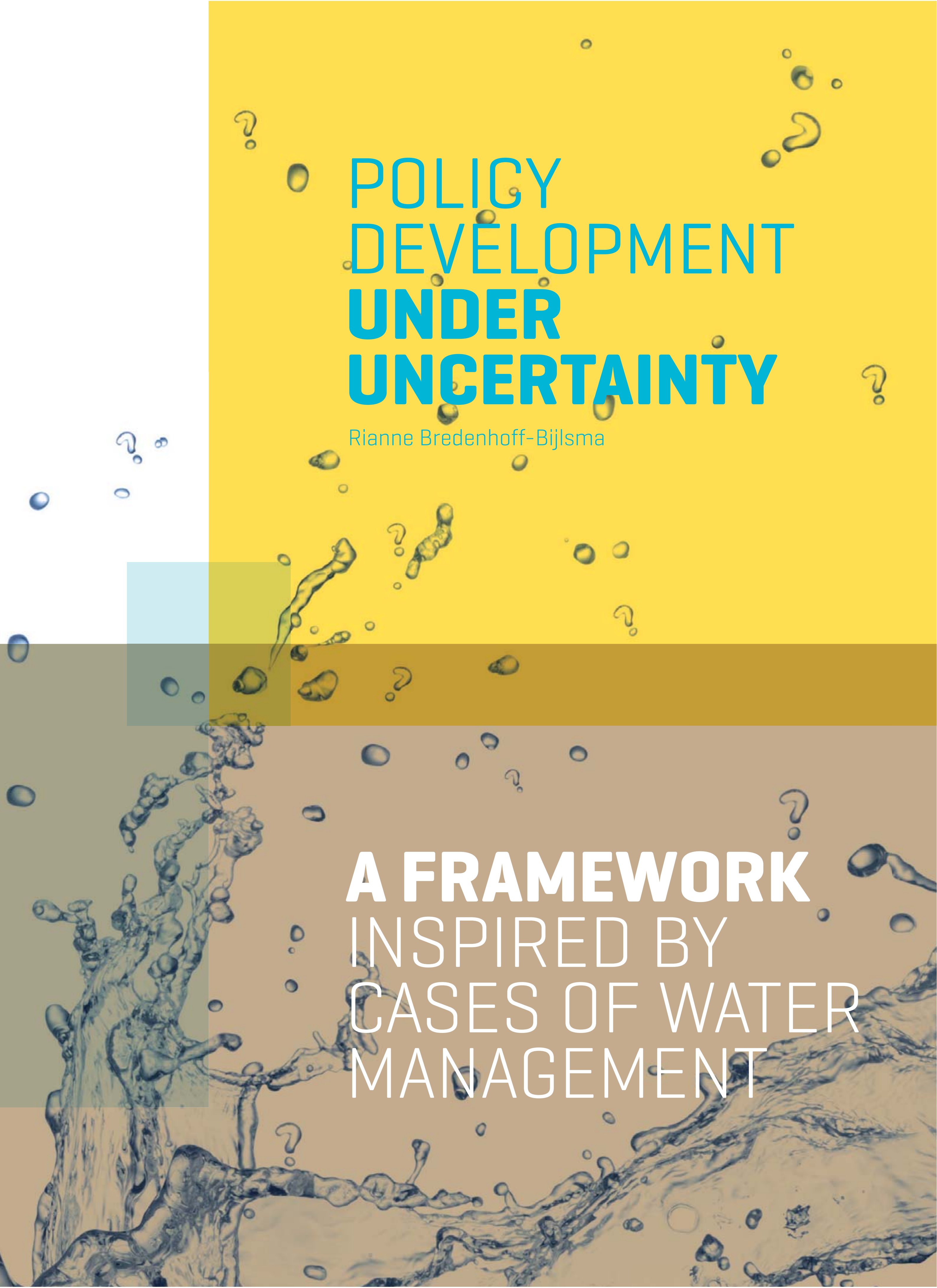

POLICY DEVELOPMENT **UNDER UNCERTAINTY**

Rianne Bredenhoff-Bijlsma

A FRAMEWORK INSPIRED BY CASES OF WATER MANAGEMENT

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A FRAMEWORK INSPIRED BY CASES OF WATER MANAGEMENT

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Preface

To be uncertain is to be uncomfortable, but to be certain is to be ridiculous.
Chinese Proverb

