

CRANFIELD UNIVERSITY

**Marc Spiller**

**EU WATER POLICY: POLLUTION SOURCE CONTROL BY  
WATER COMPANIES IN ENGLAND AND WALES**

School of Applied Sciences

PhD

Academic Year: 2007 - 2010

Supervisor: Dr. Brian McIntosh  
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This thesis is submitted in partial fulfilment of the requirements for the  
degree of PhD

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# Abstract

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Water management is undergoing a transformation towards integration, source control and ecological thinking. In the EU, the Water Framework Directive can be considered as a driver towards this new approach to water management. Innovations are deemed necessary to deliver this ideal of water management. In this thesis efforts by water sewerage companies in England & Wales to rectify agricultural pollution at source are viewed as an organisational innovation towards more sustainable water management. These source control interventions can help achieving the goals of the Water Framework Directive by reducing diffuse pollution from agriculture, fostering participation in water management and by reducing overall cost of implementation.

This thesis contributes to understanding the process of change in water management by developing a model of the innovation-decision process. Insights about how innovation and therefore change can be influenced is generated by applying this model to the process of source control intervention adoption by water and sewerage companies.

This research employed a flexible research design using comparative case studies. Each of the 10 water and sewerage companies in England and Wales represented an individual case. Data were collected in two phases using semi-structured interviews with selected water and sewerage company representatives. Thematic analysis, recurrence counts and content analysis were applied to analyse interviews.

It was found that water companies are likely to contribute towards integrated approaches to water management, since there is a trend to adopt source control intervention. Change in water management is influenced by the interaction of factors from the domains: ‘Natural-Physical’, ‘Organisational Characteristics’, ‘Regulatory-Institutional’ and ‘Innovation Attributes’. The rate of change by water and sewerage companies is governed by a combination of asset characteristics, environmental state changes and the funding cycle. Furthermore, innovation is triggered by direct regulation and regulation that requires the gathering of information. Contrary to this flexible or framework regulation performs better in guiding the direction of change.

Keywords: factors, catchment, innovation, flexible design, water framework directive

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# Journal articles and conference presentations

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## **Journal papers**

Spiller, M., McIntosh, B. & Seaton, R.A.F. (2009) The influence of supply and sewage area characteristics on water and wastewater service provider response to the WFD. *Water Science and Technology* 60 (7) 1811-1819

Spiller, M., McIntosh, B. & Seaton, R.A.F. Water Framework Directive – a stimulus for change? (Submitted to *Urban Water*)

## **Conference papers**

McIntosh, B.S., Seaton, R.A.F., Schilt, O., Spiller, M. & Jeffrey, P. (2009) Understanding opportunities for change under the Water Framework in England and Wales. KSI conference - Dynamics & Governance of Transitions to Sustainability, 4<sup>th</sup> and 5<sup>th</sup> June 2009, Amsterdam

Spiller, M., McIntosh, B. & Seaton, R.A.F (2009) The influence of supply and sewage area characteristics on water and wastewater service provider response to the WFD. IWA UK Young Water Professionals conference 22nd-24th April 2009, London

Spiller, M., McIntosh, B. & Seaton, R.A.F (2008) Implementing the Water Framework Directive: a characterisation of responses by UK Water Service Providers. IWA World Water Congress 7<sup>th</sup> to 12<sup>th</sup> September 2008, Vienna, Austria. Abstract published in conference proceedings

Spiller, M., McIntosh, B. & Seaton, R.A.F (2007) Implementing the Water Framework Directive – UK water and wastewater service provider response Conference on Adaptive and Integrated Water Management (CAIWA). Coping with complexity and uncertainty.' *Newater*, 12<sup>th</sup> – 15<sup>th</sup> November 2007, Basel





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# List of acronyms and terms

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AMP	Asset Management Plan
CAs	Co-operative Agreements
CAP	Common Agricultural Policy
Capex	Capital Expenditure
CSFI	Catchment Sensitive Farming Initiative
DAF	Dissolved Air Flotation
Defra	Department for Food and Rural Affairs
DPSIR	Driver Pressure State Impact Response
DWQS	Drinking Water Quality Standard
DWSPs	Drinking Water Safety Plans
DWSZs	Drinking Water Safeguard Zones
EA	Environment Agency
GAC	Granulated Activated Carbon
NFU	National Farmers Union
NGOs	Non Governmental Organisations
NR	Nutrient Removal
Ofwat	Office for Water Services
Opex	Operational Expenditure
Pesticide	Pesticides means: <ul style="list-style-type: none"><li>— organic acaricides,</li><li>— organic algicides,</li><li>— organic fungicides,</li><li>— organic herbicides,</li><li>— organic insecticides,</li><li>— organic nematocides,</li></ul>

— organic rodenticides  
— organic slimicides,  
— related products (*inter alia*, growth regulators)  
and their relevant metabolites, degradation and reaction products (EC 1998).

PR	Price Review
PS	Priority Substances (does include Priority Hazardous which are toxic, persistent and liable to bio-accumulate)
RBMPs	River Basin Management Plans
RSPB	Royal Society of the Protection of Birds
RWQ	Raw Water Quality
SCIs	Source Control Interventions
SDS	Strategic Direction Statement
UWWTD	Urban Wastewater Treatment Directive
VI	Voluntary Initiative
WFD	Water Framework Directive
WQ	Water Quantity
WTW	Water Treatment Works

# Chapter 1

## Integrated water management and innovation

---

### **1.1 Change in water management – an organisational innovation perspective**

Scholars and practitioners argue that the present water management system cannot stand up to the challenge of improving the aquatic environment while pressures from climate and population increase (Mitchell 2006; Niemczynowicz 1999; Novotny & Brown 2007; Pahl-Wostl *et al.* 2008). They advocate the transition towards more sustainable water management approaches, away from the throughput of resources in a centralised system, towards integration across sectors, actors and disciplines; making use of wastewater re-cycling and source control in a decentralised system that is based on ecological thinking.

In the EU, the Water Framework Directive or WFD (EC 2000) can be viewed as a driver for change towards such sustainable water management approaches (see the preamble of the WFD). The overarching goal of the WFD is to achieve good ecological status and to prevent further deterioration of all waters in the EU. Contrary to previous EU directives, which focused on chemical parameters to assess water quality, ecological status is an assessment of water quality that combines water chemistry, morphology and biological indicators. The WFD also introduces the river basin (i.e. hydrological catchment) rather than administrative boundaries as management units. It requires cost effectiveness and public participation in the process of implementation; states that water management should, as a priority, rectify pollution at source, and that the polluter should pay. Article 7 of the WFD asks member states to establish water safeguard zones for drinking water abstractions, to avoid deterioration of water resources and to reduce the level of purification required.

Examples from NYC (Council 2000) or Germany show (Heinz 2003a) how the ideals of the new approach to water management can be put into practice. They also provide evidence that, by attempting to control pollution in the hydrological catchment, benefits for the environment, agriculture, water utilities and their customers can arise. Other examples that follow the new ideal of water management show how wastewater can be reused for toilet flushing or washing, by employing simple treatment options and re-piping of households (Novotny & Brown 2007). Technologically more advanced examples, from Australia and Singapore, they show that by applying a combination of innovative technologies (desalination, membrane bio-reactors, demand management) wastewater can be purified to levels that enable in-direct potable reuse (National Water Commission 2008; Seah *et al.* 2008). Here treated wastewater is discharged, for instance into reservoirs from which potable water is abstracted. Yet, other approaches such as Sustainable Urban Drainage Systems (SUDS) and separation of surface water from sewerage infrastructure improve the effectiveness of wastewater treatment and avoid Combined Sewer Overflows (CSOs), while not requiring technological advances but rather a re-conceptualisation of traditional drainage practice.

From the examples above, it becomes apparent that change in water management is a result of technological progress and innovation, but more importantly it is a process of implementing these technologies. In other words, the challenge of achieving change in water management is more a matter of adoption of available knowledge and technology, rather than developing it anew. This is so because much of the required technologies and knowledge is already available, but there is inertia of relevant actors to adopt these innovations (Daigger *et al.* 2007). Thomas and Ford (2005) as well as Cave (2009) argued that water and sewerage companies (WaSCs) in E&W give preference to engineering solution leading to the replication of traditional approaches to water management. Furthermore, these authors suggested that WaSCs lack a systematic approach to R&D therefore stifling to the adoption of innovation.

In this study the population of WaSCs in E&W, a key player in water management (see next section), are used as a case study example to investigate the process of change in water management. Theories of organisational innovation and decision making are employed as a theoretical framework. Innovation is defined as the adoption of a

behaviour, practice, object or idea perceived as new to an organisation (Rogers 2003). This definition is adopted for this research, because it focuses on the adoption of existing knowledge or technology new to an organisation, rather than investigating artefacts or behaviours new to the world. More specifically this thesis examines the adoption process of source control interventions (SCIs) as an innovation. SCIs describe efforts by water suppliers to tackle drinking water pollution by agriculture. Evidence suggest that SCIs have, in E&W, only been adopted in few isolated cases (Andrew 2003a, Ofwat 2009a), while there are more common in Germany, the Netherlands and France (Brouwer *et al.* 2003a). The initial explorative part of this research indicated that this situation is in the process of change, thus offering an opportunity to investigate the factors influencing change in water management.

Literature suggests that innovation and change should be perceived as a multi-factorial process (del Rio Gonzalez 2009; Geels 2002, see also Chapter 2). It is affected by the organisations capability to adopt knowledge and technology. Furthermore, innovations will only be adopted if it can be embedded in suitable regulatory frameworks, markets or other groups of actors (e.g. private households, NGOs). Fewer evidence is provided for the impact of natural physical factors in shaping the opportunities of organisations to change (Russo 2003). Finally, the process of innovation adoption is also a function of the attributes of an innovation itself.

In this research organisational innovation theories were employed as a framework of investigating change in water management. These theories propose to view the organisation to exist in a multi factorial enabling environment for change (Rogers 2003, del Rio Gonzalez 2009). This enabled in particular those authors that studied populations of organisations, to make claims about present and future change as well as the factors that influenced innovation (Cleff & Rennings 1999). Authors that followed this tradition also provided evidence for the impact of natural physical factors (Russo 2003) and innovation attributes (Rogers 2003).

An alternative concept to the organisational view of innovation is the multi level perspective, here the level of analysis is the ‘organisational field’ defined as (Geels & Schot 2010): “*Those organisations that in aggregate constitute a recognised area of institutional life: Key suppliers, resources, and product consumers, regulatory agencies*

*and other organisations that produce service or products*". The challenge of this approach is to investigate change at these different levels. In the present study the application of the multi level perspective was not feasible due to the scale of the enquiry this would entail (i.e. study the population of WaSCs including the organisational field surrounding each WaSC). Furthermore, the multi level perspective does not account for the natural physical factors and innovation attributes which may affect innovation adoption and change.

In the next section relevant background about WaSCs and their regulatory framework will be provided. Thereafter, SCIs will be defined and described as an innovation for WaSCs in E&W (Sections 1.3. & 1.4). In the subsequent two sections (Section 1.5. & 1.6.) the knowledge gaps in the understanding of WaSCs innovation process, and the factors affecting it, are discussed. From these knowledge gaps the research questions are derived and the contributions of this research specified (Section 1.7. & 1.8). This introductory Chapter concludes by giving an overview of the thesis structure.

## **1.2 Water and sewerage companies and their regulatory framework**

The unit of analysis in this study were the 10 WaSCs in E&W. In 1989 ownership of water and wastewater assets was transferred to private undertakers. This resulted in the creation of 10 relatively large (turnover in 2007 £m 344–1334), vertically integrated and fully privatised WaSCs (Figure 1-1). These private organisations control all aspects of water supply and sewerage services (i.e. from abstraction to discharge). They have the following statutory duties as defined in the Water Act 2003 (UK 2003):

- to develop and maintain efficient and economical systems of water and sewerage service provision;
- to ensure a secure service of water in a sufficient quality;
- to adhere to the prescribed discharge of pollution into waters regulated by discharge consents;
- to comply with abstraction licenses;
- to draw up 25 year water resource plans and drought management plans.





**Figure 1-1: Map of the 10 water and sewerage companies (WaSCs) in E&W (from DWE 2010).**

These statutory duties are controlled in a regulatory framework that ensures health protection, equity, efficiency and environmental protection. The key regulators of WaSCs are the Environment Agency (EA) the Office for Water Services (Ofwat) and the Drinking Water Inspectorate (DWI; Figure 1-2).

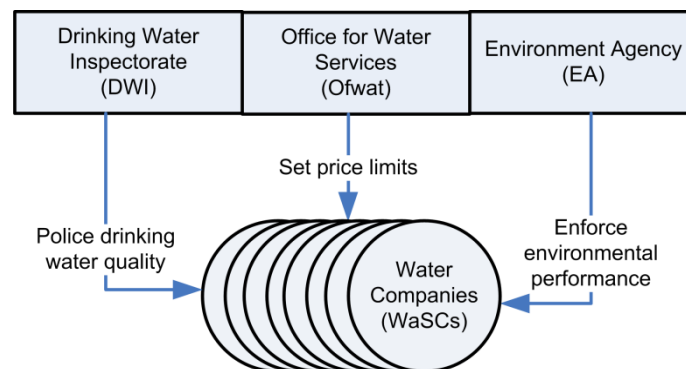
The EA, the Ofwat, and the DWI are the non departmental public executive bodies to the Department for Food and Rural Affairs (Defra) the UK governments department responsible for the formulation of policies on the environment. These non departmental bodies have to adhere to the policy guidelines formulated by Defra.

The EA is responsible for the monitoring and enforcement of environmental regulations including discharge consents and abstraction licences. The EA is also the competent authority for the implementation of the WFD.

In the absence of a water market Ofwat is responsible for economic regulation of private water companies. To ensure efficiency and equity Ofwat carries out Price Reviews (PR) in a five year cycle. For these reviews WaSCs need to draw up Business Plans including Asset Management Plans (AMPs), which have to be approved by Ofwat. Using these information Ofwat conducts a comparative assessment through which it determines water bills, operational expenditure and capital investment of WaSCs (Allan 2006). The

current AMP (AMP 5) follows on from the PR 2009 (PR09) and commenced in April 2010 (Ofwat 2009a).

Policing the quality of water delivered by water companies to customers is the duty of the DWI. The DWI has the legal power to enforce adherence to drinking water quality standards. For PR09 the DWI requires WaSCs to develop drinking water safety plans (DWSPs), so safeguard the health of water customers (Section 1.2.2).



**Figure 1-2: WaSCs regulators in E&W.**

Natural England (NE) is another non departmental public executive meaningful to this study, as it is delivering the catchments sensitive farming initiative (CSFI) on behalf of Defra. In Chapter 6 it will be shown that the CSFI plays a crucial role in motivating WaSCs to adopt SCIs. NE is the government's advisor on the natural environment (NE 2010b). Furthermore, it has statutory functions relating to wildlife protection and the agri-environment and rural development.

### 1.2.1 CSFI and Agri-environment schemes

The catchment sensitive farming initiative (CSFI) is a Defra-funded (£12.9m annually from 2008-2010) initiative which is part of the governments response to meet the requirements of the Water Framework Directive (Defra 2009a). The initiative is also anticipated to contribute towards achieving conservation objectives under national and EU policies (e.g. Habitats Directive). It operates on priority catchments which are sensitive to pollution from nitrates, phosphorous and sediments. The CSFI was rolled out in 2006, initially comprising 40 catchments. Due to the success of the initiative 10 new catchments have been added. In total the area covered by the CSFI accounts now for about 40% of agricultural land in England (Defra 2009a).

The CSFI roles are described by NE as (Defra 2009a):

- encouraging changes in behaviours and practices by engaging with farmers through workshops, seminars, farm demonstrations, self-help groups and undertaking 1:1 farm visits delivered by Catchment Sensitive Farming Officers;
- co-ordinating Catchment Steering Group activity;
- undertaking communications and publicity;
- signposting of agri-environment schemes and other incentives; and
- assisting farmers with CSF Capital Grant applications.

Since the CSFI does not aim to tackle pesticide pollution to water courses EN has entered into a partnership with the pesticide Voluntary Initiative (VI). The VI was formed in 2001, it is funded through sponsorship by organisations including the NFU. Staff of the VI will assist the CSFI in pesticide risk assessment of catchments, provision of best practice advice.

As a result of the CAP reform 2003 and 2004, a number of agri-environment grants were introduced in E&W. It is beyond the scope of this thesis to discuss these reforms in detail (for details see Kay *et al.* 2009; NE 2010a). The key point for this research is that these grants make finances available to farmers to prevent water pollution from agriculture. As argued above (see also Chapter 6) these grants also acted as incentives for water companies to adopt SCIs, partly because to access grants farmers may require advice and support.

The two key grant schemes in E&W are the Entry Level Steward (ELS) the Higher Level Stewardship (HLS) schemes. ELS provides grants to farmers for delivery of a range of 50 different options to improve environmental quality (e.g. buffer stripes, fencing, reducing of soil erosion). HLS is an extension to ELS. They offer additional grants for more complex environmental management activities that require advice and support. For instance they require the development of a Farm Environment Plan, which include an inventory of the condition of any features of historical, wildlife, resource protection, access and landscape interest.

### **1.2.2 Drinking Water Safety Plans**

The DWI describes drinking water safety plans as:

*“The most effective way of ensuring that a water supply is safe for human consumption and that it meets the health based standards and other regulatory requirements. It is based on a comprehensive risk assessment and risk management approach to all the steps in a water supply chain from catchment to consumer.”*

Amongst other things the DWSPs require WaSCs to have a thorough understanding of each element in the water supply chain including the catchment. To generate this understanding the DWI recommends having appropriate monitoring in place and the development of a team of experts. Subsequently, WaSCs are required to identify the most measure to control risks, taking into consideration all elements of the water supply system.

Of interest to this study are the requirements of the DWSPs with respect to water pollution risk arising from the catchment. In brief the DWSPs require WaSCs to gather data including the hydrogeology, land use, water source type, seasonal variability of water quality etc. Thereafter WaSCs are required to identify and assess the hazards arising from the catchment. Recommended control measures in response to identified risks do then include catchment management, reservoir management and strategic compliance planning.

### **1.3 Source control interventions a broader definition**

Throughout the EU, water pollution from agriculture is one of the main reasons for the poor quality of water resources. Nitrates in groundwater or phosphorous (nutrient) in surface waters are natural phenomenon, caused by the percolation of water through soil or by the run-off of water from land. The levels of these substance in surface water and groundwater can be significantly increase by agricultural practice in terms of nutrient application (or their handling), soil cultivation and drainage. In addition, pesticides applied by farmers or land managers may be detected in ground or surface waters. The cost to drinking water companies in E&W for treating water polluted with nitrates,

pesticides or nutrients originating from agriculture have been estimated to total between £127m and £148m annually (O'Neill 2007).

By changing agricultural or land management practices, pollution to drinking water sources can be reduced, resulting in environmental and economic benefits. Examples from the USA show that activities which aim to control pollution from agriculture at source can avoid significant operational and water treatment costs (Table 1-1).

**Table 1-1: Selected US cities that have avoided construction of filtration plants through catchment protection (adopted from Postel & Thompson 2005).**

Metropolitan area	Population [1000's]	Avoided costs through catchment protection
New York City	9,000	\$1.5bn spend on catchment protection over 10 years to avoid at least \$6bn capital costs and \$300m annual operating costs
Boston, Massachusetts	2,300	\$180m avoided cost
Seattle, Washington	1,300	\$150-200m avoided cost
Portland, Oregon	825	\$920,000 spend annually to protect catchment is avoiding \$200m capital cost
Portland, Maine	160	\$729,000 spend annually to protect catchment has avoided \$25m in capital costs and \$725,000 in operating costs
Syracuse, New York	150	\$10m catchment plan is avoiding \$45-60m in capital cost

In an EU context, cases studies from the Netherlands and Germany showed that SCIs by water companies can contribute towards implementing EU water directives such as the WFD (Box 1-1) and that they can be more cost efficient than treatment alternatives (Andrews 2003b; Bach *et al.* 2007; Heinz 2003a). The experience in the EU is based on investigations of agreements between water suppliers and farmers; while the cases from the USA used the city as the unit of investigation. This entails that the investigations in the USA include other constituencies than solely water suppliers and the farming community (i.e. municipalities, local governments).

**Box 1-1: Benefits of SCIs for WFD implementation (Heinz 2008).**

- Preventing pollution and reversing trends (WFD Article 1).
- Contributing towards drinking water protection in terms of reducing water pollution below statutory limits (WFD Article 7).
- Offering a means for cost effective implementation of the WFD through win-win situations such as more efficient farming methods and cost savings in the water sector (WFD Article 16(6)).
- Supporting the objective of the WFD for public participation (Article 14) through self-regulation between water suppliers and farmers.
- Producing learning outcomes which maybe transferred to a river basin scale.

For the purpose of this thesis focus is on the interaction between water suppliers (i.e. WaSCs) and the land managers or farmers. Source control interventions are characterised as follows:

- SCIs are based on the co-operation between WaSCs and farmers or land managers. This can also include the interaction between WaSCs and farmers via intermediaries. Intermediaries are defined as individuals or organisations who facilitating change in agricultural practice (i.e. agronomists, NGOs, governmental catchment officers).
- SCIs are intended to rectify agricultural pollution at source through change of farming practices.
- SCIs are targeting specific raw water quality problem.
- SCIs are operating at a catchment scale.

The characterisation of SCIs adopted in this study is broader than the definition employed by other authors. For instance Brouwer *et al.* (2003a) characterised a specific type of SCIs, namely Co-operative Agreements (CAs) as follows:

- CAs are established on a voluntary basis between farmers and water suppliers (but can include other stakeholders) and rely on the self interest of the parties involved;
- CAs are based on the self-regulation among actors;
- CAs involve the water supplier, either in the negotiation process and/ or in the provision of financial resources;

- CAs target specific areas (e.g. catchments, water protection zones) of different size.

For the case of France, Brouwer *et al.*'s (2003b) indicated that this definition of CAs was too narrow to capture the various ways in which WaSCs can rectify pollution at source. Brouwer *et al.* (2003a) argued: "*As the involvement of the water suppliers is generally limited in the French CAs most of them fall outside of our strict definition of CAs.*" Likewise, Andrews (2003a), who investigated CAs in the UK, recognised that this definition resulted in the exclusion of activities such as the production and distribution of leaflets by WaSC and the co-operation of WaSCs with green NGOs or governmental bodies. Thus, by framing the research in terms of CAs these authors omitted certain interventions from analysis which aim to address pollution at source. Thereby they also excluded consideration of approaches which can facilitate an integration and participation in the process of water management as advocated by the WFD. By adopting the broader characterisation of SCIs proposed in this study, a greater variety of SCIs than other studies will be described.

#### **1.4 Source control interventions an innovation for WaSCs**

In E&W source control intervention or catchment management activities by WaSCs have, until recently, been the exception. Andrews (2003a) found one WaSC to have implemented CAs in 2003. Similarly data from the last price review in 2004 suggest that only two organisations applied for funding of catchment management schemes (Ofwat 2009a). Hence, this evidence indicate that SCIs have in the recent past only been adopted by a small minority of SCIs in isolated catchments.

This is partly so because source control interventions have until recently not been part of the responsibility of WaSCs. They were rather concerned with the maintenance and operation of water treatment assets and supply networks. Furthermore, Andrews (2003a) suggested that the economic regulation of privatised WaSCs in E&W was a key barrier to the adoption of CAs, since they were not permitted to raise money for land management activities through customer bills. To stimulate the adoption of CAs Andrews (2003a) recommended the removal of regulatory barriers and establishment of agri-environment schemes. More recently Kay *et al.* (2009) argued that the new agri-

environment schemes introduced as a result of the Common Agricultural Policy reform (CAP; EC 2003) provide an incentive for WaSCs to enter into SCIs. They proposed that these schemes offer an opportunity for WaSCs to fund and to encourage farmers to alter agricultural practices. In addition to the changes driven by the CAP the implementation of the WFD has progressed since Andrews' study. It is thus likely that the WFD initiated policy changes which give opportunities for WaSCs to adopt SCIs.

The brief review of SCIs in the last two sections would suggest that there is a need to update the state of implementation of SCIs in E&W in terms of the characteristics (types of) of SCIs adopted and the number of WaSCs adopting them.

### **1.5 Lack of innovation process understanding of WaSCs in E&W**

WaSCs in E&W have been criticised for a lack of an overall holistic or systematic approach to innovation (Cave 2009; HOL 2007; Thomas & Ford 2005), which is deemed necessary to prepare for the water management challenges ahead (e.g. population growth, climate change). Having identified this inadequacy authors have made several recommendations of how best to stimulate innovation. Amongst these recommendations are (Cave 2009):

1. Companies should be given a greater efficiency incentive for significant and sustained outperformance (i.e. efficiency and service outperformance).
2. To give the industry the confidence it needs to invest in new ways of working, the UK and Welsh Assembly Governments and Regulators should agree clear objectives, including legislation and guidance, and communicate them in a timely fashion.
3. UK and Welsh Assembly Governments, the industry, regulators, suppliers, the research councils, the Technology Strategy Board and other stakeholders should come together to produce a vision for the industry and create a national water research and development body.
4. The economic regulator should be given a statutory duty to promote innovation. The Office for Water Services (Ofwat – see Chapter 4) should also have a statutory duty to report to the UK and Welsh Assembly Governments every five years on the measures it has taken.



5. The government should encourage both head-to-head competition – where companies seek to replace each other to gain market share - and collaborative competition – where groups of companies work together to attract new customers.

Whilst these recommendations may be effective in stimulating more or better innovation, evidence for this has not yet been provided. For example, the author is not aware of research which has shown that encouraging efficiency has lead to innovation in the water sector. With regards to recommendation five above it is also unclear whether any of the forms of competition proposed will stimulate innovation of WaSCs successfully and whether it will steer innovation towards desired outcomes.

It appears that these recommendations were developed without specifying the innovation process they are trying to influence; since the author is not aware of any description of such processes for WaSCs in E&W. Influencing a process without first generating an understanding of the process itself is likely to generate unexpected outcomes. For WaSCs in E&W experience from other sectors, in particular network industries (i.e. energy suppliers), are transferred to WaSCs. However, there is a lack of understanding of innovation from the WaSCs perspective in terms of the processes and decision making involved in adapting to change. Understanding these processes might also assist the economic regulator in more adequately promoting innovation (recommendation four). The development of such a conceptual model of WaSCs innovation can contribute to an appreciation of where and how specific measures affect the process.

## **1.6 Factors affecting innovation by WaSCs**

Transferring the understanding of the innovation processes from other sectors to the WaSCs may also be inappropriate because factors affecting innovation are context dependent. In particular, WaSCs ability to adopt innovations maybe influenced by the spatial characteristics of their territory. This is because the 10 WaSCs in E&W operate within a specified territory or water supply catchment. Unlike other network industries, for instance rail or energy, WaSCs cannot expand into new areas (common carriage for large water supplies is an exception). Furthermore, WaSCs, unlike other sectors, need to

source their raw material (i.e. water) almost exclusively from these catchments. Thus WaSCs are significantly influenced by the land use practices within their territories. In particular when considering that, with few exceptions, water companies do not own land in these catchments.

Indeed, the geography of WaSCs water supply catchment largely dictates organisational characteristics of WaSCs. In the present study, geography describes the ‘Natural-Physical’ factors: hydrology, land use and demography in WaSCs catchment areas. In other words aspects of human geography are included (i.e. patterns of human distribution and behaviour in space see Massey 2001) as well as physical geography (i.e. hydrology, soils, geomorphology, ecology Polmin 2001).

To clarify why water supply catchments have a significant influence on the characteristics of WaSCs as an organisation consider the following:

- The physical geography determines the local water quality for instance through mediating run-off patterns, soil erosion, nutrient load, hardness, water source and temperature. Thus, the physical geography has an impact on the type of water pollution and the vulnerability of pollution of WaSCs water resources.
- The hydrogeography in different areas can influence number, size and technological requirements of water treatment assets. For instance, river intakes are usually larger than groundwater abstractions, but require more sophisticated treatment processes.
- The size of the population supplied with water is directly associated with the economic turnover of WaSCs. Consequently, WaSCs which serve a larger population have larger turnovers.

This leads to two conclusions. Firstly, transferring assumptions about how to affect innovation from other sectors to WaSCs may not be appropriate, since the factors affecting the innovation process differ. Secondly, there is a need to consider ‘Natural-Physical’ conditions when studying WaSCs innovations. Especially when considering that there is considerable variation between WaSCs, which may influence their opportunity to respond through SCIs (Table 1-2). So far this relationship between the

‘Natural-Physical’ environment and innovation has only been investigated by few researchers. For WaSCs in E&W there is little understanding of how ‘Natural-Physical’ factors influence innovation, although recently this has been appreciated by Cave (2009).

**Table 1-2: Descriptive statistics of WaSCs characteristics**

	<b>Descriptor</b>	<b>Mean</b>	<b>SD</b>	<b>Max</b>	<b>Min</b>
<i>Catchment Characteristics</i>	<i>Environment</i>				
	Groundwater abstraction (% of total)	24	23	71	4
	Surface water abstraction (% of total)	68	26	95	22
	Catchment area water (km <sup>2</sup> )	12184	5775	21874	4638
	Land cover: urban, industrial and mining (% supply area)	9	4	17	4
	Land cover: Agricultural areas (% supply area)	70	9	83	58
	Land cover: Forest and semi natural areas (% supply area)	14	7	29	7
	<i>Demographic</i>				
	Total connected properties to water (000)	1903	1129	3509	511
	Supply/demand balance 06/07 (MI/d)	0	106	178	-214
Distribution input 06/07 (MI/d)	1241	785	2642	363	
<i>'Organisational Characteristics'</i>	<i>Assets</i>				
	Length potable water mains (km)	26380	11859	44537	11067
	Length sewers (km)	29462	19657	66898	8738
	Number of WTW	94	47	181	31
	Number of STW	579	231	1017	349
	<i>Financial</i>				
Mean turnover 04-07 (£m)	752	388	1334	344	

## 1.7 Aims and objectives - research approach

The overall aim of this study is to develop a model of the process of source control intervention adoption and to determine the factors influencing the adoption of these interventions by WaSC in E&W.

In support of this aim the following research questions were formulated.

- I. What are the types of source control interventions adopted by WaSCs in England and Wales?
- II. What are the factors influencing the characteristics of the adoption process of source control interventions by WaSCs?
- III. What are the implications for innovation decision theories?

IV. What are the implications of the findings for the implementation of water regulation (e.g. WFD)?

The research questions must be understood in the context of the overall research design. This study followed a flexible case study design using semi-structured interview with WaSC representatives as the primary data source. Robson (2002) describes flexible design as enquiries that require no pre-developed analytical framework or knowledge of the phenomena under investigation; they rather evolve and develop as the understanding of the researcher grows. This flexible design was implemented in two phases, a first exploratory phase followed by a phase of detailed investigation of the adoption process of SCIs.

The research questions were developed after the first exploratory research phase. In this phase the WFD was used as a framework for interviews to investigate the key challenges for change faced by WaSCs in E&W in terms of change issues, problems and response options. This revealed that raw water quality and associated SCIs were change issues of relevance for WaSCs. The term relevance is used to signify that SCIs (and the associated driver of raw water quality) were mentioned frequently during interviews across the population of WaSCs.

Research question I and II were investigated in the second research phase. This phase too employed semi-structured interviews with open questions with representative from all 10 WaSCs in E&W. These research questions guided the research to develop a conceptual model of innovation adoption and decision making and to collect the empirical data to investigate the characteristics of SCIs adoption in E&W (Chapters 5 and 6). The innovation adoption model and the empirical data were then integrated to respond to research question III by developing an adapted innovation decision model. In turn this model enabled insights into water regulation and policy relevant aspects of innovation (research question IV).

## 1.8 Contributions

This research will make three contributions to knowledge by:

- Developing an innovation decision process model adapted to WaSCs in E&W, which explains the interaction between factors of influence from the domains innovation attributes, organisational characteristic, regulatory-institutional environment and ‘Natural-Physical’ environment.
- Providing an update on the state of implementation of integrated land management solutions in terms of SCIs by WaSCs. More precisely it will assess the different stages of WaSCs in the innovation decision process, including the different SCIs design types WaSCs have developed.
- Providing insights into how WaSCs innovation process can be influenced, enabling conclusions about how to influence the progression towards more sustainable solutions to water management.

## 1.9 Thesis structure

This thesis is organised in nine Chapters. The present Chapter has introduced the organisational perspective on change adopted by this study and outlined SCIs adoption by WaSCs in E&W as the case of investigation. The aims, objectives and contributions of this study were specified based on the knowledge gaps identified.

In Chapter 2, the understanding of organisational innovation, decision making and the factors influencing these processes is deepened, by reviewing the relevant literature. In this Chapter the conceptual model of innovation decision making employed to structure and analyse the empirical data in subsequent Chapters is developed.

In Chapter 3, the flexible research designs, the methods used and the strategy of enquiry adopted in this study are described.

In Chapter 4, the empirical results of the initial research phase are presented. The Chapter is concluded by demonstrating how the final research questions of this study were derived.

In Chapters 5 and 6, the empirical results of the second research phase are presented. The difference between WaSCs in terms of SCIs adoption process stages and SCIs types adopted are identified in Chapter 5. The factors found to influence the innovation decision process are populated Chapter 6.

In Chapter 7, the empirical results are used to respond to research question I and II by discussing evidence for SCIs adoption in the EU and analysing reasons for the variation between WaSCs in E&W in terms of the innovation decision process stage and SCIs types adopted.

In Chapter 8, implications for theory and policy are discussed in response to research question II and IV. Taking into account the empirical findings the final model of innovation decision making applicable to SCIs adoption by WaSCs in E&W is arrived at.

Finally, in Chapter 9, the main insights gained in this study are presented and final conclusions drawn. Furthermore, the study limitations are discussed briefly and recommendations for future research are made.

## Chapter 2

# Literature review: Innovation decisions – the analytical framework

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### 2.1 Introduction

The purpose of this review Chapter is to define innovation, explain its importance for studying change and to develop the analytical framework for this research. The Chapter is structured as follows. In the next Section the study focus will be defined as innovation and change in organisations. Thereafter, innovation models will be reviewed before turning to intra-organisational innovation models in Section 2.4. This Section will first present the core structure of the innovation process model and will then discuss the literature in support of this model. In Section 2.5 the boundary conditions of the model will be outlined, mainly drawing on decision making theories. Next the factors that influence the innovation process will be discussed and incorporated into the model, resulting in final analytical framework of this study. To develop this framework evidence for factors influencing innovation of WaSCs in E&W is reviewed; where available factors affecting the implementation of SCIs are emphasised (Section 2.6). Finally, in Section 2.7, the analytical framework used in this thesis will be presented.

### 2.2 Definitions and scope

In the preceding Chapter it was argued that WaSCs have a key role to play in deliver the innovations necessary to meet the challenges of water management in the future (Mitchell 2006; Niemczynowicz 1991; Niemczynowicz 1999; Novotny & Brown 2007; Pahl-Wostl *et al.* 2008). WaSCs in themselves can be considered as organisations, which are defined as groups or coalitions of individuals with shared goals. Cyert & March (1963) argued that these shared goals are often highly ambiguous and that individuals within organisation may also pursue their individual interest. However, there is also evidence that key individuals in organisations play a decisive role in changing organisational practices (see Section 2.6.1). When specifying the methods

used for interviewee selection in Chapter 3 the significance of individuals within organisation will be revisited.

Innovation is defined as the adoption of a behaviour, practice, object or idea perceived as new to an organisation (Rogers 2003). This definition is most appropriate for the context of WaSCs and SCIs; because it proposes that an innovation is an adoption process and that it is sufficient for an innovation to be new to the organisation rather than new to the world. A range of alternative definitions stress that an integral part of an innovation is its implementation. Indeed, implementation is part of the innovation adoption process. This process begins with recognition of an issue and the decision to make use of an innovation followed by its implementation (i.e. the adaptation, 'Diffusion', application and 'Routinisation' of an idea or artefact - Section 2.4). Thus, definitions that consider innovation only as those ideas or artefacts that have already been implemented, will lead to a restrictive perspective on innovation. Innovations may be dismissed for analysis that are only at the point of being recognised as an issue and formulated as a problem. This is relevant for this study because SCIs are only recently emerging in the context of E&W. Hence, it is likely that WaSCs may only begin the process of adoption. Indeed, in Chapter 5 it will be demonstrated that as a result of this recent development, a number of WaSCs are not yet in a situation where they have implemented SCIs.

The innovation considered in this study (i.e. SCI) can be considered 'environmental or green', because it adheres to the following definition of environmental innovations (Rennings 2000): "*Environmental innovations are all measures of relevant actors (firms, politicians, unions, associations, private households), whether technological, organisational, social or institutional, which:*

- *develop new ideas, behaviour, products and processes, apply or introduce them*
- *contribute to a reduction of environmental burdens or to ecologically specified sustainability targets.*"

As indicated by this definition, environmental innovations are not substantially different from 'normal' innovations. Rather green innovations differ in one attribute, namely that they do not exhibit an environmental burden. Research also suggests that 'green



innovations' do not differ, in terms process or factors of influence (del Rio Gonzalez 2009). Thus, no explicit reference to 'environmental' innovation will be made in this study. Nevertheless, where the evidence point towards substantial difference, such as for regulation (see Section 2.6.3), the focus shall be narrowed to 'environmental' aspects of innovation.

The definitions of the process of innovation adoption discussed above underline a view held by many who stressed the importance of knowledge transfer in innovation (Cohen & Levinthal 1990; Trott 1993). These authors suggested that most knowledge exists outside the organisation, providing a resource to be exploited by organisations. This notion is reflected in the contemporary models of innovation, which are discussed now.

### **2.3 Innovation models**

According to Rothwell (1992), innovation models have evolved in five stages. Initially, the view on innovation was dominated by the linear 'technology push model'. In this model a strong science base provides the innovative spark leading to design, manufacturing, marketing and sales activities; emphasising the importance of R&D in the process of innovation. At the beginning of the 1970s a second linear model emerged. Here, customer needs provide a 'market pull' which initiates R&D, leading eventually to innovations. Subsequently, the 'coupling model' was developed; it suggests an integration of science, technology manufacturing and marketing to generate innovation. Although this model was still conceived as a sequential, though not necessarily continuous process, it began to underline the importance of communication paths to transfer knowledge between the in-house functions, the broader scientific and technological community and the market place. The focus on knowledge transfer grew in the fourth model. Here the various departments of the firm work simultaneously on the development of a new product or process, linked together through flow of knowledge. Finally, the fifth model sees innovation as a multi-actor process; where individuals make extensive use of knowledge that is external – but also internal - to the organisation. In this 'networking model' actors are closely linked through IT based webs (networks) of knowledge, which enable swift communication and knowledge transfer. The concept of innovation 'Diffusion' is closely associated with the later innovation models. It describes (Rogers 2003) "*The process by which an innovation is*

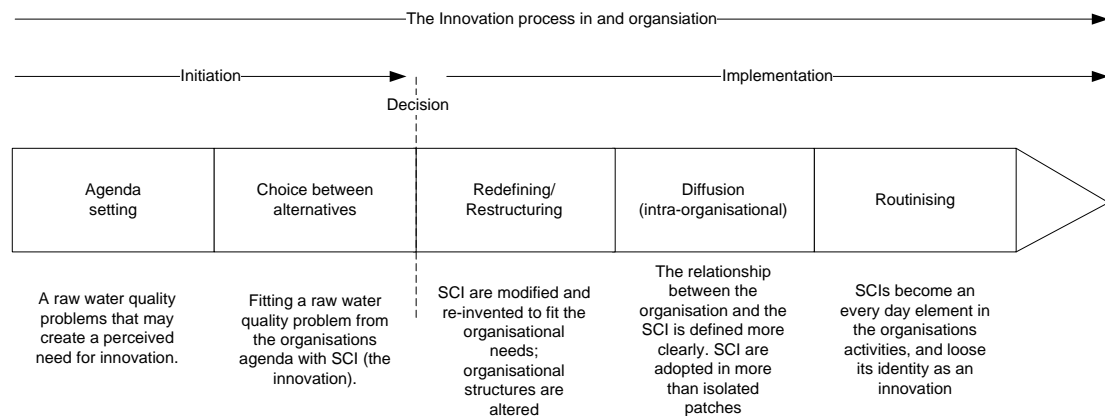
*communicated through certain channels over time among members of a social system.”*

In other words, ‘Diffusion’ can be regarded as the spread of an innovation in space and time across members of a social system. In this study the innovations under investigation are SCIs and the social system is the population of WaSCs. Below it will be pointed out that this ‘Diffusion’ process has an inter- and intra-organisational dimension.

The models of innovation have been taken up by businesses shaping the way in which innovation is managed (Rothwell 1992; Tidd 2006). Hence, theoretically developed models became management reality, therefore shaping the evidence gathered. All these models essentially suggest that the innovative organisation is an open system that is influenced and indeed dependent on its context – environment. In Section 2.6 the discussion of innovation as an open system influenced by its context is deepened. Now, attention is drawn to a set of models that can assist in managing the innovation.

## **2.4 Organisational view on innovation adoption – the analytical framework**

The models outlined in the preceding Section have made a valuable contribution to the present understanding of innovation; leading to the conceptualisation dominated by the flow of innovation through networks and therefore turning the focus from innovation production to innovation adoption. Furthermore these models provide the vital context in which innovation occurs, thereby highlighting the factors that influence innovation. However, to understand why organisations show different innovation behaviours (i.e. rate of adoption, ability to generate and adopt innovation, type of innovation) a different set of theories is required (Tidd *et al.* 2005). One appropriate theory is provided by Rogers (2003) perspective on the intra organisational innovation adoption process (Figure 2-1).



**Figure 2-1: The innovation process in organisations (adapted following Rogers, 2003; for the purpose of this thesis the original names of the second (Matching) and third (Clarifying) process stage of Rogers model were altered. The rationale for this is explained in the text. In addition, Rogers (2003) explanations were specified to include SCI).**

According to Rogers (2003) an organisation first needs to perceive a need for an innovation. This occurs when the organisation is dissatisfied with its performance. This process of 'Agenda Setting' consists of identifying and prioritizing the focus of attention on one or a number of key issues and searching for potentially useful innovation in the environment. After this initiation of the adoption process Rogers (2003) suggested that the organisation will engage in 'Matching' the key issues identified during the 'Agenda Setting' with innovations which may resolve the issue. Rogers proposed that this process can be conceptualised as a reality testing where an organisation attempts to anticipate feasibility and benefits of the innovation. As a result of this process the organisation will make a decision whether to adopt an innovation. For the purpose of the model developed in this thesis the 'Matching' phase is labelled as 'Choice between Alternatives'. This was done to emphasise that at this point in the conceptual model, response options are accepted or rejected in a process of 'Choice between Alternatives'. Conceptualising the 'Choice between Alternatives' stage in this way moves the model closer to the understanding of innovation as a decision making process which will be developed below (Section 2.5).

The subsequent phases of the model are concerned with the implementation of the innovation. 'Reinnovation/ Restructuring' is the first part of the implementation process. In this phase the organisation designs innovations to fit its objectives and capabilities or, alternatively, the organisation re-structures to accommodate the

innovation. Thus suggesting that, at this stage, both the innovation and the organisation are modified in order to implement change. It is at this point where new SCIs design types are developed. For instance, WaSCs may develop an approach where they pay farmers to change agricultural practice or where they collaborate with the intermediate actors to achieve change in agricultural practices. ‘Restructuring’ of the organisation on the other hand can take place through the import of knowledge by employing new staff or assigning new tasks to existing staff (e.g. development of new departments).

At the ‘Reinnovation/ Restructuring’ stage the innovation is often only implemented in an isolated part of the organisation, to trial and test its performance. More widespread application of an innovation (i.e. SCI) may take place after such trials and experimentation, because relevant knowledge has been developed leading to a re-framing of the innovation that is meaningful to the organisation. This, ‘clarifying’ is thus linked to the intra-organisational spread or ‘Diffusion’ of an innovation. In this research the term ‘Diffusion’ will be adopted, to emphasis this aspect of this stage in the innovation decision process, (Figure 2-1). Hence denoting that knowledge (innovations) need not only be communicated across organisation, but also within organisations (e.g. departments) to be more widely adopted.

Finally, the last phase is called ‘Routinising’. At this point the innovation process is completed by incorporating the innovation into day-to-day activities. This may be considered as a change to organisational culture by altering the ‘way things are done around here’; suggesting that innovation has lost its novelty.

#### **2.4.1 Innovation process in literature**

Reviewing the literature on innovation adoption, innovation management, and knowledge transfer, it appears that Rogers (2003) innovation adoption process is of little controversy. In fact Rogers (2003) work reflects the views on intra organisational innovation held by other scholars. Table 2-1 is a collation of some of this literature, emphasising the critical features of the intra organisational innovation processes considered in this study. All of the innovation and management literature and knowledge technology transfer literature reviewed, suggested that innovation begins with the realisation of a demand for innovation. Knowledge was considered to be the pivotal in this. Simon & March (1958) were the first to realise the relationship between

information, knowledge and innovation in the 1950s. They reasoned that organisations will innovate when 'dissatisfied' with their performance. The organisation needs to become aware of a 'performance gap', through knowledge of their own performance benchmarked against the external environment (e.g. competing organisations, legislation). The organisation will establish 'aspiration levels' based on the available information to decide whether to innovate (March & Simon 1958). Trott (1993) suggested that this performance gap is established through internal – within organisation - and external scanning.

Christensen (1997) underlines the difficulty of becoming aware of the 'performance gap' in a rapidly changing environment. Here inappropriate mental models de-sensitise for important signals within a new context. This is in line with Cohen & Levinthal (1990) who emphasise that sufficient relevant prior knowledge has to be available to evaluate and to utilise the information gathered through scanning. It is only then that the organisations can become aware of the 'performance gap'. In their influential work Cohen & Levinthal (1990) establish the concept of 'absorptive capacity' defined as *'the ability to recognize the value of new information, assimilate it and apply it to commercial ends'*. They underline the dual importance of R&D activities as a means to generate internal relevant knowledge. If an organisation lacks 'absorptive capacity' Cohen & Levinthal (1990) reason a firm may never assimilate and exploit new information. This situation is termed 'lock out'. It can be thought of as a situation where the company is blind to external changes, resulting in a cycle of ignorance to external information. From the notion of absorptive capacity the idea of dynamic capabilities has developed (Teece *et al.* 1997). That is, an organisation is capable to reconfigure and integrate internal and external practices and knowledge. Both Rogers (2003) and Trott (1993) suggested that these capabilities need to be developed to match or overlap in order to enable adoption an innovation. This makes explicit what Cohen & Levinthal (1990) argued; namely that relevant knowledge provided a nucleus for further adoption of new knowledge. The innovation and management literature reviewed for this thesis delineated a process resembling the descriptions of 'absorptive capacity', search and 'performance gap' (Table 2-2); essentially highlighting the confluence of external and internal information using prior knowledge to trigger innovation activities.

From this common point, where the confluence of external and internal information triggers innovation activities, the descriptions of the process start to diverge in terms of the number of stages, sequence and the labels given. However, it seems that these inconsistencies are more a result of the different perspectives authors adopted. The processes described were in their core very similar. They all explained a process that moves from the realisation of a need for innovation to its final use and exploitation of an innovation (implementation). The authors with a technology transfer perspective such as Trott (1993; Trott *et al.* 1995) Gilbert (1995) described a process generating business opportunities as the third stage (Assimilation) or fourth stage respectively. Contrary to this Tidd *et al.* (2005) from an innovation management perspective and Rogers (2003), who is more concerned with ‘Diffusion’ of innovation, proposed a implementation stage comprising of three sub-stages. As in the Trott’s (1993) and Gilbert’s (1995) description, knowledge is applied, but for Tidd *et al.* (2005), this took place through a design and redesign of the innovation and through ‘Restructuring’ of the organisation. Redesigns of innovations occur in R&D departments. Thereby providing a link back to Cohen & Levinthal’s (1990) absorptive capacity, indicating that R&D departments need relevant prior knowledge to fulfil this task.

