblages, which is a common sociological term for bounded groups of actants in relation to each other (Law 2004a).

**4 Stages of Translation: problematisation, interressement, enrolment, mobilisation**

Callon (1986) describes the four stages of human and nonhuman translation by which an actor-network of new material and social configurations are brought into the world. These translations are problematisation, interressement, enrolment, and mobilisation. New material and social configurations can also be seen as an effect of design, and thus these ANT translations have an application to the design process.

Problematisation is when an actant frames a matter of concern. Interressement is when this actant seeks to define the roles of other potential actants within a network through action. During this moment these other interested actants are also actively defining their roles in relation to one another. Callon (1986) describes enrolment as the successful result of interressement; it is the moment when the negotiation between the actants is stabilised within a network and representatives of the actants are accepted. The network is then mobilised into active support to answer the matter of concern. If these relations continue to be enacted, then stabilisation is achieved, which can then be considered as black boxes, matters of fact and matters of value.

**Black box**

Actants which are not the matter of concern being traced are considered 'black boxes' (Latour 1999b). This means they are taken as a stabilised network and thus not a part of the process of formation under consideration. Without black boxes, an ANT method of analysis would disintegrate into an infinite number of relationships.

Even though these black boxes are necessary, they are also impermanent. An ANT researcher may choose to probe the black box to reveal its contingent network. Black boxed actants may negotiate new roles or endeavour to frame a matter of concern; and previously active actants may choose not to mobilise their effects and thus become unenrolled.

For example, if one year there should be a drought, the rain-water that had always been enlisted into a centralised piped drinking-water network would no longer be present, there would be a shortage of water for humans subscribed to this network. The stable black box of centralised drinking-water supply would be opened to reveal the networks of relationships between rainfall, aquifers, rivers, reservoirs, engineers, pipes, taps, toilets, gardens and so on. New problematisations, interressements, enrolments, and mobilisations would need to be sought for this new matter of concern for the humans. This would result in the negotiation of new actants and the coalescence of new networks. In this example the new negotiation of actants may be a change of behaviour of the humans, a change in water source, or a change in water delivery method and so on. However, should all the actants remain enrolled, enacting their effects in the drinking-water network, then these networks are considered stable and are thus 'black boxed' (Sofoulis 2005).

Equally a researcher may unravel a 'black box' of assembled actants to reveal the effects such an actant is contingent upon. The tracing of the urban water-cycle in the lower Lea river basin is one such instance.

**Boundary objects**

While 'black boxes' help to constrain the work of the researcher, an actant that constrains the work of other actants is a boundary object. A boundary object is an actant which is formulated by the work other actants to be flexible enough to serve as a container that allows the translation of knowledge between the different social worlds creating knowledge and constraining enough that it can be applied with specificity within each social world (Star and Griesemer 1989).

In the case of this research the river basin/watershed/catchment has been found to be such a boundary object because it allows a translation of water concerns between ecology, geography, water management, engineering, landscape architecture, planning, and urban design. Each discipline uses the river basin/watershed/catchment actant to generate different types of knowledge, but these knowledges can be translated between disciplines through the use of the common understanding of the river basin/watershed/catchment. These translations are important to each discipline because it embeds their knowledge within other fields thereby stabilizing its continued validity.

**Delegation**

While the boundary object helps stabilise the actor-network that creates new knowledge, delegation to new material configurations helps stabilise the actor-network that creates social practices (Latour 2000a; Latour 2000b). This delegation to a new material configuration is also a black box because it implies certain thinking and action that constrains humans to particular practices and makes these practices habitual and therefore not questioned.

**Ontological Politics**

'Black boxes', 'boundary objects' and 'delegations' are instances of the enactment of ontological politics. There is no knowledge that has not been created by humans and all knowledge is therefore value and power laden firstly by why humans want to know, then by how that knowledge is created, and how the knowledge is used (Law 2004a). All knowledge begins as matters of concern that are stabilised over time into matters of fact, matters of value, or delegations. Natural science produces 'black boxed' matters of fact; social science produces 'black boxed' matters of value; design produces 'black boxed' delegations. The use of matters of fact, matters of value and delegation are as political as matters of concern except that their presumptions are now unquestioned and therefore gain power by becoming an actant (a stabilised enactment of an actor-network) within other networks of effects.

The use of a 'boundary object' is an instance of ontological politics because it becomes the unquestioned basis upon which more knowledge is built. It stabilises the relations between multiple, not necessarily related actor-networks that use the boundary object as a black box to mobilise and stabilise relations between these different actor-network assemblages.

The idea of ontological politics leads to a dispersal of politics and power through all human and nonhuman translations and it is therefore difficult to pinpoint a locus within which power resides. Instead power is the result of many enactments that mobilise particular network outcomes.

**ANT Implications**

For actor-network theory the things in themselves can never be known because there is always a translation between the thing itself and human ways of knowing. The realities of the world are then always jointly composed of humans and nonhumans. In other words, ANT considers that ontology and epistemology cannot be divided. What there is to know in the world is tied to how we can verify what is in the world in an indivisible loop of circulating effects (Latour 1993).

Within this method of tracing effects that answer the questions of ontology and epistemology simultaneously there are no more matters of fact or matters of value in the world, everything we want to know and how we know it is now becomes a matter of concern (Latour 2005). The difference between matters of fact or value and matters of concern, is that matters of concern are always subject to debate. New actants can be enacted and new understandings developed. The reason why there are no matters of fact in ANT and only matters of concern is because it is impossible for humans to know anything without first wanting to know something. This initial question delimits the effects that are of interest to the human, thus all knowledge is made up of matters of concern, not matters of fact or value, and hence they can be overturned or altered at any time. Moreover the use of matters of concern as matters of fact or value enacts the ontology from which the initial question arose, giving this ontology a power that would be nonexistent without its enactment.

Latour points out that the modern is an enactment of a particular ontological stance, which has created both a science that is a "political discourse from which politics is to be excluded" and a society that is based on "scientific politics from which experimental science has to be excluded" (Latour 1993, 27) because of the accepted approach of purification that does not see the multitudinous connections between what is seen as nature and what is seen as social. This means that the social political world includes scientific discovery and evidence, but it is not acknowledged that the science itself is not a matter of fact, but a matter of concern, which was predicated on particular political viewpoints. This science of concern has enlisted appropriate actants to formulate the knowledge that was created, hence it is imbued with social values that has been ignored by the social political world including the scientists. The implication of this point of view is that power is dispersed through the ontologies and epistemologies that are accepted as creating knowledge, it is not concentrated in one particular person or group of people. Instead it is embedded in the enactment of matters of fact in the world.

The way ANT has bypassed the modern approach of purification has been to use anthropological ethnographic and historic approaches to carefully trace and describe the relations of effects between actants to reveal the entanglements between nature and culture. This is why ANT is a versatile framework that has been able to be successfully applied to a diverse range of case studies in different disciplines, despite its beginnings in Science and Technology Studies to answer specific matters of concern. It has been used to depict ways that describe the city of Paris (Latour and Hermant 2006); the differing world views in the medical diagnoses of anaemia (Mol and Law 1994); the development of domesticated scallops (Callon 1986); as well as the creation of museum collections (Star and Griesemer 1989). More recently it has been identified as a potentially useful framework to analyse the spatial disciplines of planning (Doak and Karadimitriou 2007; Hommels 2008) and architecture (Fallan 2008; Yaneva 2009a; Yaneva 2009b), which relate to the research questions of reconfiguring water-cycles in existing urban areas. Each case study has added another interpretation of ANT, and some have added additional tools such as the boundary objects described by Star and Griesemer (1989) or ontological politics coined Law and developed by Mol (1994).

This characteristic of concentrating on networks of relationships between actants, both human and nonhuman leads ANT to being about particularities. An ANT approach can never generate a universal law, or a global view. Latour (2005) in fact insists that there is no such thing as the global, only local effects at any point on the network, therefore there is no such thing as a 'context', political, economic, class, nature or otherwise because ANT locates these generalised 'context' effects within highly local translations between humans and nonhumans. That is politics, economies, class, nature and all other 'contexts' cannot occur without a network of local human and nonhuman exchanges that produce certain effects. Latour (2005) has called this a 'flat ontology' because ANT neither looks up to a macro-scale for explanations, nor down to a micro-scale, but rather looks across the network of material relationships to explain the phenomena it finds. ANT argues that the idea of a 'context' or a global point of view assumes a coherence and smoothness that belies the translation and negotiation of "small, sensuous, specific, heterogeneous, noncoherent"(Law 2004a, 13) networks that make up things in the world.

An example of this is the wing design of a Royal Air Force aircraft in the 1950's in which there was the use of an algebraic formula to determine gust response (Law and Mol 2001; Law 2004b). This formula that determines the acceptable figure for gust response is shown to be dependent upon pilots whose experimental flights reveal the limits of the human body to cope with gusts; the assumptions that make up the enemy against which the aircraft will be used against; the budget to produce the aircraft; the space where the aircraft will be housed; and the safety of the engine configuration. The formula is not a 'global context' that can be applied universally, even though it is often treated as such. The formula is a translation or abstraction of both a network of specific material relationships between specific actants such as the pilots, aircraft hangers, engines and military budgets, but it also performs as an actant within a network that will ultimately be materialised in the form of a wing design. This example shows how actants are themselves also networks.

Actor-network theory concentrates on using ethnographic or historical methods to follow actants to show how things are made both by humans and nonhumans, what types of translations have occurred and how. This is an important way to understand how different knowledge is made. It shows how the different ontologies and epistemologies embed structures of power when they are accepted as matters of fact.

**ANT and Co-evolution**

Actor-network theory has also been referred to in the context of understanding the changing technologies and practices of water and sanitation (Shove 2004; Geels 2005; Gandy 2006a). However these case studies mostly use a historical rather than the anthropological ethnographic approach of ANT inspired research. Due to this longer timeframe this research is able to trace not only how controversies are made and resolved, but also the ongoing controversies that surround the same actants, and thus how the actants co-evolve over time. The actants change both materially, and culturally stabilising the resolutions of new controversies. The insight that these historical case studies reveal is that there is no end to the cycle of unstable actants becoming stable and then becoming unstable again.

ANT does not use the term co-evolution to describe the changing effects between actants that are also changed by these effects. This is because the timeframe of most ANT research has been of a short duration and have examined the eventual stabilisation of one resolution to one matter of concern, rather than many resolutions to one matter of concern that were generated over a long period of time. This is because ANT was developed to investigate the making of knowledge and technologies rather than tracing the ongoing effects of knowledge and technologies (Latour 2005).

The insights of co-evolution of water infrastructures and society (chapter two) are complementary to ANT because they show how human and nonhuman relational networks change over time. It supports the ANT conception of these network relations as effects that need to be constantly enacted and therefore continuously being remade. In addition it identifies that in the remaking, things can shift and be translated differently, and more or different actants and networks relations can be added or subtracted, whereby co-evolutions occur.

Socio-technical co-evolution also concurs with ANT in that water infrastructures constrain people to behaving in certain ways; people were enlisted in a particular network of effects, regardless that their stated political and social values were in contradiction to the behaviour they were enlisted in by the nonhumans (Allon and Sofoulis 2006; Shove et al. 2008; Sofoulis 2005; Van Vliet, Chappells, and Shove 2005). The material world of water infrastructure and how it is organised was shown to embed and effect an enactment of particular values that may be in contradiction to the individual values. Latour (Latour 2000a; Latour 2000b) also found that the material items of everyday life, such as door closers, seatbelts and keys, with their specific material properties enact particular behaviours in relation to humans. These material items of everyday life, anticipate a certain behaviour and will only perform if that behaviour is enacted, thus he argues, social morals are stabilised by the material world in which humans perform and exist within.

While social morals have been shown to be stabilized by the material world, neither of these elements are immutable. They only continue to function in a similar way, so long as all the actants are mobilised. Should any actant disappear or behave differently, then the network necessarily modifies and new social behaviours are enacted and new material configurations are performed. This would give rise to rapid change within the system as was seen with the implementation of centralised drinking and wastewater infrastructure, and the changed understanding of the health benefits of cleanliness (Shove 2004; Geels 2005; Gandy 2006a). These two changes co-evolved simultaneously so that it is impossible to pinpoint which change inspired which.

While socio-technical co-evolution has referred to ANT, ANT has not used the idea of co-evolution to describe ongoing changes to network relations because this is not a matter of concern for most ANT research. However the matter of concern for this research is the reconfiguration of the water-cycle in the lower Lea river basin. Research using a socio-technical framework has shown how these water infrastructures and water practices have co-evolved over time. Therefore this research adds the concept of co-evolution to ANT to form a more coherent framework in which to project reconfigurations to the water-cycle. Thereby it extends ANT from a short time frame to one that can span longer durations and socio-technical co-evolution from its socio-technical constraints to one that involves limitless types of actants.

**ANT and Water**

Actor-network theory has not been used as a framework to understand urban water-cycles. However it has been used to understand different forms of water technologies. For example, a bush pump in Zimbabwe (de Laet and Mol 2000); the circa 2006 Paris drinking-water supply system (Latour and Hermant 2006); and the development of centralised drinking-water supply in Istanbul (Dinckal 2008). It has also been used to describe how water quality and biota are used to generate knowledge (Gramaglia 2005) and how the Rhine river and urban forms have been mutually shaped (Disco 2008; Kropp 2005). The two most interesting examples for this research are the Zimbabwe Bush Pump Type B and the Rhine river. The Zimbabwe Bush Pump for the successful dissemination of a new water technology, and the Rhine river as an example where a geographic feature co-evolves with urban form through the mutual shaping of the river, settlement patterns, ships, and governance structures.

The Zimbabwe Bush Pump Type B example, describes a fluid actant whose boundaries change depending on the network relations in which it is enacted. The Zimbabwe Bush Pump Type B is of particular interest because it is a pump that has been very successfully used and distributed all over Zimbabwe improving access to clean water, where many other pumps have failed. De Laet and Mol describe the relational networks of actants that built around the Zimbabwe Bush Pump Type B to allow it to proliferate successfully and found that it was the fluidity of many actants that allowed it to act in such a way.

Some of these fluid qualities, such as the easy repair of the pump with substitute materials were designed to be so and others such as nation building depended on its enrolment in a nationwide rollout programme. It argues that the assemblage of such a fluid actant requires some of the other actants that interact with it to be fluid too. In particular de Laet and Mol (2000) note that the lack of a patent by a single inventor has meant that the boundaries of the pump could be continuously shifted and be adopted by different actants for different purposes. The design actant, Dr Peter Morgan, was particularly clear in understanding himself as an actant within a larger network of co-evolving things, "in Morgan's eyes the current pump is no more than a perfected version of a long-established and locally-developed technology that has always been part of, and belongs in, the public domain. It is not the result of the product of the eyes, the hands and the brain of a single man, but a result of collective action and of evolution over time." (de Laet and Mol 2000, 249). By having no single actant owning the pump, the pump could be owned by all human actants and in this way the central matter of concern "to get clean water flowing everywhere" (de Laet and Mol 2000, 252) could be achieved.

An ANT approach has also been used to describe the different human interventions along the Rhine river as a confluence of geographic advantages that were actively modified in order to achieve several different stabilisations of shipping configurations along the Rhine (Disco 2008). The Rhine has a uniquely stable water level throughout the year because it is fed both by alpine and pluvial water sources which are in seasonal balance. This has meant that the Rhine is a consistently navigable river throughout the year, hence attracted settlements that take benefit from the shipping trade along the river. This began a co-evolution between different vessels to negotiate the different river geographies, different river modifications that then made certain vessels obsolete, settlement patterns that alter depending on the successful negotiations of river modifications and governance regimes that depend and influence the strategic locations of trade that in turn change settlement patterns. These different actants stabilise for a period of time, before one or another will change or a new actant enters that then alters their relations and negotiates a new stability.

These two examples show how ANT has been used to analyse a water technology and water in relation to urban form. The example of the Zimbabwe Bush Pump Type B is interesting because it is describes the successful dissemination of a technology. The ANT analysis found that there was fluidity to particular actants and their boundaries that was necessary to the successful dissemination of the bush pump. Also to be noted within this example was the idea that the Zimbabwe Bush Pump Type B actant was not a completely new technology, but rather an evolution of pre-existing pump technology which supports the use of co-evolution in the research framework. The designer believed that this quality of evolution contributed to its success. Similarly the ANT analysis of the Rhine river shows the co-evolution from one stable network of shipping to another and how this involves mutual changes to the river, ships, settlements, and governance. These two examples show how ANT is compatible with a socio-technical co-evolutionary analysis of water technologies and water infrastructures.

**ANT and the Urban**

Actor-network theory has been used to inform research in architecture, urban planning and urban studies, but it has not been used to inform urban design, which is how it has been used in this research. This is because to date, urban design has been largely undertaken by professional consultants for commercial clients who have not chosen to use theoretical frameworks to develop design proposals. However because it has been successfully applied in an academic setting to the related fields of architecture (Fallan 2008; Latour and Yaneva 2008; Yaneva 2009a; Yaneva 2009b; Yaneva 2005), planning (Doak and Karadimitriou 2007; Hommels 2008), and urban studies (Farias and Bender 2010; Latour and Hermant 2006), it therefore seemed a reasonable extension to apply ANT to urban design.

Fallan (2008) reviewed the use of ANT in architecture. He found two researchers that had formerly used ANT to investigate the networks that formed technology, had applied this approach to understand the networks that formed architecture. One researcher, Thomas Gieryn, used it to understand how people and buildings mutually transform each other such that they are more than what the architects envisaged and also more than what was built. The other researcher, Marianne Ryghaug, used it to understand how architects translated green energy policy into buildings. Fallan argues that ANT was more poorly used by architectural researchers because two of the three pieces of research use the theory of ANT superficially. The first architectural researcher, Anders Toft, used ANT to argue for a particular vernacular aesthetic based upon Latour's (1993) dictum "we have never been modern", but does not move beyond a casual citation; the second, Inge Mette Kirkeby, used ANT post factum to explain how pedagogy is translated into school buildings, but ANT was not instrumental in the research method. The third architectural researcher, Mattias Karrholm, combined ANT with Foucault's idea of power to understand the distribution of power in the territories of architecture, which is the only architectural research that Fallan believes begins to explore the potential contribution ANT may have to architecture and vice versa. While ANT has not been used extensively in architectural research Fallan believes that "theoretical frameworks like ANT may help explicate the roles and contributions of all parts of these complex networks" of architecture (Fallan 2008, 11). This view is also held by Latour and Yaneva (2008) who also suggest that architectural theory would be enriched by an ANT approach.

This has been shown to be true by the work of Albena Yaneva who used ANT to both understand the emergence of the OMA design for the Whitney Museum extension (Yaneva 2009a) and the design process by architects working in OMA (Yaneva 2009b). Both these case studies show how ANT offers a different view of the processes of design than can be garnered by looking at design in the contextual frameworks of history, style, social limitations etc. Instead it shows how actants interact and mutually define one another until stable relations are reached and how these stabilities are contingent on all actant relations. The Whitney Museum extension being a case in point, where the multiple proposals were never realized in built form due to the withdrawal, disengagement, addition or change of different actants from the network that thereby dissolved the stable relations and the possibility of construction.

While Yaneva (Yaneva 2009a; Yaneva 2009b) used ANT to understand the stabilisation of architectural designs, Hommels (2008) used ANT to understand the obduracy of certain urban elements in the city. Obduracy was interpreted here as material elements of an urban environment that remain fixed despite the work of other actants to alter its material form or dismantle it altogether. Hommels found ANT combined with insights from other frameworks such as history of planning, technology, urbanism, urban geography, social construction of technology and large technical systems approach, to be a useful way to describe the relations that cause this obduracy for case studies in the Netherlands that included public housing, an elevated walkway and a highway. In each Hommels identifies three models of obduracy within which one main model might prevail. The first model is 'dominant frames' in which human actants are so tightly enrolled within a particular role that they are unable shift frames and form new relations. The second model is 'embeddedness' in which actants are integrated into multiple network relations, these relationships mean that any enactment of change to that particular actant is resisted by its other network relations and so that little change can occur. The third model is 'persistent traditions' in which practices by human actants and the material stability of nonhuman actants cause certain relations to endure. In each of these models Hommels uses network formations to explain what urban elements remain obdurate and what urban elements are open to change and how actant relations cause these instances to occur.

Actor-network theory can be applied to bring another way of understanding many aspects of urbanity as has been shown by Fallan (2008), Yaneva (2009a; 2009b) and Hommels (2008)and most recently by the edited volume "Urban Assemblages" (Farias and Bender 2010) in which seventeen contributors use ANT to trace many different actant relations that make a widely varying urban phenomena, from the emergence of international marathon races (Latham and McCormack 2010) to political soundspheres (Giralt, Gomez, and Lopez 2010). None of these case studies trace the relations of water in the urban environment, which is where this research makes a contribution. Nevertheless they all show how ANT has been effectively applied to describe urban phenomena.

**ANT and design**

The different stages of network formations described by ANT in relation to the creation of scientific knowledge (Callon 1986) can also be related to the process of design, design realisation and the ongoing evolutions of designs and things in the world. Design begins with a matter of concern about the material world whether it be how things function, how things look, how things communicate, and how things feel. This is the stage of problematisation. From this follows the question of how things could be changed, which is the stage of interressement when potential actants for a design begin to be mutually defined in relation to one another. The interressement and stabilisation of these actants are enrolled through a representation in designs that become more detailed, incorporating more actants over time. Finally, these networks of stabilised actants are mobilised for a prototype or a construction whereupon new actant relations are formed and the designed actant emerges from the particular network relations. At any point these actants can renegotiate or withdraw from their role, which would alter the network and hence the material form of the design, in much the same way actants can betray network relations in forming scientific knowledge. Design, like scientific knowledge or the technologies that ANT describes is an emergent effect of a configuration of actants. ANT has been used in this way to relate to design in this research. The research methods perform three of the four stages of ANT, problematisation, interressement and enrolment, to define new actants and networks in the urban water-cycle of the lower Lea river basin.

However these stages described by ANT for the forming scientific knowledge have not been related to design research in this manner. This is because other ANT design related research has not used design as a research method, therefore they have not been concerned with the initiation of a design by designers in the same manner that Callon (1986) was concerned with the initiation of scientific knowledge by scientists. The initiation of design is of concern to this research because it seeks to understand different ways the urban water-cycle can be reconfigured, which necessitates the understanding of how new actants are formed.

Other ANT research related to design uses ANT to understand the emergence of a particular design as a stabilised outcome (Fallan 2008; Hommels 2008; Law and Callon 1988; Yaneva 2009c) (see previous sections). De Laet and Mol (2000) have shown how this stabilised outcome can be fluid, which expands the territory of the designed object without every object being identical. ANT has also been used to open the black box of a particular formula based calculation within the design process to show the human relations embedded within an engineering formula that at the outset seems wholly objective and nonhuman. The formula is shown to contain the human subjectivity towards acceptable turbulence, nausea, ability for clarity of thought to control the aircraft, budget, space to store the aircraft, safety of the engine housing, and assumptions about the enemy aircraft rather than the simple capability of the aircraft structure to withstand wind gusts (Law and Callon 1988; Law and Mol 2001; Law 2004b). These examples show that "design is also a mode of connection that cannot be explained by other economical, social, political means. It has its own way of spreading, its own objectivity, its own solidity" (Yaneva 2009c, 281) which ANT is able to trace and explain.

In particular Yaneva notes the role of design in stabilising the social. Design gives the material world certain affordances that implies certain thinking and action that makes them consistent and repetitive. Therefore design is instrumental in "producing additional attachments that make a variety of actors congregate, forming different groupings and assembling social diversity...[by] linking disparate heterogeneous elements and effects, thus entering a game of producing, adjusting and enacting the social" (Yaneva 2009c, 282). These observations of how designed, technological artefacts frame and afford particular social practices and values are supported by other STS research around water technologies, such as washing machines and showers (Allon and Sofoulis 2006; Shove 2004; Shove et al. 2008).

This is taken further by Latour (2009) who argues that the concept of design has a unique perspective that makes it a useful approach to the world. Design unlike science is nonfoundational, contested meanings are absorbed into matter which is constantly being redesigned. Design begins with a matter of concern that may stabilise momentarily, but this is only a transitory stage before things are reconsidered. Moreover design is always explicitly concerned with ethics because there is always a question as to whether or not a particular design is good or bad. These aspects give design a particular perspective of the world because it constantly reconfigures the human and nonhuman relations in the world.

Actor-network theory has been used to research the stabilisations of particular designs from architecture to urban planning (Fallan 2008; Hommels 2008; Yaneva 2009a; Yaneva 2009b). It has been used to open the black box of seemingly objective design decisions to show the embedded human subjectivity that were concealed (Law and Mol 2001; Law 2004a). Design has been shown to be instrumental in altering material configurations that then become an actant to stabilise particular social practices and thinking (Yaneva 2009c; Sofoulis 2005; Shove et al. 2008), and conversely how stabilised practices can make the designed object fluid (de Laet and Mol 2000). These studies show how ANT can be used to understand design and also how design can be used to formulate different understandings of the world (Latour 2005). However the parallel between the process of network and actant creation for the making of scientific knowledge and the process for making designed artefacts has not been explored because these studies concentrate on the stabilisation of designs rather than the initiation of the process in altering material configurations through design. This research explored how Callon's (1986) stages of network and actant configuration in initiating the process of creating scientific knowledge can be used to initiate design.

**ANT Co-evolution Limitations**

The use of actor-network theory co-evolution as a theoretical framework to investigate the reconfiguration of the urban water-cycle in the lower Lea river basin has several limitations. Firstly the relational understanding of phenomena in the world means that all research that uses ANT or co-evolution is bound to particular actants at a particular time. This means that the empirical outcomes of this research cannot be generalised to other situations and it will only have a short lived relevance in the case study area. Networks and actants are constantly re-enacted and in that re-enactment it can also change. Therefore the research is only applicable in places with similar actant relations and only relevant in the case study area while the networks that have been traced remain enacted. This is a deliberate limitation of ANT to the local which leads to the second limitation of ANT, its description of scale.

Latour (Latour 1987; Latour 1993; Latour 2004; Latour 2005) has consistently argued strenuously against the idea of a preconceived definition of a global, local, context or any other scale. "That there exists no place that can be said to be 'non-local'" (Latour 2005, 179) in other words, what is perceived as global can be located in local conditions. His example is of the railroad, is it local or global? "Neither. It is local at all points, since you always find sleepers and railroad workers, and you have stations and automatic ticket machines scattered along the way. Yet it is global, since it takes you from Madrid to Berlin...There are continuous paths that lead from the local to the global, from the circumstantial to the universal, from the contingent to the necessary, only so long as the branch lines are paid for" (Latour 1993, 117). This makes it difficult to describe the effects of scale in the form of the magnitude of replication of a similar actant network over a geographic territory. For example, it does not allow the description of how the replication of fairly similar actant relations of water infrastructure and water practices over a physical geographic territory can also be assembled to be an actant in the world. In other words one person using a flushing toilet does not have the same effect as one million people using one million flushing toilets. This assembled actant has effects that are different from the actant networks within it because the magnitude of scale and its physical size and distribution make different effects, but ANTs method of tracing only the intimate human to nonhuman relations does not allow these observations to be made.

Actor-network theory's concentration on the relational effects between actants to create a 'flat ontology' to reveal that what has been considered global is always composed of local actants and networks (Latour 1993; Latour 2005) embeds a bias towards the scale of the individual human because this is presumed to be the smallest unit of the social. Most of the relational effects that are mapped are those that are experienced by a single human being in relation to other actants, most of which are technological artefacts (doors, keys, buildings, water pumps, etc) that have been designed for human use or relations with other humans. These case studies usually involved tracing network effects usually in a sequence of human, nonhuman, human, nonhuman etc (Latour 1987; Latour 2005; Law 2004a). Even though Latour acknowledges "Scale is the actor's own achievement" (2005, 185), ANT does not offer a clear understanding of how these scales can be defined and how an assembled actant made of humans and nonhumans can be shown to have effects on other actants.

One way in which Latour has approached scale has been to define it by the length of the network of effects that are generated by an actant (Latour 1993; Latour 2005). But the actant is presumed to be a thing related to a human scale: an office, a laboratory, a station, a ticket machine, not an assemblage of humans and nonhumans that create a unique effect.

The assembling of larger than human scaled actants has begun to be addressed by Star and Greismeier (1989) in their description of the emergence of Berkeley's Museum of Vertebrate Zoology through the use of boundary objects by different social worlds; and de Laet and Mol (2000) when they mention the social worlds that are involved in creating the fluid actant, the Zimbabwe Bush Pump Type B, but how these social worlds are assembled and defined is not explained. The vocabulary of 'social world' also seems to leave out the nonhuman, which sidelines the effects of assembled nonhumans such as infrastructures or geographic features have in social worlds. Gathered effects of assembled actants are also addressed by Latham and McCormack (2010), who try to reconcile geographic understandings of global, national, regional, local and individual scales with ANTs 'flat ontology'. They reaffirm Latour's (Latour 1993; Latour 2004; Latour 2005) argument for the importance of dissolving the hierarchy between global and local scales to use a flat ontology, moreover through their case study of marathon events, they show how actants shift between scales and create their own scales of effects that are not necessarily defined by geo-political or administrative boundaries. They also make good arguments for the need to identify and understand the effects of large assemblages of actants. However, like Laet and Mol, while it is clear that these assembled actants have an effect different from the local relations from which they are composed, it is not clear what the assemblage is, how it might be defined, what is its extent, how the physical size alters its effects, and for how long it exists.

Scale and magnitudes of actants of assembled humans and nonhumans remains an unresolved aspect to ANT. Latour does not deny the effects of scales and magnitudes, "It is indeed difficult for us to deny the effects of scale"(Latour 1993, 126), but the idea of a lengthened network to understand scale embeds a presumption that the only relevant scale to understand actants and networks is the individual human. Thus ANT does not give insight into how these assemblies might then be considered an actant with effects that are different from those that are generated from the networks and actants that were traced. More recent applications of ANT have begun to explore ways that assemblies of humans and nonhumans might be assembled into actants, but this research has not yet come to a method to define these boundaries. The other limitations of ANT lie in its methodology of tracing specific networks of effects, which means that ANT research is limited to a short time frame of relevance and modest applicability to places beyond the case study.

**Conclusion**

Actor-network theory relates humans and nonhumans symmetrically in all things in the world. It has developed a specialised vocabulary to describe various different types of relational effects. This vocabulary has developed through the use of empirical case studies that have used this framework to analyse the formation of new knowledge, new technological artefacts, and new social institutions. This framework has proved useful in offering new insights into understanding how the world is formed, and as a consequence, new insights into different ways we, as humans, might act in the future. Actor-network theory has some limitations in that it has not yet developed a method to describe actants that are assemblages which have effects that differ from their constituent actor-networks. It is also limited in providing insights to situations beyond that of the immediate case study. However these limitations do not prevent ANT from being a useful framework for understanding the urban water-cycle because other frameworks from other disciplines (chapter 2) have proven to be inadequate in describing the urban water-cycle because they only attempt to explain it by either the human or nonhuman actants. ANTs primary supposition that all things in the world can only be understood by a composition of human and nonhuman actant relations bypasses this inadequacy.

The applicability of actor-network theory has been expanded in this research by adding the insights of socio-technical co-evolution in order that new network enactments can be projected from those that that have been observed. Socio-technical co-evolution shares the idea of relational effects with ANT, but traces these over a longer timeframe to show how they change over time. It shows that these changes are dependent on pre-existing network relations and their continued modification. However, the limits of the networks that socio-technical co-evolution explores are only the social and the technological, therefore adding it to ANT opens these explorations to actants beyond these two categories. Adding co-evolution to ANT allows this framework to be projective rather than historical. The combination of ANT with co-evolution is unique to this research and was done in order to explore network reconfigurations of the water-cycle in the lower Lea river basin, based upon the empirical insights both these frameworks provide.

Actor-network theory has not been applied directly to the water-cycle or the urban water-cycle, which is another contribution of this research. However, it has been successfully used to understand water technologies and water infrastructure in relation to urban settlement patterns, which makes this a valid application of this framework. There is also a body of literature that comes from many disciplines that have looked at water, water systems and water technologies that suggest that ANT combined with co-evolution would be an effective framework to use for studying the water-cycle and the urban water-cycle.

The use of actor-network theory's insights into the formation of scientific knowledge and how this process is similar to the formation of new designs has not been applied to other ANT research about design. This is because these studies do not use the initiation of design as part of their research method, instead these studies were concerned with the stabilisation of particular design outcomes. The use of ANT as a basis to initiate design is a further innovation of this research.

While the use of ANT for this research necessarily limits the results to a short time frame and a particular network configuration, the insights of the process can be used to inform other research. ANT also proves valuable in collecting the human and nonhuman relations that occur to make the water-cycle in the lower Lea watershed through its supposition of the symmetrical human and nonhuman composition of all things, thereby bypassing the inadequacies faced by other frameworks that have investigated urban water. By expanding ANT to include co-evolution, the timeframe of the network relations it describes shifts from the historic to encompass some projective qualities. These projective qualities have been complemented with ANTs insights into the creation of scientific knowledge which involves the configuration of a new network of material and social relations. This has been seen as the same process in which new designs are brought about. This research extends the use of ANT and socio-technical co-evolution through their combination. Furthermore it brings a new application of ANT to design research and the urban water-cycle.

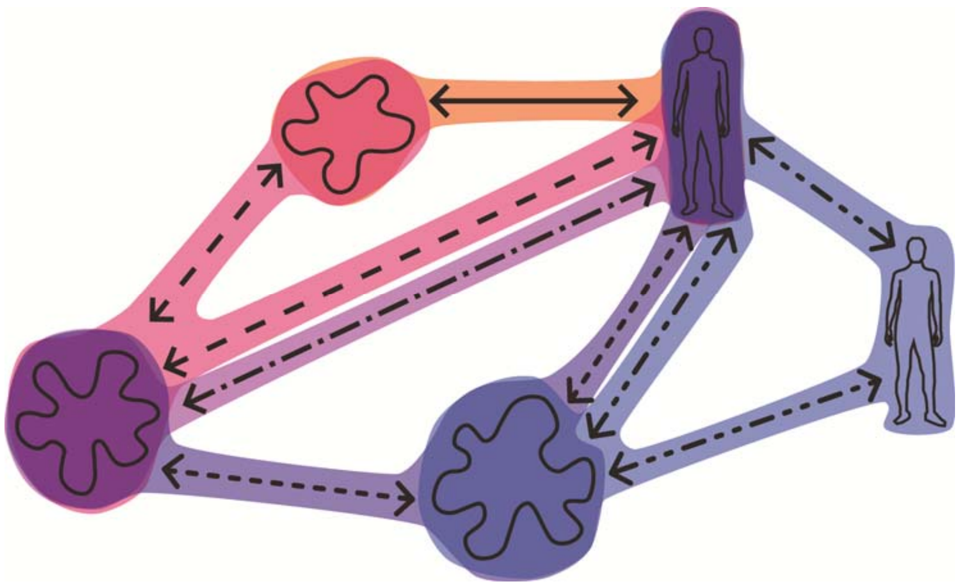
## Chapter Four

# ASSEMBLING THE ACTANTS

The matter of concern for this research is the urban water-cycle and its ongoing ability to provide water that humans and other biota require to create a world environment conducive to the continuous flourishing of human life. The urban water-cycle that has been the focus of this research is confined to the geographic area of the lower Lea river basin. A river basin was selected because rain, surface water runoff and rivers are actants that define a territory within terrestrial water-cycles. Moreover the river basin is a boundary object that is commonly used by ecologists and water planning managers, thus it is an actant that forms a starting point that is easily engaged with by water professional actants to understand the relations that assemble the urban water-cycle.

The water-cycle is a large network of infinite interactions between many humans and many nonhumans that exchange, control, convey and change the quality of water. Within this infinite network, interrelations have been traced between individual humans and their relations to the urban water-cycle in the lower Lea river basin. These relations have been traced from the points of view of environmentally aware citizens and water professionals affecting the water-cycle in the lower Lea river basin within the London boroughs of Hackney, Haringey, Tower Hamlets, Newham and Waltham Forest. These relations are individual water-cycle assemblages that open the black box of the urban water-cycle in this river basin. These water-cycle assemblages give an understanding of how water, urban form, infrastructure, practices, and expectations are mutually articulated and what the strengths of these relations might be.

The methodology consisted of a two part semi-structured interview or group discussion with a time gap of at least six months duration, a water diary and a workshop. In between the first and second interviews or group discussions, participants completed a water diary which was optional for those who participated in group discussions. The time between the first and second interviews and group discussions was also used to analyse the verbal data and water diaries for common themes and unique circumstances of changing practices to synthesise into design propositions that would create urban water-cycles that increased the residence time of terrestrial freshwater resources. These were then workshopped with the same people in a second interview or group discussion. These results were then analysed for ideas around which new networks were forming amongst the human and the new nonhuman actants. These design propositions around which there were a density of new network formations were then modified and designed in further detail to respond to some of the concerns that were raised. These new nonhuman actants were then introduced to new human actants and the previous human actants in a workshop comprised of many group discussions. These results were then analysed to see if there were any further development of co-evolutionary pathways within the new relations (figure 4.1).



**Stage1:** existing relations

**Stage 2:** new nonhuman actants

**Stage 3:** new relations

**Stage 4:** new nonhuman actants

**Stage 5:** new human actants, new relations

**Figure 4.1**
**Iterative research method**

The methodology for this research is a combination of qualitative and design research methods that investigates the interrelations between humans and nonhumans that form current and future water-cycles in the lower Lea river basin. It first investigated the interrelations between human and nonhuman actants that formed existing water-cycle phenomena in the lower Lea river basin. It then looked at how these could be reconfigured in an iterative process between human and nonhuman actants in order to simulate and stimulate co-evolutionary processes that could form future water-cycles.

**Actor-Network Theory Coevolution Methodology**

Actor-network theory argues that both nonhumans and humans are continuously present in creating the world that we, as humans know. Thus, to work within an actor-network theory framework, all water phenomena were examined for both human and nonhuman entanglements. At the outset, it is presumed that humans and nonhumans have a symmetrical influence on all phenomena experienced by humans. Most actor-network theory research has been used to analyse networks that form and dissolve in a short space of present time relative to either the researcher or a historical controversy (Latour 2005; Law 2004a). Socio-technical co-evolution on the other hand, looks at the effects between actants on a longer timescale to trace how actants mutually affect change in one another. Adding the idea of socio-technical co-evolution to the ideas of ANT opened ANT to the study of the network of entanglements that are in a slow state of continual reformation; and opened socio-technical co-evolution to a multitudinous range of actants that mutually affect one another.

A typical ANT analysis that tried to concentrate only on an initial stage of formation of a water infrastructure would not capture these slow shifts in behaviours, values and technologies. Nor would it be useful in this case study of the urban water-cycle because this research was not about the initiation of a new technology into the relational network, but what new water-cycles are made possible by the shifting constitution of the human and nonhuman relations that already exist. Socio-technical co-evolution research has already shown how values, culture, technologies and practices have mutually influenced one another around daily practices such as washing, drinking and sanitation that are persistent but changing throughout human history. Therefore ANT and co-evolution were joined as a single framework to investigate the possible reconfigurations of the water-cycle in the lower Lea river basin.

The actants are gathered in the interressement (interviews, group discussions and water diaries) and are brought to bear in an enrolment of a selection of these actants in the reconfiguration of these relations by several design propositions that were created. The design propositions were devised by the changing of network formations between the interests of the representatives of human actants and nonhuman actants. Some of these design propositions chose to exclude certain actants from the new network, assign new effects to other actants, and inscribe new actants. The network relations of these design propositions were not only initiated from a point of co-evolution found in the existing water-cycle relations, but also tried to find co-evolution pathways for new actants over a timescale from the immediate up to one hundred years. These new nonhumans attempted to be enrolled and renegotiated into new network relations with human actants through the second stage of semi-structured interviews and group discussions. Following this, another iteration of negotiation occurred with the nonhuman actants through another set of design propositions. These were then renegotiated with a new set of human actants in group discussions.

Mobilisation is never really achieved for the design proposition actants in this research framework because there is no stage of implementation of material change to the existing water-cycle relations. However, a degree of mobilisation may occur if the representatives of the human actants chose to alter their effects on the urban water-cycle as the result of participating in this research. This would initiate a co-evolution that would reconfigure the water-cycle in the lower Lea river basin.

The methodology has used the relational aspect from both the ANT and co-evolutionary frameworks. It uses ANT in presuming that the water-cycle phenomena are made symmetrically by both human and nonhuman actants, thus both types of actants need to be investigated. More similarly to socio-technical co-evolution, it encompasses a longer time span to develop propositions of how the changing practices of the present day and imagined adaptive strategies might influence future co-evolutions of practices, technologies, ecologies and urban landscapes. The methodology extends both these research frameworks by finding areas of changing relations in order to test co-evolutionary pathways for future change.

**Use of a Case Study**

The actor-network theory co-evolutionary framework required the use of a case study approach in order for this research to trace the network of relational effects between specific actants (Latour 2005). Case studies are used in social science research to look at a bounded situations in depth. The boundary of the case study can be defined geographically, by people who exhibit similar traits, people belonging to the same group and so on (Yin 2009).

In this research the case study is primarily bounded geographically by a river basin. The river basin was selected for two reasons. Firstly it is defined by the central actant of this research, water, whose relations are traced to form an understanding of the urban water-cycle. Secondly it is a commonly used boundary object that is often used by water managers and planners who practice integrated water resource management (IWRM) (Agarwal et al. 2000), best management practice (BMP) (US

EPA 1999), and integrated water management (IWM) (Vries 2004). Thus using this boundary object enables the research to have a common basis on which to engage with these professionals.

The selection of a geographic area also helped concentrate human actants in one location which made it easier to organise group discussions convenient to actants to encourage greater participation. It also increased the likelihood of interrelated human and nonhuman effects.

A case study was also a useful way to combine several methods of research that included semi-structured interviews, group discussions, ethnographic photographic diaries and design (Yin 2009). This research has used an iterative and novel combination of methods that was tested using this case study, the lessons from which can inform future research.

The research concentrates on a single case study due to reasons of time and resources. Further insights could be gained by applying the same methodology to different cultural, ecological, and geographic situations to compare the degrees of stability of human and nonhuman relations in the water-cycle.

**Selection of the Lower Lea River Basin**

The rationale for the selection of the lower Lea river basin as the case study was because it was located in London, which is one of the most water stressed locations in the UK that is also projected to grow in population (GLA 2009). Therefore the results of this research would be applicable to both the adaptation of the existing urban environment and proposed areas of urban expansion to accommodate the population growth.

London was important as the site of the case study because it was one of the first urban areas to invent and implement centralized drinking-water, sewers for waterborne sanitation and the flush toilet. Its infrastructure was the model that continues to be emulated and refined in cities around the world (Hard and Misa 2008; Melosi 2000; Tarr and Dupuy 1988). It is a model that is mostly seen as the most desirable, "It can be argued that every urban dweller has a right to a standard of water and sanitation provision that matches the standards in high-income nations. Certainly, this level of provision produces the greatest health benefits" (United Nations Human Settlements Programme. 2003, xix). The long history of its implementation in London has shown the limits of this technology in terms of growing water consumption; the continual search for new water sources; and the environmental degradation that occurs due to the over abstraction of water and sewerage system overflows. The longevity of this water infrastructure in London also means that the management and technologies of abstraction, wastewater discharge, water distribution, and water users are a mature system that have gone through many modifications over time therefore any changes made to this system are likely to be seen as models for system modifications throughout the world.

The lower Lea river basin was slightly unusual as a case study because it contains a combination of typical and strategic relationships to London's water infrastructure. Case studies are generally either typical or extreme circumstances (Yin 2009). It was typical in that all the people living in the area were served by potable mains water supply and mains wastewater sewer drainage, which is similar to other situations in London, other cities and towns in the United Kingdom, and many other wealthy urban areas worldwide. It was strategic in that the largest reservoirs in London are located in the river basin; it is the largest tributary on the north bank of the Thames river; all of north London's sewerage converges here to be pumped towards Beckton wastewater treatment plant; and the Olympics site was being constructed here which entailed many modifications to the water of the river Lea.

Choosing this case study area opened the research to the potential of intersecting with work being done at the Olympic site, which aimed to be 'green' and the prudent use of water resources is part of this ethos. However, access to people who had worked on the final design of any of the water systems could not be found, so this possibility did not eventuate. On the other hand, its strategic location for water enabled interviews with water professionals involved with groundwater, wastewater, drinking-water, water ecology management and various nongovernment agencies that would not have occurred in another case study area. The case studies mixture of typical and strategic characteristics means that it can be presumed that the insights generated from this in depth study of a local situation will have insights that can be extrapolated to other similar situations (Denscombe 2003), but it could also provide some unique insights through the special relations it has with the wider network.

**Stage 1: Following Today's Water Interaction and Tomorrow's Changes**

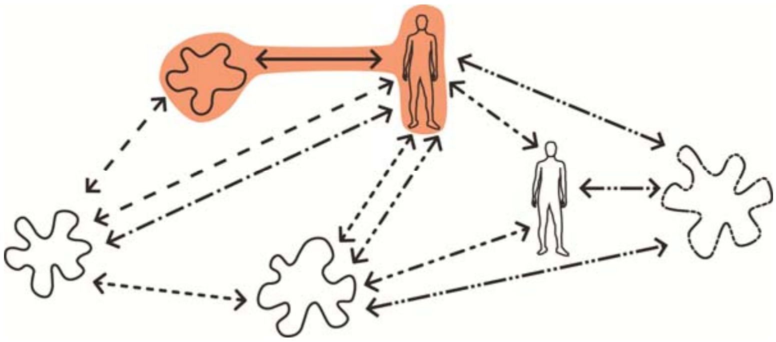


**Figure 4.2**
**Stage 1: Existing human and nonhuman relations**

The first interviews and group discussions aimed to find the different kinds of personal interactions people had with the water-cycle. This first group discussion and individual interview asked slightly different questions, but both were centred on understanding people's individual impacts on water. The common questions were their daily water use, regular water use, and non-consumptive water use; recollections of how these practices had changed; speculations of what they would do in the time of an extreme water circumstance such as drought; and to allocate responsibility for preventing this situation from occurring.

In addition to this, the group discussion asked people how they came to a particular understanding about water consumption and pollution. It also asked how this knowledge affected the way they used water and if this information could be better disseminated in order to mobilise more people to change their behaviour. The supplementary themes in the individual interviews were the professional water-cycle and to consider how their behaviour and technologies might change in cases of regular flooding and who would be responsible for the prevention of this circumstance (appendix F and G for scripts).

The individual interview did not query how people came to particular water understandings; instead it asked people to explore their personal and professional daily lives for its impact on water. This was because most of the individual interviews were with water professionals who have had formal education about water; read trade journals on water; are involved with research about water; and continue their water education through meetings, seminars and conferences; hence asking them about how they formulate their understandings of water would involve delving into a whole set of other interrelations of their personal history and professional underpinnings that are beyond the scope of this research project. This meant that there was extra time to explore professional water-cycles and further changes to the water-cycle in times of flood.

The individual interview and the group discussion were both designed to be of one to one and a half hour duration, which was the amount of time that could reasonably be expected for people to voluntarily give without recompense. The two forms of interview method were different because the group discussion was constrained by time. The group discussion had more views to gather and voices to be heard. It was also difficult to know the different levels of knowledge that the environmentally aware citizens participating in the group interviews would bring to the water issues to be discussed, thus the group discussion also needed to find common understandings amongst the group and also probe what this knowledge was founded on.

It was decided to go with two types of interview methods because the group discussion made possible the gathering of greater numbers of opinions in the same amount of time. Proportionally there are more environmentally aware citizens in the community than there are water professionals, thus a method needed to be found to gather more of their viewpoints within the given time constraints.

The individual interviews took place at a location convenient to the interviewee. This was usually at their office, for water professionals; and at home, for environmentally aware citizens. A few interviews were taken in other locations such as cafes or meeting rooms at the University College London campus. The group discussions generally took place in a place convenient to the participants and capable of holding talkative and noisy large groups. The pub was found to be a location that fulfilled both these criteria, however one group discussion was taken in a seminar room at the University College London, and another at a community hall.

In the realisation of this methodology, four out of five of these first group discussions were undertaken by MSc student, Ud Doron, under my supervision and with myself as an observer. I undertook one group discussion with Doron as an observer. The group discussion script was jointly formulated and the themes and order of the script adhered to for all five group discussions. I undertook all the individual interviews.

This format was piloted before being used as my interview and group discussion script. Pilots of both these scripts were successful in eliciting the responses that were useful for this research and there were no substantial changes.

**First Assemblage of Human Actants**

My research was directed towards identifying potential co-evolution pathways for future water-cycles, therefore I chose to target this research to two particular types of human participants that I hypothesised would be positioned to change future water-cycles. The first of these were water professionals who have an influence over large quantities of water that flow in the lower Lea watershed due to the nature of their work. They affect the quantity, quality and location of water over both current and future water infrastructures and management. The second group was self-professed environmentally aware citizens because these were the most likely people to be motivated to be conscious of their water consumption and experiment in changing their behaviour and technologies to align with their environmental concerns, thus they would be engaged in co-evolutionary change. This group was also targeted because of their willingness to talk about their water interactions. An initial pilot study with a non-environmentally aware citizen showed that this person held suspicions about the motive of questions about water use as they believed the interviewer wanted them to modify their behaviour to conserve water. It was assumed that these people would exhibit a mix of typical and unusual water behaviour as they would have different degrees of commitment to their environmental values.