In these matters the only certainty is that nothing is certain.
Pliny the Elder

Maturity of mind is the capacity to endure uncertainty.
John Finley

When I started this research I jumped straight into the interesting and challenging topic of uncertainty, soon to realize that uncertainty handling in policy development has many different dimensions. The field of policy analysis, which forms the basis for my research, fails to capture some of these dimensions. The literature focuses on techniques and procedures to identify, and then quantify or qualify, the risk involved in a policy intervention. In my opinion the applied techniques are valuable, though limited in scope and costly. This may be one of the reasons why their application in policy practice is restricted.

Uncertainty may be – and in practice is – handled in diverse ways in the process of policy development. Authors in several fields of policy science, such as process management, political science and resilience management, discuss uncertainty handling from different perspectives. What appears to be missing, however, is a wider and more interdisciplinary perspective on uncertainty handling, focused specifically on policy development. To develop this broader perspective I linked different strands of scientific literature, resulting in the framework presented in this thesis. I hope this framework will enable scientists and practitioners involved in the design and evaluation of policy development processes to more consciously handle uncertainty.

The five years of research underlying this thesis have been an incredible learning experience. I would like to thank everyone involved.

To start with, I would like to thank RIZA, later Deltares, for financing the first years of my PhD. My work on the European research projects HarmoniRiB and Aquastress, on the case studies underlying this thesis, have been enriching and shaped my thinking on policy development. I want to thank all my colleagues at RIZA and Deltares for making me feel a part of their organization and at home, and my fellow researchers at HarmoniRiB and Aquastress for the inspiring and enjoyable collaboration. I wish to thank several people in particular.

Michiel Blind, thank you for our close and excellent cooperation on HarmoniRiB. We have had many good discussions about uncertainty and together with Alterra set up a most interesting uncertainty analysis. I highly appreciate the genuine interest you showed in the development of my thesis. I would also like to thank Piet Groenendijk of Alterra for our useful collaboration. During our discussions I learned a lot about handling large models and uncertainty in data, not forgetting the ins and outs of manure. I also wish to thank Christian Siderius, Dennis Walvoort and Gerard Heuvelink of Alterra and Paul Boers of RIZA for their cooperation.

Henk Wolters, thank you for our great association on Aquastress. I highly appreciate the opportunities you gave me for carrying out my research in the Bargerveen case study. I want to thank the project team of the Bargerveen policy process, starting with special thanks to Nicolien van der Fluit. Nicolien, I have great respect for the way you organized the process and I have warm memories of our picnic during which we discussed my research! In particular I thank you for arranging the expert session at the water board Reest en Wieden. Next, I wish to thank Arnold Lassche and Thomas de Meij of water board Velt en Vecht for our helpful collaboration and the interest you have shown for my research.

Pieter Bots, thank you for enriching this thesis. We worked together as researchers in Aquastress and the project team of the Bargerveen case study, based on which we have co-authored two articles that feature in this thesis. I warmly remember our good and insightful discussions during your trips to Apeldoorn and my trip to Delft.

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Arjen Hoekstra, thank you for your critical, analytical view and your valuable comments on the outline and details of my thesis. I have tried to find my own path, which you have always been able to support and willing to facilitate. Jean-Luc de Kok, for the first three years you were my day-to-day supervisor and I would like to thank you for your stimulating enthusiasm and support. Maarten Krol, you took over the day-to-day supervision in the final two years of my PhD and provided me with valuable comments. Most of all, I appreciate that you always found time for a chat and a discussion of my thesis when I needed encouragement. I also want to thank my roommates Blanca Perez-Lapeña and Arjan Tuinder. You have made my research so much more fun!