Routines may be established subsequent to ‘Restructuring’ and redesign. Gilbert (1995) and Tidd *et al.* (2005) made use of the term routine, which was suggested by Rogers (2003) above. Indeed, the term was coined by Nelson & Winter (1982) to describe behaviours that are engrained into organisational activities. All three authors suggest that such ‘Routinisation’ leads to the incorporation of the innovation in to day-to-day activities; and subsequently to changes in attitudes towards the innovation by altering the way things are done. This in turn suggests that the innovation has passed through its novelty phase. Turning to Gallouj *et al.*’s (2002) process descriptions it is found that the stages described by them resemble, in its core themes, the previous models. However, Tidd *et al.* (2005) and Gallouj *et al.* (2002) provided additional features that round up the final stages of the innovation process. Gallouj *et al.* (2002) iterated the importance to protect the innovation, while Tidd *et al.* (2005) suggested a reassessment and ‘Reinnovation’ phase. Re-assessment provides the unique opportunity for the firm to learn from its innovation process through evaluation. These additional features are suggested by these authors because they are not exclusively focusing on adoption of

innovation but also on truly new ‘inventions’. Hence, they include stages that aim to protect and promote the innovation.

Rogers’ (2003) description of the innovation process stands out, because it includes a phase where the innovation spreads or diffuses through the organisation. This step draws attention to the fact that organisations consist of numerous individuals and departments which all individually have to adopt an innovation. This is crucial also for WaSCs since they are large geographically distributed organisations with functionally differentiation of departments.

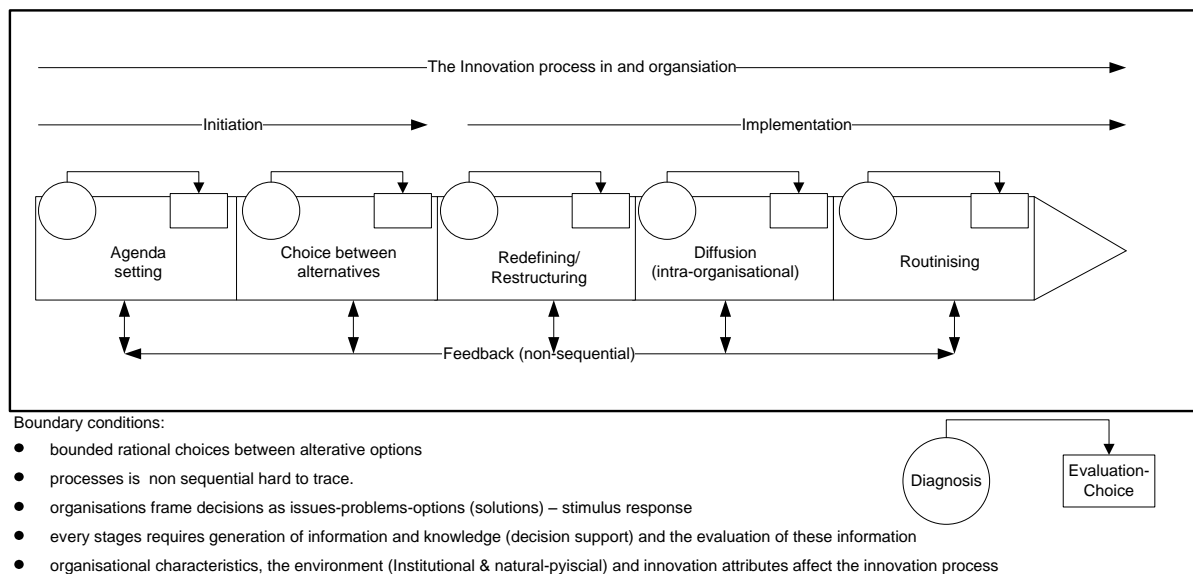
**Table 2-1: Comparison of some innovation management, technology transfer and knowledge transfer models.**

(Trott 2005, 1993) (Jeffrey & Seaton 2004)	(Gilbert 1995)	(Tidd <i>et al.</i> 2005)	(Gallouj <i>et al.</i> 2002)	(Rogers 2003)
<i>Awareness</i> Capability to scan for internal capabilities and external information and to match these to realise business opportunities	<i>Acquisition</i> The process of acquiring knowledge by the organisation, the ability of an organisation to learn from its experience, by employing individuals with new knowledge and by scanning.	<i>Search</i> Searching and selecting incoming signals about potential for change applying mechanisms for identification, processing and selecting information	<i>Gathering information and ideas on a problem</i> – Any kind of information whether internal or external, collected formally or informally, “associated with the activity of problem formulation – which may in itself be a source of innovation”	<i>Agenda Setting</i> General organisational problems that may create a perceived need for innovation.
<i>Association</i> Internal capabilities and external information are linked and an association to the commercial exploitation is made.	<i>Communication</i> ‘Diffusion’ of the acquired knowledge through communication mechanisms to encourage the spread of new knowledge.	<i>Selection</i> Selection of the of technological and market opportunities which fit the technology base of the firm (strategy) and develop an innovation concept that matches the overall business	<i>Research</i> Creation of new knowledge through combining various stocks of knowledge	<i>Matching</i> Fitting a problem from the organisations agenda with an innovation.
<i>Assimilation</i> The organisational process of transforming commercial associations into a business opportunity	<i>Application</i> Adoption of the knowledge helping the organisation to store the information and transform it into routine procedures	<i>Implementing</i> <i>Acquiring knowledge resources</i> A gradual process in which pieces of knowledge are pulled together and conceptual design is generated	<i>Conception and development</i> Transformation of the ideas gathered into a solution of the problem, test and customise the design	<i>Reinnovation/Restructuring</i> The innovation is modified and re-invented to fit the organisation and organisational structures are altered
<i>Application</i> The ability to apply knowledge to achieve a benefit as judged by the recipient	<i>Assimilation</i> of knowledge into routines, involving the transformation of individuals’ perceptions, attitudes and behaviours	<i>Executing the Project</i> – Integrating various discipline and backgrounds (incl. market related) and redesigning the innovation <i>Launching the Innovation</i> – Preparing the market (external) and the organisation (internal) for the innovation	<i>Production of the solution</i> In services client participates in the production process	<i>Clarifying</i> The relationship between the organisation and the innovation is defined more clearly.
		<i>Learn and Reinnovate</i> Exploit successful innovations further through modifications and redefinition of features; assess failing innovations to learn form experience	<i>Marketing of the solution</i> Selling the innovation internally or externally (external or internal marketing), can involve the protection of the innovation	<i>Routinising</i> The innovation becomes an ongoing element in the organisations activities, and loses its identity as an innovation



## 2.5 Decision making – boundary conditions of the framework

Models of (analytical) decision making and innovation processes share a common ancestry. Both have been significantly influenced by the thinking of Simon (Simon 1997, 1955) and therefore share a number of features. They are further closely associated, since it can be claimed that every innovation requires one or a sequence of decisions whether implicit or not (Heerkens 2006). Few authors however have made this relationship explicit (exception are Du *et al.* 2007; Heerkens 2006; Rennings 2000; Rogers 2003). Indeed, Rogers (2003) referred to an innovation decision process, because at the end of the matching phase a decision to innovate must be made. However, the contribution of decision making to the understanding of innovation goes beyond that. From theories of decision making important assumptions and boundary conditions that govern the innovation process can be derived. Figure 2-2 shows how these boundary conditions (i.e. the assumptions and limitations underlying the conceptual model) are integrated into the model developed in the previous Section. In the next Sections this review provides the background for understanding additions made to the model.



**Figure 2-2: The innovation process in organisations including boundary conditions and assumptions including elements of decision making.**

For the purpose of developing an analytical and conceptual model unstructured decision making process are reviewed. These are relevant for innovation because they describe novel and non recurring decisions. The processes reviewed next also fall under the umbrella of analytical decision making. Yet, this is not to suggest that decisions do not rely on intuition (heuristics), politics or power (Eisenhardt & Zbaracki 1992). The political model will be

presented briefly in the context of organisational factors that influence innovation in Section 2.6.1. Heuristics can be viewed as automated and inexplicit analytical or bounded rational decision making process based on expert knowledge (Simon 1997; Todd 2007). These are mainly appropriate to understand decision making of individuals, but have also been detected in organisations as simple screening or prioritisation processes (see next Section). Lastly, the garbage can model (Cohen *et al.* 1972), which describes decision making as the random interaction between problems and opportunities (i.e. solutions to problems), will not be discussed here, as there is little empirical evidence in support of it (Eisenhardt & Zbaracki 1992).

### **2.5.1 Definition**

Amongst the various definitions of decision making available in literature, decision making has been defined as ‘commitment to action’ (Mintzberg & Raisinghani 1976). The process of arriving at a decision can be viewed as *“a set of actions and dynamic factors that begin with the identification of a stimulus for action and ends with the specific commitment to action”* (Mintzberg & Raisinghani 1976). This definition hints towards the first parallel to innovation, namely a stimulus is necessary to generate a decision. This stimulus – response concept resembles Simons (1992) notion of scanning and performance gap.

More simply, decision making could also be regarded as a process of selecting from several alternatives and taking action, which emphasises that decision making comprises a choice between different possibilities or responses.

### **2.5.2 Rational and bounded rationality**

In the classical - economic decision making model the goals and objectives of decision makers are well defined at the outset of the process. The choice alternatives and consequences of choices are known and optimal (maximisation) rational decision making is undertaken. In his publication from 1955 Simon (1955) described this paradigm of the economic man as follows:

*“Traditional economic theory postulates an ‘economic man’, who, in the course of being economic is also rational. This man is assumed to have knowledge of the relevant aspects of his environment which, if not absolutely complete, is at least impressively clear and voluminous. He is assumed also to have a well-organised and stable system of preferences, and a skill in computation that enables him to*

*calculate, for the alternative courses of action that are available to him, which of these will permit him to reach the highest attainable point on his preference scale.”*

In this and following publications (Simon 1997, 1955, 1983) challenged this conception, arguing that in real world situations choices are not perfectly rational. The known alternatives are limited as search for them is costly and future consequences cannot fully be known or even taken into account in the process of choosing. Therefore decisions are ‘boundedly rational’. The concept of bounded rationality is embedded into a four stage process comprising of:

- Setting the agenda,
- Representing the problem,
- Discovering alternatives, and
- Choosing alternative.

The first stage (setting the agenda), resembles in core the first phase of the innovation model proposed for this thesis. It is concerned with determining what decisions are made at a particular time. In a real world context, a variety of decisions require the attention of the decision maker, hence decision issues must be prioritised and dealt with sequentially. Simon (1997) argued that prioritisation is depending on the degree of urgency (timely action) of an issue. The process is iterative as the agenda is likely to change over time and requires, according to Simon (1997), no complex search mechanisms. It is rather a comparative analysis between the urgency of a set of search priorities. The agenda arrived at in this manner will consist either of problems or opportunities.

After the agenda has been set, the problem is formulated. Simon (1997) underlined the importance of the problem formulation. He argued that it has significant influence on how the problem is approached and hence solved. In his work he also hinted that the problem formulation requires intimate knowledge of a situation. Thus a formulated problem reveals relevant information about an issue and its solution (Rittel & Webber 1973; Simon 1997). More precisely when a problem can be formulated it can be solved. For instance, a problem can be solved if it can be expressed as an equation that contains all the necessary variables.

However, the limits to problem formulation are highlighted by Rittel and Webber (1973). These authors suggested that most real world or planning problems are ‘ill structured’ or ‘wicked’, defined as problems where goals cannot easily be attested and well defined

generators for solutions do not exist. Furthermore, ‘wicked’ problems can be formulated in multiple ways, because a large number of potential solutions exist which depend upon the decision makers idea of solving the problem.

In the context of this thesis, interviewees could formulate a drinking water quality problem as (I): “*water treatments works are not capable of removing pollution*” or alternatively as (II): “*farmers pollute the raw water quality, adversely affecting drinking water quality*”. Both problem formulations are likely to lead to different solutions. In the first instance (I) the decision maker may opt for investment into the water treatment work. While in the second (II) scenario a SCI may be attempted. In Chapter 4 this concept of problems and solution will be employed to investigate WFD response.

As the knowledge to solve a given problem is not always readily available to an organisation, they need to discover alternatives (generate options) through searching and customising (designing) discovered options (alternatives). Decision makers ‘satisfice’ rather than maximise, suggesting that in accordance with their computational abilities and the resources allocated towards searching for information, satisfactory choices are made (Simon 1997). This is achieved by developing an ‘aspiration level’, which can be understood as a choice criteria or a minimum value that the searcher will try to attain (Todd 2007). The decision maker will subsequently make a satisfactory choice, through choosing the alternative that best meets the established aspiration level.

Several variations and additions to Simon’s model have been made. One that has received much attention is Mintzberg & Raisinghani’s (1976) study of 25 organisational decision processes. They argued for a non sequential model of bounded rationality (Figure 2-3). This model has been conceived in particular to describe unstructured decision processes (“*process that have not been encountered before and for which no predetermined and explicit set of ordered response exists in the organisation*” (Mintzberg & Raisinghani 1976). The central framework of Mintzberg & Raisinghani’s (1976) resembles Simon’s (1997) concepts of ‘Agenda Setting’, discovering alternatives and choice, but consists of more phases and highlights the non sequential nature of decisions (Figure 2-3).

First identification; where crisis, problems and opportunities are recognised is described as: “*a difference between information on some actual situation and some expected standard.*” The second routine in the first stage is ‘diagnosis’, here existing and new information

channels are opened to clarify and define issues. The second phase (development) of Mintzberg & Raisinghani's (1976) model comprises the search routine and the design. The search routine is made up of different search activities; the design routine is then used to modify the solutions discovered in the search routine.

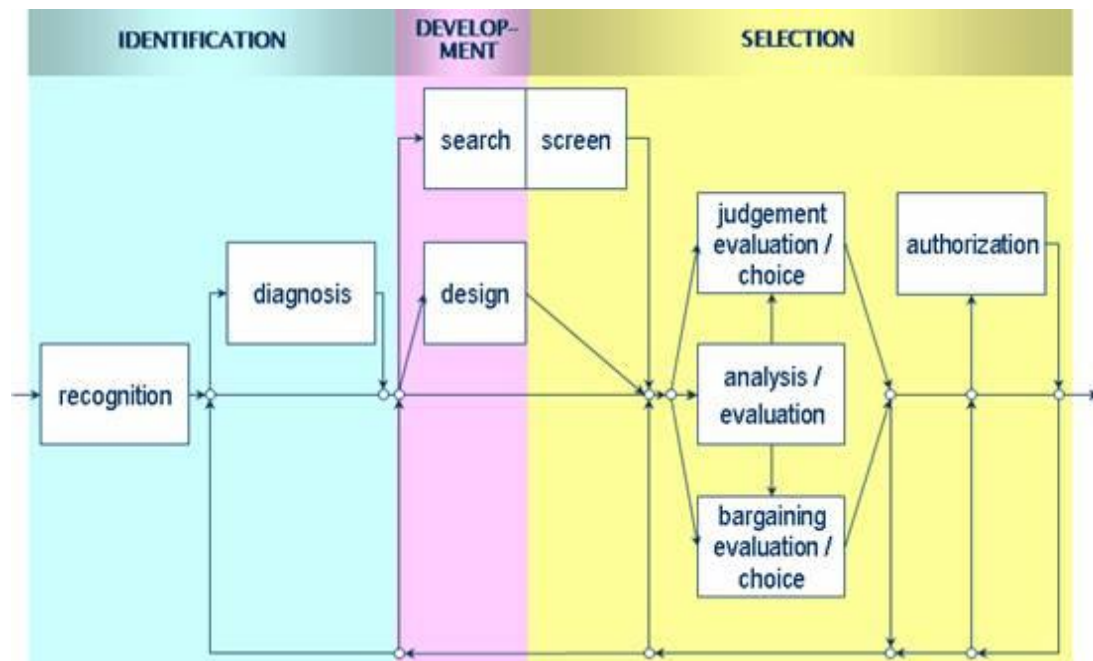


Figure 2-3: Mintzberg & Raisinghani's (1976) model of the strategic decision process.

The last phase is the selection phase, described as a “*multistage iterative process involving progressive deepening investigations of alternatives*”. Within this phase the screen heuristic is eliminating what is infeasible, the evaluation-choice routine is used to judge, negotiate and analyse the solution. The last routine in this phase is authorisation (a fact also mentioned by Simon 1997 but not formally integrated into the model), which is required when the choices are made by individuals that are not in the position to commit the organisation to action.

Analysing 25 organisational decision making processes (six manufacturing firms, nine servicing firms, five government institutions and five government agencies) Mintzberg & Raisinghani (1976) suggested that opportunity and crisis decisions, which need immediate attention, present themselves easily. Contrary to this, problem decisions require multiple stimuli and intense scrutiny of the situation. Furthermore, Mintzberg & Raisinghani (1976) classified seven decision process types, spanning from those that involve only recognition, diagnosis and evaluation-choice routines to highly complex processes that use most stages and exhibit feedbacks. Hence, suggesting that decision making does not follow a uniform

pattern. In fact non routine decision making processes are built around multiple feedbacks between decision support routines and choice routines.

Mintzberg & Raisinghani's (1976) model resembled the innovation decision process described in Section 2.4.1 in a number of ways. The recognition and the design phase maybe conceptualised as 'Reinnovation' in Roger's (2003) model. Also the notion of search is explicit. However, Mintzberg & Raisinghani's (1976) major contribution maybe to have demonstrated how these phases interlock. Their findings suggested that some form of 'Diagnosis' and 'Evaluation-choice' always occurs. This may therefore indicate that all innovation stages have a 'Diagnosis' and an 'Evaluation-choice' phase, too. Whether this is setting the agenda, matching, designing, 'Diffusion' or maybe even 'Routinising'. The linked rectangle and the circle included in each process in Figure 2-2 visualise this concept.

### **2.5.3 Evidence for and limitations of decision models**

It is widely accepted that organisational decisions are bounded rational rather than rational (Dean & Sharfman 1993; Eisenhardt & Zbaracki 1992). Empirical studies of organisational decision making revealed the cognitive limitations of decision makers (Todd 2007). Evidence gathered by Eisenhardt & Zbaracki (1992) suggested that the decision making processes are not sequential, goals are not clearly defined, even shifting. Moreover, their review indicated that goal definition and alternative generation occur nearly simultaneously. Equally, it could be found that alternatives are generated in a haphazard and opportunistic fashion, resulting in a situation where only few alternatives are reviewed (Todd 2007). Decision makers further rely on standard decision making procedures rather than systematic analysis of alternatives.

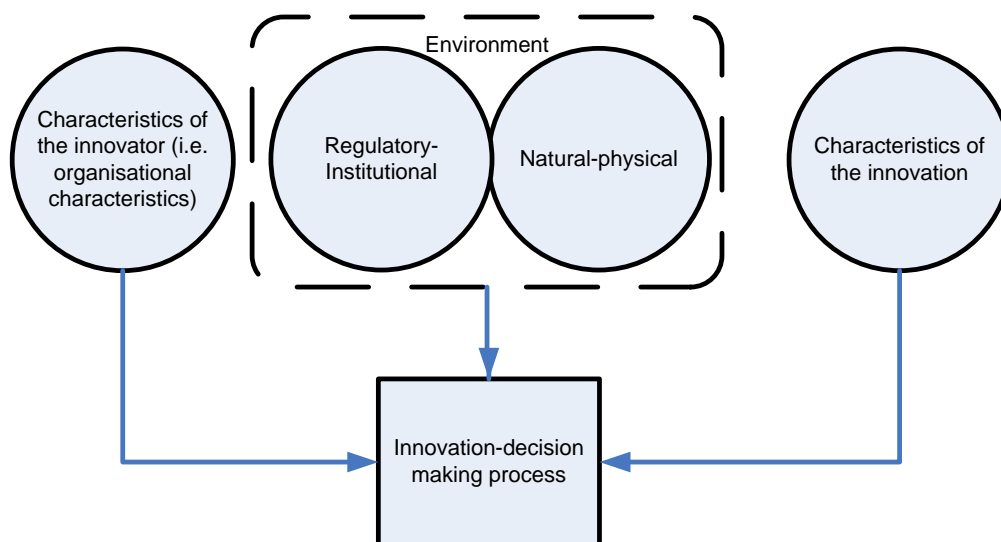
Yet, other studies analyse the relationship between the environmental factors and rational decision making. They found that threatening environments, high uncertainty and external control decrease rationality (Dean & Sharfman 1993). Finally, a number of studies highlight that decision processes vary depending upon decision characteristics (Mintzberg & Raisinghani 1976) and are rational in some ways but not in others (Eisenhardt & Zbaracki 1992).

Langley *et al.* (1995) argued that decisions do not always manifest themselves and hence lack evidence. Rather than appearing at a point in time these authors view decision making as a process that "*follows a trajectory of general convergence on the image of some final action*". According to Langley *et al.* (1995) this entailed that instead of viewing the decision making

process as a series of steps, “*it is more seen in an integrative way, as the construction of an issue.*” Hence they proposed the use of issue streams, in which decision become “*events that punctuate and modify the flow of issues*” and move beyond decision process per se (see Chapter 3 for application of this concept in this thesis).

## 2.6 Factors influencing innovation – factors in the framework

Factors that influence the process of innovation adoption have been of interest to many authors from different disciplines such as innovation management, policy and economics (del Rio Gonzalez 2009). This review draws on evidence from these different fields, because each perspective emphasises different factors or aspects of influence. The factors of influence can be summarised in four different domains (Figure 2-4).



**Figure 2-4: Factors influencing the innovation process in three domains.**

Firstly the characteristics of the innovator-decision maker itself; if this is an organisation as in the present case for WaSCs, then the organisational factors are such as size, structure, normative beliefs, investment into innovation activities and knowledge have been found to be of influence. The influence of knowledge was already introduced when discussing the innovation decision process, but will be expanded upon when discussing the ‘Organisational Characteristics’ as a factor of influence below (Section 2.6.1).

The external environment influences innovation and decisions, too. In this thesis the external environment is defined as everything outside the direct influence of the organisation. For

instance, organisational knowledge, assets, structure of assets and departments and innovation activities can be influenced by the organisation (here WaSCs) and they thus are 'Organisational Characteristics'. Contrary to this WaSCs do not have control over regulations and institutions they are surrounded by. Likewise, in the specific case of WaSCs they cannot influence the geology of their catchments, the water resource etc. However, this distinction into external and internal is imperfect. In Chapter 1 it has been shown that the external environment does influence WaSCs 'Organisational Characteristics'. Indeed, this research focuses on the notion that WaSCs are capable of influencing their surroundings, to improve water quality. The external environment is subdivided into the 'Regulatory-Institutional' environment and 'Natural-Physical' environment to make their different characteristics explicit. Finally, the characteristics of the innovations itself are relevant for the adoption of the innovation. Specifically, these are the relative advantage, compatibility, complexity of innovation and trialability (Section 2.6.4).

Few authors make explicit where factors affect the organisational innovation process. In the literature there is rather a tendency to assess implemented or completed innovations. Due to this lack of evidence and the multiple feedbacks involved in the innovation-decision process; it is proposed here that factors from all three domains can influence the process at every stage. Nevertheless, where the literature provides evidence some inferences were made as to where factors affect the innovation process (Table 2-2).



**Table 2-2: Literature of factors influencing innovation-decision making categorised in the three domains that moderate organisational innovation**

Description	Reference
<b>‘Organisational Characteristics’</b>	
The organisational structure (mechanic vs. organic) affects the capability of organisations to innovate because they create different preconditions for the communication and development of ideas, knowledge and inventions.	(Burns & Stalker 1968)
Larger organisations have more slack resources to invest in innovation activities; they are more likely to be target of stakeholder/ regulatory pressure.	(Quinn 1985; Stanwick & Stanwick 1998)
Customer/ stakeholder preferences influence adoption of innovation, because they can act as a selection pressures (e.g. organisational images).	
Attitudes towards innovations and framing of innovations influences adoption, for instance through preference of a particular alternatives.	(Buisse & Verbeke 2003; Sharma 2000)
The ability to accumulate, use and transfer knowledge is crucial to develop and adopt innovations.	(Cohen & Levinthal 1990; Rothwell 1992; Sharma & Vredenburg 1998; Teece <i>et al.</i> 1997; Trott 1993) (Horbach 2008)
<b>Water industry evidence</b>	
WaSCs give preference to established engineering solution rather than innovation. It is proposed that they are locked in to specific engineering approach to innovation, which replicates old structures.	(Cave 2009; Thomas & Ford 2005)
WaSCs show a comparatively low investment into innovation, which is though to stifle advancements in technology.	
<b>Attributes of innovation</b>	
The rate of adoption of an innovation is higher when innovations provide a relative advantage, are compatible with existing organisational capabilities, are easily trialable and outcomes are easily observed their. Complexity of the innovation is negatively related to adoption.	(Rogers 2003)
<b>SCI attributes</b>	
SCIs are uncertain and long term which makes outcome of SCIs difficult to observe and trial SCIs were also incompatible with existing regulations in E&W	(Brouwer 2003a; Heinz 2003b)
<b>Natural-physical location – natural capital)</b>	
Local context can be conducive to the adoption of innovation, because of greater urgency or suitable conditions.	(Hart 1995; Ormrod 1990; Russo 2003)
<b>Water industry evidence</b>	
No evidence	

<b>Regulatory and institutional environment</b>	
Sudden and unexpected changes (disruptions) in markets and environments can lead to radical technological change. Established companies can find it difficult to adapt to these new circumstance, since prevailing mental models become unsuitable in a new context.	(Christensen 1997)
Environmental regulation can act as a selection criteria or stimulus for innovation.	(Porter & van der Linde 1995)
Competition can lead to more R&D investment and innovation potentially resulting in higher rates (or more success) of innovation.	(Tang 2006)
<b>Water industry evidence</b>	
Market and regulatory frameworks should encourage competition to generate efficiency gains through innovation.	(Cave 2009)
The regulatory framework is a barrier for change towards mores sustainable practice in WaSCs in England and Wales.	(Cashman & Lewis 2007; HOL 2007, 2006; Thomas & Ford 2005)

### 2.6.1 Organisational factors

It is well established that organisational learning or the ability of organisations to generate, accumulate, use and transfer knowledge is essential for successful innovation. In addition, there is a large spectrum of authors proposing other factors that affect knowledge transfer. Burns & Stalker (1968) suggested that management structures affect innovation. They identified ‘flexible’ organic structures and ‘mechanic’ organisational structures and proposed that the former is conducive for innovation. Organic structures are characterised by the absence of formality, lateral hierarchies and short communication channels and a low degree of specialisation of individual tasks. Mechanistic structures represent the other end of the spectrum with a high degree of formality, vertical hierarchies, longer or indirect communication and high levels of specialisation of individual tasks.

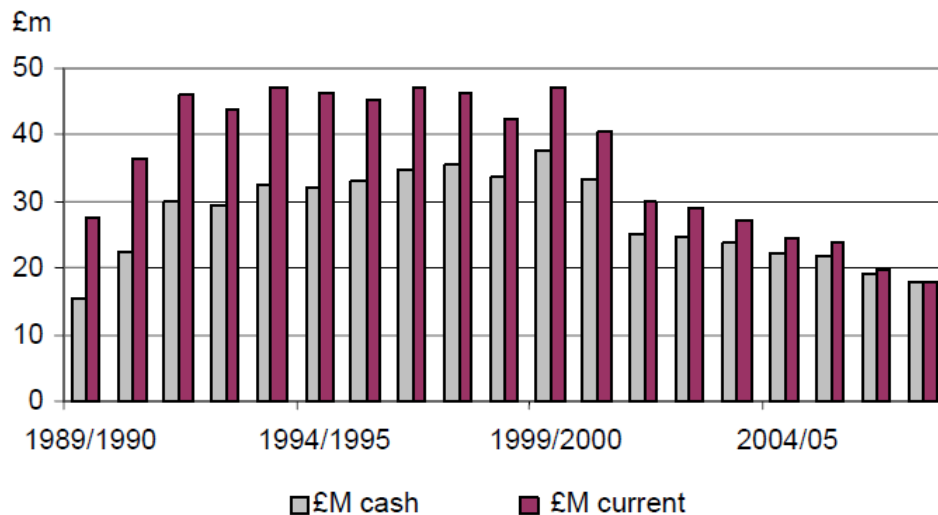
Closely related to the notion of organisational structure is organisational size. While it has been found that smaller organisations tend to have more flexible organisational structures, larger organisations were shown to have more resources available to invest into knowledge generation and the search for knowledge (Quinn 1985; Rothwell 1992; Sharma 2000). Larger firms were also found to receive a higher level of attention from external stakeholders, which can result in pressures to invest into innovation (Gonzalez-Benito & Gonzalez-Benito 2006; Stanwick & Stanwick 1998).

It can be assumed that WaSCs are large engineering organisations (turnover > £1bn). Hence, it could be possible that mechanistic structures dominate (Thomas & Ford 2005). Whether this leads to Thomas and Ford’s (2005) finding that WaSCs in England and Wales have an underdeveloped innovation culture and are lacking an overall holistic approach to innovation is uncertain (see also Cave 2009).

One expression of the lack of innovation by WaSCs in E&W is thought to be the low investment into innovation (Figure 2-5). The relevance of R&D spend was discussed in Section 2.3. There it was suggested that R&D is crucial to avoid knowledge lock-ins, which are described as the ignorance towards new knowledge resulting in ever similar technological (innovation) trajectories (Geels 2002; Rotmans *et al.* 2001; Smith *et al.* 2005). In the context of this thesis, Thomas and Ford (2005) proposed that it is the

dominance of engineering knowledge within WaSCs that poses a barrier to the adoption of certain types of innovation.

For SCIs specifically, Heinz (2003b) highlighted that their adoption was constrained by water companies preference to resolve raw water problems through technological options such as treatment or blending. Furthermore, Brouwer *et al.* (2003a) suggested that a lack of raw water and soil monitoring can constrain the implementation of SCIs. Hence, emphasising that a lack of relevant knowledge (here knowledge of the problem and its causes and effects), makes a transition to other new approaches to water management, such as SCIs, more challenging (see Section 2.3 when discussing the relevance of relevant prior knowledge).



**Figure 2-5: Research and development spending by WaSCs. Spending is between 0.02 - 0.66 % of industry turnover compared to 1.7 % spend by all the UK industry (Cave 2009).**

Other authors emphasised the role of individuals in promoting innovation and developing knowledge (Buysse & Verbeke 2003; Sharma 2000). Research of relevance for the present study is Sharma's (2000) analysis of the environmental strategy of Canadian oil companies. He found that the likelihood of adopting a voluntary environmental strategy was greater when issues were framed as opportunities rather than threats. Associated with this was also a more open search for solutions. Other roles of individuals were described as (Roberts & Fusfeld 1987):

- Gatekeepers – keep abreast with change outside the company and interpret and communicate information into the firm,
- Innovators – experts in a small number of fields and producers of new ideas,
- Champions – promote new ideas to others in the organisation.

However, individuals can also have negative influence on organisational innovation. This was underlined in the political model of decision making, which argues that individuals within organisations can have conflicting preferences (Pfeffer 1981). Power and negotiation are here central elements to arrive at a decision or innovation. The author is not aware of research in the UK water sector which has investigated the role of the individual. Indeed, the notion that specific people in an organisation take vital roles in stimulating and shaping innovation is exploited in this study, since interviews with people in specific functions (gatekeeper, innovators) to investigate change in WaSCs (see Chapter 3).

Which stages of the innovation decision process do the factors reviewed above affect? The ability of an organisation to accumulate, use and transfer knowledge can affect every stage of the innovation process. This was discussed in depth in Sections 2.4. There it was demonstrated that knowledge is crucial to recognise a need for change and that internal and external knowledge is necessary to match external options to organisational capabilities, thus affecting the ‘Agenda Setting’ and the ‘Choice between Alternatives’ stage. Knowledge and learning were also argued to be relevant to reframe an innovation, thereby contributing to its ‘Diffusion’ and finally to turning it into routines.

The size of the organisation appears to be of relevance for the recognition of a problem, when stakeholders exert pressure for change. However, as larger organisation also have more resources to invest in knowledge generating activities it is likely that size may affect all stages of the innovation process. Similarly, organisational structures may affect all stages of the process, because they influence how information and knowledge are communicated in the organisation. Individuals too were suggested to be crucial at every point of innovation process. Gatekeepers will inform about new external development and may even match them to organisational needs; thereby, recognising problems and potential opportunities. Innovators can be capable of redesigning

innovations and champions promote the ‘Diffusion’ and ‘Routinisation’ of the innovation. Management on the other will play a role in restructuring the organisation to accommodate the innovation.

### **2.6.2 Natural-physical environment**

The models of innovation reviewed above (Section 2.3) demonstrated that the organisational ‘context’ is affecting innovation. This ‘context’ is commonly referred to as the organisational environment. Shrivastava (1994) noted that this term was almost exclusively reserved to denote economic, social, political and technological aspects of organizational environments, omitting considerations of the natural environment such as availability of resources. Since Shrivastava (1994) there have been few studies which have viewed the ‘Natural-Physical’ environment as a variable that influences organisational behaviour and innovation. Often these studies are founded on the thinking of Hart (1995), who argued that the resource based view of the firm (a view which suggests that knowledge, human capital and financial capital are resources that influence the performance of a firm) systematically ignored the constraints imposed by the biophysical (natural) environment. In later publications Barney (2002) included the natural capital (i.e. ‘Natural-Physical’) as a resource of the firm. This entails that, the natural and physical environment can be perceived as being internal rather than external to the organisation, because they are now regarded as a resource (an asset).

One of the few organisational studies that were able to demonstrate the impact of the natural environment on organisational innovation is Russo (2003). In a study investigating the growth of sustainable wind industry Russo made a number of points of importance to this study. Firstly, he indicated that wind is an immobile natural capital, while for instance coal or oil is routinely moved over great distances. Secondly, he noted that therefore the location relative to such immobile resources is of influence. This notion was refined by drawing attention the fact that the dependence on location or spatial characteristics is continuous. Applied to the present context, WaSCs are dependent on the availability of water of an adequately quality to supply customers. Unlike wind, water can be moved, but only if there is a negative difference of height this does not require additional inputs, while any positive difference of height will involve pumping. Indeed, pumping costs are by far the highest cost item for WaSCs,

making a transport over longer distances undesirable and thus WaSCs revert to end of pipe treatment alternatives. Hence, WaSCs operations are site dependent, but only continuously so, because with increasing transport distance cost increase. In Chapter 1 it was further underlined that WaSCs in E&W operate in discreet areas –catchments- from which they have to draw water resources. Hence, this emphasises their dependence on location and the natural environment, which is proposed to be a variable affecting the adoption of SCIs in Chapter 6.

Russo (2003) concluded from his research that the presence of natural capital, in his case wind, is necessary to stimulate the adoption of a certain technologies. Similar results were obtained in research concerned with the ‘Diffusion’ of air-conditioning. Ormrod (1990) and Minerva (2007) concluded that local natural environmental factors, here temperature, humidity and wind constrain and shape the decision to install air conditioners in private household and offices. These studies hence suggested that the natural environment is associated with location and affect the decision to adopt specific innovations.

The only independent account about the effect of geographical properties on WaSCs operation and innovation comes from Cave (2009). He makes several recommendations to stimulate innovation in the UK water industry, but also notes that *“because of the very different circumstances prevalent across England and Wales [i.e. nature of water and wastewater markets and company structures], the Review does not recommend a one-size-fits-all approach. Some recommendations will be more applicable in some areas than others and should be taken forward accordingly.”* Beyond that there are claims by WaSCs themselves arguing that certain technologies are necessary or not implementable because of specific hydrologic, consumption or asset characteristics. International evidence about the impact of location and the natural environment for the adoption of SCIs (specifically CAs) was provided by Brouwer *et al.* (2003b) and Heinz (2003b):

- Environmental pressures must exist (i.e. nitrate, pesticide etc.)
- Size of catchment features make cause-effect relationship difficult to establish
- CAs are more likely on groundwater catchments but can be found on large catchments where they provide mainly advisory service

- Farm size - small farmers are more receptive to agronomic advice

Russo's (2003) and Ormrod's (1990) studies discussed above also showed that natural capital alone was not sufficient to explain innovation adoption. Natural capital must rather act in concert with converging economic and social factors (Russo 2003). In a similar vein Berkhout & Green (2002) and del Rio Gonzalez (2009) argued that multiple factors with similar orientation are necessary to stimulate change. Likewise, Mintzberg & Raisinghani, (1976) argued that some problem decisions need multiple stimuli (Section 2.5.2). Contrary to Russo (2003) and Ormrod (1990), these authors were concerned with investigating the interaction between innovation, environmental policy, stakeholders and other organisations. In short, the institutional environmental factors that affect the organisation.

### **2.6.3 Regulatory-institutional environment**

The institutional environment of organisations does not only comprise markets, but it also includes rules and regulations. Specific focus in this study is on the impact of environmental regulation. In the EU one of the key objectives of environmental regulation is to stimulate innovation (Maria 2005). In line with this is Porter & van der Linde's (1995) now famous proposition that "*properly designed environmental standards can trigger innovation*" (regulation push/pull). This relationship was confirmed by Horbach (2008; Jaffe & Palmer 1997) who analysed 753 firms in the German environmental sector. Cleff & Rennings (1999) also found evidence for the accuracy of this hypothesis and argued that, as in Porter & van der Linde's (1995) hypothesis, companies understand eco-efficiency as overall efficiency. However, Porter & van der Linde's (1995) hypothesis offered more detail. They argued that regulation that requires organisations to gather information can result in improved environmental performance by raising companies' awareness, which could suggest that this type of regulation can affect the 'Agenda Setting' process.

Porter & van der Linde (1995) proposed further that more stringent regulation can lead to more radical changes. They argued that light touch regulation can be addressed by end of pipe solutions or secondary treatment without innovation, while stricter regulations requires more fundamentally new solutions, like reconfiguration of products



and processes. Therefore, environmental regulation potentially also affects the ‘Choice between Alternatives’.

Several regulatory instruments exist. Relevant to this study are command control approaches or direct regulations, where a legal requirement is specified and enforced by a regulator. Examples relevant for the present context are for instance the drinking water standards (see Chapter 5). Further, economic instruments which create incentives and or disincentives for change, in the present context this is for instance the role of the economic regulator. Other instruments are negotiated agreements. They are similar to SCIs, but usually involve the bargaining of regulations between organisations and the regulator (Harrison 1999). In Chapter 5 the notion of flexible regulation will be introduced, which is an umbrella term for regulations which grant a firm freedom on the choice of how to achieve its goals, by setting ambitious frameworks for change (Majumdar & Marcus 2001).

In E&W, the view of the EA on 21<sup>st</sup> century environmental legislation is that direct regulation is to be avoided where appropriate and replaced by flexible regulations including voluntary agreements, education and negotiation (EA 2007). This because direct regulation can stifle innovation, can be economically inefficient, can be difficult to enforce and places a great regulatory burden on the government (Georg 1994; Harrison 1999; Steinzor 1998).

For WaSCs in the E&W it was found that innovation was driven by top down (e.g. EU) water and environmental standards (associated with direct regulation). This resulted in, predominantly, large scale capital expenditure on incremental improvement to existing technologies or approaches (Cave 2009). National policies and regulation of WaSCs in E&W was criticised by many (Cashman & Lewis 2007; HOL 2007, 2006; Thomas & Ford 2005). Cashman (2007) suggested that it is the focus of the regulator on rationally measurable outcomes and efficiency gains embedded in a short term five year cycle that constraints innovations for sustainability. In a similar vein, but for the specific case of CAs, Andrews (2003a) concludes that: *“One of the main reasons for this [absents of CAs in the UK] is that water suppliers are heavily regulated and are unable to pass on the cost of CAs to the consumer. It has been demonstrated that if this obstacle can be overcome, CAs offer a plausible alternative to water treatment.”*

Internationally, other regulatory aspects that affect SCI implementation specifically are provided by Brouwer *et al.*'s (2003b) investigation of CA adoption in Europe; these are:

- Livestock farming is more difficult to manage under CAs because of potential high compensation payments for livestock changes
- Establishment of water protection zones provides financial support and improves enforcement of behavioural changes in agriculture

One way proposed to overcome this 'lack of innovation' by WaSCs in E&W is the introduction of competition and market based instruments Cave (2009). It is however still questionable whether the introduction of competition is possible and whether it will stimulate innovation. The underlying concept of competition is closely associated to the market pull model discussed above. A positive relation between competition and innovation was for instance found by Tang (2006). He concluded his research of 8916 manufacturing firms in 21 industries by arguing that market completion between similar products is positively correlated to R&D investment and product innovation.

Yet, another way the institutional environment can affect the ability of organisation to innovate is through disruptive events (see Section 2.4). Christensen (1997) has showed that established companies struggle to adopt to rapidly changing external conditions. Here things happen outside the normal frame and what was once 'good practice' might now be inappropriate to deal with new challenges. Realising that the rules of the game have changed becomes a challenge itself as organisations might be sensitive to inappropriately defined criteria under the new situation. Hence, the rate of change in the environment appears to be a factor that tends to affect problem recognition and matching. In the context of E&W the WFD can be viewed as such a disruptive element. Though water policy has a long history it is frequently claimed that the WFD is the most challenging piece of water legislation so far. Hence, it raises questions whether WaSCs are able to break out of their old frames of reference quickly, so as to achieve the changes that maybe necessary to meet the WFD objectives by 2015 deadline.

#### **2.6.4 Innovation attributes**

There is further evidence that the adaptation process is influenced by characteristics of the innovation. Rogers (2003) provided evidence that relevance of the perceived

characteristics of the innovation affects its rate of adoption. Indeed, he found that they can explain up to 50% of the variance of the rate of innovation adoption. These characteristics are (Rogers 2003):

**Relative advantage** – Is the degree to which an alternative/ innovation is perceived as being better than the idea it supersedes. The criteria for judging ‘better’ are dependent on what the decision maker believes to be of relevance. The relative advantage as perceived by the organisation is positively related to the adoption of the innovation.

**Compatibility** – Is the degree to which an innovation is perceived as consistent with the existing values, past experiences and needs of potential adopters. An innovation can be incompatible or compatible with (1) socio-cultural values and beliefs, (2) previously introduced ideas and/ or (3) organisational needs for innovation. Good compatibility of an innovation supports the adoption.

**Complexity** – Is the degree to which an innovation is perceived as relatively difficult to understand and use. The complexity of an innovation is negatively related to its adoption.

**Trialability** – Is the degree to which an innovation may be experimented with on a limited basis. New ideas that can be easily tried are generally adopted more rapidly.

**Observability** – Is the degree to which the results of innovations are visible to others. An innovation that leads to easily observable results is generally adopted more readily.

SCIs have not been described in terms of these five characteristics. However, from studying relevant literature the attributes were assigned to SCI innovations (Bach *et al.* 2007; Brouwer *et al.* 2003a; Heinz 2008). SCIs are complex and difficult to trial, due to the long time delays and complex hydrogeology. Likewise, results of SCIs are not easily observable, precisely because of a delayed cause-response relationship. In addition the review of literature indicated that SCIs may not be easily compatible with existing regulations. However, as will be outlined in Chapter 5, SCIs may provide a relative advantage, since they can potentially resolve multiple pressures (i.e. win-win situation) including higher cost efficiency.

### 2.7 Summary – the analytical framework

In summary, this Chapter showed that innovation in organisations can be thought of as a process that involves multiple decisions in a five stage innovation process (Section 2.4 and 2.5; Figure 2-6). Furthermore, innovation is complex, non linear, bounded rational and frequently hard to trace (Section 2.5). In addition innovation is affected by a large array of factors in the domains ‘Organisational Characteristics’, ‘Regulatory-Institutional’ and ‘Natural-Physical’ and ‘Innovation Attributes’ (Section 2.6). With regards to the WaSCs in E&W it could be shown that they appear to be influenced by the factors identified form literature. However, the evidence is limited and exactly how factors affect the innovation-decision process is not understood. In Chapter 5, WaSCs, will be located along the innovation-decision process; and in Chapter 6 the factor influencing the implementation of SCIs, with specific attention to ‘Natural-Physical’ characteristics, will be presented and discussed. The methods employed to generate these results are presented next.

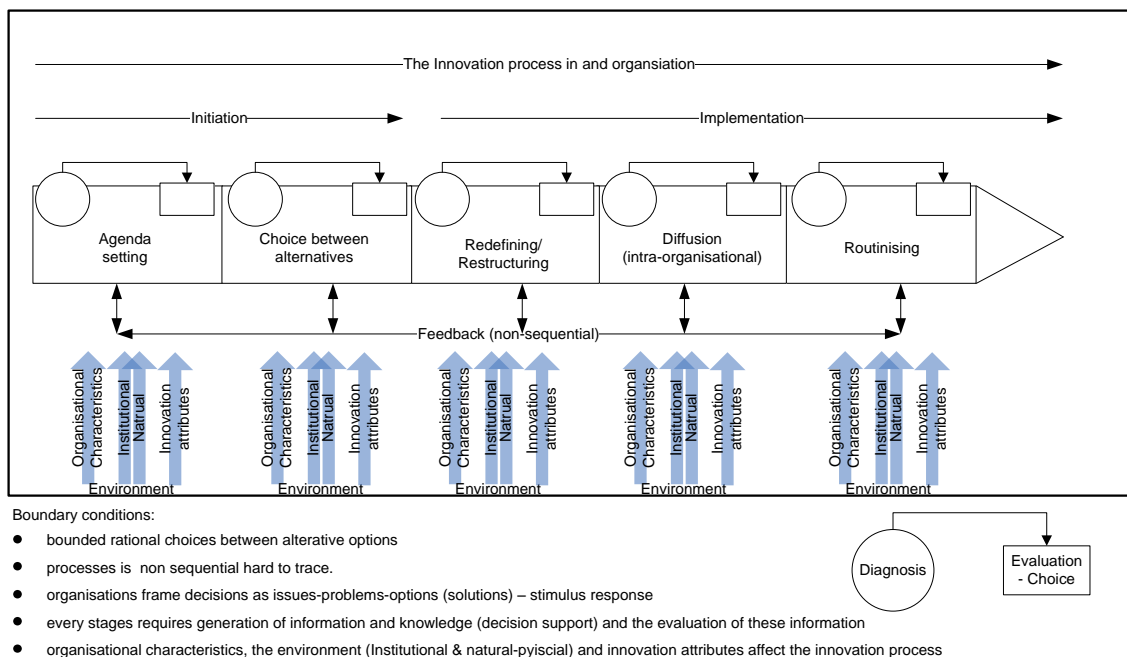


Figure 2-6: The innovation-decision making model and the factors of influence in three domains.

# Chapter 3

## Methodology

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### 3.1 Introduction

This Chapter gives a detailed account of the research strategy, design and methods employed in this study; thereby offering the opportunity to assess the validity of the results and conclusions reached. Likewise, it is also understood as a source of designs, methods and ideas for future researchers interested in flexible qualitative designs. This Chapter commences by defining the research strategy in terms of its underlying ontological assumption. Thereafter, in Section 3.2 the overall research design and the analytical tools used are introduced and discussed (Section 3.3). In Sections 3.4 and 3.5 the fieldwork design and analysis in two research phases is set out. The Chapter is concluded by describing how an ethical research process was ensured (Section 3.6).