Water professionals were recruited to participate in my research through unsolicited emails, cold calls, and through my own professional network. I had not met any of these water professionals prior to my research. Environmentally aware citizens were engaged through face-to-face meetings at local Green Drinks (a loose worldwide movement, where environmentally engaged people meet casually in a pub or bar to exchange experiences and informally network with people of similar interests), at local sustainability meetings, the Green Party email list, postings on websites, friends and friends of friends who lived in the study area, local community centres, unsolicited emails, and snowball emails (emails that went to someone I knew, and then forwarded to people that I did not know). Most of the participants in the category of environmentally aware citizens were people that I had not met previously.

In total there were fifty three participants for the first stage of interviews and group discussions. All these people gave their time freely. The interviews began in mid-summer 2009 and finished in early winter. The group discussions began in midsummer and were finished before the end of summer 2009. Thirty people were individually interviewed and twenty three people participated in facilitated group discussions. Of the thirty people interviewed, twenty-five were water professionals, five were environmentally aware citizens and five were both water professionals and environmentally aware citizens living in the lower Lea river basin (figure 4.3). Throughout this thesis participants have been referred to by pseudonyms (appendix C).

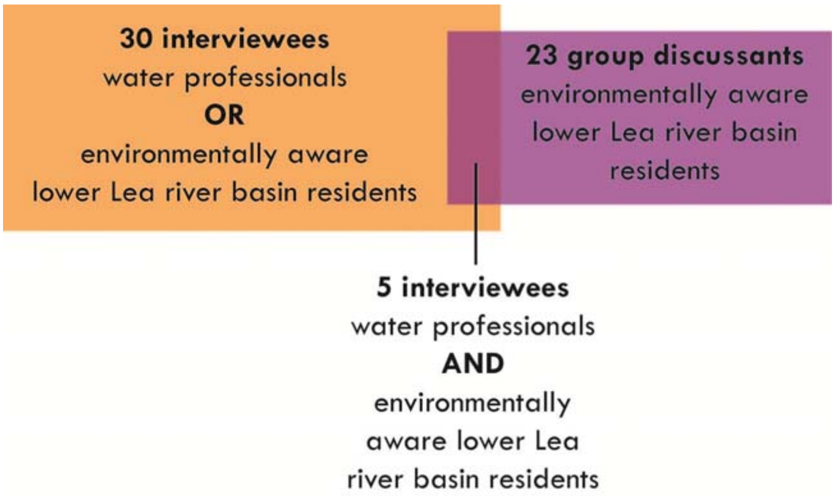



**Figure 4.3**
**Interview and group discussion participant types**

The human actants gathered for the interviews were from a broad age range and were equally distributed between male and female participants (appendix D). Most of the environmentally aware citizens that participated came from the London boroughs of Hackney, Haringey and Tower Hamlets. There was a varied mix of different responsibilities and professional experience amongst the human actants who were professionally involved with the water-cycle. The majority of these people interviewed were from the government, councils and regional authorities, and the water company, which is representative of the greater impact that these institutions have on the water-cycle due to the larger scope of management that they undertake (figure 4.4).


**Figure 4.4**
**Interview and group discussion I participants**

While the sample of human actants assembled contains a diverse range of age, sex, professional knowledge, practices, and geographic representation within the one watershed, it did not seek to be representative of all the human actants involved in this urban water-cycle. It has concentrated on actants likely to be in a position to make changes within the water-cycle in the lower Lea river basin through personal motivation and/or professional responsibility. The sample of human actants also examined the potential differences of current practices between human actants that are a part of the same material system, but with different types of knowledge, influences, responsibilities and motivations in participating, creating and being formed by the system. Therefore the results from this sample of human actants were formulated to be indicative of initial relational changes over a demographic range.

### Use of Interviews and Group Discussions

Interviews are a common method of qualitative research. It aims to gather systematic descriptions about an "interviewee's lived everyday world…from their own perspective and in their own words" (Kvale 2007, 11). In this case it was considered an appropriate method to gather a wide and diverse set of descriptions of water interactions that were both personal and professional. This was a good method of gathering data about the water interactions of different people because the sites of water interaction were scattered over a large geographic area amongst many people who were not part of one social group that could be observed. Observing individual people in their daily lives would have been intrusive, time consuming to do with many people and would possibly yield no additional information than the interview and water diary. Also ideas of future water interactions could not be observed and could only be obtained verbally in interviews.

Furthermore, environmentally aware citizens were also interviewed in group discussions. Group interviews are an increasingly used qualitative research method (Barbour 2007; Kvale 2007). It allowed many more descriptions of existing water interactions to be gathered and ideas for future water interactions to build between participants. This process of building ideas in a group was more reflective of ideas that were considered socially acceptable in comparison to individual interviews where people could only express their own opinion and would indicate if they thought that it was a widely socially unacceptable future scenario by couching their opinions of its general applicability in 'theoretical' terms. Group discussions could not be used for professional water influences because there would be inadequate time to explore specific professional water interactions that varied greatly unlike people's personal water use. A few environmentally aware citizens were interviewed individually to ensure the quality of the responses from the group discussion were similar to that which was obtained through an individual interview.

To make certain that the interviews and group discussions were systematic in gathering descriptions of water interactions, scripts were generated for both. These scripts formed the structure of the interviews and group discussions though the implementation of the script was semi-structured allowing interesting themes to be probed as they arose. Generally the flow of the script followed the flow of the conversation and the themes of the questions were asked in the same order with near identical phrasing.

The form of the scripts began with a few warm up simple to answer questions, followed by the more important data gathering questions, closing with less important more speculative questions, warming down with open questions to allow people time and space to reflect on the all they had just said (Flick 2002; Kvale 2007). The questions started with fact gathering and became increasingly more open ended, asked for elaboration and considered projective circumstances and closed with summative questions. It was aimed to minimize the use of leading questions during the interviews and group discussions because these would reduce the credibility of the responses by suggesting a correct response.

While the interview allows the interviewee to describe their own actions, motives and meanings, there is still an asymmetrical power relation between the interviewee and the interviewer with more power resting in the interviewer because they ask the questions and interpret the answers. This power asymmetry is inherent to the process of all research, however in order for the participants to feel as safe and comfortable as possible in answering the questions posed, the interviews and group discussions took place primarily in places that they suggested themselves, were familiar with or local to their workplace or abode. The purpose of the interviews and group discussions was made clear right at the start, with an assurance that no judgment would be passed on anything they chose to share and no consensus needed to be reached amongst the group to ensure that people felt free to speak as honestly as they could (F. Bee and Bee 2004).

Interviews and group discussions were found not only to be a historically proven method to systematically gather data, but to also be a good method for this research to obtain information about people's water interactions now and in the future. The interviews and group discussions were carefully planned and thought through to increase the freedom and comfort of participants to give honest responses to the questions asked.

**Gathering Today's Nonhuman Actants**

Following the first interview people were given a water diary to complete. The water diary was optional for people who participated in the first group discussion. The water diary aimed to find out what nonhumans were involved in the water-cycle and what similarities or differences there might be in these people's water practices.

The water diary consisted of a twenty-seven exposure disposable camera with a flash and a small booklet in which to note down what was photographed. The 27 exposure camera was decided on, based upon my own pilot study photographing my own water use over the course of 24hours. People were asked to take a photograph and make a note every time they used or had an impact on water during the course of any twenty-four hour period. Furthermore, if there were any exposures left after recording this daily water impact, more pictures were to be taken to record less daily but still regular water impact, for instance using the washing machine, or watering the garden; and also water that had particular meaning for them, such as a pond, or a holiday snapshot.

People were asked to categorise these entries in the water diary into three categories: typical (T), unusual (U), and meaningful (M). Typical was to denote something done daily; unusual to identify something done infrequently, which could be weekly, monthly, quarterly, or annually; meaningful to note something that had a special significance to their life. Meaningful uses could cross with things that were typical or unusual. This was done to gain some understanding of any aspects of water that enriched people's lives beyond utility, and what these were. These categories were also interpreted to indicate the level of conscious or habitual engagement that human actants had with the nonhuman actants. Nonhumans categorised as meaningful were conscious acts of engagement by the human making the record, the unusual indicated semi consciousness, while the typical was considered habitual where consciousness would only be raised when the system failed.

**Use of Photographic Diaries**

The use of a camera to record images during a person's life with accompanying notes that describe the images recorded, which is then returned to the researcher for review is known as photo ethnography (Laurel 2003). This is a recent qualitative research method because it required photographic technology to become easy to operate and inexpensive to use before it could be widely implemented.

The photographic diary allows a wider context to be recorded than what can be described in words. In this case it gives a record of the nonhumans that people interact with in order to use water. It gives a pictorial record confirming the nonhumans described in verbal description and additional nonhumans that were forgotten during the interviews and group discussions. It verified that people were served by similar technologies, which would have been convoluted to verify verbally. It captured the more commonly used technologies during people's personal daily lives and across different individuals. It also easily recorded unusual nonhumans which could not have been easily described to a person who had never seen such technologies before.

The diary format, unlike interviews and group discussions does not rely on people to recall what they did, however it does require them to make a record when they do something. A few people found this very challenging and some diaries were never returned because the person never remembered to take photographs or felt that they inadequately recorded their water use.

The other problem with the use of the photographic diary was the type of disposable camera that was provided. The camera required people to turn on the flash, wait for it to charge and wind the film. Most participants were in the habit of using fully automated digital cameras that do not require any additional manual effort other than pressing the capture button, therefore a lot of film was developed that was underexposed and had less exposures than what was expected from the written record. However, the return rate for the disposable cameras was far higher than the people who had made a commitment to use a digital camera to complete their diary. Therefore the use of the disposable camera as a diary was probably the best type of technology for the purposes of this research.

**Stage 2: Synthesis to First Water-Cycle Reconfiguration**

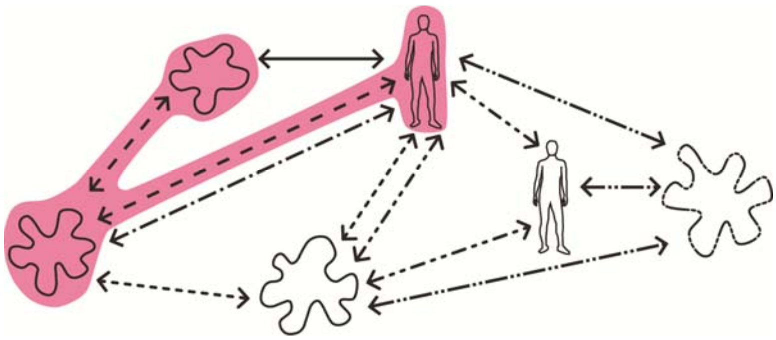


**Figure 4.5**
**Stage 2: New nonhuman**

The second stage of the research methodology was to synthesize the results of fragile actant relations from the first interviews, group discussions and water diaries into changes in nonhuman configurations through the use of design propositions. Thematic analyses of the first individual interviews, group discussions, and water diaries found consistent and unique, existing and future projections of human practices and nonhuman material configurations. The existing unique and future projections of water-cycle practices that were described by the participants indicated that some relational configurations between humans and nonhumans were more loosely bound than others in their network relations. These loosely bound nonhuman actants were the possible co-evolution pathways that could be extended by design propositions to reconfigure the current water-cycle.

The thematic analysis for the individual interviews and group discussions were based on notes taken during these sessions. These were clarified by digital audio recordings that were taken during the original session. The notes were first reviewed for major points that each interview and group discussion covered in relation to water practices. These points were then grouped thematically across all the interviews and group discussions to find the confluences and divergences of practices described, nonhuman actants mentioned, and opinions about possibilities for change. Similarities and differences were the focus of the thematic analysis because similarities generally suggest areas of strong stable relations between actants; and differences generally suggest areas of weak changing relations between actants. The exception to this is when difference of opinions still lead to the same relations between humans and nonhumans, in which case, the differences create a strong stable network, possibly one more immutable than a similarity of opinion because it indicates a multiplicity of reasons for the same relations to continue to be reproduced.

The water diaries used to gather the nonhumans involved in these particular water-cycles were also analysed for similarities and differences between the nonhuman actants photographed and the types of water impacts that were viewed as being typical, unusual or meaningful.

The opportunity for a new actant to mobilise new relations occurred where unstable network relations currently exist, or would exist when the water actant was unstable. These were the points of design synthesis. The design propositions to reconfigure the current water-cycle with new actants and networks were generated by me. They were organised into three themes: flooding, water reuse, and pollution prevention, with an overriding theme of nutrient and water recovery. These themes contained multiple design propositions that built on each other over time. That is there was a design for a material change that could be done immediately at a local scale, evolving into a design that could be done in 25-50 years at an adjacent neighbour scale, evolving into another design proposition that could be done in 75-100 years at a neighbourhood scale. The presumption being that as new methods of water use became common, the infrastructure to support it would co-evolve to be more sophisticated, larger in size, and involve more relations. This presumption is based on the evolution of the existing water and wastewater infrastructures that have developed in this manner (Graham-Leigh 2000; Halliday 1999; Hillier 2009; Magnusson 2001; Melosi 2000).

The designs of the same theme over multiple time frames tested the ability for people to imagine themselves co-evolving with different relations to nonhumans. It also tested the possibility of the particular co-evolution pathway that the designs suggested. Moreover it tested the different sizes of change that people felt were effective in reconfiguring water-cycles towards something they felt would lead to a sustainable future.

The primary aim of the design propositions to reconfigure the water-cycle were intend to address ways in which the existing water-cycle could extend its duration in terrestrial ecosystems so as to improve the quantity of freshwater available for human use and freshwater environments that are presently over abstracted. The design propositions concentrate on extending the duration of water terrestrially because water-cycles that have been intervened by humans hasten the movement of freshwater from terrestrial areas to the ocean. This is one of the prime reasons for the over abstraction of freshwater resources, which has contributed to the degradation of river, estuary, and wetland ecosystems (Acreman 2000; Newson 2007).

Secondarily the design propositions also aim to address other urban issues that might simultaneously be tackled with the same solution that will attenuate the water-cycle. For example, creating a permeable landscape for flood water can simultaneously create land area for food production, thereby allowing local food production, which reduces the carbon footprint of food consumed in the locality. In this way the new design actants attempt to multiply human and nonhuman relations. "As we know it from science and technology studies if a fact or an artefact gains more allies and supporters (see Latour, 1987), and relevant groups (see Bijker, 1995), it has a bigger amount of linkages, resources and allies locally available; it is more social. The same is relevant for design projects." (Yaneva 2009a, 81). Urban environments are emergent from multiple factors, therefore the presumption is that a multiplication of the possible relations that the same design proposition can generate, which answer the manifold requirements of people, the more stable the design proposition becomes as a ANT co-evolutionary pathway to change future water-cycles.

**Use of Design**

People designing make propositions to change the future material states of the world around them (Clark and Brody 2009; Downton 2003; Michel 2007). The motivation for making these changes is generally to improve the current material configuration for themselves or for other people. These improvements, first perceived by the designer, can be to facilitate greater utility, or give greater pleasure to the senses, or communicate a nonverbal idea, or all of these qualities (Downton 2003; Michel 2007). Designs are therefore embedded within specific legacies of material circumstances and social understandings; but can also change or be used to critique these specific legacies of material circumstances and social understandings.

In this case design is used to critique the specific legacies of water-cycle configurations in people's daily and professional lives. The designs formulated material reconfigurations that synthesised possible enactments of some of the multiple ANT co-evolutionary pathways identified through the interviews, group discussions and water diaries. These designs also synthesise these co-evolutionary pathways with known technological actants. Design was used as a method to respond, extend and propose specific material changes to actant configurations that were found in this particular circumstance.

These designs were then used as new actants to test the strength of these ANT co-evolutionary pathways in a further set of interviews and group discussions. These participants imagining enacting these new actants show whether or not the new actants are perceived as facilitating a desired new water-cycle, the importance of its relation to other actants, and what other network relations would need to be created or modified in order to make these actants a reality.

This is not a common way to use design in research. Design research is generally conceived to have three streams: research in design; research for design; and research by design (Clark and Brody 2009; Downton 2003; Michel 2007). Research in design, is research that seeks to understand designers, design methods, and designed objects. Research for design, is research that is conducted in order to generate new material configurations. The interviews, group discussions and water diaries of this research fall into this category. Research by design, is knowledge created through the act of designing. This is typically knowledge that is held by the design team, writings, drawings and models of the designed object and in the object itself. There is some element of this knowledge in this research. However the main use of design in this research is to generate knowledge about the network enactments and alterations that would be or need to be produced in order for these new water-cycle actants to emerge.

The use of interviews, group discussions and water diaries in research for these designs comes close to what Shove identifies as a yet unchartered "practice oriented design" (Shove et al. 2008) because the designs used as its basis ANT co-evolution pathways that were identified by people's daily domestic water-cycles. However because the research uses an ANT framework, it used these new design actants as a catalyst to open the black boxes of proposed actants and in so doing, it allowed an articulation of existing and yet to be actants that operate within the network. Thus the use of design reached beyond the use of practice to inspire design and beyond the knowledge acquired by designers and their designed objects, to use design as a method to investigate the network relations that enable the enactment of new actants. These new network relations also opened the "black box" of existing network relations to facilitate a critique of their enactment without their disruption, which is the typical moment in which black boxes are opened (Kaika 2005; Sofoulis 2005).

Introducing this method of design to an actor-network theory socio-technical co-evolutionary analysis is also a methodological innovation. ANT has been used to investigate the process designing and the coming into being of an actant or dissolution of a potential actant (Callon and Law 2005; Latour 2009; Yaneva 2009a). The socio-technical co-evolutionary perspective has been used to investigate the introduction, acceptance and continuing modifications of designed objects (Shove et al. 2008). However neither of these frameworks has used design to project the possible trajectory of new ANT co-evolutionary pathways and what networks and actants would evolve and emerge from these possibilities.

Designs, as proposals for possible reconfigurations of the material world, have been used as a way to investigate existing and potential networks and actants from which today's water-cycles are made and tomorrow's water-cycles might be made. Using design as a method of research is a development of research by design, and also an innovation to ANT and socio-technical co-evolutionary analysis.

**Stage 3: Following First New Networks**

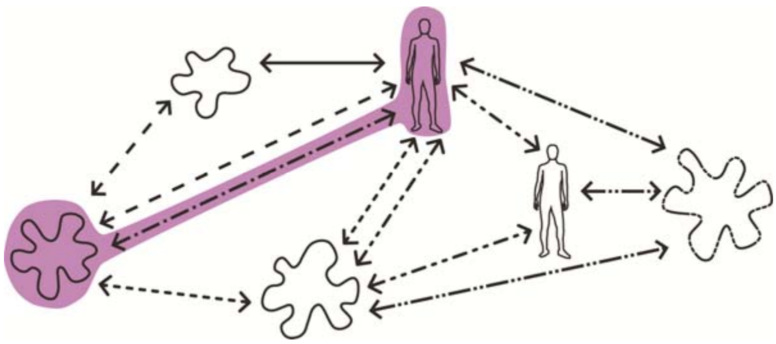


**Figure 4.6**
**Stage 3: New human and nonhuman relations**

The second individual interviews and group discussions were aimed at exploring how the original participants in the first interviews and group discussions reacted to the ideas of material and implied social change described in the design synthesis. These second group discussions and individual interviews asked the same questions and used the same materials. There was no need to change the script between the group and individual format because having completed the first group discussion and a water diary, most people now had a similar level of consciousness about their own water use and the same knowledge base about water use that was provided in the first discussion, hence it was unnecessary to allow additional time for the group discussions to find a common understanding of water to formulate amongst the group.

This second stage of engaging in discussion with the participants first asked if the first interview or group discussion or water diary had any impact on their lives. It then asked if there had been any changes to their water use in the intervening period through the installation of new technologies or changes to water practices. This was used to both recall the previous discussion and to see if there had been any changes to their personal and professional water-cycles over that time. Then the designs were workshopped, starting with flooding, then water reuse, and finally pollution prevention (appendix H and I for scripts). Each thematic design set was workshopped from the present time to the 100 year time to see if it was possible for human actants to anticipate their own co-evolutionary change if they were placed in a new imagined circumstance.

The design workshop component of the discussions started with the flooding scenario because the responses in first interviews towards flooding were polarised, simplistic and also improbable actions to implement in reality. It was also the scenario had not been covered by the group discussion, therefore the designs for this theme was used as a warm up for the respondents to get used to the materials that were shown to them. Water reuse was placed in the centre of the three circumstances because this was the most likely area for change as it had a strong thematic agreement in both individual interviews and group discussions. It also had the most design propositions of the three scenarios. The last set of design propositions to be workshopped was pollution prevention and fertilizer creation. The designs of toilet modification were the last ones of the interview because the previous group discussions and interviews indicated that this would be the most challenging changes to people's current practices of sanitation. This was a two stage rather than a three stage design proposition because toilet technology is a material actant that is difficult to modify, therefore the first stage involved a behaviour change, while the second stage was a replacement of the existing toilet actant for a new dry sanitation system. These were the most radical suggestions of material change and provided a foil against which the participants could reflect on the other two sets of propositions. The final question asked for any additional questions or comments.

The pilot of this interview was mostly successful in eliciting new network relations from the participants. The only modification of the script was to drop the third scene from the pollution prevention and fertilizer creation proposal because it illicted no further actant relation insights than the second scene.

**Second Assemblage of Human Actants**

The second interviews began in the spring of 2010, and were finished at the beginning of summer 2010. There was a six month interval between the last interview of the first stage and the first interview of the second stage. The group discussions began in the spring of 2010 and were finished by midsummer 2010. There was a seven month interval between the last group discussion of the first stage and the first group discussion of the second stage.

In total there were forty participants for the second stage of interviews and group discussions. Twenty nine people were individually interviewed and eleven people participated in facilitated group discussions (figure 4.7). All the people who participated in this stage had previously participated in the first stage of interviews or group discussions. Of the twenty nine people who were individually interviewed in the second stage, two had previously participated in group discussions. This means that amongst the individual interviews there was a 90% return rate, and a 56% return rate for the group interviews. Overall 75% of my respondents returned for the second stage of interviews or group discussion. This means that the age range and mix of professionals participating in the second stage of research remained as diverse as the first stage, but there were significantly less environmentally aware citizens in their 20's and 40's participating in the group discussions.


**Figure 4.7**
**Interview and group discussion II participants**

The reasons for the discontinuation rate from the individual interviews was that one person was on maternity leave, and two people were not recontacted from the first interview as one would not consent to an audio recorded interview and the other was not willing to answer the questions asked. The higher discontinuation rate from the group discussions was due to the fact that this stage was presented as an option for additional participation in my research, whereas the individual interviews had a committed obligation to participate in both interviews and the water diary from the outset.

The interviews and group discussions mostly took place in the same location as the first interviews and group discussions. Only three group discussions could be organised as there were not enough participants to form five groups. These groups retained the same participants as the first group discussion. Two people who initially participated in a group discussion were interviewed individually because they could not attend the scheduled time of second group discussions. I undertook all the second individual interviews and group discussions.

**Stage 4: Synthesis to Second Water-Cycle Reconfiguration**

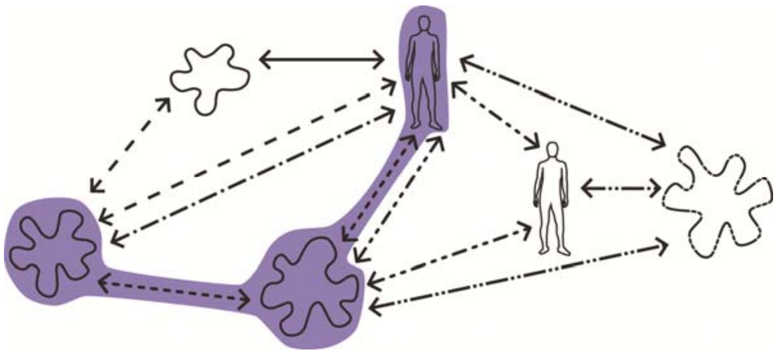


**Figure 4.8**
**Stage 4: New nonhuman**

The second individual interviews and group discussions were thematically analysed for particular nonhuman material changes that were strongly favoured by the human actants. The three strongest changes: water reuse, polyculture, and remove and compost, were then further developed by altering the material configurations of the design in ways that responded to the barriers expressed by the humans imagining the implementation of these changes, and by finding physical prototypes of these material changes where possible. These three material changes were expressed as a single step change that could be implemented today, rather than repeating the format of suggested ANT co-evolutionary changes over time that was undertaken in the second interviews and group discussions.

There were three reasons why these material changes were expressed as a single stage change. Firstly, the second interviews and group discussions showed that people did not imagine themselves co-evolving. Most steps were assessed in comparison to the existing relations with the material world today, rather than a future point in time where their material world would have changed. Secondly, these nonhuman design proposition actants would be used in a third group discussion, which would include human actants not previously involved with the research. These included the people facilitating the group discussions as well as people participating in the group discussions. Therefore more time had to be allowed for finding a common water understanding, clarifying the design proposition and the discussion to develop. Thirdly, the previous discussion tested a wide range of design ideas whereas these design propositions tested for changes that showed a high probability of co-evolving today.

These design propositions only covered water reuse and transforming waste because there were no ANT co-evolution pathways related to flooding described within people's reactions to the proposed actant changes in the second interviews and group discussions, regardless of whether or not they lived in an Environment Agency designated flood prone area.

**Stage 5: Following Second New Networks**

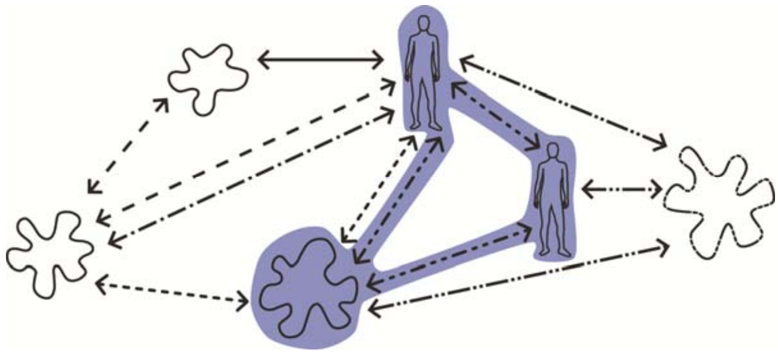


**Figure 4.9**
**Stage 5: New human and nonhuman relations**

The third set of group discussions were conducted in a workshop format held on a single evening on the 24th November 2010 at Abbey Mills Pumping Station in Stratford, London. This workshop examined how new human actants and previously enrolled human actants would react to the new nonhuman design actants developed from the ANT co-evolutionary pathways found by investigating the daily and imagined water-cycles of the previously enrolled human actants. All the group discussions at the workshop followed the same script and used the same materials. There was no necessity to vary the script because every table contained a mixture of previous and new participants to the research.

After general introductions, the participants were asked to locate themselves in the water-cycle by drawing a diagram or writing words. Drawings were encouraged because this is the format of communication in which designs are usually conveyed, but not a typical form of communication for people outside of the design and fine art disciplines. Drawings can quickly describe changes in material relations that can be hard to convey in words therefore this was an opportunity for participants to warm up both their visual skills to understand the design drawings and their own drawing skills to gain confidence in conveying information in this manner for use during the design discussions. This part of the discussion also allowed an exchange of information and understandings of how people affect water in an urban environment and gave each group a common set of ideas from which to work with.

Following this the designs were workshopped starting with the "Take Away Sink", then the "Polyculture Reuse Community" and closing with "Remove, Gas and Compost" (appendix J for script). The design workshop component started with the "Take Away Sink" design because this proposal was only about personal change and was an easy to understand design; therefore it was a gentle introduction to the material with the least complicated set of relations to respond to. The "Polyculture Reuse Community" was discussed second because it was a complicated design diagram to absorb and represented a substantial shift to the current urban water-cycle as it was originally presented as the 75-100 year design and therefore would require more time and energy to understand and debate. The final design proposal discussed was "Remove, Gas and Compost" because it represented the most substantial change to people's daily lives and wastewater infrastructure. The final part of the workshop asked for any additional questions or comments.

The pilot of this script did not change the order of the script however some additional diagrams were added to help describe the changed water relations.

**Third Assemblage of Human Actants**

In total there were thirty five participants who took part in one of eight group discussions. The workshop formed part of a public engagement event that also included a tour of the historic pumping station, a presentation of sewerage upgrade works by Thames Water Utilities, and a presentation of the preliminary results of this research. Participants to the workshop were invited by previous participants in the research, email invitations, and newsletter notices.

Sixteen people had participated in the first two interviews and group discussions, nineteen people were new to this research. Of the nineteen new people, seventeen were environmentally aware citizens and two were water professionals working with Thames Water Utilities. There were eight water professionals participating in this stage of the research, which was a significantly less proportion of professionals than the previous stages. Of these eight water professionals, five had participated in the previous stages of the research, four of whom also lived in the lower Lea watershed. There was also less diversity amongst the companies represented by the water professionals who participated, three of whom worked for Thames Water (figure 4.10).

There were a mix of ages of the participants ranging from people in their 20's to people in their 70's, however no precise figures were recorded for the age distribution amongst the participants. There was a fairly even mix between male (19) and female (16) participants. The participants in this workshop were mostly from London, only one participant came from Cambridgeshire outside of London. A wide spectrum of London boroughs were represented including: Hackney (10), Haringey (7), Tower Hamlets (3), Camden (2), Lambeth (2), Kensington and Chelsea (2), Westminster (2), Barnet (1), Brent (1), Waltham Forest (1), Havering (1), Newham (1), and Islington (1). Approximately twenty two of the thirty five (63%) of the participants lived within the lower Lea river basin. This large portion of people from the lower Lea river basin was achieved by the personal invitations sent to all the previous participants in my research for this event. Furthermore, they were also invited to bring along someone who was interested, or to forward the invitation to people they thought would be interested in participating, some of whom were likely to be friends and neighbours who lived within the watershed.

These participants represent a diversity of sex, age, and boroughs in London. However they also represent a select group of people who are most interested in water infrastructure, and very motivated towards finding ways to change for environmental health and human sustainability in the future. The venue, Abbey Mills Pumping Station, was a motivator for a small proportion of participants who wanted to visit this historic piece of London's sewerage infrastructure, but its difficulty of access by public transport was an impediment for those less motivated about discussing change to water. The broad range of age and sex of these motivated individuals show that in London, water is an issue that cuts across age and gender differences.

The people in each group discussion were partly determined by me and partly determined by the people who attended the event. The table seatings were such that each participant was to feel secure to express their personal opinions, without inhibition from the potential judgements from colleagues, friends, or family; or be coerced by the strength of a particular direction of opinion that could result by supportive opinions from family, friends and colleagues within a dialogue. To achieve this, it was necessary to divide colleagues, friends and families into different groups. It was easier to determine the range of experience with my research, mix of genders, and mix of ages, via table settings.

On the actual evening, the table settings provided a rough framework around which I could adapt. Fourteen people who accepted the invitation did not attend and three additional people who had not replied attended. These changes meant that though it was intended to have tables of 5-6 participants spread over 9 group discussions, on the evening there were 8 group discussions with tables of 4-5 participants and one table of 3 participants. This table was deliberately left small in order to accommodate any late comers. All tables were a mix of men and women, and every table had an age range of at least two decades.

One group had no water professionals within it; one group had no previous participants; and one group had two water professionals. Two groups had a majority of previous participants, five groups had a majority of new participants, and one group had an equal number of previous and new participants (figure 4.10). The results show no discernible difference between the conversations between these different groupings of people. Each group had a unique set of concerns, some of which were common across many groups.

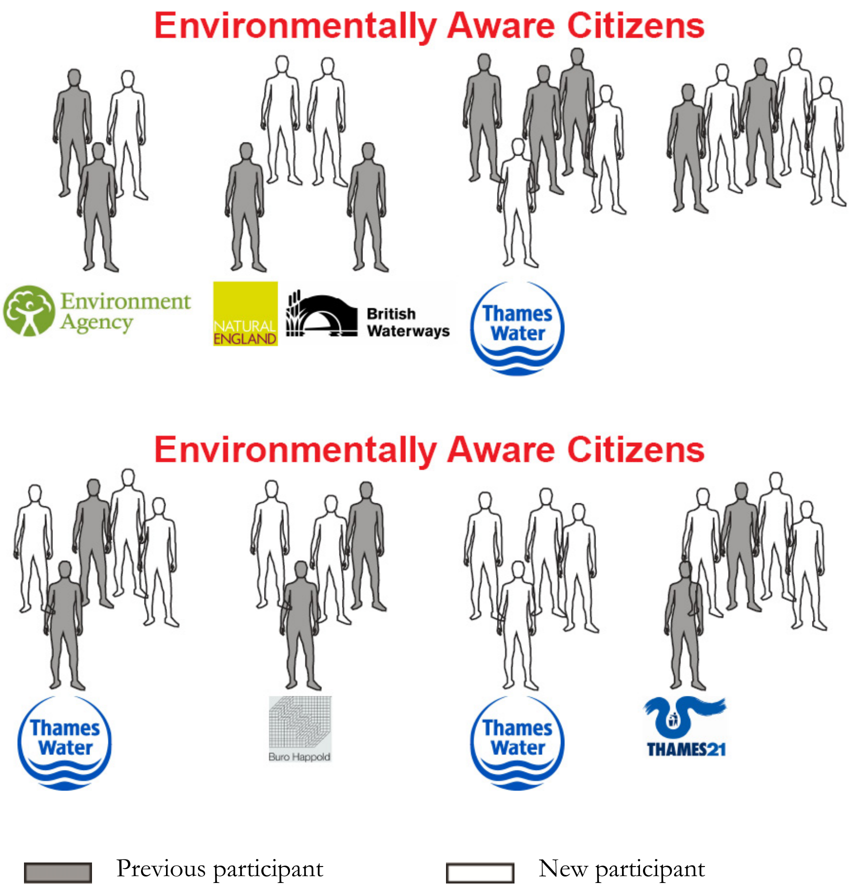



**Figure 4.10**
**Workshop group discussion tables**

All of the group discussions were conducted by two trained facilitators trained by me. These facilitators were MSc and PhD student volunteers. For each group there was one verbal facilitator whose main role was to introduce each nonhuman actant, to ask pertinent questions to draw out the conditions of human enrolment or nonenrolment with the new actant. The other facilitator's role was to note what was said and to observe the group dynamics to make sure that all viewpoints had been given the chance to be heard.

Each facilitator attended one three hour training session. Prior to the training session they were given an extract to read about facilitation in general. The training was a mixture of general facilitator skills such as question types and body language, and specifics for the group discussion they were conducting such as the script and additional technical information. All the facilitators felt that they received adequate training to undertake this role.

**Conclusion**

The method of research was an iterative process that first began with an ANT understanding of existing human and nonhuman relations that make the water-cycle in the lower Lea river basin from the points of view of multiple perspectives made by environmentally aware citizens and water professionals. It then tested the network relations of this water-cycle by changing the water actant to be scarce or cause flooding. The changing relations in the existing water-cycle and the changed water-cycle were then merged to form an idea of fragile and strong network relations in which a new actant could be mobilised. This new actant was synthesised in a process of design. These new actants were then inserted into existing and future network relations in further interviews and group discussions, which resulted in ideas that indicate ANT co-evolution pathways that are available to reconfigure the urban water-cycle in the lower Lea river basin given current practices and material legacies.

This methodology combines qualitative data gathering with design synthesis to initiate an ANT co-evolutionary projective process for the reconfiguration of the current water-cycle in the lower Lea river basin. The design projections mimic the types of ANT co-evolutionary processes described in historical studies (Geels 2005; Melosi 2000; Shove 2004; Shove et al. 2008). This identified and tested the strength and fragility of relations between actants within the existing network and tested them for potential ANT co-evolutionary pathways for future water-cycles. This is a new way of using design as a method of research and extends the application of ANT and co-evolution from historic case studies to potentially projective case studies. In addition, the methodology examines whether or not human actants can anticipate or imagine co-evolutionary change of extended timeframes from today to 100 years hence.

## Chapter Five

# WATER-CYCLES FOR OTHERS

Water-cycles for others were only created by water professionals in this research. These water-cycle assemblages were characterised by the management of water quality, quantity and location for purposes that firstly and predominantly benefit other people or other biota rather than the individual causing this effect. This included water for ecological purposes, planning policy for water management, surface-water, site planning and design for water, water resource planning, drinking-water conservation, canal-water management, groundwater, drinking-water, wastewater, river-water quality improvement and public engagement with water. These water-cycle influences showed the greatest amount of diversity because no two people had the same matter of concern about water.

Typically these water-cycles were also characterised by a narrow water concern, with an actor-network assemblage that covered a wide geographical territory. While these water influences also assembled the water-cycle of the lower Lea river basin, the water-cycle assemblages often covered territories that were much larger than the lower Lea river basin. The size of each territory that was assembled depended on the different actor-networks within which the water professional was enrolled or was attempting to enrol. These territories were often dependent on nonhuman actants such as piped water networks, canals, administrative boundaries, land tenure, monitoring equipment, reports, and so on.

The water-cycles formed by these water professionals do not form a single coherent actor-network assemblage of all the relations that form the urban water-cycle because these water professionals have different matters of water concern that relate to different actants. Furthermore they do not share the same boundary objects or describe closely linked actor-networks. Moreover within each water-cycle influence described by individual water professionals, there were nearly no daily regularities. This meant their effects fluctuated within different networks and depended on the project that they were enrolled in at any point in time.

Each professional water-cycle reflected the fact that each person took part in managing a narrow specialised matter of concern within the urban water-cycle of the lower Lea river basin. Most water concerns developed over time within a project. This accounts for the lack of daily regularity because actants, including the water professional, were continually being problematised, interressement, enrolled, mobilised and stabilised for the different stages of the project. For the water professional this meant that they would have different inputs during the different stages of a project. During this time their influence over the water-cycle was also varied.

This lack of similar matters of concern across the water professionals who participated in this research and the continual process of problematisation, interressement, enrolment, mobilisation and stabilisation in which the water professionals were engaged meant that there were no obvious ANT co-evolutionary pathways for water-cycle reconfigurations in the lower Lea river basin to be found within these water-cycles for others. Even though there were no obvious ANT co-evolutionary pathways for water-cycle reconfigurations within the professional water-cycle, there was also no obvious end to the process of continual problematisation, interressement, enrolment, mobilisation and stabilisation. This means from the perspective of individual water professionals and their matters of concern the water-cycle is in a continual process of co-evolution, but it is difficult to identify any dominant ANT co-evolutionary pathways.

This chapter describes the relational effects of four water professionals on each other through the use of other actants. These four water professionals do not know each other, yet they can be traced as one actor-network that has a concerted effect on the urban water-cycle in the lower Lea river basin. Anne is concerned with water to maintain and enhance ecological habitats; Felicity is concerned with regulating groundwater levels; Samuel is concerned with ensuring adequate water resources for the future; and Roger is concerned with the efficient supply of drinking-water to Thames Water customers. Each water-cycle assemblage recounts the limits of the influence of each water professional, their matters of concern and how their professional role might change in times of regular flooding, or prolonged water scarcity.

This chapter also looks at the types of nonhuman actants that were typically mentioned by water professionals in their explanation of their water influences and the types of nonhuman material relations that were documented in their water diaries. Finally it summarises the changes that were imagined by water professionals in assembling water-cycles for others in times of regular flooding or water scarcity.

**Ecological Water Management**

This professional water-cycle is from a Senior Conservation Officer at the Lea Valley Regional Park Authority (LVRPA). The water which is Anne's matter of concern flows within the boundaries of the park (figure 5.1) and is used to maintain particular ecosystems within the park. She is also a statutory consultee for a bigger boundary that ensures that drainage and biodiversity within the park are not damaged by new developments beyond the park boundaries.

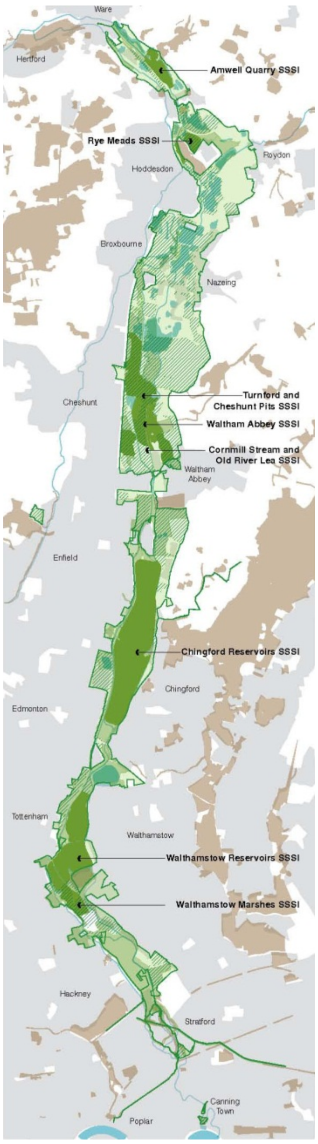



**Figure 5.1 Lea Valley Regional Park Authority**
**(Lee Valley Regional Park Authority 2007)**

To manage flows within the park, there is an abstraction licence managed by the Environment Agency (EA) that allows Anne to pump water out of lakes, rivers or boreholes to add water to habitats as needed. Anne instructs for the abstraction and distribution of water around the land where it is needed to preserve the water meadow habitats within the park boundaries. These volumes of water abstracted are reported to the EA annually.

The maintenance of these particular habitats and their water flow is dependent on fulfilling the species targets that are set in the Biodiversity Action Plan (BAPs) documents. These BAPs are nested targets that cover the national area, then a regional area, and finally down to a local area. These plans give targets for the conservation of species which need to be reported back nationally through the biological actions recording, which is a computer package hosted by the Joint Nature Conservation Committee. At present, the focus of the north east London BAP is changing from being centred on species conservation to habitat conservation. Anne believes that this will result in a more integrated landscape scale approach to managing the park and its surroundings. She is involved with writing the BAP for the local scale of the Lea Valley Regional Park and sits on the committee for regional BAP.

Restoration plans detailed how the park aims to achieve BAP targets. Ponds and reed beds had particular wildlife importance. The two restoration plans mentioned all involved creating and changing water habitats, which were planned to occur over long periods of time. There was the restoration of the gravel pits that has been ongoing since World War II, which involved the creation of ponds, where the great crested newt now lives. The other place was Holyfield lake, which has a 15 year restoration plan and for which two years of restoration work had just been completed.

The Lea Valley Regional Park also has a development plan as a whole park, which has a 10 year time frame. This "Park Development Framework" (Lee Valley Regional Park Authority 2007) document was out to public consultation at the time of the interview. This plan has taken a few years to formulate by the planning and environmental design team to direct the landscape character of the park and hence water management over this next time period.

The 2012 Olympics to be held in London has temporarily altered the park boundaries and have also focussed attention on improving the water quality in the Lea river. In particular the water quality between Tottenham and the Olympic site has been improved. This improvement was a project between British Waterways and the Environment Agency and did not involve Anne or the LVRPA though it does improve the amenity of the park.

Particular creatures in the LVRPA which are the focus for the public engagement events that Anne takes part in are bats, moths, birds and water voles, dragonflies, and wading birds, all of whom have a favourable habitat in the park due to Anne's water management that maintains the habitats in which they live.  These biodiversity events for the public are held in partnership with Hertforshire and Middlesex Wildlife Trust and The Royal Society for the Protection of Birds.

Fishing and sailing are two types of recreation in the park that involve open water bodies. LVRPA manages these water bodies and leases them to clubs who manage the recreational activity. To maintain fishing stocks, the fisheries department manage the licenses for fishing, while the LVRPA monitor the fish population and pay for new small fish to boost the population in the lakes. After the 2012 Olympics, the white water rafting venue is an additional open water body recreation that will be added to the management by the LVRPA.

Anne mainly manages two types of water: surface and groundwater. Her main aim is to ensure that water is diverted to maintain the habitats important to species in the BAPs. Additionally she ensures that this water management maintains its significance by being involved in public events that educate other citizens about the biodiversity in the park. Anne's surface-water management also affects the diversity of ways people can interact with water bodies by creating areas in which they can fish and sail.

Prolonged water scarcity or flooding would change habitats. It may no longer be possible to achieve BAP targets. In this extreme, it might be necessary to consider moving habitats to other locations and Anne would manage different ecologies suited to the altered water regimes.

**Groundwater Abstraction Licensing**

Felicity works for the Environment Agency as a hydrogeological technical officer in the North East Thames Region. About 70% of her work is to assess groundwater licenses in accordance with the Catchment Abstractions Management Strategy (CAMS) produced by the EA. She is part of the team responsible for providing the assessment that allows Anne to continue abstracting groundwater to maintain ecologically significant habitats. The other 30% of her work is to represent the groundwater in the CAMS in order for the EA to achieve an integrated strategy for water management in order to accomplish the targets set in the EU Water Framework Directive. Abstraction licensing forms part of the national integrated water management strategy. Felicity is directly responsible for assessing Section 32 of the applications, which is the hydrogeological assessment of the impact of the requested abstraction. She also does some work with shallow surface-water bodies such as fisheries or lakes, and checks on water flow from springs.

The abstraction licenses that Felicity assesses are all over $20m^3$/day because each landholder or household has the right to abstract $20m^3$/day without a license. Water flow measurements from pump tests, water feature surveys, and maps of locating other approved abstraction licenses, help Felicity make her assessment as to whether there is sufficient groundwater for an additional abstractor. She will usually form a first impression from this data,

> *If it's favourable I'll ask them to do a water features survey which they have to look within a specific radius of the abstraction to see if there's any surface-water and groundwater abstractions and anything else that could be impacted. I review that, then if I decide it's ok, then it will go forwards to issuing a consent, to allow them for up to six months, drill test and anything to do with the boreholes. And then from there, if I decide there isn't any impact on any of the other abstractors or any surface-water features or anything else, it could go forth to national permitting, and then they could get a license.*
> *Felicity, 24 July 2009*

Felicity's assessment is one step towards national permitting. Felicity makes her recommendation to another set of people who assess it for a wider environmental impact. If they feel that there might be an adverse impact, they will add restrictions to the permit to ensure that this can easily be monitored.

All the applications that she has recommended for approval will expire March 2013. After this date the abstraction will be reassessed, may be removed, or the abstractor might revoke it. Each application is assessed individually as their relative location changes their influence on the derogation of other abstractions and water features such as springs or water courses. This makes the impact of each abstraction on groundwater different.

The monthly spring surveys in the upper Lea river that Felicity takes are used as an early warning sign to indicate the level of ground water. A high flow indicates a high water level and flooding maybe imminent; and a low flow indicates a low water level and drought may be imminent. The information that Felicity gathers is passed through chains of people who then act on this advice to direct the management of water. Additional groundwater might be abstracted to prevent flooding, or warning might be given to water companies to prepare for drought conditions.

Felicity has a strong sense that the water-cycle is highly modified and managed by people. In London the groundwater is managed because

> *You don't want water levels in the Chalk to get to far above the base of the London Clay because then that can cause pressure issues and problems with flooding; and you don't want it to go too far down into the Chalk because then you have management issues because you won't have as much water as people want and...it will go too deep to be got at...You have to make sure that the levels are well enough managed that they're kept at a nice sort of straight level almost. There's going to be a little to-ing and fro-ing, but that's the general idea of it.*
> *Felicity, 24 July 2009*

Even though the EA works toward protecting the environment, what is natural is hard to define.

> *We've changed the landscape so much I don't know if people really remember what it was before. I guess it was just woodland thousands of years ago, but I'm not sure again where you draw the line and say that was natural before. I think it's been changed for so long, we don't know really.*
> *Felicity, 24 July 2009*

A new source of concern for Felicity are the ground source heat pumps that people are installing into the chalk aquifer for heating and cooling buildings. These heat pumps are creating artificial water mounds in the Chalk that are starting to interact with one another.

Felicity has a direct influence over the water-cycle because through the granting or denial of licenses she influences how much groundwater becomes surface-water or drinking-water at a particular location. Her management of abstractions is based on interpreting nonhuman signals of water levels from pumps and springs in conjunction with the EU Water Framework Directive. She also has a diffused influence over the water-cycle because her monthly spring surveys are reported to other people who then decide how to act on the information she has interpreted from the water measurements she has taken. Felicity's other diffuse influence is in her translation of her matters of concern about groundwater into matters of fact by their stabilisation in the CAMS document, which is then used by other water professionals as a matter of fact.

In the case of flood and scarcity Felicity imagines that the role of licensing would not change. Abstraction would be more stringently monitored in times of scarcity and perhaps license holders will need to be told that they may not abstract. This would cause them problems, particularly as the large abstractions are for public water supply. Information about groundwater levels will then need to feed into other government reports that would look to reduce water consumption and abstraction to manage the water resource.

**Water Resource Planning for Domestic Development**

Samuel works for the Environment Agency as a Principle Officer for water. He impacts on many types of water in a diffuse way through his assessment of planning applications for building developments of regional significance. His approval or suggested changes directly alter the quantity and location of drinking-water flows, rain-water, and surface-water. He provides opinions about water on a daily basis to local authorities, water companies, and other government departments about their water strategies. Samuel leads a team of people that have an overview of water development in England and Wales, which provides the central government position on water and support to the area officers of the Environment Agency. This team has an influencing role on the water-cycle through their response to various development frameworks. Samuel and his team's assessment of the appropriate management of water mobilises Felicity's assessment of groundwater resources as a matter of fact amongst other sources of evidence on which to base their advice.