Finally, I would like to thank my parents and my sister Astrid for their support during my research and long before that. But most invaluable of all have been the love, positiveness and support of my husband during the writing of my thesis.

Eelco, I dedicate this book to you.

Summary

A thoughtful consideration of strategies for handling uncertainty in policy development offers advantages in the management of a social-ecological system. Uncertainty is inherent in policy development and introduces a risk of adverse consequences of policy and a blockage in the policy development process. Scientists and practitioners often consider the handling of uncertainty difficult. The contribution of this thesis is that it connects the understanding of uncertainty and related methods and rationales of uncertainty handling from different fields of scientific literature: (participatory) policy analysis, network and process management and adaptive and resilience management.

This thesis offers a comprehensive and interdisciplinary conceptual framework for handling uncertainty in policy development. The framework is inspired by water management cases, but is expected to be more widely applicable in such fields as natural resources and environmental management, transport policy and spatial planning. Uncertainty in policy development is defined as the absence of complete and shared understanding of the system subject to policy development, a definition that frames uncertainty as related to both substantive and process aspects of policy development. The primary focus of the thesis is on the substantive aspects of policy development and related substantive uncertainty, but it specifically considers the close relationship to the process of actor interaction resulting in strategic and institutional uncertainty.

The core of the framework consists of two variables to classify uncertainty handling in policy development, represented by two intersecting axes. The first is the method used for handling uncertainty, for which the framework reflects a variety of methods based on scientific analysis and process management. The second variable is the rationale of uncertainty handling, for which the framework shows a range of rationales from system control to system resilience. The chapters of this thesis provide insight into the merits and trade-offs of one-sided uses of a type of method or a specific rationale, and opportunities for complementary approaches.

Chapter 2 discusses the scientific analysis of uncertainty in a modeling case study. The method applied is the quantification of uncertainty in an uncertainty distribution and its propagation through the model. The main strength of this method is the clear visualization of the effects of identified uncertainty sources on the preferred policy. On the other hand, the chapter convincingly illustrates the drawbacks. The method is not well equipped to assess deep uncertainties and there is inherent subjectivity in the assumptions made in the analysis, which has a substantial effect on the outcome. The discussion and conclusion section shows that these merits and trade-offs apply to methods of scientific uncertainty handling in general.

Chapters 3 and 4 discuss the combined use of methods of scientific analysis and process management to handle uncertainty. Chapter 3 shows the interaction between these methods in policy development. The chapter describes the uncertainty handling applied to a case study of participatory policy development and compares it to handling uncertainty in expert-based

policy development for the same case. The uncertainty handling in the participatory policy development relied increasingly on process management methods such as trust building and negotiating commitment, in interaction with methods of scientific analysis. In the expert-based approach the dominant process management method for handling uncertainty was following established procedures. The chapter shows that the application of different methods of uncertainty handling enables consideration of other policy measures. Uncertainty handling based on process management limits actor behavior, increases uncertainty tolerance and develops capacity to deal with uncertainty. Persisting conflict in actor interaction (not confined by process management) may seriously downplay, and even reverse, the merits described.

Chapter 4 discusses 'rules of the game' for actor interaction in participatory policy development that embed favorable handling of both process and substantive uncertainty. The presented code of conduct serves to guide process management in facilitating a constructive discussion on substance. The chapter makes favorable informal institutions to limit complexity and conflict between actors in participatory policy development explicit. It proposes four sets of rules, related to agenda management, information sharing, model use and option development. The focus of these rules is on creating a 'fair process' and transparent model-based analysis, to enhance the trust between actors and so exploit the merits of process management discussed in Chapter 3. Chapters 3 and 4 both show that uncertainty handling is inherent in all activities of policy development and is not a separate activity. Choices to handle uncertainty are made continuously throughout the activities, but they often remain implicit.