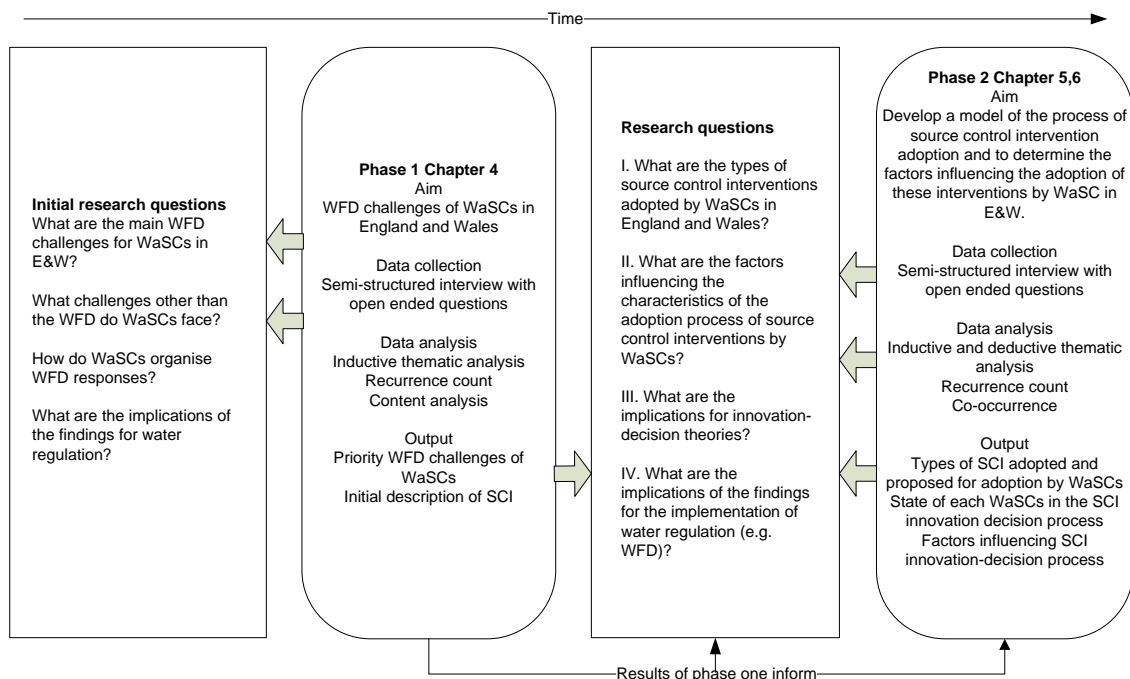
### 3.2 Research strategy

Four research strategies, or the logics of enquiry, can be distinguished: Induction, Deduction, Retroduction and Abduction (note: research strategies describe the approach taken to answer research question in terms of the underlying ontology and associated epistemology). These research strategies differ in terms of their ontological assumptions, starting points, sequence of steps, use of theory, explanation, understanding and the character of their outcomes (Blaikie 2000). Blaikie (2000) argues that the choice of a research strategy is a matter of judgment involving personal criteria, but he also emphasises that the research strategy adopted must be suitable for answering the research questions. An abductive research strategy is adopted in this study, thereby following the philosophy that the perception of social actors can explain observed patterns and phenomena. In other words, the interpretation of events or rules by social actors (such as WaSC representatives) can explain decisions and the unfolding of events. Abductive designs are suitable to describe and understand change processes. They also enable evaluation and impact assessment (Blaikie 2000).

### **3.3 Research design - flexible**

This study followed a flexible case study design (i.e. research designs describe how a research is implemented and operationalised). Robson (2002) describes flexible design as designs that require no pre-developed analytical framework or knowledge of the phenomena under investigation; they rather evolve and develop as the understanding of the researcher grows. Contrary to this, fixed designs demand the development of an analytical framework and thus rich knowledge of the research problem prior to the investigation. In other words, flexible designs offer the opportunity to first explore social phenomena and then develop the analytical framework to match the empirical data. Flexible designs are frequently referred to as qualitative studies, because they are dominated by methods that lead to the collection of qualitative data. In this study too, the primary data collected are qualitative, but as will be discussed later (Section 3.3.1) the distinction between qualitative and quantitative is not entirely adequate and flexible designs should make use of both techniques. The explorative character of flexible designs implies that research questions have a tentative character at the outset of the study. In other words, research questions may be reformulated or the research itself can undergo a reorientation (Eisenhardt 1989). However, Eisenhardt (1989) as well as Miles & Huberman (1994) emphasise that an initial definition of research questions is essential to provide an initial research focus.

This research has been designed in two phases. The first fieldwork phase was explorative, aiming to develop an initial understanding of the key water and wastewater management challenges WaSCs will face in the future. For this purpose the WFD was viewed as a stimulus for change in water management. This thinking has been set out in Chapter 1. Thus the case, or the unit of analysis, in this research phase was defined as ‘WaSCs in the context of WFD implementation’. Furthermore, access to the interview partners was hoped to be easier when choosing a theme of contemporary controversial debate to frame the inquiry. Semi-structured interviews with open-ended questions were employed to collect qualitative data; where appropriate qualitative data was transformed into quantitative data through an assessment of interview coverage and recurrence (Section 3.3.3). This enabled comparison and identification of variety.



**Figure 3-1: Overview of the flexible research design adopted in this study (arrows indicate which research questions are responded to in each research phase)**

The first research phase resulted in a prioritisation of the key water management challenges faced by WaSCs in the context of the WFD. Informed by these findings the initial research questions were revised (Figure 3-1). The most prevalent WFD change issue, namely raw water quality issues and associated SCIs responses became the focus of investigation. Following this reorientation of the study the unit of analysis was redefined to be ‘WaSCs in E&W in the context of SCI adoption’. A subsequent research design was conceived, which employed the Driver-Pressure-State-Impact-Response (DPSIR) framework (Section 3.4) and innovation decision making theories as frameworks for investigation and analysis (Chapter 2). Explorative design elements, such as open ended interview questions, were maintained in the fieldwork, as research questions I and II required the further exploration of SCIs and the factors influencing innovation decision making. The analysis of interviews combined theory driven analytical techniques with data driven design elements.

### 3.3.1 Data type

In social scientific literature it is common to distinguish designs that aim to collect data as words, qualitative, or data collected in numbers, quantitative. However, since data can be transferred into either form this distinction is not wholly adequate (Blaikie

2000). Qualitative data may be transferred into quantitative data by counting the occurrence of concepts to establish their representativeness (Silverman 2001). Numbers on the other hand are readily turned into verbal descriptions as a means of interpretation:

*“Quantitative data is usually produced by coding some other data, which is reduced to a number by stripping off the context and removing content from it. Later, after manipulating the numbers, they are interpreted, that is, expanded by adding content and context which enables one to see through the numerical tokens back to the social world.” (Halfpenny 1996)*

Although this study employed methods to turn qualitative data into quantitative data, the primary data (i.e. data produced by the researcher Blaikie 2000) collected in this research was qualitative (i.e. interview text); thus it is necessary to discuss some of the advantages and limitations of qualitative data.

The key advantage of qualitative designs is that they generate detailed insights into the processes underlying causal relationships. Thus these studies can surface complexities in ‘rich descriptions’ of processes and causal relationships. In the context of this research a qualitative approach can hence contribute towards providing insights into the causal decision making processes of WaSCs. As indicated above, flexible qualitative designs are also appropriate when the research aims to generate a better understanding of a new field or phenomena (explorative research) where little prior knowledge exists. Therefore, flexible designs are able to investigate the unexpected and unusual. Thus, qualitative designs are suitable to explore SCIs and for change in water management perceived by WaSCs. The characteristic of qualitative designs to explore the unexpected and new, is closely related the most crucial advantage of flexible designs; namely that they can function without pre-selection of a theoretical framework or perspective. Eisenhardt (1989) underlines the value of this by arguing that pre-selection of an analytical framework may bias and limit the findings. In addition, qualitative designs are also useful to generate and advance theory; which, in the context of this study, is relevant to develop and adapt innovation decision making theory for the context of WaSCs in E&W (i.e. research question III).



Qualitative designs do however have limitations. Miles & Huberman (1994) argue that qualitative data are often messy and time consuming to analyse, potentially resulting in ‘data overload’ for the researcher. Furthermore, there are concerns about reliability and validity. Reliability can be understood as an internal consistency and replicability (Silverman 2001). Validity refers to the extent to which a finding reflects the reality of social phenomena (Silverman 2001). Silverman (2001) differentiates between two types of threats to validity:

- Type one error is believing a statement to be true when it is not
- Type two error is rejecting a statement which, in fact, is true

Some scholars argue that these positivistic measures of validity are inappropriate for qualitative social inquiries (Eisenhardt 1989; Robson 2002). The key argument of these scholars is that it is not possible to test for validity by replicating the findings, because in non experimental designs the exact equal circumstances cannot be replicated. Another argument suggests that results are subjective and not replicable because the ‘researcher is the instrument’ of analysis. Contrary to this, the natural sciences rely on specialist standardised tools and instruments, which are better suited to produce replicable results (Eisenhardt 1989; Robson 2002). In this vein Miles & Huberman (1994) argue:

*“The most serious and central difficulty in the use of qualitative data is that methods are not well formulated. For quantitative data there are clear conventions the researcher can use. But the analyst faced with a bank of qualitative data has very few guidelines for protection against self-delusion, let alone the presentation of unreliable or invalid conclusion to scientific or policy audience.”*

Miles & Huberman (1994) suggest that concerns about validity can be overcome by using analytical methods that enable a transparent and traceable account of how results and conclusion are generated. Analytical software (such as the software used in this study – NVivo<sup>®</sup> 7&8) is helpful in this process as it assists the researcher to structure and analyse large amounts of data.

The scholarship that rejects positivistic measures of validity argues for alternative considerations of validity. For instance, Hodkinson & Hodkinson (2001) suggest judging qualitative case studies on questions like: Do the stories ring true? Do they seem well supported by evidence and argument? Does the story tell us something new and/ or different, that is of value in some sort of way? Is the theorising better or more valuable than alternative models? However, other authors argue that, although more difficult, a positivist measures of validity can be adopted (Blaikie 2000; Eisenhardt 1989; Robson 2002). Here reliability is established when two or more researchers obtain the same results from similar observation. Alternatively, participant validation can be used to ensure that an adequate account of observed phenomena is given. Nonetheless, these methods of validation pose their own challenges. These include the difficulty accessing participants for validation and the fact that the peoples attitudes and views may change as time passes. Therefore, participant validation may not confirm the findings of previous enquiries. This does not necessarily signify that results are ‘wrong’ but rather it can reveal a process of change (this property is for instance used in longitudinal studies).

Other limitations of qualitative studies are the high cost of data collection and analysis and the difficulty of presenting quantitative data simply, but adequately.

### **3.3.2 Sampling method - case study**

This research generates data in a semi-natural setting (as opposed to natural – or experimental settings); that is individuals are asked to provide accounts of their activities, perceptions, attitudes and knowledge. Semi-natural sampling methods can be surveys or case studies. The main difference between surveys and case studies is the sampling strategy. While surveys use statistical sampling methods (e.g. random sampling), case studies are based on theoretical sampling methods, most frequently, purposive sampling. This is because case studies are defined as empirical in-depth investigations of specific contemporary phenomena taking into account the natural setting of the case (Yin 2003). Case studies require the definition of cases that include the research object and its context, as they aim to investigate a specific problem or phenomena, often a situation that is extraordinary or special.

Case studies as a research design have the advantages of qualitative enquiries discussed above. Yet, they have a number of characteristics that make them appealing as a design for this research. A key strength of case study research is that it can be designed as a multiple case study to compare different cases or units of analysis. Between four to 10 cases was found to be an appropriate number to maintain complex insights on the one hand, while also ensure empirical grounding of results (Eisenhardt 1989). In multiple case designs, each case is equivalent to an experiment and multiple cases are equivalent to multiple experiments (Yin 2003). Contrasting between cases can be applied to tease out idiosyncrasies of cases and to validate cases against one another (Eisenhardt 1989).

In this research, such a multiple case study design was adopted. Each of the 10 WaSC in England and Wales presented a case enabling the comparison between the WaSCs and the elicitation of differences and similarities. The approach was also vital to determine factors of influence, because multiple samples (i.e. WaSCs) permitted identification of recurring causal relationships or such relationships that were idiosyncratic. Case studies are also practical to study specific contexts or sites where social phenomenon occur (Miles & Huberman 1994). Hodkinson & Hodkinson (2001) argue that case studies retain more of the external context than other types of research and that this context can be highly significant to expose complexities and causal relationships. Indeed, one of the objectives of this research was to investigate whether and how environmental factors (i.e. the context) affect innovation decision making (see Chapter 2 for a discussion of factors influencing innovation and change). Thus a case study design was useful, since it offered a means for corroboration of the findings through comparison, while also being able to highlight idiosyncrasies in rich descriptions and accounted for the context as a potential explanatory variable.

Case study designs also share the disadvantages of qualitative studies, but researchers carrying out case studies are faced with some more specific challenges. By definition, case studies investigate one or a few specific cases in depth, therefore it is often challenging for researchers to draw general conclusions from case study research. For instance Eisenhardt (1989) finds that a number of case studies only produced narrow and idiosyncratic theory. However, she also suggests that:

*“The likelihood of valid theory is high because the theory-building process is so intimately tied with evidence that it is very likely that the resultant theory will be consistent with empirical observation.”*

She continues by arguing that:

*“Creative insight often arises from the juxtaposition of contradictory or paradoxical evidence. That is, attempts to reconcile evidence across cases, types of data, and different investigators, and between cases and literature increase the likelihood of creative reframing into a new theoretical vision.”*

Careful sample selection can further improve the generalisations made from empiric enquiries. Since statistical rigour through selection of a large number of samples is neither possible nor desired in case studies designs, the selection of theoretically relevant cases (purposive sampling) is vital to produce relevant outcomes. In the specific case of this study, the entire population of WaSCs in E&W was sampled, thus the results can be assumed to be applicable for the WaSCs in E&W. The application of the findings beyond the context of E&W may however be limited, because of different organisational and governance structure in addition to different geographies and geologies.

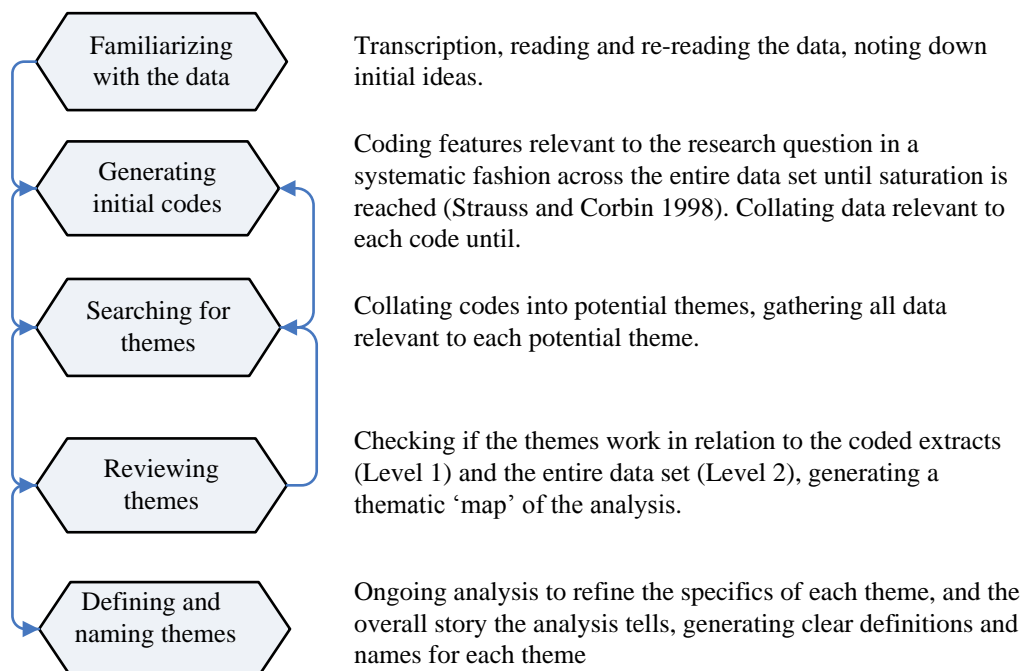
### **3.3.3 Analytical tools employed**

Three analytical tools of fundamentally different character were applied in this study, namely thematic analysis, content analysis and narratives. Each of these methods have their strengths and weaknesses, but in combination they can perform well, providing insights about causal relationships, structures and scientific rigour.

#### **Thematic analysis**

The primary analytical tool employed in this study was thematic analysis. It is a method to identify patterns or themes in transcribed interviews. Braun & Clarke (2006) argue that thematic analysis is widely used but a *“poorly branded method, in that it does not appear to exist as a named analysis in the same way as other methods”* (e.g. narrative analysis, grounded theory, qualitative content analysis). Indeed, the literature shows that a variety of labels (or no label at all see Macht *et al.* 2005) is given to processes which resemble the stepwise and iterative approach of thematic analysis (Elo & Kyngas 2007;

Hsieh & Shannon 2005; Miles & Huberman 1994; Strauss & Corbin 1998). Familiarising with the data, defining, collating and renaming themes are the phases of thematic analysis (Figure 3-2). Therefore, rather than entering into a discourse about the different names given to qualitative data analysis techniques, the following discussion is restricted to crucial considerations which provide necessary background knowledge. Grounded theory will be discussed, because it is close to the approach adopted in this research and it is an established method of data analysis. Similarly, content analysis is a method with a long history, but is more frequently associated with quantitative aspects of text analysis. To avoid confusion, the decision was made to reserve the term content analysis for quantitative assessment of the text.



**Figure 3-2: Description of the phases of thematic analysis (modified following Braun & Clarke 2006)**

The coding of text is a key characteristic that thematic analysis shares with other approaches such as grounded theory. Strauss and Corbin (1998) define coding in two stages, open coding which is “*the analytical process through which concepts are identified and their properties and dimensions are discovered in the data*”, and axial and selective coding where broader categories are developed and linked to form a theoretical scheme. In more simple terms, coding breaks up the text in discreet parts such as events or decisions and subsequently collates related concepts in broader

categories (in this study for instance issues, problems, options Section 3.1). Miles & Huberman (1994) suggest that coding begins with descriptive codes, which require little interpretation, but are rather based on attributing phenomena to a segment of text. Later in the process, when the researcher has gained knowledge about the data, codes might become more interpretive and inferential. This research follows this guideline. It begins by employing abductive coding, which is similar to descriptive coding and then makes use of deductive coding, which is comparable to interpretative coding. The distinguishing features of abductive coding is that it stays as close as possible to the language, the concepts and meanings of the social actors rather than imposing their concepts and categories (Blaikie 2000). This closeness to the lay language warrants, to an extent, the direct reflection of the perceptions of social actors. In grounded theory abductive coding is not used. Blaikie (2000) argues the following:

*“The various forms of coding [in grounded theory] are a search for technical concepts that will organise and make sense of the data. While these concepts can be either those that are already in use, or can be developed by researcher for a particular purpose, there appears to be little attempt to derive them from lay concepts, to make use of lay meanings associated with the concepts, or to tie them to lay concepts. For this reason, grounded theory is not strictly an abductive research strategy.”*

Coding further requires labels that reflect the coded content, a definition that delineates the boundaries of the coded theme (or concept) and a definition of the coding unit. Coding units are the elements of the text which constitute an analytical entity. They can be as small as words and as large as whole paragraphs. There are no generic guidelines in literature about the size of these units. Rather coding units should be appropriate for the purpose at hand, and typically this can be sentences or monothematic chunks of text (Miles & Huberman 1994).

The principal advantages of thematic analysis compared to grounded theory are that it is theoretically less bound and is more open to integrate various analytical methods. For instance grounded theory analysis requires the development of a ‘useful theory’ that is grounded in the interview data. Grounded theory assumes that themes can be derived from the text without the application of an underlying theoretical framework. This conceptualisation of an objective researcher, which simply echoes the participant’s

views, has been criticised. Critics claim that researchers introduce bias by inexplicitly applying theories to analyse data (Silverman 2001). Contrary to this thematic analysis does not demand the development of a ‘useful theory’. It is rather a flexible research method, capable of integrating a variety of research tools, because it is compatible with multiple research strategies (Braun & Clarke 2006).

### **Content analysis**

Content analysis is a method for making replicable and valid inferences from texts by condensing the data into categories (Krippendorff 2004). In this vein, content analysis is very similar to thematic analysis, but contrary to thematic analysis, content analysis has a tradition of quantitative data analysis. However, the quantitative/ qualitative distinction is considered inadequate because both methods are indispensable for text analysis (Krippendorff 2004); in this thesis the term content analysis shall be used as an umbrella term to cover all and only quantitative data analysis techniques. This is done to avoid confusion of terms. The qualitative elements of content analysis are provided for by the thematic analysis.

Like thematic analysis, content analysis requires the definition of codes and units of analysis. In its simplest form content analysis is based on a word count usually applied for defined units of investigation (for instance certain articles, Sections of articles or even titles). In more complex forms content analysis focuses on the relationships between units of investigation (relational content analysis Busch *et al.* 2005). In this study a number of methods were used, namely recurrence counts of themes, interview coverage of themes and a modified relational content analysis.

The representativeness of certain concepts was assessed using recurrence counts of coded themes. Interview coverage assessed the penetration of themes or codes in interviews. In other words it showed how (I) frequently a theme occurs and (II) the amount of ‘space’ it occupies in the text. Recurrence and interview coverage therefore provide an assessment of prevalence, which can be associated with importance of themes within single interviews and between multiple interviews.

However, it is not proposed here that only frequently recurring themes or themes with a high coverage are of relevance. Rather themes must reveal information with regard to the research question. Accordingly unusual themes (i.e. themes with low recurrence or coverage across interviews) provide valuable insights that enable the explanation of relationships (see Section 3.3.1 on Eisenhardt's (1989) discussion on qualitative data above). Furthermore, counting recurrence and prevalence (interview coverage) was an important tool in identifying difference and similarities across the population of WaSCs (Sections 3.4.2 and 3.5.2).

The specific type of relational content analysis used in this study is proximity analysis (Busch *et al.* 2005). Proximity analysis describes the co-occurrence of two codes in a unit of analysis. Co-occurrence can be understood as an indication for correlation or relationship between codes. To clarify, a co-occurrence takes place when in a coding unit two concepts are coded individually. For instance the sentence: "*Poor raw water quality increases treatment costs.*" can be coded as 'raw water quality' as well as 'costs'. Therefore the themes raw water quality and costs occur together once. Themes that occur more frequently together can therefore be considered to indicate a frequently stated relationship.

### **Narratives**

Narratives are suitable to explain a process by describing its stages in the order of their occurrence (Robson 2002). Moreover, narratives also generate in-depth understanding and explanations of causal processes. This crucial role of written accounts for analysis is emphasised by Eisenhardt (1989).

*"Within case analysis typically involves detailed case study write ups for each site. These write ups are often simply pure descriptions, but they are central to the generation of insight because they help researchers to cope early in the analysis process with the often enormous volume of data."*

In this vein, the narratives in this study were constructed by describing process and causal relationship in the words of the author. Narratives were constructed for each WaSC rather than for each interview. Since narratives are extensive and long, they are



not presented in full in this research. Rather Chapters 4, 5 and 6 contain elements of the narratives and are outcomes of the sense making process facilitated by writing.

### **3.4 Phase 1**

The first fieldwork phase was designed as an explorative enquiry with semi-structured interviews and open ended questions as a method of data gathering. An interview guide was used to structure the interviews; this ensured some degree of comparability between the interviews. The interview guide consisted of the following four main questions:

1. What are the main challenges posed by the WFD?
2. What priority does the WFD have in relation to other activities?
3. How are responses to the WFD being organised?
4. What kind of benchmarking information would be useful to have?

The first interview question aimed to explore the WFD change issues faced by WaSCs. It was anticipated that this question would result in the population of key areas of concern to WaSCs. Therefore providing an assessment of where SCIs can be positioned in the context WFD driven change. The second question was developed to capture other stimuli for change perceived by WaSC representatives. Question three was intended to deliver an understanding of the mechanisms of responding to the WFD. The purpose of this was to generate a comparison of the approaches to WFD response adopted by WaSCs. At this early stage of the study, it was anticipated that an understanding of how responses to the WFD were organised may have explanatory value for differences and similarities between cases. However, this was not followed up, because the orientation of the research changed as a result of the outcomes of the first phase enquiry. Finally, question four aimed to elicit benchmarking information of interest to WaSCs, to inform the next phase research design. However, only very few interview partners expressed a need for benchmarking information; as a result this question did not contribute to the subsequent research design.

#### **3.4.1 Fieldwork**

Interviews were carried out in 2007. Participants were identified through internet search, consultation with industry bodies (Water UK, British Water) and snowballing. Sampling was purposive with all interview partners selected based on their function in

the WaSCs. Accountability for WFD response planning was a precondition to be considered for interviews. Individuals with this duty were considered ‘gatekeepers’, who filter the data and information the organisation receives. Thus they influence which issues are emphasised or subdued in processes of setting objectives, formulating problems and generating responses (Checkland & Holwell 1998). Hence, the interview results served as a proxy for the response of the organisation to the WFD.

In total 13 interviews, with 17 individuals in nine English and Welsh WaSCs were conducted in phase one (Table 3-1). Each interviewee received a short document prior to the interview outlining the research and presenting the questions to be asked during the interview (Appendix I). All interviews lasted between 40 and 90 min and were recorded with a digital voice recorder.

**Table 3-1: Distribution of interviews and interview partners across the population of WaSCs in fieldwork phase 1.**

WaSC	Number of interview	Number of interview partners
A	1	2
B	1	1
C	Could not be accessed for interview despite several attempts	
D	2	2
E	1	1
F	1	1
G	3	4
H	1	2
I	1	1
J	2	3
Total	13	17

### 3.4.2 Interview analysis

Recorded interviews were transcribed and imported into the software Nvivo<sup>®</sup> 7. To understand change issues and associated problems and response options thematic analysis was applied. Prevalence of issues, problems and response options was assessed using recurrence counts and interview coverage. Written accounts of issues, problem and response options were generated through narratives.

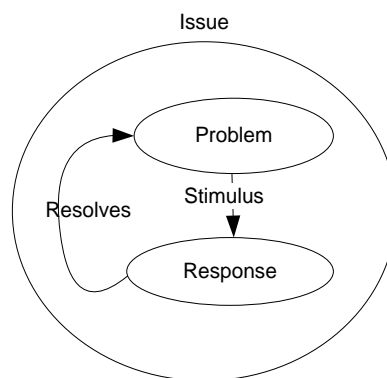
#### Thematic analysis

Thematic analysis as described in Section 3.3.3 was applied to analyse the interview transcripts. Data were coded in an abductive fashion, using labels directly derived from the language used by the interview partner (e.g. investment, benefits, cost, treatment etc.). Thereafter codes were collated and summarized in broader categories issues,

problem and options. These broader categories too were directly derived from the data. To clarify, consider the following quote which demonstrates that interview partners conceptualised problem and response in issue streams as proposed by Langley *et al.* (1995) and discussed in Chapter 2: “So we are reasonably optimistic that the framework directive will give us the opportunity to highlight those issues, we are expecting to see, measures being taken like special protection areas under Article 7...” (a water only company) or “The driver behind all of this isn't necessarily the issue as such it's how they're addressed in terms of programs of measures. (F)”

The hierarchical coding function of NVivo<sup>®</sup> 7 was used to facilitate coding. The categories derived were (Figure 3-3):

- issues - important topics of debate or symptoms of importance to one or more actors, e.g. water quality in the environment
- problems - the specific implications of issues for each actor that present some need for change, e.g. achieving good ecological status
- options - a set of possible alternatives (solutions to problems) considered by different actors, e.g. bundles of possible treatment technologies



**Figure 3-3: Coding framework of this research**

The logic of the coding framework was the following. Options and problems are entities of issues. Issues are very much like themes, a global title for a situation. On the other hand, problems arise from an issue within a specific context and might therefore be case specific; they require analysis and understanding of the specific characteristics of an issue (Simon 1997). Response options, are generated as a result of the problem constituting an activity that aims (the sample included also desired or anticipate

activities) to resolve the problem, but not necessarily the issues as such. In other words the coding framework follows a stimulus response concept, where problems trigger innovation. From this perspective innovation decision making as discussed elsewhere in this thesis (Chapter 2), provides the core theories to explain the relationships between issues, problem and option (i.e. performance gap, recognition). To clarify consider a hypothetical example of two water companies.

Two organisations A and B face an increase in investment to install a nitrate removal plant (i.e. ion exchange), costing £100m [issue]. These investments are usually financed through water bills. For organisation A this implies an increase of water bills to say 2 £/m<sup>3</sup>. However, company B already charges a water price of 2 £/m<sup>3</sup> and cannot increase their water price due to existing regulations [different problems]. Hence due to different preconditions the two companies have to follow different approaches [responses] to raise the necessary funds; while company A simply increases water bills. Company B might need to borrow money. In this, admittedly simple example we can observe how an issue – investment - is perceived as a problem depending on the context (i.e. water company A increased water bills, while water company B cannot increase water prices) and how this can generate different responses.

Since it was the objective of this first research phase to understand the key challenges posed by the WFD it was necessary to distinguish the issues driven by the WFD from those driven under other EU directives or other business concerns. To do this the following criteria were applied:

- Issues directly associated with the WFD by the interviewee (i.e. interviewee refers to the WFD as a driver for this issue) and
- Issues legislated for in the WFD (i.e. ecological status, balanced abstraction)

If both criteria were met, the issue was termed a WFD change issue. By applying this approach it could be ensured that the issues were perceived to be stimulated by the WFD. However, this does not preclude that other stimulus are irrelevant. Indeed, it has been argued above that a combination of pressures rather than a single stimulus maybe necessary to trigger change. This is reflected in the coding framework through the

creation of a separate ‘issue stream’ under which ‘other change drivers’ are collated (Chapter 4).

### Content analysis

Two modified content analysis methods were applied to assess the prevalence of issues, problems and options. These methods were recurrence counts and coverage analysis. Recurrence counts simply enumerate how frequently a theme (i.e. issue, problem or options) occurred in the text. Coverage analysis is more complex and was only applied to determine the prevalence of issues. For this purpose the unit of investigation was set to be the text coded as issues in the thematic analysis. Then redundant words, such as articles, pronouns and common verbs (i.e. to be), which contribute to understanding in context, but do not convey issue specific information, were deleted. By removing these words from the transcripts, a text was produced which was free of ‘irrelevant’ words. Hence, the transcripts were considered as ‘standardised’, reducing the content to core words. The advantage of this approach is that it can, to an extent, account for the complexity of language (i.e. words can have different meanings in different contexts), because it uses monothematic chunks of text as a unit of analysis.

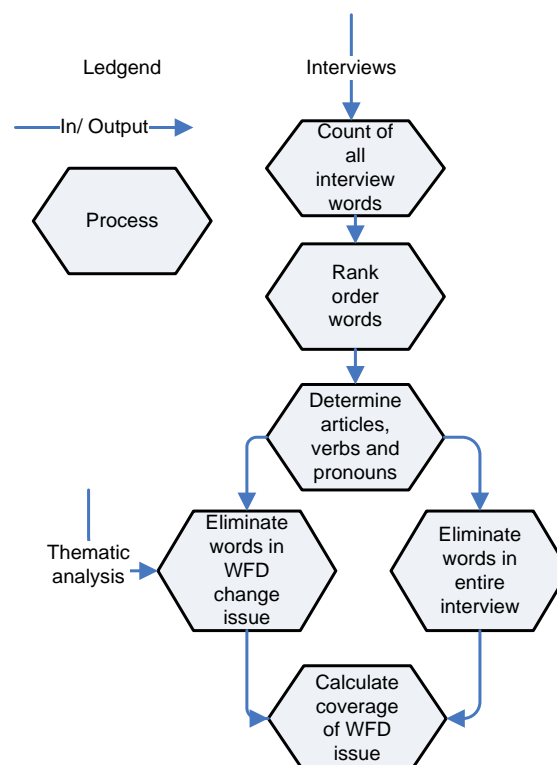
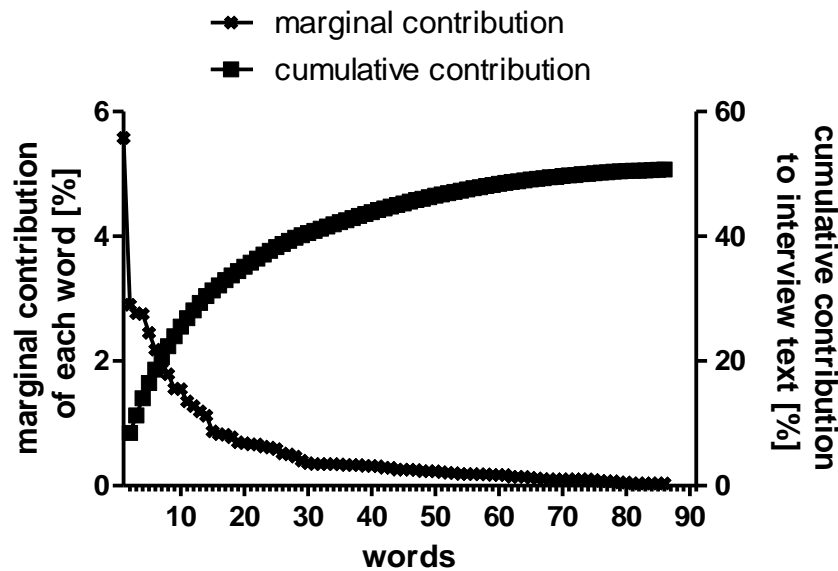


Figure 3-4: The process of content analysis and coverage of WFD change issue assessment.

The selection of words to be excluded from the text was approached using the following technique. The words of all interviews under investigation were listed and rank ordered according to their marginal contribution to text coverage (Figure 3-4; using the Software Hamlet II<sup>®</sup>). Moving from high ranks to low ranks, words were eliminated from the list until the marginal contribution of each word approached zero (Figure 3-5). In total 86 words were selected, with their summed marginal contributions constituting more than 50% of the entire interview text (Figure 3-5). Finally the remaining words under each WFD change issues were counted and expressed as the percentage of words remaining in the transcript.



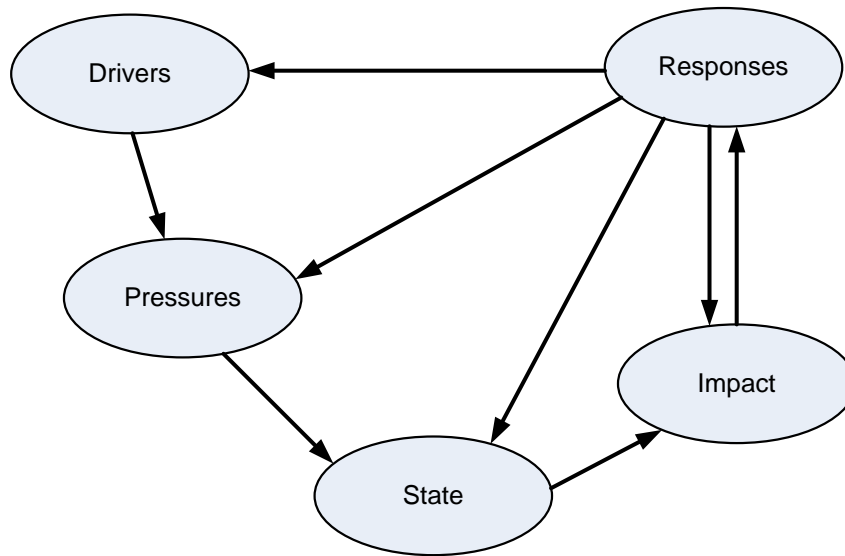
**Figure 3-5:** Culminating distribution function of ‘redundant’ words in all interviews (the function displays how the marginal contribution of words in the text diminishes with increasing number of selected words).

### 3.5 Phase 2

The second fieldwork phase employed semi-structured interviews. The Driver-Pressure-State-Impact-Response framework (DPSIR) was used to structure and analyse the interviews (Figure 3-6). It is a framework developed by the European Environment Agency to analyse and structure environmental problems in terms of DPSIR. At the EU level DPSIR now acts as an approach to reporting of environmental problems and as a tool for policy makers to develop and assess policy choices (Kristensen 2004). According to the DPSIR framework, developments in society exert pressure on the environment, which lead to changes in environmental conditions. Subsequently, these

changes have an impact on individuals, sectors or whole societies and their ability to function. Impacts then may trigger a feedback (response) towards drivers, pressures, states or impacts (Smeets & Weterings 1999).

For the purpose of this study the elements of the DPSIR were defined as follows (Smeets & Weterings 1999):



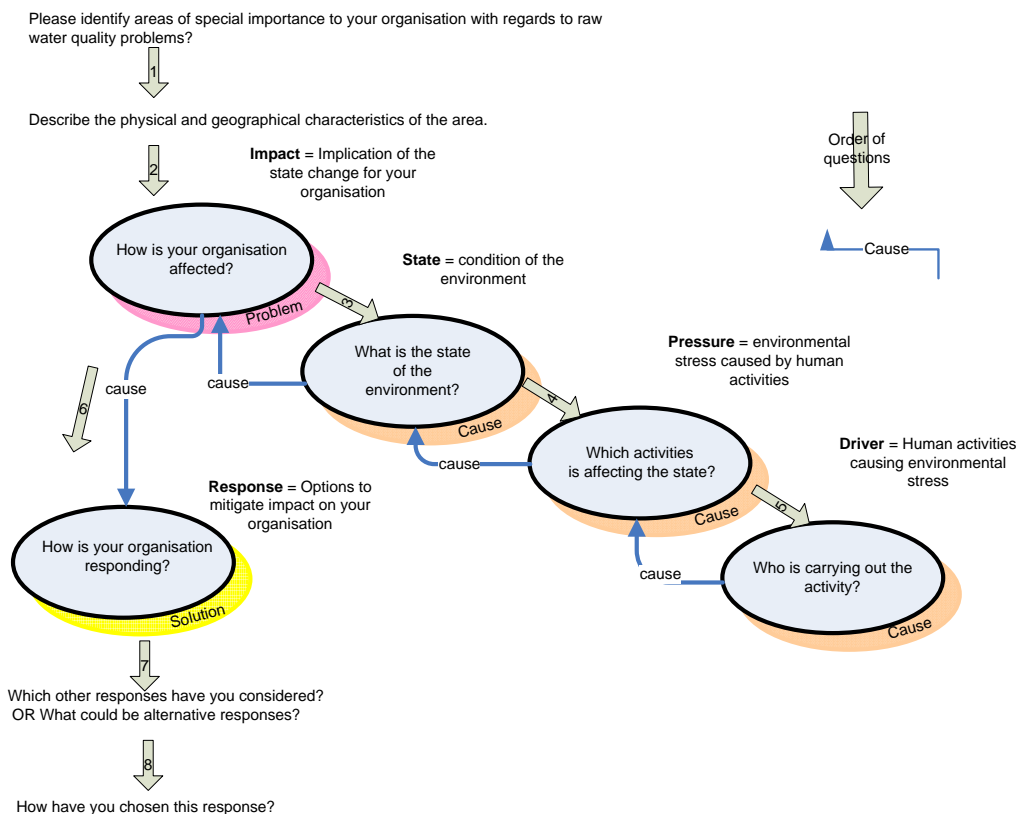
**Figure 3-6: The Driver Pressure State Response Framework (Smeets & Weterings 1999)**

- The Drivers are the social, demographic and economic developments in societies that influence the pressure on the environment. In this research this could be the WFD or the CAP, but also changes in agricultural practice driven by market forces (i.e. prices of crops and fertiliser).
- The Pressures describe developments in release or consumption of substances, physical and biological agents, the use of resources and the use of land. Examples are the agricultural practices in terms of land use and agro-chemical application. The pressures exerted by society are transported and transformed in natural processes to manifest themselves in changes in environmental conditions.
- The State reflects the environmental conditions of natural systems using quantitative and qualitative indicators of physical phenomena (such as temperature), biological phenomena (such as fish stocks) and chemical phenomena (such as nitrate concentration in the water).
- The changes in the state of the environment then have impacts on social and

economic functions. In the present, case for instance, the costs of water treatment to reduce nitrate levels.

- Response refers to solutions, approaches, options or alternatives of WaSCs to compensate, ameliorate or adapt to changes in the state of the environment.

Figure 3-7 shows the DPSIR framework as applied during the fieldwork. As can be seen the DPSIR was not facilitated in its original sequence. The sequence was altered, because 5 pilot interviews (with University staff and students) indicated that the logical sequence of the DPSIR should commence with the description of impacts and their causes, followed by the investigation of the responses. The pilot interviews further demonstrated that questions containing words like drivers, pressures or state were difficult to respond to; rather why, who or where questions performed better in eliciting causes for perceived raw water quality problems.



**Figure 3-7: DPSIR as sent to the interview partners**

In addition, the interview protocol (Appendix II) required participants first to identify geographical areas where their organisation faced raw water (water resource) quality issues. Interviewees were then asked to group the geographical areas in types as they



felt appropriate. Subsequently, the physical and geographical characteristics of these areas were described by the interviewees. Then the DPSIR framework was applied. In a last step, the interviews explored in detail how specific responses were selected, why others were rejected, and which role the local physical and geographical characteristics played during the choice of alternatives.

Compared to the first fieldwork phase the DPSIR presented a more structured interview framework. This design was chosen to improve the comparability between interviews. A higher degree of comparability between interviews was essential to produce the outputs necessary to meet the research objectives. Furthermore, data were to be gathered in a single contact event of little more than one hour. Longer or more frequent inquiry was assessed to be infeasible or too risky, because of limited access to participant and the limited period of funding.

Methods such as problem structuring or causal mapping are alternative to the DPSIR (Ackermann *et al.* 2004; Belton & Stewart 2002). As the DPSIR they are suitable to investigate a problem and to detect causal relationship. However, problem structuring and causal mapping are time intensive and usually require more than one contact event. Moreover, these designs are less suitable for understanding the environmental context in which SCIs or other raw water quality responses take place. DPSIR on the other hand was specifically designed for this. Root cause analysis (Belausteguigoitia 2004) or impact pathway analysis (Rabl & Peuportier 1995) are alternatives to the DPSIR framework, which were designed to elicit environmental cause effect relationships. However, these methods (and in fact causal mapping and problem structuring) do not formally introduce the concept of impact or response. Hence, the DPSIR was more suitable for the central task of this study, which was to identify the relationship between multiple factors and their influence on causal processes as perceived by WaSC representatives. The DPSIR offered an opportunity to work from the perception of a problem back to its cause, and similarly to work from the perception of a problem forward to the solution (Figure 3-7).

### **3.5.1 Fieldwork**

In Phase two, 17 semi structured face to face interviews with 21 individuals were conducted from May to August 2009 (Table 3-2). Interviews were recorded with a

digital voice recorder and lasted between 40 and 90 minutes. The selection of interview partners was purposeful. All interview partners were responsible for water quality management and drinking water asset management and planning. Their responsibilities included the implementation of the Drinking Water Safety Plan (DWSP) approach (Chapter 4), ensuring compliance to drinking water standards and the protection of drinking water resources. WaSCs staff in these positions was likely to hold knowledge about the causes of raw water pollution and the action taken by WaSCs to resolve these problems, including SCIs.

Interviewees were identified through snowballing, during conferences and via internet search. To ensure all individuals held the knowledge necessary to answer the interview questions two documents outlining the aims of the research (Appendix III) and the interview questions (Appendix II) were sent to the interview partners, along with an opening letter asking them to assess their expertise against these documents. Through this process it became apparent that in a number of organisations no positions that unified all required characteristic existed. For instance, some interview partners were more familiar with surface water quality rather than ground water quality problems and responses. In other instances, different interview partners focused on different regions in a WaSC catchment or specific aspects of the business (coordination of activities - strategic, implementation of activities on the ground – construction, sampling, advice).

For the majority of WaSCs the different focus and knowledge of interviewees could be compensated for by interviewing two or more individuals. However, in a number of organisations (i.e. F, H, D) individuals that could provide the required addition insights could not be identified or accessed. In some of these instances it was suggested that the desired knowledge was not held within the organisation (i.e. H, D). For instance, catchments could not be described in detail or pressures and their causes were not known.

**Table 3-2: Distribution of interviews and interview partners across the population of WaSCs in fieldwork phase 2.**

WaSC	Number of interview	Number of interview partners
A	2	3
B	2	3
C	2	2
D	2	2
E	1	2
F	1	1
G	2	2
H	1	1
I	2	3
J	2	2
Total	17	21

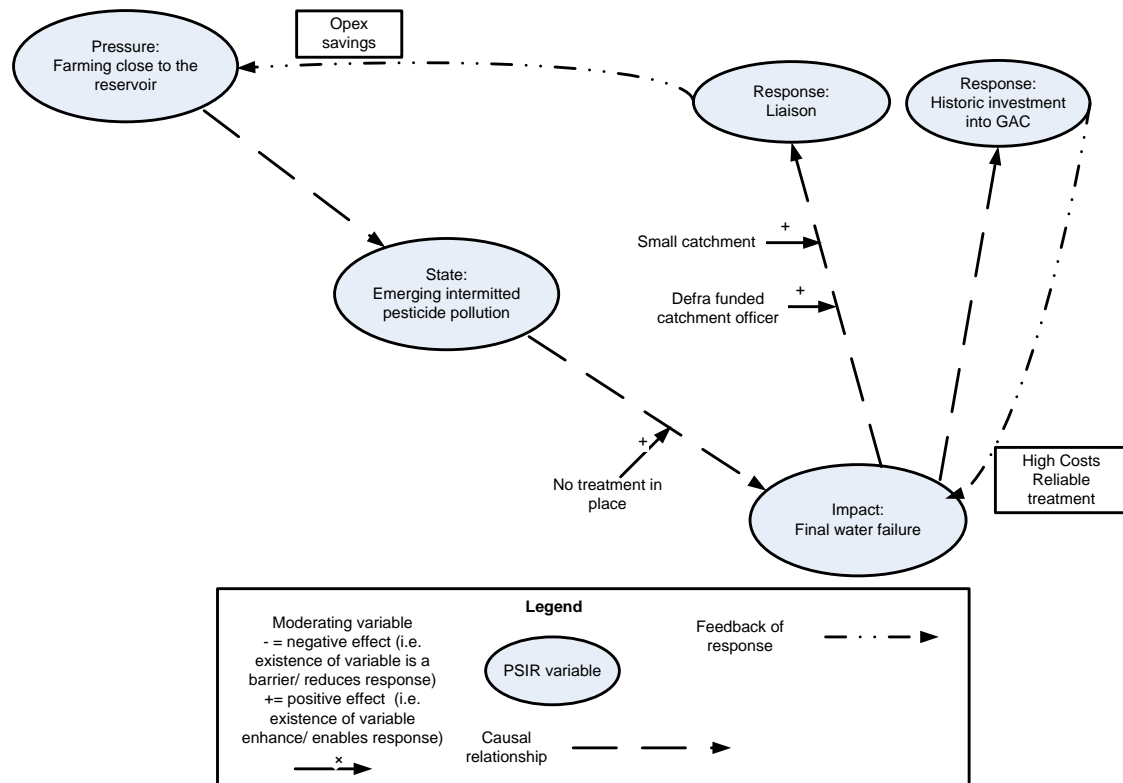
### 3.5.2 Interview analysis

The analysis of transcribed interview text used narratives, inductive and deductive thematic analysis. As in phase one all interviews were transcribed and imported into NVivo 8 for analysis.

#### Narrative and thematic analysis

In phase two, data analysis commenced with writing of narratives for each catchment area identified during the interviews. Narratives were written to reflect and summarise the interviews in a structured way. They contained information about roles and responsibilities of the interview partners, descriptions of catchments, raw water problems, proposed causes and responses to these problems as well as information about choices made.

Each narrative was supplemented with an influence diagram of the DPSIR (Figure 3-8). This graphical representation provided as summary of the written text. Drivers were not represented as the data gathered about drivers was limited. The narratives also provided a first insight into the factors that influenced causal relationships. The concepts of causal factors and ‘Moderating’ variables were used to elicit the factors influencing decision making and innovation. Moderating variables are defined here as variables which affect the relationship between a dependent and independent variable, but are themselves not altered (Van de Ven 2007; Whetten 2002). The outcomes of this approach were descriptions of the factors and their effects on planned raw water problem responses of WaSCs.