Samuel has four projects that he is working on: "Water Neutrality", "Water-cycle Strategies", "Water Framework Directive", and "Ground Source Heat Pumps". The aim of "Water Neutrality" is to create guidance for new urban developments so that these developments would cause no net increase of drinking-water use from the water utilities provider.

The "Water-cycle Strategy" aims to link potable water, sewerage capacity and flood water in an integrated approach between water companies and development objectives. The link between potable water and sewerage capacity is discussed with the water companies and is included with the review of their 5 yearly asset management plan. The flood-water aspect is beyond Samuel's remit.

Samuel plays a support role for the "Water Framework Directive" for water efficiency and retrofit. This has a domestic focus because it is generally believed that industrial and commercial water uses are efficient in order to save money by saving water. Samuel believes there is a lack of evidence to support this claim, especially with regards to water use in offices. Within this project Samuel also aims to promote the exploitation of local water sources and reduce bulk water transfers.

"Ground Source Heat Pumps" are increasingly being implemented in new developments especially in north London. At present there is no overview of these projects. Closed loop heat pumps are not regulated but as Felicity identified, it causes artificial water mounds in the aquifer. As an initial step

Samuel feels that a register needs to be created for these systems. It is currently under discussion as to how and to what extent this new groundwater use needs to be monitored.

Samuel's water impacts are diverse, but also diffuse. His advice impacts on all aspects of the water-cycle: groundwater, surface-water, rain-water, drinking-water, and wastewater, at a planning stage. Samuel influences the general direction of the quantity, quality and location of these waters, but this influence relies on his advice being correctly interpreted and agreed with by other humans, which then leads to creation of documentation to direct the alteration of these waters, which need to be again interpreted and transformed many more times by many more humans and nonhumans before it becomes a built reality. At any point these interpretations and transformations by humans and nonhumans could betray Samuel's advice, in which case his influence over the water-cycle would be lost.

In times of flooding and scarcity Samuel anticipates that his professional role to give advice to the UK government would change its focus with regards to the changed water actant.

**Drinking-water Infrastructure**

Roger works for Thames Water Utilities as a Senior Consultant for the Networks Supply Chain. He impacts directly on water through the development, installation and maintenance of pipe technology for drinking-water supply. The matter of concern for Roger is to create ways that drinking-water can be conveyed to Thames Water customers using as little energy and with as little leakage as possible so as to lower the unit cost of drinking-water. Roger's work is influenced by Samuel's assessment of the available quantity of drinking-water in the Thames Water drinking-water service boundary for new developments because this will result in more customers. New customers require new efficiencies to be found to deliver to the expanded network whose source of water is limited by water abstraction licenses and rainfall; and techniques to make new connections that minimise disruption to existing customers by shutting off mains and digging up roads.

In order to lower the unit cost of drinking-water by using as little energy and with as little leakage as possible Roger researches different types of materials for pipes, different methods of their installation and invents new configurations and techniques that can be used to deliver a lower drinking-water unit cost. Roger's research investigates both the replacement of existing pipes and the laying of new network connections. Before these new configurations and techniques are rolled out to where they are applicable within the Thames Water Utilities drinking-water service boundary, Roger trials the new materials and methods of installation. During their installation, Roger is on hand to troubleshoot any unusual problems. After their installation he investigates any failures looking for its causes, finding solutions to repair the failure, and adapting the configurations and processes he created to prevent future failures in new installations.

Roger is on a constant look out for any innovations for water distribution including products and processes of systems of delivery, management of people and new technologies. This is done through informal professional networks; people moving from other drinking-water suppliers; and direct contact with the suppliers of the material components. There are also formal nationwide networks of people who work together on research projects for which they have common matters of concern. This research is funded by the UK water suppliers and the UK government, through the Technology Strategy Board in the Department for Business, Innovation and Skills. These projects are expected to develop new products and exchange knowledge of the new products developed. These research projects are usually done in conjunction with universities. The findings of this research are then expected to be exported overseas to benefit the UK economy.

The materials and techniques that Roger has configured involve polyethylene pipes and trenchless techniques to thread them through the ground to replace old water mains or to expand the drinking-water network. The trenchless technique is very different from cutting a trench, laying the pipe, and then covering it to remake the ground surface. The trenchless technique does not disturb the ground surface. Roger estimates that this equates to a cost saving of 30% in comparison to traditional methods of cut and cover. This trenchless technique uses polyethylene pipes because they come in long strings that can be threaded through the ground unlike traditional iron pipes. Polyethylene has the additional advantages of being smoother than iron pipes, therefore it has less hydraulic resistance thus takes less energy to convey the water through it; they are also more hygienic because they can be sealed in the factory; the joints can be welded together so leakage can be reduced; they do not discolour the water due to corrosion in the manner of iron pipes; and they can be commissioned with under pressure techniques so that existing water mains to which they connect do not need to be shut down during the installation. The trenchless technique with polyethylene pipes answers Roger's main matter of water concern to lower the unit cost of drinking-water delivery by increasing the energy efficiency of water supply and reducing water leakage. It also answers two subsidiary matters of concern for Roger, to maintain the flow of water to existing Thames Water customers during installation, and maintaining water quality.

Roger is also involved in mobilising and stabilising this outcome of the processes and materials that he has configured for future installations of trenchless technology to lay pipes, by co-authoring standards that are intended to be published by the International Organization for Standardization (ISO). The standards published by the ISO are intended to stabilise materials and processes around the world. If these standards are enrolled in future projects, Roger's configuration of materials and processes will be enacted and become more stable through their continued use. Thus Roger's work will have a worldwide effect if this standard is adopted. It will also become a 'black boxed' actant because the matters of concern that initiated its development as a network of relations such as cost, hydraulic efficiency, prevention of leakage, and water quality will no longer be evident, instead a series of processes and products will be described to be adhered to if ISO accreditation is to be achieved. This changes the matter of concern to achieving ISO accreditation and the standard is a 'black boxed' actant in its achievement.

Roger's water impacts directly affect drinking-water. His material configurations direct new flows of drinking-water and the manner in which it flows. Roger is also actively involved in stabilising these material configurations by writing standards for a worldwide application. When these standards are enrolled and mobilised in creating new drinking-water networks with ISO accreditation, Roger's matters of concern that initiated these standards become 'black boxed' because the effect of the ISO standard is to shift the matter of concern from effective drinking-water delivery relative to a particular set of material relations, to ensuring that the materials and processes described within are adhered to.

In times of flooding and scarcity Roger anticipates that his professional role would expand. In times of scarcity, new efficiencies would need to be found within the drinking-water supply delivery. This calls for new material configurations and techniques to be developed. In addition new water sources such as grey-water might need to be exploited, in which case more pipes would need to be laid and new tests made to ensure the suitability of the material configurations and processes developed for drinking-water would deliver the intended result with the new water type. In times of flooding Roger anticipates that the distribution of where the population lives would change. Once more, this would result in the laying of new pipes and an expansion of his role within the water-cycle.

These four professional water-cycle assemblages show how each person has a narrow matter of water concern, but a wide geographic territory of effect. These four professional water-cycles have been shown to effect each other, however this link is not direct, but diffused through other actant relations such that these water professionals do not necessarily know their effect on each other.

This has been a linear tracing of one actor-network water-cycle that is assembled within the lower Lea river basin. Each water professional has more effects on more actants and the water-cycle than can be described here.

**Typical Nonhuman Actants In Professional Water-Cycles, 2009**

The most outstanding feature of the professional water-cycle was the number of documents that were mentioned in relation to water. Only one environmentally aware citizen named books that they had read in relation to water, all other reading material related to water was mentioned by water professionals. Most often people mentioned reports, policy, and legislation that they were translating into practice (appendix E for list and summaries). These reports, policy and legislation helped to stabilise a particular enactment of the water-cycle because they were mostly enrolled as matters of fact to be mobilised.

Most documents were cited by only one professional, seven documents were cited by two professionals, and four documents by three professionals. This low level of cross referenced documents shows that each water professional had a narrow water concern in the water-cycle and also shows the diversity of roles professionals play within the water-cycle of the lower Lea watershed.

The four documents cited by three water professionals were the "Catchment Abstractions Management Strategy", the "Site of Special Scientific Interest" designation, "Planning Policy 25: Development and flood risk", and "The London Plan: Spatial development strategy for greater London". These four documents represent the overlapping matters of water concern.

The "Catchment Abstractions Management Strategy" (CAMS) was mentioned by Elsie, Natural England; Daniel, Waterwise; and Felicity, Environment Agency. Elsie, Daniel and Felicity's water concern was to preserve aquatic environments. Elsie did so by enrolling the public to appreciate and care for aquatic environments. Daniel did so by enrolling public and private enterprises in networks that conserved the domestic use of drinking-water. Felicity did so by being enrolled in the process of issuing limited abstraction licenses. The CAMS describes the state of rivers and streams within a catchment area at a particular point in time. It also documents the water quality aims of the Environment Agency with regards to the development these rivers and streams. The CAMS is updated on a regular basis. Elsie, Daniel and Felicity used the CAMS in a different manner. Elsie and Daniel used CAMS as a matter of fact, to identify rivers of varying ecological quality to inform the more urgent areas for their work. CAMS was a matter of concern for Felicity because she could alter the water quality to different rivers through the management of water licenses that she assessed. The CAMS also formed a benchmark for Felicity, whereupon she could assess some of her effect on the water-cycle through the re-evaluation of the ecological condition of these rivers over time.

The "Site of Special Scientific Interest" (SSSI) designation was mentioned by Anthony, Tower Hamlets Council; Elsie, Natural England; and Anne, Lee Valley Regional Park Authority. Anthony, Elsie and Anne's matter of water concern for the preservation of significant wetland habitats overlapped. Anthony did so by creating Tower Hamlets Council policy documents that enrolled the areas designated SSSI. Elsie did so through the enrolment of the public to appreciate areas of SSSI. Anne did so through her mobilisation of water to maintain the SSSI. The "Site of Special Scientific Interest" is a national designation set by Natural England, which identifies the best examples of different habitats throughout the UK. This designation means that these areas are protected from being used as a place of human settlement and should also be protected from the harmful effects of human settlement in the surrounding areas. The SSSI was used by Anthony as a matter of fact for areas that must be protected within policy documents and the approval of new projects within the borough. The SSSI was also used as a matter of fact by Elsie who used it to identify areas for the public to engage for specific ecological qualities. The SSSI was both a matter of concern and a matter of fact for Anne. The SSSI was a matter of concern because it required particular water management strategies to maintain the ecology that made the area a "Site of Special Scientific Interest" and therefore was not a permanent ecology without her active assemblage, but it was also a matter of fact within the Biodiversity Action Plans that she was involved in writing because it was an unquestioned area for protection.

The "Planning Policy Statement 25: Development and flood risk" (PPS25) was mentioned by Alan, Private Civil Engineer; Anthony, Tower Hamlets Council; and Frank, Environment Agency. The overlapping matter of concern was the prevention of damage from flooding for the planning and design of new buildings. Alan did so through the mobilisation of PPS25 in the detailed design of rainwater drainage systems for individual private plots of land and how they relate to other surface drainage systems. Anthony did so through the writing of borough council planning policy that enrolled PPS25. Frank also enrolled PPS25 through his advice on reports, policies and projects. PPS25 is national policy that guides the development in areas of differing flood risk. All three people used PPS25 as a matter of fact that they were to implement by enrolling and mobilising other actants to create a compliant design, or enrolling PPS25 in other policy documents.

The final document mentioned by three water professionals was "The London Plan: Spatial development strategy for greater London". This was mentioned by Humphrey and Nick, Greater London Authority; and Heather, Hackney Council. Both Humphrey and Nick were part of the stabilisation of the London Plan because they both wrote and advised on the water strategies documented within it. Heather enrolled the London Plan in her assessment of planning applications for developments submitted to Hackney Council and the writing of council policy. The London Plan outlines the current state of London's environs, economies and communities and identifies problematic areas that can be improved by the adoption of particular strategies in the future. Humphrey, Nick and Heather all used the London Plan as a matter of fact to be enrolled and mobilised in their advice and approval of planned developments within their area of concern, Greater London and the borough of Hackney respectively.

These four documents that were cited by three professionals show that the same actant affords different effects that were dependent on the matter of concern in which the document was being enrolled by the human actant. The effects of the document also changed depending on whether it was thought of as a matter of fact, incontrovertible; or a matter of concern, negotiable. When the document was a matter of fact, the effect was to alter the behaviour of other actants to suit the contents of the document. In other words the document was a black box. When it was a matter of concern, the document was not a black box, therefore the effect of the document was to provide an entry point from which to alter the assemblage of actants on which the document was based. The same document can also be thought of both as a matter of concern and a matter of fact by the same person, depending on the assemblage of the actor-network in which it was to be enrolled or mobilised as was seen in the example of Anne and the SSSI.

Even though there were many different types of documents being used by professionals to influence the water-cycle, there were some common nonhuman actants, such as paper, pens, computers, computer software, printers, telephones, mobile phones, cables, all of which allowed ideas, decisions and information about water to be exchanged between people at varying speeds. These common nonhumans allowed water professionals to be enrolled within the water-cycle of the lower Lea because they conveyed instructions to other people that affected water; they directly affected technologies that changed the quality, quantity and location of water; and they also conveyed information from the use of specialised nonhumans such as monitoring equipment, particular pipe materials and diameters, fittings and fixtures, pumps, and drilling equipment and so on and so forth, which the water professional depended in order to make changes to the water-cycle.

Without these common nonhumans used to assemble networks of connections to other water professionals, humans and nonhumans, water professionals would not be able to enrol in a wide territory of water effects. The common document nonhumans also work to stabilise the enactment of particular water-cycle assemblages when they were taken as matters of fact to be mobilised by the water-professional.

**Professional Water Diaries**

The majority of the water diaries of water professionals mostly contained nonhumans from their domestic personal water interactions, but they did also include a few nonhumans from their professional lives. These nonhumans included reports being written, computers, telephones, monitoring equipment, pumps, controls, pipes, and hydrants, which were mostly marked as typical nonhumans. There were no particular recurring nonhumans amongst water professionals that were only involved with their professional water-cycle.

There were a few nonhumans that were marked as unusual and meaningful. Unusual nonhumans were usually involved with the unenrolment of the nonhuman in the part of water-cycle that the water professional was trying to assemble. For example, Roger marked the cracking of a joint between pipes *"Failed 450 Butt Fusion Weld. Very Rare"*. Meaningful nonhumans directly involved with the stabilisation of effects for the professional water-cycle were recorded by three people, Harry, Roger and Anne. Harry's stabilising and meaningful nonhumans included pumps, control boards and water valve boxes which were his methods of controlling the flow of water. Roger's stabilising and meaningful nonhuman was a report he was preparing for the ISO for a "Pipeline Renovation Standard". Anne's stabilising and meaningful nonhumans were mink traps, and electrofishing, which helped her assess the effectiveness of her ecological management of water.

Within the professional water diaries there were no evidence of particular nonhuman trends. This is most likely due to the different matters of water concern requiring different nonhuman interactions. However, it could also be because the water diaries do not provide a complete record of the nonhumans water professionals interact with that effect water because many of these interactions are part of an actor-network that includes an indirect effect on water, rather than a direct effect on water in the way a tap, basin, or kettle would have in the domestic water-cycle.

**Unstable Professional Water-cycle Moments in Flooding and Scarcity**

The way in which each water professional assembled the water-cycle was consistently imagined to be changed in times of both flooding and water scarcity. Every water professional imagined that their role would respond to the changed water actant. All the roles changed to enable the correct water availability for human habitation, except for Anne, whose role focussed on ecological water management. Anne imagined that her role would alter to facilitate the changing of ecosystems whereupon the habitats she now managed might move location and new habitats formed in their place.

In the case of flooding, the matter of concern for all other water professionals was to prevent loss of life and reduce water damage. In the case of water scarcity, the matter of concern was to find additional water sources and redistribute the water that was available. This shows that the water professional roles documented here are responses to particular matters of water concern that have co-evolved with the urban water-cycles that are now assembled in the lower Lea river basin. This means that all water professional roles are unstable and co-evolve with their ongoing problematisation, interressement, enrolment, mobilisation and stabilisation of actants assembling the water-cycle.

Ten water professionals noted that their influence on the water-cycle had altered between the first interview and the second due to projects being completed and new projects beginning, new technologies being introduced at work, or a shift in focus of the types concerns. Elsie, Sally and Bill noted that this shift was influenced by a change in government in 2010, and subsequent changes to funding. This shows that the role the water professional plays in assembling the water-cycle is fragile and they can easily be unenrolled, thus each water professional is in a continual and rapid process of ANT co-evolution to respond to actant changes and new actants.

**Conclusion**

Water professionals co-evolve with matters of concern about the water-cycle. This co-evolution involves all actants, including water, in the assemblage of the water-cycle that is their matter of concern. The water professionals that participated in this research do not have similar or overlapping matters of concern about the water-cycle in the lower Lea river basin. However it was possible to trace an actor-network theory water-cycle assemblage through the diffuse effects of four water professionals. Their effects were conveyed through documents that translated their matters of concern into matters of fact.

All water professionals were in a continual and rapid process of co-evolution with other actants around them to maintain their enrolment in the assemblage of the water-cycle therefore there were no particular ANT co-evolutionary pathways to be found. However the finding that water professionals co-evolved with the water-cycle means that they can also be enrolled and mobilised in different assemblages of the water-cycle and therefore do not present an immutable obstacle to reconfiguring the water-cycle of the lower Lea river basin.

## Chapter Six

# WATER-CYCLES FOR SELF

Water-cycles for self were those created by each person for their personal water needs. Unlike the water-cycles for others, the water-cycles that people developed for themselves were mostly very regular and similar across different people as well as in its daily assemblage. This was because these water-cycles overlapped in both matters of concern and were created by similar types of material relations. These matters of water concern included water for drinking, washing, sanitation, cleaning, irrigation, water for animals, water for decoration and water for recreation. The types of material relations in the lower Lea river basin were typically associated with a continuous flow piped drinking-water supply system and a piped wastewater drainage network. The piped drinking-water supply was connected to taps, spouts, showers, toilets, dishwashers, washing machines, basins, glasses, cups, pots, washing up bowls, buckets, washcloths, hoses, and watering cans to provide access to water. While the piped wastewater drainage network prevented water inundation by removing water from basins, toilets, shower trays, sinks, gutters, paving, and drains. These similar material configurations stabilised particular social behaviours and practices regardless of personal values and levels of water related knowledge of the individuals as argued by Latour (Latour 2000a; Latour 2000b).

Most of these networks were stable because they were widely practiced by nearly all the participants in this research using the same or similar nonhumans on a regular basis. Both environmentally aware citizens and water professionals assembled water-cycles that were very similar. There were no consistent differences between the answers given in either the individual interview or the group discussion for questions regarding daily water-cycles, unusual water interactions, responses to flooding, or responses to water scarcity despite the wide range of different knowledge and values held by individuals. However, there were a few differing practices and material relations that responded to the same matter of concerns, but took as a matter of fact that the world was water scarce. These different water-cycle assemblages were reinforced by similar reconfigurations when people imagined how they would alter the assemblage of their water-cycle in times of water scarcity. These different assemblages of material and human relations were identified as actor-network theory co-evolutionary pathways that moved towards extending the residence time of water in terrestrial ecosystems.

These pathways could be identified because the matter of water concern was the same, but the current or imagined assemblages of human and material relations were different. These different assemblages of the water-cycle showed where existing network relations were fragile with loosely bound actants. A coalescence of similar relational changes created more likely co-evolutionary pathways because they indicated a widespread adoption of similar human and material assemblages thus they inform new set of stable relations between humans and nonhumans.

This chapter looks at the existing material relations and practices of people's water-cycle assemblages for their own water use. This is described in two parts, firstly for those who thought it a matter of fact that they lived in a water plenty world and secondly for those who thought it a matter of fact that they lived a water scarce world. These two opposing matters of fact lead to differences in the water-cycle assemblages. Frank's water-cycle is used to exemplify a water plenty world. Rose, Elsie, Tom and Samuel illustrate the diversity of responses to a water scarce world. This is then followed by a summation of the most common material relations that were documented by the water diary, which show how these water-cycle assemblages are formed by matters of concern that mobilise the water actant. Finally this chapter describes the most common imagined reconfigurations of the water-cycle if the water actant changes quantity and location by extreme and regular water scarcity and seasonal flooding. These imagined reconfigurations reinforce some of the ANT co-evolutionary pathways that were identified in the existing water-cycle assemblages.

**Personal Water-Cycles in a Water Plenty World, Lower Lea River Basin, 2009**

Typically the first water interaction of the day was to flush the toilet, wash the face, brush the teeth or have a shower. A few people had water by the bedside to drink first thing when they woke up. Most people then moved on to have either a tea or coffee for/or with breakfast, before water was used for washing the dishes. People with pets or animals would also use water to feed these creatures. At work, most people used water for drinking and flushing the toilet. On returning home, water was again used for meal preparation, washing up, having showers, having a bath, flushing the toilet and brushing teeth. All bar one person interviewed was on mains water supply and drainage. The one person who was not on mains supply and drainage lived on a canal boat and thus filled a tank with water from the mains and flushed directly into the canal or river where the boat is moored. However apart from the lack of shower and flushing toilet facilities on board, the canal boat was fitted with piped water supply from the tank to a tap in a kitchen with piped drainage from the sink. This was the same material configuration and technology used by other participants in this research. The most substantial difference was that the water tank promoted water conservation in order to reduce the inconvenience of having to fill the tank often. All these water-cycle assemblages change the location of water and its chemical and bacteriological content. Sometimes the temperature of water was also changed if it was heated for drinking, cooking and washing, or if it was cooled for drinking.

These assemblages of the water-cycle are dependent on a wider actor-network of people, matters of fact, matters of concern, reports, legislation, policy, monitoring stations, pumps, controls, valves, reservoirs, treatment works that form the piped drinking and wastewater infrastructure. This network is in turn dependent on rain, surface-water sources from the Thames and Lea rivers, ground-water sources from the chalk aquifer underlying south east England, the Thames estuary-water to receive treated wastewater discharge and the health of particular species that form ecologies that are favoured by humans.

For the personal water-cycle the connections to these networks are via taps, buttons and drains, which also forms the boundary to the water assemblages described by most people. This boundary is formed because the effects of people's actions perceptible to them halt here; beyond the taps, buttons and drains are material configurations that are often unchanged when people assemble their personal water-cycle. As long as the water continues to flow from the tap and at the push of a button it is a matter of fact that the world is water plenty; and as long as water continues to be removed by drains the effects of water quality entering the drainage system is not a matter of concern.

The personal water-cycle assemblages were mostly described as actions that involved water, in other words matters of concern that could be resolved by water use. Unless the verb and noun happened to coincide, then the material configuration used to assemble this portion of the water-cycle remained invisible. This was especially apparent when people were asked to verbally describe their water interactions. The water diary which required people to photograph their material configurations showed more instances where the materials of the water-cycle assemblage were noted, such as kettle, when making tea, or sink when washing the face. However it was still more typical for people to record the matter of concern that involved water, for example "brushing teeth", "cooking dinner" and "washing up". The material configurations that enabled these water-cycle assemblages are thus obscured from consciousness through the language used to describe the processes of using water. This shows the importance of solving the matter of concern and the relative fluidity of the actor-network configurations assembled to achieve it. Therefore these matters of concern could be reconfigured so that they do not use water and thus would no longer be part of the urban water-cycle.

During the interviews and group discussions there were some instances of forgetting a water use, which were mostly self-corrected later in the interview or during the review of the responses in the group discussion. These instances of forgetting included: flushing the toilet, drinking water and watering plants. Forgetting the toilet and drinking are especially interesting instances of forgetting because these two actions were both recorded as being amongst people's first water interactions in the water diaries. In the water diary flushing the toilet was the most frequent first water interaction documented, but it was a water use so unimportant or habitual that it was forgotten in conversation. This forgetting is an instance which shows that using water to flush waste is not important, what is more important is that the sight and odour of the waste has disappeared. The omission of toilet flushing could also be attributed to some people's discomfort in talking about body expulsions. Forgetting the use of water for drinking was surprising and could be attributed to some people's water intake being made mostly of flavoured water, such as juice, coffee, tea, cordials, beer, wine, soup and so on. The watering of plants was easily overlooked as this was not necessarily a regular matter of concern and for some people, it only occurred if there was inadequate rainfall.

There was a consistent difference between people with children and those without. People with children used the washing machine at least once a day, sometimes doing up to 3 loads of washing a day. While people who lived alone would launder once a week, and those with a partner would launder twice a week. The increased use of the washing machine was especially noticed by a young mother, as well as a father.

> *I probably use loads more than I used to do. I've got a 2 year old, I'm doing the washing every day. I used to do it once or twice a week. I must be above 150L a day, definitely. Because I'm doing 2 or 3 loads of washing a day.*
> *Esther, 12 August 2009*

> *yeah, I mean as a family, yeah, I've got a couple of kids and that, so the washing machine's always going… They've got, ah, sports activities going on all the time. And I'd imagine we'd probably use the standard washing machine probably, I said all the time, probably three or two times a day.*
> *Frank, 15 September 2009*

The dishwasher was another technology that was used by some people as a daily practice and others less frequently, depending on the size of the household. Most people tended to wait for a full load of dirty dishes before running it; this could take up to 3-4 days.

Interestingly, people tended to leave this question reluctantly, with the feeling that there were water uses that they practiced and had forgotten to mention.

> *There are probably are things I haven't thought of.*
> *Isabelle, 27 June 2009.*
>
> *You've interviewed a couple of people, am I missing anything obvious?*
> *Humphrey, 5 November 2009.*

This indicates that people were aware of how some of their water use is an unconscious habitual function of everyday life that is an unquestioned matter of fact that they do not expend energy being conscious about.

Many people mistakenly believed that asking them about their daily water interactions was to judge how many water saving devices they had installed, or how well they practiced forms of water conservation, therefore many people mentioned these particular nonhumans, such as low or dual flush toilets, low flow showers, tap aerators, and rainwater butts. This shows that in the context of discussing water many participants felt that water conservation reconfigurations demonstrated more likeable, virtuous and socially responsible behaviour than high water consuming practices.

There were other differences amongst the water-cycles assembled by people who thought it a matter of fact that they lived in a water plenty world. These modifications altered the water-cycle assemblage to increase the level of human comfort (power shower) or convenience (pressure cleaner). Both the power shower and pressure cleaner use an additional pump to produce greater water pressure and therefore uses more water than an ordinary shower or hose at any one time, this has the added effect of increasing water consumption unless it is used for a very short period of time. The implementation of these technologies was recounted with caveats to explain how these technologies were used judiciously, or that the use of these technologies fulfilled normal desires.

> *My philosophy is to have a good shower for a short time, rather than having a poor one for a longer time.*
> *Humphrey, 5 November 2009*
>
> *But being absolutely honest, we like our power shower, we like using, I don't want a dribble coming out of the tap, I want a lot of water coming out of the tap. You know. And I think a lot of people are the same actually, if they're honest. You know, that's just how it is.*
> *Frank, 15 September 2009*

The amount of water consumed did not play a significant role in deciding to use this technology. Comfort and convenience were the main deciding factors. These reconfigurations show that there were also ANT co-evolution pathways where the matter of concern was to increase human comfort and convenience.

Only one person, Daniel, noted that there were chemical changes made to the water-cycle from the exhaust and leaking of combustion engines and material erosion of tyre and road materials during his regular transit to work. Other people such as Susan, Tom, Neil, Heather and Samuel incorporated rivers and canals into their daily commute to work. These people noted the calming or picturesque landscape qualities of the water courses that they crossed or walked along as a particular part of their journey to work that they enjoyed. The enjoyment of these landscapes is an ANT co-evolutionary pathway to increase the residence time of water in terrestrial ecosystems by creating more water landscapes.

Within the typical daily water-cycle assembled by people who thought they lived in a water adequate world there was a description of similar and stable assemblages. The similarity of the material configurations used by water professionals and environmentally aware citizens is formed by solving the same matters of concern in the same way depending on the same types of water access and drainage. These water-cycle assemblages were bounded by the perceptible effects of material change that could be wrought by an individual. The co-evolution pathways within these existing water-cycle assemblages of a water plenty world were additional technologies that aimed to give people greater comfort and convenience. These variations consumed more rather than less drinking-water resources because it was assumed that there were adequate water supplies to accommodate these new water uses and the existing material world which continues to provide adequate water supplies does not contradict this matter of fact held by these people.

There were no obvious ANT co-evolution pathways in these people's technologies or practices that would extend the residence time of water in terrestrial ecosystems. However, the enjoyment of landscapes containing water shows a potential ANT co-evolution pathway that creates greater comfort for people by expanding water ecosystems thereby extending the residence time of water in terrestrial ecosystems. In addition, should material configurations be more convenient to use less water or different water, then an ANT co-evolution pathway could also be generated to extend the residence time of water in terrestrial ecosystems.

**Frank's Water-cycle Assemblage in a Water Adequate World**

Frank's water-cycle (figure 5.1), describes the typical water-cycle assemblage that most people practice. The illustration includes interactions that are daily as well as those that are less frequent, but still regular. Frank lives with his wife and two children in a semi detached house located in an area just beyond the borders of London in the middle Lea river basin. Frank's work directly involves the improvement of the fresh-water and estuarine aquatic environments and thus he is an environmentally educated citizen as well as a water professional, but this knowledge has not altered the assemblage of the water-cycle in his personal life

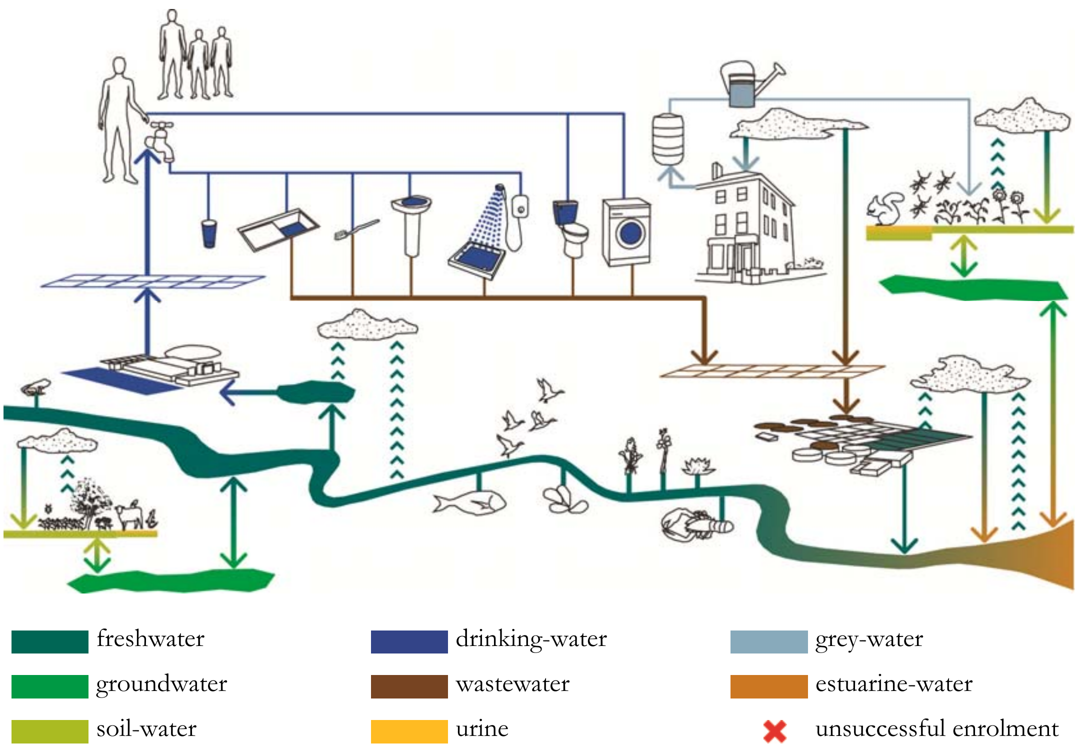



**Figure 5.2**
**Frank's Water-cycle assemblage**

Frank's first water interaction of the day is to clean his teeth. Frank uses a power shower and has not made any water conservation modifications to his water technologies. However, he does have a water butt to collect rain water for his garden. Like many of the participants interviewed, he notes that he rarely washes his car, which he jokingly states mitigates the additional water use of the power shower. Living with an active family doing lots of sporting activities means that the washing machine is in constant use, with two to three loads being done a day. Frank's wife does the majority of the laundry and therefore there are no details as to whether these were on a water economy cycle.

Frank's actions demonstrate that he assembles his water-cycle on the matter of fact that the world is water plenty. His assemblage has never run out of water, so there is no material evidence within the boundaries of his water-cycle to suggest otherwise. However Frank's job contradicts this matter of fact. Sometimes he makes presentations about the necessity of water conservation to school children. This usually results in a short burst of water conservation efforts by changing his water practices directly after the presentation, but aside from the installation of the water butt, this does not have a lasting effect as it was easy to resume the water plenty assemblage of the water-cycle within the unchanged material and social configuration of his home.

Frank's assemblage of the water-cycle was typical of people for whom a water plenty world was a matter of fact. This world could be punctuated by moments when the water could become a matter of concern, but the enrolment and mobilisation of the human actant in new water-cycle assemblages was short lived because there were no other actant changes within the water-cycle assemblage, thus the human actant would resume its assemblage of a water plenty water-cycle. In contrast, the water plenty water-cycle was reinforced by new nonhumans such as the power shower. This actant enrolled, mobilised and stabilised a new quantity of water use within Frank's water-cycle assemblage that reinforced the matter of fact that the world was water plenty by the tactility of high pressure, high volume water pouring out of the shower on a regular basis.

**Personal Water-Cycles in a Water Scarce World, Lower Lea River Basin, 2009**

Even though there were no consistent differences between the daily water practices between water professionals and environmentally aware citizens resulting from their different access to knowledge about water in the lower Lea watershed, there were consistent differences between those who operated on a matter of fact that the world was water scarce or that the world was water plenty. Those who thought it a matter of fact that they lived in a water plenty world did not question how their water-cycle assemblage shaped the quantity of their water use. In contrast, those who believed they lived in a water scarce world actively modified these material arrangements in order to reduce their water consumption of drinking-water until they were satisfied that they had made an effective change within their means.

The amount of water consumed modified decisions about how different areas of the water-cycle were assembled. This included reduced toilet flushing, adjusted bathing habits, changed garden watering habits, added new technologies to households, and altered methods laundering and house cleaning, and garden planting. Within these changes was the greatest potential to find co-evolution pathways to reconfigure the urban water-cycle to ensure its ongoing ability to provide water that humans and other biota require to support human life because it reduced the quantity of water needed to fulfil the same matters of concern and redistributed the location of water in the urban environment. However, the majority of the water-cycles assembled in the water scarce world were the same as those who lived in a water adequate world. They mostly accessed water from the same piped water infrastructure and relied on the same piped wastewater infrastructure and had the same matters of concern that led to water use: drinking, washing, sanitation, cleaning, irrigation and water for animals. Therefore the majority of their water-cycle assemblage was the same as those who lived in a water adequate world because of the stability of the material configurations of these water-cycles.

These people were conscious that these reconfigurations were modifications to common practices. These changes were fragmentary alterations to the relatively stable assemblages of the water plenty water-cycle. A minority of people implemented water conservation to all their water uses, most people assembled water conservation to selected areas of their water-cycle assemblage, while others used conservation in one part to offset what they knew to be higher consumption in other parts of their water-cycle thereby attempting to introduce greater comfort and convenience without increasing their total water consumption.

One change that eight people made to conserve water was to practice limited toilet flushing. The toilet flush was only used to remove faecal waste. The common ditty used to describe this behaviour was “If it’s yellow, let it mellow. If it’s brown flush it down.” This was practiced in the privacy of their home in order to conserve the amount of water used in flushing the toilet. The “yellow mellow” ANT co-evolution pathway is a change in the way an existing nonhuman actant, the toilet, is used. This is an unstable change because it was very easy to switch back to old practices because the new practices are not stabilised with the incorporation of a new nonhuman. New humans to the network such as a guest to the house, could not be enrolled in the new behaviour because there was nothing to prevent old practices, nor was this change communicated to them verbally or with a sign. Some people even ran around making sure all the toilets were flushed before guests arrived, which ensured that guests were encouraged to continue old flushing practices. The "yellow mellow" pathway shows the limits of changing the practice of the existing toilet actant. A new actant or actants need to be added to the assemblage to stabilise the new water-cycle assemblage.

Rainwater collection in a rainwater butt or water tank was used by nine people as an alternative water source for watering the garden. The rainwater butt is a step change to people's water-cycles because it added a new nonhuman actant to people's water-cycle. This was a step change that was only available to owner occupiers of a house with a garden. It required finding space for the tank, altering existing nonhumans such as downpipes in order to divert water into the butt. Some people with large roof areas increased their capacity for storage by having a series of cascading tanks. Other people found that their drain pipe was the wrong shape to be fitted to the rainwater butt they had bought and thus were prevented from using it. People who leased their property were not motivated to make this change to their water-cycle assemblage because it required permission from the property owner to make this material change. Two people, Harry and Michelle, found that they watered the garden so infrequently that the water from the water butt became stagnant before it could be used and therefore disconnected their rainwater butts.

The rain water butt is a co-evolution pathway for alternate water sources and localised systems of water collection and distribution. It was an unusual ANT co-evolution pathway because it was not only taken by people who thought water was a scarce resource, but also by people who wanted to behave sustainably. Installing a rainwater butt was one means that had been promoted by various organisations as a way to behave sustainably. The rainwater collection for gardens also had the additional advantage that people using this water could grow different plants because rainwater had less minerals salts dissolved in it (soft-water) than the drinking-water (hard-water) in London.

The rainwater butt also changed other actants within the water-cycle assemblage. A hose was now impractical because there was no water pressure to create a spray therefore a watering can had to be used. This limited the amount of water use as it was heavier and more time consuming to manoeuvre. The water butt also meant that there was a visual volume of water that could be checked on and the amount of watering could be tailored to the amount of water remaining in the tank. Many people were proud to say that they did not need to use drinking-water to water the garden because their water butt could provide the adequate amount of water.

> *Normally we get by with the five water butts.*
> *Roger, 25 September 2009*

The introduction of a new nonhuman actant in the form of a rainwater butt into the personal water-cycle assemblage, changed the relations between human, rain, roof, downpipe, watering can, watering, and garden. Further ANT co-evolutions of the rainwater butt could occur because it can inspire humans to divert other types of water, such as that from the shower or washing machine, into the butt for later use. Or it could inspire new water uses from the new water source, such as washing windows, flushing toilets, which in turn could be encapsulated into other nonhumans. The step change of a rainwater butt shows that ANT co-evolution requires new nonhuman actants to stabilise new practices that then feedback new ANT co-evolution ideas.

Nonhuman actants can also encourage water conservation by chance. Maria's water conservation efforts were stabilised due to the toilet actant having a "rubbish flush". This meant that flushing the toilet with a bucket was more effective than flushing with the toilet flush, therefore her collection of the first cold flush of water in buckets from the shower served the dual purpose of water reuse and the problem of a bad toilet flush. Very few other participants went to this effort, which shows that the bad toilet flush combined with the belief of living in a water scarce world had an influence on her behaviour.

These were the typical water-cycle assemblages of people responding to the matter of fact of living in a water scarce world. Water scarce water-cycle assemblages feature water conservation, different water sources, and water diversion. These water-cycle assemblages revealed potential co-evolution pathways towards extending the residence time of water in terrestrial ecosystems and increasing the productivity of existing water resources. The pathways identified in these daily water-cycles include: "yellow mellow" practices, reuse of bath and shower water, and water butts for rainwater collection. These assemblages had different degrees of stability that were dependent on the introduction of new actants within the water-cycle assemblage. "Yellow mellow" was the least stable, while rainwater as an alternate water source stored in rainwater butts were the most stable.

In addition to the overall trends of ANT co-evolution pathways that have been described above, the following four water-cycle assemblages made considerably more reconfigurations some of which are are further developments of these ANT co-evolution pathways. These water-cycles ranged from substantial behaviour change with no new technological modifications through to the introduction of extensive technological modifications with few behaviour changes. These assemblages included reusing bath water with a simple bucket for flushing the toilet, house cleaning, and watering the garden; siphoning bath or shower water for drip irrigation; installing a grey-water recycler; and installing water saving devices to all possible fittings. Some of these attempts to reconfigure the water-cycle were successful and others could not successfully mobilise or stabilise the material configurations to achieve the water flow desired by the person.

**Rose's Water-cycle Assemblage in a Water Scarce World**

Rose is a semi-retired woman who lives on her own in her own flat with garden on the ground floor. Rose is an environmentally aware citizen with no professional links to water. Rose has attempted to make two changes to her infrastructure in order to improve her water conservation efforts, but neither of these has been successful, which has meant that she has modified the way she uses existing technologies to achieve her desired water savings (figure 5.2).

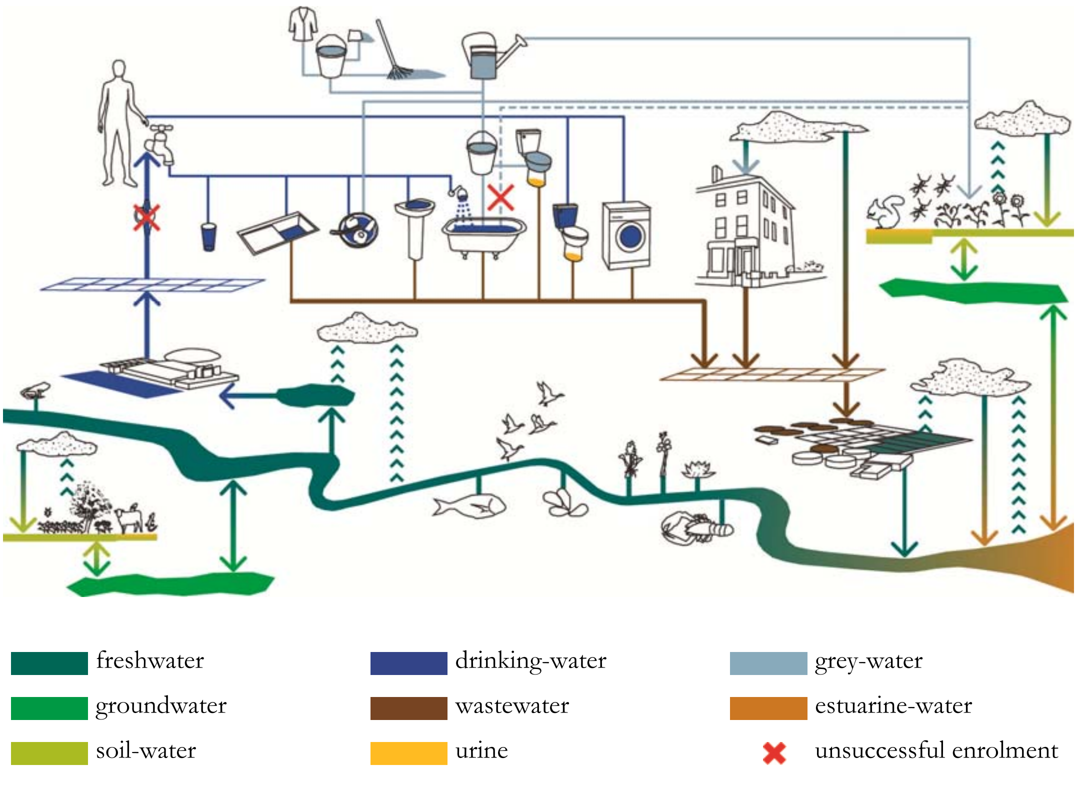



**Figure 5.3**
**Rose's Water-cycle assemblage**

Rose goes through a lot of effort to reuse water from bathing. This is because it is the most obvious and easiest source of water to reuse as it can be immediately collected in the bath and scooped out with a bucket, or with a container to a bucket. Rose bathes (either a shower or bath) every other day with a flannel wash between. This water is collected in her bath, which she reuses with a bucket to flush the toilet, hand wash clothes, wash the floor, general cleaning and watering the garden. The collection of water in the bath tub gives her direct visual feedback as to how much water she has used to bathe and how much she has recycled. She feels guilty if she has to release this water before her next bath, because this water is wasted for reuse.  However, if she is feeling particularly tired, she is unable to do this labour intensive reuse and her grey-water goes to waste.

Rose realised that the effectiveness of her water reuse of bath water relies on her own fluctuating energy levels, and attempted to make this water reuse more convenient by delegating the task of moving water from bath to garden to a siphon. Unfortunately for Rose, the material configuration of the level of her bathroom relative to the garden did not enable sufficient water pressure for the siphon to be effective. Rose also tried to receive additional feedback about her water use and make a saving on her water bill by requesting a water meter for her flat from the water service provider. However a water meter could not be installed due to the configuration of water distribution in her building, thus she does not have a measured volume for her water use. This has led her to be as frugal as possible in her habits using the existing technologies available to her. Rose cannot measure how much lower her water consumption is in comparison to other people, her only benchmark is the volume of grey-water stored and used in her bath. This has led her to co-evolve evermore water-cycle assemblages that will use the grey-water in her bath and by doing so fulfil her matter of concern to conserve water for the water scarce environment.

Visitors to her home are not at all enrolled in this labour intensive water reuse because Rose would not impose on guests her labour intensive water reuse values when the conventional alternative is present. Rose herself is not always enrolled in water reuse because if she is tired, she will turn back to using the conventional system.

The ANT co-evolution pathway illustrated by Rose's water-cycle is one of water reuse. It shows that the reuse of bath or shower water is acceptable for other uses such as clothes washing, housecleaning, toilet flushing and irrigation. This water reuse ANT co-evolution pathway could be improved by new nonhumans that would make water reuse more convenient by reducing the amount of workload of moving the water from place to place. Rose's reuse of water from the bath also showed the importance of visual feedback from the volume of water in the bath. This feedback led to further ANT co-evolutions by Rose to reconfigure her water-cycle to make use of all of this water source before having to drain it for her next shower or bath.

**Elsie's Water-cycle Assemblage in a Water Scarce World**

Elsie lives in a semi-detached house with her husband. Elsie is an environmentally aware citizen and a water professional whose work involves encouraging public engagement with open bodies of water: lakes, canals, rivers, estuaries and the ocean. Elsie's water reuse system requires some conscious effort and also involves some material changes to her water system. Elsie has diverted her shower and bath water to a drip irrigation system in her garden using a proprietary water diverter that allows her to switch between watering the garden or disposal to the sewer. Elsie also practices water reuse in the kitchen by using a wash up bowl. If the water in the bowl is not greasy after she has finished using it, she uses that water to splash on her garden (figure 5.3).

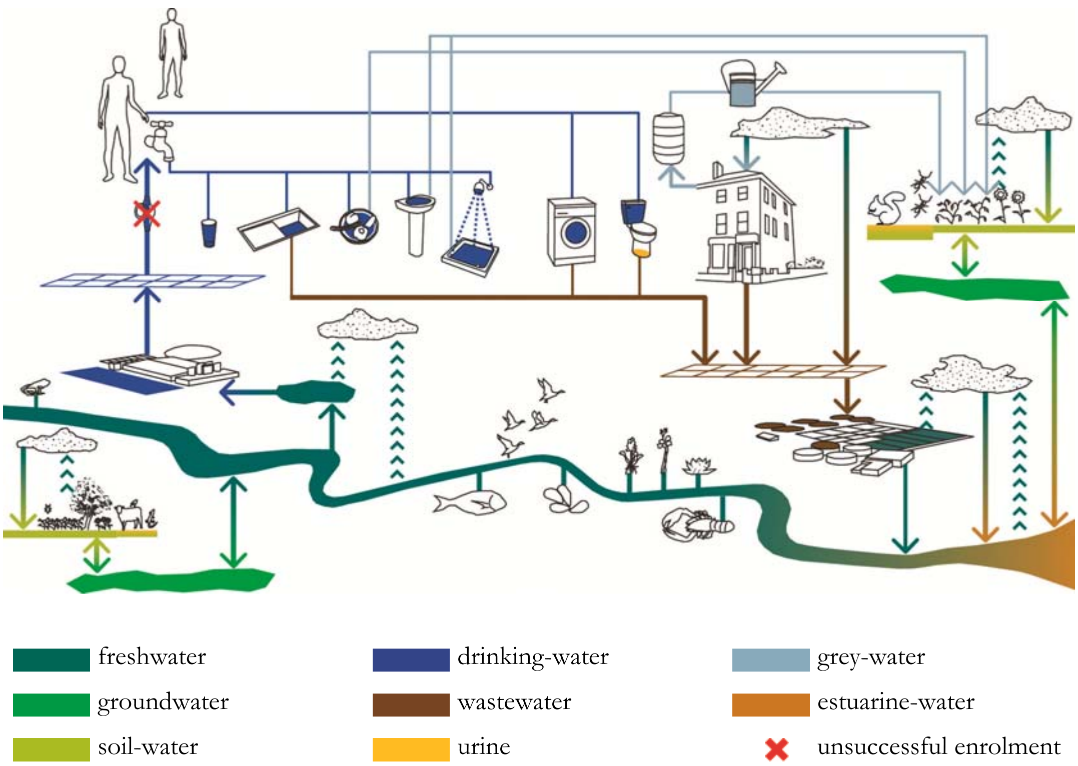



**Figure 5.4**
**Elsie's Water-cycle assemblage**

Elsie's water reuse practices require her to actively participate by shifting the water diverter into the appropriate position or deciding on the appropriate water quality for the washing up water to be absorbed by the soils and vegetation in the garden. Water reuse at Elsie's home is a combination of behaviour and technology. Visitors to her home have a limited enrolment in water reuse. Their water will be reused if the water diverter has been previously switched to the garden, otherwise it will go to the sewer system. Visitors are unlikely to know that she would like them to splash water from the wash up bowl into the garden, thus they are unlikely to do so unless directly instructed.