**Figure 3-8: Example of DPSIR moderating variable technological externalities and management objectives (note drivers are omitted in this figure as no direct evidence on drivers was gathered).**

**Thematic analysis**

Abductive thematic analysis was employed to determine the factors influencing the innovation decision process. Text was coded as a factor influencing the innovation decision making process when a causal relationship was expressed by the interview partner. In other words the text was isolated, if the interviewee indicated that aspects such as costs, assets, land use or any other feature influenced their decision. For instance (A): “Carbon footprints, sustainability, energy, WFD is driving us that way so a whole host, operating costs, customers bills, you know, it is just the right thing to, that’s what we should do.” Each code was given a label that reflected the coded text. The coding unit was here the smallest monothematic unit. In the example above this is a word or two words (e.g. operating costs). But coding units usually encompassed a sentence or paragraph.

The factors of influence were populated, through several iterations of this process and until saturation was reached (i.e. no new themes were detected). Subsequently these factors were allocated into the domains of factors of influence developed in Chapter 2,

namely: ‘Natural-Physical’ environment, ‘Regulatory-Institutional’ environment, ‘Organisational Characteristics’ and ‘Innovation Attributes’. The allocation criteria for factors into these domains are presented in Table 3-3. Apportioning of factors in these groups was ambiguous in a number of cases because the factors matched more than one allocation criteria. This ambiguity appeared to be a function of cross correlations between factors. In Chapters 6 and 7 these interrelationships will be exposed, thus accounting for the shortcoming of this allocation framework.

**Table 3-3: Criteria for allocating factors into factor domains (for more information about the factor categories see Chapter 2)**

<b>Factor category</b>	<b>Reference or statement indicating</b>
Natural-Physical environment	geographical circumstance, land use, hydrogeology
Organisation Characteristics	knowledge, organisational structure, assets owned by the organisation
Regulatory-Institutional environment	markets, regulation, laws
Innovation attributes	complexity (i.e. difficulty of adoption), trialability, relative advantage i.e. cost, observability

To differentiate types of SCIs an abductive coding process was employed. Types of SCIs were distinguished according to the following criteria:

- requirement on organisational knowledge (i.e. the level of detailed agricultural and catchment knowledge),
- method of intervention (i.e. direct or indirect involvement with farming community),
- financial commitment by the WaSCs (e.g. employ staff, sampling, compensation payment) and
- the scale of intervention (i.e. national, regional, catchment, individual farm).

Through deductive coding, the innovation decision process was described and determined at which stage of the innovation decision making process WaSCs were located at the time of interviewing. The innovation-decision making process model developed in Chapter 2 was employed as a coding framework. Text was considered to provide evidence for a process stage when the features described in Table 3-4 were detected.

**Table 3-4: Criteria for coding text as a stage in the innovation-decision process (i.e. ‘Agenda Setting’, ‘Choice between Alternatives’, ‘Reinnovation’, ‘Diffusion’ and ‘Routinisation’)**

<b>Process Phase</b>	<b>Evidence as a statement or reference to</b>
Agenda Setting	Reference or statement describing the identification of a problem or issues
Choice between Alternatives	Reference to alternatives to resolve the problem identified,
Reinnovation	Reference to design or adaptation of the organisation or the innovation to specific contextual features
Diffusion	Further adoption of an intervention within the organisation
Routinisation	Intervention as a standard response mechanism embedded in organisational practice

### Content analysis

The factors and process stages identified using the methods above were then integrated through proximity analysis (Table 3-5). Proximity analysis was applied to reveal co-occurrence of process stages and factors of influence. More precisely, proximity analysis revealed whether text coded as a factor has also been coded as an innovation-decision process. Thus this indicated where factors from each domain affect the innovation decision process. The matrix coding function in NVivo 8 facilitated this assessment, resulting in a recurrence count of each co-occurrence (example Table 3-5).

**Table 3-5: Example matrix of co-occurrence of factors in innovation-process stage for innovation attributes**

<b>Process stages</b>	<b>Trends and peaks</b>	<b>Hydrogeology</b>	<b>Source type</b>	<b>Catchment size</b>	<b>Land use</b>
Agenda Setting	10	1	0	0	0
Choice btw Alternatives	2	3	3	7	1
Reinnovation	1	3	2	6	0
Diffusion	2	0	2	1	0
Routinisation	0	0	0	0	0

### 3.6 Ethics

When using interviews as a method of inquiry researchers must be aware of their obligation to research subjects. The Social Research Association (SRA 2003) defines this obligation as:

*"Social researchers must strive to protect subjects from undue harm arising as a consequence of their participation in research. This requires that subjects' participation should be voluntary and as fully informed as possible and no group should be disadvantaged by routinely being excluded from consideration."*

The obligations towards the research subject were addressed in the following way.

### **3.6.1 Informants consent**

All interviews were conducted after permission to do so was obtained. Participants were informed of their right to refuse or to withdraw from participation. Any refusal or withdrawal was final and no further attempt was made to obtain consent. Furthermore, interviewees were asked for permission to take notes and voice record the interview. The recording device was turned off at any point during the interview if the researcher was asked to do so. Interview partners were also asked to complete and sign a consent form prior to starting the interview (Appendix IV). The purpose of this was to provide evidence that interview partners were informed about their rights, the research process and limitation to the access of data.

### **3.6.2 Deception**

When obtaining the interviewee consent it was important to provide honest and transparent insight into the purpose and the aims of the inquiry. To ensure transparency both fieldwork phases used an interview primer which was sent to the interviewee before consent of participation was obtained. The interview primers comprised brief descriptions of the research objectives, output, method of inquiry and an outline of the questions that would be asked during the interview (Appendix I, II & III).

### **3.6.3 Avoid undue intrusion**

Physical activities, intrusive questions or disclosure of information can cause physical and psychological harm (defined here as any form of emotional distress) or harm to the career of the interview partner. There was a low risk in this research for any physical harm to be inflicted during interviews. To pre-empt any harmful behaviour or questioning, the interview questions were carefully prepared and reflected on prior to the fieldwork. In this process consideration was given to the following:

- Are the questions intrusive and harmful to the interview partner?
- Attempt to place myself in the shoes of interviewees.

### **3.6.4 Protecting the interests of subjects**

Information revealed during the interviews can be harmful to the participants when made public. In the specific case of this research it was necessary to ensure that no

information was revealed which could cause harm to the individual or the organisation (i.e. financial loss, harm to the image of companies). Thus, data were codified at an early stage of the analysis process. In addition, any data collected during the interviews was only published with the consent of the interviewee. To ensure this, interviewees were provided with a copy of documents before publication. Publication only commenced if no objections to the content of the document were received.



# Chapter 4

## Source control interventions and WFD change

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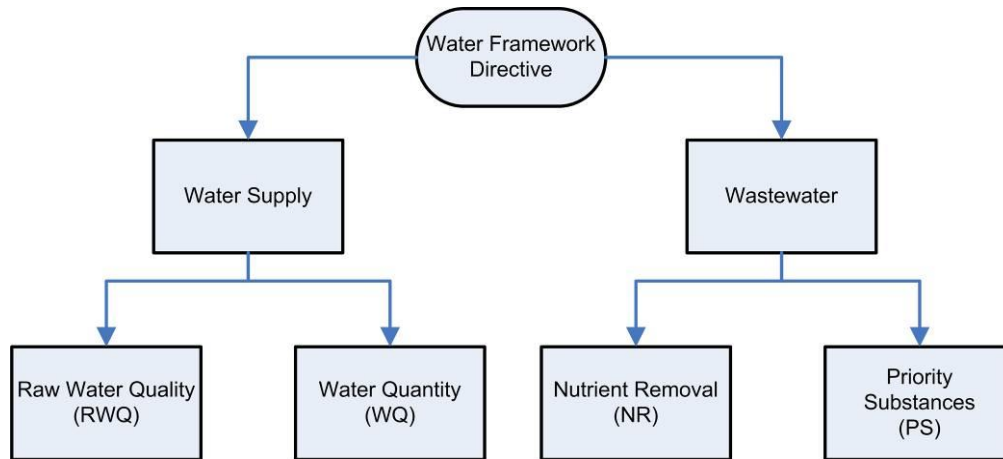
### 4.1 Introduction

This Chapter reports the results of the first fieldwork phase. The purpose of this Chapter is to demonstrate how the initial explorative research phase contributed towards the development of the final research questions. To do so, the key water and wastewater management challenges perceived by WaSC representatives in terms of issues and problems will be described. Furthermore, the proposed responses to these problems will be populated and described. The investigation centred on the changes stimulated by the WFD as the general, broad, framework of enquiry (Chapter 1). Due to the broad focus of this first inquiry this Chapter does not solely focus on SCIs, but rather investigates SCIs in the context of other WFD change issues.

In Section 4.2 & 4.3 WaSC representatives' interpretations of the WFD in terms of change issues and problems will be presented. Responses to the WFD are classified and described in Section 4.4. Sections 4.3 & 4.4 also investigate the variety and the recurrence of WFD problems and proposed responses across the population of WaSCs. Following on from this the findings are discussed (Section 4.5) resulting in the development of the final research agenda (Section 4.6).

### 4.2 WaSCs - perception of WFD change issues

Interviewees' conceptualised WFD implementation pressures as issues related to wastewater and water supply (Figure 4-1). 'Water Supply' comprised activities that related to the delivery of clean water to the customer, while 'Wastewater' included activities associated with the collection, treatment and discharge of effluent.



**Figure 4-1: WFD change issues perceived by WaSC representatives.**

In the analysis, ‘Water Supply’ was further distinguished into ‘Raw Water Quality’ management (RWQ) and ‘Water Quantity’ management (WQ). RWQ concerns the quality of the water environment in general and water quality at point of abstraction more specifically (relevant WFD Articles 1a, b and 7). WQ encompasses issues about flows of water in the environment, abstraction and demand (relevant WFD Article 1c). Aspects concerning wastewater treatment were divided into Nutrient Removal (NR) Priority Substances (PS). NR describes efforts to reduce emission of nutrients and associated substances (COD, BOD<sub>5</sub>, TSS, N and P - relevant WFD Article 10). PS comprises efforts to phase out chemicals harmful to human health (relevant WFD Article 16 and Annex X).

Not all WFD change issues were referred to with equal intensity (Figure 4-2). For instance, WaSCs I, A and E addressed RWQ issues more intensively than other issues. WaSC F on the contrary exhibited a clear focus on WQ. Other organisations were more balanced in their reference to particular issues. For example, WaSCs J addressed all issues, except WQ, relatively frequently. Similarly, D and H perceived RWQ and NR with similar strength, but focused less on WQ and PS.

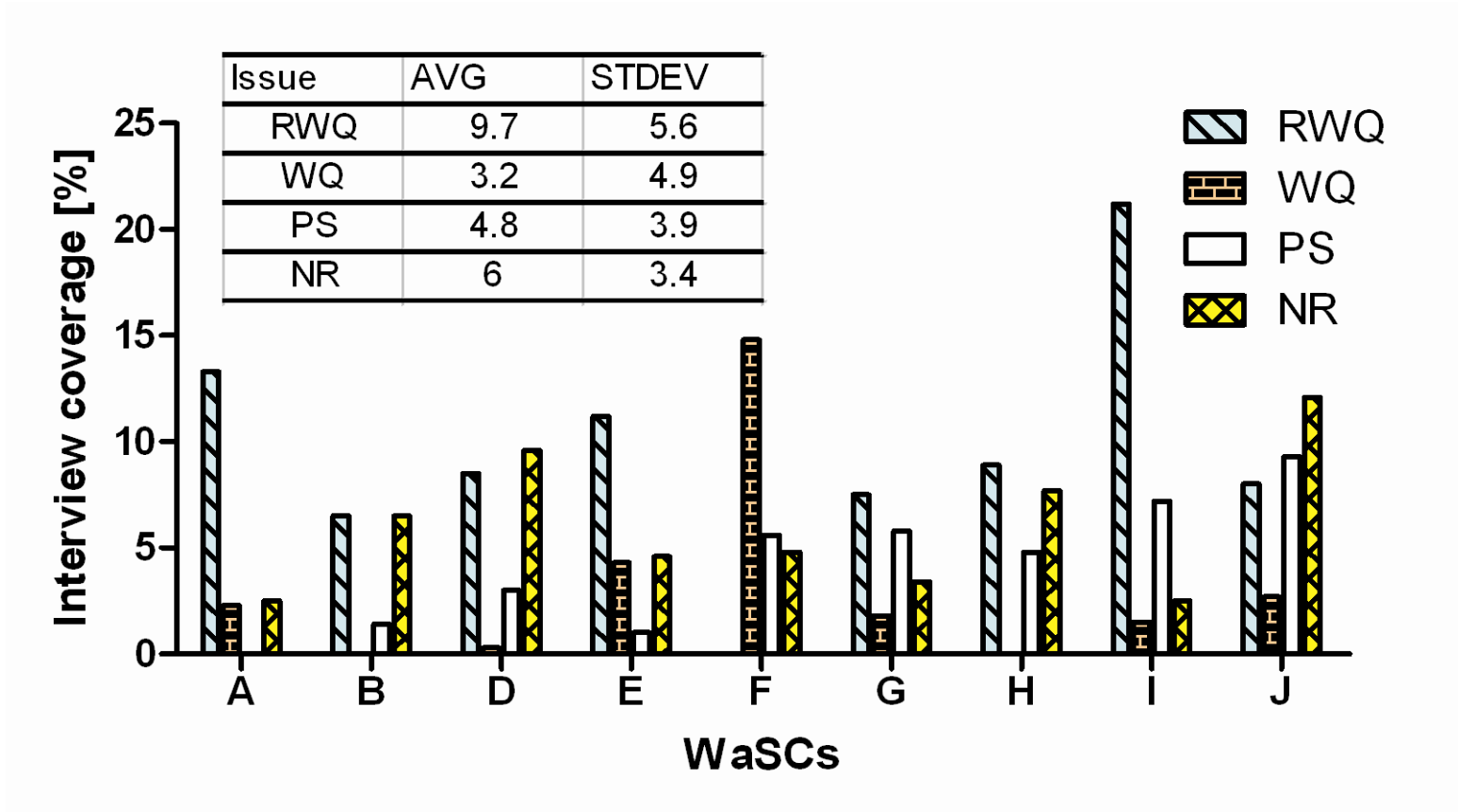


Figure 4-2: Coverage of the four WFD implementation issues in the interviews and descriptive statistics (RWQ – raw water quality, WQ – water quantity, PS – priority substances, NR – nutrient removal, AVG – average, STDEV – standard deviation)

More detail about the prevalence of issues was revealed by the descriptive statistics (Figure 4-2). RWQ is, on average, the most frequently mentioned WFD issue. The average coverage of RWQ across the sample is 9.7%. The issues PS and NR show mean values of 4.8% and 6%, hence they can be considered to be perceived as less significant to WaSC representatives. The least coverage with a mean of 3.2% was found for WQ, which constituted a third of the coverage of RWQ.

The standard deviations suggest that there was more consensus about wastewater issues than water supply issues. The highest deviation from the mean was found for the supply issues RWQ and WQ, implying that responses showed a greater variety. The maximum coverage in the sample of 20% was detected for the issue RWQ (WaSCs I). The second highest value was 13% (WaSC A). The lowest value was associated to company B with 6.5%. Finally, company F did not address RWQ issues during the interview.

Strong positive and negative outliers were detected for WQ. Company F showed a coverage three times higher than the remainder of the sample (i.e. 15%). Reference to WQ issues could not be detected for two organisations (H, B).

The standard deviation for both wastewater issues is comparatively low (PS 3.9, NR 3.4). In both instances company J shows the highest coverage (PS 9% NR 12%). Likewise company A is located at the other end of the spectrum in both instances, not mentioning PS issues and, together with company I, attaining the lowest coverage of 2.5% for NR.

### **4.3 WFD problem perception**

The WFD implementation problems indicated by WaSC representatives are now presented for each issue.

#### **4.3.1 Raw water quality (RWQ) problems**

Interviewees viewed the ‘holistic perspective’ of the WFD as an opportunity to improve water quality and therefore to save water treatment costs. Specifically, water safeguard zones required under Article 7 of the WFD were considered as an opportunity to

achieve such cost savings (J): *“I think Article 7 is a big opportunity for us, in terms of reducing our water treatment costs in the future “.*

However, concerns were raised whether this new approach can be implemented under the present regulatory framework. Ofwat was the prime focus of criticism. The enforcement of the ‘polluter pays’ principle as well as the asset based funding mechanism were specific examples of the current regime's policy constraints. More specifically the polluter pays principle in the WFD states that pollution should be rectified where it arises (WFD Article 9). Ofwat followed this principle and did not permit WaSCs to fund SCIs through customer bills. Asset based funding arises because Ofwat assesses company efficiency and allows returns based on the cost of capital, thus may encouraging asset investment rather than investment into SCIs (Allan 2006; Cave 2009 E): *“The problem we’ve got with Ofwat is that their system is designed to fund us to improve our assets...So if we go and invest in third party land or third party activities which we don’t own, then we’ve effectively lost the money...”*.

RWQ problems were also expressed as related to diffuse pollution. Here the gains that can arise from the improvement of environmental water quality were not expressed. Problems were rather externalised, emphasising the role of agriculture in the pollution of the aquatic environment, as one WaSC representative formulated it (D): *“...diffuse pollution from agriculture will be present. That's probably from our point of view a slightly lower order, because we're not in the firing line”*.

Uncertainty was often expressed as a hindrance to the implementation process of the WFD, which was considered not to be transparent enough and lacking in measurable targets (G): *“Article 7 is exercising us a lot. What does it mean for the upstream catchment?”*. Also WaSCs (J) *“organisational culture of treatment and supply”* rather than environmental management on a catchment scale was considered inadequate to tackle water pollution issues effectively.

### **4.3.2 Water quantity (WQ) problems**

Water quantity problems arising for the WFD included the impact of abstraction on protected sites and the associated reduction of abstraction licenses: *“The WFD is coming along and pretty much all our licenses are under review...”* (F).

However, it was also argued that the WFD brings the opportunity to improve river flows, which will secure water availability and contribute towards a better water quality in the future. As a result reducing treatment costs and ease of achieving discharge consents: “...if you have things right in terms of flow...then it helps to achieve consents, because you have more dilution” (J). Exogenous pressures such as increasing household demand, demographic changes and climate change were further viewed as factors generating increasing water consumption and hence the need to abstract increasing volumes of water from the environment.

### **4.3.3 Nutrient removal (NR) problems**

Interviewees indicated their concern that more stringent requirements for nutrient removal were likely to arise as a result of the ‘good ecological status’ objective (i.e. an integrated assessment of biological, chemical and physical water quality – WFD Article 4) of the WFD. However, the way this was expressed in terms of problems varied. Companies pointed towards the need to invest in technologies for phosphorous and nitrogen removal. Other companies indicated concerns about the uncertainty of required standards and treatment technologies: “I think at the moment we don't know which standards to achieve.” (I). The representatives of other WaSCs viewed higher treatment requirements as a driver for increased CO<sub>2</sub> emissions (J): “If we are forced down the route of having to implement new solutions, install new plants, that's going to have an impact on energy consumption, and clearly an impact on carbon emissions”.

### **4.3.4 Priority substances (PS) problems**

Across the sector, a lack of appropriate technology as well as scientific and engineering knowledge about PS was a recurring problem. The detection of PS and the approach to treatment were specific problems of concern. Statements similar to the following occurred throughout the interview survey: “...currently we are technically not able or we don't know for certain how we actually treat this kind of substance (J)”. As in the previous statement uncertainty was a problem that occurred several times in conjunction with concerns about knowledge and technology. This problem not only included a lack of knowledge but was also focused on missing standards and criticised the WFD implementation process. WaSC representatives indicated further that technological

adaptation will “*drive huge expenses in the industry*” (H) and potentially increase CO<sub>2</sub> emission.

#### 4.3.5 Other WFD implementation problems

The discourse about WFD implementation revolved around the mismatch between the WFD and the AMP 5 funding period: “*In particular the first round [of the WFD], doesn't fit very well with our funding structure...we could be going into AMP 5, without a clear view of what we're required to do for the WFD.*” (I). This is because “*the Programme of Measures doesn't come out until after*” water companies have finalised their asset management plans, which bears a commercial risk, as investment might be underestimated. However, one interviewee perceived the mismatching cycles as a constraint, but also argued that: “*Our engagement with the process [of establishing WFD measures carried out by the EA] means that we can get a reasonable insight into the kind of issues that are likely to be addressed*” (D).

Uncertainties related to the definitions of requirements and responsibilities were another concern associated with WFD. For instance, the definition of good ecological status and associated definitions, such as disproportionate costs (WFD Article 4a), were unclear (A): “*To understand disproportionate cost you need good estimations of both the costs and the benefit. Economic valuations of benefits are very woolly; it's a very new science at the moment.*”

Interviewees also highlighted the conflicts arising from the interplay between the WFD and other EU directives. The clash between Habitats Directive and WFD was a specific case of concern for about half (five) of the interviewees. The WFD requires member states to conduct a cost assessment of implementation measures and allows for extension of deadlines as well as achievement of less stringent objectives based on disproportional costs (Article 4.4 and 4.5, 4.7). On the contrary, the Habitats Directive (EC 1992), which requires the protection and restoration of biodiversity at designated sites, does not include cost considerations. It leaves the potential for implementation of disproportionate costly alternatives: “*Sometimes the Habitats Directive within the WFD can have more of an impact on us (D)...there is no delegation for cost, technical difficulty or anything else, so we have got Habitats Directive which is being wheeled out*

*at the moment to take away just under 6Ml of water and there is no appeal mechanism against that...and nowadays it costs between £ 3million – £5 million per Ml to restore it. (E)”*

Moreover, the Urban Wastewater Treatment Directive or UWWTD (EC 1991) presents a pressing concern for WaSCs in England and Wales. This Directive required member states to put in place specific levels of treatment and infrastructure to achieve effluent quality standards. In areas designated as nutrient sensitive higher infrastructure and treatments obligations need to be met. In the view of the EC, several coastal waters surrounding the British island (i.e. Wash, Humber and Thames estuaries, North Coast of Wales, South Coast of Scotland) should be designated as nutrient sensitive under the UWWTD (EC 2007b). If the appeal of the UK government against this decision fails, it would result in the designation of large river stretches as nutrient sensitive (personal communication with company A). The investment to meet the associated treatment and infrastructural targets could be substantial (A): *“...if that would be designated as sensitive we would have to put nitrate removal in for about half of our population equivalent. That would cost about £1.2 billion of capital and a massive amount of operating expenditure.”*

#### **4.3.6 Variety of problem perception**

Table 4-1 shows that the set of WFD problems perceived were, with exception of the PS issue, heterogonous cross the population of WaSCs. Not once did two organisations exhibit the same problem perceptions across all issues. Instead, it appeared that there were clusters of organisations with similar problem perceptions for specific issues. For instance, WaSCs A, E, I and J were similar in terms of perceptions about RWQ problems. They perceived benefits from the WFD and found the legal framework to be constraining. Four organisations point towards additional investment needs arising from the WFD for NR. Smaller clusters are detected for WQ. Three organisations were concerned about the impact of abstractions, another three perceived benefits from improved flows, yet another three did not express any WQ problems.



**Table 4-1: Problem perception of WaSCs across the WFD change issues (abbreviations CC=Climate Change).**

	Water Supply					Wastewater					Overall							
	RWQ		WQ			NR		PS										
	Benefit	Diffuse pollution	Business culture	Inadequate policy	Uncertainty	Impact of abstraction	Increased demand	CC water stress	Benefits from improved flows	Investment	CO <sub>2</sub> emissions	Uncertainty	Discharges to GW	Uncertainty	Inappropriate technology	CO <sub>2</sub> emissions	Investment	
A	X			X				X	X	X								5
B		X		X						X				X				4
D		X			X	X				X	X		X	X				7
E	X			X			X	X	X					X				6
F						X	X				X					X		4
G	X	X												X	X			4
H					X					X				X		X		4
I	X			X	X	X					X			X				6
J	X		X	X							X	X		X		X		7
N=9	5	3	1	5	3	3	2	2	2	4	2	3	1	2	6	1	2	

PS was the only issue that showed relatively homogenous problem perceptions. Seven of the nine investigated companies expressed concerns about inappropriate technologies and uncertainties.

A general finding is that investment was more of a concern for wastewater issues rather than for water supply issues (Table 4-1). Likewise uncertainty or technological inabilities are emphasised for wastewater. For water supply positive incentives arise from the WFD. In this vein, wastewater is dominated by negative financial incentives while for water supply financial benefits play a more important role. This finding was supported by a representative of company A: “*You have the potential benefits on the drinking water side, hopefully we can realise that through the Article 7 requirement. But most of the risks for us are on the wastewater side, so that is where it sits at the moment. (A)*”

#### 4.4 Response options

Response options to the WFD were classified as follows:

- Diagnosis – Activities to better understand and define a problem through investigation of the properties of a system, aiming to identify the character of viable response options (Mintzberg & Raisinghani 1976). Examples: monitoring and modelling;
- Process R&D – As distinct from the diagnosis process R&D is not focused on understanding systems, but rather on improving or installing technical processes or artefacts. Examples: development of new treatment technologies and their installation;
- Management - Non technical interventions that seek to change a process, not excluding the use of technology to achieve management goals. These include SCIs and catchment management approaches. Example: metering to reduce water consumption, advising farmers on land management options;
- Change legal framework – Activities aiming to influence and thus change the legal framework under which WaSCs operate. Examples: lobbying policy, collaboration with policymakers;
- Wait and see - Deferral of action (see Berkhout *et al.* 2006). Examples: delay action until legal requirements are specified.

#### 4.4.1 Raw water quality (RWQ) responses

The findings suggest that there are three response options for RWQ, i.e. ‘diagnosis’, ‘management’ and ‘change legal framework’. Managerial options (i.e. SCIs) focused predominately, but not exclusively, on the farming community. “*We do a lot of catchment management work whereby we help farmers to apply for high-level stewardship schemes and the agri-environment schemes.*” (I). Frequently, these managerial responses focused on liaising with land managers or farmers to improve water quality at the point of abstraction thereby reducing water treatment costs (opex and capex). Two managerial response mechanisms could be distinguished, integration of pollution source control measures into organisational decision making and project based response. Evidence for integration into organisational decision making was directly expressed by WaSCs staff (e.g. “*All these - threats to reservoirs - need different collaborative decision making and that is what we do.*” WaSC E) and manifested in the employment of agricultural extension workers, readily available cost benefit analyses

and close cooperation with local green NGOs (WaSCs: E and I). Project-based managerial responses were single or time limited activities (WaSCs: A, J and G).

Diagnostic response options aimed to identify sources of pollution and to model their impact on the aquatic environment on a catchment scale: *“What is needed is a catchment based approach, now possible by catchment based monitoring and modelling.”* (J). Four WaSCs explained how they influence policy (i.e. ‘Change legal framework’) through successful implementation of case examples: *“The techniques and methodologies have been adopted by Defra for the catchment sensitive farming work”* (E); *“Ofwat were not keen on this approach [working with farmers to improve groundwater quality], it was funding the polluter and using customer money to support agriculture. But we've got a lot of support from the DWI. They were really keen that we actually tried this out. But at the end of the day if this approach doesn't work, we will still have to build these treatment plants.”* (I). Other organisations suggested lobbying to change the legal framework: *“I think you probably have to review the common agricultural policy.”* (B). Finally, one organisation indicated a “wait and see” approach, deferring decision making until the PoMs will be available (C): *“The driver behind all of this isn't necessarily the issue as such it is how it is addressed in terms of Programs of Measures.”*

#### **4.4.2 Water quantity (WQ) responses**

The response options considered for WQ problems are ‘diagnosis’, ‘management’ and ‘process R&D’. Here diagnosis is concerned with modelling and assessing flows and their impact on water quality. Management is aimed at reducing water consumption through managing demands using education, metering or a combination of both: *“So we need to encourage people to change their behaviour which we can do if they are on a meter.”* (E). Another response was to manage the upstream catchment in order to improve flows and water quality: *“Things like catchments sensitive farming, improved infiltration, reduced runoff; you address quantity issues but you also potentially address quality issues by losing less water straight out into the sea.”* (A). Lastly, process R&D was used as a response to address the design of technological options to increase water supplies: *“How would you replace that water? The only alternative is to continue down desalination routes...”* (F).

#### 4.4.3 Nutrient removal (NR) responses

Nutrient Removal responses focused on influencing the legal framework either through joint projects with regulating authorities: *“In the trade effluent we are working with Defra to develop the program of measures....”* (G) or negotiation with the regulator *“We said hold on, this is not sensible [the discharge consent] you know the discharge is very close to the mouth of the river”* (B). Other WaSCs specifically lobbied for change in trade effluent regulations or for a ban of phosphorous in detergents.

Furthermore, WaSCs argued for a strategy that aimed to improve treatment processes (process R&D) to meet tighter standards. An important criterion of these process innovations was to reduced CO<sub>2</sub> emissions or energy costs: *“The key thing would be what we can innovate to reduce energy costs [of treatment]”* (D). Furthermore, two organisations pointed towards diagnostic activities such as modelling of discharges or investigations into implementation of phosphorous source control measures (H): *“And this year we are actually leading a project on source control of phosphorous.”*

Management activities such as maintenance of sewage treatment works: *“maintenance spend is actually WFD spend...make them [treatment works] work at full design spec that would make an improvement.”* (H) or management of sewers to improve treatment efficiency of sewage treatment works (E only): *“We want to separate all property and surface water drainage and foul sewers because that reduces the amount of sewage that we get when it rains... that means you can do a better job treating”* were proposed as response options. Furthermore, catchment consenting, an approach where discharge limits are set on a catchment rather than individual sewage treatment works basis, was also proposed by one organisation: *“If you are looking at abstractions, discharges and diffuse pollution separately you will come to a point where you can't make decisions any more unless they are all integrated.”* Lastly, a strategy of deferral (wait and see) was proposed: *“We expect that probably in the first round we will be doing more of the same sort of things...”*(F).

#### 4.4.4 Priority substances (PS) responses

The major response to PS problems is to change the legal framework; predominantly aiming to control PS at source. Lobbying was indicated as one way for achieving policy change *“Do they [government] not want to start and think about where the dangerous*

*substances are being used in the first place*". Alternatives were evidence based approaches to influence regulation: "...you want to influence regulation so you get into a position of influence...you use research as much as you can and still work on action" (G). 'Process R&D' and 'Diagnosis' were seen as activities that took place simultaneously to driving policy change.

'Process R&D was experimental, almost like diagnosis, aiming to understand the fundamentals of PS detection and removal "*for some of the priority hazardous substances, the value of the environmental quality standard is actually less than the limit of detection of the analytical method*"; "*And we are doing work on a pilot plant as part of this five year investment plan, looking at that with our R&D department.*" (D). Diagnosis was a descriptor for research that focuses on isolating the origin and fate of PS in the wastewater system: "*We have been heavily involved in the research on PS and their source...*" (D). Education and new approaches to trade effluent charging were proposed as managerial measures aiming to change behaviour: "*We have to make sure that people are aware of it...and education that they cannot put certain kind of things down the sewer. We are looking at how trade effluent is being charged.* (F)"

#### **4.4.5 Variety of response**

The mix of responses along the four WFD change issues varies significantly across the sector and no organisation proposed the same set of responses (Table 4-2).

Similar to the problem perceptions, there was no obvious response pattern. It appeared that there were types of responses preferred by groups of companies. For instance, under the change issue RWQ, five companies used management responses, while the remaining four WaSCs did not indicate this. Rather they relied solely on 'Change of the legal framework', 'Diagnosis', 'wait and see', or a combination of this. Closer investigation further revealed that companies which indicated management responses also tended to engage in 'Diagnosis'. NR issues showed a mix of responses, with preference for 'Change of legal framework' and 'process R&D'. Somewhat more homogenous responses were detected for PS and WQ. For PS, it was found that 'change of legal framework' was the dominant response option. Likewise, the majority of WaSCs did not propose any response to water quantity issues and just one organisation indicated a 'process R&D' response.

**Table 4-2: Responses of the population of WaSCs across the WFD change issues.**

	Water Supply				Wastewater				Overall							
	RWQ		WQ		NR		PS									
	Diagnosis	Change legal framework	Management	Wait and see	Diagnosis	Process R&D	Management	Diagnosis	Change legal framework	Process R&D	Management					
A			X					X				2				
B		X						X	X			3				
D	X			X				X	X	X		6				
E	X	X	X				X		X	X		8				
F					X	X	X			X	X	8				
G	X			X				X	X			5				
H		X							X			3				
I	X	X	X		X					X		7				
J	X			X		X				X		6				
N=9	5	4	5	1	3	1	3	2	5	3	2	2	2	6	5	1

A general conclusion from these data was that water supply problems are mainly responded to through ‘Diagnosis’ and ‘Management’. On the other hand, wastewater problems are approached mainly through actions seeking to ‘Change the legal framework’ and ‘process R&D’. However, ‘Diagnosis’ is of relevance for wastewater issues too. In particular for NR, diagnostic responses were of importance, while under PS process R&D and influences on the legal framework dominated.

#### 4.5 Relevance of RWQ and SCI responses

RWQ change issues showed the highest high mean values and standard deviations in the coverage assessment. From this it can be concluded that RWQ issues are of variable, but significant concern to WaSCs. Maybe more noteworthy however are the results obtained for WFD responses. These findings indicate that the WFD was more successful in stimulating innovative approaches to water supply rather than to wastewater arrangements. This is so because for the water supply issues, RWQ and WQ, responses were detected that contained aspects of the new water management approach (Chapter 1). Of specific interest for this thesis is that source control through integration of land and water management was put forward by a number of organisations. In addition, desalination, a technological innovation, was proposed by one organisation as new response mechanism.

Contrary to the findings for water supply, few organisations referred to new technologies or fundamentally new approaches for the wastewater issues. There was nearly (exceptions E, J) no reference to membrane technologies, decentralisation or wastewater reuse, which are innovations advocated as part of the new water management paradigm (Mitchell 2006; Niemczynowicz 1991).

Furthermore, the evidence suggested that two types of SCIs can be distinguished, namely project based SCIs and SCIs which appeared to be part of the standard response of WaSCs. What were the factors responsible for the development of two different SCIs types by WaSCs in E&W? And, what can explain the difference in response to water supply and wastewater issues? These questions will now be addressed.

#### **4.5.1 What can explain the difference in response to water supply and wastewater issues?**

In the majority of cases, WaSCs argued that the national regulatory framework needs to change to stimulate innovation in wastewater. For instance, it was mentioned that source control of phosphorous is best achieved through a ban of phosphorous in detergents or zinc in skin creams. In the few instances where innovative wastewater management solutions were mentioned (e.g. SUDS and catchment consenting) regulation was also found to be a constraining factor.

Water supply innovation also faced regulatory constraints. In the case of SCIs the enforcement of the polluter pays principle by Ofwat constrained WaSCs ability to fund land management activities. Furthermore, benefits likely to arise from land management activities are often long term and could not be accounted for in the five year funding cycle of WaSCs. Similar conclusions were drawn by Andrews (2003a) who suggested that the most significant barrier for SCIs implementation was the economic regulation in E&W, which does not allow costs for SCIs to be passed on to customers.

Hence, regulatory constraints alone cannot explain why innovations, such as SCI, were more readily taken up for water supply issues rather than wastewater issues. A potential explanation can be offered when climate change as a selection pressure is taken into account. Climate change and associated CO<sub>2</sub> emissions were often perceived to be in conflict with the demands of the WFD for higher, more energy intense treatment

standards. Pollution source control on the other hand has the potential to reduce energy demands for pesticide, nitrate or dissolved organic carbon (often associated with water colour) removal, while requiring little investment. Likewise, SCIs can, in specific circumstances, assist in meeting WaSCs conservation interests (such as those driven by the Habitats Directive), through restoring habitats, reducing pollution and ameliorating summer low flows. This finding could provide evidence for the argument that to stimulate pro-environmental change and innovation, perception of policies, financial interest and other force must converge (see Berkhout & Green 2002; Kagan *et al.* 2003; Smith *et al.* 2005).

Another explanation can be offered when considering the past investments in the water sector. The UWWTD (EC 1991) required significant wastewater asset investments in the in the 90s and the early 21<sup>st</sup> century. For instance, it required all agglomerations (population equivalent > 2000) to have a sewage collection system and sets out specific wastewater treatment targets. The investment (unintentionally) encouraged by the UWWTD was characterised by centralised solutions to wastewater treatment, more closely associated with the water management paradigm of throughput, conveyance and treatment rather than one of recycling, reuse and decentralisation. Hence, it is possible that WaSCs are still locked into their past investments. The opportunity for innovation may therefore arise when assets approach the end of their useful life (see also Chapter 8).

It further appeared that the innovative responses were occurring where there was a more immediate opportunity for cost cutting, financial gain or simply urgency. This corresponds to Geels' (2006) finding that local factors influence the technical and economic viability of change options. The desalination plant implemented by one particular WaSC was an example for the site specific nature of responses. In addition to the influence of location, innovative wastewater treatment solutions (e.g. catchment consenting) were constrained, because they appeared either not yet possible for regulatory reasons, not yet financially attractive for particular WaSCs or possibly not yet technically understood sufficiently. The last two aspects were especially relevant for PS responses, as was evident in the frequent reference to diagnosis and process R&D. Lastly, it could also be demonstrated that 'Organisational' factors such as the preference



for treatment played a role in fostering similar technological trajectories. However, there was no immediate evidence that could explain why this would lead to differences between water supply and wastewater approach. Literature suggests that the framing of a problem can have significant impact on environmental responses of organisation. Sharma (2000) found that the implementation of pro-active environmental strategies was more likely in organisations where managers formulated problems opportunities. The findings of the present investigation showed that water supply issues were perceived as opportunities by many WaSCs, while wastewater issues were always viewed as problems. Hence, Sharma's (2000) findings may offer a perspective where the problem perception of water supply issues leads to more innovation in water supply.

#### **4.5.2 What are the factors that are responsible for the detection of different types of SCIs?**

At this stage of the research in can only be hypothesised as to factors responsible for the detection of different SCIs types. One hypothesis is that the detected SCIs types present different development stages of an innovation. Another hypothesis is that these different approaches have developed as a result of favourable environmental conditions. Lastly, these types could have been chosen to fit organisational characteristic. Indeed a fourth proposition could be made, namely that the SCI types are a representation of a combination of all three factors.

When SCIs are viewed in terms of the innovation decision making process, project based responses and integrated responses maybe understood as the same innovation at different stages of development. This view suggests that the project type is symptomatic for WaSCs which are in the process of testing and 'Reinnovating' SCI. In the language of the innovation-decision making model these WaSCs are therefore in the 'Reinnovation' phase. Contrary to that, the integrated type of RWQ responses would indicate a SCI which was widely applied throughout the organisation. According to the innovation decision making model this would thus signify 'Diffusion' across the organisation or even 'Routinisation'. In this framework WaSCs which did propose SCIs as a response could be considered to have not started this innovation decision process, they were either not aware of this response option or did choose not to engage in this type of response.

An alternative explanation for the variety of SCI types might be sought in ‘Natural-Physical’ and ‘Organisational’ factors. One line of argument is that different geographical or spatial conditions favour the adoption of certain SCIs types. That is, in certain circumstances specific types of SCIs may offer an advantage, while in other situations these advantages do not materialise, because of differences in geographical or spatial conditions (for examples see Chapter 6). In the case of WaSCs this could imply that organisations A, J, G found favourable conditions only at isolated sites, while WaSCs I and E found favourable conditions in most of their catchments. Alternatively, an explanation could be sought in the differences between organisations in terms of structure, knowledge, managerial attitudes, size etc. In this case the argument is that different design types of SCIs were selected because they better match existing organisational structures, knowledge, management objectives. This idea is developed in Chapter 8 when discussing the different types of SCIs designs detected in the phase two of this study.

#### **4.6 Summary - a research agenda**

The major purpose of this Chapter was to report on the first research phase and to develop a research agenda for the second fieldwork phase. The rationale for this flexible design was set out in the previous Chapter 3.

It was found that RWQ problems and associated SCIs are of concern to WaSCs in E&W. RWQ issues were shown to attain on average the highest interview coverage, recurred frequently and also exhibited rich responses. Furthermore, results indicate that responses to raw water quality issues undergo a change and innovations orientated on the new ideal of more integrated water management are being adopted by WaSCs. Therefore, the results of this first research phase indicated that further research into the development of SCIs in E&W presented an opportunity to observe and describe change in water management towards more integration and sustainability.

The findings of this research phase already hint towards the responses to research question I and II. Two different types of SCIs were found to be implemented by WaSCs. The reasons for observing these different types can however only be

hypothesised at this stage of the study. In the next Chapter types of SCIs will be distinguished using the interview data from the second research phase.



# Chapter 5

## Source control intervention types and the innovation decision process

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### 5.1 Introduction

The purpose of this Chapter is to show differences between WaSCs in terms of the innovation decision process stages and in terms of the types of SCIs adopted by them. The structure of the Chapter follows the innovation decision making framework (Chapter 2). Each Section responds to a specific question:

- **Section 5.2 ‘Agenda Setting’**  
*What are the raw water quality problems WaSCs in E&W face?*  
In this Section the raw water quality issues of concern to WaSCs are being defined and enumerated.
- **Section 5.3 ‘Choice between Alternatives’**  
*Which WaSCs chose SCIs as a response to raw water quality issues and what were the alternative responses considered?*  
In this Section the responses to raw water quality issues proposed by WaSCs are set out. Then it is shown which WaSCs chose to adopt SCIs. Finally, the purposes of SCIs adopted in E&W is outlined.
- **Section 5.4 ‘Reinnovation’**  
*What are the different types of SCIs designs WaSCs in E&W have implemented or are considering?*  
In this Section SCIs designs (types) are defined and described.
- **Section 5.5 ‘Restructuring’**  
*Do WaSCs as an organisation adapt to SCIs?*  
In this Section evidence is provided to show which WaSCs have set up departments and developed relevant expertise to implement SCIs.
- **Section 5.6 ‘Diffusion’**  
*Is there evidence that WaSCs begin to adopt SCIs more widely across the organisation?*  
In this Section it is evaluated whether WaSCs did adopt SCIs more widely within their water supply areas.
- **Section 5.7 ‘Routinisation’**  
*Have SCIs become part of WaSCs standard response mechanism?*  
In this Section it is shown which WaSCs can be considered to have turned SCIs into routine operations.

Table 5-1 provides an overview of the findings presented in this Chapter. It shows where WaSCs can be located in the innovation decision process. All WaSCs perceived raw water quality issues, inferring that water quality is on the agenda of WaSCs. Eight WaSCs chose SCIs as a response alternative and were found to be in the process of implementing or planning designs. Of these eight, three organisations provided evidence for ‘Diffusion’ and four for ‘Routinisation’. One WaSC appeared to routinise without intra-organisational ‘Diffusion’. While for another two companies ‘Routinisation’ was inferred from secondary evidence (i.e. departments, time of involvement). Next each of these innovation-decision phases will be described more closely, beginning with ‘Agenda Setting’.

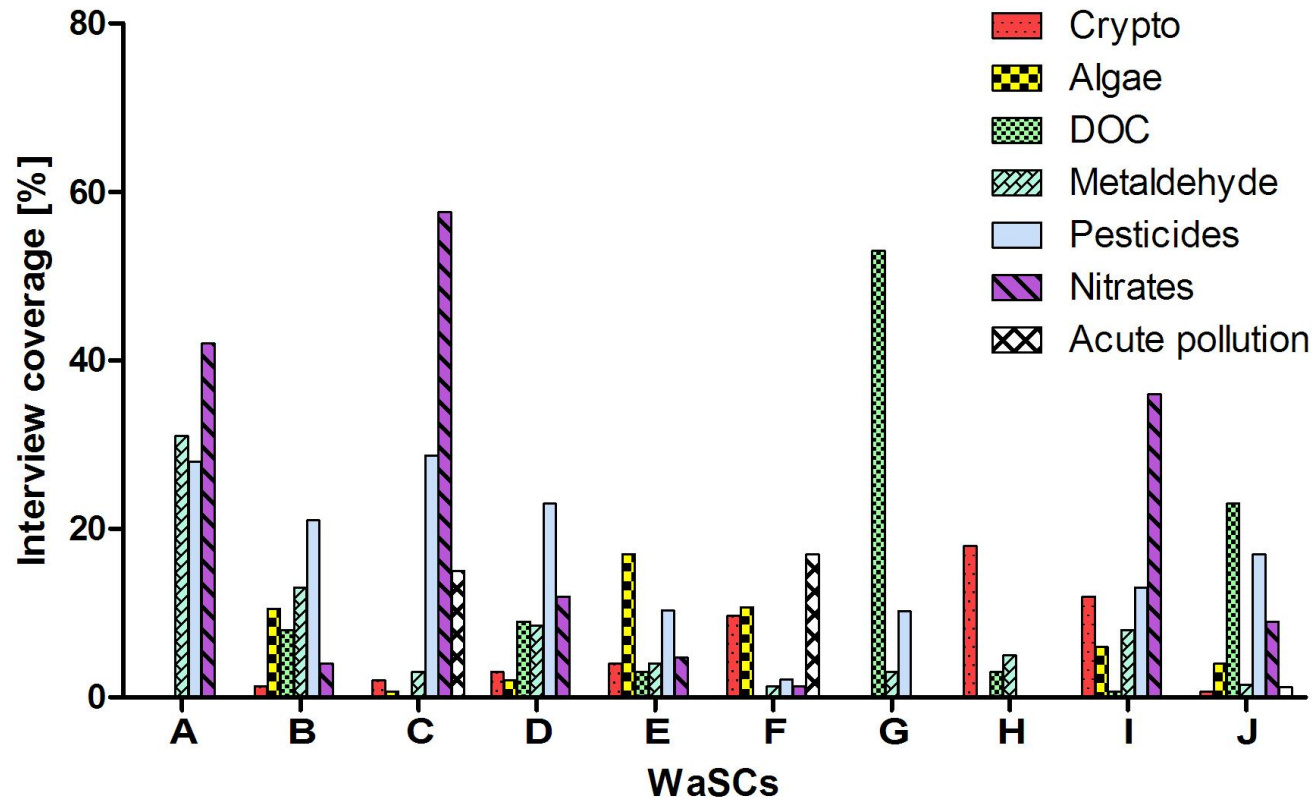
**Table 5-1: WaSCs and their position (stage) in the innovation decision process. (Coloured boxes signify that a WaSC is in the according innovation decision process stage. Vertical lines indicate secondary evidence for ‘Routinisation’).**

WaSCs	Agenda Setting	Choice between Alternatives	SCI design	Diffusion	Routinisation
A					
B					
C					
D					
E					
F					
G					
H					
I					
J					

## 5.2 Agenda Setting - Raw water quality issues of concern to WaSCs

Cryptosporidium, Dissolved Organic Carbon (DOC), pesticide pollution, algae, nitrates and acute pollution incidence were the raw water quality issues identified by WaSCs in E&W (Figure 5-1). Nitrates are naturally occurring nutrients, which, when ingested in excess, can cause a lack of oxygen in the blood (Methaemoglobinaemia). The drinking water quality standard (DWQS) for nitrate in drinking water is 50mg/l (EC 1998). Pesticides describe a group of chemicals, which can be harmful to human health. The EU drinking water standard for pesticides is 1µg/l for individual pesticides, but a maximal 5µg/l for a combination of pesticides (EC 1998). Metaldehyde was perceived

as different from other pesticides as present treatment methods failed to remove it. Dissolved Organic Carbon (DOC) is an umbrella term for a range of complex organic molecules. Discolouration of water is often associated with DOC. There is no statutory limit for DOC as long as it is acceptable for customers. However, DOC contamination of drinking water is a precursor for the creation of carcinogenic disinfection by products. Algae are pelagic protozoa or metazoan (phytoplankton). Nutrients, here mainly Phosphorous (P) can cause excess growth in the summer months when solar radiation is high. Some species of algae can release toxins when they die off. There is no drinking water standard for algae; however they are associated with DOC and Microcystin (a Hepatotoxin statutory standard 1µg/l). Cryptosporidium is a protozoa parasite which can cause severe diarrhoea. The disease is transferred by the ingestion of the Cryptosporidium oocyst. After a change of drinking water regulations Cryptosporidium can now be inactivated rather than removed physically. Acute pollution refers to spillages or other one-off pollution incidence of various types. Further background information about raw water quality issues is summarised in Parsons and Jefferson (2006).



	Crypto	Algae	DOC	Metaldehyde	Pesticides	Nitrates	Acute pollution
AVG	8.8	6.7	18.4	5.1	11.4	14.3	5.1
STDEV	5.9	2.5	19.0	3.2	5.7	13.7	6.6

Figure 5-1: Variation of raw water quality issue perception between WaSCs. (AVG = average; STDEV = standard deviation)



The coverage or the time spend discussing a specific RWQ issues during the interviews is displayed in Figure 5-1. This is taken to provide an indication as to which RWQ issues are perceived important for WaSCs (i.e. are on their agenda - see Chapters 2 and 3). On average nitrates and pesticides were the most frequently mentioned RWQ issues (nitrate AVG = 14.3%; pesticides AVG = 11.4%). Pesticides showed a low standard deviation, while the standard deviation for nitrate pollution issues was the highest in the sample (nitrate AVG = 13.7%; pesticides AVG = 5.7%; Figure 5-1). In other words pesticides were a concern for most interviewees, while the perception of nitrate issues varied more significantly between interviews. The average coverage for the remaining issues was lower (Figure 5-1). Of the remainder, DOC showed the highest average and a high standard deviation (AVG = 18.4%, STDEV = 19). Thus indicating a large variability in the perception of DOC issues (i.e. G and J emphasised DOC issues while A, C and F did not mention them at all). Cryptosporidium was not a major topic in most interviews (AVG = 8.8%), with the exception of interviews with H, I and F. Interviews with WaSC A and B showed comparatively frequent references to Metaldehyde issues, followed by interviews with D and I. Algae was no major concern on average (6.7%), with exception of interviews with B and E. Finally acute pollution was not specifically referred to by most interviewees, but representatives of F and C. For the water representative of WaSC F acute pollution had the highest priority.

The factors that influence the 'Agenda Setting' process will be analysed in Chapter 6. For now it is crucial to emphasise that the issues identified in this Section are perceptions. They do not reflect the reality of the state of the environment. For instance, the issue coverage of company F suggests that nitrates are of no or little concern (Figure 5-1). To conclude from this that the nitrate levels in raw water were below the statutory standard of 50 mg/l is not necessarily correct. The perception of raw water quality issues depends rather on a combination of asset characteristics, environmental trends and attitudes towards risk (Chapter 6).

### **5.3 Choice between alternatives – SCI choice**

In the previous Section it was illustrated that WaSCs perceive a number of raw water quality issues as problematic. According to the innovation decision making model it would be expected that WaSCs choose from a number of alternative options. The

alternatives considered by WaSCs are shown in Box 1. Metaldehyde was the only raw water quality issue where only one alternative, SCI, was mentioned. This reflects the perception of interviewees that no viable treatment for Metaldehyde existed, and hence SCIs remained as the single response. For the remainder, multiple alternatives were proposed by WaSCs which can be described as technological or end-of-pipe responses. Exceptions are de-stratification, where the nutrient cycle in lakes or reservoirs are manipulated and river flushing, which is associated with the management of pollution incidence by altering river flows. The following analysis is restricted to SCI alternatives.

**Box 2: Technological responses to the raw water quality issues nitrate, pesticides, Metaldehyde, DOC, crypto, algae and acute pollution (\* Parsons & Jefferson 2006).**

Raw water quality issues							
	Nitrates	Pesticides	Metaldehyde	DOC	Crypto	Algae	Acute pollution
Responses	I/B/A SCI/ Liaison	GAC/ Ozone/ SCI/ Change the standard	SCI	MIEX <sup>®</sup> / SCI	UV/ Coagulation flocculation/ Micro- filtration	SCI/ Coagulation flocculation/ Destra./ DAF	Flush rivers, A., GAC

**\*Ion exchange (I)** for nitrate exploits the different affinity of anions to a resin. For nitrate removal, nitrate rich water flows over a resin saturated with chloride ions. In the process the chloride ions are exchanged with the nitrate ions, because of their higher affinity to the resin.

**\*MIEX<sup>®</sup>** is the acronym for Magnetic Ion Exchange. In principle it functions like Ion Exchange for nitrates. However, the MIEX<sup>®</sup> resin is suitable to remove DOC, which adsorbs to its surface.

**\*Granulated Activated Carbon (GAC) or Powdered Activated Carbon (PAC)**, is, as the name suggest, a carbon based powder or granular, which absorbs molecules to its surface.

**\*Ozone** is a strong oxidant, in water it generates free hydroxyl ions, which break down larger molecular structures such as pesticides. These smaller molecules can be easily absorbed by GAC.

**\*Coagulation and flocculation** is a process where the surface charges of sub-micro particles are overcome by adding a coagulant. Subsequently this leads to the formation of larger particles (flocks), which settle on the bottom of clarification tanks. From there they are easily removed.

**\*Blending (B)** is a process where nitrate rich water is mixed with water of lower nitrate concentrations to reduce nitrate levels in the drinking water.

**\*Dissolved Air Flotation (DAF)** is a process by which makes particles or flocks rise to the surface, from where they can be skimmed off. To achieve this fine air bubbles pass through the water column and rise to the surface.

**Abandoning (A)** is an approach where WaSCs will cease to abstract from a specific water source.

**\*Microfiltration** is a filtration process, which depending of the pore size of the membrane presents a physical barrier for particles of different size ranges. The size range of microfiltration is between  $10^{-7}$  to  $10^{-6}$  m.

**\*Ultra Violet (UV)** radiation is a light of very short wavelengths (UVC: 280-200nm). This low wavelength light can penetrate living cells and disrupt the DNA rendering the organism incapable to reproduce. UV is therefore used to inactivate rather than kill micro organisms.

**Destratification (Destra)** is mixing surface (epilimnion) and subsurface (hypolimnion) water in deep lakes. By steadily mixing the water de-stratification introduces competition between algae species, thus reducing overall algae (phytoplankton) biomass (Simmons 1998). Continuous mixing also oxidises element which entered into solution in the anoxic hypolimnion (Simmons 1998).

**Flushing a river** is a method that artificially increases the flow a river to reduce the time of contamination or pollution to pass raw water intakes.

### 5.3.1 Choice between alternatives

Eight of the 10 WaSCs chose to engage in SCIs, while two WaSCs were aware of SCIs but did not yet choose to adopt them (Table 5-2). Of these two WaSCs, organisation F had on occasion communicated with farmers, but did not provide evidence that SCIs were to be part of its operations. On the contrary, the interviewee rejected SCIs several times during the interview, giving reasons such as the natural eutrophication of low land rivers and inadequacy of EU drinking water standards (see Chapter 6 for more information on factors of influence): *“Algae is a natural phenomenon of low land eutrophic waters and I think that, unless I’m kidding myself, we got to put up with those in the longer term”* and *“I would even say we shouldn’t be speaking to farmers, changing their practices because it’s [Metaldehyde] a good molluscicide for slugs and snails I wouldn’t like to see a loss of production for agricultural land.”*

**Table 5-2: SCI approaches adopted (or planned) by WaSCs and type of water source. Eight WaSC adopted SCIs on surface waters (SW) and three on groundwater (GW) sources.**

WaSC	Nitrate		Metaldehyde		Pesticides		Algae		DOC		Acute pollution	
	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW
A												
B												
C												
D												
E												
F												
G												
H												
I												
J												
Total		3	3		7	1	2			4		0

The other WaSC which was found not have chosen SCIs was H. This interviewee suggested that catchment investigation were conducted once as a response to acute *Cryptosporidium* incidents but no further such activities were carried out. Rather than providing evidence for the choice of SCIs the interviewee saw himself as a champion of this type of response aiming to promote future feasibility studies (H): *“I think historically there hasn’t been the interest in catchment that there is now... I think that’s changing and there’s people like myself who’ve got a specific interest in it.”*

Another particular case was WaSC C. The two interviews resulted in conflicting perspectives. This was not common throughout the case studies. Interviewees rather complemented or confirmed each others perspectives. The first interviewee from WaSC C indicated that catchment management was a future option and should be considered. Indeed, he pointed out that the company did apply to the DWI to undertake a SCI pilot project: *“But here we are actually looking at the potential for catchment management, so we’ve agreed, or we are in the process of agreeing undertaking through the DWI to put in place catchment management.”* Contrary to this the second interviewee was critical and not in favour of SCI: *“I’ve got to be honest with you, land management is no where near the top of our priorities, I’m not a great believer in it, we are open minded and I’m suggesting to you an area where we might consider it say in five or ten years time if it’s track record proves...”*. Despite such contradicting evidence it was decided that WaSCs C has chosen SCIs, because from the perspective of interviewee one there was firm evidence that the WaSC was committed to pursuing SCIs. Evidence in the public domain confirms this conclusion (Horton 2009).

Of the eight WaSCs that made the decision to begin to implement SCIs the majority were considering this for pesticide raw water quality problems. Only three organisations proposed SCIs for nitrate and two for algae raw water quality problems. SCIs for DOC were mentioned three times; which represents all those WaSCs that perceived a DOC raw water quality problem. For acute pollution no SCI was employed. Furthermore, most SCIs were implemented (or planned) on surface water catchments, exceptions were SCIs for nitrate issues and the SCI for pesticide issues of WaSC I (Table 5-2).

### 5.3.2 Purpose of Source control interventions

Source Control Interventions in E&W were adopted for four main purposes:

- to comply with the statutory drinking water standard
- to save operational costs and/ or to avoid asset investment
- to reduce CO<sub>2</sub> emissions
- to protect water resources

These purposes were mostly perceived to be in alignment; that is, WaSCs may aim for compliance with standards, reduction of costs, CO<sub>2</sub> emission and protection of water

resources simultaneously. Thus it was argued that SCIs can achieve win-win outcomes (G): *“...we have some environmental benefits something to do with win-win situations so there is habitat creation and restoration. And then there are risk reduction measures, water quality risk reduction measures. And that is in terms of the colour the turbidity and the pathogens.”*

In all cases SCI aimed to achieve compliance with drinking water quality regulations (see Chapter 6), or, in few cases, compliance with conservation targets under the Habitats Directive or WFD (B): *“But also these are European designated sites for biodiversity and the water quality of the lake is a key reason why they are not meeting good conditions status. So that is an additional, kind of driver for us as well.”* In the special case of Metaldehyde, SCIs are implemented or planned because water companies perceive that there is no viable treatment for this pesticide. Hence, to comply with the DWQS some WaSCs pursued SCIs (A): *“Metaldehyde...we are finding elevated concentrations in raw water, we’re finding that our treatment processes at our works, our standard treatment processes at the surface water sites, that would be ozone and GAC, it’s proven ineffective...so they’re leading us to very serious compliance issue for us we are still looking at optimising our water treatment works if we can... and then really move into the catchment management arena.”*

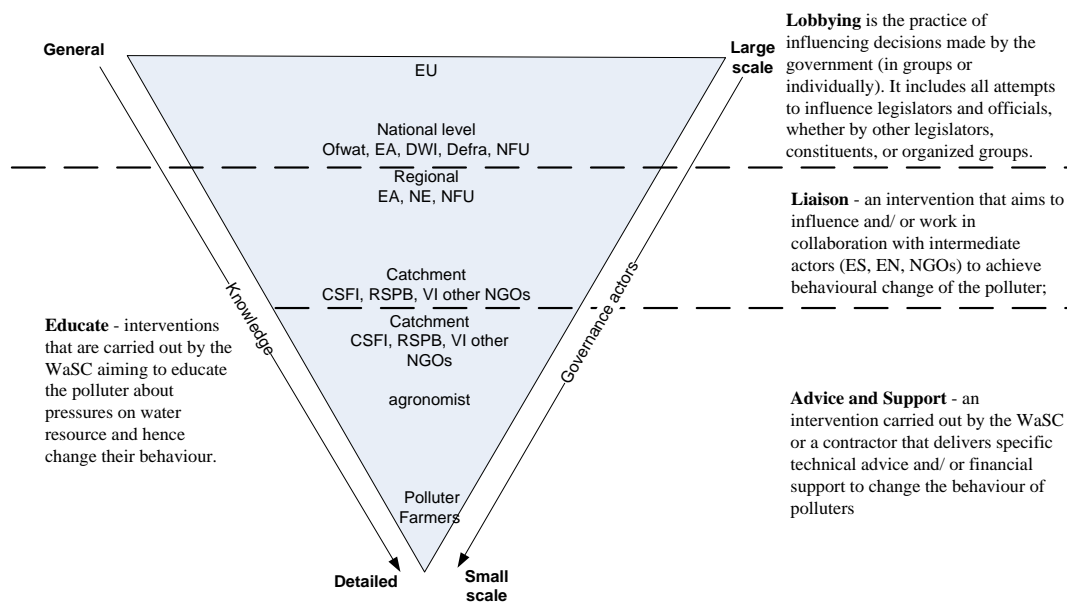
SCIs were also carried out to reduce operational expenditure and/ or to avoid investment into new assets. For all raw water quality issues it was suggested that improved water quality at point of abstraction can reduce operational expenditure. For example, it was argued that the regeneration cycles of the GAC can be extended when pesticide loads are lower: *“Let’s help minimise what is coming into the treatment works by more proactive catchment management...you can extend the frequency between regeneration of that carbon. Instead of looking at a two year regeneration period that goes to eight years and you have again a significant impact on the cost of that.”* (B). Capital expenditure (capex) was a concern where raw water quality was above the DWQS and no treatment was in place to remove the pollution. It was then frequently perceived that to avoid investment into treatment assets a more cost effective solution was to address pollution at source (C): *“That’s [catchment management] something we should be looking at in the future, because that may save some significant expenditure on building*

*pesticides plants and on running them.” Reduction in Carbon dioxide emission was a benefit and an objective frequently associated with cost savings: “Again carbon footprints, sustainability, energy, WFD is driving us that way so a whole host...”*

Less emphasis was put on SCIs for water resource protection. The purpose of this approach was that by controlling pollution at source, water quality can be maintained at a good quality level which reduces future risks and permits sustained use without the need for a multi stage treatment process (E): *“As we said before when it comes to the end of that asset life, our long term vision is we don’t replace because we’ve actually resolved the issues within the catchment, so less reliant on enhancing processes.”* In particular company E, J, G and B expressed this as a key consideration.

#### **5.4 Reinnovation - SCI design types**

The innovation decision framework suggests that the organisation will adapt the design of chosen alternatives to specific needs. This process is called ‘Reinnovation’. Designs or types of SCIs may be distinguished based on which level of the governance systems they seek to influence (Figure 5-2). In E&W the EU level, the national level (i.e. EA, Ofwat, DWI), the regional level (EA, NE, NFU), the local catchment level (CSFI, Agronomists, RSBP other NGOs) and the individual polluter (i.e. farmer) were found to be targeted by SCIs. ‘Lobbying’, ‘Liaison’, ‘Education’ and ‘Advice and Support’ (‘A&S’) were the options employed.



**Figure 5-2: Definitions and levels of intervention of source control designs.**

At the EU and national level ‘Lobbying’ was used to lever policy for better drinking water source protection. ‘Liaison’ was operated at the regional to local scale. This approach made use of influence and collaboration with regional and local actors such as CSFI, EA, RSPB other NGOs to deliver SCIs. ‘A&S’ activities were restricted to catchments and individual water sources. They comprised the detailed technical advice and/ or financial support of polluters. The ‘Education’ type was an intermediate between ‘Liaison’ and ‘A&S’. Here WaSCs engaged directly with polluters from the regional down to the local or individual water source level.

Each of these design types required a different level of involvement and knowledge about the situation. ‘Lobbying’ required relatively little knowledge of the specific dynamics within a catchments; conversely ‘A&S’ activities rely on more detailed knowledge of catchments, its hydrogeology, land use, pollution pathways and not least the local actors (i.e. farmers). Furthermore, ‘A&S’ activities were based on agricultural knowledge of individual farms and a regular direct involvement with the farmers or polluters. In comparison, to qualify for ‘Education’ designs one-off engagement with farmers was sufficient. Here advice provided was generic rather than specifically tuned towards the needs of individual farmers. The attributes of these designs are summarised



in Table 5-3. To further clarify these designs, and their knowledge demands, the activities they comprise are described in more detail below.

**Table 5-3: Attributes of SCIs design types (relative scale)**

<b>Attribute</b>	<b>Lobbying</b>	<b>Liaison attributes</b>	<b>'A&amp;S' attributes</b>	<b>Education attributes</b>
<b>Resource commitment</b>	<b>Limited resource commitment</b> e.g. staff	<b>Limited resource commitment</b> e.g. staff	<b>Substantive resources commitment</b> e.g. staff, compensation payment	<b>Limited resource commitment</b> e.g. staff
<b>Knowledge requirement of catchment and agriculture</b>	<b>Very limited detail</b> i.e. sufficient to be aware of raw water quality problem without apportioning pollution	<b>Limited detail</b> i.e. some ability to source apportion pollution useful to prioritise activities of intermediaries	<b>Very detailed</b> i.e. ability to source apportion pollution is crucial	<b>Detail</b> i.e. some ability to source apportion pollution necessary to educate polluter
<b>Type of relationship with farming community</b>	<b>Indirect through legislators</b>	<b>Indirect through intermediaries</b> - e.g. EA, CSFI, VI	<b>Direct</b> - often associated with voluntary agreements	<b>Direct but one way</b> - no mutual commitment
<b>Scale</b>	<b>National and EU scale</b>	<b>Large catchments</b>	<b>Relatively small catchment</b>	<b>Larger and smaller scale catchments</b>

Across the population of WaSCs SCIs were not restricted to a single design, but rather different designs were found to complement each other. Table 5-4 gives evidence which show that five WaSCs are planning to combine Liaison and Advice & Support designs. One representative of WaSC G gave an illustration of how different SCIs designs are combined (G): *“We have a five stage process. Starting at the top where we lobby government, EU, for the legislation that will protect our catchments. You then come down to our regulators, so you’ve got Natural England, you’ve got the Environment Agency, you’ve got Ofwat to make sure that the way they carry out their work also protects our catchment. You then come down to the next level which is NGO and RSPB, Natural Trust, Forestry Commission and you work with them specifically the large media of land owners, I then have another layer which is data collection so we are collecting agricultural consensus data, septic tank data. Any data for anybody which will show what risks there are to our catchment, then you come down to the lowest level which is about identifying specific risk on the catchment, either working with that farmer, polluter or whoever it is to tackle that issue, so you start from trying to influence the EU CAP reform, right down to actually dealing with a specific field or*

*trough or an outfall within a catchment, so depending on where you are, various people are involved within that process.”*

**Table 5-4: WaSCs source control designs and the associated activities in E&W (X = implemented; O = planned SC activity; \* are activities frequently summarised under on farm management plans)**

Type	Issue	Activities	Design																			
			A	B	C	D	E	F	G	H	I	J										
Lobbying		No activities detected										X										
Liaison	DOC	Nitrate	Make use of CSFI and VI and other Green NGOs	O	O	O	O	X			X			X	X							
			Educate farmers			O						X										
Educate	DOC	Nitrate	Leaflet/ Newsletter	O	O						X			X	X							
			Alternative crops*																		X	
Advice and Support	Pesticides & Metaldehyde	Nitrate	Technology & maintenance*								X		X	X								
			Alternative pesticide*												X	X						
			Application agreements*										X		X	X						
			Soil and crop assessment*					O							X							
			Use of advanced technologies*																		X	
		DOC	Algae	On farm infrastructure investment*									X		X							
				Extensivisation of land use*																		
				Buffer stripes & fencing*										X								
				Remove heather																		X
				Land use change						O												
			Grip blocking			X	O			X									X			

In Table 5-4 it is shown which WaSCs planned or had implemented the different SCI designs. With the exception of WaSC H and F all organisations employed ‘Liaison’. A minority of four WaSCs used ‘Educational’ approaches, with preference for leaflets. Further evidence for Lobbying was found for four WaSCs G. Five WaSCs showed some form of ‘A&S’ activities. In two instances this was restricted to DOC raw water quality issues and comprised grip blocking or conversion of land to set aside. In Chapter 6 it will be shown that these two companies restricted these types of approaches to sites where they owned land (and also only on one occasion). Of the remaining three companies each showed a diverse set of different, case specific ‘A&S’ activities for more than one raw water quality issue.

### 5.4.1 Lobbying

‘Lobbying’ is the practice of influencing government policy. In accordance with the definition of SCIs, the second phase of the research did not set out to investigate Lobbying. It rather focused on water supply and environmental operations on catchment scale. However, in Chapter 4 it was shown that four WaSCs aimed to change the legal framework as to better address raw water quality problems. This could be viewed as being equivalent to ‘Lobbying’.

### 5.4.2 Liaison

Nearly all WaSCs adopted ‘Liaison’ SCI designs. Using ‘Liaison’ WaSCs influenced or worked together with intermediaries such as EA, EN, RSPB, VI and green NGOs to facilitate source control. Rather than being simply a lobbying effort as proposed above; the distinguishing feature of this SCI type was that it involved the mutual co-operation and support between the WaSCs and intermediaries. This did, for instance, comprise data sharing or collaborative work (e.g. joint events) in the field through catchment officers. Furthermore, WaSCs may communicate directly with the polluter, but the intermediaries were crucial in facilitating this. For instance WaSCs used the CSFI events as a platform to communicate raw water quality problem to farmers. The following quote illustrates these characteristics of Liaison (B): *“So by employing the catchment office we are doing a lot more upstream sampling, we are sampling 10 points upstream of our intake... We will be putting together a program of events trying to piggy back on some of the events that the catchment sensitive farming officers are organising.”*

This quote indicates that data gathering was a key element of Liaison designs. For instance, representatives of WaSC A argued that modelling and data sharing with the EA was a crucial part of their approach to ‘Liaison’. In other words rather than collecting data this WaSCs wanted to generate knowledge of the catchment thought mining existing data sources (also WaSC J). Using this data this WaSCs aimed to develop pollution pathway models to prioritise areas for intervention. It was suggested that this knowledge can then be used to guide the activities of intermediaries. Who these intermediaries (liaison partners) were going to be was still under development. WaSC representatives proposed the CSFI, NFU and agronomists: *“...we would use that*

*information to develop strategies and look at mitigation and then we would probably share that with other interested stakeholders such as catchment sensitive farming, the NFU or whoever has influence.” This WaSC emphasised that they did not intend to develop agricultural skills themselves for instance by employing catchment officers: “...we don’t believe that it’s a water company’s role to be possibly talking directly to farmers or whatever, there are other people that are more skilled, that have more knowledge than us, so it’s really trying to identify what are we good at as a water company and then how can we make that better.”*

Another modified Liaison design was implemented by company E. In this case a regional green NGOs [cannot be named to maintain anonymity] was the key facilitator of source control intervention. In collaboration with the WaSC this NGO engaged with farmers and provided agricultural advice, such as fencing streams to reduce the access of livestock (E): “... people that we have engaged with in terms of the NGOs and other bodies like that... also fencing and to keep livestock back from feeder streams”.

A special case of ‘Liaison’ was implemented by WaSCs B. This WaSCs collaborated (incl. financial support) with the EA to prioritise a catchment risk assessment activity that contributed towards the development of DWSPs: “*The EA named what the risk were, gave us some quantitative assessment around the risk, gave it a risk score, and try to give an idea of time and travel as well. So they [EA] pulled that into a piece of work that we thought was probably as robust as we could probably get it for our water safety plan submission and that is where we are now as a company...we helped them to re-scope the project and part finance it.*”

### **5.4.3 Advice and support**

The distinguishing attributes of ‘A&S’ activities was that they required specific knowledge of the problem situation and direct engagement with the polluter (see Table 5-3 above). Catchment officers employed by the WaSC facilitated this higher demand for knowledge and direct involvement at a local scale. ‘A&S’ activities were also based on agreements between WaSCs and the polluters. Thus while still being voluntary, farmers had some form of commitment to change practices. It is also under this type of design that compensation or direct investment into farm infrastructures occurred. ‘A&S’ activities comprised a large variety of activities (see below). These activities were often

summarised under the umbrella of ‘farm management plans’ (Table 5-4). One of the aims of these plans was to make agri-environmental grants available to farmers, and thus cross finance activities which are thought to lead to environmental and water quality improvements. In the following such activities will be briefly explained and illustrated using representatives’ quotes. However, first a special case of ‘A&S’ will be described, to illustrate how ‘A&S’ activities can contribute towards achieving self-regulation between WaSCs and the farming community.

In one catchment of WaSC I the EA limited its regulatory activities (see quote at end of paragraph) as a result of the ‘A&S’ interventions implemented. The catchment officers (i.e. a WaSC employee) working in this catchment visited the 40 local farmers regularly facilitating advice on a range of subjects (e.g. nutrient and pesticide management). This won the trust of the farmers, which in turn resulted in a relationship where information could be accessed that would otherwise have been challenging to obtain (e.g. spraying records, fertiliser application, observation boreholes). Since there were concerns that the EA could adversely affect this relationship, a mutual agreement was reached which reduced involvement of the EA to a minimum (I): *“I mean the other issue that I need to mention is the relationship with the EA, now we have spoken to the EA and the agreement that we’ve had or come to with the EA is that we will monitor them, we’ll give them a heads up with what’s happening, we’ll keep them involved but they will not get directly involved with us at this stage because the fear was that if they did, that would just spoil that relationship all together, if they went in there heavy handed which is not what they wanted to do, given that the farmer was very willing to work with us, very willing, he has opened his books to us, he has allowed us onto his farm, he let us take samples, we had to drill bore holes, so its been a very open relationship but if the EA enter into things heavy handed that would stop and then almost certainly we’d have to put treatment in, so that was the decision that was taken.”*

### **Alternative cropping**

To reduce pesticide use, alternative crops were introduced. For instance, working with the agronomist WaSC J developed a different crop mix for silage production. This Avon mix requires less spraying, thus reducing the risk of drinking water contamination: *“...it’s a mixture of Triticale wheat but under sown with white lupine. The benefits of*

*that is from a pesticide point of view, it only needs one spray from the pre-emergent called Pendimathlin which is the active ingredient and that stays in the soil a lot better than IPU, so it doesn't need another spray, so that's good from my point of view, there's only one product going on the field...".* Converting to this different crop mix improve the protein content of the final silage, hence, resulted in a win-win situations for the WaSC and the farmer: *"The real benefit I think comes in terms of when the crops in, the mixture of the lupine spray, it puts nitrogen into the soil around 50 kg per ha every year, and you get 30% more protein in the Silage".*

### **Technological change and maintenance**

Technological change and maintenance comprise such activities as calibration of sprayers or financial assistance in purchasing technological equipment: *"We have identified the highest priority areas and we are running a program of 1 to 1 meetings with the farmers, we have ran and produced leaflets and newsletters, we have run several meetings and we are offering to calibrate peoples sprayers for them."*(G). These activities involve the commitment of financial resources by the WaSCs to pay the trained staff and to purchase or partly finance the equipment.

### **Application agreements**

Application agreements between WaSCs and framers require the farmers to stop the application of specific agro-chemicals in certain areas (J): *"...the three fields where we detected Pastel are those, we won't allow him to spray those, he's accepted that because it's a compromise on his behalf, he's lost three fields but he's gained the use of the other fields in a more controlled fashion ..."*. Alternatively the application of chemicals and nutrients was restricted to certain times of the year (i.e. spring and summer - I): *"...Nutrient management plans, moving from autumn to spring, applied slurry"*. The agreements also included the expectation that the farmer adheres to the codes of good agricultural practice, which requires, for instance, that pesticides are not sprayed in high winds or slurry is not applied during, after and before rain events (Defra 2009b).

### **Alternative Agro-chemical**

WaSCs also helped conversion to alternative agrochemicals – mainly pesticides. In one case Metaldehyde was replaced by a ferric phosphate product, which was thought to be

more easily treatable. The water company championed this product and compensated farmers for the price difference (I): *“We go and talk to every farmer, every time, it’s not just Metaldehyde, we’ve done it with other pesticide issues and we look at their spray handling and such like, so it’s very much you call in on the farm and speak to someone and discuss it, ... we just remind them at crucial times and we go round and say look we are doing this, please send the invoice if you want to use slug pellets, please use these ones.”* Another example is given by WaSC J; here the WaSC advised the change of grazing practice, combined with the use of weedwipers. This enabled farmers to convert to the total herbicides with the active ingredient glyphosate, which was considered to be easily treatable rather than the alternative (i.e. Isoproturon): *“so then we can use ground up glyphosate, if we spray glyphosate on the field it will kill everything but if you wipe it on thistles it only kills the thistles and the grass underneath is protected.”* (J)

#### **On-farm infrastructure investment**

The improvement of slurry storage facilities, but also investment in new sprayer washer basins were mentioned as examples for on-farm infrastructure investments: *“So we did that, we entered into an agreement where he stopped spraying, he also built a new spray store facility on his farmyard and we monitored ...We paid that for him as well.”*(I)

#### **Extensivisation**

Extensivisation was proposed on arable land and pasture. The benefits of this were associated with agri-environmental payments, but also with erosion reduction and pesticide use. WaSC G gave an example of such activities: *“So for instance like going down from 1000 sheep to say 500, so half the stock and if you just spoke to a tenant farmer and said, well we gone reduce your stock by half.”* On the other hand WaSC D considered extensivisation for agricultural land next to reservoirs: *“Basically what we’ve discussed over the last couple of years is actually potentially getting the land right next to the source into higher stewardship, basically taking out agriculture.”*

#### **Laboratory assistance**

In some instances there was reference to soil nutrient load testing and assessment of crop nitrate content. Both activities aimed to optimise fertiliser application in nutrient management plans (I): *“We give out a lot of free advice, we do a lot of free soil*

*sampling which is of value to them, we give them fertilizer, we do manure testing, grain testing, so we look at ways of saving them money, a win-win situation.*” Similarly other WaSCs also suggested that they would offer laboratory assistance (G, B).

### **Grip blocking and heather management**

Heather management and grip blocking were two activities exclusive to DOC raw water quality issues. Grip blocking, is the obstruction of peat drainage channels (i.e. grips). In theory, when these grips are block the water table rises and reduces the oxidation of the peat – which is thought to be the principal cause of rising DOC trends (G): *“Now what drives the sudden increase within the colour, well we believe it is largely driven by a combination of factors, but all leading to the same thing, which is cyclic drying and wetting of the peat and oxidation of the peat.”* Heather management aims to achieve the same, namely a reduction of the breakdown of the peat, by minimising the risk for wild fires or ‘hot’ burning. It is explained as follows by a representative of WaSC (J): *“...we’ve got a better way of doing it, we’ll continue to support burning but in the best practice available which is the cool burn.”*

#### **5.4.4 Education**

Education is positioned between Liaison and Advice & Support. Unlike Advice & Support where detailed knowledge of the local situation is required, Education SCIs designs, can function without a detailed understanding of the source pathway of pollution in a catchment. This is for instance evident when WaSCs used leaflets to raise awareness and to educate (B): *“...doing 12 newsletters over the next two years.”*

Nevertheless, knowledge of the origins of pollution pressures was useful when the ‘Education’ was to be implemented on the scale of the individual water source or even individual polluter. As for Liaison, this enabled the prioritisation of a specific target group. In the case of WaSC B, the ability to isolate a group of farmers that were thought to contaminate a reservoir with a mix of pesticides resulted in a unique approach to education. This WaSC invited a group of farmers and agronomists into the water treatment work to demonstrate the technology involved in the treatment and explained how raw water pollution affects treatment: *“we got those farmers and agronomists into the treatment work themselves, to show that works, showed what the implications were to ban poor pesticides practise on site, and ultimately, we’ve come back to them*



*because they could be charged with water rates for example. I showed them were the loop lies and how we as an end user have very little influence on what they are doing, though it has a huge implication to us if they adopt bad practices. (B)*” This open door approach was only implemented by company B, other companies communicated their problems to farmers, which in some cases resulted in reduction of pollutant pressures at the treatment works (A): *“Talk to farmers make them aware of the problem, try and change their behaviour because this is all about behavioural change amongst the agricultural community...”*.

## **5.5 Restructuring**

In Chapter 2 it was suggested that the adoption of SCI innovations may require some restructuring of the organisation. This was described as a process that comprised importing new skills and expertise. It was further found that WaSCs may re-structure to accommodate SCIs innovation. This is so because WaSCs were assumed to be engineering organisations with little relevant knowledge to implement SCIs. Indeed, some interviews hinted towards the knowledge constraints (A, J) and the preference of engineering solutions (i.e. treatment – E, A, J – see Chapter 6).

Thus, it appears possible that WaSCs will have to ‘Restructure’ to implement SCIs. The roles and responsibilities of interviewees provided a source of information about whether the organisation holds the relevant skills and knowledge for the implementation of SCIs.

Table 5-5 shows the descriptions of the relevant business functions of WaSC interviewees. It can be seen that one WaSC developed knowledge about their catchments recently (A). Furthermore, the function of the individual or department appeared to be either associated with development and testing (A, D, J) or with the delivery of SCIs (B, E, G, I). In five instances WaSCs were also found to employ or plan to employ catchment officers or other staff to conduct one-to-one farm visits. No reference to staff designated to catchment management or source control functions was made by companies C, F, H. The exact configurations of departments are difficult to compare with the information from the interviews. However, the key point is that seven WaSCs (A, B, D, E, G, I, J) maintained specific departments or employed individuals

that held or generated knowledge relevant (i.e. catchment and agricultural knowledge see Chapter 6) for the implementation of SCIs. This implied that seven out of the eight WaSCs which were found to plan or have implemented SCIs showed evidence for ‘Restructuring’ of their organisation. Likewise, all WaSCs which employed or planned to employ catchment officers had implemented ‘A&S’ activities.

**Table 5-5: Roles and responsibilities of interview partners or descriptions of other peoples roles in the organisation (O = planning to employ catchment officer; X = do employ catchment officer)**

WaSC	Quote	Catchment officer
A	<i>My current role has developed over the last year and so concentrates on source protection and some new areas of catchment management, so it is protecting ground water and surface water sources.”...</i>	
B	<i>I actually have a role of delivering catchment management projects... also now employed two catchment officers.... it is time to build the relationships, because we are starting form a very low base to be honest.</i>	O
C	<i>Technically ground water protection, ground water around a risk assessment, ground water engineering, anything along those lines also on water resources I also go into surface water and very much I do a lot of ecology environmental work because of sustainability which was what I was doing when you came in which is looking at appropriate assessment from the Habitats regulation</i>	
D	<i>I’m currently trying to promote catchment management ...but we’ve now gone out and looked at what’s going into the catchment as well</i>	O
E	<i>We went round and visited and photographed all the farms and the evidence was all the drainage was very straight in to the river.</i>	
F	<i>I am very interested and involved with raw water quality both in rivers and ground water and have strong links to Thames region of the Environment Agency with regard to real time monitoring and picking up what’s going on there.</i>	
G	<i>I am catchment management program manager and another representative... I am responsible for reducing risk to raw water quality and quantity on the catchments we own</i>	X
H	<i>I do not know...To be honest maybe we do not have an expert.</i>	
I	<i>So my particular area of responsibility is looking after the catchment management program and we have two agricultural people X who is an agronomist and another chap called Y whose background is in farming who is an agronomist</i>	X
J	<i>My role is catchment and development leader; I’m responsible really for implementation of findings from research and development we’ve undertaken over the last seven years...I’ve been left pretty much to my own devices to try and improve water quality specifically with an end of reducing treatment costs.</i>	X

## 5.6 Diffusion of source control interventions

Three WaSCs showed evidence that SCIs were developed beyond a pilot stage and were implemented more widely in the organisation. For instance WaSC E indicated that their ‘Diffusion’ process began with a specific small scale project and had since spread across their region: *“It started there really, I mean we then sort of said well hang on a minute, this reservoir and this reservoir and this reservoir they are all eutrophic,*

*they're all full of nutrients, some of them are full of pesticides as well. They're all suffering from the land management practices in their catchments, so we decided that it was cheaper and better for our customers if we could sort out the catchment."* Similarly, WaSCs I suggested that one successful project was a precursor for the implementation of further projects: *"And it was during a course of that investigation that we hang on if we said if we can deal with pesticides in this way, what about nitrates, is it possible to take this view on nitrates, so instead of moaning and complaining all the time to the Environment Agency aren't doing anything, let's just get on and do something."* WaSC G too indicated that they were expanding SCIs on owned and non owned land: *"So you're trying to expand [SCIs]? Yes."*

Two other organisations shall be mentioned here, though they were not considered to be diffusing SCIs. In the case of WaSC B new projects were about to begin, but others were closing down or were completed: *"And then we could close the project down and have not done anything since...So there were certainly two or three small projects like that over the last 6 or 7 years. "*

A different example is WaSC A. This WaSC was aiming to implement SCI for 20 sites: *"So that's seven high risk ground waters and 13 major surface water abstractions."* Yet, in Section 5.3 it was shown that they had no prior experience with SCI. Thus, it appears this organisation was planning to implement at a comparatively large scale, without prior piloting in few cases. In the case of WaSC D on the other hand it seems, the number of SCIs remained stagnant, because projects are initiated and closed on demand. In Chapter 8 it will be discussed whether these two types can or should be considered to provide evidence for 'Diffusion'.

## **5.7 Routinisation**

According to literature an innovation has turned into a routine when it ceases to be novel to the organisation (Chapter 2). If an innovation has turned into a routine it maybe assumed that it is part of the repertoire of an organisation – or the way things are done. Thus an innovation such as SCIs may become a standard response or alternative that WaSCs routinely chose from. Therefore, if evidence can show that SCIs are part of the

standard response of WaSCs, then it could be inferred that WaSCs have ‘Routinised’ this alternative.

Interviews with WaSCs B and E seemed to suggest that SCIs were a standard response. It appeared that they integrated catchment management or source control in the overall organisational approach to drinking water supply. This was evident in references to ‘Upstream Thinking’ (E) and ‘Two Tiered Approach’ (B). The former suggests that the catchment is an integral part of the treatment process and that pollution can be rectified there (E): *“It’s part of our approach; it’s one of the options. If we have a problem on a site it’s one of the options that’s available, so we have end of pipe solutions and we’ve got an upstream approach.”* The – Two Tiered Approach– claims essentially the same, but emphasises that catchment solution [SCI] and treatment solutions are not mutually exclusive but complement each other (B): *“So it is a two tier approach if you like... There are two stages of it; you can try to be as much proactive as possible, doing the sort of studies we are doing with the agencies and highlighting risks through safety plans and effective catchment management, and that’s great and it will be an ongoing requirement, but there’ll always be things that will take you by surprise. So if monitoring is put in places where we highlight an emerging issues like Metaldehyde then you have to react, you cannot be that forward looking all the time, so I think there is a balance there, about what we can practically achieve as a company.”*

Evidence was less profound for other organisations. For instance WaSC I did not suggest that SCIs are a standard alternative, but it showed leadership in terms of ‘A&S’ designs (i.e. only company to have developed alternatives to Metaldehyde; a SCI resulting in limited engagement with the EA). Furthermore, WaSC G maybe at a stage similar to ‘Routinisation’, since it has a department specifically designated to develop a catchment policy. Given these evidence for WaSCs I and G, and considering that these two organisations also showed evidence for ‘Diffusion’ (see above), it is likely that these WaSCs have turned SCIs into a routines.

Yet, in other instance it was evident that ‘Routinisation’ was still in the process of becoming a standard alternative (J): *“You know I talked about the abandon, blend, treat and in fact we are adding a fourth option which is catchment management. And that is*

*the concept within companies to bring the land management in...conceptually it is the first stage of water treatment or avoiding water treatment.”*

## **5.8 Summary**

In summary, in this Chapter it was demonstrated that there is variation between WaSCs in terms their choice to adopt SCIs, their position in the innovation decision process, and the type of SCIs adopted. More specifically it was shown that all WaSCs had a raw water quality agenda and eight decided to implement SCIs (eight implemented Liaison, two Education, five A&S). Three WaSCs provided evidence for ‘Diffusion’ and four for ‘Routinisation’. The reasons for these differences will be discussed in Chapter 7; by integrating the observed variation with the factors influencing the innovation decision making process, which are described next.

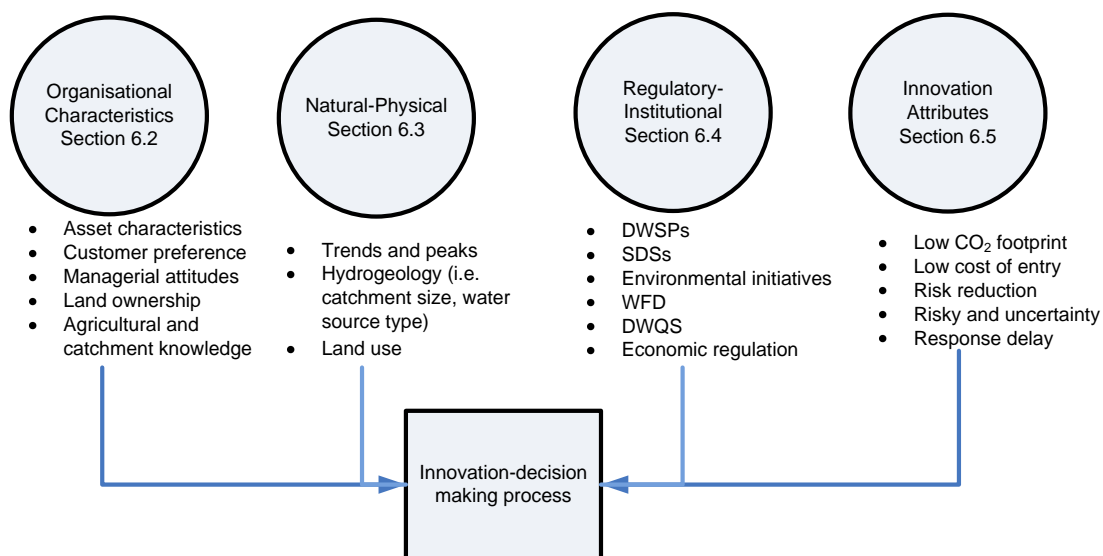


# Chapter 6

## Factors influencing the innovation decision process

### 6.1 Introduction

The factors perceived to influence the process of SCI adoption are explored in this Chapter. The interview results are structured using the classification of factors influencing innovation developed in Chapter 2 (Figure 6-1). Factors in these domains are presented depending on where they affect the innovation decision process. In other words it will be demonstrated where factors affect the ‘Agenda Setting’, ‘Choice between Alternatives’, ‘Reinnovation’ and ‘Diffusion’ stage (for example see Figure 6-2).

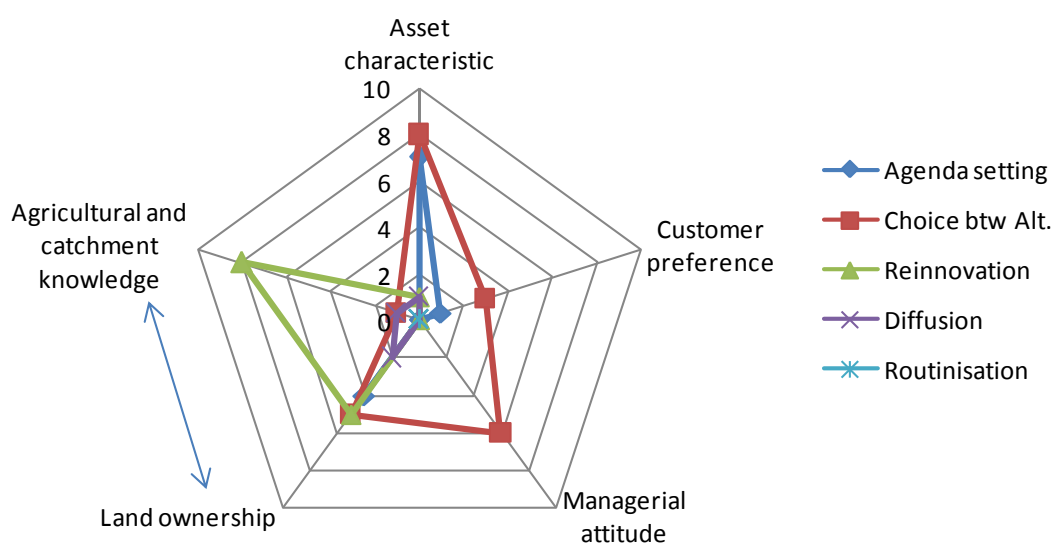


**Figure 6-1: Factors influencing the innovation process in four domains.**

In Section 6.2 the ‘Organisational’ factors influencing the innovation decision process are described. Subsequently the ‘Regulatory-Institutional’ and ‘Natural-Physical’ factors are presented (Section 6.3 & 6.4). Thereafter, the attributes of SCIs are characterised (Section 6.5). Finally, the Chapter is summarised in Section 6.6.

## 6.2 Organisational characteristics

Five organisational factors of influence were detected (Figure 6-2). The ‘Agenda Setting’ process was found to be influenced by two factors land ownership and asset characteristics. These two factors were also the key aspects in the ‘Choice between Alternatives’. In addition customer preference and managerial attitudes affected the decisions between alternatives.



Factors	Asset characteristic	Customer preference	Managerial attitude	Ownership	Agricultural and catchment knowledge
Agenda Setting	A/B/D/F/H/I/J	E	0	B/D/G/J	0
Choice btw. Alt.	A/B/C/D/E/H/I/J	A/E/J	C/ G/ H/ I/ J/ E	B/C/D/G/H	D
Reinnovation	B	0	0	A/B/D/G/J	A/B/D/E/G/H/I/J
Diffusion	J	0	0	G/J	J
Routinisation	0	0	0	0	0

**Figure 6-2: Recurrence of the factors relating to ‘Organisational Characteristics’ across the population of WaSCs and their influence on the stages of the innovation decision process (Figure shows at which stages of the innovation decision process ‘Organisational Characteristics’ affect the innovation decision making process. Recurrence is counted across the population of WaSCs (i.e. 10). Arrow indicates relationship between factors, the relationship is elaborated on in the text.)**

Catchment and agricultural knowledge was most frequently suggested to affect the ‘Reinnovation’ stage, while it was almost never mentioned to influence other process stages. ‘Reinnovation’ was further, as ‘Agenda Setting’ and ‘Choice between



Alternatives', influenced by land ownership. Land ownership, agricultural and catchment knowledge and asset characteristics were mentioned only infrequently to affect the 'Diffusion' stage of the innovation decision process.

### 6.2.1 Land ownership

Whether or not WaSCs own the raw water quality catchment can have an influence on the 'Agenda Setting' process. This is so, because under WFD WaSCs are obliged to work towards good status of water resources (and land under the Habitats Directives EC 1992). WaSCs J, G but also WaSC B are examples where this was a consideration, which lead to a perceived need for change and eventually to the uptake of SCIs (G): *"And that is our primary driver the site of special scientific interest status..."*

Land ownership was also found to be conducive to the choice of SCIs. Interviews G and J provided examples for this. These interviews suggested that land ownership gives some control of land use. WaSCs which own land can use tenant agreement to induce agricultural behaviour change and can access the land to collect data. However, it was indicated that the effectiveness of land ownership to change behaviour was limited. This was partly a result of the type of tenancy agreements (i.e. agricultural holding act) that prevailed between WaSCs and farmers in E&W. Under these agreements the ability of WaSCs to enforce change of agricultural practice is limited (G): *"You know if you see stock in an area where it should not be then again we would talk to the tenant and say look. And we can issue things called notices to remedy, so we can tell them "stop doing that". Now the tenancy... if you cannot get rid of them as tenant the only thing that is certain death is if they do not pay their rent. You can be sure that the worst tenants always pay their rent. The only thing that we are able to do is we could say to a farmer you should not do that and give him a notice of seven days, but then he does whatever it is again. The problem is that it does not accumulate every instance is separate so he can do that as many times as he wants."*

Contrary to this a number of organisations, which did not own land, held the view that land ownership is essential for the implementation of SCIs. They argued that limited rights to entry and the inability to enforce land use changes severely constrain implementation of SCIs, and indeed fostered end of pipe treatment. This was evident in statements similar to the following (H): *"So without owning the land which we don't,*

*what can we do? That is why we're still steered towards end of pipe solution because that's the only way that we feel you are entirely comfortable.*" Rather than aiming for a direct engagement with the farming community some of the WaSCs which argued along these lines preferred 'Liaison' or 'Education' as a SCI designs.