Elsie's ANT co-evolution pathway for water reuse shows that the reuse of bath or shower water is acceptable for irrigation. The use of a water diverter ensured that visitors to her home would be enrolled in Elsie's preferred water-cycle assemblage with no effort on their part.

**Tom's Water-cycle Assemblage in a Water Scarce World**

Tom is an owner of a semi detached house located in a flood prone area of London where he lives with his wife. Tom is an environmentally aware citizen and a planning professional with some water influences in other locations in the world. Tom has refurbished his house to be an eco-house. This involved modification to the water systems as well as building a full height basement into the water table.

The biggest change to Tom's personal water-cycle with the house renovation is the addition of a grey-water recycling system that collects water from all wash basins and showers for reuse in flushing the toilets, laundering, cleaning and gardening (figure 5.4). The grey-water recycling system was included in his refurbishment because it was a very easy piece of technology to use, source and purchase from Germany. It was not as easy to install as he had hoped because the piped connections assumed that it would be installed in a standard German home, which were not the same as those in his house in London. This has meant that an additional pump is required to drain excess water into the piped waste-water infrastructure.

After its successful installation the recycler has not needed any additional modifications and the only maintenance required is the need to be cleaned every few years. The grey-water recycler is located in the basement, hidden from view, which means that unless something goes wrong, there is no reason to be aware of this additional piece of infrastructure in his home. There is no feedback on the system to let users know how much recycled water contained in the tank is used. Tom therefore has no idea if there is a balance between the volume of grey-water collected and treated with that which is used. There is just a small screen at the front of the system that constantly reads 'OK', which is both reassuring and uninformative. This lack of feedback is not helped by the fact that the water meter was installed incorrectly by the drinking-water service provider and constantly reads zero.

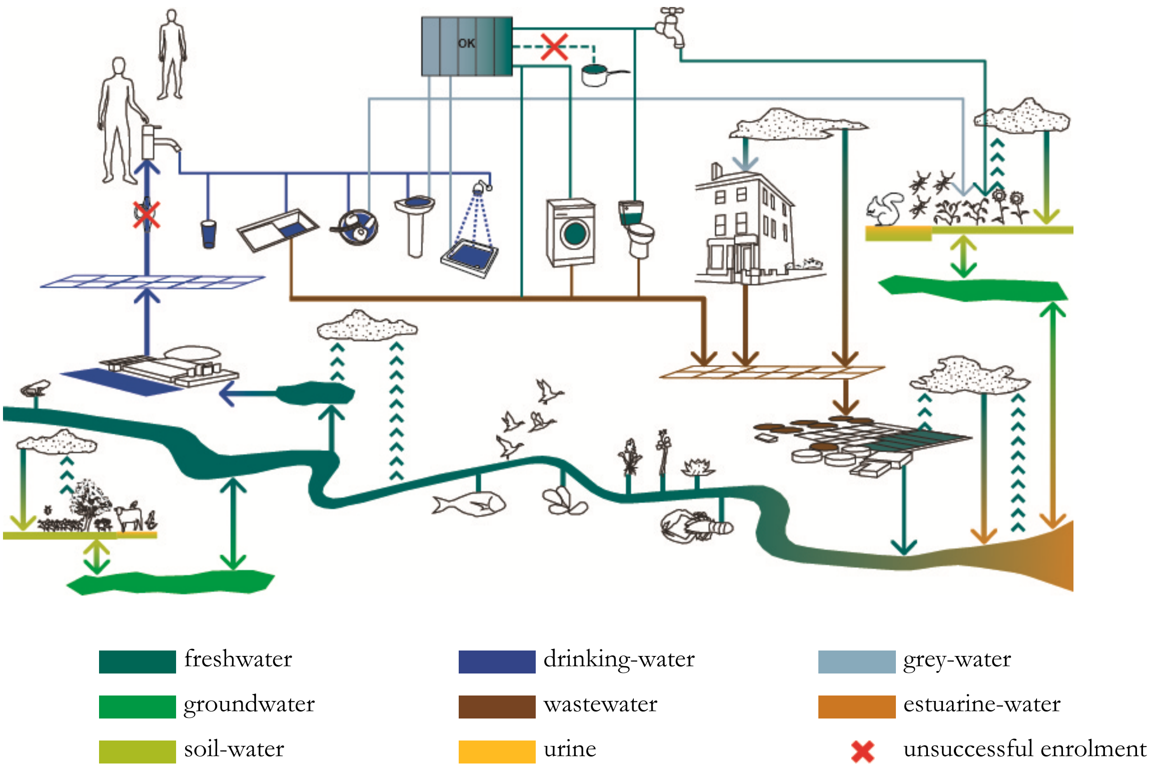



**Figure 5.5**
**Tom's Water-cycle assemblage**

Tom also decided that it was worthwhile to spend money on the grey-water recycler because it was cheaper to install in the basement during the refurbishment work in comparison to photovoltaic cells which would not cost significantly more to add at a later date. Tom was also aware that London water supplies are stressed. By using grey-water he would help mitigate this and also ensure that he is buffered against any rise in the future cost of drinking-water.

The quality of the grey-water from this system is very high. The kitchen installers made a misconnection from the grey-water pipe to the kitchen tap, so for the first three months of living in his newly renovated home Tom and his wife were using the grey-water for cooking with no ill effects. It was Tom's wife who relies on her sense of smell to cook, who identified that the water from the kitchen tap smelt slightly different from other taps in the house and thus the misconnection was discovered and rectified. This unintended mistake has changed Tom's perception of the quality of the recycled grey-water

> *"…colourwise it was totally transparent. There were no solids in there or anything. But basically they say it isn't legally potable…but yeah, we drank it for three months and we were completely fine."*
> *Tom, 12 August 2009*

This has meant that if there was an extreme water shortage, Tom would feel confident in taking the risk of using his recycled grey-water for drinking.

Tom is not yet satisfied with the water system he has put in place as he feels there is scope for additional water reuse to improve biodiversity by using this water to feed a pond in the garden.

All of Tom's guests are enrolled in grey-water reuse whether or not they value this practice because it would be difficult for them to flush the toilet with drinking-water without asking Tom for a bucket and laundering clothes in drinking-water would require changing the pipes or hand washing. However, they are unlikely to know that they were enrolled in a water reuse system because the water is clear and odourless, hence it seems to be like drinking-water in appearance and is accessed from the same fixtures and fittings from which drinking-water flows.

Tom has developed an ANT co-evolution pathway of water reuse similar to Rose's in terms water source and the purposes for which the water is used. However Tom has enrolled and mobilised multiple new actants to ensure that the water reuse assemblage is stabilised for himself, others living with him and guests to his home. Any human who enters this system of material relations is immediately enrolled in the grey-water use that Tom has assembled. This means that water reuse within the boundary of his home is consistent and regular. Tom's reconfiguration is much more consistent than Rose's because the grey-water use is delegated and stabilised by a material configuration, it does not rely on his effort to transport the water from one place to another and thus Tom's assemblage is also arguably more effective than Elsie's because she is only able to reuse her water for irrigation. However this is only because he has added more piped connections to his assemblage than Elsie.

The disadvantage of the actants that Tom stabilised as his water-cycle assemblage is that unlike Rose's configuration, they do not indicate the water balance between the grey-water source and grey-water reuse, so he cannot quantify his effects. This prevents him from making further co-evolutions to make more efficient use of his grey-water.

**Samuel's Water-cycle Assemblage in a Water Scarce World**

The final example of efforts made to reconfigure personal water assemblages to a water scarce world is Samuel's household. He lives in a semidetached house located in London where he lives in a four person household with his partner, child and lodger. He is an environmentally aware citizen who is also a water professional, his job entails improving the quality and quantity of water in the natural environment by planning future drinking-water demand. Samuel is extremely knowledgeable about the effects of his water use and existing technologies to enable him to reduce his water use and thus his water abstraction. He was one of the few interviewees that knew and monitored the water consumption of his household and actively intervened to promote change in behaviour as well as modified fittings in his home.

Samuel has every possible system of water saving device installed in his home bringing the water consumption of his household to 70L/person/day in the first interview, to 52L/person/day in the second interview. Samuel has an ecosaver shower which means that it uses less water per minute than a typical shower. His taps are also fitted with aerators and his toilets are dual flush. He has a water butt for watering the garden. His household also does not flush the toilet unless they defecate. This measure of water restriction was contentious within his household and was debated before it became their household practice.

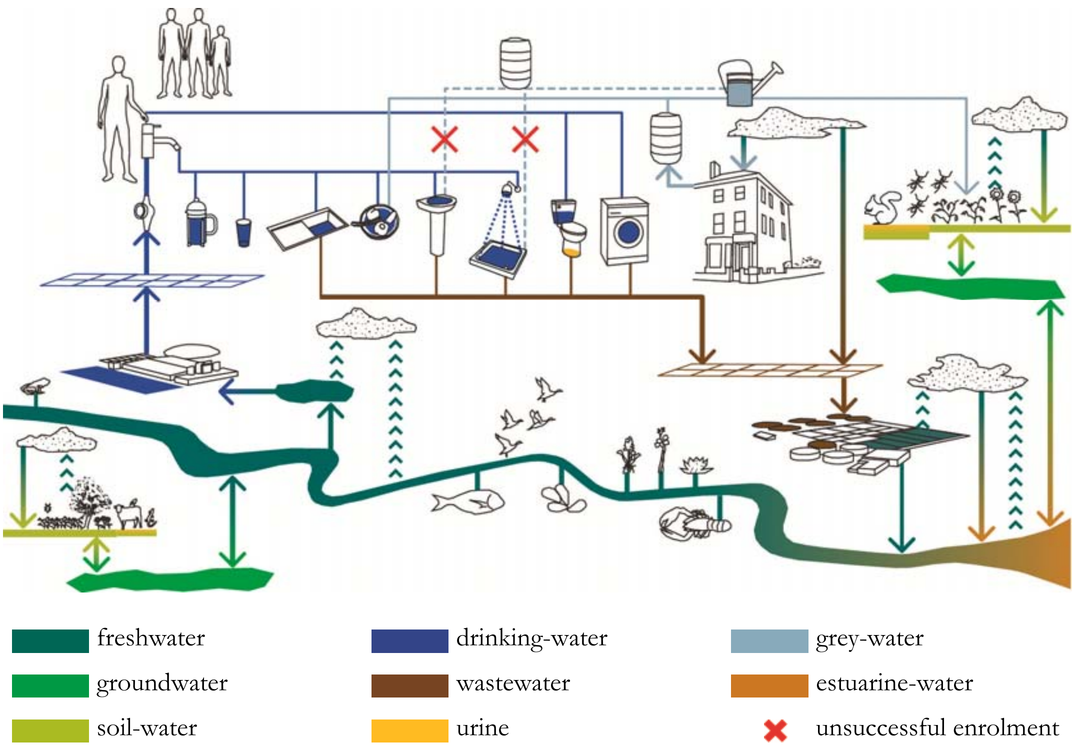



**Figure 5.6**
**Samuel's Water-cycle assemblage**

Samuel has a water meter that he had fitted by the water service provider which has meant that *"we discuss our water consumption as a household"* because there is a yardstick to compare against. For example, given that his daughter and lodger are not always in residence, they are able to determine with the water meter that his daughter is not a big water consumer while the lodger is. Furthermore he was able to identify the habits that consumed more water:

> *"She takes baths and very long showers and has long hair. So you know, if it's 3mins for that product, and it's 3mins for that product, and 3mins for the next product, you're already in there for 9mins and actually she has about 20mins showers, which we have discussed. But, there's no movement on that. And she also works in the water industry…she's an environmental consultant specialising in water."*
> *Samuel, 15 September 2009.*

This suite of water conservation efforts has resulted in a water consumption of 70L/person/day, which is less than half the average domestic water consumer in London (163L/person/day) reported by this water service provider (EA 2010). This is only one of two instances amongst all the people participating in my research where there was a monitoring of water meter readings, both of these people were water professionals. However, this meter reading impeded Samuel in his efforts to promote greater water conservation because the knowledge from the water meter that the household consumption is already very low in comparison to the average consumer makes it more difficult for Samuel to convince other people in his household to implement further water-cycle changes. A similar effect occurred with the other water meter monitor whose household use was 125L/person/day, which is also below the London average. This is opposite to Rose whose lack of feedback inspired continued co-evolutions because conserving water continued to be a matter of concern.

Samuel also tried to implement a grey-water recycling system for his garden, but his partner was not supportive of this action. However, he is going to persist:

> *"We did it at our last place and my partner wasn't too happy with it. We were using shower water. Well, she felt that it was not very nice to use on the garden, but we're going to get around that because what I think I need to do is just to fit a filter on the system, so then she'll see it's not a problem."*
> *Samuel, 15 September 2009.*

Samuel's water-cycle assemblage shows the effect of the interpretation of nonhuman meter readings on human behaviour. Samuel's matter of concern was to prove how little water could be consumed while still being a functioning and accepted member of society. For him, the meter reading monitored the effect of each change that he had made to his water system. For the rest of his household, the meter reading was used as proof that they used a below average amount of water and therefore had done enough. Luxuries such as long showers and using drinking-water to irrigate the garden were seen as acceptable behaviour.

Guests are partially enrolled in Samuel's water conservation efforts. Not everyone will remember or be comfortable with the household's "yellow mellowing" practices. However they will use the eco-shower, aerated taps and dual flush toilet, all of which use less water per time period of use than conventional fittings.

The co-evolution pathway of Samuel's water-cycle assemblage was the mobilisation of existing water conservation technologies, combined with new behaviour such as "yellow mellow" and short shower practices to substantially reduce drinking-water consumption. This requires an enrolment of the human actant to behave differently. This requires water conservation to be a socially lauded quality and high water consumption to be a taboo. This change is difficult to enrol, as was evidenced by Samuel's lodger, a water professional with knowledge of London's drinking-water stress who still found it more socially acceptable to use a large volume of drinking-water to maintain her hair in a certain way rather than conserve this water through shorter showers, alternative water sources or alternative methods of hair maintenance.

The other co-evolution pathway of Samuel's water-cycle assemblage was using the water meter for feedback to monitor the water consumption of the household. This co-evolution pathway would only be effective in reducing drinking-water consumption if the matter of concern that human actants were enrolled was to reduce drinking-water consumption to the minimum or a particular standard. If the human actant is not enrolled in such a matter of concern, then the information from water meter would have no effect. Moreover should the matter of concern to be to achieve a socially acceptable average, where slightly higher than average was still acceptable, then water use would still increase over time because the average would rise over the reported periods.

**Nondaily Water-Cycles for Self**

There were also infrequent water-cycles that people assembled for themselves. Some of these were pragmatic, such as house cleaning, car cleaning and watering the garden. Others were more meaningful or pleasurable, such as outings or holidays by lakes or the sea, holidays on the water and water recreation. Recreational and appreciation of water landscapes were unusual water assemblages because they did not involve the relocation of water relative to the person; instead the person relocated themselves relative to the water. These infrequent water-cycles also offer ideas of ANT co-evolutionary pathways that could strengthen reconfigurations to the water-cycle.

One of the most frequently mentioned nondaily water-cycle was the washing of cars. This was most often mentioned in the context of the infrequency of this water-cycle assemblage. Roger even noted that the last time his car had been washed was in the north of England, with the implication that this was more acceptable because the north of England does not suffer from water stress.

> *We very rarely wash the car. I think it's been washed this year? And then it was done in the north of England, because it got filthy doing something, so I took it to a car wash. But normally it don't get done. The same with my wife's car. I can't remember the last time my wife's car's been washed.*
> *Roger, 25 September 2009*

This lack of car cleaning was both a form of water conservation and convenience because it takes less effort to leave the car dirty and conserve water than to use water and wash it, therefore ANT co-evolution pathways that involve less effort on the part of humans will be more likely to be mobilised and stabilised and new social values enacted.

Other pragmatic nondaily water uses mentioned included cleaning the patio, cleaning window frames and watering the garden. For most people, these water uses were done sporadically, when it was felt necessary. It is very ambiguous how this necessity is determined because it relies on the personal judgement of one particular person. For example:

> *I'm just thinking, last weekend I washed all the window frames down. That was with a bucket and sponge, but then I hosed it down with a hosepipe with a trigger gun. That was very atypical, I only do that once every six months or maybe once every year.... I think it's because it was covered in dirt, and I thought 'I must do it'.*
> *Bill, 28 July 2009*

Thus it is not possible to determine an ANT co-evolution pathway from these water-cycle assemblages.

Pleasurable moments of the water-cycle assemblage were particularly focussed on large open expanses of water. This included walking by lakes, rivers and the sea for Matthew, Anne, Susan, Harry, Linda, Elsie, Humphrey, Rose and Jack; the ocean for Eleanor, Phillip, Daniel, Felicity, Tom, Heather, Alan, Sally and Richard; kayaking for Bill and Daniel; scuba diving for Sally and Charlie; canal boat tours for Matthew and Jack; the sauna for Ron and Isabelle; boating and sailing for Frank and Harry; rowing for Eleanor; taking ferries for Humphrey; and surfing for Anne. Many of these pleasurable water moments were located far from the homes of these people and were not within the lower Lea watershed. These pleasurable moments add to the comfort of people through the particular material forms of open water. This is an ANT co-evolution pathway that suggests that increasing the open water landscape accessible to individuals for recreation in the lower Lea watershed would not only extend the residence time of freshwater in the river basin, but also offer new moments of pleasure to the people living in this area.

The nondaily water-cycle assemblages indicate that an additional two ANT co-evolutionary pathways exist: one that reduces the effort on the part of humans and another that favours open water landscapes that are accessible for recreation.

**Nonhumans Actants Captured in Action**

The water diary captured the material configurations that people used to assemble the water-cycle. It verified that most people interacted with similar water technologies such as taps, wash basins, sinks, toilets, showers, dishwashers, washing machines, and water filters, all of which rely on pressurized water supply. Washing up bowls, glasses, cups, bottles, dishes, and pans were receptacles for water, which was conveyed from a tap or water filter. The water would be temporarily stored for a period of time. Some of the water in these receptacles would be consumed by the person, but eventually most of it would enter the wastewater system via a plug hole or a toilet. These domestic water uses made up the bulk of most people's water diaries and water-cycle assemblages. This reveals material configurations that stabilise people's water use and affects their expectations. These material configurations are the legacy from which future ANT co-evolutions will occur in the lower Lea river basin.

The two most photographed nonhumans involved with water were the tap and spout, or mixer arrangement (180); and the wash basin (108). These two nonhumans were also the most consistently invisible in terms of written reference. Photographs containing taps, spouts, mixers, and basins would constantly be referred to as "washing hands", "brushing teeth", "washing face", "shaving", rather than "using tap, basin and drain to access and discharge water". This same phenomenon happened with the kitchen sink (78), which was the fourth most photographed nonhuman. Pictures containing kitchen sinks were referred to as "washing the dishes", "washing fruit for lunch", and "washing vegetables". These nonhumans operated for multiple water uses, therefore the specific use of the water was foregrounded rather than the material configuration that enabled the water use. There was a single mention of a tap by Emily in the water diaries because it was dripping and needed to be repaired. This shows that the human focus in assembling water-cycles was to fulfil a matter of concern that was not primarily concerned with water use. The tap and the drain are both black boxes, which were not foregrounded as a matter of concern until the output was not desired, as exampled by the dripping tap.

The regular, continual and ubiquitous use of taps and sinks by all people show that this is one of the most stable actor-networks. The significant (72) discrepancy between the numbers of taps and basins photographed also indicates that the focus for the water-cycle assemblage of most participants was the water source rather than the drainage of wastewater. This concurs with the more numerous institutions that manage drinking-water in the lower Lea river basin.

The third most photographed nonhuman actant was the toilet (83). In contrast with taps, basins, sinks and drains, it was consistently referred to as "toilet". This nonhuman is only used to dispose of human waste, thus the noun also conveys a specific set of verbs. 37% of people's first documented water-cycle intervention was flushing the toilet and nobody photographed any alternate forms of sanitation, which shows that it is also a very stable material configuration in the lower Lea river basin. However, the mention of it as a material configuration that uses water also meant that water reconfigurations to the toilet were also specifically mentioned in the interviews and group discussions where many people mentioned installing saver flushes, hippos and bricks in the cistern of the toilet, the installation and use of a new low flush toilets, and flushing practices. This shows that while the flushing toilet is stable because it is commonly used, it is currently in a process of being co-evolved to suit people's water values which were different from those held by the people who designed the toilet that they were using.

Similarly "washing machine" and "dishwasher" were specifically listed rather than "laundering", "doing the laundry", "doing the washing", or "doing the dishes". In the interviews and group discussions this also led to the mention of eco-cycles or research that had been done to purchase a low water use machine, whereas people who hand washed never mentioned their perceived or understood water consumption connected with this activity. The co-evolution of specific technologies to fulfil a single matter of concern also had the additional effect of making the water consumed by the technology a matter of concern for some people.

Likewise the nine people who had a rainwater butt or a garden tank mentioned these technologies specifically within the water diary, rather than the action of "watering the garden" which was mentioned by those who used a hose to access water for this use. This is another case where enrolling a new technology also generated water as a matter of concern.

"Shower" was another specifically mentioned technology; however its convergence of verb with noun makes it difficult to tell if it was the act of showering or the shower itself that the person was referring to.

Strangely, water itself was only referred to when people noted they were drinking a glass of water, or filling up a water bottle for later use. While water was part of every material configuration photographed, people were not explicit about its use. This shows that water is not the main matter of concern for the majority of water-cycle assemblages, rather it is an actant that has been enrolled and stabilised to fulfil other matters of concern to the human. If the matter of concern can be fulfilled by other means, water need not be enrolled within the network.

Seventeen people noted that the water diary had made them more conscious and observant of the water that they used and therefore had modified their behaviour to conserve water use. Most people felt surprised by the number of times that they used water because they began the water diary feeling that they had high water awareness, yet found themselves making a lot more photographs than they had anticipated. Others observed that the water diary made them reflect on how repetitive their water use was. A few people found the water diary difficult to complete because of the number of times water was used during the day. They found themselves forgetting to photograph their interaction with water over the course of the day. This corresponds with the observation that water is not the main matter of concern for most assemblages of water-cycles for personal use. As water is not the main matter of concern, this opens ANT co-evolution pathways to replace water with other means of fulfilling these matters of concern, thus reconfiguring the urban water-cycle by changing the existing location of water.

**Unstable Water-cycle for Self in Times of Scarcity**

In times of water scarcity there were many reconfigurations to the water-cycles that people imagined they would assemble. Firstly there were ideas of reducing the amount of water used to fulfil their needs. Then there were also suggestions of reusing water, collecting rainwater and finding other alternate water sources. People would also reconsider their practices and technologies of sanitation. People's garden planning and gardening habits would alter to suit the availability of water. All these represent different ANT co-evolutions, some of which concur with the unique water-cycle assemblages that some people have already created in the lower Lea river basin.

The most often mentioned reconfiguration of the water-cycles assembled for self in times of water scarcity was a reduction in the amount of water used to fulfil the different matters of concern: laundering, washing, sanitation, cooking. Some people even suggested decreasing the amount of water for drinking. This shows that people consider that amount of water they now use is not the minimum that they could use. These reductions in water use were only temporary changes because most people stated that they would revert back to normal water usage when water became available. These reductions were also counterbalanced by greater water consumption when water became available because people intended to save their less urgent water using activities until this point in time. However if the scarcity of water proved to be a stable condition of this actant, water conserving behaviour would stabilise and new actants mobilised to maintain this behaviour.

> *"I suppose it's how long it goes for as well, if it's just for a few weeks, you kind of, maybe make a few change and then you go back straight away, whereas say, if it'd gone on for a number of months, you would start to be more ingenious about what you're going to do. So, I guess I would maybe start to think about constructing my own grey-water system or something like that. Maybe like collecting shower water and then using that."*
> *Emily, 7 July 2009.*

This shows that if the water actant changes, then so will the behaviour of people and ANT co-evolution of water-cycle assemblies will occur.

The next most often cited reconfiguration was to find alternative water sources to supplement the drinking-water source. Grey-water reuse was the alternative most often suggested (30) followed by rainwater (17). Water from the sewer system and river-water were mentioned once each. This shows that while drinking-water is currently used for all water uses, there are ANT co-evolution pathways for alternative water sources for uses other than drinking, which reinforces the reuse reconfigurations assembled by Rose, Elsie and Tom as a likely ANT co-evolution trajectory. Furthermore rainwater was reconfigured to become a source of drinking-water by a few people.

> *"…if it was like a long term thing, then I would look at ways in which I could actually collect water myself…get a water butt and stuff, then, I'd pump it through that from that and try and, I don't know, get my own little domestic sort of purifier."*
> *Matthew, 6 August 2009.*

This shows that the source of drinking quality is also an unstable actant.

The third reconfiguration suggested by people was to change their toilet habits, firstly by practicing "yellow mellow" and for 7 people, to change their toilet technology altogether so that it no longer needed to use water to flush waste. The majority of the technologies mentioned were composting toilets, but nightsoil collection and a chemical toilet were also put forth as options. This shows that the flushing toilet actant is not as stable an actant as its common usage would imply. The change in toilet flushing habits towards "yellow mellow" supports the current practices of a few participants as an ANT co-evolution pathway with a wider application. However the suggestions of replacing the flushing toilet with a new actant reveals that the flushing toilet actant can only be modified to a certain degree before it is considered an ineffective as a means of sanitation and new technologies would be co-evolved to replace it, thus reconfiguring the toilet actant represents another possible ANT co-evolution pathway.

The imagined reconfigurations of the water-cycle generated by changing the water actant to become scarce all corresponded with those assembled by people who took it as a matter of fact that they lived in a water scarce world. The only additional ANT co-evolution pathway found was numerous suggestions to replace the flushing toilet actant with a new sanitation technology.

**Unstable Personal Water-cycle Moments in Flooding**

The most unstable actant that people identified during times of regular seasonal flooding was the location of their home. Participants overwhelmingly responded to say that they would move house if their current home was flooded on a regular basis. The only ANT co-evolution pathway from this is to develop strategies to enable to people to move to areas that do not flood without causing social and ecological deterioration and preferably improve both social cohesion and ecological functions.

The few people that had experience of regular flooding either personally or through friends or family did not suggest moving, instead they mentioned modifying their home to prevent water damage. This shows that experience and knowledge limits imagined reconfigurations.

When asked to imagine behavioural change in the extreme circumstances of flooding or water scarcity, it is notable that people who had experiences of other water assemblages either over time or in different places and countries, had a greater range of how they could respond and more detailed imaginings of their reconfigurations. This shows that communities that have older, well travelled and immigrant populations will more quickly assemble new water-cycles to respond to changed water circumstances.

**Changing Water-cycles for Self in 2010**

For the majority of people, the assemblage of the water-cycles for themselves had remained stable between the first and second interviews and group discussions. Some people qualified this by saying that they were water conserving before the interview and therefore they saw no need to change their behaviour or water technologies. However eleven people noted twenty one changes to their water cycle. Sixteen of these changes were related to changes in technology such as putting in a new water tap, installing a water butt in the garden, fitting a tap aerator, fitting a water saver flush, and installing a water meter. Daniel had moved house and jobs, which meant that his personal water use no longer had a direct impact on water in the lower Lea watershed.

Two people had modified their gardens which altered the location and types of water in the landscape. Felicity had made a landscape change to her water-cycle by relining the pond in her back garden and establishing new plants with a bug house and a new habitat for newts. Sally mentioned having recently installed a water butt with a hand pump to divert water to the vegetable patch.

Two people had made a change to their behaviour, Linda now used the shower rather than a bath, Daniel had reduced the number of showers he took. His reduction of showers was a temporary change due to the boiler being broken and thus a lack of hot water to take a comfortable shower.

For two households, the numbers of people living there had reduced. Samuel's household had gone from four people to three and noticed a significant drop in water use from 70L/person/day to 52L/person/day. Bill's household had gone from four to two, but could not recall whether or not there was a drop in the water bill or the volume of water used.

There were a few people who reported technology changes. Tom had his water meter fixed, but this did not result in any substantial change to their water-cycle as they could not read the meter because it was now in a locked box. Tom also had not noticed the change (if any) in the water bill, so it had no impact on the way that his water-cycle was assembled. Ruth and Michelle both had water meters installed. Michelle remarked that her water bill had stayed the same.

Four people indicated that their water use had changed between the winter and summer seasons. Linda noted that they used less hot water in the summer for showers. Elsie, Felicity and Richard observed that more water was used for the garden during the summer months.

These changes to the water-cycles assembled by these people for their own use shows that they are continuously being modified in a state of ANT co-evolution. It also showed that the interviews and group discussions had the effect of galvanising some people to alter their water-cycles to conserve water use. The number of mobilisations of technologies to delegate the task of water conservation means that many of these changes will be stable. This shows that by making water a matter of concern, reconfigured water-cycle assemblages can be mobilised and stabilised.

**Conclusion**

The water-cycles assembled for self were shown to be in a state ANT co-evolution. A few distinctive ANT co-evolution pathways were revealed by unique variations to water-cycle assemblages by people who considered a water scarce world a matter of fact. These pathways were reinforced by people's imagined reconfigurations to their water-cycles in times of water scarcity when they would assemble similar water-cycles. The ANT co-evolution pathways found in these existing and imagined water-cycles that would enable the achievement of reconfiguring the urban water-cycle to ensure its ongoing ability to provide water that humans and other biota require included: grey-water reuse, rainwater use, "yellow mellow" flushing practices and the replacement of toilet technologies. Two additional ANT co-evolution pathways that were found in nondaily water uses included material relations that reduced the amount of work done by people and large open water landscapes for recreation and leisure.

The research also showed that the majority of water-cycles assembled did not consider water as a matter of concern. This means that if the matter of concern could be solved by other actants and material configurations, this part of the water-cycle would not be assembled. It also showed that the stability of the water-cycles assembled depended on the material configurations. Without change to the material configurations new water-cycle assemblies were not likely to stabilise.

## Chapter Seven

# INCREASING FRESHWATER PRODUCTIVITY

The main matter of water concern that drives these proposed reconfigurations to the lower Lea river basin is to improve the aquatic and wetland environments in the Lea watershed by preventing its deterioration from two causes: the abstraction of water for human uses and the additional nutrient load from treated wastewater, both of which cause the eutrophication of the water and the subsequent devastation of oxygen dependent aquatic ecologies. Subsidiary matters of water concern are increasing the residence time of freshwater in terrestrial areas and to develop different water ecologies beneficial to people. Further matters of resource concern not directly related to water are to localise the production of food to reduce the amount of energy needed to transport it to its point of consumption; and to maximise local energy harvest and production to limit the amount of energy transmission loss.

The existing ANT co-evolution pathways that have been used in these propositions are the systems of water reuse assembled by Rose, Elsie and Tom and also suggested by people imagining how they would reconfigure their water-cycle in times of water scarcity; as well as alternate water sources as assembled by people who used rainwater collected in water butts to water their garden and also conjectured as a new water source in times of scarcity. Water reuse and alternate water sources were respectively the second and third most suggested reconfigurations during times of water scarcity. The first most suggested reconfiguration was to be more frugal with water use, which did not involve a material reconfiguration of the existing water-cycle assemblages. The other ANT co-evolution pathways that are used were the appreciation of open water landscapes by people for recreation and leisure; the creation of convenient ways for water to be reused that also accomplished the matter of concern which required water; and the visual feedback of volumes of water use.

These altered actor-network relations of unique and changing water-cycles were combined with the common pattern of the existing urban fabric in the lower Lea, existing components of water technologies, water productivity and treatment in order to suggest how new actants could be added to the existing water-cycle to co-evolve an increased freshwater productivity in this urban area by reusing water and harvesting the energy and nutrient inputs from humans and other biota. This increased freshwater productivity results in less drinking-water consumption per capita, which allows a greater capacity to serve a larger population, greater tolerance in the existing water storage capacity for extreme climate variation, and more water flow in surface-water, groundwater and evapotranspiration, for greater ecological functions. In addition it also generates energy and food close to where it will be consumed.

This chapter first problematizes the water-cycle assemblage of the lower Lea river basin. Then it describes the ANT co-evolution pathways for the reconfigurations of the proposed water-cycle assemblages to increase freshwater productivity. It follows this with how the participants problematized and interressement the relations to these reconfigured assemblages in an iterative process where the proposed water-cycle assemblages alter in response to these human actants.

**Problematisation**

The lower Lea river has poor water quality because it is over abstracted to fulfil the drinking-water demands from the people of London. The Lea also has poor water quality because of the numerous combined sewer overflow events that release untreated wastewater into the river to prevent sewer pipes from backing up and flooding streets and homes (Thames Water c2008). These sewers date back to Victorian times and were not designed for the increased population and per capita water consumption of contemporary London (Halliday 1999; Thames Water c2008). The poor water quality of the Lea affects ecologies that contain habitats for fish which are part of the food stocks for people, and vegetation which produces oxygen for human respiration (Acreman 2000), therefore the poor water quality of the Lea needs to be remediated through reconfigurations that improve these aspects of human livelihood.

It has been observed that people served by piped drinking-water supply continually increase their water use due to changing water practices, the addition of new water consuming technologies and little personal awareness of the environmental consequences of their water use (Chapter 2) (Butler and Memon 2006; Geels 2005; Gandy 2003; Metropolitan Water Board 1961). Hence creating material configurations that indicate levels of water availability and amount of water use would give a new source of information about personal water impacts which enables a greater sense empowerment to evoke change, and/or responsibility to use water equitably. This change in understanding would lead to new water-cycle assemblages that would improve the water quality of the lower Lea river.

The Lea river has poor water quality because it is a beyond over abstracted source of raw-water for the drinking-water of London (EA 2006). London is an area that is drinking-water stressed because there is a lack of sufficient water sources from which raw-water can be abstracted to treat to a drinking-water standard to serve the demands of the population (GLA 2009; Thames Water 2007). In climate change projections, this water stress is likely to get worse in the summer months (GLA 2009; Jenkins, Perry, and Prior 2009). In this case, drinking-water restrictions may come into effect, therefore the use of drinking-water for things such as watering the garden would not be allowed for a certain time period.

This research has indicated that in times of scarcity, people are likely to find alternative water sources to make up the difference between their restricted drinking-water access and their desired water use. Should this occur, then people would collect different types of water for different uses and reuses. This would create much more standing freshwater in the urban environment. This would require space for vessels within houses and outside the house. This would result in less space for living areas or gardens, which would also result in greater amounts of impervious area which adversely affects ground-water recharge. If this standing water was not properly managed it would form a breeding ground for mosquitos and give rise to an increase in vector borne diseases. Therefore reconfigurations for future water-cycle assemblages needs to take into account the likely changes to people's personal water-cycle assemblages and find ways for material reconfigurations to enable this to occur while increasing groundwater recharge and human health.

In addition the urban configuration of the lower Lea river basin is also deleterious to human livelihood because it relies on the importation food with a high energy expenditure and consequent pollution for its transportation (Landry 2006; Register 2002). Some people living here also suffer from the lack of appreciation between people and people, or people and endemic biota or people and geological landscapes (research interviews, 2009-10). A reconfiguration of the water-cycle that also affected improvements to these problems would gain more interressement from human actants living in this location.

**First Iteration of Design Interressements of Co-evolving Actants**

In order to improve water quality, these reconfigurations need to decrease combined sewer overflow events and water abstractions from the river. Water reuse and alternative water sources were two ANT co-evolution pathways which would allow this to occur within the existing urban form of the lower Lea river basin. Three supplementing ANT co-evolution pathways were used to support the interressement of water reuse and alternative water sources; they were ease of water use, appreciation of open water landscapes, and visual feedback from volumes of water.

The design interressement of the co-evolving actants that increase freshwater productivity in the lower Lea river basin, occurs in four moments depicted over a 100 year period beginning from 2010. All the design actants were premised as alterations and additions to existing urban areas because the reuse of existing urban fabric is more resource efficient than extracting new resources to build over demolished areas. In addition, these four ANT co-evolutions of water reuse build upon one another escalating the urban effect and the change to water-cycle assemblages from contemporary accounts. These new design actants begin with a washing up bowl with a lid and handles, in 10 years grey-water tanks, in 25-50 years neighbours sharing a grey-water recycler, and in 50-100 years polyculture reuse.

**Washing Up Bowl With Lid and Handles**

The first design interressement was to modify the existing washing up bowl actant. This was a discrete, widely used actant that was already being used by a few people to assemble water reuse water-cycles today. However the convenience of this water reuse was hampered by the awkwardness of handling the bowl because it did not have handles to pick it up, nor a lid to prevent water from splashing out and causing a mess or damage to areas that need to be kept dry.

The alteration to the washing up bowl was to provide lids and handles so that it would be easier to lift out of the sink and move around without splashing water around the house (figure 7.1). The cleanliness of the water after its initial use would determine its next use. Suggested uses included flushing the toilet, watering the garden, cleaning bikes and the house. More sophisticated lids could also be developed that also incorporated spouts and water roses to enable the watering of pot plants, or sprinkling the garden. This new actant was projected to be implemented in the immediate moment.

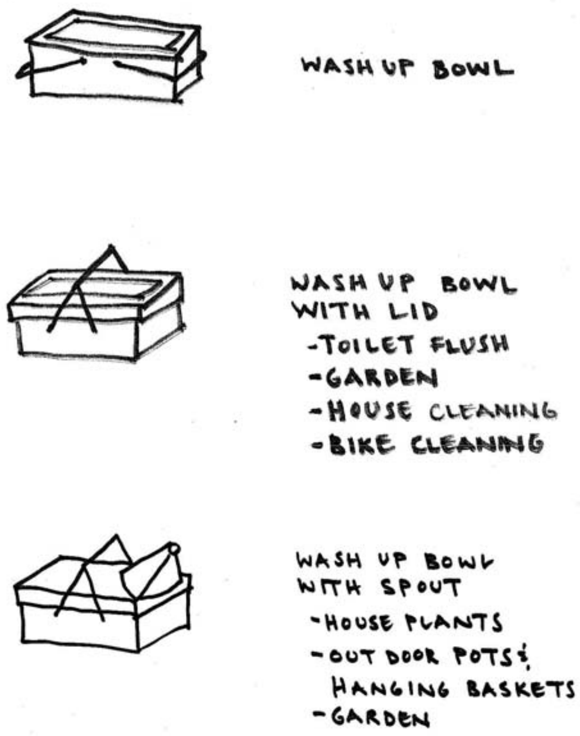



**Figure 7.1**
**Washing up bowl with lids and handles**

The majority of human interressement in relation to this actant was agreement that this water-cycle assemblage was one which they could enact as a mobilisation for water reuse. Six people affirmed that they did something similar now, or had thought about doing so, which verifies that this is an ANT co-evolution pathway in the lower Lea river basin.

Nine people suggested how this actant could be modified in order to make it more appealing to a wider number of human actants to increase this practice of water reuse. Elsie, Frank and Heather thought that the style of the modified washing up bowl would make a difference to its adoption, this included shape, colour and material form. Claire, Vishtu and Heather all thought that the spout should contain filters of some sort to improve the quality of the water that was being reused.

Tom suggested that an additional actant be added in relation to the washing up bowl. He suggested that the washing up bowl could come with a fridge magnet with ideas about what this water could be reused for. Anne also identified that education about how the water could be reused was needed, but did not make a suggestion about how this could be achieved. Roger and Elsie thought that the kitchen sink would be an actant that also needed modification in relation to the modified washing up bowl in order to make it easier to lift out of the sink.

People noted that this design actant would not interressement people who were unable or lacked motivation to lift water, which can be heavy if the washing up bowl contains a large volume of water. This led to alternate material configurations to be proposed by these human actants to make water reuse even easier. These suggested reconfigurations included dual wastes for the kitchen sink which could divert water to either an irrigation tank or the sewer and using a hand powered pump to drain water to a tank outside.

Another matter of concern was the effect of detergents in the reused water on plants. Only Samuel saw this as a positive relation because it prevents aphids multiplying on rose plants. Most other people felt ambivalent as to whether or not it would be harmful or helpful to the plants that they cultivated.

A further matter of concern was time and space. Water use requirements were not necessarily timed with when there might be water available to reuse. Conversely water to be reused would need space to be stored in order to be reused at a later date.

Several people also noted that amount of water which can be reused from a washing up bowl was small in comparison to other water uses. Daniel and Ruth both thought that water from showers would be a more effective source for water reuse. Another alternative source of water suggested by Ron was rainwater.

The washing up bowl with lids and handles was a new actant that successfully interressement these human actants. The imagined reconfiguration also found further pathways for ANT co-evolution that included new material configurations to make water reuse even less taxing on the human actant; water filters to improve the quality of the water being reused; aesthetic considerations to create a washing up bowl with an appealing character; and the expansion of water reuse to encompass alternative water sources.

**Grey-water Reuse Tanks**

The second design interressement was to modify the water flow from shower trays and baths from discharging into the centralised wastewater system. Instead it would be held in a tank for reuse primarily for toilet flushing. The grey-water in the reuse tank could also be connected to drip irrigation in the garden and a garden tank for other water uses. The tank would also overflow into the centralised sewer system once it was full, or if it needed to be drained for maintenance. On the tank itself would be an indicator, much like those on the side of an electric kettle that would show the water volume inside the tank.

This system was gravity fed and relied on a common configuration of housing in the lower Lea river basin, whereupon most houses were two storied attached single dwellings with the wet areas of the house stacked on top of each other to the rear of the building. These houses were on their own individual lots with both a front and back garden. This means that a grey-water tank installed between the two levels would collect water from the shower and basin on the upper floor to flush the toilet on the ground floor and irrigate the garden without requiring a pump. The grey-water tank would have a screen to make sure solids, such as stray hair could be removed before reuse. If the ground floor toilet was the only one used, on average (Butler and Memon 2006), the shower and basin water would be used within a 24 hour period for toilet flushing. The same arrangement could be made with apartments, but this may mean using grey-water from the neighbours above if the apartment did not have stacked wet areas over two stories. This enables a low energy system that only requires gravity to drain the water from upstairs to downstairs and to garden areas (figure 7.2).

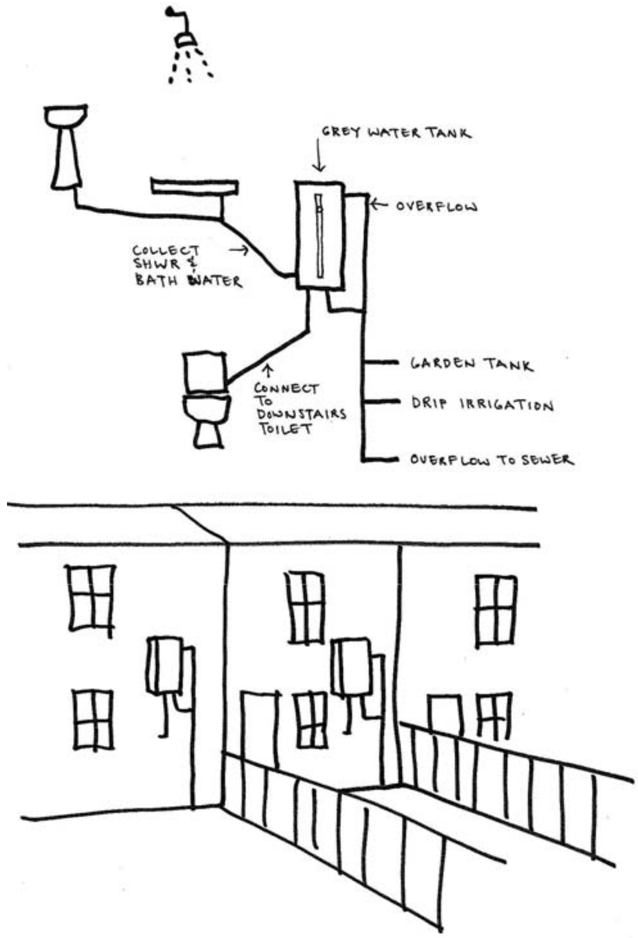



**Figure 7.2**
**Grey-water tanks**

This alteration to the pipes was to provide easy access to an alternative source of water for toilet flushing, garden irrigation, and other non-potable uses. In addition it would provide visual feedback to both the house owner and the neighbouring properties as to the effectiveness of the household's grey-water reuse by the indicator on the tank. This new actant was projected to be implemented in a 10 year timeframe.

This second design interressment was indicated as an ANT co-evolution pathway from the responses from the first design interressement. Daniel and Ruth both thought that using water from showers would be a more effective source of water reuse than the washing up bowl. Moreover others had suggested that water reuse would be more likely if water was diverted to a tank for future reuse, rather than having to haul water in a washing up bowl. This second design interressment responds to these ANT co-evolutions.

The majority of human interressement with this actant was agreement to be enrolled in this water-cycle assemblage. Twenty seven people thought that it was a good idea that they would use.

Twelve people thought that a filter or some other type of treatment was necessary in the tank to improve the visual quality of the water in the toilet bowl. For example, a filter to ensure that the water reused for flushing does not have any solid things in it, soap scum, or grease that would make the toilet bowl look dirty.

Seven people thought that reuse could be improved by adding more alternative water sources to the tank or adding alternative uses for water from the tank. Most people suggested adding rainwater to the tank, but Jack also suggested washing machine water and Tom suggested adding water from the hand basin. Adam suggested that an additional use of the grey-water could be for the washing machine and Richard thought that some of the grey-water could be pumped to a tank in the attic which would serve the upstairs toilet. Jack thought that if the water was also treated, it could be used for drinking. Samuel suggested that heat could also be extracted from the grey-water to heat the house.

Some people were concerned that there would be insufficient water from showering or bathing to flush the toilet, thus they thought that the grey-water tank should be connected to the mains to top up the water source, should there be insufficient of grey-water.

Some people were concerned about the complexity of installing such a system. Most people were concerned with the number of extra pipes that would need to be installed and connected. Daniel and Anne thought that plumbers would need to be trained to make such installations. Furthermore, Daniel sought to stabilise this configuration by suggesting the creation of a grey-water manufacturers association that would train plumbers and standardize all the installations. This stabilisation of people, processes and materials would make the grey-water tank a trustworthy technology that was easy for homeowners to purchase and have installed.

Due to the perceived complexities of the installation of the tank and associated pipes, six people thought that this was an idea that could be applied immediately to new housing developments rather than existing housing stock. In addition, Paul did not think that this could be applied to existing housing at all and should only be applied to new housing developments.

Four people were concerned about the aesthetics of the tank. Frank and Anne thought that the tank could be installed internally to preclude any alteration to the exterior character of the house. Humphrey and Ruth both expressed that they thought the tank was ugly.

Elsie, Harry and Roger noted that it was possible that this system would encourage greater water use because people may take longer showers and bigger baths more frequently in order to gain more water for the garden. Both Daniel and Ben thought that Thames Water Utilities would object to such a system because it would change the quantity of their drinking-water distribution and hence their profits.

The grey-water tank was a new actant that successfully interressement these human actants. The imagined reconfiguration also found further pathways for ANT co-evolution that included new material configurations to make water reuse even more effective by adding new water sources and water uses; harvesting heat from the warmed water; and setting up an association to train plumbers and standardise installations. People also noted ways in which this new actant might be betrayed. These were because of its perceived ugliness; the water company's demand for profit; and people bypassing the system to gain additional water in a water scarce situation.

**Neighbours Sharing Grey-water Infrastructure**

The third design interressement was to modify the water flows even further. It proposed to divert all water from baths, shower trays, hand basins, and washing machines for reuse. This design uses the same technology as Tom's grey-water recycler to gather and treat the water before it is pumped to a reservoir tank, from which water is then gravity fed and distributed into the house for reuse in the washing machine, for toilet flushing, for irrigating the garden, and for house cleaning. The tank would also overflow to a wetland that would provide additional polishing to the water and recharge to the soil-water and groundwater, before it is either pumped to the reservoir tank or discharged to the centralised wastewater system. This wetland system would only be wet when the grey-water recycler overflowed and would give visual feedback as to the water availability and water balance between grey-water creation and grey-water use.

In order for the grey-water recycler to be more effective in terms of initial cost, energy efficiency, water treatment and continuing operating costs, the grey-water recycler was proposed to be shared amongst a few (3-4) neighbouring households. This relied on the repetitive forms of the building stock common in the lower Lea river basin. The repetitive forms meant that house lots were approximately the same size, as were the buildings, which meant that household sizes were also approximately alike. From the similarities of the water-cycles for self, assembled by the participants in this research, most households would also assemble analogous water-cycles. The similar housing lots sizes also meant that each household would donate the same amount of garden space for recycling the grey-water.  Thus the sharing of this technology would be relatively equitable (figure 7.3 and 7.4).

The sharing of the grey-water recycling system and the wetland overflow also addressed the additional problems of the lack of appreciation between people and people, and people and biota, which were expressed by the participants. The shared grey-water recycler provided a common actant that was assembled by the neighbours, moreover they had to continue to enact its assemblage in order for it to operate to the advantage of all, and this meant that there was a continued reason to form a community. The wetland overflow was another actant that enabled people to observe biota, their effect on it, and its changes over time as new species colonise the habitat. This new actant was to co-evolve in the 25-50 year timeframe.