However, in particular the case of WaSC I showed that 'A&S' activities can be implemented even if the land is not owned by the WaSC. This conclusion is further supported by the finding that WaSC which have previously carried out 'A&S' activities on land they own, aim to extent these design into non owned land. This may suggest that landownership is not essential for the implementation of source control approaches.

Nevertheless, land ownership offered a chance to experiment and learn (see below for the affect of knowledge on the innovation decision process), which was suggested to be important for the further adoption of SCIs (J): *"We start, I'd like to think of it as an example of best practice but our land holding is not perfect, I've got to tidy up our own act really before I can sell that to other people..."* In addition the evidence suggested that land ownership offers a source of prior knowledge, relevant for the implementation SCIs. For instance WaSC G indicated that because the organisation owned much land it had long employed staff to carry out catchment investigations. This lead to sensitivity towards raw water quality issues, existence of relevant knowledge and thus possibly to the wider adoption SCIs (i.e. 'Diffusion' - G): *"Because we do own land, we have in each area an estate team. And the numbers of staff in each area vary, but essentially each one has a catchment manager, we have a land agent...." "We own so much land already, we've been managing catchments already on the land we owned...so the risks are there, just because you don't own it, it doesn't mean you can ignore the risks on the raw water."*

### **6.2.2 Catchment and agricultural knowledge**

Knowledge (or the lack thereof) of pollution pathways, catchments, agricultural practice and actors was found to have a major influence on the SCI designs adopted or planned. For instance WaSC A implemented a Liaison approach, rather than for instance an 'A&S' approach. It appears that this design was chosen partly because the organisation did not hold agricultural knowledge and did not intend to develop it: *"... we don't believe that it's a water company's role to be possibly talking direct to farmers or*

whatever. There are other people that are more skilled, that have more knowledge than us, so it's really trying to identify what are we good at as a water company and then how can we make that better." Contrary to this, where the knowledge had been developed or existed historically (i.e. in WaSCs which owned land and thus employed land managers – see above) WaSCs more readily adopted 'A&S' activities (see above statement from G).

**Table 6-1: Evidence for the relevance of agricultural and catchment knowledge.**

WaSCs	Quote
A	<i>It was only identify that there was no real link or communications with the CSFI as part of my research and the fact the we weren't necessarily involved in any of the proposed catchment initiatives...we don't believe that it's a water company's role to be possibly talking direct to farmers or whatever, there are other people that are more skilled, that have more knowledge than us.</i>
B	<i>But at the moment we are collecting more data... Fertilisers and pesticides, we never realised that there is a huge array of chemicals. The catchment officers we have taken on have agronomy qualifications. And they do have agricultural backgrounds and they are bringing new expertise into the business.</i>
C	
D	<i>We as a company need to learn what the catchment is and what it can bring, knowledge about the problems that are coming in and where they are coming from, information about water quality, so there are various things we need to be doing. I'm very conscious of that's what we do and we need to do a bit of work to understand what catchment options we need to achieve the required output, but how will we quantify the cost of that measure so if that measure for example is</i>
E	
F	
G	<i>It is really an extension of what we have been doing and it has been born out of experience.</i>
H	<i>There's still a lot to learn I think it's fair to say... I think historically there hasn't been the interest in catchment that there is now</i>
I	
J	<i>They come from farming stock, they've been to college and they know more about farming...what I'm trying to do from there is certainly learning from experience.</i>

In addition to the above it also appeared that there was a more general lack of catchment related knowledge across the entire sector (Table 6-1, D): *"We do not know enough about that... if we're funded for it we're proposing to do some work to understand that."*

### 6.2.3 Asset characteristics

The interview results suggested that asset characteristic influenced the 'Agenda Setting' and the 'Choice between Alternatives' (Figure 6-2).

WaSCs perceived a problem and thereby a need for innovation ('Agenda Setting') where treatment processes could not reduce raw water pollution below DWQS (A): *"So*

*yes, just blended to be sure that it meets the internal standard, 44 mg/L is the standard within WaSC A. If that gets exceeded we see it as a major issue.”*

‘Asset Characteristics’ were usually a function of the raw water quality status that prevailed in the past. In other words, where the raw water quality was poor, for instance in low land surface waters, treatment processes were more resilient because they were designed to treat a larger spectrum of pollutants (F): *“On the river works you had treatment for crypto anyway because you’ve got lots of particles and that’s how you remove them.”*

One interviewee suggested that the size and number of water supply assets has an influence on the choice between end of pipe solutions and source control approaches. More specifically, it appeared that where no economies of scale of WTW could be realised WaSCs were more likely to enter into SCIs. Reason for this appeared to be a ‘reluctance’ to invest into multiple small sites (I): *“It’s lots of small sites so people are reluctant to spend a lot of capital money in lots of small sites. If you put capital money in a big site, you can put the best quality treatment in, you know you’re going to get however how many mega litres out the door and it’s fine. But if you’ve got, you know 80 Ml than that is different...”*

The inverse was confirmed by company F, which was the only WaSCs not to show evidence for a SCI program. This WaSCs owns some of the largest WTW in Europe and showed evidence for centralisation and up scaling of WTW: *“...whereas the river works are five hundred, six hundred, seven hundred mega litres per day, some of the biggest outputs in Europe... One thing we have done over the decades is where I refer to those very small treatment works, we have transferred the license from there to another works and invested in the asset enhancement there and done away with previous ones, so it’s reducing the asset base and it’s improving our cost effectiveness by doing that, so we’ve rationalised that.”*

In addition to the above, smaller treatment works can also pose physical constraints that make the uptake of SCI alternatives more attractive. Thereby affecting the ‘Choice between Alternatives’ (I): *“...so on the back of that suddenly it appeared that we were*

*going to have to build pesticide treatment in and there was big concern about it...and the land required, we think now we could have fitted it in at site."*

Lastly, the asset life played a role in determining the 'Choice between Alternatives' too. WaSCs E wanted to avoid investment into asset near the end of their useful life, thus giving preference to options such as SCIs: *"It certainly makes more sense to try and address the catchment issues than say for instance put GAC in a site that's nearing the end of it's normal life and would be very expensive to try and retrofit another stage of process on there. Environmentally it's got to be better to sort the catchment out, rely on less energy in terms of treatment and financially it's very difficult to shoe horn additional process into an old site that probably needs knocking down and starting again to be honest, so it's not good to invest more money."*

#### **6.2.4 Managerial attitudes towards the environment and sustainability**

Managerial attitudes or value judgements about the environment and sustainability to influenced the 'Choice between Alternative'. WaSCs tended to adopt SCIs where it was expressed that protection of raw water quality at source was the right thing or the more sustainable thing to do. Conversely, SCIs were advocated, when the externalities of treatment were perceived as environmentally adverse and financially costly. Examples for such externalities were CO<sub>2</sub> emissions and sludge production. However, sustainability was often understood in terms of costs, thereby solely focusing on one pillar of sustainability (E): *"Our biggest asset are our of raw water sources so we should invest in the raw water, to continue to bolt on additional layers of treatment to mitigate the various risks is not going to be sustainable, so we have to address the problem at source in order to become less reliant on some of these high energy, high cost treatment processes."*

In few instances it was also argued that higher level management played a role in stimulating SCIs. SCIs were also stimulated from higher levels within the company or supported by them (G): *"No we had a lot of support from our board. Our senior managers have been out so see it; we have invited also loads of people from all over UK and regulatory people."*

**Table 6-2: Preference of treatment alternatives.**

WaSC	Quote
A	<i>Prevent deterioration, rather than saying all these trends in raw water are static...and then long term you're reducing and their severity, rather than bolting on an additional treatment processes, the easiest thing for us to do.</i>
B	<i>I think the future is catchment management. I don't think any company has genuinely put efforts into this historically.</i>
C	
D	
E	<i>We have to address the problem at source in order to become less reliant on some of the high energy, high cost treatment processes.</i>
F	
G	
H	<i>The water industry 10-15 years ago the perception was if it's wet, we'll treat...</i>
I	<i>Historically we have looked at the hole in the ground and that's been our focus you know</i>
J	<i>And if we look forward we can keep building or enhancing WTW, we know about that.</i>

In the context to the above considerations of sustainability and environmental values it was also found that WaSCs representatives began to challenge the generic application of end-of-pipe treatment (Table 6-2). They rather appeared to suggest that SCIs maybe more suitable in specific situations. Evidently though, it was argued that in the past approaches to water supply have been dominated by engineering solutions (i.e. treatment).

### 6.2.5 Customer preference

Customers are here included as an organisational factor, because customers cannot choose between alternative water suppliers. From the perspective of WaSCs this implies that the demographics and consumption patterns significantly shape 'Organisational Characteristics' such as turnover, water consumption and networks (Chapter 1).

In only one case it was expressed that the customer had a direct influence on the 'Choice between Alternatives'. One representative of WaSCs E argued that their customer surveys had shown that customers are willing to pay for environmental improvement rather than for improvements to WTW. Thus it was suggested that SCIs were an option that would satisfy customers' aspirations for cleaner environment. The interview partner suggested that this view was expressed in this region in particular because it is a popular destination for holiday makers (E): *"Working in the catchment and cleaning up the rivers and stuff has an element of increasing the biodiversity and the habitats and things like that. Our surveys show that customers are certainly very willing to pay for that in terms of enhancing their natural environment. And people who*

*come and visit, one of the reasons they come is to enjoy the countryside so there is willingness for people to pay... Whereas to be honest, you can turn on the tap for a glass of water and you don't know the little box it's been through is. So do you want to pay for another little box that it goes through, no because it's safe already isn't it, otherwise they wouldn't let us drink it. Whereas actually yes you're going to create some habitat... I like that because I can see that and walk round, so I don't mind paying..."*

In the majority of other cases it was perceived that the customers interests were served when cost could be reduced to a minimum. This was so because it was argued that customers do oppose a rise in water bills (D): *"Yes and you have to explore that so to get money off customers, you have to make sure it's the right cost solution and the treatment process costs £20 million. If customers give us £20 million then we need to make sure that we cannot do it for less in the catchment."* Thus when SCIs were perceived to offer a more cost effective solution WaSCs suggested acting on behalf of the customers.

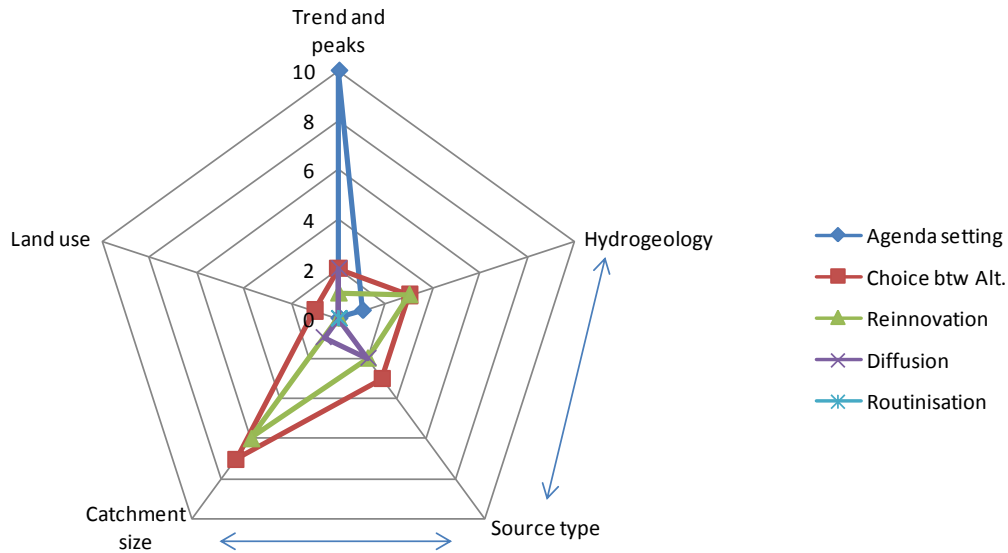
### **6.3 Natural-physical factors**

Five 'Natural-Physical' factors influencing the innovation decision process were isolated from the interviews (Figure 6-3). The 'Agenda Setting' phase was dominated by the influence of raw water quality trends and peaks (i.e. all 10 WaSCs mentioned this factor). No other natural environmental factor affected the 'Agenda Setting' process as strongly. When pollution loads were increasing (i.e. a trend) WaSCs tended to perceive a raw water quality problem, thereby beginning the 'Agenda Setting' process. The majority of statements indicated rising trends, rather than declining trends.

The 'Choice between Alternative' was influenced by 'Natural-Physical' factors too (Figure 6-3). Mainly catchment size, the hydrogeology and the water source type were influencing the choice for or against SCIs. The direction of influence of these variables varied and was case dependent; thus the influence of these factors will be discussed in more detail below.

'Natural-Physical' variables also affected the 'Reinnovation' stage of SCIs. In particular the interrelated factors catchment size, water source type and hydrogeology influenced

this stage of the innovation decision process. The character of their influence was governed by the specific local circumstance which is further discussed below.



	Trend and peaks	Catchment size	Hydrogeology	Source type	Land use
Agenda Setting	A/B/C/D/E/F/G/H/I/J	0	F	0	0
Choice btw. Alt.	B/I	B/C/D/E/F/I/J	C/D/I	C/D/J	C
Reinnovation	J	A/B/D/E/I/J	A/E/J	A/I	0
Diffusion	E/D	J	0	E/J	0
Routinisation	0	0	0	0	0

**Figure 6-3: Recurrence of Natural Physical factors across the population of WaSCs and their influence on the stages of the innovation decision process (Figure shows at which stage of the innovation decision process Natural Physical factors affect the innovation decision making process. Recurrence is counted across the population of WaSCs (i.e. 10). Arrows indicate relationships between factors, the relationships are elaborated on in the text.)**

### 6.3.1 Trends and peaks (rate of environmental state changes)

The rate of environmental state change expressed in terms of raw water trends or peaks was the key factor for WaSCs to begin the innovation decision-process (i.e. ‘Agenda Setting’ - J): “*It tends to be the change that you are worried about, the status quo tends to be ok.*” The reason for this was that change in raw water quality conditions required adaptation by WaSCs in order to maintain water quality output standards (Section 6.4). Contrary to this, a steady state enabled the continuation of present practice; whether technical or else. For instance, trends or peaks could render a treatment process ineffective to meet output requirements (J): “*This site was chosen because we looked at*



*the water quality problems that they have at the treatment works, so we know what the trend is and we look at the treatment process at that treatment works and how it is performing and we know that in AMP 5, if we don't do something, that works will no longer be able to treat the water, so the alternatives are to build a MIEX<sup>®</sup> plant or try catchment management."*

This statement indicated that whether an issue was perceived appeared to be inseparably linked to the ability of installed technologies to mitigate raw water pollution. In Section 6.2.3 it was shown that these asset characteristics have a profound influence on the 'Agenda Setting' process and on the choice of alternatives.

Two characteristics of raw water quality trends were key to stimulate 'Agenda Setting'. Regional upwards trends, in particular for nitrates, were mentioned to be a concern because these trends limited the ability of WaSCs to respond through blending, (A): *"We can blend it to meet the standards of drinking water. But there is a strong awareness that in the future, in the next 10-15 years; we won't be able to provide supply."* Likewise, short spikes of raw water pollution, such as seasonal fluctuation of nitrates or pesticides, were perceived not to justify large scale asset investment (I): *"...can you justify actually building millions of pounds worth of nitrate treatment because your source has failed once in a year, you may have had two or three days where nitrates have peaked."*

Though less frequently, trends and peaks were also mentioned to affect that 'Choice between Alternatives' (Figure 6-3). Mainly, when trends were anticipated early enough for SCIs to deliver successful outcomes WaSCs opted for this type of response (B): *"It kicks in if we see an emerging risk. One where we think we have a good enough lead in time to get catchment management up and running, before we actually have failures."*

In one instance the influence of the trends and peaks, or more precisely the influence of the environmental state, was affecting the intra organisational 'Diffusion' of the innovation (E): *"This reservoir and this reservoir and this reservoir are all eutrophic, they're all full of nutrients, some of them are full of pesticides as well, they're all suffering from the land management practices in their catchments so we decided that it was cheaper and better for our customers if we could sort out the catchment."* This

indicates that WaSCs assessed different situations (i.e. catchments) using the same approach as described above. Namely, an environmental pressure of a certain type must be perceived for SCIs to be adopted. Indeed, viewing 'Diffusion' from this perspective it appears that WaSCs generally looked for favourable situation and raw water problems to spread SCIs (D): *"...we have some problems which have quite a fast response time so we will probably start investigating in the catchment and eventually doing something in the catchment or trying to attract other parties."*

### **6.3.2 Hydrogeology, water source and catchment size**

The inter-related factors hydrogeology, type of water source and the catchment size were found to affect the innovation decision process at the point of 'Choice between Alternatives' and the 'Reinnovation' stage.

The impact of the hydrogeology is best illustrated when comparing the groundwater source of WaSCs C and I. In case C it was argued that a significant barrier to adopt source control solutions were the properties of the fractured chalked aquifer. In this dual porosity aquifer nitrate or pesticide pollution can remain in the chalk matrix for decades and thus delay response to source control actions. Further, it was perceived that due to the intense surface connectivity land management changes would need to be drastic to improve groundwater quality to desired levels (C): *"...before the water reaches the water table the majority goes through the matrix which is slow, though some of it will bypass it. Ok but imagine, I've just quoted two ends of the spectrum, it's actually a whole spectrum, I'm simplifying it, there will be small fractures that are slower...So therefore, you can often see double peaks; which is one peak is coming out of the fissures, the other one is leaking into the fissures...Just to carry on with the nitrates, what you're seeing therefore is the majority of nitrates but not all of it is historical, so what you do on the land surface is not going to make much difference. Not in the sort of pay back period modern accountants and businesses want. So that's why I think land management is only going to work in very particular circumstances."*

Contrary to WaSC C the karstic limestone in a catchment of WaSC I appeared to be an opportunity for the adoption of SCIs. In this case historic pollution of the aquifer maybe minimal (limestone is not a dual porosity aquifer, thus water cannot be stored in a matrix and released into the fractures) and cause effect relationships are more direct (I):

*“The geology is unique, it’s very broken limestone, almost karstic limestone, the particular section of the catchment that the boreholes are drilled in and the wider catchment is chalk as well but the catchment that we’re concerned about is limestone...his spraying dates, we lined those up with dates of rainfall and dates of our problems in our site and very clearly, whenever he sprayed and it rained, we had a problem, it was very, very clear.”*

Moreover, the specific geology was a factor determining the design of the source control response. Referring back to example the catchment of WaSC I above, it was only due to the clear cause effect relationship that direct payment of the farmer was chosen and approved by the DWI (an ‘A&S’ response). Another example was WaSC B, where an ‘Education’ approach was chosen. In this specific catchment it was expressed that this design was only possible because the hydrogeology enabled pollution source apportioning.

The hydrogeology did also influence where WaSCs source their water from; in other words, whether water originated from groundwater or surface water sources. It was generally perceived that small surface water catchments, such as those of reservoirs, were appropriate for SCIs because pollution could be more easily apportioned to source. For groundwater areas this relationship was perceived to be too complex, subject to substantive response delays and difficulties to source apportion pollution. Therefore, with exception of WaSCs I above, it appeared that SCIs were more likely to be adopted on small surface water catchments (E): *“To be honest above the lake it’s a relatively small catchment, so therefore it was relatively easy to identify the main pollution potentials.”*

Conversely large surface water catchments were generally perceived as unsuitable for the implementation of SCIs (I): *“We’re blessed by the fact that we don’t have many river off takes, we have one or two but they are more problematic and I do feel for [WaSCs F], they have major river off takes because then your catchment is thousands of kilometres.”*

As indicated by the statement above the size of catchments was found to affect the design of the SCIs at the ‘Reinnovation’ stage. More specifically WaSCs tended to opt

for 'Liaison' designs in larger catchments. For examples, the representatives of organisation A argue that the WaSCs has a large area with many raw water quality issues being present, which appeared to drive them towards adopting Liaison designs (A). *"I think it's a big issue, we have such a large area and that gets so many issues. It's a key point! It can be difficult to prioritise and to work out what to do where... we have to work on the good will of others I suppose but we've found that albeit developing our strategy that there were people out there that did visit farms and had roles to play."* One representative of WaSC B was more explicit: *"...but that's very much localised, when you are talking about a catchment of the size of the two rivers here your ability to influence on the size of that catchment is much reduced, so therefore that's why you could only do this two tier approach [which involved Liaison – see Chapter 5]."*

Conversely, it could also be found that when 'A&S' interventions were employed they tended to be restricted to small catchments (J): *"...they're [the catchments] fairly small and what they'll do is replicate the work that we've done here."*

Lastly, it was found that WaSCs identify favourable hydro-geographical conditions to spread or 'Diffuse' SCIs (J): *"Certainly going into AMP 5 and AMP 6 where we'll be looking at land management, catchment management to influence particularly water colour in the little catchments, which to date has been done on our own land holding."* Contrary to this, where hydro-geographical conditions were unfavourable more widespread implementation of SCIs did not occur.

### **6.3.3 Land use**

Only very limited evidence could be found for the influence of land use on the innovation decision making process. That land use had an impact on the 'Choice between Alternatives' stage could only be identified for the case of WaSC C. This WaSC's representative argued that catchments with homogeneous land use would be ideal to implement SCIs: *"We may consider it [catchment management] where there is a uniform land use within the majority of the catchment."*

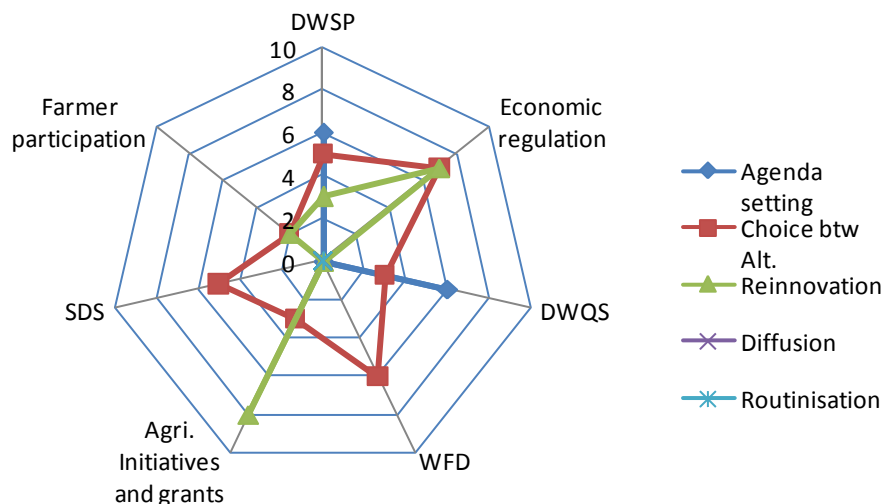
However, land use could explain why certain activities are carried out under the 'A&S' type of SCIs. This maybe expected as specific land use types permit some responses

while others require different activities. The clearest example is heather management which can only be conducted on moorlands, where heather grows.

While land use can explain the specific activities on the ground, there was no evidence that it influenced the choice between 'Liaison', 'Education' or 'A&S'. Thus land use has not been considered to affect the 'Reinnovation' stage (Figure 6-3). This is so because the interest of this study is to understand the reasons for the adoption of the different SCIs designs, rather than what shapes specific 'A&S' activities.

#### **6.4 Regulation and institutional factors**

Seven regulatory and institutional factors were isolated from the interviews. In Figure 6-4 it can be seen that these factors affect the 'Agenda Setting', the 'Choice between Alternatives' and the 'Reinnovation' stage of the innovation decision making process. The DWSP (4) and drinking water quality standards (DWQS - 5) lead to an 'Agenda Setting' by WaSCs. The 'Choice between Alternatives' was affected by all regulatory factors, namely the WFD, economic regulation, DWQS, Strategic Direction Statements (SDS) and the WFD. Economic regulation and DWQS had a negative influence on the choice of SCIs. While on the contrary, the WFD, the DWSPs and the SDS were factors conducive to adoption of SCIs. 'Reinnovation' was only influenced by the factors argi-environment grants and initiatives, economic regulation and the DWSPs.



Factor	DWSP	Economic regulation	DWQS	WFD	Agri-Env. Initiatives	SDS	Framer participation
Agenda Setting	A/B/C/G/H/J	0	A/B/G/I/J/F	0	0	0	0
Choice btw. Alt.	A/B/G/H/J	A/B/C/E/D/F/J	B/D/E/J/H	A/B/C/D/H/J	A/C/D	A/B/C/D/J	I/F
Reinnovation	A/H/D	A/B/C/E/D/F/J	0	0	A/B/C/D/F/G/H/J	0	E/I
Diffusion	0	0	0	0	0	0	0
Routinisation	0	0	0	0	0	0	0

**Figure 6-4: Recurrence of Regulatory-Institutional factors across the population of WaSCs and their influence on the stages of the innovation decision process (Figure shows at which stages of the innovation decision process Regulatory-Institutional factors affect the innovation decision making process. Recurrence is counted across the population of WaSCs (i.e. 10). Arrows indicate relationships between factors, the relationships are elaborated on in the text. )**

### 6.4.1 Drinking water standards and risk based standards

Drinking water quality standards (DWQS) were key drivers for the ‘Agenda Setting’ process. They presented the minimum value WaSCs were aiming to achieve. If this value was failed, or anticipated to be failed, WaSCs perceived a problem and began the search for alternatives (B): *“I am in water quality. The main area is making sure that all the water quality is up to the required standard. And then when it is not we have to*

*investigate or initiate investigation as to why it is not to the required standard and obviously how it is resolved.”*

While DWQS trigger the ‘Agenda Setting’ process, they were perceived as a constraint to the choice of source control approaches. The central argument was that the DWQS requires 100 percent reliable outputs which cannot be delivered through SCIs (see Section 6.5). This lead water companies to propose that if they had some leeway in the delivery of standards, for instance by using a risk based approach, there would be a lower threat to non compliance; and thus WaSCs maybe more likely to choose SCIs. A representative of WaSC E expressed this as follows (E): “...*absolute quality standard, so maybe if we have a non health based standard, 95% percentiles or rolling averages or whatever, that will encourage more of these types of things because at the moment you’ve got to meet less than 0.1 µg/l for individual pesticides and if you have 0.101 µg/l you fail. ... even if they said to you ok we’ll give you a rolling degrading and reducing standard, start off with an average of 0.09 µg/l but we expect in five years with the catchment efficient that average to 0.07 µg/l, I think companies would even go for that; but if you’ve got to meet a 0.1 µg/l and if you fail a 0.1 µg/l you’ll be enforced to do X, Y, Z.*”

#### **6.4.2 Economic regulation**

The negative influence of the regulatory framework has already been highlighted in Chapters 4 and 5. In essence these views were echoed in the present analysis. For instance it was argued that the enforcement of the polluter pays principle; in combination with the short term management cycles of five years are barriers to select SCIs as response option (E): “*I think the biggest barrier to investing in the catchment is that Ofwat will not fund.*”

In addition, the fact that Ofwat’s position on catchment management is changing was supported by the interview findings. A number of WaSCs suggested that Ofwat will permit the implementation of SCIs or catchment investigations where a case for cost benefits can be made.

In association with the above WaSCs expressed concerns as to whether Ofwat would fund catchment measures in parallel to treatment solutions. WaSC representatives felt

that SCIs best operate in concert with treatment to achieve long term protection of resources and reduce uncertainties (see Section 6.5). They were concerned that a case for cost benefit would be difficult to make when SCIs and treatment operate simultaneously (A): *”...it’s just whether Ofwat fund us to do two things at the same site or whether they just say well here’s the money for the ion exchange plant and then come back and talk to us later.”*

The influence of the economic regulations on ‘Reinnovation’ was frequently mentioned too. The enforcement of the polluter pays principle by Ofwat appeared to drive WaSCs to develop approaches which require little financial commitment, while still offering the chance to mitigate pollution. ‘Liaison’ and ‘Education’ designs offered a such an opportunity (D): *“What we did do was limited, we had to be quite careful, we could have been seen charging customers their water rate and then some of that money going to pay farmers to do different things in their farms and almost paying for set aside, that would not have been the right thing to have done.”*

### **6.4.3 Drinking water safety plans (DWSPs)**

The DWSPs affected the innovation decision process in three ways. Firstly, the DWSP raised the awareness of raw water quality risks in the catchment supporting the ‘Agenda Setting’ process (B): *“The Drinking Water Safety Plan concept, so you’ve got your catchment, treatment, distribution and the customer and the regulations require us to monitor but we also look at what the background risks are from the catchment...”*

Secondly, DWSPs were argued to stimulate a new view of water supply management by asking WaSCs to consider various options to mitigate water quality risks, including the catchment, (H): *“My kind of experience is that the attitude of the water industry 10-15 years ago was: we’ll treat it as long as it physically flows we’ll do something about it and we’ll try and treat it. I think that safety plans have certainly made us think: can we do anything to actually improve the quality before it reaches the works.”*

Thirdly, there was evidence that DWSPs stimulated the ‘Restructuring’ of WaSCs. As a response to DWSPs nearly all WaSCs developed new roles (Chapter 5), some of which comprised or will comprise responsibilities associated with SCIs (H, B, - D): *“You know they [DWSPs] require us to know about and manage where possible, risks of the*



*whole supply chain including catchment and I think that has, certainly within this company, resulted in four new positions being filled for DWSP” and H: “I think prior to DWSPs we certainly didn’t have people where a big part of their role was catchment, that is certainly new to following safety plans.”*

#### 6.4.4 Water framework directive (WFD)

The WFD was found to affect only the ‘Choice between Alternative’ stage. The elements of the WFD mentioned were:

- Article 7,
- the source control principle,
- the polluter pays principle.

This indicates that it were mainly the basic principles of the WFD in terms of source control and polluter pays that affected the innovation decision process. Possibly as a result of this it was found that the WFD’s main influence was a change of the mind set of WaSC representative (Table 6-3).

**Table 6-3: Evidence for the influence of the WFD on WaSCs perception of SCIs**

WaSC	Quote
A	<i>This is actually linked into the WFD principles as well in terms of sort the problem out at source, you know prevent deterioration, get ourselves so all these trends in raw water are static and then your long term reducing and their severity, rather than bolting on an additional treatment process, the easiest thing for us to do</i>
B	<i>But I think now with both the WFD and DWSP regulations, there is a growing appreciation amongst all the regulators that it does make sense for water companies to look upstream of their intake and look at their raw material before it gets to the treatment stage.</i>
C	<i>However you could say the WFD has brought about greater visibility of catchment management.</i>
D	<i>The WFD actually come in, I wouldn’t say that’s why we did it, but now we see a greater chance of success.</i>
E	
F	
G	<i>We are using the water framework directive to push measures which will benefit our catchment.</i>
H	<i>I’m still unsure about whether it’s achievable is this whole almost WFD notion of sell off your works because the environment is so good. I am yet to be sold on whether we’re ever going to get to that – I think if you take it to the n-th degree, if you have a fully coordinated, fully catchment, drinking water sensitive, fully catchment aware kind of aquatic environment and if you have the legislation I mean enforcement of legislation on the environmental side that is strict enough then maybe you can get there.</i>
I	
J	<i>But Article 7 is the. Well actually a sea change in water resource terms... the water framework directive has the potential to massively influence the shape of Britain.</i>

However, while the WFD appeared to perform well in changing WaSCs conception of water supplies, translation of this into activities on the ground was poor. For instance, it was suggested that the Article 7 of the WFD was an opportunity for WaSCs to see improvements in their raw water quality (see also Chapter 4). However, much uncertainty still surrounded the implementation. At the time of interviewing (May-August 2009) all WaSCs were uncertain which areas of their catchments would be designated as drinking water safeguard zones (DWSZ). Some organisations were also dissatisfied with the designation procedure. The process was suggested not to be transparent, and the designation of DWSZ seemed to be limited to very few sites. The negative influence of this on the choice of SCIs is shown in the following statement (J):

*“...that’s why I wanted my safeguard zones under the Water Framework Directive because I had nothing to say – I would go to somebody and say I want to work on your land, I can make it better and make it less heather, the person would say well I shoot grouse, I like heather and what can you do to stop us and at the moment I can’t do anything, so if I had the safeguard zone and I could say well actually if you don’t work with me and the water quality gets worse and I can prove that you are damaging the water quality, then the Environment Agency have the rights to take you from the safeguard zone to statutory water protection zone, your choice.*”

*We have the RBMP which we’ve been consulting with them for the last six months and in our area we thought we’d work with the Environment Agency designated safeguard zones because nobody knew what this should be. So I said to the Environment Agency if you look at the water quality problem, so the water quality problem is colour, where does the colour come from, it comes from the deep peat, so your safeguard zone would be the area of deep peat within the catchment of the reservoir. It doesn’t need to be the whole catchment and that was agreed, but unfortunately Nationally – I don’t know what they’re playing at, they said they didn’t have enough data and they’re not designating it...”*

Implicitly the WFD also had an influence on the design of SCIs. The key reason is the polluter pays principle of the WFD (WFD Article 9). As described before (Section 6.4.2), Ofwat interpretation of this concept did not permit WaSCs to fund SCI activities; thus re-enforcing end-of-pipe solutions to raw water quality pollution.

#### 6.4.5 Agri-environmental grants and initiative

The availability or presence of these agri-environmental initiatives and grants in WaSCs catchments was relevant for the decision to adopt SCIs and SCIs design. Most frequently it was mentioned that the CSFI and VI were important for water companies as agents to facilitate SCIs. Thus these initiatives appeared to stimulate the adoption of 'Liaison' designs specifically (D): *"Yes I haven't really been involved myself with that...we're trying to get into a partnership agreement with the EA...and here there's a Defra funded officer working part time in the catchment to look at the issues to do with pesticides."*

Grants, such as ELS and HLS were further consciously built into 'A&S' designs to finance these schemes (G): *"The reason being that, different areas at the moment have different agri-environment schemes, so we utilise which ever are the most appropriate agri-environment scheme for that particular farm. So what we have looked at is basically, our investment is an enabler for the tenant to get access to revenue payments from another source. I mean they could have done it on their own. In some instances some of the tenant had a bit of a history of doing something along these lines. But now we are talking about quite radical change."*

Agri-environmental grants and initiatives also influenced the choice of SCIs (i.e. 'Choice between Alternatives'). Companies in the early stages of the innovation decision process (i.e. companies which were only planning SCIs designs – WaSCs A, C, D) perceived grants and initiatives as a stimulus to take up this kind of alternatives. For instance WaSCs C argued that the CSFI in their catchments is encouraging them to consider SCIs: *"The WFD and the CSFI is bringing different players into the game which is allowing us to say: Yes there is an opportunity to effectively influence land management. So we now actually question do we go with treatment or do we give catchment management a trial."*

The geographical distribution of argi-environment initiatives and grants may offered different opportunities for WaSCs to adopt SCIs and therefore influenced the process of 'Diffusion' of SCIs. This was indicated by one WaSCs representative (G): *"Because the HLS scheme is everywhere. Ok you could have land designated as a site of special scientific interest then it is easier to get the points to get into the scheme."*

#### 6.4.6 Strategic direction statement (SDS)

The requirement of WaSCs to develop 25 year strategic planning documents (Ofwat 2009b) appeared to have a positive impact on the choice of SCIs (i.e. ‘Choice between Alternatives’), because it provided a framework under which WaSCs could account for the long term outcome of SCIs (D): *“We used to think in five year blocks, now it’s the new executive team, they are focusing on the long term 25 years plus as well as the short term and making sure that our investment is right both now and for the future. That’s why our business plan, our strategic direction is 25 years ahead. So there maybe some groundwaters where there is some benefit in giving catchment management a try.”*

#### 6.4.7 Farmer participation

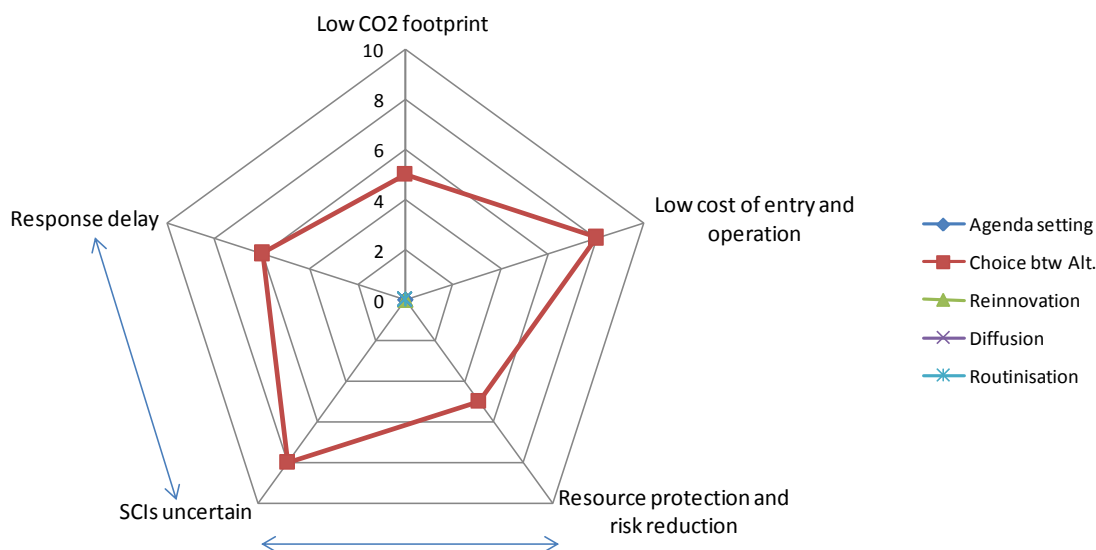
Farmer participation affected the ‘Choice between Alternative’ stage. It was pointed out that the willingness of the farmer to participate was a key enabler for the adoption of SCIs (I): *“...to be fair this only really worked because the farmer was very open with us.”* Conversely, where farmers did not co-operate this was perceived as significant barrier to the implementation of SCIs (J): *“And the agricultural sector behaves very differently. Parting a farmer from his nitrate is hard work...There is a set of individuals. Very much individuals, that are quite slow and resistant to change in many ways.”*

The co-operation of farmers could also influence the SCIs designs. ‘Liaison’ and ‘A&S’ approaches could be implemented where the buy-in from farmers allowed assess to land, since then data collection was possible. In other instances, the receptivity of farmers for WaSCs concerns enabled an Educational approach (E): *“He lived the other side of the abstraction but he didn’t want the cows right outside his back door ...and I’m saying well if you stand here you can see the intake, what if the ditch washes away, they all just go for it and march around and all escape one day, it’s too late, they are 50 yards from our abstraction point, if he builds it the other side of the intake, it’s downstream, if they all make a run for it, it’s fine. So he moved it voluntarily, no forcing.”*

### 6.5 Innovation attributes

Five innovation attributes were perceived to influence the innovation decision process (Figure 6-5). All of these attributes were related to the relative advantage (or

disadvantage) SCIs can offer compared to other alternatives. The main point of influence of innovation attributes was the ‘Choice between Alternatives’ stage of the innovation decision process. Risk associated with SCIs and costs were the most frequently recurring factors. Their orientation was however, diverging. While perceived risks reduced the likelihood that WaSCs chose SCIs, costs of SCIs were suggested to be comparatively low, thus stimulating choice in favour of SCIs. Another important characteristic of SCIs was their low carbon footprint. This factor promoted the selection of SCIs. In addition the ability of SCIs to reduce risk from the catchment (incl. reduction of Metaldehyde risks) was of influence, encouraging the adoption of this alternative.



Factor	Low CO <sub>2</sub> footprint	Low cost of entry and operation	Resource protection and risk reduction	SCIs uncertainty	Response delay
Choice btw. Alt	A/ B/ D/ E/ J	A/B/C/D/E/G/I/J	A/B/D/E/J	A/ B/ C/ D/ E/ G/ H/ J	B/C/D/E/ H/J

**Figure 6-5: Recurrence of Innovation Attributes across the population of WaSCs and their influence on the stages of the innovation decision process (Figure shows at which stage of the innovation decision process attributes of SCIs affect the innovation decision making process. Recurrence is counted across the population of WaSCs (i.e. 10). Arrows indicate relationships between factors the relationship is elaborated in the text.)**

### 6.5.1 Source control interventions an uncertain alternative

Barriers to the selection of SCIs as a response option were the uncertainties associated with it. WaSC representatives suggested that SCIs were less reliable in delivering

DWQS than technological alternatives. This was due to the complex, and often insufficiently understood, cause effect relationships between pollution and water quality; but also because SCIs are dependent on the actions of others (i.e. farmers) to deliver drinking water quality objectives. Contrary to this technological end of pipe alternatives were perceived to be more certain, since WaSCs had direct control over every stage in the treatment process (E): *“The problem with upstream stuff is that the science is a bit thin, end of pipe solution you can do this, do that, that will happen, if you do the catchment approach, do this, do that and this might happen or should happen not it will happen, you can’t guarantee it.”* and B: *“A treatment solution gives you a certain degree of control and certainty. Relying on other people not to do things or to do other things in a certain way on their own land, whether what you are asking them to do might compromise their business liability to a certain extent is a tough one and in terms of how much risk we can except in terms of taking that approach, relative to other issues of controlled risk and to have that amount of control over the final water is always gone be the main sticking point I think.”*

### **6.5.2 Resource protection and risk reduction**

In the Section above it was argued that SCIs are often thought to be associated with a risk of failing regulatory requirements. Contrary to this an increasing involvement at the catchment level was also considered to mitigate operational risks. WaSCs which argued along these lines suggested that knowledge of the dynamics within a catchment and the ability to influence these dynamics may deliver the ability to anticipate pollutions trends (or events) and affect raw water quality. This consideration was a factor in favour of SCIs (B): *“In terms of trying to prevent deterioration, building stronger networks within catchments so that we have more of an idea of the trends of nutrient use...so that we can be more proactive.”*

Metaldehyde was a specific example for this risk reduction approach. Most of the organisations which found Metaldehyde in their raw water indicated that they control or will try to control Metaldehyde risks by implementing SCIs (exceptions F and J). The driver for this was the perceived absence of viable treatment alternatives for Metaldehyde at the time of interviewing (Chapter 5). Thus, risk reduction in this case

was closely associated with the ability of technologies to be resilient against raw water contamination (see also Section 6.4 when discussing asset characteristics).

It must be noted here that WaSC F, which was shown not to adopt SCIs, has implemented a risk reduction approach as described in this Section. However, rather than seeking to reduce the risk at source this WaSC managed the risks of acute pollution incidence. This was implemented through in-stream monitoring and a combination of interrupting abstraction, managing river flows and levying environmental regulators (F): *“In many cases out here together with the EA we’re monitoring well upstream, so we get a warning of what’s coming down the river and we can then apply time of travel models and predict when a pollution event is going to arrive at the intake point so we close the intake point when we have to rather than prematurely. And then quite often there is the opportunity to flush the river.”* This statement indicated that rather than tackling pollution incidence at their source, WaSC F developed a sophisticated emergency response strategy. Therefore this strategy did not qualify for being a SCI, though it bared resemblance to ‘Liaison’ SCI designs.

### **6.5.3 Delayed response**

Source control interventions were, with few exceptions, exclusively perceived as medium or long term responses (depending on hydrological factors in combination with the raw water quality issue – Section 6.3.2). Water quality improvement, the final objective of water companies was though to be achievable only within a few years to several decades (B): *“I don’t think you can put necessarily any short term measures around a catchment management, it is definitely the medium to long term.”*

Thus SCIs were perceived to be unsuitable for (I) immediate responses to raw water quality problems and that their effects may not be (II) easily observable. The lack of an immediate response is therefore a disadvantage of SCIs compared to many treatment options, which are likely to achieve management objectives quicker and more reliably (see above). In conclusion response delays generally had a negative or inhibiting influence on the choice of SCIs.

Similarly, the long response delay may make the attribution of effect to cause very difficult. Therefore, results of SCIs can be considered as not easily observable. In

Chapter 7 it will be argued that this can present a significant barrier to finance SCIs, thus limiting its wider adoption.

#### **6.5.4 Low costs of entry and operation**

Source control interventions were generally perceived as being significantly less costly than competing end of pipe treatment alternatives, which was considered to encourage choice in favour of SCIs (B – about Metaldehyde): *”Catchment management is far cheaper. You are talking about hundreds or thousands of pounds a year perhaps, whereas if you are talking about installing treatment you are talking about another 50 million maybe.”* This statement hints towards the consideration of ‘costs of entry’; for technological alternatives these costs are usually high because of the infrastructure investment required. While costs of entry exists for SCIs too (i.e. through employing new staff or infrastructure investment on farm –depending on the types of SCIs) they were usually considered to be much lower. SCIs, if anticipated to be successful, were therefore often associated with significant cost saving in places where installation of additional treatment process could be avoided.

#### **6.5.5 Low CO<sub>2</sub> footprint**

SCIs were associated with reduction of CO<sub>2</sub> emission. End of pipe treatment was perceived to be energy intense and thus to have a large CO<sub>2</sub> equivalent footprint (in addition construction is likely to have a significant CO<sub>2</sub> equivalent). Contrary to this SCIs were argued to be significantly less CO<sub>2</sub> intensive; thereby offering a relative advantage in comparison to end of pipe solutions.

WaSCs G and E also highlighted that their SCI activities could help capture and store carbon. In these specific cases SCIs were carried out on moorlands. It was suggested that rewetting the moor can reduce mineralization (and thereby CO<sub>2</sub> release) and contribute to the formation of new peat layers, as a form of carbon capture. However, at least one WaSC suggested that it could not claim this benefit in terms of carbon credits or similar. Nevertheless, this attribute of SCIs may, in specific circumstances, be a relevant choice criterion for WaSCs.



## 6.6 Summary

In this Chapter it was illustrated that the process of SCIs adoption is influenced by multiple factors from the domains ‘Innovation Attributes’, ‘Natural-Physical’ environment, ‘Regulatory–Institutional’ environment and ‘Organisational Characteristics’.

It could further be shown that a number of factors were more frequently mentioned to influence specific stages of the innovation decision making process than others. For instance innovation attributes only affected the ‘Choice between Alternatives’, but did not affect other stages of the innovation decision processes. Contrary to this, factors from the remaining domains affected most innovation decision making stages. In each stage of the process some factors stand out. The ‘Agenda Setting’ process was mainly affected by trends and peaks, asset characteristics and drinking water standards.

On the contrary the ‘Choice between Alternatives’ was dominated by a larger array of factors of that were mentioned with similar frequency. Amongst them were hydrogeographical factors such as catchment size, organisational factors including asset characteristic, managerial attitudes, land ownership; innovation attributes such as uncertainties and risk, low CO<sub>2</sub> emission, low cost of entry and operation; finally also Regulatory-Institutional factors had a role to play including economic regulation, the WFD and DWSPs.

The factors influencing the ‘Reinnovation’ were less numerous, the key factors appeared to be catchment size, land ownership, knowledge and existence of environmental grants and initiatives.

Finally, the ‘Diffusion’ of SCIs was influenced by factors such as trends and peaks, hydrogeology and agricultural and catchment knowledge. In the next Chapter, it will be discussed how the factors described in this Chapter interact.

# Chapter 7

## Implications for innovation by WaSCs in E&W

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### 7.1 Introduction

In this Chapter empirical evidence is discussed to respond to research questions I and II.

- I. What are the types of source control interventions adopted by WaSCs in England and Wales?
- II. What are the factors influencing the characteristics of the adoption process of source control interventions by WaSCs?

First the findings presented in Chapter 5 and 6 are compared against other EU countries underlining differences and similarities of SCIs and factors influencing their adoption. Next, the reasons for the differences between WaSCs in terms of the innovation decision process stages and SCIs design types are discussed, drawing on the factor identified in Chapter 6.

### 7.2 Characteristics of SCIs - EU comparison

In the context of the EU, Andrews & Zabel (2003b) suggested that CAs are established for three main purposes:

- Remedial-statutory – Where the drinking water standards are exceeded, the aim is to reduce the concentration below the DWQS, to avoid treatment.
- Preventative-statutory – Where the standard may be exceeded in the future, the aim is to ensure that pollution is stabilised or the trend reversed to avoid the need for treatment or the development of new water source.
- Discretionary – Where the intention of the water supplier is to provide drinking water with the lowest achievable concentration without treatment.

In the E&W, SCIs were mainly set up to accomplish remedial-statutory and preventative-statutory objectives. This is evident in the four main purposes of SCIs in E&W (see also Horton (2009) for a similar classification):

- to comply with the statutory drinking water standard and conservational objectives
- to save operational costs and/ or to avoid asset investment
- to reduce CO<sub>2</sub> emissions
- to protect water resources

Thus, a vital purpose not described by Brouwer *et al.* (2003a) is the reduction of CO<sub>2</sub> emissions and in some special cases also the pursuit of land conservation interests. This emphasises that SCIs can offer win-wins for water companies.

Further, evidence from Germany and the Netherlands suggests that CAs were mainly established for ground water sources (Brouwer 2003a). Contrary to this the findings presented in Chapter 5 indicated that only three WaSCs developed SCIs for groundwater catchments, while all eight WaSCs applied SCIs for surface water sites. In addition, Brouwer *et al.* (2003a) found that 430 agreements addressed nitrate pollution issues. Yet, only 100 CAs schemes tackled nitrate pollution issues and about 20 schemes targeted water quantity. In E&W pesticide schemes in surface water catchments dominated. Only three companies implemented SCIs for nitrate pollution in groundwater catchment. A key reason for this difference may be that the primary source of drinking water in E&W is surface water (see Chapter 1). In addition, the perceptions of WaSCs representatives that surface water sources may show quicker and more direct responses to SCIs may stimulate the adoption of SCIs on surface water sources (Chapter 6). Lastly, the application of SCIs for DOC and associated discolouration has not been addressed in the literature, but was shown to be of concern to WaSCs in E&W.

### **7.3 Factors influencing adoption – EU comparison**

The study published by Brouwer *et al.* (2003a) is the only research the author is aware of, which investigates the factors influencing the adoption of SCIs. Brouwer *et al.* (2003a) explored the adoption of CAs at the EU member state level (i.e. Germany,

France, Netherlands, and UK). They did not employ an innovation decision process framework. Consequently, they did not provide information about where factors affect the innovation decision process.

For the purpose of the comparison, Brouwer *et al.*'s (2003a) factors will be grouped according to the four domains employed in this study. Table 7-1 contrasts the findings of Brouwer *et al.* (2003a) with the findings of the present research. Most of the factors proposed by them were also detected in this study.

Firstly, the inferences made about SCIs characteristics (i.e. 'Innovation Attributes') from literature were largely confirmed (Chapter 2). Additions are that SCIs can provide a relative advantage compared to treatment alternatives, because of a low CO<sub>2</sub> footprint. Compatibility with regulation was shown to improve as a result of recent regulatory changes thus encouraging the adoption of SCIs (Chapter 8). In addition, compatibility of SCIs knowledge requirements with existing organisational skills and expertise was limited, thus constraining implementation.

The effect of hydrogeology and the impact of catchment size on the adoption of SCIs (CAs respectively) was similar. In both studies the more complex cause effect relationships in larger catchments were found to be constraining the implementation of SCIs. Likewise, different forms of SCIs appeared in larger catchments. Brouwer *et al.* (2003a) proposed that in larger catchments advice activities prevail. Unfortunately they fail to define these activities more closely. Contrary to Brouwer *et al.* (2003a) who suggested that CAs are more likely on groundwater catchments; the present research indicated that SCIs of all kinds are predominantly adopted on surface water rather than ground waters catchments.

**Table 7-1: Comparison of factors affecting adoption of SCIs as identified in this study and by Brouwer *et al.* (2003a)**

Domain	Factor	Description	Brouwer <i>et al.</i> (2003a)
Innovation attributes	Relative advantage	<b>Low CO<sub>2</sub> footprint</b> - SCIs have CO <sub>2</sub> footprints, which provides a relative advantage to energy intense end of pipe alternatives	
		<b>SCIs outcome are uncertain</b> - SCI cannot deliver 100% certain drinking water quality standards, which is considered a disadvantage of SCIs	CAs outcome are uncertain and suffer from time delays
		<b>Low cost of entry and operation</b> - SCI are comparatively low cost in terms of operations and installation. Thus they provide a relative advantage over SCIs.	CAs can be more cost effective than treatment solutions
		<b>Catchment risk reduction</b> - SCI can reduce risk of pollution from catchments, thereby providing a relative advantage over technological alternatives	CAs can proactively reduce pollution
	Compatibility	In some cases SCIs were shown to be incompatible with business knowledge, attitudes and regulatory system, here in particular the DWQS. Nevertheless, SCIs were compatible with a number of organisational needs including: CO <sub>2</sub> reductions, energy efficiency and raw water quality risk reduction.	CAs are incompatible with regulatory framework in E&W
	Complexity	SCIs were perceived to be complex because cause effect relationships were often not well understood.	SCIs are perceived to be complex because cause effect relationships are often not well understood.
Environmental physical factors	Observability	Outcome of SCIs were difficult to observe because of complex and delayed environmental responses.	Outcome of SCIs are difficult to observe because of complex and delayed environmental responses.
	Trialability	SCIs were shown to be difficult to trial and test due to significant response delays. Issues about rights of access to land and cooperation of farmers were also relevant in this context.	SCIs are difficult to trial and test due to significant response delays
	Character of trends and peaks	Trends and peaks rather than historical pollution are conducive to perceive a raw water quality problem (i.e. an environmental pressure) and begin the innovation process.	Environmental pressures must exist (i.e. nitrate, pesticide etc.)
Environmental physical factors	Land use	There is some evidence that land use affects the adoption of SCIs and their design. Possibly through its effect on raw water quality.	Livestock farming is more difficult to manage under CAs because of potential high compensation payments for livestock changes
	Hydrogeology, source type and catchment size	SCIs are more likely on surface waters. Size of catchment makes cause-effect relationship difficult to establish. Larger catchments are dominated by Liaison approaches.	CAs are more likely on small groundwater catchments, but can be found on large catchments where they provide mainly advisory service. Size of catchment make cause-effect relationship difficult to establish

Regulatory institutional factors	DWSPs	DWSPs require monitoring of catchment risks and risk response planning; thereby they stimulate adoption of SCIs.	
	Economic regulation	Constraints SCIs through enforcing the polluter pays principle and short evaluation time frames. Economic regulation can stimulate the development of 'Liaison' SCIs designs.	Cost of CAs cannot be passed on to the customer through an increased water price
	WFD	Changes WaSCs perception of water supply delivery. Initiates development of DWSZ which provide opportunity to engage in SCIs.	Establishment of water protection zones provides funds and improves
	Farmer participation	Participation of farmers precondition to enter into 'A&S' activities.	Farms size: small farmers are more receptive for agronomic advice Farmers age: young farmers are more innovate and more receptive for CAs
	Environmental initiative and grants	Environmental initiative and grants (i.e. such as agri-environments schemes) support the implementation Liaison designs.	Agri-environment schemes support CAs
	SDS	Extent the planning perspective of WaSCs to 25 years, thereby providing a better fit with the long term outcomes of SCIs.	
	Drinking water standards	Fixed drinking water standards constraints the implementation of SCIs, because it is though that SCIs cannot deliver the standard 100 % of the time.	
	'Organisational Characteristics'	Agricultural and catchment knowledge	There is a lack of agricultural and catchment knowledge by many WaSCs, which constraints the implementation of SCIs.
Managerial attitudes Customer preference		Positive attitudes towards SCIs appear to be conducive for the uptake of SCIs. Customers can affect the choice of SCIs through environmental and efficiency targets.	Preference to abandon, blend or treatment approaches to deal with water quality problems. Preference to go beyond standard by providing water with the lowest achievable concentration of pollutants.
Asset characteristics		If assets fail to deliver to the DWQS, WaSCs begin to innovate.	
Land ownership		Where WaSCs own land they may hold more relevant knowledge and have responsibility for land management issues, this seems to be conducive to the adoption of SCIs.	

In this study, it was shown that the perception of environmental pressures in terms of trends and peaks is crucial to initiate the innovation decision process. Brouwer *et al.* (2003a) also suggested that environmental pressures must exist, but they omitted to refer to the perception thereof. In Chapter 6 it was shown that this is misleading, since the perception of an environmental pressure depends on the rate of change in raw water, environmental standards and not least on the character of assets. Thus emphasis should be on the perception of pressures.

Brouwer *et al.* (2003a) showed that land use in terms of livestock farming had an impact on how CAs were conducted. In the present study, interviewees made similar statements (I): *“What we have said is that it’s not artificial fertilizer that causes us the problems, it’s organic fertilizer and therefore intensive livestock areas are going to cause us more problems or historic intensive livestock than say mainly arable areas because in this day and age the price of fertilizer is high and farmers are looking more closely at what they have to buy in.”* However, in this study the influence of land use was shown to be more complex. Data were too limited to make firm judgement about the mechanisms through which land use is influencing the innovation decision making process.

Akin to Brouwer *et al.* (2003a) the present study found that Ofwat’s interpretation of the polluter pays principle constrains adoption of SCIs. Furthermore, both studies found evidence that agri-environmental grants, DWSZ and farmer participation were factors with a positive influence on SCIs adoption. Nevertheless, the current research revealed some additional factors. For instance, it was shown that the short evaluation period (i.e. five years) in the present economic regulation system constrains the implementation of SCIs, because outcomes of these interventions are unlikely to materialise within five years. In this context it was shown that the introduction of 25 year planning perspectives can be conducive to the adoption of SCIs. The DWSP and the WFD were further supportive to SCIs implementation, since they ‘introduced’ the catchment into the focus of WaSCs. Furthermore, the demand of 100% compliance with the DWQS was shown to affect the innovation-decision process adversely, because SCIs were perceived to be too uncertain in achieving compliance.

Looking at organisational factors; Brouwer *et al.*'s (2003a) emphasised the importance of a widespread monitoring framework. This could be interpreted as an indicator for the relevance of data, information and knowledge. Thus it can be argued that the present findings concur with Brouwer *et al.* (2003a), since it was shown that the lack of experience with SCIs and the lack of knowledge about catchments constrained the adoption process.

Brouwer *et al.* (2003a) further suggested that in countries such as Germany the adoption of CAs was stimulated by the customers preference for drinking water purer than required by the drinking water standards. This factor was not applicable for E&W. On the contrary, SCIs were rather established for the purpose of meeting statutory standards. The preference for technological alternatives (factor: managerial attitudes) was shown to be a barrier to the implementation of SCIs. Indeed, this study too found evidence that technological alternatives were preferred in many instances, but it was also demonstrated that this view was changing.

The factor asset characteristic suggested that WaSCs will begin to consider SCIs when all technological alternatives are exploited, no viable technological alternatives exist or if technological alternatives are too costly. While this indicates preferences for technological solutions as a relevant factor, this study advanced to some of the underlying reasons for this preference. Firstly, it was shown that DWQS were conducive to the choice of technological options. Secondly, until recently WaSCs could not be funded for SCIs, thus forcing them to adopt technological alternatives.

Finally, the factor land ownership was not proposed by Brouwer *et al.* (2003a), but was found to be significant for the adoption of SCIs in E&W. This factor supported adoption of SCIs, and 'A&S' design more specifically, because WaSCs were legally required to engage in land management activities. This presented a direct stimulus for the engagement in SCIs. In addition, ownership of land required WaSCs to employ staff to manage the land holdings and offered opportunities to experiment with land management solution; thereby generating relevant agricultural knowledge. Thus, land ownership can offer a source of knowledge and skills, which was argued by Brouwer *et al.* (2003a) to be relevant for the adoption of SCIs.



In conclusion, it appears that literature confirms the relevance of some of the factors presented above. However, the findings of this study also point towards a number of key factors that have not previously been described.

#### 7.4 Variation between WaSCs

In Chapter 5, it was shown that WaSCs were at different stages of the innovation decision process and that they implemented or planned different SCIs design types. Table 7-2 summarises these findings. It shows that all WaSCs perceived raw water quality issues, inferring that water quality is a concern and on the agenda of WaSCs. Eight WaSCs chose SCIs as a response alternative. Recent results from the Water UK Catchment Management Forum substantiate this finding. There it was found that nine WaSCs are implementing (or planning) SCIs (Horton 2009 more detailed analysis is avoid to prevent disclosure of WaSC identity). The observed difference between the data presented and the Water UK data maybe due to WaSC H having recently decided to adopt SCI; this WaSC had used catchment investigations in response to cryptosporidium incidence before and also had SCI champion in the interviewee.

**Table 7-2: WaSCs and their position in the innovation decision process. (L/ E/ A&S = Liaison/ Education/ 'A&S' SCIs designs; \* indicates that this response design was planned only)**

WaSCs	Agenda Setting	Choice between Alternatives	SCI design	'Diffusion'	'Routinisation'
A			L*		
B			L/E/A&S		
C			L*		
D			L*/A&S*		
E			L/E		
F					
G			L/A&S		
H					
I			L/A&S		
J			L/A&S		

Whether the number of SCIs adopted by WaSCs in E&W is eight or nine is not key for this discussion, but rather the finding that this represents an increasing trend towards adoption of SCIs. In the last PR in 2004 only two WaSCs applied for catchment management schemes (Ofwat 2009a), while Andrews (2003a) found that only three

WaSCs in the UK implemented some form of SCI in 2003 (Chapter 1). This poses the question why can this change be observed? In Chapter 8 it is argued that recent changes in policy converged, thereby stimulating the adoption of SCIs.

SCIs Designs were distinguished into three design types ‘Liaison’, ‘Education’ and ‘A&S’. All eight WaSCs which chose to implement SCIs opted for ‘Liaison’ design types. In addition five organisations implemented ‘A&S’ and two ‘Education’ designs. However, instead of having implemented these designs four WaSCs were still in the process customising the designs (i.e. A and C planned Liaison designs; B and D planned A&S). Of the eight WaSCs which chose to implement SCIs only three organisations provided evidence for ‘Diffusion’, but four for ‘Routinisation’. Considering these results it is concluded that there was variation between WaSCs in terms of their location in the innovation adoption process and their choice of SCIs types. The question that arises from this is how can this variation be explained?

#### **7.4.1 Reasons for different process stages of WaSCs**

Table 7-2 shows that WaSCs F and H are at the beginning of innovation adoption process, which is explained differently for both companies. For F it was argued that this WaSC faces hydrogeological conditions and asset characteristics which are not conducive to the implementation of SCIs. More specifically, this organisation abstracts most of its water from large river catchments, which were argued to make the implementation of SCIs challenging. Likewise, the fact that this organisation operates some very large WTW was found to drive a preference for technological solutions rather than SCIs, due to economies of scale.

A key reason that WaSC H was still at an early stage in the innovation decision process appeared to be a lack of relevant agricultural and catchment knowledge held within the organisation. Representatives of this WaSC suggested that there was a lack of such knowledge within the organisation. In Chapter 6, knowledge was argued to mainly affect the design of SCIs; hence knowledge should not impede adoption at the ‘Choice between Alternatives’ (i.e. choice of SCIs) stage. However, in Chapter 8 it will be shown that the ‘Choice between Alternatives’ and the ‘Reinnovation’ stage are inseparably linked, since choices require an understanding of possible designs. Another major constraint for this WaSC was that it is located in a part of E&W where agri-

environmental initiatives such as the CSFI are not established; thus, there was no opportunity to exploit the knowledge and financial resources of these initiatives.

At the other end of the innovation decision process were the WaSCs B, E, G and I, since these organisations showed evidence for ‘Diffusion’ or ‘Routinisation’ (Table 7-2). For WaSC G a key factor to trigger innovation (i.e. ‘Agenda Setting’) was the fact that it owns significant proportions of its water supply catchment. This land ownership provided relevant agricultural and catchment knowledge, which enabled the WaSC to implement SCIs (i.e. by customising them). ‘Diffusion’ and ‘Routinisation’ are now following on from this initial implementation.

However, land ownership is not sufficient to explain how far advanced WaSCs were in the innovation decision process. Evidence for this was provided by the case of WaSC J. The interviewee said that this organisation owns significant amounts of land. However, in the past it had not engaged in land management. As a result, this WaSC had to develop relevant expertise and processes to implement customised SCI designs. This observation draws attention to the fact that managerial attitudes such as the preference for certain response options had an impact on where the WaSCs were located in the innovation decision process. More specifically, in the case of WaSC J, it was found that the decision not to engage closely with tenants has led to knowledge deficits and a different landlord tenant relationship than in the case of WaSC G. Thus while WaSC J was, at the time of interviewing, in the process of developing their own approach to SCIs, this past decision has delayed their implementation process.

Managerial attitudes were also a reason that WaSCs E and I have completed the innovation decision process. In both cases it appeared that specific raw water quality problems at a site with favourable hydrogeology lead to the choice of SCIs. For WaSC E this was an algae problem in a small surface water catchment, while WaSC I addressed a groundwater problem in a catchment that permitted swift and direct cause effect relationships. Both instances were identified more than five years ago and the managerial decision was taken to implement SCIs. This finding indicates, perhaps unsurprisingly, that the position of WaSCs in the innovation decision process is associated with how far in the past the adoption process commenced. In this vein, the distinctions into early adopter, early majority, late majority and innovation laggards

proposed by Rogers (2003) can be applied. However, as these terms have negative or positive connotations they will not be applied in this study (see also Rogers 2003).

In all cases where WaSCs were considered to be at an advanced stage in the innovation decision process (i.e. B, E, G, I), the choice to adopt SCIs was taken before the beginning of AMP4 (i.e. more than five years ago). This finding may hint towards the fact that continuous improvements are difficult under the present funding system. They rather appeared to be periodic and governed by the AMP funding cycle. Similar observations have been made by Thomas and Ford (see also Thomas 2006; 2005). They found that asset investment by WaSCs follows the five year funding cycle of the water industry and that AMP 3 spurred technical efficiency gains.

The reasons why WaSC B had adopted SCIs earlier were more speculative than for the organisations above, since information about the early SCIs projects of this WaSCs was not detailed. From the limited information available it appeared that this WaSC gained early experiences with SCIs in small surface water catchments around reservoirs. There the pollution pathway of pesticides could be traced easily. Thus again it seems that the 'Natural-Physical' conditions had a role to play in the adoption of SCIs.

#### **7.4.2 Reasons for different adoption of 'A&S' designs**

Turning to the reasons for the differences between WaSCs in terms of SCI design types; there appeared to be a tendency that 'A&S' were adopted by WaSCs in later stages of the innovation decision processes (i.e. WaSCs B, G, I). However, there was also contradicting evidence. For instance, WaSCs E showed evidence for 'Diffusion' and 'Routinisation', but did not adopt A&S. Furthermore, WaSCs J had implemented 'A&S', but did not provide evidence for 'Diffusion' or 'Routinisation'.

Above it was explained why WaSC J was at an earlier stage of the innovation decision process. The exceptional result for WaSC E could be due to two factors. Firstly, the interviewees argued that they did not want to be seen to fund farmers for behavioural change. Thereby they followed the polluter pays principle. The interviewee indicated that this was not due to pressure from Ofwat, but his attitude as drinking water quality manager. By following this approach WaSC E limited the opportunities to implement 'A&S' activities as they often require financial commitment. The second reason

proposed here is that this WaSCs worked in cooperation with a regional green NGO. It could be that the existence of this specific NGO offered an opportunity to implement a 'Liaison' approach that is more effective than 'Liaison' with the EA or the CSFI. Indeed, a representative of this WaSC argued that this NGO served as an example for the development of the CSFI. Thus the local circumstances may provide a better opportunity for this WaSCs to implement 'Liaison' designs than in the rest of the country: *"Yes, the people who have got a long track record in this part of the world are called the [cannot be named here] and they were formed about ten years ago to benefit riparian owners by getting rivers capable of maintaining good migratory fish population...So we have got a big shared agenda and their techniques and methodologies have been adopted by Defra for the catchment sensitive farming work which is being rolled out partly in our area and I am in touch with all of those people."*

Land ownership as a variable that affects SCI designs was put forward by a number of interview partners. They hypothesised that 'A&S' SCI designs were only feasible where WaSCs own significant amounts of land, since it enabled access to land and permitted enforcement measures. In the case of J and G this could be confirmed, as land ownership and associated knowledge was evidently a key reason for the choice of 'A&S' approaches. However, WaSCs I and B, which had implemented 'A&S' SCI designs, did so also on non owned catchments. For WaSC I it was suggested that this was possible due to hydrogeological conditions which enabled a quick and direct environmental response to 'A&S' activities (see Chapter 6). This WaSC continued to implement 'A&S' designs, due to positive experience gained in this single catchment with favourable hydrogeology.

It is uncertain why WaSCs B was able to implement 'A&S' designs, it maybe possible that the experience gained in the water companies upland regions played a role in this development. This suggestion is made because it was found that in all cases, but the case of WaSC I, 'A&S' interventions were adopted in the context of DOC (i.e. DOC is originating mainly from upland moors) raw water quality issues (Table 5-4). It is unclear why this was found. Reasons could be that these upland areas are associated with small reservoirs, land ownership, sites of conservation and an extensive land use

dominated by pasture and grouse shooting. In combination these factors could be encouraging the adoption of 'A&S' SCIs types.

# Chapter 8

## Innovation decision process – implications for theory and policy relevance

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### 8.1 Introduction

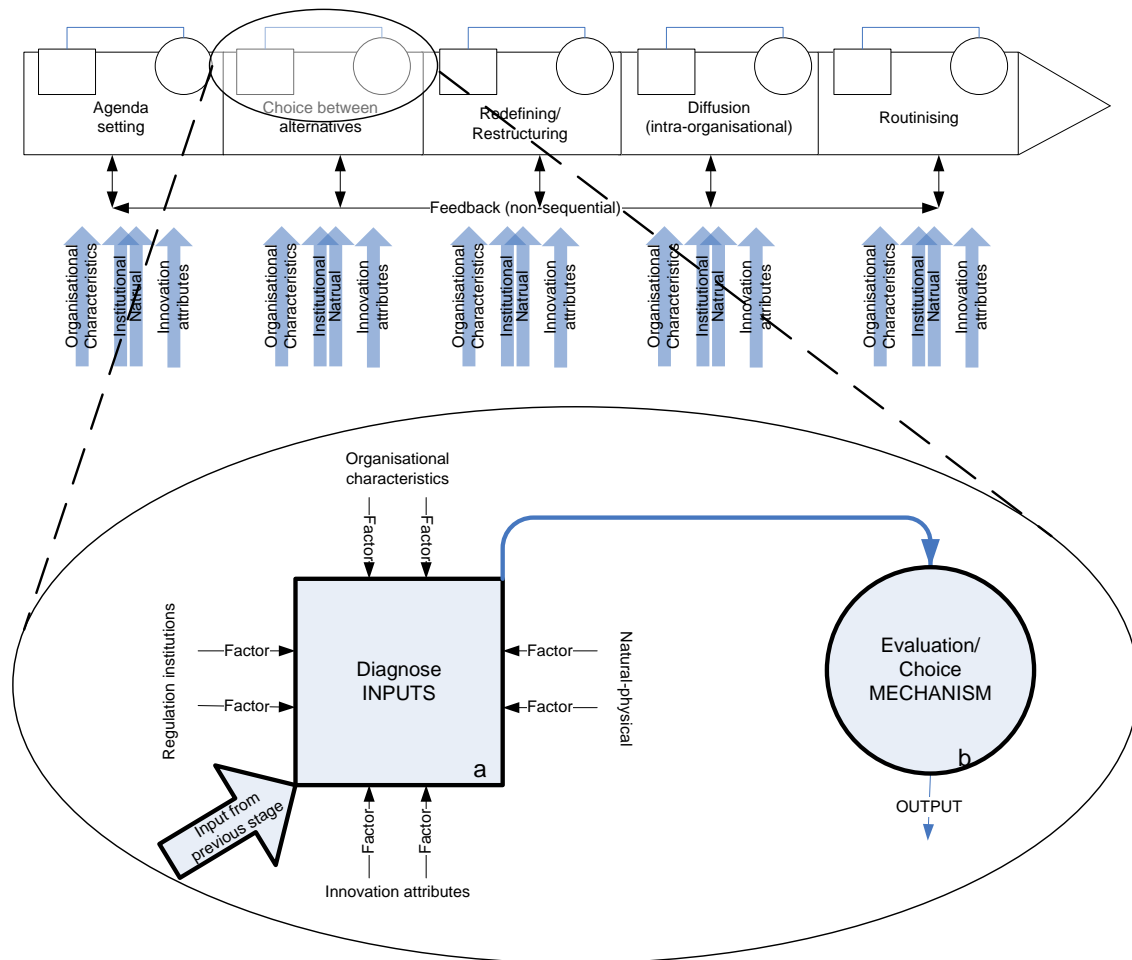
The implication of the findings for innovation decision theories and policy are discussed in this Chapter. Thus responding to research questions III and IV:

- III. What are the implications for innovation-decision theories?
- IV. What are the implications of the findings for the implementation of water regulation (e.g. WFD)?

In Section 8.2 SCIs are analysed from the perspective of the innovation theories reviewed in Chapter 2; resulting in the development of an adapted model of innovation decision making applicable to SCIs adoption. This model is then used to derive the implications for policy in Section 8.3.

### 8.2 Innovation decision process – implications for theory

In this Section the factors identified in Chapter 6 will be revisited and collated from the perspective of each individual process stage (Figure 8-1, domain a). This will generate insights about the mechanisms of choice at each stage of the process (Figure 8-1, domain b).



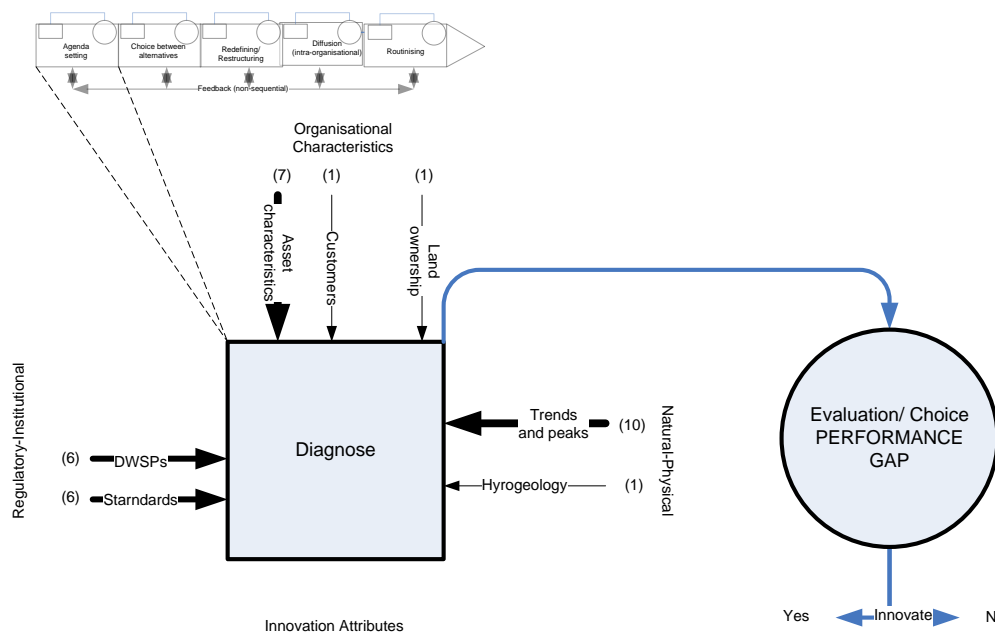
**Figure 8-1: Intra innovation decision process conceptualisation of the factors affecting evaluation and choice.**

To summarise how the factors and the choice mechanisms interact the graphical representations developed in Chapter 2 are used (Figure 8-1). The focus in this Section is on the elements ‘Diagnosis’ and ‘Evaluation and Choice’, which were the intra-process elements in the innovation decision model. At the ‘Diagnosis’ element the factors from the four factor domains converge. They are the inputs to the ‘Evaluation and Choice’ process which follows. In the ‘Evaluation and Choice’ process these inputs are used to generate an output. These outputs differ at every stage of the innovation decision process. At the ‘Agenda Setting’ stage the output is the recognition of a problem and at the stage of ‘Choice between Alternatives’ a commitment to implement SCIs (or another alternative). Contrary to this, at the ‘Reinnovation’ stage the output is a new SCI design, whilst at the ‘Diffusion’ stage the innovation decision process is re-entered at the ‘Agenda Setting’ stage.

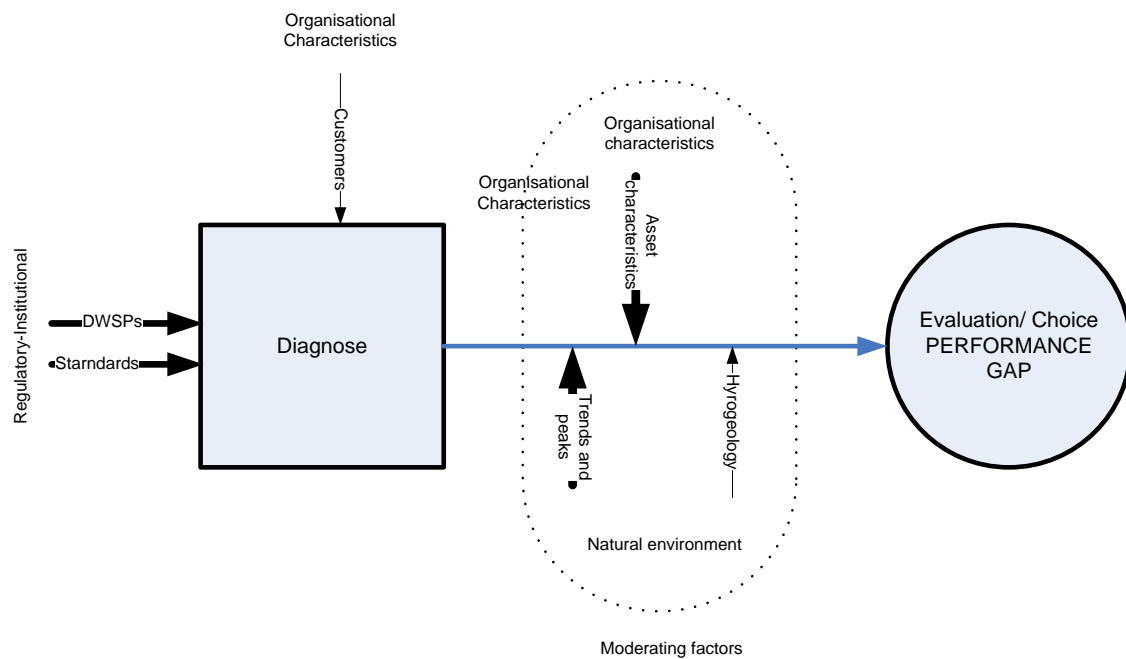


### 8.2.1 Agenda setting – performance gap and direct regulation

In Figure 8-2 the factors influencing the ‘Agenda Setting’ process are displayed. This perspective reveals that factors from the domains of ‘Regulatory-Institutional’, ‘Natural-Physical’ environment and ‘Organisational Characteristics’ influence the ‘Agenda Setting’ process. The results showed that these factors interacted closely to stimulate WaSCs to innovate. DWQS served as an aspiration level or minimum values to be attained (Simon 1997). Trends and peaks (i.e. the state of the raw water quality) marked the deviation from the aspiration level; while asset characteristics moderated (see Chapter 3 on moderating variables) the perception of trends and peaks as a problem. More specifically, where treatment assets could not mitigate raw water quality below the DWQS, a problem was perceived. This was most likely where trends and peaks occurred rather than where deteriorated raw water quality had persisted for some time. Thus asset characteristics could be viewed as a filter or moderator which alters the relationship between raw water quality and problem perception (Figure 8-3).



**Figure 8-2: ‘Agenda Setting’ process and the factors influencing the process (recurrence of factor displayed in brackets after arrow).**



**Figure 8-3: Conceptualisation of factor moderating the perception of the performance gap during the 'Agenda Setting' phase.**

Another way for 'Agenda Setting' to occur involved the factors land ownership and standards. WaSCs had to ensure adequate status of their land holdings, since owned land brought the responsibility to maintain prescribed environmental objectives (i.e. Habitats Directive EC 1992; WFD EC 2000). In this situation, the same key elements as above can be identified; namely an aspiration level (i.e. the prescribed objective), the deviation or threat of deviation from this aspiration level (environmental status) and moderating factors, here land ownership. Land ownership is a moderating variable, because only if a WaSC owns the land can this route to 'Agenda Setting' materialise.

Yet another pathway to 'Agenda Setting' was found to be the DWSPs. These required WaSCs to map and assess the risks to raw water quality from the catchment. As a result WaSCs built up an awareness of potential risks, understood as the deviation (or anticipated deviation) from an aspiration level. The aspiration level was again the DWQS.

The key point of these considerations is that there are two mechanisms to initiating the innovation process. Firstly, specific and concrete criteria perform, because they provide

an aspiration level the organisation has to work towards. Secondly, regulation which is requiring WaSCs to gather information is raising awareness of the existence of a performance gap through information gathering.

Nevertheless, it was also shown that regulation alone was insufficient to establish a performance gap. Whether or not a performance gap could be identified was shown to be context dependent (i.e. things like assets and trends). More precisely, it was dependent on the 'Assets Characteristics' and the state of the 'Natural-Physical' environment. The latter determined the deviation from the aspiration level, while the former affected the perception of the deviation.

Therefore, the findings reflect the 'Agenda Setting' process as first conceived by Simon (1958; Simon 1997). In addition awareness of environmental (i.e. external) change, which have been frequently described to be necessary to trigger innovation, was detected (Christensen 1997; Trott 1993). The DWSPs were an example for this, since they stimulated innovation through data gathering and catchment risk assessment.

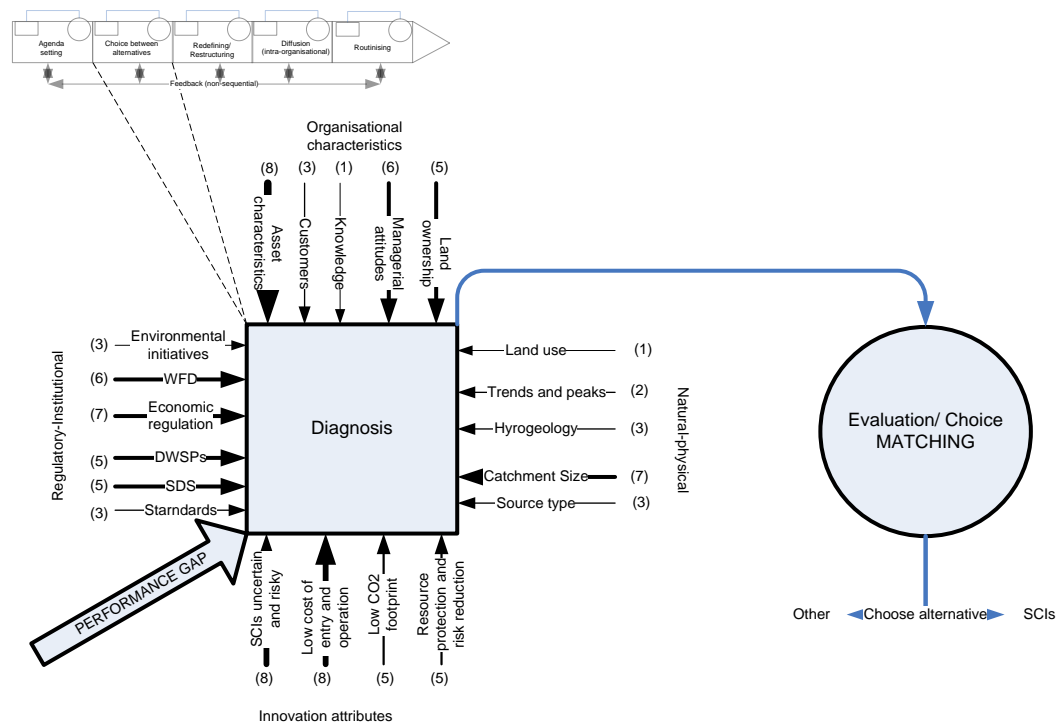
It may further be argued that notions of the re-enforcement or lock into certain technological trajectories can be rediscovered (Geels 2002). The findings of this study suggested that technologies themselves prevented the perception of a need for innovation. This becomes clearer when the notion of moderating factors or filters is introduced. These factors emphasis or mitigate the perception of a performance gap and therefore they initiate or subdue the trigger for innovation (Figure 8-3). More precisely, when an adequate technology was in place to meet the DWQS the technology tended to be maintained. Contrary to this, if no technology was in place the innovation decision making process was initiated.

A last observation was the role of 'market' elements, which were discussed under the market pull model of innovation (Rothwell 1992). In the present analysis customer preferences were the market factors that seemed to stimulate innovation. One representative of WaSC E argued that their customers preferred investment into environmental improvements rather than additional treatment technologies (see Chapter 6). It is further noteworthy that no innovation attributes affected the first stage of the innovation decision making process. This would indicate that innovation theories which

assumed that new technologies can stimulate innovation (technology push) do not perform well for explaining ‘Agenda Setting’ in the context of SCIs.

### 8.2.2 Choice between alternatives – matching and aligning factors

Following the decision to innovate it was proposed that a ‘Choice between Alternatives’ takes place. Figure 8-4 shows the factors influencing whether WaSCs chose or rejected SCIs. It can be seen that the choice of SCIs was affected by factors from all four domains. Looking at the descriptions in Chapter 6 it appears that multiple factors from each domain are brought into alignment for a choice of SCIs to take place. For example, it was shown that WaSCs chose SCIs when catchments were small and their hydrogeology was suitable. However, WaSCs only did so when these conditions were matched with the ‘right’ customer preferences, managerial attitudes (such as notions of sustainability), asset characteristics (such as investment needs) or land ownership. Furthermore, these ‘Natural-Physical’ conditions and ‘Organisational Characteristics’ needed to meet an enabling environment in terms of regulation and other institutional factors.



**Figure 8-4: The ‘Choice between Alternatives’ process and the factors of influence (recurrence of factor displayed in brackets after arrow).**

Finally, the attributes of SCIs also needed to fit the ‘Natural-Physical’, ‘Regulatory-Institutional’ and ‘Organisational Characteristics’. Moreover, the attributes of the innovation must indicate that the problem identified in the ‘Agenda Setting’ process could be resolved by the solution (i.e. innovation) to be chosen. In the present case this entailed achieving statutory drinking water objectives and in some instances conservation targets. If the innovation (here specifically SCIs) was assessed to achieve these ‘primary’ objectives, second order objectives were introduced to further distinguish and evaluate alternatives. These criteria are here called second order, since they were mainly formulated as an ‘added benefit’ of SCIs rather than the primary purpose (D): *“Our main priority is the supply of water to drinking water quality standards...in terms of catchment there are two things that potentially tick the box, one we watch the catchment, secondly carbon, so I think in terms of the company, there aren’t any numbers around it, where we are presenting putting in more energy hungry processes, if we can get cheaper solutions out of the catchment, it will tick that box as well.”* Second order criteria were about CO<sub>2</sub> emissions, cost efficiency and long terms risks to raw water quality. This finding could be interpreted as a situation where WaSCs first aimed to satisfy their basic statutory duties, here the supply of potable water, and only then would they consider long term goals and environmental objectives.

The process described above resembles what Rogers (2003) described as matching. He argued that at the point of ‘Choice between Alternatives’, an organisation will assess whether alternatives are compatible with organisational needs and organisational structures (see next Section). This involves anticipating the outcomes of an innovation and is thus closely associated with the next phase of the innovation process where innovations are ‘Redesigned’. However, Rogers (2003) did not make explicit that alternatives must also match the ‘Natural-Physical’ conditions and that they must be embedded into a suitable ‘Regulatory-Institutional’ environment. Rogers (2003) simply referred to an assessment of feasibility.

Other authors have suggested that environmental innovation is a multifactor process, which requires integration across domain (Berkhout & Green 2002; del Rio Gonzalez 2009). Yet, as argued in Chapter 2, few studies have integrated across all four domains. In particular the role of the ‘Natural-Physical’ environment was neglected in literature.

While omitting the 'Natural-Physical' environment maybe appropriate for certain innovations the present research showed that it had significant influence on the adoption of SCIs. An innovation where the environment has a lesser role maybe the change of an organisational practice or computer software, which would appear to require little matching with 'Natural-Physical' environmental characteristics. This may suggest that SCIs are a special type of innovation, in that they require suitable 'Natural-Physical' (i.e. natural environmental) conditions. More evidence is necessary to better understand how 'Natural Physical' factors affect innovation decision process in the context of other innovations.

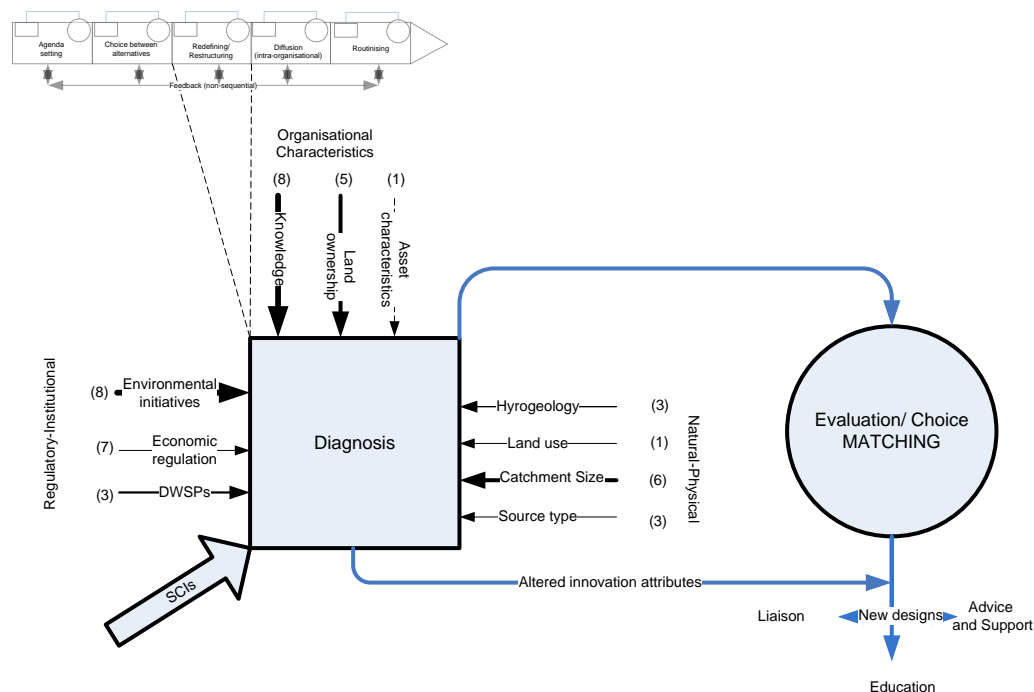
An additional complication of the 'Choice between Alternatives' processes was introduced when considering that SCIs may be considered as a complement to technological alternatives, rather than as a substitute to end of pipe treatment. It could be argued that under this scenario the first order criteria, namely meeting statutory criteria, will be attained by the end of pipe solution, but secondary criteria such as efficiency, reduced CO<sub>2</sub> emissions and sustainability will be met by SCIs.

### **8.2.3 Reinnovation and restructuring – matching and design**

'Regulatory-Institutional', 'Organisational' and 'Natural-Physical' factors influenced the 'Reinnovation' stage (Figure 8-5). The key difference to the 'Choice between Alternatives' was that, at this stage, innovation attributes were outcomes of the process rather than inputs. In other words at this stage the WaSCs designed SCIs to fit 'Natural-Physical' characteristics, the 'Regulatory-Institutional' parameters and 'Organisational Characteristics' (see Chapter 7).

The 'Reinnovation' process thus resembled the process of matching described before. However, now, rather than choosing the alternatives that best fitted multiple criteria, alternatives and the organisation were adjusted to achieve the best fit possible. This finding was again similar to the descriptions in literature (Mintzberg & Raisinghani 1976; Rogers 2003). There it was argued that 'Reinnovation' is a key process to make an innovation a permanent feature of the organisation. The rationale for this was that, 'Reinnovation' results in a better fit of the innovation with local or organisational circumstances, and thus is more likely to be successful.

A final observation is that there were fewer factors influencing the ‘Reinnovation’ stage than in the ‘Choice between Alternatives’ stage. This is despite the fact that both the ‘Choice between Alternatives’ and the ‘Reinnovation’ stage were based on matching of multiple factors. The factors not detected in the ‘Reinnovation’ stage were those that did not specify or influence a specific customised design. For instance the SDS extended the evaluation period to 25 years, which gave an opportunity to evaluate SCIs, but did not stimulate preference to any design. Likewise, to avoid asset investment was a feature of all SCIs design types, thus this factor did not affect matching at the ‘Reinnovation’ stage.



**Figure 8-5: The ‘Reinnovation’/ ‘Restructuring’ process and the factors of influence (recurrence of factor displayed in brackets after arrow).**

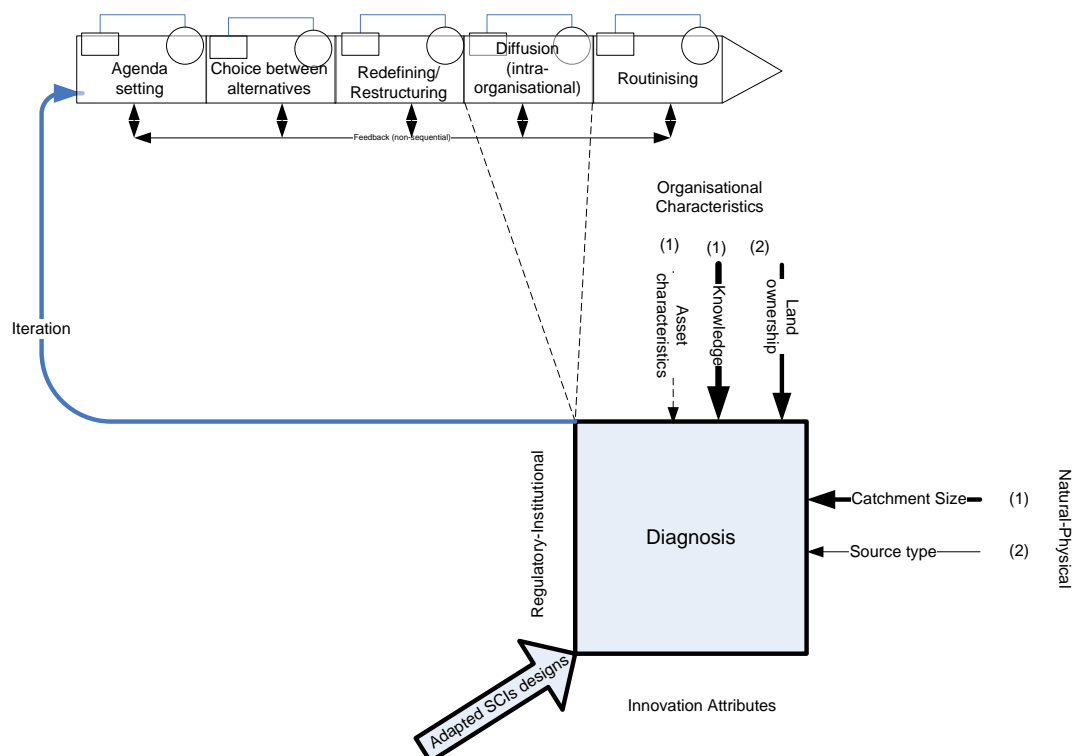
However, what this points towards is that the ‘Choice between Alternatives’ stage and the ‘Reinnovation’ stage were operating in a close feedback (Mintzberg & Raisinghani 1976). Rogers (2003) suggested that mental experiments take place during the ‘Choice between Alternatives’ to assess feasibility of innovations. These ‘mental experiments’ do comprise the tinkering with different designs of innovations. This feedback or better forward loop complicated coding in this research as it could be difficult to distinguish

which stage of the process a factor affected. In such cases text was coded to influence both process stages (see Chapter 3).