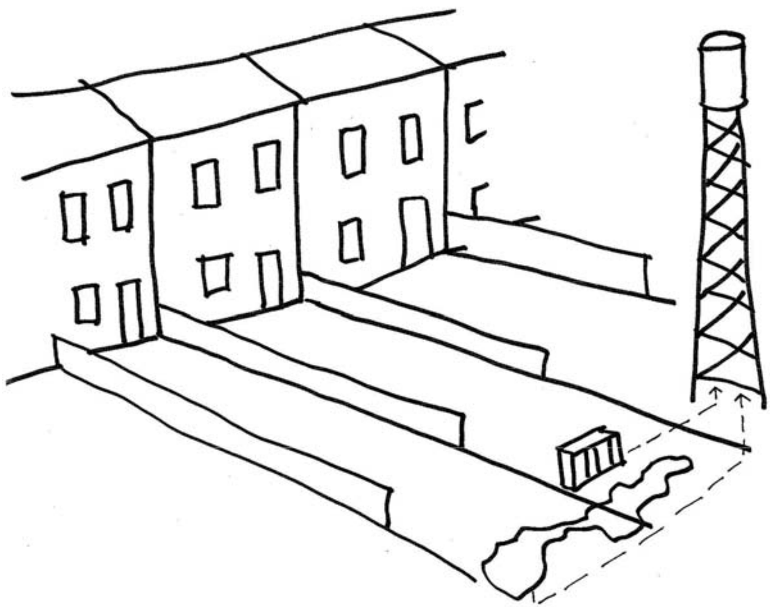


**Figure 7.3**
**Neighbours sharing grey-water recycler**


**Figure 7.4**
**Common repetitive urban form in the lower Lea river basin**

This reconfiguration of the water-cycle was to reuse all the grey-water produced in the household for uses that do not require drinking quality water such as house cleaning and laundry. In addition it proposes the use of a wetland to provide a visual indicator of water availability and water balance between grey-water production and grey-water use, thus it forms a connection between people and biota. This reconfiguration of the water-cycle also required new relations between people because it suggests the sharing of common resources. This forms a connection between people and people.

Some of the responses from the second design interressement indicated ANT co-evolution pathways that were included in this third design interressement. These included adding filters and treatment for the water before reuse; adding more alternative water sources as suggested by Jack and Tom; and more water uses for water reuse as suggested by Adam and Richard. It also uses a pump to fill a reservoir tank so that all possible water reuses in the house can be connected and gravity fed as Richard had mentioned as an improvement to the grey-water tanks.

The majority of the responses to this design actant were resistance to enrol; most people were conditional in their agreement to enrol in this actor-network. This included limiting the building type it could be applied to, such as flats, estates, or social housing; or that it was best applied to new housing developments; or places that were centrally managed such as cooperative housing or housing associations.

Fourteen people thought that it was a good idea; however 31 people felt that it would not be possible to enrol other neighbouring people into this network relation. This was for a variety of reasons, some people thought that London had a rapid turnover of tenant occupants and absentee landlords owning houses would prevent people from making a commitment to install such a technology. Other people thought that it would be difficult to talk to neighbours or find neighbours with similar commitments towards water conservation or improving the environment. Four people thought that the negotiations with the neighbours would be so problematic that it would be best if all water reuse was done on a household level. Many people were concerned that agreements between neighbours might be betrayed by people selling their house and/or moving. Conversely there were 6 people thought that the negotiation, delivery and ongoing use and maintenance of the shared grey-water technology would help create communities. Furthermore Rose, Samuel and Sally thought that implementing such a system would help people understand their water use and its effects on the environment

Eighteen people raised concerns about the management and maintenance of the new water reuse system. Most people queried who would be responsible. Some people thought that this was too much responsibility for one person to bear for its implementation, management and ongoing maintenance. Other people suggested that this could be done by an existing institution such as the council or water authority.

Thirteen people were concerned over who would pay for this new technology and how much it would cost. Two people felt that it would be expensive and therefore only appeal to wealthy environmentally concerned people.

Six people thought that there was insufficient garden space to implement this system either because the building lots were too small, or because garden space was maximised for private use. They were also concerned about which parts of the system would be in their space.

This was especially in relation to the reservoir tank. Thirteen people thought that the reservoir tank was unsightly and would prefer that the tank was concealed with a building roof space. Only Elsie thought that the tank was useful and decorative. Ruth noted that places like Cyprus had water tanks and it caused no sense of ugliness. Sally and Susan saw the wetland as a biodiversity benefit for people rather than a restriction on recreation space.

Daniel, Harry and Adam raised concerns about the water balance between grey-water produced and reused and the equity of water and maintenance distribution between households. Some households might produce more grey-water than they used or vice versa, some households might not produce or use much grey-water, and so on.

Four people thought that the carbon dioxide emissions from the energy production needed to pump the water to the reservoir tank would cause greater environmental damage than the environmental benefits of conserving drinking-water. Overall nine people did not believe that there were enough benefits to this system to warrant its existence.

Neighbours sharing a grey-water recycling system was a new actant that failed to interressement these human actants. The most prevalent ANT co-evolution pathway was for the centralised management of grey-water treatment and reticulation. Many people thought that this could be done in existing centralised managed buildings such as flats, housing estates and social housing. Most people thought that this new actant would not be able to enrol the other humans that are necessary for its implementation. People also thought that the actant would be betrayed by a lack of garden space to assemble the new material configuration and the lack of aesthetic appeal of the reservoir tank.

**Polyculture Reuse**

The fourth and final interressement of these co-evolving design actants was polyculture reuse. This was based on the reuse of grey-water, but primarily used a set of constructed ponds and wetlands to treat the water rather than a grey-water recycler (figure 7.5). This allowed the nutrients in the grey-water to be used to feed plants and fish that could then be used as a food stock for livestock, humans, or for biofuel. The uptake of nutrients by plants, fish and other biota cleans and filters the water for reuse by people. This system is based on a successful integrated aquaculture agriculture system that began in northern Vietnam, but is now widely used throughout the country. In Vietnam this system is known as VAC (Vuon: garden; Ao: fish- pond; Chuong: pigsty or poultry shed) (Hop 2003; Luu 2001; Ogle et al. 2003). This design actant adds electricity microgeneration from the running water between ponds to this established system of water treatment, this also aerates the water increasing its oxygen content.

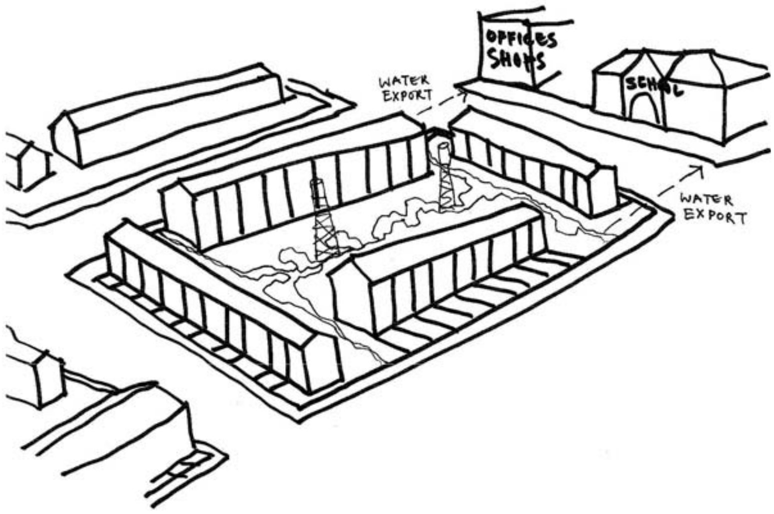



**Figure 7.5**
**Polyculture reuse**

The modification of the grey-water treatment to provide food stocks responded to the additional deleterious relations of the urban configuration of the lower Lea river basin. These were the high energy, pollution and resource costs of importing food, and the lack of appreciation between people and people, and people and biota. The production of food stocks from the nutrients of local grey-water treatment reduces the transportation of food; the wetlands and ponds provides an actant that will continue to be a matter of concern for the people connected to the system because their water and food depends on its operation and thus people will need to interact with each other to ensure that the appropriate water inputs and outputs are assembled. The wetlands and ponds also form a changing landscape where people can observe biota and their shared effects on ecologies.

This polyculture reuse was projected to be implemented in a 50-100 year timeframe. It was presumed that in 50 years' time many neighbours on a block would have cooperated to share a grey-water recycler and reservoir tank system. At this point, when the majority of households on a block had shared grey-water recycling systems, these people would start to think about gaining even more efficiencies and amenities from their water and energy use by joining their grey-water systems together. In this way people who had not been able to be enrolled in the initial neighbour share projects could join; the number of grey-water recyclers, reservoirs, and pumps could be reduced, and the wetland overflows could become a wetland water treatment system with integrated agriculture and aquaculture and the grey-water recyclers would be used for the overflow from this system. Energy from the water moving between the different treatment ponds could be used to generate electricity. Furthermore, this larger shared network of grey-water recycling also enables longer network connections to develop beyond the scale of the block and residential water uses, to other uses such as offices, light industries, schools, and other public buildings that do not generate much grey-water, but could use grey-water for cleaning, watering, and toilet flushing. Moreover in a special case, properties close to the New River (an open ground level aqueduct transporting raw-water to be treated for drinking-water) in Haringey, could transfer any additional treated grey-water into the raw-water system for treatment to a drinking-water standard and used as drinking-water supply for London.

The fourth design interressement was not indicated as a co-evolution pathway from the responses of the third design interressement because most people did not think that the third design interressement was a viable actant due to the difficulties of enrolling their neighbours into the actor-network. However it does build upon the ANT co-evolution pathway of the six people who observed that the assembling of the new actant, would also assemble a new community of people; the convenience of piped water connections; and of open water and water features that were documented in participants' water diaries as being meaningful to their lives.

The majority of human interressement in relation to this new design actant was agreement that this was a water-cycle assemblage that they believed they could enact as a mobilisation. This was a surprising result given the low level of intereressement of the previous design actant. There were only 10 responses that identified that other humans would betray this actor-network by failure to enrol and mobilise, in comparison to the 31 responses of the previous actant. Thirteen people thought that polyculture reuse was a good idea. Only three people: Alan, Humphrey, and George, thought that this was an impossible new actant. This indicates that polyculture reuse is a possible ANT co-evolution pathway in the lower Lea river basin.

The overall enthusiastic interressement for the new design actant was tempered with concerns about garden space. Elsie and Anne identified that the wetlands and ponds constituted a new shared space in the backyard, which are currently private. However they both remained positive that the territorial disputes could be negotiated. Ben was unwilling to use any part of his backyard for a wetland because it is currently used to grow vegetables, have a paddling pool, for outdoor dining and to dry the laundry. But some of these uses could be incorporated into the wetland and pond system, and others are not mutually exclusive to the shared wetland and pond system. Phillip wondered if there would still be space for children to play. These matters of concern require further negotiation between actants.

Seven people thought that treated grey-water going to the New River as a source of raw-water supply for drinking water was a good idea. Moreover Roger suggested that the water could be treated at point of use to produce drinking-water. This was similar to the suggestions of Jack in the neighbours sharing grey-water design interressement and Tom (owner of a grey-water recycler) in times of water scarcity. This indicates an ANT co-evolution pathway for an alternative source of drinking-water.

Five people thought that polyculture reuse would create a new market with the benefits of jobs for more people to manage and maintain the water-cycle assemblage and the development of new technologies. Roger thought that if this proved viable through a built actant, it could offer competition with water companies.

Twelve people thought that a new single institution would be needed to manage polyculture reuse. Four people suggested that this would be better implemented on large estates or flats where the estate management would also manage the polyculture system. Six people thought that it would be better applied to new developments where the developer who built the polyculture reuse system would also set up and implement the management system. Heather suggested the councils could manage the system. Cassie thought a residence association would be able to. Alan, Felicity and Rita thought the water company should do it. Eight people thought that the new types of management needed for this water-cycle assemblage would also build a stronger community from people working together. This shows that polyculture reuse would enrol and mobilise a new set of yet unknown actor-networks in order to assemble and continue to enact this water-cycle assemblage.

Nine suggestions were also made to improve the design actant. Rainwater was suggested as an additional water source for the grey-water system by Charlie and Elsie. Sally thought that this could be developed in collaboration with the water company so that water could be fed back into the water grid for reuse. Elsie also thought that the water could be reused to irrigate street trees and front gardens. Charlotte wondered if the canals of London could also be incorporated into this scheme as a source of water or for water distribution.

Tom, Heather and Richard thought that more opportunities could be incorporated to harvest resources and improve the urban landscape beyond grey-water reuse. Richard suggested that the heat from grey-water could be harvested before it entered the wetland and pond system. He thought that this could represent a substantial cost saving to the homeowner because approximately 25% of his heating bill went towards heating hot water. Frank suggested that polyculture reuse could improve its green credentials by adding wind turbines and solar panels. These suggestions all indicate the formation of new relations that polyculture reuse could mobilise in order to gain further stability in the urban environment of the lower Lea river basin.

Polyculture reuse was a new design actant that successfully interressement these human actants. It found a new ANT co-evolution pathway for an alternative source of drinking-water. It also identified that the additional matters of concern for the assemblage of polyculture reuse were continued accessibility to garden space for uses other than water filtration, aquaculture and agriculture, and the need for a centralised institutional arrangement to manage the new water-cycle assemblage.

**Second Iterations of Design Interressement of Co-evolving Actants**

The washing up bowl with lids and handles, the grey-water tank and polyculture reuse all successfully interressement these human actants. The washing up bowl and polyculture reuse showed the most enrolment by people, therefore these two were selected to test further co-evolutions. These two co-evolutions were also selected because they are complementary to each other. The use of a washing up bowl to immediately reuse grey-water from a kitchen sink does not exclude the use of polyculture for other sources of grey-water.

These co-evolutions were considered only from the immediate timeframe of 2010 because the first iteration of design interressement showed that people continued to consider the material actant relative to their own actor-network configurations as enacted in the present time.

The additional matters of concern for these two actants to interresement were different, but both respond to the co-evolutions suggested by the participants. For the washing up bowl it was the aesthetic appeal of the bowl, and modifications to the sink to make it easier to lift the washing up bowl. For the polyculture reuse the matter of concern was to enable further resource harvesting beyond the water-cycle assemblage such as wind power, heat and solar energy. A design actant that co-evolved to address these matters of concern would possibly enrol and mobilise more human actants into the actor-network being assembled.

These new design interessements continue to limit water pollution and reduce water abstraction by finding alternative water sources for different water uses and harvests nutrients from grey-water thus any water that returns to the centralised sewer system has less pollutants dissolved in it.

**Take Away Sink**

This second iteration design interressement replaced the kitchen sink with a removable bowl on a drainage board that had a waste connected to a drain. This was designed and prototyped by a Royal College of the Arts design student, Jessica Nebel in 2007. The removal of the sink meant that the bowl could be easily removed for water reuse because there was no need to lift it over the side of a sink, or manoeuvre in the space between a water spout and the side of a sink. The take away sink also has a waste and plug in the base, so if the water is too dirty for reuse it can be easily drained away while it sits on the drainage board. This removes the doubling up of functions between the sink and the washing up bowl, while retaining the portability of the washing up bowl for water reuse (figure 7.6).

**Figure 7.6**
**Take away sink**
(Jessica Nebel, www.jessicanebel.com/)

The take away sink had diminished interressement from the human actants throughout all the group discussions in comparison to the washing up bowl with lid and handles. People felt that it was too big a change to existing infrastructure, without a significant volume of water saving. Nobody felt that the take away sink would be more manoeuvrable than having to lift a washing up bowl over the side of the sink therefore these material relations could be more simply and inexpensively achieved with an existing actant. A few people were concerned that the plug at the bottom of the sink would fall out or not be water tight should they lift up the sink to reuse the water elsewhere.

People were divided over the aesthetic appeal of the take away sink. Some people remarked negatively about the design style of this actant. Most comments indicated that these people felt uncomfortable with the character of the aesthetic because it did not fit with the style of their kitchen. However an equal number of people thought that the take away sink was very attractive. Two people mentioned that a lid would improve the use of this actant.

Only one person remarked that the design of a removable sink might help people remember to reuse their washing up water rather than simply tipping it away. Another person suggested removing the connection to the sewer in the take away sink and drainage board so that reuse would be stabilised because there would be no other way to drain the water contained in the take away sink. One other person thought that the take away sink might be better located in the bathroom, where water that had been used for washing the hands or the face could be easily used to flush the toilet.

Interestingly unlike the washing up bowl with lid and handles which was the previous iteration of this design actant, less people remarked that the quality of water in the take away sink would prevent them from considering reusing this water. Many people still felt that a piped water diversion from the sink to a garden tank, bottle or jerry can would be a better material configuration for water reuse.

The take away sink did not successfully interressement these human actants, hence it is not an ANT co-evolution pathway for futher development. This design actant required too many material changes to the configuration of people's homes without assembling a significant clean and convenient method of reusing water. The preferred co-evolution pathway was for a piped water reuse connection rather than the human manoeuvring of water.

**Polyculture Reuse Community**

This second iteration design interressement adds more energy harvesting functions, water sources and water uses to the previous polyculture reuse design actant. There was no prototype for this design actant because there were no communities that have adapted an existing urban area with such a comprehensive harvesting of nutrients and energy.

The polyculture reuse community is plumbed to collect grey-water from washing machines, basins, baths and showers in all buildings in the surrounding area. It uses a heat exchanger to harvest the heat from the grey-water, which can be used as a source of heat for the buildings. This grey-water first fills a grey-water tank that is used for any flushing toilet. When this is full, the water is then used in a series of ponds and wetlands where its nutrients are used to grow food and the energy of flowing water is used for electricity microgeneration. These ponds and wetlands also collect surface-water from rainfall. Overflow water from the ponds and wetlands are treated by a grey-water recycler. The water, that has been treated either by the wetlands and ponds or the grey-water recycler are pumped up to communal reservoir towers. These reservoir towers are located in the street and combine photovoltaics and wind turbines for electrical energy generation. The towers ensure that the photovoltaics gain maximum sunlight; the wind turbines maximum airflow; and the reservoirs adequate water head for pressurised water distribution. At the base of each tower is a small rain garden, which indicates the availability of water in the local environment. These towers are also a tangible material signal of a polyculture community. The treated water is reused in all building types in the local area as well as irrigation for street trees and parklands. In addition the water can be boiled and used as a source of drinking-water. However this is not a closed system and assumes that centralised piped drinking-water will still be supplied and wastewater sewer systems used for toilet flushes, surface and grey-water overflow.

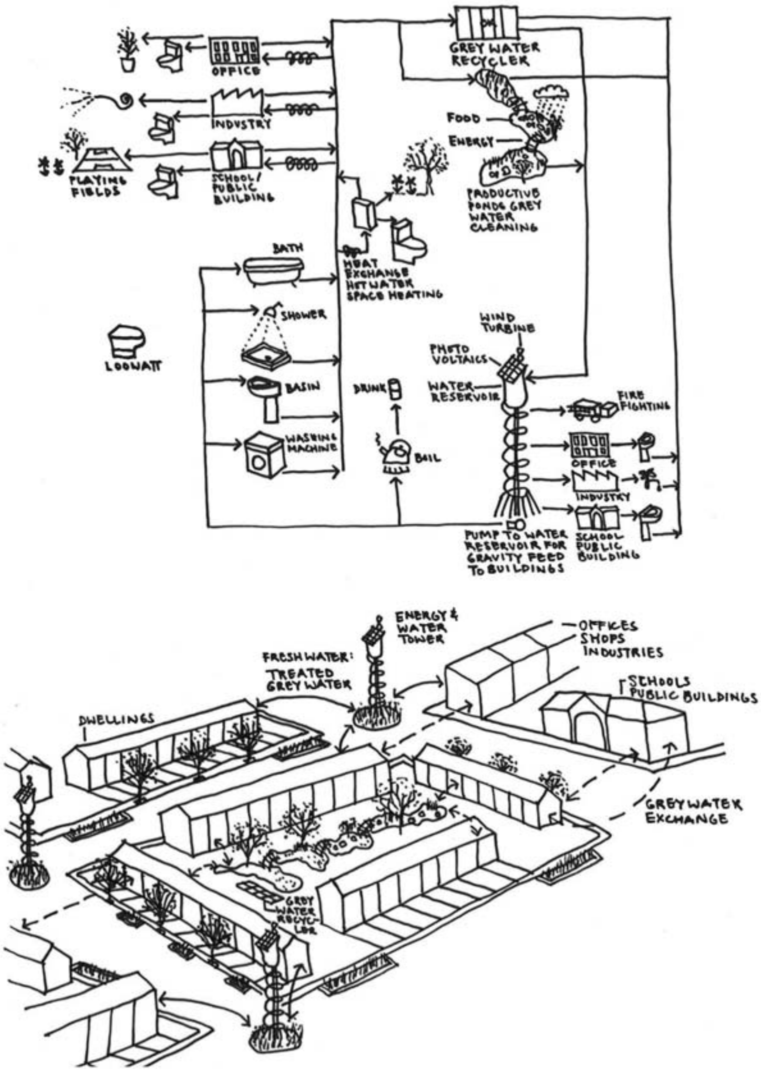



**Figure 7.7**
**Polyculture reuse community**

The interressement of this new design actant was mostly agreement that this was an actant that people would enrol and mobilise with much the same enthusiasm as the first iteration of the design. Very few new actant relations or co-evolutions emerged from the discussions. Many of the matters of concern require creating more actant relations that move towards enacting the design actant into a built form in a specific place.

Three people thought that this system could be used in ecotowns. Two people thought that it should be applied to new building developments. One person suggested that this could be implemented in flats, student housing and prisons; four people suggested that this could be made in a rural area; and one person suggested that it should be used in developing countries. These responses show that while people have interressement this design actant, some did not see themselves as mobilising the required material assemblages to bring it about.

Four people felt that the level of agreement amongst people would betray the mobilisation of this actant. Three people thought that assembling polyculture would create a sense of community amongst people because of a shared matter of concern. Six people thought that a new type of management system would be required to enact this water-cycle assemblage. Councils, housing associations were existing institutions that were suggested as possible managers of polyculture. These are new actant relations that would need to be formed if this design actant were to be mobilised to be built.

Six people were also concerned about who would pay for the installation, running and maintenance of the system. Two people thought that they would not mobilise such a system if it were to cost more than the existing system. The cost is an actant that is indeterminate without the design actant being mobilised for implementation and will not stabilise until it is constructed and continually enacted.

Three people wondered what scale would be required for this material assemblage to operate effectively. One person speculated that a village scale would work. This is another matter of concern that requires the mobilisation of even more specific actant relations such as the types of heat transfer technologies will be used; the types of plants and aquatic biota that will be used to harvest nutrients; the particular people and their water use patterns; the particular relations between people; the size of open space available for ponds and wetlands; and so on.

Four people mentioned other places where they believed that such a system was already in place: Germany; Portland, USA; Spain; and Sweden. These examples were used as matters of fact by the participants to indicate that the assembly of these material and social relations are possible. These actants reinforce that this ANT co-evolution pathway.

No new actant relations were found in this iteration of the design actant. However its successful interressement of new human actants and people's use of other examples of similar material relations strengthen the polyculture reuse community as an ANT co-evolution pathway to reconfigure the water-cycle in the lower Lea river basin.

**Conclusion**

Six design actants were investigated as possible ANT co-evolution pathways to reconfigure the urban water-cycle in the lower lea river basin in this chapter. These six design actants all improved the aquatic and wetland environments by reducing water abstractions, water treatment and the nutrient content of water returning to aquatic environments. Four out of the six design actants were successful at interressement the participants. These were the washing up bowl with lids and handles, grey-water reuse tanks, polyculture reuse and polyculture reuse community. These design actants found additional actants that were related to their enrolment and mobilisation. They also found new ANT co-evolutionary pathways for further development.

The ANT co-evolutionary pathway that was developed in these design iterations were different methods of water reuse. The iterations found that the two types of grey-water reuse that continued to interressement people were household grey-water reticulation using gravity, pipes and tanks; and community scaled grey-water treatment and reticulation with the additional benefits of integrated agriculture aquaculture and community relationships based on a common matter of concern. Therefore these are two ANT co-evolution pathways that could continue to be developed to mobilise reconfigurations of the urban water-cycle in the lower Lea watershed. Both these reconfigurations would contribute to the flourishing of human life by improving sources of nutrients, increasing the residence time of freshwater in the environment, decreasing the volume of freshwater abstraction from aquatic environments, and building social relations that are based on maintaining and improving these systems.

## Chapter Eight

# TRANSFORMING WASTE TO RESOURCE

The reconfigurations proposed in this chapter are also driven by the matter of water concern to improve the aquatic and wetland environments of the lower Lea river watershed by reducing water abstractions and additional nutrient load from treated wastewater. The supplementary matters of concern are increasing sources of fertilizer and energy for human use by the harvesting of these resources from urine and faeces which is treated as waste in the current configuration of the urban water-cycle.

The existing ANT co-evolution pathways that are developed in these propositions are "yellow mellow" and replacing the flushing sanitation technology with waterless sanitation. "Yellow mellow" was an existing practice by eight participants and a further nine people imagined that they would practice this behaviour in times of water scarcity. This coalescence of similar practices demonstrates that this is a likely ANT co-evolutionary pathway. The replacement of flushing sanitation that was an imagined reconfiguration by seven people in times of water scarcity is a progression of this pathway.

These ANT co-evolution pathways were used in combination with the existing urban fabric and combined with pre-existing toilet technologies and known ways to reuse and treat human waste to come up with water-cycle assemblages that reconfigure the system for the sanitary disposal of human waste. It transforms human waste into resources that can be used to continue the viability of human life by fertilizing crops and providing a source of energy.

This chapter describes the proposed water-cycle assemblages that transform human waste to resource. It examines how the participants problematized and interressement the relations to these assemblages in an iterative process where the water-cycle assemblages alter in response to these human actants.

**Problematisation**

The wastewater infrastructure in the lower Lea river basin contributes to the poor water quality in the Lea river because when the pipes are full they are designed to release the excess untreated wastewater into the river Lea. The major components of this wastewater infrastructure date back to the Victorian era and were designed to transport much less water from the smaller population using less water per capita than the people it serves today (Halliday 1999; Thames Water c2008). This wastewater infrastructure was also not designed for the extensive impermeable surfaces from the growth of urban areas, which flush an unanticipated amount of surface-water into the sewer (European Environment Agency 2011). Therefore while sewer overflows were designed to be exceptional events, today these occur about fifty times a year (Thames Water c2008). In order to instigate improvements to the water quality of the river Lea in order to reinstate its ecological functions that benefit humans, it is necessary to reconfigure the wastewater infrastructure to prevent sewer overflows from occurring.

Toilet flushing comprises about 30% of average household drinking-water use (Butler and Memon 2006). The average person in London uses 163L of water a day (EA 2010), therefore toilet flushing can be considered to use about 49L of drinking-water a day. To replace the flush system reduces the use of a considerable amount of water, which would then increase the amount of flow available to aquatic environments between the water intake for drinking-water treatment and water discharge for treated wastewater. It also reduces the amount of water treated to a drinking-water standard and the amount of wastewater treated. It also removes from the water-cycle the pathogens most harmful to human health, which are contained in the faeces; and the nutrients most harmful to aquatic health, which are the nitrogen, and phosphorus in the urine (Acreman 2000).

Furthermore the use of water in the current water-cycle assemblage to convey human waste dilutes it and mixes it with other pollutants from other sources, such as heavy metals from roadways, so that it is difficult to successfully extract it for use as a soil fertilizer. This means that valuable fertilizer becomes a pollutant and additional energy and resources are needed to make the necessary supplies of inorganic fertilizer used for food production. A reconfiguration of the water-cycle that prevented human waste from becoming a pollutant and repurposed it as fertilizer would gain more interressement from actants concerned with improving water quality, food production, and conserving energy and resources.

**First Iteration of Design Interressements of Co-evolving Actants**

Water-cycle reconfigurations that decrease the number of combined overflow events would improve water quality in the lower Lea river. "Yellow mellow" and replacing the flushing toilet sanitation system were two ANT co-evolution pathways indicated in the analysis of existing water-cycle assemblages, which would allow this to occur within the existing urban form of the lower Lea river basin.

The design interressement of the co-evolving actants that limit water pollution and transforms human waste into a resource in the lower Lea river basin, occurs in two moments depicted over a 50 year period beginning in 2010. They build on one another from contemporary accounts of water-cycle assemblages and the existing urban form in the lower Lea river basin.

**Yellow Mellow Rain Refrain**

The first design interressement was to lessen the use of the wastewater infrastructure by modifying the practices of how people used the wastewater infrastructure. This new material relation was currently practiced by eight participants to assemble a water-cycle with a reduced water consumption. This practice could be more widely applied to lower the volume of water in the wastewater pipes during rain events, thereby allowing more room for the transport of wastewater without overflowing into the Lea river.

The modification of wastewater infrastructure practices was encapsulated and made memorable by an additional two phrases to the already well known "Yellow Mellow" ditty:

> *If it's yellow, let it mellow. If it's brown, flush it down.*
> *If it's raining, keep refraining. When it stops, then it drops.*

This verbal actant reminds people to desist from using the wastewater infrastructure until the weather is dry. This includes not only toilet flushing, but all forms of non-urgent wastewater producing usages such as washing machines, showers, dishwashers, and kitchen sinks. This new actant was projected to be implemented in the immediate moment.

There was a mixed human interressement in relation to this actant. The larger portion of people, stated that they would be happy to mobilise this behaviour. Six people said that they would not "yellow mellow" and thus would not enact this water-cycle assemblage. Eight people thought that while they would assemble this water-cycle within their home, they would not be willing to do so if they lived in a shared household or if they were using public facilities. This shows that shared facilities are an actant that stabilise different water-cycle assemblages than those of private facilities in relation to flush toilets. Even though this new water-cycle assemblage was not thought of as generally applicable or acceptable in public a large proportion of people were happy to modify their behaviour in their own homes. This indicates that this is a strong potential ANT co-evolution pathway in the lower Lea river basin

Some people explicitly speculated how this new behaviour might or might not be mobilised by other humans. Five people thought that other humans would not be happy to "yellow mellow rain refrain", while four people thought other humans would be happy to "yellow mellow rain refrain". Two people who thought that this would not mobilised by others were still positive that they would do so themselves, while three would not. Four comments queried the number of human actants that would need to mobilise this practice in order for it to have a significant impact on CSO events. These conjectures about other people's mobilisation and stabilisation in this water-cycle assemblage imply that the magnitude of similar material relations is an actant that can strengthen or weaken this ANT co-evolution pathway.

Daniel noted that he thought that this reconfiguration of the flushing toilet was vulnerable to media attack because it altered the contents of the toilet bowl from always clean water, to sometimes water and urine. This introduces a new actant in relation to the enrolment, mobilisation and stabilisation of the water-cycle assemblage. The media is an actant that has an influence over what relations are explicated to people as matters of concern or matters of fact, therefore it has the ability to persuade or dissuade some people to enact or betray this water-cycle assemblage.

Five people mentioned that they thought that the ditty was an effective actant to communicate the idea of not using the sewer while it is raining. Tom and Elsie commented that this would be particularly memorable for children. This shows that the ditty had effectiveness to problematise and interressement new human actants to enrol them to mobilise this new water-cycle assemblage.

Adam, Anne and Qamar commented that the ditty explicated a link between their sewer use and combined sewer overflow events that they had not been aware of. It was also effective at opening the black box of the drain, making the discharge wastewater an ongoing matter of concern.

There were seven comments, six of which were from water professionals that offered alternative problematisation for the cause of CSO events. These shifted the problematisation away from human water-use to nonhuman assemblages. Elsie and Ruth thought that the increased amount of impervious surfaces which shed water quickly into the sewer system were the problem. Harry and Richard thought that the domestic component of the sewer system was a far smaller component than the rain-water, thus the base load would only be reduced by a small amount by this change in practice. Bill thought that the CSO event was more significantly influenced by misconnections in the sewer system. Harry and Humphrey thought that the pollution content of CSO events was from solids that were already within the sewer system. Each of these comments propose that different nonhuman actants have a larger effect on CSO events than the water-cycles assembled for self. These different problematisations would enrol and mobilise different actants to reconfigure the water-cycle.

Eight people offered alternative solutions to "yellow mellow rain refrain" to address the matter of concern about water quality in the river Lea. This included the use of low flush toilets, dry toilets, composting toilets, finding new sanitation technologies, rainwater butts to retain rainwater and prevent it from entering the sewer system immediately, and decentralised sewerage plants so that less transport is required before the wastewater treatment. All of these ideas involved introducing new material configurations to the assemblage, which use the ANT co-evolution pathway of greater convenience to the human to stabilise different reconfigured water-cycles. In this instance other people were seen as being potentially recalcitrant within the desired water-cycle assemblage, hence their practices required delegation to new material configurations in order to ensure the ongoing enactment of the required water-cycle assemblage.

The "yellow mellow rain refrain" was a new actant that successfully interressement these human actants. The imagined reconfiguration identified two additional actants that participated in stabilising the current water-cycle assemblage. These were the media and the magnitude of similar actant relations. A magnitude of similar actant relations would strengthen this ANT co-evolution pathway because the more acceptable and normal this practice becomes the more people would continue to enact this material relation. The media is an actant that has an influence over what relations are considered a matter of fact or a matter of concern. In addition three new actants were suggested for interressement into this actor-network relation such that the "yellow mellow rain refrain" would become an obsolete water-cycle assemblage. This included alternative sanitation technologies, rainwater detention and decentralised wastewater treatment. The problematisation of this reconfiguration was also called into question, which opened new matters of concern that would create different water-cycle reconfigurations.

**Remove and Compost**

The second design interressement was to replace the flush of the toilet actant with an almost dry urine separating sanitation system. The removal of the flush takes away the decision of what is an appropriate time to flush, thereby stabilising non-flushing behaviour. The replacement of the flushing toilet with dry sanitation occurs because the flushing toilet is a technology with a scope of reconfiguration that is limited to altering the volume of water used for flushing and finding alternative water sources used for flushing. Replacing the flushing toilet technology with dry sanitation is an ANT co-evolution trajectory that maximises the water conservation of the flushing toilet. Using a dry sanitation system removes human waste from the water-cycle thus removing pollutants from entering waterways during CSO events. It also reduces the number of CSO events because wastewater drains would not contain the volume of water from the toilet flush. Moreover dry sanitation responds to the supplementary matter of concern of repurposing human waste was a resource by concentrating the nutrients in human waste making it simpler to extract.

The human waste of urine and faeces are chemically different. Urine is sterile and can be used as a fertilizer immediately, while faeces contain pathogens that need to be broken down through a composting process to become sterile. Hence separate collection means that urine can be repurposed immediately and faeces can be decomposed to treat the pathogens. This is done by using a urine separating toilet bowl. This is similar to current toilet bowls, but has a division between the front and the back, so that the urine is separated from the faeces. To use this effectively all people will need to sit to pee. This type of toilet bowl is available on the market and has been installed in an office in Switzerland (Tilley et al. 2008). The two types of human waste are collected in two removable canisters beneath the toilet bowl.

These canisters would be collected every 2-3 days, similar to the collection of recycling or the milk delivery whereby the filled containers are collected and cleaned empty ones are delivered simultaneously. The nutrients that are removed from the water-cycle can then be applied as fertilizers to the land for agriculture or gardens, thereby addressing the additional matter of concern about improving the sources of nutrients for agriculture.

The remove and compost system responds to the existing built form of most dwellings in the lower Lea river basin, where there is no space to store the waste from a composting toilet on site as suggested in "A Pattern Language" (Alexander, Ishikawa, and Silverstein 1977). This means that dry sanitation requires the removal of the waste to compost off site. This new actant was projected to be implemented in the 25-50 year timeframe.

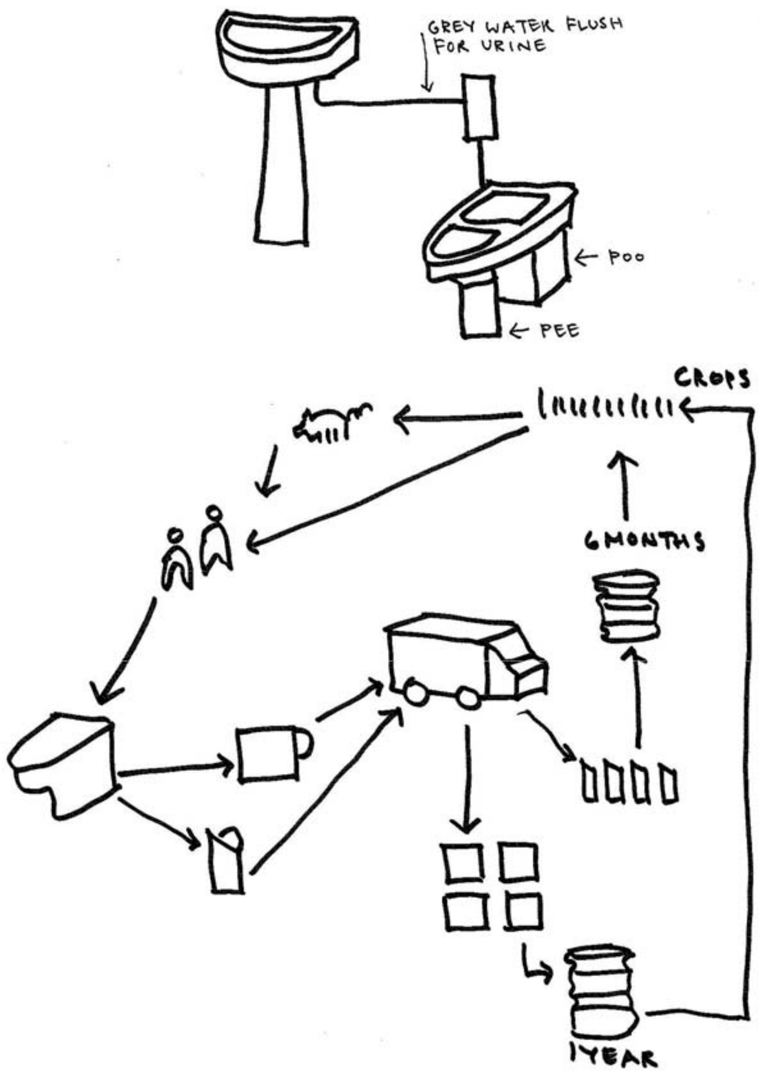



**Figure 8.1**
**Remove and compost**

This second design interressement follows the ANT co-evolution pathway suggested by some people during times of water scarcity whereupon several people suggested that they would consider changing their toilet infrastructure to a composting toilet in order to save water and the suggestion by other people as an alternative to the previous "yellow mellow rain refrain". It also responds the

the ANT co-evolution pathway of magnitude of similar practices of non-flushing. By removing the flush from the system any person using this toilet is immediately enrolled in this behaviour.

Overall the replacement of the existing toilet for a new infrastructure was thought to be a good idea by most people. Thirteen people said that they would be willing to change their infrastructure given certain caveats of smell, collection, and hygiene. Five people would be happy to do so if they were forced by external circumstances. Another thirteen people thought that the idea was laudable, but they did not yet feel comfortable enough to change their toilet. Only nine people were outright negative about changing their toilet infrastructure, seven of these nine people were water professionals. Ten people thought that this new actant might not be embraced by other human actants. However Jack and Heather thought that it would have appeal to affluent environmentally aware citizens. Maria mentioned that if it were designed by a famous designer, such as Philippe Starck, it would become a desirable item for many more people. This showed that this actant had successfully interressement these humans.

Roger, Phillip and Sally wondered whether or not it would be acceptable by other people to eat crops fertilised by human waste. Alan felt certain that other people would not like to do so and Anne thought that it might concern people at first, but they would soon get used to it. Felicity said that she would feel more comfortable if the crops were only used to feed animals rather than humans. This is the opposite attitude to the engineers of the nineteenth century who objected to the waterborne transportation system of human waste on the grounds that it diluted and squandered a valuable resource (Chapter 2) (Halliday 1999; Gandy 2006a). This shows that the flushing toilet helps to stabilise views of human waste as dangerous through its material disassociation once it is flushed from view.

Associated with this were seven people who were concerned about the more intimate contact with human waste that this removal system requires. A few people suggested ideas such as chutes or vacuums to maintain their distance from human waste. This shows an ANT co-evolution pathway for a less labour intensive, less intimate contact with human waste would interressement more human actants.

The proposed vehicular collection system for the waste, caused some concern for a few people because of the carbon dioxide emissions from a petrol combustion engine. Daniel suggested that it could be jointly collected with the recycling. Esther suggested that biogas from the decomposing human waste could be used to run the vehicle and Alan thought that the biogas could harvested for general use. This showed that this new actant would have further network stability if it also addressed a reduction in the use of fossil fuels.

The remove and compost dry sanitation system was a new actant that successfully interressement these human actants. The ANT co-evolution pathways found were for a more convenient less carbon dioxide emitting waste removal system, and a harvesting of more resources from human waste. It also showed that the formation of the actor-network might be betrayed by humans who refuse to eat crops fertilised by human waste.

**Second Iteration of Design Interressement Co-evolving Actants**

Changing toilet flushing practices and replacing the flushing toilet with dry sanitation were both shown to be possible ANT co-evolution pathways in the lower Lea river basin. Changing the material relations of the toilet to a remove and compost system was more enthusiastically embraced by the human actants therefore this is the design actant that was further developed in the second iteration of design interressement.

These two design actants of the first iteration of design interressement were both considered relative to existing attitudes and material relations of the participants. Therefore this next iteration of the design interressement assumed a new design actant that was proposed to be implemented in the immediate timeframe.

The two additional matters of concern revealed by the first iteration of the design interressement were more convenient and clean way for waste removal and the additional harvesting of energy from human waste in order to produce an alternative energy source from fossil fuels. A design actant that responded to these matters of concern would possibly enrol and mobilise more human actants into the actor-network being assembled.

This design interressement of the co-evolving actant continues to limit water pollution and reduce water abstraction. It transforms human waste into a fertilizer and energy resource in the lower Lea river basin.

**Remove, Gas and Compost**

This design interressement modifies the previous remove and compost dry sanitation system by adding uses for the gas produced by the decomposing faecal waste. It also uses a prototype of a remove and compost toilet that is currently being developed at Imperial College (Gardiner 2010) (figure 8.2).

The prototype dry sanitation toilet uses a starch liner within the toilet bowl to seal and package the human waste. It separates the urine and faeces using patented manufacturing separation techniques, thus the bowl does not have a separating division for the urine and the faeces. The packaging system is operated by a hand crank that winds the waste down into the removable storage chamber below. The urine is separated from the faeces at this point in time. Once the hand crank has been wound, all that remains in the toilet bowl is the clean starch bag ready for the next toilet use. The removable storage chamber below the toilet is about the size of a wheeled carry-on piece of luggage for passenger aircraft and can contain up to 15kg of waste. One person produces approximately 1kg of waste a day, therefore this toilet needs to be emptied at least once a week for a two person household. The chamber is sealed on removal from the toilet bowl and can be taken to an anaerobic digester for decomposition. The starch bag is decomposed at the same time as the human waste, thus there is no need to open the starch storage bag prior to its deposit in the digester. The storage chamber is reused.

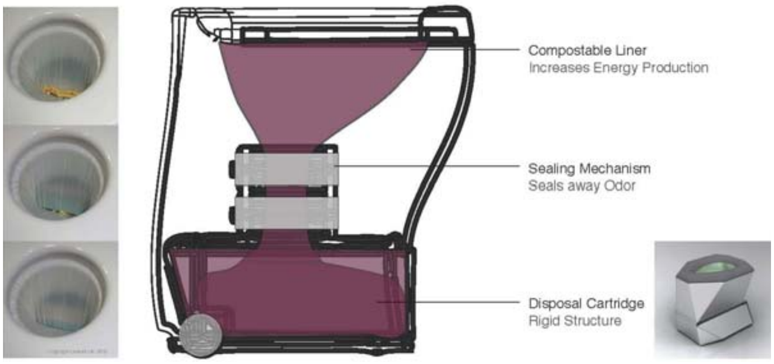



**Figure 8.2**
**Loowatt**
(Loowatt, www.loowatt.com/)

The decomposing of faecal waste produces two gases that are useful to human life. One is biogas (methane produced from a contemporary decomposition of organic matter) that can be used to drive turbines to produce electricity, used immediately for cooking or lighting, or compressed and used as a fuel to power vehicles (figure 8.3). The use of biogas as a cooking fuel is a technology that has been applied globally, but usually in rural areas of developing countries (Tilley et al. 2008). The

Loowatt pilot installation in west London has included a system to siphon and use the biogas produced by the anaerobic digester that decomposes the human waste (Gardiner 2010).

The decomposition of faecal wastes also produces carbon dioxide, this could also be siphoned off and used to fertilise the air in greenhouses for growing food. This is a technology being used in a combined heat and power power plant in Ontario (EBR Staff Writer 2009).

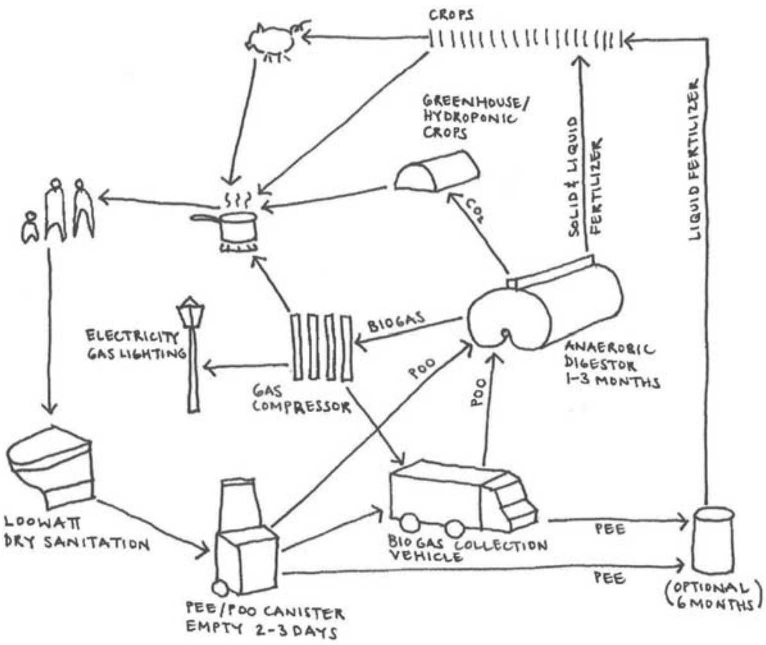



**Figure 8.3**
**Remove, gas and compost**

This new design actant did not show any significant additional human interressement in comparison with the remove and compost system, despite the addition of better uses for all the products produced from the anaerobic digestion process and a cleaner more convenient method of removing the waste.

Most matters of concern were exactly the same as those from the first design interressement: smell, collection, and hygiene. The main difference was the concern of consuming crops fertilised by human waste was not raised.

Interestingly while three people were concerned about its social acceptability, fourteen people suggested that this system would be better applied in public buildings or areas of communal use such as parks, stadiums, hotels, schools, offices and at festivals. This interressement of collective dry sanitation use would test the technology and its acceptability to other people without risk to the individual and is an ANT co-evolution pathway.

Furthermore five people added examples of where such systems were already in use such as Mexico, South Africa, Shanghai, the National Trust in England and the Massachusetts Institute of Technology in the USA. One person said that he had used such a system for three years in Mexico. Another person said that he already did half of this as he puts his pee on the compost. These new actants verify that the remove, gas and compost system is a current ANT co-evolving actant.

Similar sorts of improvements were suggested to this second iteration of the design interressement as the first, such as having a chute, vacuum or conveyor belt to collect the waste rather than a manual system. One person suggested that food waste could also be added to the biodigestor. These new material configurations are additional actants that could stabilise the assembly of the actor-network.

Three people were concerned about whether conserving carbon dioxide emissions or water was more critical to maintaining an ecology that favoured human life because the environmental impacts were different. Four people thought it preferable to conserve carbon dioxide emissions more than water use. This shows that other matters of concern are actants that affect the urban water-cycle assemblage.

Many people were concerned with how to add more actants as incentives to this actor-network in order to enrol and mobilise other people to change. One person suggested that celebrities be used to promote the system. Two people suggested raising the price of water so that it became unviable to use water to flush. Another suggestion was to pay people for their urine and faeces. One person devised a complex scheme of points whereby people would get points for their urine and faeces, their recycling and any other environmentally helpful behaviour which would then be redeemable for more things to make them more environmentally helpful, such as seeds for plants, or gardening equipment. This shows that this actant needs to interressement more actants in order to mobilise and stabilise this new configuration of the water-cycle.

Overall, this design successfully interressement these human actants. New actant relations to existing examples of similar systems were used by other people in conversation to provide new matters of fact that were used as benchmarks against which this local co-evolution could be assessed. These new actants indicated that this new assemblage was a viable system. More actant relations beyond the water-cycle were added to the actor-network including carbon dioxide, money, status and alternate building typologies where the design actant could be applied. If these relations were mobilised these could enable a stabilisation of this actor-network.