### 8.2.4 Diffusion – iteration of the adoption process

Only in few cases direct evidence were found for factors that support the intra-organisational ‘Diffusion’ of innovations (Figure 8-6). The reason for this could be that only three WaSCs were assessed to be in the ‘Diffusion’ stage (Chapter 5). Thus the data collected was limited and did not provide detailed insights.

Alternatively, ‘Diffusion’ could be seen as a reiteration of the first three innovation decision process stages (Figure 8-6). The first indicator for this was found in Chapter 5 (also Table 7-2). There it was shown that WaSCs B did not provide evidence for ‘Diffusion’, but was considered to be at the ‘Routinisation’ stage. According to the logic of the innovation decision making model, this could be a symptom of the fact that the innovation decision process is not linear and routines can precede ‘Diffusion’ (Mintzberg & Raisinghani 1976).



**Figure 8-6: Intra-organisational ‘Diffusion’ process and factors of influence. Recurrence of factor displayed in brackets after arrow.**



Yet, on the other hand it is also possible that a wide adoption of SCIs was unnecessary or impossible due to the configuration of 'Organisational Characteristics' and external conditions (i.e. 'Regulatory-Institutional' factors, Natural-Physical factors for a similar example see Russo 2003). Thus, although the innovation maybe a routine, evidence in terms of numerous applications of SCIs ('Diffusion') could not be detected. This may provide evidence for what some authors referred to as niche innovations. These are innovations, which develop in specific locations where conditions are favourable (see also Section 8.3.3). For the Dutch water sector in the 19<sup>th</sup> century Geels' (2006) found that certain innovations established in niches where financial gains could be made. This may suggest that all situations were reassessed on an individual basis to determine whether alternatives can be cost efficient. In other words, intra- organisational 'Diffusion' is a re-iteration of 'Agenda Setting', 'Choice between Alternatives' and 'Reinnovation' (Figure 8-6).

Further support for 'Diffusion' being a re-iteration of 'Agenda Setting', 'Choice between Alternatives' and 'Reinnovation' was provided by the cases where there was evidence for 'Diffusion'. There, it appeared that WaSCs implemented SCIs where an agenda was perceived and conditions were favourable for its implementation. The development of specific designs may follow on from this (E): *"It started there really, I mean we then sort of said well hang on a minute, this reservoir and this reservoir and this reservoir are all eutrophic, they're all full of nutrients, some of them are full of pesticides as well, they're all suffering from the land management practices in their catchments, so we decided that it was cheaper and better for our customers if we could sort out the catchment.*

If 'Diffusion' is indeed a re-iteration of the previous stages then this can explain why evidence for this process was absent. The coding of the interview text followed the definitions of each stage of the innovation decision process (Chapter 3) and hence could not distinguish iterative or non iterative processes.

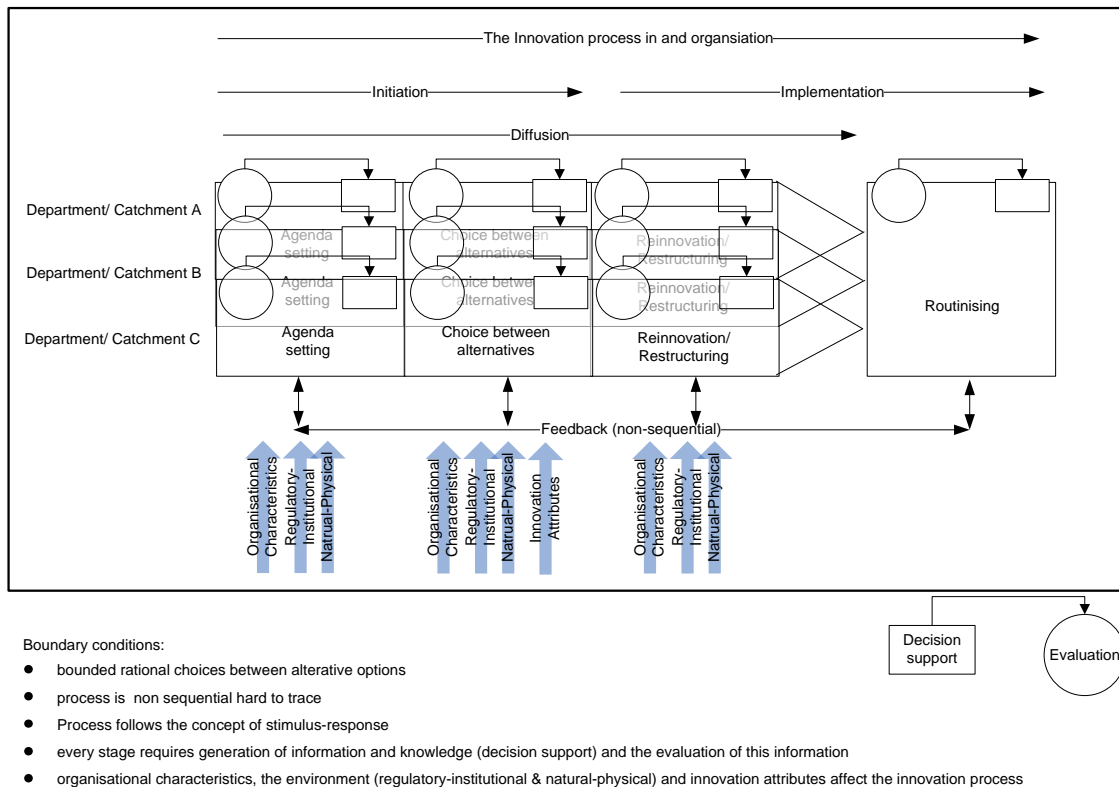
Literature did not suggest that intra-organisational 'Diffusion' is a re-iteration of the previous three stages. It has rather been argued that at this stage the meaning of the innovation itself is clarified and re-conceptualised, which then leads to an intra-organisational spread (Rogers 2003). The realisation by WaSC representatives that SCIs

maybe better operated alongside treatment processes rather than replacing them signals that re-conceptualisation occurred also in the present study. However, there was no indication in the data as to how this process influenced the intra-organisational 'Diffusion'.

The inter-individual perspective on 'Diffusion', rather than the intra-organisational perspectives on 'Diffusion', offer more parallels to the present findings. This perspective suggests that each individual adopter has to pass through all the phases of the innovation adoption process (Rogers 2003). Thus, the spread of an innovation takes place through iteration of the innovation decision process in multiple cases. This analogy may support the view that intra-organisational 'Diffusion' of an innovation should be viewed as a process that requires the iteration of the innovation decision process. This makes sense in particular when considering that different departments or locations within an organisation (e.g. WaSCs) may face different pre-conditions, thereby making different requirements on an innovation.

### **8.2.5 An adapted model of innovation-decision making**

Combining the elements of the innovation decision process discussed in the preceding sections the overall innovation decision process can be conceptualised as show in Figure 8-7. Innovation decision making was shown to be a multi factorial process influenced by variables from the four domains of 'Innovation attributes', 'Natural-Physical' factors, 'Regulation-Institutions' and 'Organisational Characteristics'. It was further demonstrated that the present understanding of innovation decision making process is, with the exception of 'Diffusion', applicable to WaSCs process of SCIs innovation (Figure 8-7).



**Figure 8-7: The modified innovation decision process, showing re-iteration of ‘Agenda Setting’, choice between alternative and ‘Reinnovation’/ ‘Restructuring’ as to achieve ‘Diffusion’.**

‘Agenda Setting’ was shown to make use of the ideas of aspiration levels and performance gap. Specific measurable statutory criteria or policy requirements (i.e. direct regulation) served as aspiration levels. The deviation from this aspiration level (i.e. the ‘performance gap’) was found to be moderated by the asset characteristics and environmental state changes in terms of peaks and trends. The ‘Choice between Alternatives’ was based on the process of matching factors from all four domains; the alternative selected at this point was required to resolve the problem identified during ‘Agenda Setting’, here mostly compliance to a standard. If this primary objective was thought to be met, second order criteria such as efficiency, CO<sub>2</sub> emission cuts and raw water quality risk reduction influenced the ‘Choice between Alternatives’. The ‘Reinnovation’ stage of the innovation decision process was found to follow a matching process too. However, rather than selecting the alternatives with best fit, at this stage the innovation (i.e. SCIs) is modified to achieve the best alignment of multiple factors. The ‘Diffusion’ stage of the processes appeared to exhibit different characteristics than described in literature. It was suggested that this stage of the process is better

conceptualised as a re-iteration of the three preceding process stages (i.e. ‘Agenda Setting’, ‘Choice between Alternatives’ and ‘Reinnovation’), thus organisations seem to reassess each innovation for each department or catchment individually. The interview provided little evidence about the process that influenced ‘Routinisation’, future research is necessary to reveal more information about the properties of this process.

The implications of the described SCIs innovation decision making process on the implementation of water policy are discussed next.

### **8.3 Innovation process - policy implications**

The innovation decision process model developed above can be valuable for policy makers to assess and design policies. It offers the opportunity for policy makers to understand:

- how to foster problem identification and thereby higher rates of SCIs in the ‘Agenda Setting’ process;
- how to affect the character of innovations during matching in the ‘Choice between Alternatives’ stage;
- how to increase the variety of innovations by influencing the designs of SCIs during ‘Reinnovation’ and;
- how to encourage a wider adoption of SCIs within organisations.

#### **8.3.1 Agenda Setting – direct regulation as a key stimulus**

In the preceding Section it was suggested that direct regulation is a trigger for innovation. The DWQS was an example of such direct regulation. It was founded on the notion that a specific, measurable, requirements enable the easy identification of a performance gap. A second mechanism that triggered innovation was found to be a demand for data gathering, which lead to the awareness of a performance gap. This was represented by the DWSPs which made specific requirements on WaSCs to understand catchment risks. This findings provides evidence for Porter and van der Linde’s (1995) hypothesis that regulation which requires information gathering can have a positive effect on organisational innovation.

Whilst it was shown that the direct regulation through DWQS performed well in initiating the innovation decision process, it was also evident that the WFD and economic regulation largely failed to do so. At the time of interviewing, the WFD was not perceived to set specific targets. It rather set broad aspirations that challenged the present view of WaSCs representatives about how to deliver water services. This perception of the WFD did not suffice to initiate the innovation decision process, but as will be argued in the next Section, was crucial to affect the ‘Choice between Alternatives’.

Like the WFD, economic regulation of WaSCs in E&W was not found to be a trigger for innovation. The repercussions of this are vital as economic regulation in E&W is widely discussed as a tool to stimulate innovation (see Chapter 1 & 2). This is so because in the absence of a market, economic regulation sets cost efficiency targets which, in order to be outperformed, are thought to require the adoption of new processes or technologies. The present finding would suggest that this approach to economic regulation fails to stimulate a higher rate of change. However, when discussing the ‘Choice between Alternatives’ below, it will be pointed out that economic regulation has a role to play in determining the character of innovations.

The underlying reason for this weakness of economic regulation is unlikely to be associated with the absence of a performance gap. There was no evidence which could confirm that economic regulation was failing to stimulate the identification of a performance gap. On the contrary, Thomas (2006) found that efficiency targets were a key incentive for innovation for WaSCs in E&W. The ineffectiveness of economic regulation to trigger the innovation decision process could be rooted in the characteristics of the water sector. Close examination of the interview findings suggested that the demand for efficiency was inhibiting more rapid asset renewal (investment), thus limiting the break up of old structures and as a result enforcing maintenance of incumbent technologies. To clarify, the results presented in Chapter 5 and 6 indicated that water treatment assets are multi-million pound investments. Their expected replacement period is often in the range of decades (Brint *et al.* 2009). This replacement period is based on the asset book life or modelled using the asset failure rates. Consequently, “*if an asset is believed to be operationally sound, then its*

*replacement may very often be delayed*” (Brint *et al.* 2009). This entails that WaSCs will look for opportunities to implement innovations at sites where assets need replacement, because they near the end of their useful life or fail to meet statutory standards.

Further research is necessary to confirm this proposition. A case study approach could be taken to investigate under which conditions WaSCs renew their technology, and what could stimulate them to do so before assets reach the end of their useful life. Nonetheless, if the proposition made here holds true then it is suggested that the rate of innovation for WaSCs in E&W can only be influenced positively if one of the following situations occur:

- asset lifetimes are shortened;
- drinking water standards are tightened (or customers make demands to exceed the drinking water standard);
- or the raw water quality is deteriorating.

There is evidence that direct regulation was successful in stimulating change (Maria 2005). In the water sector, the drinking water regulations and UWWTD have led to changes in water and sewerage service provision (EC 2007a). Whether this change has also lead to innovation and adoption of new technologies or approaches is questionable. For instance the UWWTD rather reinforced (unintentionally) the replication of the traditional approach to water management based conveyance and treatment in centralised systems. In this vein it has been demonstrated that direct regulation can stifle innovation, by encouraging replication of incumbent approaches (Georg 1994). In the next Section it is shown that this was also found for DWQS in relation to SCIs.

### **8.3.2 Choice between alternatives – flexible policy for innovation**

A variety of national and EU driven regulations influenced the ‘Choice between Alternatives’. The WFD, DWSPs, SDS and environmental initiatives were found to be conducive to the choice of SCIs. Contrary to this economic regulation and direct regulation including the DWQS were mentioned as posing barriers to the implementation of SCIs. The mechanism of ‘Choice between Alternatives’ was formulated as a process of matching multiple factors from the domains ‘Innovation

Attributes, 'Organisational Characteristic', 'Natural-Physical' environment and 'Regulatory-Institutional' environment to detect the alternatives which minimise trade offs between these factors. Alternatives were only considered for this matching when it was thought that they can resolve the problem identified in the 'Agenda Setting' process. These findings have two implications for policy. Firstly, DWQS and economic regulations re-enforce incumbent approaches to water service delivery. Secondly, flexible policy making is more suitable to encourage adoption of innovation in terms of SCIs. These implications are discussed next.

### **Drinking water standards and economic regulation re-enforce current approaches to water supply**

The first policy relevant observation from the above is that direct regulation, here in particular the DWQS, do constrain the choice of SCIs. In other words, while the DWQS could be regarded as an enabler at the 'Agenda Setting' stage, it becomes a barrier for change at the 'Choice between Alternative' stage. This was rooted in SCIs attributes. Specifically it is the inability of SCIs to reliably meet the DWQS at all times. It was perceived that the only way of meeting this standard was by using water treatment processes. Hence, it can be said that the DWQS did promote the adoption of end of pipe technologies. Georg (1994) argued in a similar vein. He suggested that in Denmark the adoption of end of pipe technologies rather than innovations into process improvements and pollution prevention was encouraged by direct regulations. Unfortunately, he did not offer reasons as to why this was found. Rogers (2003) argument that "*technologies are designed to reduce uncertainties in the cause-effect relationships involved in achieving a desired outcome*" offers an explanation. It indicates that technologies can reduce risk. Activities such as SCIs, were thus regarded as more risky, since the cause effect relationships were more complicated.

The policy implication of this is that a new approach to (pesticide) drinking water standards can further foster the adoption of SCIs. Interviewees suggested a risk based approach to DWQS. WaSC representatives suggested that this standard should be based on actual health impacts of chemicals and pollutants and should use percentile compliance rather than total compliance (see Chapter 5 for quote). The difficulty with these approaches maybe one of balancing public health risks with greater efficiency and environmental objectives.

Re-defining the role of SCIs in water service delivery may render the discussion about a new approach to DWQS obsolete. WaSCs representatives suggested that end of pipe treatment and SCIs should function in synergy to exploit the advantages of both approaches. For instance, treatment technologies can deliver standards reliably, while SCIs can facilitate conservational objectives, risk reduction and efficiency gains. Yet, this option was perceived to be constraint by Ofwat's approach to funding WaSCs operations. Specifically, there were concerns that Ofwat will not permit WaSCs to charge customers for end of pipe treatment and SCIs in parallel. Whether this concern of interviewees was justified is unclear. The fact that Ofwat funded 100 catchment management and investigation schemes would suggest otherwise (Ofwat 2009a). Nonetheless, to exploit the synergies between both approaches Ofwat should send a clear message to WaSCs whether it will allow funding for parallel operation of SCIs and treatment.

Other barriers of the present economic regulation of WaSCs were indicated to be the polluter pay principle and the short evaluation timeframe of five years. The negative effect of these regulatory factors on innovation and change have been suggested by others (see Thomas & Ford 2005 above). Cashman and Lewis (2007) investigated the barriers to sustainability in the UK water sectors. They found that regulation, and here in particular the economic regulator Ofwat, had a "*regressive impact on the promotion and implementation of sustainable practices by water companies, as they perceive that there is little space for them to create such opportunities.*" Likewise, Andrews (2003a) suggested that the enforcement of the polluter pay principle was a key constrain to the implementation of SCIs in E&W. Thus it can be concluded that looking beyond short five year cycles and a different interpretation of the polluter pays principle could help in stimulating the uptake of SCIs. How these problems can or indeed have been resolved is subject of the next Section.

### **Flexible policy making encourages innovation in terms of SCIs**

Polices and regulations which stimulated the selection of SCIs were almost exclusively new. For instance, Defra's (2008) 'Future Water' document. In this document Defra asked Ofwat to permit WaSCs to work with land owners. Consequently, Ofwat granted funding for 100 catchment management schemes in AMP5 (Ofwat 2009a), leading to



the adoption of increasing numbers of source control interventions by WaSCs (Horton 2009). The 'Future Water' document (Defra 2008) also envisioned a full contribution of the water industry to the national commitment to CO<sub>2</sub> emission reductions. This has led to a requirement of WaSCs to report their annual CO<sub>2</sub> emissions to Ofwat (see Prescott 2009 for a review). Furthermore, Ofwat also began to take a long term view on regulation by asking WaSCs to develop 25 year SDS. Thereby, extending the evaluation period of WaSCs investment to a timeframe in which outcomes of SCIs can be expected.

In parallel to the changes above, WaSCs had to implement DWSPs (DWI 2009). These DWSPs required WaSCs to assess the best point of rectifying water quality problems in the water supply chain, including the catchment. Hence, the DWSPs for the first time make a concrete requirement to consider the catchment as a potential place for intervention. However, as opposed to the DWQS, the DWSPs, did not implicitly give preference to a specific solution. On the contrary it explicitly opened up the alternatives in consideration by requiring an assessment of intervention at every stage of the water supply system. The WFD, on the other hand, stimulated the choice towards SCIs by changing the mindset of WaSCs representatives towards a holistic view of water management. It evidently challenged the assumptions about water delivery, acting in concert with the DWSPs to include the catchment into the consideration of WaSCs operations.

The policies and regulations briefly revisited in the last two paragraphs share two key characteristics, which are vital for the present discussion. Firstly, (I) all these policies could be argued to have similar trajectories. For instance the DWSPs and the WFD were both perceived to draw attention to the possibility of rectifying pollution at source. Thereby, they challenged traditional views about water service delivery. Acting in concert with this were the environmental initiatives and grants, which provided an opportunity for WaSCs to exploit the agricultural expertise of other actors. In this vein, the WFD promoted engagement with these initiatives by demanding the public involvement (WFD Article 14) and interaction of all actors involved in water management. Similarly, the WFD and SDS both adopted a long term perspective towards implementation. Lastly, CO<sub>2</sub> emission reporting requirements generated

awareness of CO<sub>2</sub> emissions, hence potentially drawing attention to CO<sub>2</sub> emissions as a relative advantage of SCIs. In conclusion it is evident that there are various parallels and synergies between these policies and regulations.

Academic literature on policy and change suggested that policies and regulations can be viewed as selection criteria in the choice between different development pathways. It was argued that coordinated policies are necessary to stimulate change and innovation (Georg 1994; Smith *et al.* 2005). Conflicting perceptions of policies on the contrary may send opposing signals about the characteristics of innovations to be selected, which, as a result, could hamper adoption of innovations. It was argued that a coordinated policy framework should address economic constraints, belief systems (incl. expectations) and the institutions (Kemp & Rotmans 2004). These categories could be identified in the present case of E&W. The WFD and DWSPs were shown to have similar orientation by challenging the perception of water service delivery of WaSCs. The SDS, 'Future Water' and recent changes in Ofwat's approach to fund SCIs provided evidence that the economic framework conditions were adapted. Lastly, the introduction of environmental initiatives (i.e. CSFI) and the requirement to report CO<sub>2</sub> emission constitute changes to the institutional framework conditions that acted in concert with the other factors.

The second (II) common characteristic of these policies and regulations was that they are flexible or outline a broad framework for change. In other words these policies and regulations were not perceived to promote a specific alternative or to constrain another. For instance the DWSPs were shown to explicitly open up the alternatives in consideration, by requiring WaSCs to assess at which stage of the water supply system it is best to rectify pollution risks. Similarly, the WFD could be argued to outline a vision of water management in the EU, but leaves it to each member state to develop its own approach to implementation. In this vein, the SDS and Future Water (and the changes to policy it stimulated) set out a national long term framework for achieving these objectives.

From the innovation decision process perspective applied in this study it can be explained why these flexible regulations were conducive to the choice of SCIs. Flexible policy will enable WaSCs to find the best match of factors from all four domains.

Thereby offering an opportunity to reduce the trade off WaSCs would otherwise have to make when a command and control approach is be used.

A number of scholars also advocated flexible policies as important in maintaining or generating a broad variety of alternatives, thereby promoting resilience and sustainability (Geels 2002; Rotmans *et al.* 2001). The basic assumption of these authors was that under conditions of bounded rationality (Simon 1997), it cannot be known which alternatives will become valuable in the future. Thus a variety of options, which are adapted to specific local circumstance may offer a resource to be exploited in the future to substitute functions when previous innovations become inappropriate or infeasible (Holling & Gunderson 2002). Maintaining a variety of innovations in the sense of management and technology might thus provide a means of guarding against unforeseen futures. In the context of water management this was iterated by Calder (2005), who, in the opening Chapter to his book the ‘Blue Revolution – Integrated Land and Water Resources Management’ stated: *“Using Herbert Simon’s (Simon 1997) concept of satisficing, finding a satisfactory solution to all parties, whilst recognising that there may be more than one solution, is perhaps the approach the Revolution should adopt.”*

Institutional and spatial niches have been proposed as places where expertise can be maintained, to be exploited in the future (Gunderson & Holling 2002). Niches were also argued to provide a protected space where economic, institutional and local conditions are favourable to develop innovations (Geels 2002). In the next Section the notion of variety is revisited when discussing SCIs designs.

### **8.3.3 Reinnovation – SCIs a niche innovation**

Economic regulation, DWSPs and environmental initiatives shaped the development of SCIs design types. The mechanism of choice in this stage of the innovation decision process was based on the same process as described for the ‘Choice between Alternatives’ (Section 8.2.3); namely the matching of multiple factors. However, rather than selecting the alternative that offers the best compromise (i.e. lowest trade off between factors), at this stage the innovation (i.e. SCIs) and the organisation were modified to achieve the best alignment of multiple factors. Hence, the outcome of the ‘Reinnovation’ stage is an increased variety of SCIs design types. Contrary to ‘Choice

between Alternatives', innovations at this stage do not represent fundamentally different approaches to resolve a problem, but rather differ in character (Chapter 5). Nevertheless, 'Reinnovation' provides an additional source of variability of solutions which was regarded as important for resilience of change processes (Section above).

The key policy relevance of the 'Reinnovation' stage is, that without its implementation of innovation change cannot materialise. This is so because 'Choices between Alternatives' and the process of 'Reinnovation' (i.e. customising alternatives) are inseparably linked. Decisions at the 'Choice between Alternatives' stage were shown to be made with a specific design in mind. Consequently, innovation will not take place if WaSCs perceived available design types as unsuitable.

To promote the development of appropriate designs, scholars argued that the role of governments is to provide a place to experiment with potential solutions. This is achieved by creating favourable conditions in 'niches' through short term subsidies, accepting failure as part of a learning process and aiding the selection of appropriate niches (Kemp & Rotmans 2004; Nill & Kemp 2009). The key objective of this 'strategic niche management' is to facilitate the creation of knowledge through learning. The findings of this research confirm that a lack of knowledge was one of the key factors which constrained design and thereby implementation of SCIs. As suggested for strategic niche management, it was shown that WaSCs selected specific sites with favourable conditions to experiment with design and to gain knowledge of catchments, agriculture and actors involved in catchment management. However, the observation that specific hydrogeological conditions were a crucial attribute of a suitable catchment (i.e. niche) entails that the influence of policy makers in promoting certain SCIs designs such as 'A&S' is limited. These designs were rather constrained by the 'Natural-Physical' condition existing within a WaSCs water supply region.

In conclusion, if policy is to stimulate the development of SCIs it could be effective for the government to further advancements in relevant knowledge of WaSCs. The DWSP is a step in the right direction. In some cases it leads to employment of new staff with catchment and agricultural knowledge. It also requires data gathering in the catchment. Supporting the experimentation with SCIs designs in specific niches through approaches similar to strategic niche management may be of value too. Indeed, the

funding of 100 catchment management schemes and investigations by Ofwat may mark process in this direction (Ofwat 2009a).

Finally, policy makers should also have realistic assumptions about where to expect specific SCIs design types. It is unlikely that SCI designs will be one size fits all, since, they rely on the interaction of multiple factors from three factor domains. However, there is a tendency that when raw water quality problems occur in large surface water catchments WaSCs will opt for ‘Liaison’ design types, while WaSCs in small hydrological catchments ‘A&S’ activities may dominate.

Environmental problems are often subject to significant delays of cause and response, thus assessing the outcomes of strategic niche experiments can be difficult. To account for this it was suggested that policy should set intermediate milestones, which are orientated on the final objective. For CAs Brouwer *et al.* (2003a) specifies these goals as immediate, intermediate and ultimate goals.

- Immediate goals are the behavioural changes of the farmer, for instance in terms of fertiliser application or nutrient management.
- Intermediate goals are the changes to nutrient soil content or pesticide runoff resulting from the behavioural change.
- Finally, ultimate goals constitute the improvement of water quality at the point of abstraction.

Adopting these indicators as performance measures for SCIs presents significant challenges to the present regulatory system, including:

- How can Ofwat account for behavioural change farmers when setting price limits?
- How can improvements in soil nutrient content or runoff be attributed to activities funded or carried out by the WaSCs?

### **8.3.4 Diffusion – coordination of policy across stages**

In Chapter 7 it was suggested that ‘Diffusion’ could be conceptualised as an iteration of the previous three process stages. In order to affect the spread of SCIs in organisations policies should be coordinated across the ‘Agenda Setting’, ‘Choice between

Alternatives' and 'Reinnovation' stage. The example of the DWQS showed that this can be challenging, since direct regulation was found to be an effective means to trigger the innovation decision process; whilst it constrained adoption of innovation at the stage of 'Choice between Alternatives'. In conclusion policy makers therefore have to negotiate the trade offs or externalities between different policy tools (Rennings 2000).

# Chapter 9

## Conclusions

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### 9.1 Introduction

In this study SCIs were viewed as an innovation. Their adoption was conceptualised as a step towards integrated and sustainable water management. The process of SCIs adoption was studied in terms of innovation decision making by WaSCs and the factors influencing this process were isolated. Data were gathered using interviews with WaSCs representatives' responsible water quality management, drinking water asset management and planning. The results provided insights into the process of change in water management from the perspective of WaSCs. The aim of this study was to develop a model of the process of source control intervention adoption and to determine the factors influencing the adoption of these interventions by WaSCs in E&W. In support of this aim four research questions were formulated:

- I. What are the types of source control interventions adopted by WaSCs in England and Wales?
- II. What are the factors influencing the characteristics of the adoption process of source control interventions by WaSCs?
- III. What are the implications for innovation decision theories?
- IV. What are the implications of the findings for the implementation of water regulation (e.g. WFD)?

The key findings of this study are presented in Sections 9.2 to 9.7. The limitations of this research are identified in Section 9.8. Finally, recommendations to future researchers are made (Section 9.9).

### 9.2 Key finding I - change towards integrated water management

Comparison with data from 2003 and 2004 showed that WaSCs in E&W were increasingly adopting SCIs. Eight out of a population of 10 WaSCs were in the process of adopting SCIs in 2009, while between two and three were found to adopt SCIs in

2003 or 2004 (Andrews 2003a; Ofwat 2009a). One of the reasons for this increase was that this research adopted a wider definition of SCIs than previous researchers. This study investigated approaches to pollution source control which included the intermediaries in the process, rather than being solely based on the direct interaction between WaSCs and farmers or land managers. Adopting this perspective it was revealed that WaSCs have a role to play in river basin management, by cooperating with actors including the EA, CSFI, farmers and green NGOs. This can be interpreted as a development towards more sustainable water management arrangements. For instance the WFD states (WFD preamble 14; EC 2000):

*“The success of this Directive relies on close cooperation and coherent action at Community, Member State and local level as well as on information, consultation and involvement of the public, including users.”*

Nonetheless, this approach by WaSCs to water management is a recent development for many WaSCs as was evident in the innovation decision process stages. Only four WaSCs had turned SCIs into an organisational routine, thus indicating that SCIs are part of their mechanism to respond to raw water quality problems. Another four WaSCs were still developing SCIs intervention; suggesting that they were still in the process of learning how best to integrate SCIs into their water service delivery system. The remaining two organisations did not choose to adopt SCIs at the time of interviewing.

### **9.3 Key finding II – innovation: a multi factorial process influenced by natural physical factors**

This study shows how factors from the domains ‘Organisational Characteristics’, ‘Innovation attributes’, ‘Natural-Physical’ environment and ‘Regulatory-Institutional environment’ influence the uptake of SCIs. Few authors previously considered factors from all four domains simultaneously. The study also advances the limited evidence in literature for the role ‘Natural-Physical’ factors play in influencing innovation (as first identified by Shrivastava 1994). For the specific case of SCIs it was demonstrated that innovation by WaSCs cannot be understood without accounting for the ‘Natural-Physical’ factors. This is so because ‘Natural-Physical’ aspects offer different opportunities for WaSCs to implement SCIs. For instance, the hydrogeology (i.e.



catchment size, properties of aquifers) and environmental state changes in terms of water quality affected the perception of feasibility of SCIs and the need for change. Indeed, also ‘Organisational Characteristics’ of WaSCs were intimately linked to the ‘Natural-Physical’ factors, example were land ownership or the characteristics of WTW.

Therefore this study showed that change and innovation by WaSCs is dependent on local catchment characteristics. The effect of these ‘Natural-Physical’ factors is likely to be more pronounced in the future, since the focus of water management is thought to shift from engineering based solutions to more integration and the achievement of catchment specific objectives as required under the WFD. Consequently, future water management may be characterised by a greater variety of approaches to deliver water and environmental services than has previously been the case.

#### **9.4 Key finding III - the innovation decision model**

The next contribution of this study is an improved understanding of innovation by merging innovation and decision theories. The innovation decision model developed in this thesis poses that decision making will occur at each stage of the process (Chapter 2). By demonstrating the choice mechanisms at the ‘Agenda Setting’, ‘Choice between Alternatives’, ‘Reinnovation’ and ‘Diffusion’ stage the innovation decision making model was further refined for the specific case of SCIs:

**‘Agenda Setting’** – At this stage the perception of a performance gap is key to start the innovation decision process. It was shown that ‘Agenda Setting’ is not just influenced by knowledge as suggested in literature (Simon 1997), but also by ‘Natural-Physical’ factors and asset characteristics in specific catchments. The concept of moderating variables was introduced, which suggests that ‘Natural-Physical’ factors (e.g. hydrogeology, pollution trends and peaks) and asset characteristics act as filters that influence the perception of a performance gap.

**‘Choices between Alternative’** – At this stage preferred alternatives are identified through a process of matching (Rogers 2003). This research showed that alternatives are selected, which best align factors from all four domains.

**‘Reinnovation’** – Is based on a process of matching factors as described for ‘Choices between Alternatives’. However, the key difference is that now innovations and aspects of the organisation are modified to achieve the best match with ‘Regulatory-Institutional’ and ‘Natural-Physical’ factors. The ‘Reinnovation’ and the ‘Choice between Alternatives’ stage were also found to be inseparably linked as they are operating in close feedback. This confirmed that innovation decision making is not a linear processes (Mintzberg & Raisinghani 1976).

**Intra organisational ‘Diffusion’** – Is an iteration of the ‘Agenda Setting’, ‘Choice between Alternatives’ and ‘Reinnovation’ stage of the innovation decision process. In literature this was only suggested for ‘Diffusion’ processes between individual organisations (inter-organisational) and people (Rogers 2003). The intra-organisational process was not previously conceptualised like this. Thus, this research emphasises that also in organisations the spread of an innovation across departments or catchments depends on a continuous assessment of a performance gap, matching and design.

### **9.5 Key finding IV - pace of change**

There was evidence in this research that the rate at which WaSCs in E&W will adapt to the new ideal of more integrated water management is governed by a combination of asset characteristics, environmental state changes and the funding cycle. More precisely, WaSCs can be considered to be locked into specific asset investments. Renewal of these assets will mainly take place as a result of actual or anticipated asset failure. This failure can be triggered by a deterioration of raw water quality (i.e. state change) or the introduction of tighter standards. Awareness of future asset failure can be generated by policies that required WaSCs to gather information about risks to raw water quality. The DWSPs were an example for this. Furthermore, there was evidence that the funding cycle of WaSCs resulted in episodic rather than continuous change.

### **9.6 Key finding V - flexible and direct regulation in water management**

The innovation model developed in this study emphasises that policy makers need to negotiate the trade off between policies and find the best mix between them. It was

further shown how policies can have undesired side effects. The DWQS was the prime example. This direct regulation performed well in generating a performance gap, but led to the replication of current approaches to water management, by encouraging preference of end of pipe technologies. Contrary to this, flexible policies or framework policies (i.e. SDS, WFD, DWSPs, Future Water) which were not perceived to give preference to certain types of solutions were less effective in triggering the identification of a performance gap. However, they performed well in enabling change in terms of new approaches to water management, such as SCIs.

These findings underline that direct regulation in terms of drinking water or environmental standards will have a continued role to play in stimulating change. Framework directives or other flexible regulations can then be employed to guide change into the desired direction. In this vein, this study cannot confirm the recommendation by Cave (2009) that encouraging economic efficiency of WaSCs will deliver innovation and change, per se. Economic efficiency is rather understood as a criterion influencing the direction of change, but in itself could not be shown to stimulate innovation by triggering the innovation process.

Similarly, the WFD was conducive to the implementation of SCIs by outlining a broader framework for change. However, uncertainties about the WFD and a lack of specific requirements render it less effective in changing water management arrangement than has been proposed (Chave 2001; Kallis & Butler 2001). In particular the cautious implementation of drinking water safeguard zones by the EA illustrates this. However, it is noted that the uncertainties and the lack of specific requirements maybe a result of the preparatory phase of the WFD, which ended with the publication of the final RBMPs in December 2009. Nonetheless, reducing uncertainties by setting clear objectives and communicating them in a timely fashion as recommended by Cave (2009), is likely to have a positive influence on innovation.

## **9.7 Key finding VI - future direction**

This study showed that SCIs can be successfully implemented by WaSCs in E&W. Indeed, it was found that WaSCs are increasingly adopting SCIs as a response to raw water quality problems. A number of coordinated policy changes were, at least in part,

responsible for this new direction in the way WaSCs in E&W approach water management. For wider water management in E&W this implies that WaSCs may begin to play a role in addressing agricultural diffuse pollution. This may not be directly through engagement with farmers as studied by Brouwer *et al* (2003a), but may rather comprise the use of ‘Liaison’ approaches that are built around cooperation of actors. This is so because in particular ‘A&S’ interventions are dependent on site specific conditions and may thus be restricted to certain areas that exhibit favourable conditions. ‘Liaison’ on the other hand could become a more broad brush approach of WaSCs to influence agricultural water management, since operation of SCIs is anticipated to be working in synergy with treatment. By combining treatment and SCIs in a ‘twin-track’ approach, WaSCs can harness the benefits of SCIs including CO<sub>2</sub> reduction, reducing raw water pollution risk and capex and opex cost saving, without risking the failure of drinking water standards, which were considered to be a key constraint towards the adoption of SCIs. Nonetheless, by adopting ‘Liaison’ more widely, it is also possible that ‘A&S’ will be appearing at sites that favour this type of approach. The reason for this is that WaSCs will learn about SCI solutions by being active at the catchment level. Thus they will be in a better position to identify situations where ‘A&S’ can be adopted successfully.

## 9.8 Study limitations

This study employed an abductive research strategy. Inherently this method has the disadvantage that the causal relationships detected are not based on the identification of patterns or statistical relationships. Thus, researchers of the positivist tradition may argue that no general conclusion from this research can be drawn. Other, more structured methods could be used to increase the rigour of the findings presented in this research (see for instance Belton & Stewart 2002 on multi criteria decision analysis). Nonetheless, the author believes that generalisations in the context of E&W are possible, since all cases taken together represent the entire population of WaSCs in E&W.

Critiques may further point out that interviews with one to three members of staff within each WaSCs cannot be taken as representative for an entire organisation. While it is appreciated that individuals within organisations do not follow universal goals and procedures (Cyert & March 1963), individuals in organisation can have a significant

influence on the organisation as a whole (see for example Sharma 2000). Hence, the research approach taken here (i.e. selection of interviewees in relevant functions) should be considered as a compromise of what has been feasible within the context of a PhD project which was constrained by the time available, access to research subjects and financial resources.

Additionally, participant validation was not feasible due to time constraints and concerns about the value of this approach. Regulatory conditions in the year 2009 were in a process of swift change as a result of the PR09 and publication of the RBMP. It is therefore likely, that an attempt to validate the data would have lead to contradictory empiric results due to the changing external conditions in the year 2009.

Lastly, the study was also limited in the amount of detail gathered about the 'Routinisation' and the 'Diffusion' stage of the innovation decision process, since few WaSCs were at these later stages of the process. Thus, the research may not result in a comprehensive understanding of the complete innovation decision process.

## **9.9 Recommendations for future research**

The following recommendations for further research are made:

- The investigation of the innovation decision making process carried out in this study did reveal only limited information about the process underlying the 'Routinisation' stage of the innovation decision process. Future work should investigate this process to understand the factors that govern the process of 'Routinisation'. Observing innovation decision making over longer periods of time maybe adequate for this task.
- The research showed that 'Choices between Alternatives' and 'Reinnovation' inseparably linked. An understanding of how knowledge and experiences gained at the 'Reinnovation' stage affect the 'Choice between Alternatives' is likely to provide insights on the barriers for adoption of innovations.
- More research on the impact of 'Natural-Physical' factors is needed to identify whether and how the findings of this study can be applied to other innovation decision processes.

- The research indicated that rates of change by WaSCs in E&W are low because assets are mainly replaced as a result of failure of a standard. Using a case study this proposition should be tested and it should be investigated how rates of change for WaSCs in E&W can be increased (see Chapter 8).
- Research should be conducted on how immediate and intermediate outcomes of SCIs could be assessed and integrated into the regulatory framework of WaSCs. In this context an option to be explored maybe the application of pay by results schemes where payment to farmers is linked to their ability to delivery defined objectives (Schwarz *et al.* 2008).

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### **Software**

Hamlet II<sup>©</sup> Downloadable <http://apb.newmdsx.com/hamlet2.html> [accessed 23/03 2010]

NVivo<sup>©</sup> 7 & 8 QSR International Pty Ltd. <http://www.qsrinternational.com/> [accessed 01/04 2010]

# Appendix I Interview primer first fieldwork phase

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Researching water company adaptation to the Water Framework Directive

*Cranfield*  
UNIVERSITY

Funded by the European Commission 'New and Emerging Science and Technology' (NEST-PATHFINDER) programme, the Centre for Water Science at Cranfield University is undertaking research to better understand the effects of the Water Framework Directive (WFD) on UK water companies. Outputs from the research will be an improved understanding of the constraints and enablers of water company innovation in relation to the WFD, recommendations about how to facilitate innovation through changing awareness and adaptation processes, and an evaluation of how the process of implementation will affect the achievement of the goals of the WFD.

To start the research a series of initial interviews are being undertaken with water companies, industry bodies and regulators across England and Wales. Each interview will last for an hour and will cover the following issues:

1. What are the main challenges posed by the WFD?
2. How are responses to the WFD being organised?
3. What priority does the WFD have in relation to other activities?
4. What kind of benchmarking information would be useful to have?

The aim is to establish a snap-shot of current issues and responses, and to provide an opportunity to shape research agenda and output. We are committed to providing research of value to the water industry.

If you have any questions please contact the project researcher, Marc Spiller, at [m.spiller@cranfield.ac.uk](mailto:m.spiller@cranfield.ac.uk)



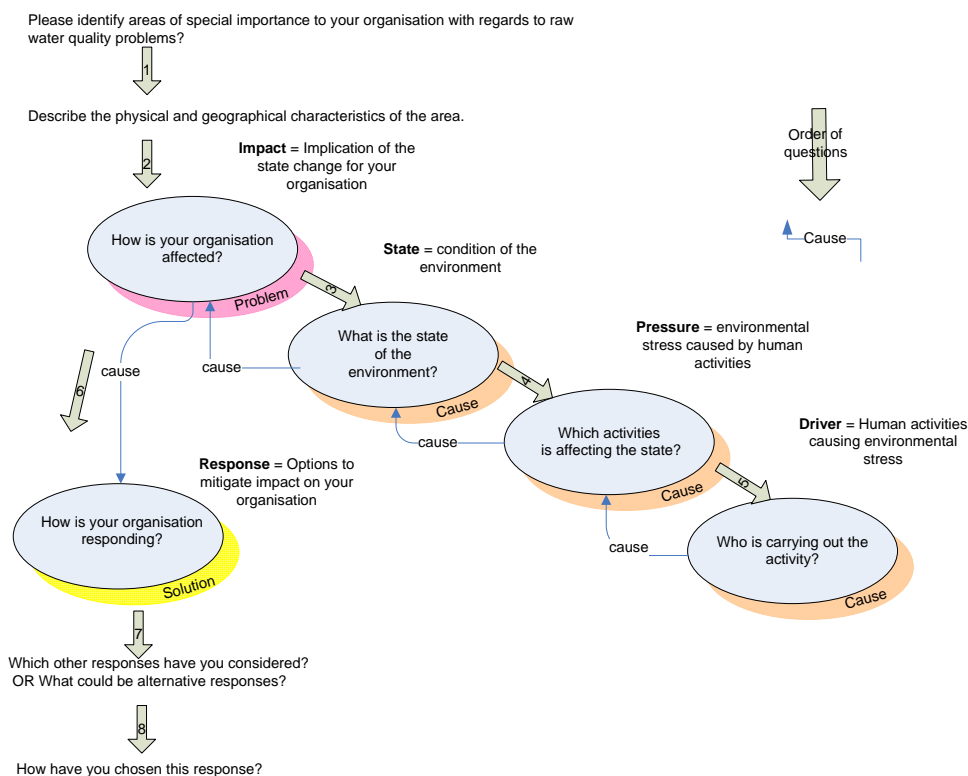
# Appendix II Interview outline for second research phase

## Causes and responses to raw water (water resource) quality problems

During the interview you will first be asked to identify geographical areas where your organisation is facing raw water (water resource) quality issues. You are free to identify as many geographical areas as you like. If you identify many areas we will ask you to consider whether these areas are of different type. If so we will continue as follows using a representative example of each type of areas.

For each of the (types of) geographical areas you identify, we will ask you to first describe the physical and geographical characteristics in some detail. Thereafter, questions will be asked employing a Driver-Pressure-State-Impact-Response (DPSIR) framework (for an explanation of this framework see below). Using DPSIR the environmental problems your organisation is facing will be investigated following the causal chain back to the origin of the problem. The aim of this process is to frame the environmental problem in its local context. Then, the interview will move towards exploring how your organisation is responding to problems faced. We are interested in how specific responses were selected, why other were rejected and which role the local physical and geographical characteristics play during the choice of alternatives.

It is anticipated that this analysis will enable this research to demonstrate that the organisational opportunities to respond to the WFD are constrained by the geological and physical preconditions encountered in specific locations.



DPSIR is an acronym for Driver, Pressure, State, Impact, Response. It is a tool developed by the EEA to structure environmental planning problems.

A Driver is a need. For an industrial sector a driving force could be the need to be profitable and to produce at low costs, while for a nation a driving force could be the need to keep unemployment levels low. These driving forces lead to activities that exert pressures on the environment. In the general model they can be divided into three main types: (i) excessive use of environmental resources, (ii) changes in land use, and (iii) emissions to air, water and soil. As result of these pressures the state of the environment changes. This state change in turn has 'impacts' on the functioning of ecosystems, their life supporting abilities, and ultimately on human health and on the economic and social performance of society. A 'response' are the actions, decisions or behaviours implemented as a result of an undesired impact.

## Appendix III Interview primer second research phase

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Raw water (water resource) quality problems – are locational characteristics a mediating factor of business response?

The Centre for Water Science at Cranfield University is undertaking a research to understand how characteristics of location (i.e. physical and geographical) affect the response of Water and Sewage Companies (WaSCs) to the WFD using the example of raw water quality management.

For this purpose we will interview WaSCs staff responsible for raw water (water resource) quality management and planning. We aim to conduct interviews in all WaSCs in England and Wales. During the interviews we will, together with the interview partner, identify catchments that exhibit raw water (water resource) quality problems of concern to WaSCs. The interviews use a Driver-Pressure-State-Impact-Response (DPSIR - for explanation see interview diagram document) framework to identify how WaSCs frame raw water problems, the problem context in terms of cause-effect relationships and WaSCs response to these problems. Each interview will last about one hour and all information gathered will be treated confidentially.

Outputs from this research are anticipated to show that characteristics of location in terms of water quality, population density, land use etc. put different constraints on WaSCs ability to respond to environmental legislation (i.e. WFD). This potentially provides evidence for the relevance of special factors of location in Ofwats relative efficiency assessment.

If you have any questions please contact the project researcher, Marc Spiller, at [m.spiller@cranfield.ac.uk](mailto:m.spiller@cranfield.ac.uk)

## Appendix IV Participant consent form

### **PARTICIPANT CONSENT FORM**

**Please tick each box to confirm that you have read and understood each section of the form:**

I, \_\_\_\_\_ (please print your name in block capitals) confirm that I have volunteered to participate in the interview.

I understand that the discussions will be audio recorded and transcribed for analysis. The analysis will only be used with the ISBP project funded by the EC and for no other purposes.

I understand that the audio recordings and transcriptions will be stored at Cranfield University in accordance with the Data Protection Act (1998).

I understand that my confidentiality and anonymity and the confidentiality and anonymity of my organisation are assured as information that I provide will be treated with the strictest confidence and it will not be possible to identify any specific individual or organisation from the final output or publications.

I understand that I am free to withdraw from the interview at any stage. I also understand that, as the data is anonymous, it will not be possible to withdraw my data from the research once my contributions have been transcribed.

## Appendices

I understand that any publication from this study will not be available to me for commercial reasons. However, publications will be send to you prior printing for approval of correct reflection of your views and prevention of disclosure of potentially harmful information.

If you have any questions about the research, please do not hesitate to ask.

I confirm I have read and completely and fully understand the information provided on this form and therefore give my consent to taking part in this research.

Full name: \_\_\_\_\_ Contact number: \_\_\_\_\_

Email address: \_\_\_\_\_

Signature: \_\_\_\_\_ Date: \_\_\_\_\_

|