The raising of the same matters of concern such as odour, collection, and hygiene show that while a working prototype of this actant was demonstrated, this was insufficient to enrol and mobilise these human actants. These matters of concern required these humans to test the material relations of the dry sanitation system to verify its ability to contain smell, be easy to dispose and hygienic to use. Without this verification people were unwilling to enrol, mobilise and stablise this system. The repetition of these same matters of concern shows that these actant relations were the most important in co-evolving this actant. It also showed that the co-evolution of this design actant had reached a saturation point through drawings. This shows the limits of the documentation of the design actant. While the drawn design actant can successfully open black boxes to explore actor-networks and co-evolve new actant propositions, it cannot mobilise these new reconfigurations of the network without also becoming a material reality.

**Conclusion**

Three design actants were explored as possible ANT co-evolutionary reconfigurations of the urban water-cycle in the lower Lea river basin in this chapter. All three design actants improve the aquatic and wetland environments in this area by reducing water abstractions, water treatment and the nutrient content of water returning to aquatic environments. Additionally, the harvesting of nutrient resources from human waste was explored in two of these reconfigurations. All three design actants were successful at interressement the participants, finding additional actants related to these reconfigured material relations, and discovering new ANT co-evolutionary pathways for further development.

The two ANT co-evolution pathways that were explored were “yellow mellow” and replacing the flushing toilet with dry sanitation. The design actant that continued to interressement people was the dry sanitation system. Therefore this is an ANT co-evolution pathway that could continue to be developed to mobilise a reconfiguration of the urban water-cycle of the lower Lea river basin that would benefit human life by improving sources of nutrients, removing water pollutants and increasing the quantity of freshwater available in the environment.

## Chapter Nine

# RECONFIGURATIONS OF THE URBAN WATER-CYCLE

By using actor-network theory co-evolution as a framework for understanding the urban water-cycle, this phenomenon can be seen as assemblages of people and things that are constantly being enacted and thus are always in a state of co-evolution. This understanding led to ways in which the assemblages of these networks could be reconfigured to achieve new productivities from freshwater for humans and other biota. This approach offered a way of thinking about the urban water-cycle that builds on, but is different to the perspectives offered by engineers, sociologists, geographers and ecologists. It followed the flow of water as the main actant and traced the relations it made between other human and nonhuman actants to create the urban water-cycle. The persistence of the water practices that created the water-cycle were tested in imagined situations where the water actant was either in short supply, or caused sustained and regular flooding. The common and uncommon but noticeably similar water practices; and unique existing personal water-cycles were described and formed the basis to develop and test design propositions that co-evolved material configurations which enable water practices that increased the duration of time water remained in the terrestrial environment in order to extend its human and ecological use.

The most likely areas for the co-evolution of water practices were found to be in transforming what is now considered wastewater into resources for the production of energy, food and biofuel. These included harvesting nutrients and energy from different water types and using waterless, urine separating sanitation. These ideas were most welcomed by people because they not only conserved water, but also offered additional benefits to humans. Grey-water treatment and reuse systems also harvested heat energy, generated energy from micro-generation, produced food and biofuel stocks all of which also improved the water quality to be reused or discharged into aquatic ecologies. Dry sanitation transformed human waste into fertilizer and energy. This represents a shift in values from increasing water consumption only to achieve greater comfort, cleanliness and convenience for people as has been the case historically (Geels 2005; Shove 2004), to values where people are willing to change their material configurations of water practices to make more efficient use of the water, energy and nutrient resources that surround them, which also requires them to reconsider what is more comfortable, clean and convenient to them.

**Water-cycles in the lower Lea River Basin**

The first part of the research methodology, which engaged with the human and nonhuman actants in the urban water-cycle through interviews, group discussions, and water diaries answered the first supporting research question: "How are the water-cycles in the lower Lea river basin assembled today?" It found that water practices of humans were closely intertwined with their personal understanding of the scarcity of water and the material configurations of their world which included: water infrastructures, water vessels, water technologies, the arrangement of rooms in the home, the relative levels between indoors and outdoors, and access to outdoor spaces especially gardens, which altered the flows of the assembled water-cycle. Professional water-cycles were assembled by particular responsibilities that were dependent on the matter of concern that were co-evolved by networks of humans and nonhumans related to the water professional.

Following how water flowed round the lives of different human actants showed that personal water practices were very similar across most participants in the urban water-cycle because the same material configurations that were dependent on centralised drinking and wastewater infrastructures were used to access and drain water. People who valued the environment had varying degrees of commitment to questioning and altering their practices to achieve what they felt was the correct amount of drinking-water consumption. Most people's personal material configurations constrained them to particular water practices. These material configurations included the piped drinking and wastewater infrastructure, taps, basins, flushing toilets, showers, cups, saucepans, kettles, and so on. The people who made the most change felt strongly that water was a scarce resource that each person in society had a responsibility to use with consideration to other's needs. People with professional involvement with water did not exhibit any special relations with water outside of their professional roles, unless they also strongly felt that water was a scarce resource.

People who felt that water was a scarce resource attempted to change these material configurations. This included adding grey-water recyclers, grey-water diverters, reusing of washing up bowl and bathwater, adding rainwater butts and hand pumps. There were four cases where people had substantially co-evolved their material configurations to achieve a water-cycle that was closer to how they felt was the appropriate use of a scarce resource. None of these people were satisfied with results of their material reconfigurations, but all felt that they had done their best within the limitations of the resources at their disposal, which included their relations to other household members, time, money, available technologies, building skills, and the arrangement of spaces in their homes and gardens.

Professional water-cycles were greatly varied in water-cycle effects because they were dependent on the matter of concern that the particular water professional was involved with regards to the use of the water: drinking, wastewater discharge, recreation, ecological or transportation. These roles co-evolved depending on the matter of concern of the professional and the actor-network that they were related to. For instance, the water framework directive influenced professional action because water professionals were responsible for its implementation; equally water professionals were involved with the negotiation of the water framework directive and how it is implemented and monitored. All the water professionals involved in this research were involved with stabilizing and co-evolving the existing water-cycle. Some of them were strategically placed to cause disruption to the water-cycle if they chose to do so, but none of them could be said to be strategically placed in the network of water interactions to influence a substantial long term change to the water-cycle in the lower Lea river basin without enrolling and mobilising many other actants. While the water professional's role in the water-cycle is individually limited by a narrow matter of water concern, if they are enrolled and mobilised they have a substantial effect on the water-cycle because they effect multiple similar actant relations, over a large territory.

The actor-network theory co-evolutionary perspective showed how both humans and nonhumans assembled the water-cycle in the lower Lea river basin through personal and professional material configurations and water practices which were in varying degrees of co-evolution and stabilisation. Water professionals played wide reaching roles in stabilising the assembled the water-cycles in the lower Lea river basin through the use of documents and enacting specialised material configurations. These roles had co-evolved and continued to do so with the matters of concern surrounding water. The water professionals involved in this research could only enact their wide reaching effects through the mobilisation and enrolment of other actants. Professional knowledge of water did not change personal water-cycles unless water was also valued as a scarce resource to be shared with others. Most personal water-cycles were nearly identical due to the similarities of the material configurations of people's homes. The co-evolved relations between humans and nonhumans occurred where people had sought to reconfigure their water practices and the material configurations if their existing infrastructures to align with their particular values of water. These were alternative water-cycles and understandings of water and water infrastructure. These multiple professional and personal water-cycle assemblages formed different urban water-cycles in the lower Lea river basin.

**Projected Water-cycles in the Lower Lea River Basin**

The second and third supporting research questions were related to the projection of ANT co-evolutionary reconfigurations of the water-cycle in the lower Lea river basin. "How do people imagine changing their water-cycle assemblages in different water-cycle circumstances?" was answered by the replies people gave for ideas of how they would alter their water-cycle in times of scarcity and drought; the unique water-cycles that were formed by people who actively sought to modify material configurations to suit the value that they gave water; and their responses to the designs of new water-cycles; all of which included changes to their water practices and changes to the material configurations of how they used water. "What are the co-evolutionary design adaptations that can be made to the existing water-cycle assemblages?" was answered by the design adaptations that were based on the ANT co-evolutionary pathways found in answering the first and second supporting research questions. These instances showed the different degrees of material and practice legacies and the potential ways they could be reconfigured, which resulted in different trajectories for ANT co-evolution.

The water scarce situation was an impetus for most people to reconsider the types of water they used for which purposes. Many people thought to reuse drinking-water for different purposes, for example, washing up water to water the garden. This potential ANT co-evolution of adjusting water quality to water use had also occurred with people who highly valued drinking-water because they thought it a matter of fact that they lived in a water scarce world. These people used rainwater for their gardens; and grey-water to flush their toilets, water gardens, clean their houses, and wash clothing. These changing relations between humans and nonhumans were an ANT co-evolution pathway for designing new systems of water reuse to find ways to directly reuse grey-water within a household. This reconfiguration was used to simultaneously improve other urban causes of environmental deterioration including food, energy, connections between other biota and people, people and people, people and water landscapes.

In times of drought many people were willing to dramatically alter their flushing toilet practices. This included not flushing after every use, using alternative water sources, or changing toilet infrastructure all together. The potential co-evolution of toilet practices was reinforced by the way people who highly valued drinking-water had altered their toilet flushing practices to conserve water. These changing relations between humans and nonhumans were an ANT co-evolution pathway for designing a new system of dry sanitation to transform human waste to energy and fertilizer resources, and increasing sewer capacity.

These ideas were directly related to interpreting the urban water-cycle as a symmetrically formed network of human and nonhuman relations that were in a state of ANT co-evolution. Furthermore the limits of these designs can also be understood through the ANT co-evolution framework. These designs will never be mobilised in their current form because they were generated from a limited number of network relations that were assembled by the participants in my research, hence they do not encompass the entire set of network relations that need to be enrolled for change to mobilise. This was evidenced by the reactions from the human participants who queried what was beyond their own known network relations. The questions that were raised included those of management, responsibility, financial devices, legislation, smell, space and so on. These relations would need to be mutually defined in order for the mobilisations of reconfigurations to occur.

**Actor-network Theory and Design Practice**

The fourth supporting research question was "What value does the actor-network theory co-evolutionary perspective have to design practice and design practice to co-evolutionary actor-network theory?" Design furthers the theoretical possibilities for ANT by using its historic insights into the formation of scientific knowledge and projecting these into near future possibilities. This theoretical development is strengthened when ANT is combined with the concept of co-evolution because these network changes are shown to have a trajectory and a rationale. Design also allows the unravelling of blackboxes without the disruption or the failure of any actant. ANT co-evolution makes design a qualitative method with which to conduct research. It also gives design an alternative starting point to build on the assemblage of actants that relate to both the design and the designer.

Designs are propositions for new things, they are a projection for a future state of material and social relations. From the point of view of ANT this means bringing about new relations in the world, which can be seen as having the same process as making scientific knowledge. However ANT only identifies this process in tandem or in retrospect in relation to making scientific knowledge or design. By applying these same processes of problematisation, interessement, enrolment, mobilisation and stabilisation during the design process, design can be used as a research method to test new material and social relations, thereby extending ANT from historic reflections, to reflections on probable soon-to-be actants and networks. The ANT co-evolutionary perspective further strengthens these projective relations because it identifies altering and loose network relations where these new relations have opportunities to form.

Design can also be used as a method to unravel black boxes without disrupting or requiring the failure of existing actants to reveal the network connections as is usually the case (Kaika 2005; Sofoulis 2005). Design unravels black boxes because it alters social and material relations, thereby calling into question existing network relations. This can be done from the perspective of the researcher, or involve multiple network relations when the design is used in discussion with other actants. This means that within the ANT co-evolutionary framework, design can become an additional qualitative research method to test changing human and nonhuman relations. This extends design research from research that is done to be able to create a design; knowledge of design that resides in the designer; the designed objects; and documentation to convey design, into a method of research.

For design, the symmetry of nonhuman and human relations in creating all things in the world and the specificity of the network relations that is assumed by actor-network theory situates the designer in a world where the material and the social require the same consideration. The designer is themselves is an actant in this network as much as their design proposition. ANT accounts for this as equal to all other relations, thereby bypassing the perennial problem of whether the designer is an original innovator, or a subject of societal and material constraints (Forty 2009). Furthermore ANT co-evolution gives designers a framework from which they have an increased capacity to generate practice oriented design, which has been identified by Shove, Hand and Southerton (2008) to be a crucial nexus in creating a world conducive to the ongoing flourishing of human life.

The actor-network theory co-evolutionary framework also gives design practice a different starting point to begin design, it allows more actants to be acknowledged in the process of mobilising designs and a diverse criteria against which to assess the effects of design. Within an ANT co-evolutionary framework design begins with pre-existing human and nonhuman relations which the designer must problemmatise to create a negotiation space for the definition of the new design actant, the new actant needs to interressement existing actants, then enrol and mobilise them in order for the new design actant to emerge and stabilise from these relations. Effective designs are then those that mobilise networks to change and allow a new actant to materialize.

Actor-network theory co-evolution combined with a design method extends both design practice and ANT. ANT co-evolution offers design a framework in which the designer can be considered an equal actant to the nonhumans and humans they seek to reconfigure, neither a subject of societal and material constraints nor a god-like original creator. This gives a different starting point for design and role for the designer because it reveals the historic trajectories of change, identifies which relations are more persistent than others, rationales on why this might be so, and suggest ways in which they might be changed. Design, when used as a method of research rather than to create products, offers ANT co-evolution a way to find and test potential reconfigurations of human and nonhuman relations and examine the usually black boxed actor-network relations. This transforms ANT co-evolution from historic analysis to one which can be projective.

**Reconfiguring the Water-cycle in the Lea River Basin**

The overarching research question was:

**Using an actor-network theory co-evolutionary perspective, how can the urban water-cycle in the lower Lea river basin be reconfigured to ensure its ongoing ability to provide water that humans and other biota require for the flourishing of human life?**

By using an actor-network theory co-evolutionary framework this research found two strongly favoured reconfigurations of the urban water-cycle that improve the quantity and qualities of water that humans and other biota require in the lower Lea river basin. These were a polyculture reuse community and a remove and transform dry sanitation system.

The use of an actor-network theory co-evolutionary framework, enabled an understanding of the types of actants which assembled the urban water-cycle in the lower Lea river basin. This included both humans and nonhumans that had co-evolved to stabilize similar personal water-cycles of all the people who participated in this research. There were some instances where co-evolution had occurred where people had altered practices and material relations in order to achieve new water-cycles that consumed less drinking-water. This did not necessarily reduce total water consumption, but instead used alternative water types to achieve the same required outcome from the services of water supply for which other people would use drinking-water. These instances were reinforced as potential co-evolutionary reconfigurations when these same co-evolutions were generated by other participants of the research when asked how they imagined their water practices would alter in times of water scarcity.

Two urban water-cycle reconfigurations were strongly favoured in the lower Lea river basin: a polyculture water reuse community and a remove and transform dry sanitation system. Both these reconfigurations not only altered the water-cycle, but also changed what are now regarded as pollutants in wastewater into nutrient and energy resources, thereby offering more advantages to the continuous flourishing of human life. The polyculture water reuse community harvests energy, food and water. The remove and transform dry sanitation system harvests fertiliser and energy.

These ideas reconfigure the private and public lives of people, as well as the material form of the lower Lea river basin. Private lives are transformed by new technologies and new practices. Public lives are transformed by new relations to space and materials, and management of these resources. The material form of the lower Lea river basin is transformed by the spatial requirements for local water treatment, reuse and the harvesting of resources.

These reconfigurations contribute to the continuous flourishing of human life by reducing the amount of water abstractions from the environment to supply drinking-water to the human population. This leaves more water in aquifers, soils, streams and rivers for other water dependent biota to flourish. These water dependent biota create ecosystems that aid human health by producing oxygen, metabolising nutrients and pollutants, and producing food. These reconfigurations enhance human life by harvesting nutrients from human wastes that can be used to produce food and energy. The harvesting of nutrients also reduces the pollution load of water returning to the environment after human intervention. The movement and temperature of water resources are also used to generate energy. Futhermore the reconfigurations also necessitate new management systems that require new social interactions between people living in proximity. This means the generation of new types of communities that work together with biota and materials to formulate cooperative assemblages that enable the flourishing of human life.

This research found that the urban water-cycle of the lower Lea river basin had two pronounced co-evolution pathways to reconfigure the urban water-cycle: polyculture water reuse, and remove and transform dry sanitation. These two reconfigurations of the urban water-cycle reduce the water abstraction from rivers and aquifers for human consumption; and improve the quality of water discharge to rivers and estuaries after human use. This contributes to the continued flourishing of human life by improving the conditions for water dependent biota to live, thereby improving the quality of environmental foundations which human life requires. These reconfigurations also contribute to the flourishing of human society by providing pursuits that build cooperation and communication between people.

**Reflections on Actor-Network Theory Co-evolution**

The actor-network theory co-evolutionary framework that was used for this research was selected in order to bypass a focus on either the human or the nonhuman by assuming that they are symmetrically involved in the formation of all things. This is because researchers that have investigated either the human or the nonhuman have found that these focuses have reached their productive limits and have started to develop methods to include both types of things in their research (Graham and Marvin 2001; Marzluff et al. 2008; Steward T. A. Pickett et al. 1997; Shove 2004; Swyngedouw 2004). However none of these frameworks have been as successful as ANT in describing both types of influences within their research because their disciplinary preference for one or the other prevents both from being given equal weight. Co-evolution was an important expansion to ANT because it enabled a longer time frame to be considered and created a way for ANT to develop projective networks. The use of the ANT co-evolutionary framework enabled an equal consideration of all the actants that form the urban water-cycle and to project new network enactments through the alteration of existing actants and the addition of new actants.

The ANT co-evolutionary framework assumed a symmetrical influence of humans and nonhumans in all things. The use of this theoretical framework focussed the research on tracing the relationships between humans and nonhumans and describing how these were co-constitutive categories that influenced the formation of each other. This influenced the methods used for this research, which was an iterative combination of qualitative and design research methods within a case study area. Without this framework, this method of investigation would not have been formulated.

The focus on relationships overcame some of the problems that have occurred when water is only considered from the perspectives of ecological sciences, engineering, or social sciences because it did not presume either society shaping nature or nature overpowering society. Instead the investigations were limited to how individual people interacted with the material world around them in order to assemble the water-cycle. This was a different view of the water-cycle, which has been typically described as a large global environmental phenomenon (Acreman 2000; Alberti 2008), rather than an intimate part of the daily lives of humans. This different view of the water-cycle enabled the formulation of how humans currently influence the water-cycle and how this could change in the future. However this perspective is problematic in that it does not enable a description of the effects of the multiplication of similar relations because it concentrates on the particulars of individual relationships.

Prior to this research, the ANT co-evolutionary framework had not been used for research about urban water-cycles. However ANT had been successfully used for research that describes water technologies (de Laet and Mol 2000; Dinckal 2008; Disco 2008; Kropp 2005; Latour and Hermant 2006), urban areas (Farias and Bender 2010; Hommels 2008; Yaneva 2009a) and the design process (Latour 2009; Law and Callon 1988; Yaneva 2009c). The results of this research show that the ANT co-evolutionary perspective can be used to give insights into the formation of the urban water-cycle. These formulations could not only be used to describe the urban water-cycle and the design process, but could also be extended to formulate possible future network assemblages of the urban water-cycle in the lower Lea river basin.

This research has extended the ANT co-evolutionary framework by applying it to understand the urban water-cycle; and to use these findings to generate designs that reconfigure the urban water-cycle thereby formulating a method in which the ANT co-evolutionary findings can be projective about future networks and actants. This research also showed that these ANT co-evolutionary projections could only be made for a short duration of the immediate timeframe in the future because possible ANT co-evolving relations over longer time spans could not be projected by the human actants participating in the research. Longer timeframes involved too many changing relations all of which were interacting and it was therefore difficult for people to conceive which relations would prevail and impact on their actions and preferences. Only a limited number of changing actants were imagined in the immediate timeframe and therefore human actants were able to imagine their roles within these altered relations.

The limitations of using the ANT co-evolutionary framework is that the relationships that have been described are limited both in time and in scope. These two limitations are typical of most research methods. The relations that are described by ANT are only present as long as the networks and actants remain enacted. These relations are also in a state of constant co-evolution as people's practices alter, new actants are added, and material relations breakdown or are replaced. Therefore the empirical findings of this research will become decreasingly relevant over time and could become rapidly irrelevant should an actant suddenly change or withdraw from these network relations.

The scope of these findings is limited by the network relations that have been traced which were dependent both on time and access to individuals willing to participate in the research. Other relational networks could have been assembled which would add and alter the understanding of the urban water-cycle in the lower Lea river basin from that which has been described in this research. These urban water-cycles would have added additional unique human and nonhuman relations and strengthened the relations of those which were similar. However the time it would have taken to enrol more participants and gather these relations would make those already gathered more historical and less relevant without necessarily adding further insights into the formation of the water-cycle.

The ANT co-evolutionary framework focussed the methods and results on describing the existing and changing relations between humans and nonhumans that assemble the urban water-cycle in the lower Lea river basin. This framework has not previously been used to describe the urban water-cycle, though it has been used to describe water technologies, urban areas and design. The ANT co-evolution framework enabled ANT findings to project new network relations into the immediate future. This extended the way both ANT and socio-technical co-evolution had been used in previous research about water technologies and infrastructure. The empirical results of this research will only remain relevant so long as the relations that form the networks and actants remain stable. In general most of these relations will alter over time therefore the empirical results will decrease in relevance as more time passes. However the methods used for this research should maintain their veracity.

**Empirical Findings in Relation to Previous Literature**

This research has made a contribution to the fields of urban design and planning, engineering, urban ecology, urban political ecology, and socio-technical co-evolution. Previous literature on urban design and planning has not looked at how water practices influence urban form, nor how these could be altered to create new urban configurations. The use of the ANT co-evolution framework also contributes to urban design, planning and engineering by creating a different understanding of the world from which to propose new designs. This different understanding situates the design and designers in equal relation to other actants, therefore any design is a response to and reconfiguration of existing social and material relations. The research also makes a contribution to urban ecology and urban political ecology by demonstrating how an ANT framework can be applied to bypass the disciplinary biases towards either the nonhuman or human actants when understanding urban areas. The empirical findings of this research confirms the socio-technical accounts of human water use and water technologies that occur with centralised piped drinking-water and wastewater in other places (Allon and Sofoulis 2006; Hand, Shove, and Southerton 2005; Shove 2004; Sofoulis 2005). It also expands the socio-technical accounts by showing the influence of other actants within the relational network and how the observations of co-evolution and practice can be used to formulate designs.

Urban design, planning and engineering are the professions that generate designs to create new and alter existing urban areas. Their matter of concern is urban form. Within the fields of urban design and planning, particular types of water: surface, flood and cultural, have been the recent focus of concern (Dreiseitl and Grau 2005; Novotny and Brown 2007; Schafer 2009), little has been developed about other ways water interacts with urban life nor how private water practices influence urban form. It is important for urban design and planning to address how all types of water relates to urban form and people because water is essential to the human physiology and the ecosystems on which we depend, but an excess of water can also kill. Climate change (Jenkins, Perry, and Prior 2009) projects that many urban areas will face increasingly variable weather patterns and sea level rise, this will make the planning and design of water resources and infrastructure increasingly important. This research makes a contribution towards finding the relations between water, urban form and people, and how urban design and planning can influence these outcomes.

The empirical research showed that different types of urban form were more conducive to water reuse than others. This included multistorey dwellings, mixed aquaculture and residential uses, and access to garden space. In order to change the ways in which water could be used by people and ecosystems required a change in land use and changes to urban configurations. This showed that while water infrastructures have not been a matter of concern for urban design, the use of particular forms of infrastructure do influence the spatial patterns of urban areas. The empirical research also showed that private water practices influenced configurations of public spaces because new water practices resulted in the need for new public spaces. This research expanded the types of water that urban design and planning are concerned with from surface, flood and cultural, to all water that assembles the urban water-cycle.

The field of engineering has been concerned with all water types, however its focus on providing technological solutions to water problems have shown decreasing success as the problems it tries to solve become too expensive or impractical to be answered only by technology and technologies not performing as expected due to the way people use them. This caused engineers to start to consider ways in which to influence human behaviour with mixed levels of success. The ANT co-evolution framework gives a different set of relationships from which engineering design, urban design and planning can initiate reconfigurations to the urban environment with a symmetrical human/nonhuman understanding of the relations that form urban areas.

The symmetrical understanding of the ANT co-evolution offers an alternative method of research to urban ecology and urban political ecology in understanding urban phenomena including the water-cycle. It bypasses the disciplinary legacy of both by tracing actant relations to reveal how humans and nonhumans are intertwined and continually enacting change in the actor-networks that they form and are formed by. The society is not subjugated to nature; and nature is not subjugated to society. Instead both are always implicated in the enactment of the actor-network.

The empirical findings of this research about the current urban water-cycles in the lower Lea river basin are similar to those that were found by socio-technical studies. This similarity not only occurred between human and technological relations, but also with the difficulties encountered by people who attempted to alter these material relations to be congruent with their values. By using ANT rather than a socio-technical approach, this research found that there were additional actants that were important to the formation of the urban water-cycle in the lower Lea river basin which included gardens, particular biota, ground-water levels, spatial configurations and more. It revealed that the focus of the socio-technical framework omitted important relations in understanding personal water consumption.

By using a framework that has not previously been used to understand the urban water-cycle this research offers a new set of insights to the many disciplines that have investigated the urban water-cycle from other perspectives: urban design and planning, engineering, urban ecology, urban political ecology, and socio-technical co-evolution. In so doing, it offers alternative ways in which the world could be assembled to generate new types of communities that work together with biota and materials to formulate cooperative assemblages that enable the flourishing of human life.

**Conclusion**

This research has found a new way of understanding the urban water-cycle through an actor-network theory co-evolutionary framework. It has developed new methods to approach reconfiguring these water qualities, quantities, locations and flows using the insights of an ANT understanding of the water-cycle and design synthesis.

The research has found that the urban water-cycle is not as homogenous as water engineers, ecologists, and geographers presume due to their studies that investigate aggregated effects. Nor is it as particular as sociologists would have us think. Instead there are many points of similarities and differences of relational effects that need to be constantly remade and can betray or transform the network at any point in time. These transformations are what sociotechnical co-evolution would identify as a co-evolution to the network. These are happening in the water-cycle of the lower Lea today.

These transformations have been used as a point of entry for a new actant that problemmatises and interressement the actants that assemble the existing water-cycle. This tests potential ANT co-evolutionary trajectories. This is a new way of conceptualising design practice. It actively incorporates the social, but does not presume that this is a stable base from which designers can work from. Instead the social and material configurations are constantly co-evolving and the design and the designer are actants in this process.

This extends the insights of actor-network theory and sociotechnical co-evolution from historical studies, to being able to transform future networks. This goes some way in answering the difficulties encountered by the technological propositions made by engineers that are betrayed by the social, or the research done by sociologists, ecologists and geographers that are betrayed by the technical and nonhuman.

This research has resulted in an understanding of an urban water-cycle that includes humans and nonhumans. It has also explored how to use this ANT co-evolution understanding to reconfiguring the urban water-cycle networks. It found two ANT co-evolution pathways to reconfigure the urban water-cycles in the lower Lea river basin that extend the terrestrial duration of freshwater resources for human and ecological purposes. These were increasing freshwater productivity and transforming waste to resource. By doing so it has extended the ANT co-evolutionary framework to address future network relations and formations. It also forms a new role for the designer in society that no longer shapes the material world to the whim of those wealthy and in power, but is able to invest and engage in materialising a society of shared values

# BIBLIOGRAPHY

Abercrombie, Patrick. 1945. *Greater London Plan 1944*. London: Her/His Majesty's Stationery Office.
———. 1998. *Town and Country Planning*. Vol. 8. 9 vols. Early Urban Planning 1870-1940. London; New York: Routledge/Thoemmes Press.
Ackroyd, Peter. 2000. *London: the biography*. London: Chatto & Windus.
———. 2008. *Thames: The Biography*. London: Chatto and Windus, November 4.
Acreman, Mike, ed. 2000. *The Hydrology of the UK: a study of change*. Vol. 1. London, New York: Routledge.
Agarwal, Anil, Marian S. delos Angeles, Ramesh Bhatia, Ivan Cheret, Sonia Davila-Poblete, Malin Falkenmark, Fernando Gonzalez Villarreal, et al. 2000. *Integrated Water Resources Management*. TAC Background Papers 4. Stockholm: Global Water Partnership, March.
Al Naib, S.K. 1997. *Applied Hydraulics: Hydrology and environmental engineering*. Romford: Research Books.
Alberti, Marina. 2008. *Advances in Urban Ecology: Integrating Humans and Ecological Processes in Urban Ecosystems*. 1st ed. New York: Springer, December 10.
Alexander, Christopher, Sara Ishikawa, and Murray Silverstein. 1977. *A pattern language: towns, buildings, construction*. New York: Oxford University Press.
Allen, Michelle. 2008. *Cleansing the City: Sanitary geographies in Victorian London*. Athens, Ohio: Ohio University Press.
Allon, Fiona, and Zoë Sofoulis. 2006. "Everyday Water: cultures in transition." *Australian Geographer* 37 (March): 45-55. doi:10.1080/00049180500511962.
Bakewell, Ian. 2008. *North London Flood Risk Assessment*. West Midlands: Mouchel, August.
Barbour, Rosaline. 2007. *Doing Focus Groups*. The SAGE Qualitative Research Kit. Los Angeles; London; New Delhi; Singapore: Sage Publications Ltd.
Barlow, Maude, and Tony Clarke. 2002. *Blue gold□ : the battle against corporate theft of the world's water*. London: Earthscan.
Barton, N.J. 1962. *The Lost Rivers of London: a study of their effects upon London and Londoners, and the effects of London and Londoners upon them*. 2nd ed. London: Phoenix House Limited and Leicester University Press.
Bee, Frances, and Roland Bee. 2004. *Facilitation Skills*. CIPD Publishing.
Botkin, D.B., and C.E. Beveridge. 1997. "Cities as Environments." *Urban Ecosystems* 1: 3-19.
Brand, Ralf. 2005. *Synchronizing Science and Technology with Human Behaviour*. London: Earthscan, December 1.
Brown, Rebekah, and Jodi Carke. 2007. *Transition to Water Sensitive Urban Design: The story of Melbourne, Australia*. Melbourne: Facility for Advancing Water Biofiltration, Monash Universtiy, June.
Buchan, S. 1938. *Water Supply of the County of London: from underground sources*. 2nd ed. London: Department of Scientific and Industrial Research.
Busquets, Joan, and Felipe Correa, eds. 2006. *Cities: X Lines: Approaches to city and open territory design*. Harvard University Graduate School of Design / Nicolodi Editore.
Butler, David, and John Davies. 2004. *Urban Drainage*. 2nd ed. London: Spon Press.
Butler, David., and Fayyaz Ali. Memon. 2006. *Water Demand Management*. Vol. 1. London: IWA Publishing.
Calder, Ian. 2005. *Blue Revolution: Integrated land and water resources management*. 2nd ed. Sterling, Virginia: Earthscan Publications Ltd.
Callon, Michel. 1986. Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay. In *Power, Action and Belief: a new sociology of knowledge?*, ed. John Law, 196-223. London: Routledge.
Callon, Michel, and John Law. 2005. "On Qualculation, Agency, and Otherness." *Environment and Planning D: Society and Space* 23 (5): 717 – 733. doi:10.1068/d343t.
Callon, Michel, ed. 1998. *The Laws of the Markets*. Oxford; Malden, MA: Blackwell.

Carr, Gemma, S. Nortcliff, and R.B. Potter. 2010. "Water reuse for Irrigated Agriculture in Jordan: challenges of soil sustainability and the role of management strategies." *Philosophical Transactions of the Royal Society A* 368: 5315-5321. doi:10.1098/rsta.2010.0181.
Carson, Rachel. 1964. *Silent Spring*. London: Readers Union Ltd.
Chang, Andrew, Genxing Pan, Albert L. Page, and Asano Takashi. 2002. *Developing Chemical Guidelines for Reclaimed Water and Sewage Sludge Applications in Agriculture*. Switzerland: World Health Organisation, May 17.
Chant, Colin. 1999. *The Pre-industrial Cities and Technology Reader*. Vol. 2. 6 vols. Cities and Technology. London; New York: Routledge.
Chen, W.F., and J.Y.R. Liew, eds. 2003. *The Civil Engineering Handbook*. 2nd ed. Boca Raton: CRC Press Inc.
Clark, Hazel, and David Brody, eds. 2009. *Design Studies: A Reader*. Oxford: Berg.
Denscombe, Martyn. 2003. *The Good Research Guide: For small-scale social research projects*. 2nd ed. Maidenhead; Philadelphia: Open University Press.
Dinckal, Noyan. 2008. Arenas of Experimentation: Modernizing Istanbul in the late Ottoman empire. In *Urban Machinery*, ed. Mikael Hard and Thomas J. Misa, 49-69. Cambridge, Massachusetts; London, England: The MIT Press.
Disco, Cornelis. 2008. Taming the Rhine: Economic connection and urban competition. In *Urban Machinery*, ed. Mikael Hard and Thomas J. Misa, 23-47. Cambridge, Massachusetts; London, England: The MIT Press.
Doak, Joe, and Nikos Karadimitriou. 2007. "(Re)development, Complexity and Networks: A Framework for Research." *Urban Studies* 44 (2) (February 1): 209-229. doi:10.1080/00420980601074953.
Downton, Peter. 2003. *Design Research*. Melbourne: RMIT University Press.
Drake, Susannah, and Yong K. Kim. 2009. "Sponge Park, New York City." *Topos: the international review of landscape architecture and urban design* 68. Water: Resource and threat (December): 23-28.
Dreiseitl, Herbert, and Dieter Grau. 2005. *New Waterscapes: Planning, Building and Designing with Water*. 1st ed. Basel: Birkhäuser Basel, October 28.
Droste, Ronald L. 1997. *Theory and Pracitce of Water and Wastewater Treatment*. New York; Chichester; Brisbane; Toronto; Singapore: John Wiley and Sons.
EA. 1997. *Groundwater Quality in the London Basin: Major ion and general chemistry for the Chalk aquifer*. Groundwater Quality Reports. Reading: Environment Agency, December. http://216.31.193.173/gwcl/Thames/Chalk-London-Basin/GW_QRepChalkLondon.html.
———. 2006. *The London Catchment AbstractionManagement Strategy*. Environment Agency, April. http://www.environment-agency.gov.uk/research/planning/33432.aspx.
———. 2008. *Water Resources in England and Wales - current state and future pressures*. Bristol: Enivronment Agency, December. http://www.environment-agency.gov.uk/research/library/publications/100582.aspx.
———. 2010. Household water use in London – indicator two. Government. July 16. http://www.environment-agency.gov.uk/research/library/publications/41051.aspx.
EBR Staff Writer. 2009. GE Energy Inaugurates First North American Greenhouse Cogeneration Facility. *Energy Business Review*. July 10. http://fossilfuel.energy-business-review.com/news/ge_energy_inaugurates_first_north_american_greenhouse_cogeneration_facility_090710.
Encarta. 2009. Lee. *Encarta*. Microsoft Encarta Online Encyclopedia. http://au.encarta.msn.com.
Ensink, Jeroen, Rizwan Aslam, Flemming Konradsen, Peter Jensen, and Wim van der Hoek. 2002. Linkages between irrigation and drinking water in Pakistan. International Water Management Institute.
European Environment Agency. 2011. Urban Soil Sealing in Europe. *Urban soil sealing in Europe*. January 19. http://www.eea.europa.eu/articles/urban-soil-sealing-in-europe?

Fagan, Brian. 2009. *Floods, Famines, and Emperors: El Nino and the Fate of Civilizations*. Revised Edition. New York: Basic Books, February 9.

Fairclough, Keith Roland. 1986. The River Lea 1571-1767: a river navigation prior to canalisation. PhD, London: University of London.

Fallan, Kjetil. 2008. "Architecture in Action: traveling with actor-network theory in the land of architectural research." *Architectural Theory Review* 13 (1): 80-96. doi:10.1080/13264820801918306.

Farias, Ignacio, and Thomas Bender, eds. 2010. *Urban Assemblages: How actor-network theory changes urban studies*. London; New York: Routledge.

Felson, Alexander J., and Steward T.A. A. Pickett. 2005. "Designed Experiments: New approaches to studying urban ecosystems." *Frontiers in Ecology and the Environment* 3 (10) (December): 549-556.

Feyen, Jan, Kelly Shannon, and Matthew Neville, eds. 2009. *Water and Urban Development Paradignms: Towards an integration of engineering, design and management approaches*. London: CRC Press/Balkema.

Flaxman, E. W., and E. W. Jackson. 2004. *Sweet & Wholesome Water: Five Centuries of History of Water-bearers in the City of London*. Cottisford. E.W. Flaxman, October.

Flick, Uwe. 2002. *An Introduction to Qualitative Research*. Second Edition. London; Thousand Oaks; New Delhi: Sage Publications Ltd.

Forty, Adrian. 2009. Design, Designers and the Literature of Design. In *Design Studies: a reader*, ed. Hazel Clark and David Brody, 16-19. Oxford; New York: Berg Publishers.

France, Robert, ed. 2002. *Handbook of Water Sensitive Planning and Design*. Integrative Studies in Water Management and Land Development. Boca Raton: Lewis Publishers.

Gandy, Matthew. 1999. "The Paris Sewers and the Rationalization of Urban Space." *Transactions of the Institute of British Geographers* 24 (1) (April): 23-44.

———. 2003. *Concrete and Clay: Reworking Nature in New York City*. illustrated edition. Cambridge, Massachusetts: The MIT Press, October 1.

———. 2004. "Rethinking urban metabolism: water, space and the modern city." *City* 8 (3): 363-379.

———. 2005a. "Cyborg Urbanization: Complexity and monstrosity in the contemporary city." *International Journal of Urban and Regional Research* 29 (1) (March): 26-49.

———. 2005b. "Learning from Lagos." *New Left Review* 33 (June): 37-52.

———. 2006a. "The Bacteriological City and Its Discontents." *Historical Geography* 34: 14-25.

———. 2006b. "Planning, Anti-planning and the Infrastructure Crisis Facing Metropolitan Lagos." *Urban Studies* 43 (2) (February): 371-396.

———. 2008. "Landscapes of Disaster: water, modernity, and urban fragmentation in Mumbai." *Environment and Planning A* 40: 108-130.

Gardiner, Virginia. 2010. Loowatt Waterless Toilet System. http://www.loowatt.com/.

Geels, Frank. 2005. "Co-Evolution of Technology and Society: the transition in water supply and personal hygiene in the Netherlands (1850-1930) - a case study in multi-level perspective." *Technology in Society* 27 (3): 363-397.

Giralt, Israel Rodriguez, Daniel Lopez Gomez, and Noel Garcia Lopez. 2010. Conviction and Commotion: On soundspheres, technopolitics and urban spaces. In *Urban Assemblages: How actor-network theory changes urban studies*, ed. Ignacio Farias and Thomas Bender, 179-196. London; New York: Routledge.

Gissen, David. 2006. "Thermopolis: Conceptualising environmental technologies in the urban sphere." *Journal of Architectural Education* 60 (1) (September): 43-53. doi:10.1111/j.1531-314X.2006.00059.x.

GLA. 2009. The London Plan: Spatial development strategy for Greater London (consultation draft replacement plan). Greater London Authority, October.

Gleick, Peter H., Heather Cooley, David Katz, Emily Lee, Jason Morrison, Meena Palaniappan, Andrea Samulon, and Gary H. Wolff. 2006. *The World's Water: The Biennial Report on Freshwater Resources (World's Water*. Washington, Covelo, London: Island Press, December 15.
Goubert, Jean-Pierre. 1986. *The Conquest of Water: the advent of health in the industrial age*. Trans. Andrew Wilson. Cambridge, Oxford: Polity Press and Basil Blackwell Ltd.
Graham, Stephen, and Simon Marvin. 2001. *Splintering urbanism: networked infrastructures, technological mobilities and the urban condition*. London: Routledge.
Graham-Leigh, John. 2000. *London's Water Wars: The Competition for London's Water Supply in the Nineteenth Century*. London: Francis Boutle Publishers, October 19.
Gramaglia, Christelle. 2005. River Sentinels: Finding a mouth for the Lot river. In *Making Things Public: Atmospheres of democracy*,ed. Bruno Latour and Peter Weibel, trans. Sarah Clift, 478-481. Karlsruhe, Germany; Cambridge, Massachusetts; London, England: ZKM Center for Art and Media Karlsruhe; The MIT Press.
Grau, Dieter. 2009. "A New Water Culture for Tianjin." *Topos: the international review of landscape architecture and urban design* 68. Water: Resource and threat (December): 46-52.
Grove, J. Morgan, and William R. Burch. 1997. "A social ecology approach and applications of urban ecosystem and landscape analyses: a case study of Baltimore, Maryland." *Urban Ecosystems* 1 (4) (December 1): 259-275. doi:10.1023/A:1018591931544.
Gual, Miguel A., and Richard B. Norgaard. 2008. "Bridging ecological and social systems coevolution: A review and proposal." *Ecological Economics* In Press, Corrected Proof (July 23). doi:10.1016/j.ecolecon.2008.07.020.
Hall, Peter. 2002. *Cities of Tomorrow: an intellectual history of urban planning and design in the twentieth century*. 3rd ed. Malden, MA; Oxford; Melbourne: Blackwell Publishers.
Halliday, Stephen. 1999. *The great stink of London : Sir Joseph Bazalgette and the cleansing of the Victorian capital*. Stroud: Sutton. internal-pdf://01_Q_Halliday_Great_Stink-0530992128/01_Q_Halliday_Great_Stink.txt.
———. 2004. *Water: A turbulent history*. Stroud: Sutton Publishing.
Hand, Martin, Elizabeth Shove, and Dale Southerton. 2005. "Explaining Showering: a discussion of the material, conventional, and temporal dimensions of practice." *Sociological Research Online* 10 (1) (June 30): 13.
Hand, Martin, Dale Southerton, and Elizabeth Shove. 2003. Explaining Daily Showering: a discussion of policy and practice. Sustainable Technologies Programme, April.
Hard, Mikael, and Thomas J. Misa, eds. 2008. *Urban Machinery: Inside Modern European Cities*. illustrated edition. Cambridge, Massachusetts; London, England: MIT Press, March 4.
Harvey, David. 1989. *The Urban Experience*. Baltimore; London: Johns Hopkins University Press.
———. 2006. *Limits to Capital*. New and Fully Updated Ed. London: Verso.
Hengeveld, H., C. De Vocht, and V. Bencko. 1982. *Role of Water in Urban Ecology: Second International Environmental Symposium of the Royal Netherlands Land Development Society*. Amsterdam; Oxford; New York: Elsevier Science Ltd, October.
Hester, Randolph T. 2006. *Design for Ecological Democracy*. 1st ed. Cambridge, Massachusetts: The MIT Press, September 22.
Heynen, Nikolas C., Maria. Kaika, and Erik Swyngedouw. 2006. *In The Nature Of Cities : Urban Political Ecology and the Politics of Urban Metabolism*. Vol. 1. Questioning cities series. Abingdon: Routledge.
Hillier, Joseph Owen. 2009. Constructing London's Water Supply: A study of engineering and modernity. London: University College London.
Hodson, Mike, and Simon Marvin. 2010. "Urbansim in the Anthropocene: Ecological urbanism or premium ecological enclaves." *City* 14 (3) (June 11): 298-313. doi:10.1080/13604813.2010.482277.
Hommels, Anique. 2008. *Unbuilding Cities: Obduracy in urban sociotechnical change*. Cambridge, Massachusetts: MIT Press.

Hop, Le Thi. 2003. "Programs to Improve Production and Consumption of Animal Source Foods and Malnutrition in Vietnam." *Journal of Nutrition* (133): 4006S-2009S.
Howard, Ebenezer. 1998. *Tomorrow: a peaceful path to real reform*. Vol. 2. 9 vols. Early Urban Planning 1870-1940. London; New York: Routledge/Thoemmes Press.
Howell, Paul Philip, and John Anthony Allan. 1994. *The Nile: sharing a scarce resource : a historical and technical review of water management and of economic and legal issues*. Cambridge: Cambridge University Press.
IPCC. 2007a. *Climate Change 2007: Synthesis report*. Geneva: Intergovernmental Panel on Climate Change. http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm.
———. 2007b. Intergovernmental Panel on Climate Change Fourth Assessment Report. United Nations Environment Programme.
Jenkins, Geoff, Matthew Perry, and John Prior. 2009. *The Climate of the UK and Recent Trends*. Met Office Hadley Centre, January. http://ukclimateprojections.defra.gov.uk/content/view/816/9/.
Johnson, Bart., and Kristina. Hill, eds. 2002. *Ecology and Design: frameworks for learning*. Vol. 1. Washington, Covelo, London: Island Press.
Jones, Michael. 2007. *Rising Groundwater in Central London*. UK Groundwater Forum. http://www.groundwateruk.org/Rising_Groundwater_in_Central_London.aspx.
Kaika, Maria. 2005. *City of flows : modernity, nature, and the city*. New York: Routledge.
Kinkade-Levario, Heather. 2007. *Design for Water: rainwater harvesting, stormwater catchment, and alternate water reuse*. Gabiola Island: New Society Publishers.
Kosmala, A., S. Charvet, M. -C. Roger, and B. Faessel. 1999. "Impact assessment of a wastewater treatment plant effluent using instream invertebrates and the Ceriodaphnia dubia chronictoxicity test." *Water Research* 33 (1) (January): 266-278. doi:16/S0043-1354(98)00176-6.
Kropp, Cordula. 2005. River Landscaping in Second Modernity. In *Making Things Public: Atmospheres of democracy*,ed. Bruno Latour and Peter Weibel, trans. Gloria Custance, 486-491. Karlsruhe, Germany; Cambridge, Massachusetts; London, England: ZKM Center for Art and Media Karlsruhe; The MIT Press.
Kvale, Steinar. 2007. *Doing Interviews*. The SAGE Qualitative Research Kit. Los Angeles; London; New Delhi; Singapore: SAGE Publications.
de Laet, Marianne, and Annemarie Mol. 2000. "The Zimbabwe Bush Pump." *Social Studies of Science* 30 (2) (April 1): 225 -263. doi:10.1177/030631200030002002.
Landry, Charles. 2006. *The Art of City Making*. London: Earthscan Publications Ltd., October.
Latham, Alan, and Derek P. McCormack. 2010. Globalizations Big and Small: Notes on urban studies, actor-network theory, and geographical scale. In *Urban Assemblages: How actor-network theory changes urban studies*, ed. Ignacio Farias and Thomas Bender, 53-72. London; New York: Routledge.
Latour, Bruno. 1987. *Science in Action: How to follow scientists and engineers through society*. Cambridge, Massachusetts: Harvard University Press.
———. 1988. *The Pasteurization of France*. Trans. Alan Sheridan and John Law. Cambridge, Massachusetts; London, England: Harvard University Press.
———. 1993. *We Have Never Been Modern*. Trans. Catherine Porter. Cambridge, Massachusetts: Harvard University Press.
———. 1999a. On Recalling ANT. In *Actor Network Theory and After*, ed. John Law and John Hassard, 15-25. Oxford: Wiley-Blackwell.
———. 1999b. *Pandora's Hope: An essay on the reality of science studies*. Cambridge, Massachusetts; London, England: Harvard University Press.

———. 2000a. Where are the Missing Masses? The Sociology of a Few Mundane Artifacts. In *Shaping Technology/Building Society: studies in sociotechnical change*, ed. Wiebe E Bijker and John Law, 341. Cambridge, Massachusetts: The MIT Press.

———. 2000b. "When Things Strike Back: a possible contribution of 'science studies' to the social sciences." *The British Journal of Sociology* 51 (January 1): 107-123.

———. 2004. *Politics of Nature: how to bring the sciences into democracy*. Trans. Catherine Porter. Cambridge, Massachusetts; London, England: Harvard University Press.

———. 2005. *Reassembling the social: an introduction to actor-network-theory*. Oxford: Oxford University Press.

———. 2009. A Cautious Promethea? A Few Steps Toward a Philosophy of Design (with special attention to Peter Sloterdijk). In *Networks of Design: proceedings of the 2008 annual international conference of the Design History Society (UK)*, ed. Jonathan Glynne, Fiona Hackney, and Viv Minton. 1st ed. Boca Raton: Universal-Publishers. www.universal-pulbishers.com.

———. 2010. *The Making of Law: An ethnography of the conseil d'etat*. Trans. Marina Brilman and Alain Pottage. Cambridge: Polity Press.

Latour, Bruno, and Emilie Hermant. 2006. Paris: Invisible city. Trans. Liz Carey-Libbrecht. Bruno Latour, February. http://www.bruno-latour.fr/virtual/index.html#.

Latour, Bruno, and Albena Yaneva. 2008. Give Me a Gun and I will Make All Buildings Move: An ANT's view of architecture. In *Explorations in Architecture: Teaching, design, research*, ed. Reto Geiser, 80-89. Basel: Birkhäuser Verlag.

Laurel, Brenda, ed. 2003. *Design Research: Methods and Perspectives*. Cambridge, Massachusetts; London, England: The MIT Press.

Law, John. 2004a. *After Method: mess in social science research*. London: Routledge.

———. 2004b. "And if the global were small and noncoherent? Method, complexity, and the baroque." *Environment and Planning D: Society and Space* 22 (1): 13 – 26. doi:10.1068/d316t.

Law, John, and Michel Callon. 1988. "Engineering and Sociology in a Military Aircraft Project: A Network Analysis of Technological Change." *Social Problems* 35 (3) (June): 284-297. doi:10.2307/800623.

Law, John, and Annemarie Mol. 2001. "Situating Technoscience: an inquiry into spatialities." *Environment and Planning D: Society and Space* 19 (5): 609 – 621. doi:10.1068/d243t.

Leccese, Michael, and Kathleen McCormick, eds. 2000. *New Urbanism Standards Manual*. New York; London: McGraw-Hill.

LeGates, Richard, and Frederic Stout, eds. 1998. *Selected Essays*. Vol. 1. 8 vols. Early Urban Planning 1870-1940. London; New York: Routledge/Thoemmes Press.

Lewis, Jim. 1999. *London's Lea Valley: Britain's best kept secret*. Chichester: Phillimore.

Luu, Le Thanh. 2001. The VAC System in Northern Viet Nam. In *Integrated Agriculture-Aquaculture: A primer*, 149. FAO Fisheries Technical Paper 407. Rome: Food and Agriculture Organization of the United Nations.

Lynch, Kevin. 1984. *Good City Form*. Cambridge, Massachusetts; London, England: The MIT Press.

Magnusson, Roberta J. 2001. *Water Technology in the Middle Ages: Cities, Monasteries, and Waterworks after the Roman Empire*. Baltimore; London: The Johns Hopkins University Press, December 4.

Malone, Patrick. 1996. *City Capital and Water*. 1st ed. London; New York: Routledge.

Margolis, Liat, and Alexander Robinson. 2007. *Living Systems: Innovative Materials and Technologies for Landscape Architecture*. 1st ed. Basel: Birkhäuser Basel, May 29.

Marzluff, John M., Eric Shulenberger, Wilfried Endlicher, Marina Alberti, Gordon Bradley, Clare Ryan, Craig ZumBrunnen, and Ute Simon, eds. 2008. *Urban Ecology: An International Perspective on the Interaction Between Humans and Nature*. New York: Springer.

McHarg, Ian L. 1995. *Design with Nature*. 1st ed. New York, Chichester: Wiley, February 6.

Meadows, Donella, Dennis Meadows, Jorgen Randers, and William Behrens. 1972. *The Limits to Growth;a Report for the Club of Rome Project on the Predicament of Mankind*. London: Earth Island.

Medema, Wietske, Brian S. McIntosh, and Paul Jeffrey. 2008. "From Premise to Practice: a critical assessment of integrated water resources management and adaptive management approaches in the water sector." *Ecology and Society* 13 (2): 29-46.

Melosi, Martin V. 2000. *The Sanitary City: Urban infrastructure in America from colonial times to the present*. Creating the North American Landscape. Baltimore; London: The John Hopkins University Press.

Metropolitan Water Board. 1961. *The Water Supply of London*. 2nd ed. London: The Board New River Head.

de Meulder, Bruno, and Kelly Shannon. 2009. "A De-poldering Project in Beveren North, Belgium." *Topos: the international review of landscape architecture and urban design* 68. Water: Resource and threat (December): 76-81.

Michel, Ralf, ed. 2007. *Design Research Now: Essays and selected projects*. Basel; Boston; Berlin: Birkhäuser Verlag.

Mol, Annemarie, and John Law. 1994. "Regions, Networks and Fluids: Anaemia and Social Topology." *Social Studies of Science* 24 (4) (November): 641-671. doi:10.2307/370267.

Molella, Arthur P., and Joyce. Bedi. 2003. *Inventing for the Environment*. Lemelson Center studies in invention and innovation. Cambridge, Mass.: MIT Press in association with Lemelson Center, Smithsonian Institution, Washington, D.C.

Moor, Malcolm, and Jon Rowland, eds. 2007. *Urban Design Futures*. London; New York: Routledge.

Moutaud, Isabelle. 2009. "Los Angeles River Revitalization Master Plan." *Topos: the international review of landscape architecture and urban design* 68. Water: Resource and threat (December): 16-22.

New London Architecture. 2006. Turning the Tide: Regenerating London's Thames gateway. New London Architecture.

———. 2008. Waterfront London: Rediscovering the rivers and canals of the capital. British Waterways London and URS.

Newson, Malcolm. 2007. *Land, Water and Development: Sustainable Management of River Basin Systems*. 2nd ed. London; New York: Routledge.

Nordenson, Guy, Catherine Seavitt, and Adam Yarinsky. 2010. *On the Water: Palisade Bay*. Ostfildern: Hatje Cantz Verlag.

Novotny, Vladimir, and Paul Brown. 2007. *Cities of the Future: Towards integrated sustainable water and landscape management*. London: IWA Publishing, August 28.

NSW Office of Water. 2010. *Climate Change and Its Impacts on Supply and Demand*. Sydney: NSW Office of Water, October. http://www.waterforlife.nsw.gov.au/mwp/understanding_climate_change/climate_change_study.

Ockman, Joan. 1993. *Architecture Culture 1943-1968: A documentary anthology*. New York: Columbia Books of Architecture/Rizzoli.

Ogle, Britta M., Ho Thi Tuyet, Hoang Nghia Duyet, and Nguyen Nhut Xuan Dung. 2003. "Food, Feed or Medicine: The multiple functions of edible wild plants in Vietnam." *Economic Botany* 57 (1): 103-117.

Ostrom, Elinor. 1990. *Governing the Commons: the evolution of institutions for collective action*. Cambridge, New York: Cambridge University Press.

Palmer, Margaret. 2010. "Water Resources: Beyond Infrastructure." *Nature* 467 (September 30): 534-535.

Paul, Michael J., and Judy L. Meyer. 2008. Streams in the Urban Landscape. In *Urban Ecology: An International Perspective on the Interaction Between Humans and Nature*, ed. John M. Marzluff, Eric Shulenberger, Wilfried Endlicher, Marina Alberti, Gordon Bradley, Clare Ryan, Craig ZumBrunnen, and Ute Simon. 207-231 ed. New York: Springer.

Peel, Charlie. 2009. Facing Up to Rising Sea-Levels: Retreat? Defend? Attack? The future of our coastal and estuarine cities. Institute of Civil Engineers/Royal Institute of British Architects/Building Futures.

Pickett, S. T. A., M. L. Cadenasso, J. M. Grove, C. H. Nilon, R. V. Pouyat, W. C. Zipperer, and R. Costanza. 2001. "Urban Ecological Systems: Linking Terrestrial Ecological, Physical, and Socioeconomic Components of Metropolitan Areas." *Annual Review of Ecology and Systematics* 32: 127-157.

Pickett, Steward T. A., William R. Burch, Shawn E. Dalton, Timothy W. Foresman, J. Morgan Grove, and Rowan Rowntree. 1997. "A conceptual framework for the study of human ecosystems in urban areas." *Urban Ecosystems* 1 (4) (December 1): 185-199. doi:10.1023/A:1018531712889.

Plunz, Richard, and Maria Paola Sutto, eds. 2008. *Urban Climate Change Cross*. Surrey: Ashgate.

Prince George's County. 1999. *Low-impact Development Design Strategies: An integrated design approach*. Largo, Maryland: Prince George's County, Maryland, June.

Read, Stephen, Jurgen Rosemann, and Job van Eldijk, eds. 2005. *Future City*. Abingdon; New York: Spon Press.

Register, Richard. 2002. *Ecocities : building cities in balance with nature*. Berkley, California: Berkley Hills Books.

Reise, Karsten. 2009. "Designing Tidal Landscapes." *Topos: the international review of landscape architecture and urban design* 68. Water: Resource and threat (December): 82-87.

Rigg, Jonathan. 1992. *The Gift of Water: Water management, cosmology and the state in south east Asia*. London: School of Oriental & African Studies, November.

Robbins, Paul, and Julie Sharp. 2008a. Producing and Consuming Chemicals: the moral economy of the American lawn. In *Urban Ecology: An International Perspective on the Interaction Between Humans and Nature*, ed. John M. Marzluff, Eric Shulenberger, Wilfried Endlicher, Marina Alberti, Gordon Bradley, Clare Ryan, Craig ZumBrunnen, and Ute Simon, 181-205. New York: Springer.

———. 2008b. Turfgrass Subjects: the political economy of urban monoculture. In *Urban Ecology: An International Perspective on the Interaction Between Humans and Nature*, ed. Nik Heynen, Maria Kaika, and Erik Swyngedouw, 181-205. New York: Springer, January 11.

Roberts, David A., Emma L. Johnston, and Nathan A. Knott. 2010. "Impacts of desalination plant discharges on the marine environment: A critical review of published studies." *Water Research* 44 (18) (October): 5117-5128. doi:16/j.watres.2010.04.036.

Rudd, Peter. 2009. Hydro-Urbanism Part 1Digital. July 28.

Schafer, Robert. 2009. *Water: Resource and threat*. Topos: the international review of landscape architecture and urban design 68. Munich: Georg D.W. Callwey, December.

Schofield, John. 1987. *The London Surveys of Ralph Treswell*. 135. London: London Topographical Society.

Schultz, Stanley, and Clay McShane. 1978. "To Engineer the Metropolis: Sewers, santitation, and city planning in the late-nineteenth-century America." *The Journal of America History* 65 (2) (September): 389-411.

Shane, David Grahame. 2005. *Recombinant Urbanism*. Chichester: John Wiley and Sons.

———. 2011. *Urban Design Since 1945: A global perspective*. Chichester: John Wiley & Sons.

Shove, Elizabeth. 2004. *Comfort, Cleanliness and Convenience: The Social Organization of Normality*. illustrated edition. Oxford; New York: Berg Publishers, April 24.

Shove, Elizabeth, Matthew Watson, Martin Hand, and Jack Ingram. 2008. *The Design of Everyday Life*. Oxford; New York: Berg Publishers, February 19.

Sijmons, Dirk. 2009. "Room for the River." *Topos: the international review of landscape architecture and urban design* 68. Water: Resource and threat (December): 60-67.

Simone, AbdouMaliq. 2005. Local Navigation in Douala. In *Future City*, 212-227. Abingdon; New York: Spon Press.

Smithson, Alison. 1967. *Urban structuring: Studies of Alison & Peter Smithson*. Studio Vista; Reinhold.

Sofoulis, Zoë. 2005. "Big water, everyday water: a sociotechnical perspective." *Continuum: Journal of media and cultural studies* 19 (4) (December): 445-463.

Southerton, Dale, Heather Chappells, and Bas Van Vliet, eds. 2004. *Sustainable Consumption*. Cheltenham, UK; Northhampton, MA, USA: Edward Elgar Publishing.

Speers, Andrew. 2007. Water and Cities - Overcoming intertia and achieving a sustainable future. In *Cities of the Fututre*, 18-31. London: IWA Publishing.

Spirn, Anne Whiston. 1984. *The Granite Garden: Urban nature and human design*. New York: Basic Books.

Star, Susan Leigh, and James R. Griesemer. 1989. "Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39." *Social Studies of Science* 19 (3) (August): 387-420. doi:10.2307/285080.

Sukopp, H., S. Hejny, and I. Kowarik, eds. 1990. *Urban Ecology: Plants and plant communities in urban environments*. The Hague: SPB Academic Publishing.

Swyngedouw, Erik. 1999. "Modernity and Hybridity: Nature regeneracionismo and the production of the Spanish waterscape, 1890-1930." *Annals of the Association of American Geographers* 89 (3) (September): 443-465.

———. 2004. *Social power and the urbanization of water : flows of power*. Oxford geographical and environmental studies. Oxford ; New York: Oxford University Press.

Swyngedouw, Erik, and Nikolas C. Heynen. 2003. "Urban Political Ecology, Justice and the Politics of Scale." *Antipode*: 898-918.

Swyngedouw, Erik, and Maria Kaika. 2003. "The Making of 'Glocal' Urban Modernities: exploring the crack in the mirror." *City* 7 (1): 5-21. doi:10.1080/13604810302220.

Tarr, Joel A., and Gabriel Dupuy, eds. 1988. *Technology and the Rise of the Networked City in Europe and America*. Philadelphia: Temple University Press.

Tatom, Jacqueline. 2006. Urban Highways and the Reluctant Public Realm. In *The Landscape Urbanism Reader*. Princeton Architectural Press.

Teh, Tse-Hui. 2009. The agency of water on urban form in London. In *Networks of Design: proceedings of the 2008 annual international conference of the Design History Society (UK)*, ed. Jonathan Glynne, Fiona Hackney, and Viv Minton, 206-2011. Boca Raton: Universal-Publishers.

Thames Water. c2008. Lee Tunnel and Beckton Sewage Treatment Works Extension. Thames Water. http://www.thameswater.co.uk/cps/rde/xbcr/corp/lee-tunnel-beckton-extension-brochure.pdf.

———. 2007. Taking Care of Water: The next 25 years our plan for a sustainable future. Thames Water.

The Dewberry Companies. 2002. *Land Development Handbook: Planning, engineering, and surveying*. 2nd ed. New York: McGraw-Hill.

Thompson, George. 1824. A New Map of London and its Environs from an Original Survey. London.

Thomson, Hedley. 2003. "Catchment Management - building catchment communities to deliver integrated natural resource management." *Environmental Design Guide*.

Tilley, Elizabeth, Christoph Luthi, Antoine Morel, Chris Zurbrugg, and Roland Schertenleib. 2008. *Compendium of Sanitation Systems and Technologies*. Dubendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology.

Toope, Stephen J., Ken Rainwater, and Tony Allan. 2003. Managing and allocating water resources: Adopting the integrated water resource management approach. In *Water Resources Perspectives: Evaluation, Management and Policy*, ed. A.S. Alsharhan and W.W. Wood, Volume 50:1-8.

Trawick, P. 2006. "Scarcity, Equity, and Transparency: general principles for successfully governing the water commons." IASCP Europe Regional Meeting: Building the European Commons: from open fields to open source.

Tvedt, Terje, Richard Coopey, and Terje Oestigaard. 2006. *A History of Water: Water control and river biographies*. Vol. 1. 3 vols. London; New York: I.B.Tauris.

UNDP. 2006. *Human Development Report 2006: Beyond scarcity: power, poverty and the global water crisis*. New York: Palgrave Macmillan.

UNEP. 2007. Fourth Global Environment Outlook - environment for development. United Nations Environment Programme.
United Nations Human Settlements Programme. 2003. *Water and Santiation in the World's Cities: Local action for global goals*. London ; Sterling, VA: Earthscan Publications Ltd.
US EPA. 1999. *Prelminary Data Summary of Urban Stormwater Best Management Practices*. Washington DC: United States Environment Protection Agency.
Lee Valley Regional Park Authority. 2007. Park Development Framework. Lee Valley Regional Park Authority.
Vitousek, Peter M., Harold A. Mooney, Jane Lubchenco, and Jerry Melillo. 2008. Human Domination of Earth's Ecosystems. In *Urban Ecology: An International Perspective on the Interaction Between Humans and Nature*, ed. John M. Marzluff, Eric Shulenberger, Wilfried Endlicher, Marina Alberti, Gordon Bradley, Clare Ryan, Craig ZumBrunnen, and Ute Simon. New York: Springer.
Vitruvius. 1914. *Vitruvius: The Ten Books on Architecture*. Trans. Morris H. Morgan. Cambridge, Massachusetts: Harvard University Press.
Van Vliet, Bas. 2003. "Differentiation and Ecological Modernization in Water and Electricity Provision and Consumption." *Innovation: The European Journal of Social Science Research* 16 (1): 29. doi:10.1080/13511610304515.
———. 2004. Shifting Scales of Infrastructural Provision. In *Sustainable Consumption*, 67-80. Cheltenham, UK; Northhampton, MA, USA: Edward Elgar Publishing.
Van Vliet, Bas, Heather Chappells, and Elizabeth Shove. 2005. *Infrastructures of Consumption : environmental innovation in the utility industries*. London ; Sterling, VA: Earthscan.
Vries, F. W. T. Penning de. 2004. *Integrated land and water management for food and environmental security*. IWMI.
Waldheim, Charles. 2006. *The landscape urbanism reader*. New York: Princeton Architectural Press. http://www.loc.gov/catdir/toc/ecip065/2005036346.html.
Waldock, Tim. 1996. *An Introduction to Water Sensitive Design*. Environment Design Guide. Canberra: Royal Australian Insitute of Architects, November.
Waring, George Edwin. 1869. *Earth-closets*. The Tribune Association.
Water Resources Board. 1972. *Hydrogeology*. Artificial Recharge of the London Basin. Reading: Water Resources Board.
Wong, Tony H F. 2007. *Water Sensitive Urban Design - the journey thus far*. Environment Design Guide. Canberra: Royal Australian Insitute of Architects, August.
Woods Ballard, B, R Kellagher, P Martin, C Jefferies, R Bray, and P Shaffer. 2007a. *The SUDS Manual*. C697. London: CIRIA.
———. 2007b. *Site Handbook for the Construction of SUDS*. C698. London: CIRIA.
World Health Organization. 2000. *Global Water Supply and Sanitation Assessment 2000 Report*. Switzerland: WHO and UNICEF.
———. 2006. *WHO Guidelines for the Save Use of Wastewater, Excreta and Greywater*. 3rd ed. Geneva: WHO Press.
WWF-UK. 2009. *Rivers on the Edge*. Surrey: WWF-UK.
Yaneva, Albena. 2005. A Building is a "Multiverse." In *Making Things Public: Atmospheres of democracy*, ed. Bruno Latour and Peter Weibel, 530-535. Karlsruhe, Germany; Cambridge, Massachusetts; London, England: ZKM Center for Art and Media Karlsruhe; The MIT Press.
———. 2009a. *The Making of a Building: A pragmatist approach to architecture*. Bern: Peter Lang.
———. 2009b. *Made by the Office for Metropolitan Architecture: an ethnography of design*. Rotterdam: 010 Publishers.
———. 2009c. "Making the Social Hold: Towards an actor-network theory of design." *Design and Culture* 1 (3): 273-288. doi:10.2752/174967809X12556950208826.

Yin, Robert K. 2009. *Case Study Research: Design and Methods*. Fourth Edition. Vol. 5. Applied Social Research Methods Series. Thousand Oaks, California; London: Sage Publications, Inc.

# APPENDICES

# APPENDIX A ETHICS APPROVAL

**UCL RESEARCH ETHICS COMMITTEE**
**GRADUATE SCHOOL OFFICE**

UCL

Dr Sarah Bell
Civil, Environmental and Geomatic Engineering
UCL

16 July 2009

Dear Dr Bell

**Notification of Ethical Approval**
**Ethics Application: 2025/001: Interviews Investigating Water in the Lower Lea River Basin**

I am pleased to confirm that in my capacity as Chair of the UCL Research Ethics Committee, I have approved your project for the duration of the study i.e. until September 2010.
Approval is subject to the following conditions:

1. You must seek Chair's approval for proposed amendments to the research for which this approval has been given. Ethical approval is specific to this project and must not be treated as applicable to research of a similar nature. Each research project is reviewed separately and if there are significant changes to the research protocol you should seek confirmation of continued ethical approval by completing the 'Amendment Approval Request Form'.

The form identified above can be accessed by logging on to the ethics website homepage: http://www.grad.ucl.ac.uk/ethics/ and clicking on the button marked 'Key Responsibilities of the Researcher Following Approval'.

2. It is your responsibility to report to the Committee any unanticipated problems or adverse events involving risks to participants or others. Both non-serious and serious adverse events must be reported.

   **Reporting Non-Serious Adverse Events.**
   For non-serious adverse events you will need to inform Ms Helen Dougal, Ethics Committee Administrator (h.dougal@ucl.ac.uk), within ten days of an adverse incident occurring and provide a full written report that should include any amendments to the participant information sheet and study protocol. The Chair or Vice-Chair of the Ethics Committee will confirm that the incident is non-serious and report to the Committee at the next meeting. The final view of the Committee will be communicated to you.

   **Reporting Serious Adverse Events**
   The Ethics Committee should be notified of all serious adverse events via the Ethics Committee Administrator immediately the incident occurs. Where the adverse incident is unexpected and serious, the Chair or Vice-Chair will decide whether the study should be terminated pending the opinion of an independent expert. The adverse event will be considered at the next Committee meeting and a decision will be made on the need to change the information leaflet and/or study protocol.

On completion of the research you must submit a brief report (a maximum of two sides of A4) of your findings/concluding comments to the Committee, which includes in particular issues relating to the ethical implications of the research.

Yours sincerely

**Sir John Birch**
**Chair of the UCL Research Ethics Committee**

Cc: Tse-Hui Teh & Ud Doron, Civil, Environmental and Geomatic Engineering, UCL

# APPENDIX B: CONSENT FORMS AND INFORMATION SHEET

**UCL DEPARTMENT OF CIVIL ENVIRONMENTAL AND GEOMATIC ENGINEERING**

## Information Sheet for Interviews Investigating Water in the Lower Lea River Basin

We would like to invite you to participate in this research project. You should only participate if you want to, choosing not to take part will not disadvantage you in any way. Before you decide whether you want to take part, it is important to read the following information carefully. Please ask, if there is anything that is not clear or if you would like more information.

This study has been approved by the UCL Research Ethics Committee Project ID Number: 2025/001

**Contact Details:**

Principal Researcher: Dr Sarah Bell, Senior Lecturer
Chadwick Building, Gower Street, London WC1E 6BT.
E: s.bell@ucl.ac.uk T: 020 7679 7874; F:020 7679 7874

Interviewer: Ms Tse-Hui Teh, PhD researcher
Chadwick Building, Gower Street, London WC1E 6BT.
E: t.teh@ucl.ac.uk T: 020 7679 1570; F:020 7679 7874

**Research Details:**

The research project aims to investigate how the existing urban area of the lower Lea river basin can be adapted to achieve sustainable water use. Sustainable water use is a combination of social practices and infrastructures, thus the research aims to recruit participants from a wide variety of organisations that effect the quality, quantity and location of water in the lower Lea river basin. Participants will include environmentally aware citizens, industries, water companies, waste-water companies, non-government organisations and government organisations.

**Process:**

You will be required to take part in two interviews at least 3 months apart. Each interview will take approximately one to one and a half hours. During this time you will be asked about your past, present and future water use; and how your job may effect the water-cycle in the lower Lea river basin. At the end of the first interview, you will also be given a disposable camera to take photographs of: the physical objects you use in your life and at work that effect the quality, quantity and location of water in the lower Lea river basin; as well as any water bodies you might come across in your daily life. Once you have used up the film, please return the camera to Ms Tse-Hui Teh. Your name will not be disclosed in the research at any time. If you decide to take part, but then find any questions discomforting, you are free to withdraw without giving reason.

**Outcomes:**

During these interviews you will also be given information that may help you make more informed decisions about how to use water sustainably in the future. If you would like an electronic copy of the complete PhD thesis, please contact the interviewer or principal researcher.

All data will be collected and stored in accordance with the Data Protection Act 1998.

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**UCL DEPARTMENT OF CIVIL ENVIRONMENTAL AND GEOMATIC ENGINEERING**

UCL

## Consent Form for Interviews Investigating Water in the Lower Lea River Basin

Thank you for your interest in taking part in this research. If you have any questions arising from the information sheet attached or the verbal explanation given to you, please ask the researcher before you sign the consent form.

The purpose of this document is twofold:

- Consent to a recorded interview
- Describe the conditions agreed regarding the use of the recordings and detailed notes and quotes resulting from these interviews
- Describe the conditions agreed regarding the use of photographs taken by the participant

**The Interviewee agrees as follows:**
I consent to participating in a recorded interview. I have been made aware of the procedure to be followed. I understand I may withdraw from the process at any time.

I understand my name will not be disclosed without my permission.

I understand that the interviewer will create detailed notes with selected quotes of the recordings which I will have an opportunity to approve prior to it being used for scholarly purposes. The recording and notes will be deposited at the UCL archive.

I understand that I am giving the interviewer the right to use and make available the content of the recorded interview and photographs I take in the following ways:

- Reputable scholarly research
- Use in educational establishments, including use in a thesis, dissertation or similar research
- Public lectures or talks
- Use in publications

Date of recording: ..............................................................

**Interviewee**

Signed: .............................................................................. Date:..........................................................

(Print name): ....................................................................

Occupation: ....................................................................... Position: ..................................................

Address: ........................................................................................................................................................

Postcode: ......................................................................... Telephone: ..............................................

Email: ..............................................................................

**Interviewer**

Signed: .............................................................................. Date: ..........................................................

(Print name): ....................................................................

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**UCL DEPARTMENT OF CIVIL ENVIRONMENTAL AND GEOMATIC ENGINEERING**

## Information Sheet
## for the Group Discussion Investigating Water in the Lower Lea River Basin

We would like to invite you to participate in this research project. You should only participate if you want to, choosing not to take part will not disadvantage you in any way. Before you decide whether you want to take part, it is important to read the following information carefully. Please ask, if there is anything that is not clear or if you would like more information.

This study has been approved by the UCL Research Ethics Committee Project ID Number: 2025/001

**Contact Details:**
Principal Researcher: Dr Sarah Bell, Senior Lecturer
Chadwick Building, Gower Street, London WC1E 6BT. E: s.bell@ucl.ac.uk T: 020 7679 7874; F:020 7679 7874

PhD researcher: Ms Tse-Hui Teh, PhD researcher
Chadwick Building, Gower Street, London WC1E 6BT. E: t.teh@ucl.ac.uk T: 020 7679 1570; F:020 7679 7874

Group Discussion Facilitator: Mr Ud Doron, MSc researcher
Chadwick Building, Gower Street, London WC1E 6BT. E: u.doron@ucl.ac.uk

**Research Details:**
The research project aims to investigate how the existing urban area of the lower Lea river basin can be adapted to achieve sustainable water use. Sustainable water use is a combination of social practices and infrastructures, thus the research aims to recruit participants from a wide variety of organisations that effect the quality, quantity and location of water in the lower Lea river basin. Participants will include environmentally aware citizens, industries, water companies, waste-water companies, non-government organisations and government organisations.

**Process:**
You will be required to take part in a group discussion about your past, present and future water use. This discussion will take approximately one to one and a half hours. At the end of this discussion you will be given the option to take a disposable camera with you to photograph the things that you operate to use water and any water bodies that you come across in daily life. Once you've used up the film, please return it to Ms Tse-Hui Teh with the stamped self addressed envelope that is also provided.

Your name will not be disclosed in the research at any time. If you decide to take part, but then find any questions discomforting, you are free to withdraw without giving reason. If you would like to participate in a further stage of the research you will be given an opportunity to put your name on a contact sheet at the end of the discussion, or you can email or telephone Ms Tse-Hui Teh. Your participation in this group discussion will not be affected should you choose not to be re-contacted.

**Outcomes:**
During these interviews you will also be given information that may help you make more informed decisions about how to use water sustainably in the future. If you would like an electronic copy of the complete MSc dissertation or PhD thesis, please contact the facilitator or principal researcher.

All data will be collected and stored in accordance with the Data Protection Act 1998.

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**UCL DEPARTMENT OF CIVIL ENVIRONMENTAL AND GEOMATIC ENGINEERING**

## Consent Form
## for a Group Discussion Investigating Water in the Lower Lea River Basin

Thank you for your interest in taking part in this research. If you have any questions arising from the information sheet attached or the verbal explanation given to you, please ask the researcher before you sign the consent form.

The purpose of this document is threefold:
- Consent to a recorded group discussion
- Describe the conditions agreed regarding the use of the recordings and transcripts resulting from these interviews
- Describe the conditions agreed regarding the use of photographs taken by the participant

**The Participant agrees as follows:**
I consent to participating in a recorded group discussion. I have been made aware of the procedure to be followed. I understand I may withdraw from the process at any time.

I understand my name will not be disclosed without my permission.

I understand that the researcher will create a transcript of the recordings which I will have an opportunity to approve prior to it being used for scholarly purposes. The recording and transcript will be deposited at the UCL archive.

I understand that I am giving the researcher the right to use and make available the content of the recorded interview and the photographs I take in the following ways:
- Reputable scholarly research
- Use in educational establishments, including use in a thesis, dissertation or similar research
- Public lectures or talks
- Use in publications

Date of recording: ..................................................

**Group discussion participant**

Signed: .................................................. Date: ..................................................

(Print name): ..................................................

Occupation: .................................................. Position: ..................................................

Address: ..................................................

Postcode: .................................................. Telephone: ..................................................

Email: ..................................................

**Researcher**

Signed: .................................................. Date: ..................................................

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**UCL DEPARTMENT OF CIVIL ENVIRONMENTAL AND GEOMATIC ENGINEERING**

## Information Sheet for a Workshop Investigating Water in the Lower Lea River Basin

We would like to invite you to participate in this research project. You should only participate if you want to. Choosing not to take part will not disadvantage you in any way. Before you decide whether you want to take part, it is important to read the following information carefully. Please ask, if there is anything that is not clear or if you would like more information.

This study has been approved by the UCL Research Ethics Committee Project ID Number: 2025/001

**Contact Details:**
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**Research Details:**
The research project aims to investigate how the existing urban area of the lower Lea river basin can be adapted to achieve sustainable water use. Sustainable water use is a combination of social practices and infrastructures, thus the research aims to recruit participants from a wide variety of organisations that effect the quality, quantity and location of water in the lower Lea river basin. Participants will include environmentally aware citizens, industries, water companies, waste-water companies, non-government organisations and government organisations.

**Process:**
You will be required to take part in a facilitated workshop, which will take approximately one to one and a half hours. Each workshop group will be made of 5-6 people and comprise of a mix of water professionals and interested citizens facilitated by one person from UCL. The workshop will build on previous research undertaken by Ms Tse-Hui Teh in this area. It will ask you to reflect on these results and discuss new opportunities and alternatives that arise from these findings. Approximately half the participants in this workshop will have been involved in the previous phase of the research.

This workshop is the part of an event that will begin with also include a tour of the historic section of the Abbey Mills Pumping Station in London, a presentation by Thames Water about the Thames Tideway Tunnel project, and a presentation by Tse-Hui Teh about the results of previous research undertaken in this area. You may attend the workshop even if you are unable to attend the other events in the evening. Refreshments will be available throughout.

Your name will not be disclosed in the research at any time. If you decide to take part, but then find any questions discomforting, you are free to withdraw without giving reason.

**Outcomes:**
During this workshop you will be given information that may help you make more informed decisions about how to use water sustainably in the future. If you would like an electronic copy of the complete PhD thesis, please contact the researcher.

All data will be collected and stored in accordance with the Data Protection Act 1998.

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UCL

## Consent Form for Workshop Investigating Water in the Lower Lea River Basin

Thank you for your interest in taking part in this research. If you have any questions arising from the information sheet attached or the verbal explanation given to you, please ask the researcher before you sign the consent form.

The purpose of this document is twofold:

- Consent to participate in an audio and photographically recorded workshop
- Describe the conditions agreed regarding the use of the audio recordings, photographs, and detailed notes and quotes resulting from this workshop

**The Interviewee agrees as follows:**
I consent to participating in a recorded workshop. I have been made aware of the procedure to be followed. I understand I may withdraw from the process at any time.

I understand my name will not be disclosed without my permission.

I understand that the interviewer will create detailed notes with selected quotes of the audio recordings to be used for scholarly purposes. The audio recording and photographs will be deposited at the UCL archive.

I understand that I am giving the interviewer the right to use and make available the content of the recorded workshop and photographs taken in the following ways:

- Reputable scholarly research
- Use in educational establishments, including use in a thesis, dissertation or similar research
- Public lectures or talks
- Use in publications

Date of recording: ..............................................

**Interviewee**

Signed: .............................................. Date: ..............................................

(Print name): ..............................................

Occupation: .............................................. Position: ..............................................

Address: ..............................................

Postcode: .............................................. Telephone: ..............................................

Email: ..............................................

**Researcher**

Signed: .............................................. Date: ..............................................

(Print name): ..............................................

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## APPENDIX C PARTICIPANTS

The table lists the pseudonyms of the participants of this research in alphabetical order. It also tabulates whether or not they were environmentally aware citizens or water professionals, their decadal age, what parts of the water-cycle they were involved in, and what professional affiliation or local borough that they lived in.

| Pseudonym | Decadal Age | Citizen/Water Professional | Affiliation | Water-cycle for Others | Water-cycle for Self |
|---|---|---|---|---|---|
| Adam | 20's | Citizen | Tower Hamlets | | Drinking-water<br>Wastewater |
| Adriana | 30's | Citizen | Tower Hamlets | | Drinking-water<br>Wastewater |
| Alan | 40's | Water Professional<br>Citizen | Private Engineering Company/ Hackney | Surface-water | Drinking-water<br>Wastewater |
| Anne | 30's | Water Professional | Lee Valley Regional Park Authority | Ecological-water<br>Groundwater<br>Surface-water<br>River-water | Drinking-water<br>Wastewater |
| Anthony | 60's | Water Professional | Tower Hamlets Council | Surface-water | Drinking-water<br>Wastewater |
| Ben | 30's | Water Professional | Thames Water Utilities | Groundwater | Drinking-water<br>Wastewater<br>Rainwater |
| Bill | 40's | Water Professional | Environment Agency | River-water<br>Surface-water | Drinking-water<br>Wastewater |
| Cassie | 20's | Water Professional | Haringey Council | Drinking-water | Drinking-water<br>Wastewater |
| Charlie | 30's | Citizen | Haringey | Surface-water<br>Ecological-water | Drinking-water<br>Wastewater<br>Grey-water<br>Rainwater |
| Charlotte | 60's | Citizen | Tower Hamlets | | Drinking-water<br>Wastewater |
| Claire | 60's | Citizen | Haringey | | Drinking-water<br>Wastewater<br>Rainwater |
| Daniel | 20's | Water Professional<br>Citizen | Waterwise/ Tower Hamlets | Drinking-water | Drinking-water<br>Wastewater |
| Dorothy | 40's | Citizen | Tower Hamlets | | Drinking-water<br>Wastewater |
| Eleanor | 30's | Water Professional | Thames Water Utilities | Drinking-water | Drinking-water<br>Wastewater |

| | | | | | |
|---|---|---|---|---|---|
| Elsie | 50's | Water Professional<br>Citizen | Natural England/Haringey | Ecological-water<br>River-water<br>Marine-water | Drinking-water<br>Wastewater<br>Grey-water<br>Rainwater |
| Emily | 20's | Citizen | Hackney | | Drinking-water<br>Wastewater |
| Esther | 30's | Citizen | Haringey | | Drinking-water<br>Wastewater |
| Felicity | 30's | Water Professional | Environment Agency | Groundwater | Drinking-water<br>Wastewater |
| Frank | 50's | Water Professional | Environment Agency | River-water<br>Surface-water | Drinking-water<br>Wastewater |
| George | 60's | Citizen | Hackney | | Drinking-water<br>Wastewater |
| Hannah | 40's | Citizen | Hackney | | Drinking-water<br>Wastewater |
| Harry | 50's | Water Professional | Thames Water Utilities | Wastewater | Drinking-water<br>Wastewater |
| Heather | 30's | Water Professional | Hackney Council | Surface-water | Drinking-water<br>Wastewater |
| Humphrey | 40's | Water Professional | Greater London Authority | River-water<br>Surface-water | Drinking-water<br>Wastewater<br>Rainwater |
| Isabelle | 50's | Citizen | Hackney | | Drinking-water<br>Wastewater |
| Jack | 50's | Citizen | Lea River | | Drinking-water |
| James | 50's | Citizen | Tower Hamlets | | Drinking-water<br>Wastewater |
| Jeremy | 40's | Citizen | Hackney | | Drinking-water<br>Wastewater |
| Judith | 60's | Citizen | Tower Hamlets | | Drinking-water<br>Wastewater |
| Julian | 20's | Citizen | Hackney | | Drinking-water<br>Wastewater |
| Laura | 60's | Citizen | Haringey | | Drinking-water<br>Wastewater<br>Rainwater |
| Linda | 50's | Water Professional | Thames Estuary Partnership | Ecological-water<br>River-water | Drinking-water<br>Wastewater |
| Maria | 30's | Citizen | Tower Hamlets | | Drinking-water<br>Wastewater |
| Matthew | 20's | Citizen | Hackney | | Drinking-water<br>Wastewater |
| Max | 40's | Citizen | Hackney | | Drinking-water<br>Wastewater |
| Michelle | 50's | Citizen | Haringey | | Drinking-water<br>Wastewater<br>Rainwater |
| Neil | 20's | Citizen | Waltham Forest | | Drinking-water<br>Wastewater |
| Nick | 30's | Water Professional | Greater London Authority | River-water<br>Surface-water | Drinking-water<br>Wastewater |
| Nicola | 20's | Citizen | Hackney | | Drinking-water<br>Wastewater |

| | | | | | |
|---|---|---|---|---|---|
| Paul | 30's | Citizen | Hackney | | Drinking-water<br>Wastewater |
| Phillip | 50's | Water Professional<br>Citizen | Hackney | Ecological-water | Drinking-water<br>Wastewater |
| Qamar | 20's | Citizen | Tower Hamlets | | Drinking-water<br>Wastewater |
| Richard | 40's | Water Professional | Thames Water Utilities | Wastewater | Drinking-water<br>Wastewater<br>Rainwater |
| Rita | 50's | Citizen | Haringey | | Drinking-water<br>Wastewater |
| Roger | 60's | Water Professional | Thames Water Utilities | Drinking-water | Drinking-water<br>Wastewater<br>Rainwater |
| Ron | 40's | Water Professional | British Waterways | Canal-water | Drinking-water<br>Wastewater |
| Rose | 50's | Citizen | Haringey | | Drinking-water<br>Wastewater<br>Grey-water |
| Ruth | 60's | Citizen | Haringey | | Drinking-water<br>Wastewater |
| Sally | 30's | Water Professional | Envirowise/WRAP | Drinking-water | Drinking-water<br>Wastewater |
| Samuel | 40's | Water Professional | Environment Agency | River-water<br>Surface-water<br>Groundwater<br>Drinking-water | Drinking-water<br>Wastewater<br>Rainwater |
| Susan | 30's | Water Professional | Thames 21 | River-water | Drinking-water<br>Wastewater<br>Rainwater |
| Tessa | 20's | Citizen | Hackney | | Drinking-water<br>Wastewater |
| Tom | 30's | Water Professional<br>Citizen | Haringey | Surface-water<br>Drinking-water<br>Wastewater | Drinking-water<br>Wastewater<br>Grey-water<br>Rainwater |
| Vishtu | 50's | Water Professional | Tower Hamlets Council | Surface-water | Drinking-water<br>Wastewater |

# APPENDIX D INTERVIEW AND GROUP DISCUSSION ONE PARTICIPANT DEMOGRAPHICS

The participants ranged in age from people in their 20's to people in their 60's. People in their 20's and 60's were mostly represented in the group discussions, while those in their 30's, 40's, and 50's were strongly represented in the individual interviews (Table D.1).

| DECADAL AGE | MALE group | MALE individual | FEMALE group | FEMALE Individual | % TOTAL |
|---|---|---|---|---|---|
| **20's** | 5 | 1 | 2 | 1 | 17% |
| **30's** | 1 | 4 | 3 | 6 | 26% |
| **40's** | 2 | 5 | 2 | | 17% |
| **50's** | 1 | 6 | 2 | 4 | 25% |
| **60's** | | 3 | 5 | | 15% |
| **% TOTAL** | 17% | 36% | 26% | 21% | 100% |

**Table D.1 Age and Group Discussion and Interview Participant Gender**

There was a fairly even mix of male (53%) and female (47%) participants. However men were predominantly represented in individual interviews, while women were predominant in group discussions (Table D.2). Despite this disparity between men and women, women participated more equally in both group (56%) and individual (44%) discussions.

| | MALE | FEMALE |
|---|---|---|
| **GROUP DISCUSSION** | 9 | 14 |
| **INDIVIDUAL INTERVIEW** | 19 | 11 |
| **% TOTAL** | 53% | 47% |

**Table D.2 Group Discussion and Interview Participant Gender**

The observed ethnicity of most participants was white and English. However, there was one participant who was of Indian descent, and eight people had immigrated from overseas: India, Australia, the Netherlands, Portugal, France, Ireland, Israel, and the United States of America. These participants drew on different experiences of different water practices, technologies, infrastructures, and cultures to inform their current water-cycle interactions. In addition, one participant had worked in a developing country where water had to be hauled from the river for use and thus was well aware of the weight of water and the amount of human effort that was necessary to move it to where it was needed. This participant was also more knowledgeable of the practices that are associated with this form of water provision

Twenty five people with a professional influence over water participated in this research. Of these professionals there was a mix of different types of responsibilities within the water management of the lower Lea watershed. 28% were from the government, 28% were from local councils or regional authorities, 20% were from the water company, 12% were from non-government organisations, and 12% were from consultancies (Table D.3). The categories of professional people most interviewed coincided with the categories of organisations which have the greatest impact in altering the water-cycle.

There was also a good mix of age range amongst the professionals interviewed. I consider this a proxy of professional experience and historical entrenchment. The majority of the participants were in their 30's (36%). There were the least number of people in their 20's and 60's, 8 % respectively. People in their 40's represented 20% of participants, and 28% were in their 50's (Table D.3). There was a dip in representation of people in their 40's, which is likely due to the time pressures experienced by people of this age who have young families and greater work responsibilities than those in their 30's.

| DECADAL AGE | GOVERN-MENT | COUNCIL/ REGIONAL AUTHORITY | WATER COMPANY | CONSULT-ANT | NON-GOVERN-MENT | % TOTAL |
|---|---|---|---|---|---|---|
| **20's** | | 1 | | | 1 | 8% |
| **30's** | 2 | 3 | 2 | 1 | 1 | 36% |
| **40's** | 3 | 1 | | 1 | | 20% |
| **50's** | 2 | 1 | 2 | 1 | 1 | 28% |
| **60's** | | 1 | 1 | | | 8% |
| **% TOTAL** | 28% | 28% | 20% | 12% | 12% | 100% |

**Table D.3 Age and Sector of Water Professionals**

The thirty three human actants who were both self proclaimed environmentally aware citizens and living within the lower Lea river basin were mostly from Hackney (36%) and Haringey (30%). The least number of participants were from Waltham Forest, Newham and the canal boat dwellers. While the boroughs of London were not equally represented, the different age ranges between those in their 20's – 60's were fairly evenly distributed (Table D.4).

| DECADAL AGE | CANAL BOAT | HACKNEY | TOWER HAMLETS | HARINGEY | NEWHAM | WALTHAM FOREST | % TOTAL |
|---|---|---|---|---|---|---|---|
| **20's** | | 4 | 3 | | | 1 | 24% |
| **30's** | | 1 | 1 | 3 | 1 | | 18% |
| **40's** | | 4 | 1 | | | | 15% |
| **50's** | 1 | 2 | 1 | 4 | | | 24% |
| **60's** | | 1 | 2 | 3 | | | 18% |
| **% TOTAL** | 3% | 36% | 30% | 24% | 3% | 3% | |

**Table D.4 Age and Borough of Environmentally Aware Citizens**

## APPENDIX E DOCUMENTS

The table lists the documents that were mentioned, the author, at what point(s) of the water-cycle this particular document was related to in the interview, and the people who mentioned this particular document and where they were from. The table is in order of number of citations, and then in order of ecological-water, surface-water, ground-water, river-water, canal-water, drinking-water, waste-water, and marine-water.

**KEY**

| **Name, Author** | **Water type** | **Number of people** | **The person, affiliation, who cited this document** |
|---|---|---|---|
| Summary of the document. | | | |

**3 PEOPLE**

| **Sites of Special Scientific Interest (SSSI), Natural England** | **Surface-water<br>River-water<br>Groundwater** | **3 people** | **Anthony, Tower Hamlets Council<br>Elsie, Natural England<br>Anne, Lee Valley Regional Park Authority** |
|---|---|---|---|
| Natural England designated areas of biological significance to be protected from damage by people. | | | |

| **London Catchment Abstractions Management Strategy (CAMS), EA** | **Surface-water<br>River-water<br>Groundwater** | **3 people** | **Felicity, Environment Agency<br>Elsie, Natural England<br>Daniel, Waterwise** |
|---|---|---|---|
| Describes the existing state of rivers and streams in the London catchment. It also sets forth the aims to improve or maintain the water quality in these rivers and streams. | | | |

| **Planning Policy Statement 25 (PPS25), UK Government** | **Surface-water** | **3 people** | **Frank, Greater London Authority<br>Alan, Private civil engineer<br>Anthony, Tower Hamlets Council** |
|---|---|---|---|
| 2006 Policy requirements for the treatment of surface-water of all new developments. | | | |

| **The London Plan: Spatial development strategy for greater London, GLA** | **Surface-water<br>River-water<br>Canal-water<br>Wastewater** | **3 people** | **Humphrey, Greater London Authority<br>Nick, Greater London Authority<br>Heather, Hackney Council** |
|---|---|---|---|
| 2009 Strategic planning guidance for coordinated spatial development for all the boroughs of London. This includes the development of water infrastructure for recreation, drinking and waste. | | | |

**2 PEOPLE**

| | | | |
|---|---|---|---|
| **Biodiversity Action Plan, GLA** | **Surface-water<br>River-water<br>Groundwater** | **2 people** | **Anthony, Tower Hamlets Council<br>Anne, Lee Valley Regional Park Authority** |
| Documents targets for species conservation within the boundaries of the Greater London Authority. The habitats of these species are water dependent. | | | |

| | | | |
|---|---|---|---|
| **Water Framework Directive, European Union** | **Surface-water<br>Wastewater<br>River-water** | **2 people** | **Frank, Environment Agency<br>Samuel, Environment Agency** |
| European river-water and coastal-water quality legislation. | | | |

| | | | |
|---|---|---|---|
| **Water Resources Strategy, EA** | **Surface-water<br>River-water<br>Groundwater<br>Drinking-water** | **2 people** | **Samuel, Environment Agency<br>Cassie, Haringey Council** |
| 2008 Assessment of the current water resources in the UK and projections of future water needs and availability. | | | |

| | | | |
|---|---|---|---|
| **Flood Risk Maps, EA** | **River-water<br>Surface-water** | **2 people** | **Anthony, Tower Hamlets Council<br>Elsie, Natural England** |
| Environment Agency categorised areas at 1 in 200 or 1 in 1000 year risk of of flooding from rivers or the sea. These flood risks are based on topography. | | | |

| | | | |
|---|---|---|---|
| **Strategic Flood Risk Assessment, Tower Hamlets Council and EA** | **Surface-water<br>River-water** | **2 people** | **Anthony, Tower Hamlets Council<br>Vishtu, Tower Hamlets Council** |
| A document that is jointly prepared by the council and the Environment Agency to understand places and services at risk of flood damage within the borough. | | | |

| | | | |
|---|---|---|---|
| **Thames Eco Region Prospectus** | **Surface-water<br>Drinking-water** | **2 people** | **Nick, Greater London Authority<br>Linda, Thames Estuary Partnership** |
| The UK government's vision for the development surrounding the Thames Estuary to be an exemplar in environmentally sustainable infrastructure. | | | |

| | | | |
|---|---|---|---|
| **Tower Hamlets Strategic Plan, Tower Hamlets Council** | **Surface-water** | **2 people** | **Anthony, Tower Hamlets Council<br>Vishtu, Tower Hamlets Council** |
| This document outlines the aims and objectives for improvements to the services provided within the boundaries of this borough. It also gives details of the projects and actions that will be undertaken to meet these goals, some of which include water. | | | |

| | | | |
|---|---|---|---|
| **Decent Homes Standard** | **Drinking-water<br>Wastewater** | **2 people** | **Daniel, Waterwise<br>Heather, Hackney Council** |
| A UK government policy for local authorities to improve the standard of social housing. | | | |

| | | | |
|---|---|---|---|
| **Thames Tideway Strategic Study, Thames Water** | **Wastewater** | **2 people** | **Humphrey, Greater London Authority<br>Harry, Thames Water** |
| Thames Water study on the viability of constructing an intercepting sewer to reduce the number of combined sewer overflows. | | | |

**1 PERSON**

| | | | |
|---|---|---|---|
| **Biodiversity Action Plan, LVRPA** | **Surface-water<br>River-water<br>Groundwater** | **1 person** | **Anne, Lee Valley Regional Park Authority** |
| Protection targets for significant biological resources within the Lower Lee Valley Regional Park. | | | |

| | | | |
|---|---|---|---|
| **Pitt Review Learning Lessons from the 2007 Floods** | **Surface-water** | **1 person** | **Richard, Thames Water** |
| 2008 Recommendations of new procedures for flood prevention and flood response. | | | |

| | | | |
|---|---|---|---|
| **Floods and Water Management Bill** | **Surface-water<br>River-water<br>Marine-water** | **1 person** | **Bill, Environment Agency** |
| This act implements the recommendations of the Pitt review of the floods of 2007. | | | |

| | | | |
|---|---|---|---|
| **Water Protection Zone 2010** | **Surface-water<br>River-water** | **1 person** | **Bill, Environment Agency** |
| A regulatory mechanism that applies to a designated geographic area of where the Environment Agency has greater power to enforce the changes required to meet the EU Water Framework Directive objectives. | | | |

| | | | |
|---|---|---|---|
| **National Indicator 188** | **Surface-water** | **1 person** | **Frank, Environment Agency** |
| 2008 Guidance for local authorities to plan to adapt to climate change. | | | |

| | | | |
|---|---|---|---|
| **History of Holy Wells in London** | **Groundwater** | **1 person** | **Elsie, Natural England** |
| Documents several holy wells located in Haringey. The title to this book is incorrect. | | | |

| **Water Neutrality, Environment Agency** | **Drinking-water** | **1 person** | **Samuel, Environment Agency** |
|---|---|---|---|
| A project to determine if new building development can occur without an overall increase of drinking-water consumption. Within this project several reports have been produced showing the economic effects of water neutrality, how this could be achieved and case studies for opportunities where a pilot project could be implemented. | | | |

| **The Mayor's Draft Water Strategy, GLA** | **Surface-water<br>Drinking-water<br>Rainwater<br>Wastewater** | **1 person** | **Cassie, Haringey Council** |
|---|---|---|---|
| 2009 Public consultation report documenting the strategy of the GLA for drinking-water, surface-water, rainwater and wastewater projects in collaboration with Thames Water Utilities. | | | |

| **Lower Lea Opportunities, GLA** | **Drinking-water<br>Surface-water<br>River-water<br>Wastewater** | **1 person** | **Anthony Tower Hamlets Council** |
|---|---|---|---|
| 2007 Strategic planning guidance for a shared vision across boroughs for the regeneration of the lower Lea Valley during and after the Olympic Games 2012. | | | |

| **Hackney Statutory Planning Document Parts 3A and 3B, Hackney Council** | **Surface-water** | **1 person** | **Heather, Hackney Council** |
|---|---|---|---|
| The planning policy that has been agreed as the policy to be fulfilled for all change to the built fabric within the borough of Hackney. | | | |

| **Berkeley Homes Report, Berkeley Homes and Thames Water** | **Drinking-water** | **1 person** | **Eleanor, Thames Water** |
|---|---|---|---|
| Report for the joint project by Thames Water and Berkeley Homes developer to test the achievability of the Code for Sustainable Homes. This report found that consumer behaviour towards some of the technological changes circumvented the full water savings that the technology could have achieved if the consumer behaviour had not altered. | | | |

| **Thames Water June Breakdown, Thames Water** | **Drinking-water** | **1 person** | **Eleanor, Thames Water** |
|---|---|---|---|
| Annual report from Thames Water Utilities to the government regulator Ofwat. | | | |

| | | | |
|---|---|---|---|
| **Envirowise Water Use Report** | **Drinking-water Groundwater Surface-water** | **1 person** | **Sally, Ripple Effect/WRAP** |

2009 Report about the water use in industry and commerce concentrating particularly on the five most water consuming sectors: electricity, agriculture, fishing, manufacture of basic metals, and manufacture of chemicals and fibres

| | | | |
|---|---|---|---|
| **Enhanced Capital Allowance** | **Drinking-water Groundwater Surface-water** | **1 person** | **Sally, Ripple Effect/WRAP** |

Government incentive that enables a business to claim 100% first-year capital allowance on their spending on qualifying plant and machinery which includes water conservation technologies.

| | | | |
|---|---|---|---|
| **Food and Drink www.fhc.gov/co.uk** | **Drinking-water** | **1 person** | **Sally, Ripple Effect/WRAP** |

Website of resources for businesses to conserve drinking-water.

| | | | |
|---|---|---|---|
| **International Standard for Trenchless Technology, International Organization for Standardization** | **Drinking-water** | **1 person** | **Roger, Thames Water** |

An international standard for pipes to be laid without the need for digging a trench. Roger is involved in drafting this standard.

| | | | |
|---|---|---|---|
| **Talk of the Thames, Thames Estuary Partnership** | **River-water** | **1 person** | **Linda, Thames Estuary Partnership** |

A biannual magazine that is written and published by the Thames Estuary Partnership about projects, activities and matters of concern to the Thames Estuary.

| | | | |
|---|---|---|---|
| **Water Control Manual Procedures for Navigation, Flood, Normal, Drought** | **Canal-water** | **1 person** | **Ron, British Waterways** |

A manual documenting the procedures that are to be undertaken when the water in the canals reach different levels.

| | | | |
|---|---|---|---|
| **Urban Wastewater Treatment Directive, European Council** | **Wastewater** | **1 person** | **Harry, Thames Water** |

European policy to implement change that protects aquatic environments from polluted urban wastewater discharge from industrial sectors.

# APPENDIX F INTERVIEW ONE SCRIPT

## PRELIMINARIES (1MIN)

This is a recorded interview with:

Conducted on:

Time:

At:

## HAVE THEY UNDERSTOOD AND SIGNED THE CONSENT FORM? (2MIN)

Consent form and information sheet?

Questions?

Signed?

Please remember that if you don't feel comfortable, you can stop the interview at any time.

## INTRODUCTION (1MIN)

We will discuss the impacts you have on water in the lower Lea river basin.

This means the quality, quantity, and location of water.

We will begin with your daily professional impacts and then your personal influences.

We will end with what your future water interactions might be.

## WHAT ARE THE IMPACTS ON THE WATER-CYCLE THAT THE INTERVIEWEE CAN IDENTIFY? (10MINS)

Before interview knowledge of lower Lea basin?

Since then, impact?

## DOES THEIR PROFESSIONAL LIFE IMPACT ON WATER IN THE LOWER LEA RIVER BASIN? (10MINS)

Work impacts?

Average day?

Other work circumstances?

How?

## WHAT ARE THE TECHNIQUES DO THEY USE TO ALTER THE WATER-CYCLE? (10MINS)

Average day?

Other circumstances?

How?

Non-average day? How?

**WHAT ARE THEIR REACTIONS TO THE PREDICTIONS OF WATER SHORTAGES? (1MIN)**

-10 years popular media coverage

-Countries far from the UK

-Drought in 2005/6 in SE England, problem home.

-June 2009 release UK Climate Change predictions, more drought SE England.

**WHAT DO THEY THINK IS THE CAUSE FOR THESE PREDICTED WATER SHORTAGES? (10MINS)**

Heard of this?

How do you think this will affect you?

**HOW WOULD THEY BE WILLING TO CHANGE THEIR CURRENT PRACTICES IN FLOOD AND SCARCITY? (10MINS)**

What would you do professional? Personal?

**WHO DO THEY THINK IS RESPONSIBLE FOR ENSURING WATER SECURITY (FLOOD AND SHORTAGES) FOR THE FUTURE? (5MINS)**

Who should be responsible?

**WHAT DO THEY THINK NEEDS TO BE CHANGED TO ENSURE WATER SECURITY (FLOOD AND SHORTAGES) IN THE FUTURE? (5MINS)**

What should be done?

**CONCLUSION (10MINS)**

Thank you very much for your interview.

Explain water diary: camera and notebook.

This was part one, the next part will be designs.

**PREPARATION FOR INTERVIEW 2 (2MINS)**

Understand representations of designs?

Will make it as understandable as possible.

Familiarity with technical drawings?

Plan, elevation, section?

Representation preference?

When would be a good date in 3 months to conduct the second interview?

Any additional comments?

Thank you very much for your time, I hope you enjoyed the discussion.

# APPENDIX G GROUP DISCUSSION ONE SCRIPT AND MATERIALS

**PRELIMINARIES (1MIN)**

This is a recorded group discussion with:

Conducted on:

Time:

At:

**HAVE THEY UNDERSTOOD AND SIGNED THE CONSENT FORM? (2MIN)**

Consent form and information sheet?

Questions?

Signed?

Please remember that if you don't feel comfortable, you can leave the group discussion at any time.

**INTRODUCTION (1MIN)**

My name is Ud Doron and I am an MSc Student at UCL at the Environmental Systems Engineering course.

This group discussion is part of my dissertation, entitled "Public Participation in Environmental Decision Making for Water" and some further PhD research by Tse-Hui Teh. My project essentially deals with how communities interact with water systems and how the public can affect future environmental decisions for water.

The dissertation is supervised by Dr Muki Haklay and Dr Sarah Bell, whose contact details, as well as mine are listed on the information sheet attached to your consent forms.

I'd like everyone to feel comfortable to participate in this discussion. Everyone's opinions count and it isn't necessary for us all to agree. We're going to start out with each person briefly introducing themselves with their name, what area you live in, and what your particular interest is in joining this discussion.

After that, I have a few questions to prompt the conversation which will go for about an hour and a half or so, until about …o'clock. Does anyone have any time constraints?

Is this okay with everyone?

**INTRODUCTIONS TO EACH OTHER (5MINS)**

Excellent! So let's begin with your name, where you live, and why you are interested in joining this discussion…would you mind starting?

(How long have you been living here for? Do you live with your family/alone? Have you always lived in the area?)

**KNOWLEDGE OF THE LOWER LEA RIVER BASIN? (3MINS)**

When you hear the words 'Lea river basin', what comes to mind?

(Would you explain further? Please describe what you mean. Is there anything else?)

**WHAT DO THEY KNOW OF THEIR WATER INFRASTRUCTURE? (3MINS)**

Do you know who's your water and sewerage service provider?

Do you know where you're getting your water from? Where?

Do you know where your wastewater is going to?

How do you know that?

**WHAT DO THEY KNOW OF THEIR WATER CONSUMPTION? (20MINS)**

Now I'd like you to take 5 mins with these post-it notes and markers and write down everything in your everyday life where you use water and what for. (Drinking, Personal Hygiene, Cooking, Washing machine, Dishwasher…)

How much water do you think you're using?

How would you describe your water consumption habits? What do you think uses the most water? Least?

**PRESENT INFORMATION SHEET 1 AND 2 (3MINS)**

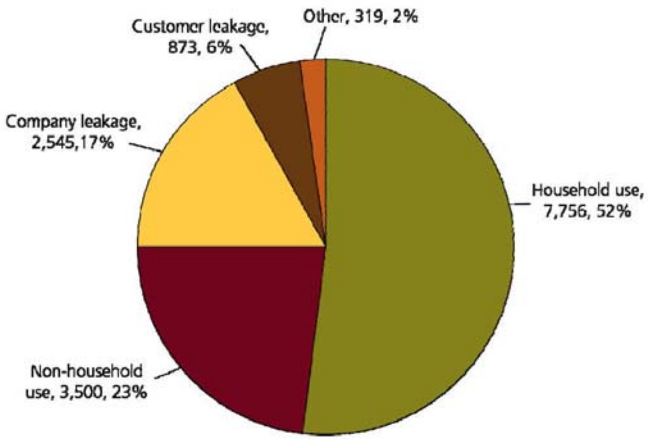
Household use in England & Wales accounts for 52% of Public water supply. The estimated average water use per head per day in England is around 150 L, similar to countries like France and Luxemberg and well below countries like Romania with an average of 294 and Spain with 265 but still more than other countries in the EU like Estonia and The Czech Republic averaging around 100. According to the WHO, a minimum of 30-50 L/head*day is considered satisfactory for personal and domestic hygiene, cooking and drinking.

The second information sheet shows how this breaks down into components of water use in the average UK household.

**INFORMATION SHEET 1**

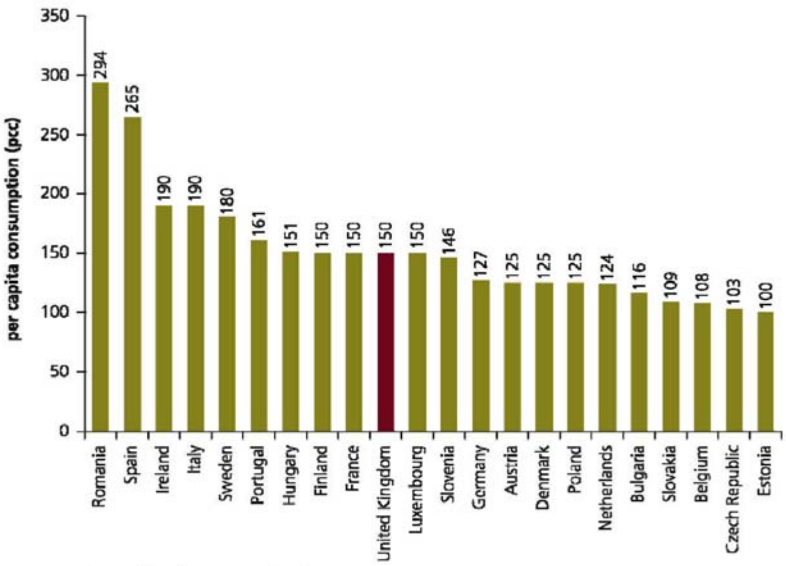
**<u>Household Water Use in England</u>**

Household use in England & Wales accounts for 52% of Public water supply.




Source: based on Ofwat 2007 data

The estimated average water use per head per day in England is around 150L, similar to countries like France and Luxemberg and well below countries like Romania with an average of 294L and Spain with 265L but still more than other countries in the EU like Estonia and The Czech Republic averaging around 100L. According to the WHO, a minimum of 30-50L/head/day is considered satisfactory for personal and domestic hygiene, cooking and drinking.



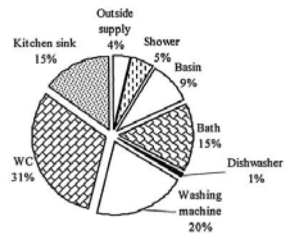

Source: based on Waterwise data, 2006

"Future Water – The Government's Water Strategy for England" DEFRA, 2008.

**INFORMATION SHEET 2**

***Household Use in England per Component***

| Household Component | Consumption (L) | Household Usage (%) | Source |
|---|---|---|---|
| Showers & Baths | 3 to 30 | 45 | The Guardian/Environment Agency |
| Washing Up (Kitchen Taps) | 2 to 25 | 8 to 14 | Waterwise |
| Washing Up (Diswashers) | 7.5 to 19 | 8 to 14 | Waterwise |
| Toilets (Old Style) | 7.5 to 13 | 33 | Waterwise |
| Toilets (newer Models) | 4 to 6 | 33 | Waterwise |
| Washing Clothes | 50 to 150 | 15 | Waterwise |
| Outdoor | Highly Dependant | 7 | Waterwise |




Water consumption per household component
"Water Demand Management" David Butler and Fayyaz Ali Memon, 2006.

**REFLECTIONS ON INFORMATION SHEETS? (5MINS)**

Do these water consumption volumes match your expectations?

Do you think that the UK water consumption rate is too much to too little?

**CHANGE IN WATER USE IN LAST FEW YEARS? (20MINS)**

Has anyone tried to change his or her water use behaviour in the last few years?

Has anyone tried to make any changes to his or her water system at home? What were the changes for? Can you tell me about them? Where they easy to implement? What did you find were the main obstacles?

How could you imagine changing your water use if there was a water shortage?

(conscious usage, new technologies, fines and punishment, water restrictions)

**PRESENT INFORMATION (3MINS)**

Now I want to change direction a bit and talk about climate change and its effect on water in london. A report published by DEFRA in 2008 (Future Water – The Government's Water Strategy for England) stated, and I quote:

"Climate change is already a major pressure. With predictions for the UK of rising temperatures, wetter winters, drier summers, more intense rainfall events and greater climate variability, we can expect to experience higher water demand, more widespread water stress with increased risk of drought, more water quality problems, as well as more extreme downpours with a higher risk of flooding. If we are to maintain our quality of life while protecting the environment, we must take action now."

**HOW SHOULD INFORMATION ABOUT WATER BE CONVEYED? (20MINS)**

How do you think the public gets information about these problems? Who do you think should be in charge of informing the public about them? (the government, water companies, the public)

Whose responsibility do you think these problems are?

How do you think the public should be involved in decisions regarding these problems? Can you think of any specific ways to do that?

**CONCLUSION (10MINS)**

Does anyone have any further comments or questions?

Thank you all very much for participating here today, I hope you've enjoyed the time talking about water.

If you'd like to know the outcomes of this discussion in my research project, just send me an email at anytime, or put your name on this list now and I can make an electronic copy available to you in October.

If you felt this discussion was interesting and you'd like to develop your ideas further, you can participate in a further group discussion that works up different water designs for a future lower lea river basin. To do this please send an email to Hui (on the information sheet) or put your name on this list now.

You can also take this disposable camera with you and over the next 2 or 3 days photograph the technologies you use everyday that affect water and then send the camera back in this stamped self-addressed envelope.

# APPENDIX H INTERVIEW AND GROUP DISCUSSION TWO PARTICIPANT DEMOGRAPHICS

The participants still represented an age range from people in their 20's to people in their 60's. People in their 60's were mostly represented in the group discussions, while those in their 30's, and 50's were strongly represented in the individual interviews (Table H.1).

| DECADAL AGE | MALE group | MALE individual | FEMALE group | FEMALE Individual | % TOTAL |
|---|---|---|---|---|---|
| **20's** | 2 | 1 | | 1 | 10% |
| **30's** | | 4 | 2 | 5 | 28% |
| **40's** | | 5 | | | 13% |
| **50's** | 1 | 6 | 1 | 5 | 33% |
| **60's** | | 2 | 5 | | 18% |
| **% TOTAL** | 8% | 45% | 20% | 28% | |

**Table H.1 Age and Group Discussion and Interview Participant Gender**

There remained a fairly even mix of male (53%) and female (48%) participants. However men were predominantly represented in individual interviews, while women were predominant in group discussions (table). Despite this disparity between men and women, women still participated more equally in both group discussions (58%) and individual interviews (42%), compared to men in group discussions (15%) and men in individual interviews (85%).

| | MALE | FEMALE |
|---|---|---|
| **GROUP DISCUSSION** | 3 | 8 |
| **INDIVIDUAL INTERVIEW** | 18 | 11 |
| **% TOTAL** | 53% | 48% |

**Table H.2 Group Discussion and Interview Participant Gender**

The observed ethnicity of these participants were the same as the previous stage.

Twenty two people with a professional influence over water participated in this stage of the research. Of these professionals there was a mix of different types of responsibilities within the water management of the lower Lea watershed. 26% were from the government, 26% were from local councils or regional authorities, 22% were from the water company, 17% were from non-government organisations, and 13% were from consultancies (Table H.3). The categories most interviewed coincide with the categories of organisations which have the greatest impact in altering the water-cycle.

There was still a good mix of age range, however there was no longer a spike of participants in their 30's. Instead participation is evenly distributed between those in their 30's and those in their 50's, which both represented 30% of those interviewed individually.

| DECADAL AGE | GOVERN-MENT | COUNCIL/ REGIONAL AUTHORITY | WATER COMPANY | CONSULT-ANT | NON-GOVERN-MENT | % TOTAL |
|---|---|---|---|---|---|---|
| **20's** | | 2 | | | 1 | 13% |
| **30's** | 1 | 2 | 1 | 1 | 2 | 30% |
| **40's** | 3 | 1 | | 1 | | 22% |
| **50's** | 2 | 1 | 2 | 1 | 1 | 30% |
| **60's** | | | 1 | | | 4% |
| **% TOTAL** | 26% | 26% | 22% | 13% | 17% | |

**Table H.3 Age and Sector of Water Professionals**

The twenty three human actants who were both self proclaimed environmentally aware citizens and living within the lower Lea river basin were mostly from Haringey (39%) and Tower Hamlets (30%). There was a marked drop in participants from Hackney and no participants from Waltham Forest. Newham and the canal boat dwellers were again only represented by one person each. While the boroughs of London were not equally represented, the different age ranges between those in their 20's – 60's were fairly evenly distributed (Table H.4). Similar to the professional age range, the number of people in their 40's was very low. The age ranges for the group discussion with the largest dropout rate were from people their 40's (80%), and 20's (50%), while there was no change in the number of group discussants in their 50's and 60's, and little change from those in the 30's (Table H.4). This is indicative that people in their 40's have time pressures that do not allow them to participate in discussions which they would otherwise be interested in pursuing. The drop out of people in their 20's was accounted for by people starting new careers, or moving house.

| DECADAL AGE | CANAL BOAT | HACKNEY | TOWER HAMLETS | HARINGEY | NEWHAM | WALTHAM FOREST | % TOTAL |
|---|---|---|---|---|---|---|---|
| **20's** | | | 3 | | | | 13% |
| **30's** | | 1 | 1 | 2 | 1 | | 22% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **40's** | | 1 | | | | | 4% |
| **50's** | 1 | 2 | 1 | 4 | | | 35% |
| **60's** | | 1 | 2 | 3 | | | 26% |
| **% TOTAL** | 4% | 22% | 30% | 39% | 4% | | |

Table H.4 Age and Borough of Environmentally Aware Citizens

# APPENDIX I INTERVIEW AND GROUP DISCUSSION TWO SCRIPT AND MATERIALS

**PRELIMINARIES (1MIN)**

This is a recorded interview with:

Conducted on:

Time:

At:

**HAVE THEY UNDERSTOOD AND SIGNED THE CONSENT FORM? (2MIN)**

This second interview is included in the same consent form and information sheet as the first interview.

Please remember that if you don't feel comfortable, you can stop the interview at any time.

**REFLECTIONS AND RECAP (5MIN)**

Last meeting: how you use water, shortage, flood responsible. Water diary

Reflections?

Behaviour change?

Lasting effects?

Any changes to technologies?

**CLARIFICATIONS (5MINS)**

Water meter? Use?

People in household?

Freestanding house and garden? Flat?

Water butt?

**INTRODUCTION (2MINS)**

At the last interview we discussed your current water interactions, and what you would do if you were facing regular water scarcity or flooding.

Since then, I've analysed all the interviews and water diaries for general trends and devised some designs that are organised by three circumstances: flooding, reuse, pollution prevention

First I'll describe what I'm responding to. Types of change.

Then I'll go through the designs. These will start with something immediate, move to a proposal for the next 10 years, then something in 50-100 years.

This is a discussion, so please take your time to clarify your understanding of each idea.

Then I'll give you a few minutes to think in silence. There are markers, paper, and tracing paper to make any comments, doodles, drawings in response to these ideas.

This response could be what you like, what you don't like. What you'd improve, or an alternative idea.

It's all open to your imagination.

We'll have a short discussion after you've thought it through, before moving onto the next idea.

**FLOODING**

**NOW: BARRIERS AND SANDBAGS (5MINS)**

2 interesting results to flooding.

The scenario we discussed was flood to home about 1foot above ground floor level, maybe once or twice a year. There were 2 strong reactions. 1) This would never happen, my home is on high ground. 2) I would move.

I'd like you to imagine that you were one of the people who has a house that floods regularly and you can't move.

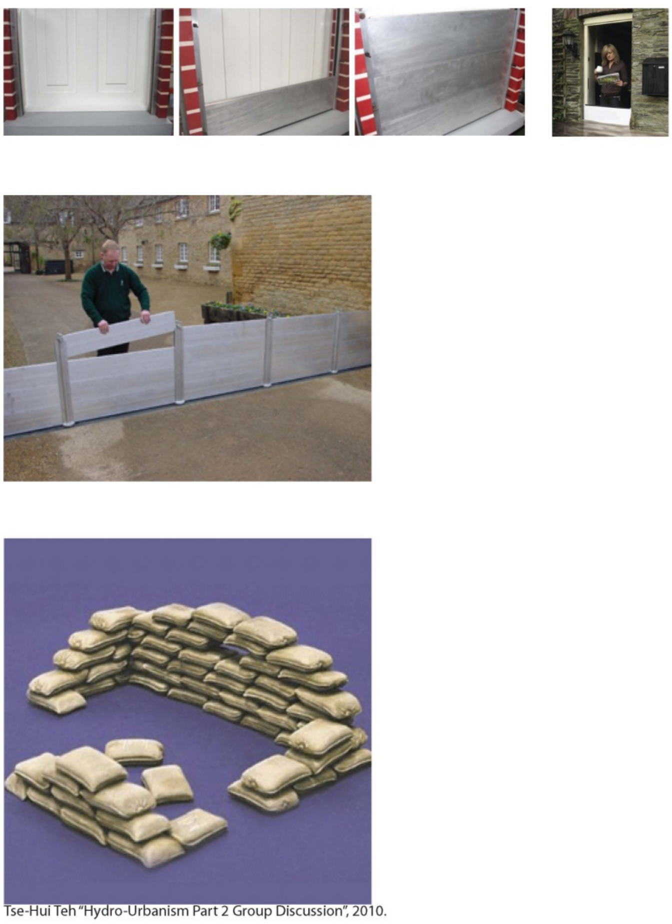
If flood barriers and sand bags like this to prevent interior of house from damage.

Would you consider it safe to stay?

Like/Don't Like/Improve/Alternative

Water-cycle/Social Practices/Opportunities

BARRIERS AND SANDBAGS



Tse-Hui Teh "Hydro-Urbanism Part 2 Group Discussion", 2010.

**10 YEARS: FLOOD LANDSCAPE (10MINS)**

Show Map: these are two locations where it would affect people in the lower Lea.

Elevate ground floor of house.

Move upstairs and extend upwards.

Change landscape of garden for flood cycle.

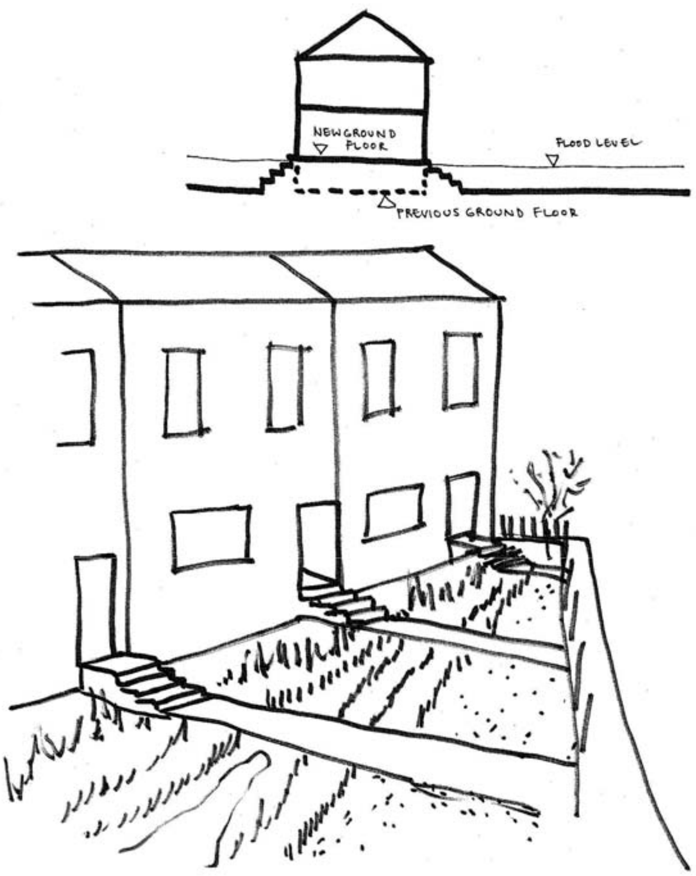
Advantages of fertile alluvial soil.

Neighbour rent garden space for market produce.

Like/Don't Like/Improve/Alternative

Water-cycle/Social Practices/Opportunities

FLOOD LANDSCAPE




Tse-Hui Teh "Hydro-Urbanism Part 2 Group Discussion", 2010.

**100 YEARS: FLOOD PLAIN LIVING (10 MINS)**

Flooding might still not suit some people.

Point when economic and ecological benefit to buy or use abandoned plots to extend space for water and fertile agricultural soils.

100 years new relationship between buildings and flooding.

Agriculture based on local ecology, retains water, protects other parts of the city from flooding.

Variations to the types of ecologies formed

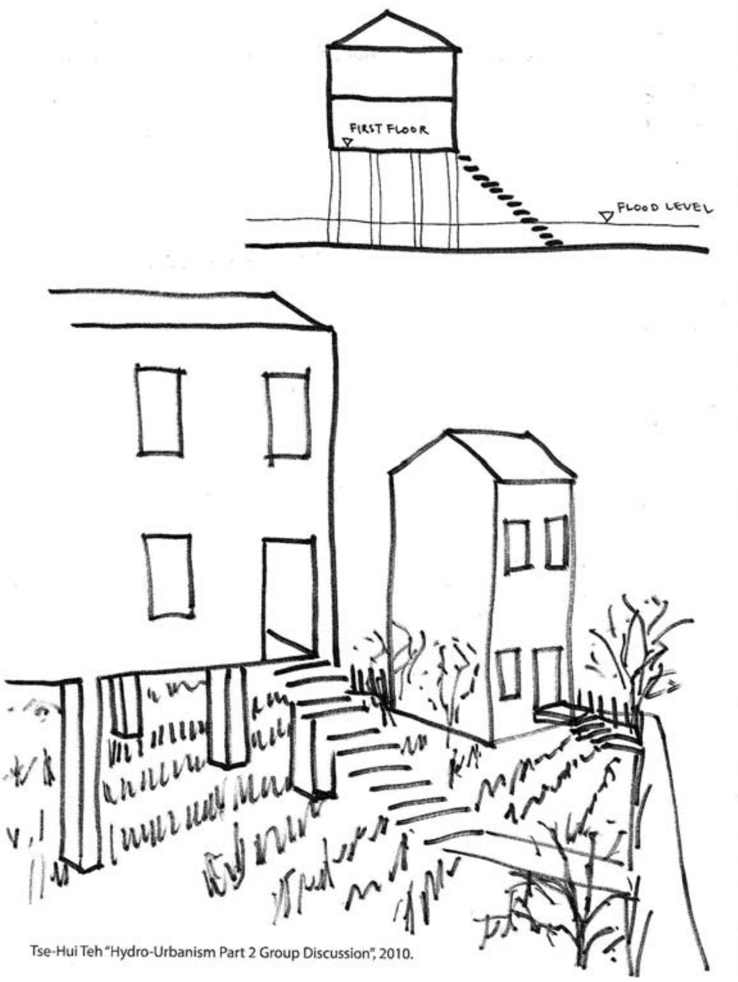
Unique place of interest and produce in the city.

Remaining built areas heritage sites, housing and shops for people who work this produce and landscape.

Like/Don't Like/Improve/Alternative/Visit

Water-cycle/Social Practices/Opportunities

FLOOD PLAIN LIVING




Tse-Hui Teh "Hydro-Urbanism Part 2 Group Discussion", 2010.

## WATER REUSE

### NOW: LIDS AND TANKS (5 MINS)

Grey water recycling was something everyone would do in water shortage.

Some people doing now, bath and bucket, drip irrigation, water recycler, mostly washing up bowl.

Awkward, slosh.

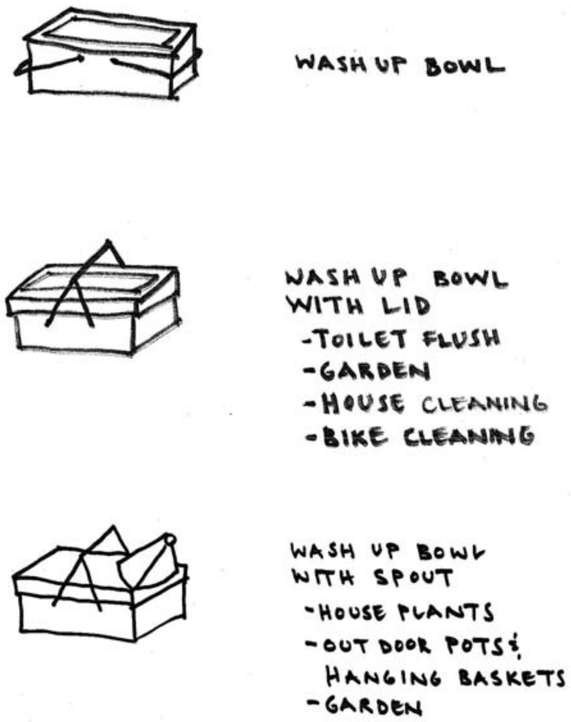
Modify the existing washing up bowl with handles and different lids.

Tank for 2 story buildings with stacked wet areas.

Like/Don't Like/Improve/Alternative

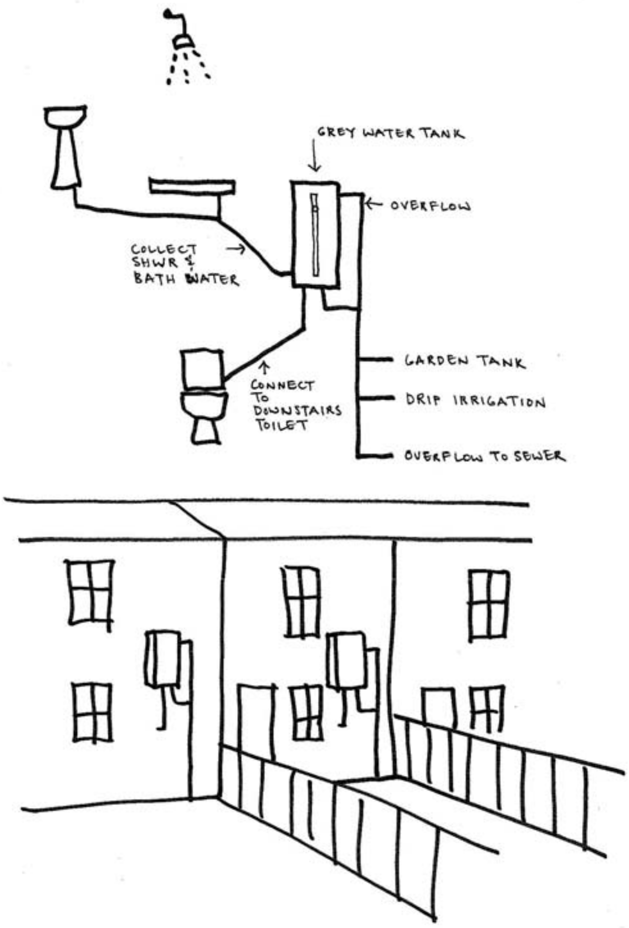
Water-cycle/Social Practices/Opportunities

WASH UP BOWL LIDS




Tse-Hui Teh "Hydro-Urbanism Part 2 Group Discussion", 2010.

GREY-WATER TANKS




Tse-Hui Teh "Hydro-Urbanism Part 2 Group Discussion", 2010.

**10 YEARS : NEIGHBOURS SHARE (10 MINS)**

This could apply in these areas of the lower Lea where the housing stock is very similar and the household sizes are quite similar.

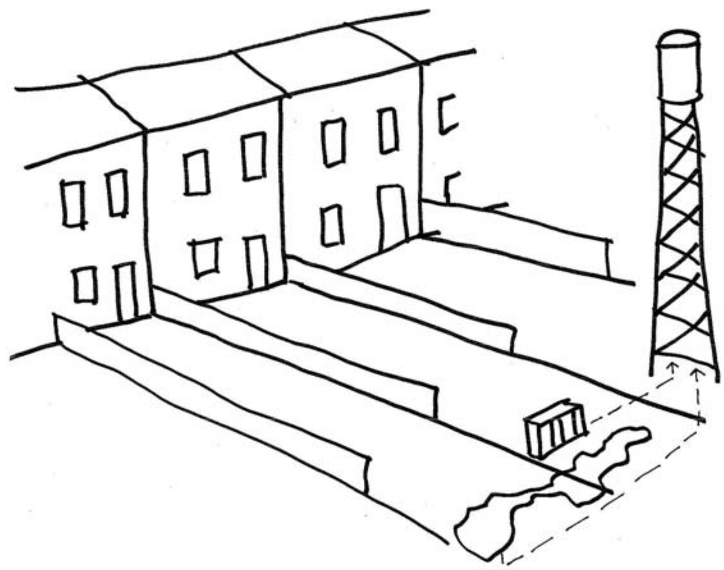
A grey-water recycler for a single household is energy intensive, but for 3-4 households it becomes more viable. Pitch together to share a grey-water recycler and wetland.

Could choose to have a reservoir tank, the grey-water is gravity fed to reduce energy intensity and make the water pressure more consistent.

Like/Don't Like/Improve/Alternative

Water-cycle/Social Practices/Opportunities

NEIGHBOURS SHARING



Tse-Hui Teh "Hydro-Urbanism Part 2 Group Discussion", 2010.

**75 YEARS: POLY CULTURE REUSE (10 MINS)**

In 75 years, more neighbours would have systems, so you could start to consolidate so they could be more productive.

This could be a private or public enterprise. Polyculture wetland for pennywort, wild rice, cranberries, water lotus, water hyacinths, fish, and frogs. If there is a steep enough fall, microgeneration.

Rainwater could also be diverted into the system.

Excess water could be sold to other water users. Commercial areas, light industries, back to water company.

This could apply in lower Lea in areas like this.

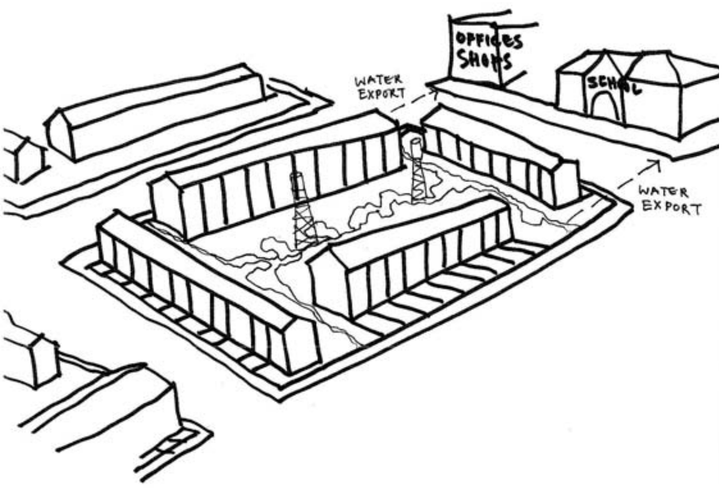
Haringey has a special opportunity with the New River which is an aqueduct for raw water and offers an opportunity to sell water into the existing centralised system of drinking-water.

Land uses might change to accommodate new water transfers.

Like/Don’t Like/Improve/Alternative

Water-cycle/Social Practices/Opportunities

POLYCULTURE REUSE




Tse-Hui Teh "Hydro-Urbanism Part 2 Group Discussion", 2010.

**POLLUTION PREVENTION**

**NOW: YELLOW MELLOW (5 MINS)**

Many people had changed toilet flushing habits to save water. More willing to change with limited supply. Great, 30% of drinking-water use if to flush the toilet. Approximately 45L/person/day is currently flushed down the toilet.

London has a sewer system that was designed in the Victorian era and while it was oversized it was never intended to have the capacity for the 7.5million or so people who live here now.

This new habit could prevent pollution with combined sewer overflows.

Ditty:

If it's yellow, let it mellow.

If it's brown, flush it down.

If it's raining, keep refraining.

When it stops, then it drops.

Don't flush things down the drain while it rains. This lowers the headroom in the sewer and gives more space for the rainwater, and it will reduce the pollution in the water from the combined overflow.

Like/Don't Like/Improve/Alternative

Water-cycle/Social Practices/Opportunities

**10 YEARS: REMOVE AND COMPOST (10 MINS)**

Selective yellow mellowing is a temporary solution, because it still uses clean water to move waste around. Reconsider this technology.

Some people responded to scarcity by changing toilet infrastructure. The majority of people suggested a composting toilet, though one person a chemical toilet and another mentioned nightsoil collection.

The composting toilet reverses idea of waste to become a resource. But a composting toilet takes up space, which there isn't much of in an urban area such as London. Instead you could do a remove and compost system where it is collected like garbage or the milkman. This would be a new infrastructure set up.

Pee is sterile and poo contains the pathogens. Urine separated from faeces, toilet bowl different.

Collection two containers. You could have a small flush for pee, paper liner for poo.

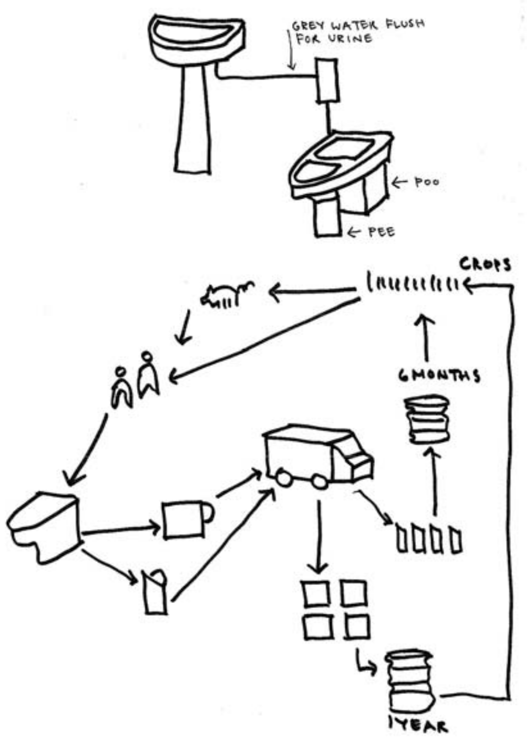
It could be collected every two days. Private or public company. Provide toilet, reusable containers.

Profit from service charge, installation and provision of kit, selling the fertilizer.

Like/Don't Like/Improve/Alternative

Water-cycle/Social Practices/Opportunities

REMOVE AND COMPOST




Tse-Hui Teh "Hydro-Urbanism Part 2 Group Discussion", 2010.

**CONCLUSION (10MINS)**

Any further questions or comments?

Thank you very much for your time, I hope you enjoyed this little workshop.

Interest in outcomes, will have a presentation/workshop in the next 5-6 months at UCL, which you are invited to attend.

If you can't come, but still interested in the outcomes, I can send the abstract of my thesis or the final version.

# APPENDIX J WORKSHOP SCRIPT AND MATERIALS

## PRELIMINARIES (1MIN)

This is a recorded group discussion with:

Conducted on:

Time:

At Abbey Mills Pumping Station

This group discussion is going to be centred around how we might reconfigure our water use in the future. We'll first think about how we relate to the water-cycle, before going through 3 different ways we could change our relationship with water.

## HAVE THEY UNDERSTOOD AND SIGNED THE CONSENT FORM? (2MIN)

Has everybody read the consent form and the information sheet? Do you have any questions about it? Has everybody signed one and given it to me?

This is a discussion, so I'd like everybody to feel comfortable to express their different points of view. There is no necessity for us to come to any sort of consensus or agreement. Please remember that if you don't feel comfortable, you can leave the discussion at any time and anything that you said before won't be included in the research.

## INTRODUCTIONS (10MIN)

Before we launch into the main discussion, it would be great if you could each introduce yourselves, let us know why you are interested in participating in this discussion and if you have any professional interests in water that you would like to share with us.

## WATER-CYCLE INFLUENCES (20MINS)

I think we are all familiar with the water-cycle from school. The idea that water flows around the world in different states, solid: in ice, snow, frost; liquid: rivers, oceans, aquifers and rain; gas: evaporation, transpiration and clouds, but the volume of water stays the same. Basically our drinking-water was once dinosaur pee. I'd like you to think about this water-cycle, and how you fit into it. How do you transport and change water in your life? I'm going to give you 10mins to think draw or write about how you fit into the water-cycle. You've each got some paper and there's coloured markers and pens here. So you have 10mins to think, draw, write and then we'll share our different thoughts.

How have you thought about yourself in the water-cycle?

**TAKE AWAY SINK (15MINS)**

You may not be aware, but the south east of England has less water available per person than Sudan or Syria, countries seen as being very arid. Most often we are short of water in the summer, especially after a dry winter when there has been little recharge to water sources, which is why we have to think of ways to save water when we can.

One of the things that this research has found so far, is that there is a lot of enthusiasm for reusing wash up bowl water, if it could be done easily. Here is an example of what this might be in reality. What do you think of this design? How would you improve it? Would you use it?

TAKE AWAY SINK: REUSE WATER


Design: Jessica Nebel, www.jessicanebel.com/

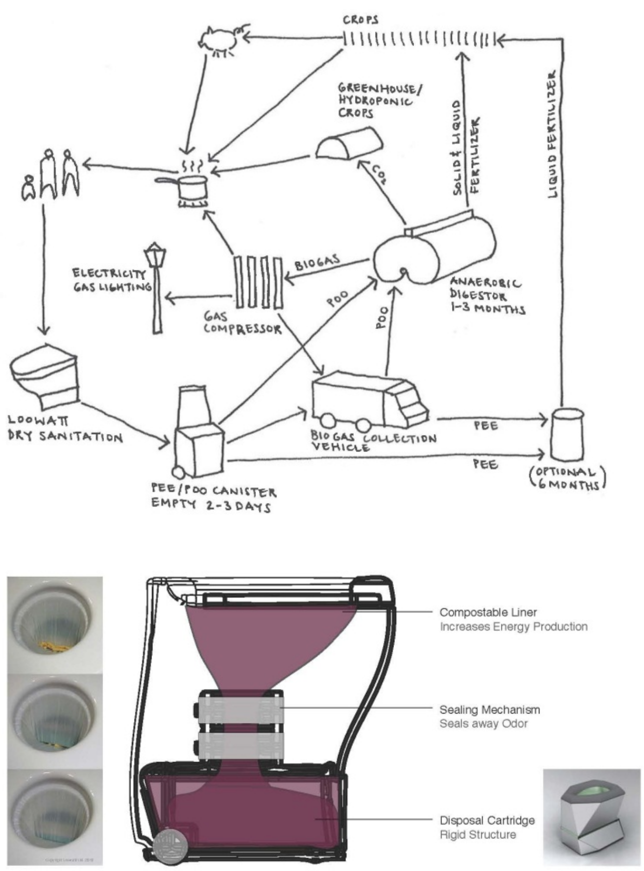
Tse-Hui Teh "Hydro-Urbanism Part 3 Group Discussion", 2010.

**REMOVE COMPOST AND GAS: LOOWATT (15MINS)**

Of course water from the wash up bowl is a very small percentage of household use. 30% of drinking-water used in a household is actually flushed down the toilet. This equates to about 50 L/person/day. This next idea not only saves that water, it also recovers the nutrients that currently pollute our estuaries and oceans and puts them to use as a fertilizer to grow food. This is important because at the moment fertilizers are produced using oil, and this is unsustainable.

This idea is to change from water based sanitation system to a remove, compost, and gas system, which is illustrated here on this diagram. The research so far has found that there is high degree of acceptance was the idea of changing from a water based sanitation system to a composting system, whereby pee and poo can be used for fertilizer and to produce biogas, which you can see here on this diagram. One of the common concerns about this system was about the smell and the hygienic disposal of the waste. Here is an example of how one designer has come up with a solution to the problem of smell and hygienic disposal. What do you think of this? How would you improve it? Would you use it?

LOOWATT: REMOVE, GAS AND COMPOST




Design: Virginia Gardiner & Loowatt, www.loowatt.com/

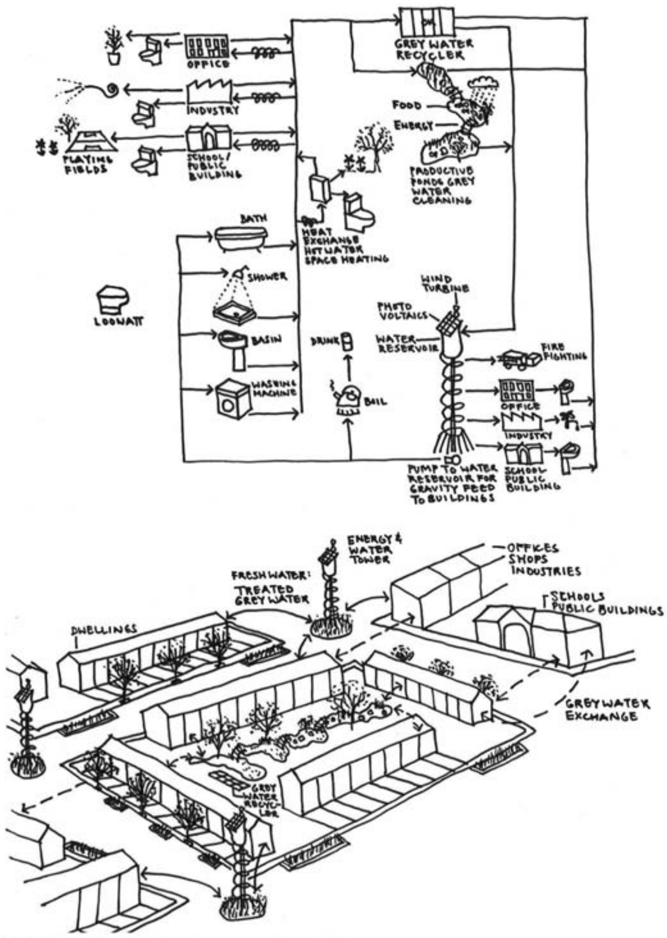
Tse-Hui Teh "Hydro-Urbanism Part 3 Group Discussion", 2010.

**POLYCULTURE RESUSE COMMUNITY (20MINS)**

Another idea that had people excited was the idea of becoming a polyculture reuse community, where water could be reused at a localised level, part of the cleaning of the water also makes it productive for growing food stocks, and water of different qualities could be matched with appropriate uses.

what you see here are water exchanges happening for grey-water resuse among different building uses, and wetlands for cleaning the water, and also growing wild rice, cranberries, water lotus, water hyacinths, fish, frogs, and ducks which can all be eaten. There could also be some microgeneration through the change in level between the ponds, and at the end, you could have UV and ozone treatment, so the water could be reused for drinking locally. Without this stage, the water could be transferred into the fresh-water supplies for a drinking-water plant. Additional rainwater not needed in water butts for garden watering and general cleaning, is also diverted into these areas. This idea was appealing to a lot of people during the previous stages of research, but it was difficult for people individually to know whether or not other people would cooperate to build such a community. If we were going to make this happen, what do you think you would need to do?

POLYCULTURE REUSE




Tse-Hui Teh "Hydro-Urbanism Part 3 Group Discussion", 2010.

**CONCLUSION (7 MINS)**

Do you have any further questions or comments you'd like to make?

Thank you very much for your time, I hope you've all enjoyed this workshop and it's given you plenty of food for thought. The next presentation by Hui will give you an overview of the research results so far. If you are interested in the final outcomes of this research, please put your name on this email list and a synopsis of the thesis can be emailed to you sometime next year.