Chapter 5 contrasts the rationales of system resilience and system control, which each enable a system to cope with uncertainty in a different way. A system control rationale aims at stability of the system and low day-to-day uncertainty by reducing disturbance. A merit is the system's efficiency under expected circumstances. On the other hand, the rationale requires advanced analysis to foresee disturbances and surprises are likely to have considerable adverse consequences. A system resilience rationale aims at developing backup mechanisms and possibilities for quick adaptation to mitigate the consequences of uncertainty. At its core is allowing day-to-day uncertainty, since this stimulates the development of favorable mechanisms for handling unexpected events. The resilience rationale decreases the dependency on detailed analysis and the risk of surprises. A drawback is the decreased system efficiency. The contribution of this chapter is to explicitly contrast preferred system attributes for both rationales to guide discussion in policy development. It illustrates this contrast in a case study of historic and current flood defense policy. System attributes that increase resilience are diversity, reserves, modular-connectivity, adaptive feedback and innovation. System attributes that increase control are optimization, intensification, connectedness, focused feedback and improvement.

The final chapter interprets the meaning of the quadrants of the framework, each of which combines a type of method and a particular rationale. When combining methods of scientific analysis and a rationale of system control, the focus of uncertainty handling is on optimizing interventions. In combining methods of scientific analysis and a rationale of system resilience, the focus is on exploring vulnerabilities. The focus in combining methods of process management and a rationale of control is on formulating procedures. Finally, when combining methods of process management and a rationale of resilience, the focus is on organizing learning.

The presented framework offers structure when choosing an uncertainty handling strategy, a choice that is currently often made implicitly. A complementary use of methods and rationales offers opportunities, because combined approaches mitigate the trade-offs related to one-sided approaches. An appropriate uncertainty handling strategy for complex policy development processes probably combines approaches from all four quadrants. The broader perspective on uncertainty handling presented is argued to equate uncertainty literature with the wider perspective on policy development emerging in water management and other fields and is considered the appropriate way forward for uncertainty research. The framework is complementary to existing uncertainty literature and does not aim to replace it.

Contents

1 Introduction and theoretical framework

1.1 BACKGROUND AND FOCUS

In the management of a social-ecological system, actors are uncertain about the behavior of the system and the consequences of policy developed for the system. This results in a risk of unintended effects of policy (including doing nothing). The stakes in public policy are often high due to the large-scale effects and the trend in contemporary policy problems is one of increased complexity and globalization (Beck 1992). On the other hand, uncertain developments offer opportunities for actors who anticipate them. In this context, the thoughtful consideration of strategies to handle uncertainty offers advantages, which is a challenge on which I reflect in this thesis.

Uncertainty is a topic that has interested scientists in many fields. A small inventory shows the breadth of uncertainty research relevant to policy development. Firstly, scholars in the field of decision theory (Tversky and Kahnemann 1986) and framing research (Dewulf et al. 2009) study the individual or group framing of uncertain situations, scholars in network theory examine strategic behavior of actors in uncertain situations (Koppenjan and Klijn 2004) and scholars in the field of psychology analyze risk perception and risk-related behavior (Slovic 1996, Loewenstein et al. 2001). Next, in the system sciences scholars have developed methods to assess uncertainty in our knowledge (Funtowicz and Ravetz 1990, van der Sluijs et al. 2003) in order to find decisions that are robust under uncertainty. Finally, scholars in the sociology of science address the origin and consequences of uncertainty from a more philosophical point of view (Douglas and Wildavsky 1982).

The development of policy benefits from insights from all these fields of uncertainty research, but there is little effort to combine the knowledge. In this thesis I develop a conceptual framework for handling uncertainty in policy development. The thesis mainly draws on environmental, water-related problems. However, the framework aims to be more widely valid, something on which I reflect in the discussion.

I define policy development as a series of activities carried out by a group of actors in deciding on a policy for a problem (see Figure 1.1). A policy problem is a current or future situation that one or more actors consider undesirable. The policy development starts when actors mobilize resources and involve themselves in activities and ends when a policy is formulated and agreed upon. This research therefore excludes policy implementation and aspects that trigger the adopting of policy, such as policy evaluation and political agenda setting (Brewer and deLeon 1983, Parsons 1995). A problem (or set of problems) is seldom solved in a satisfactory way and the actors are likely to mobilize resources again at a later time. Also, the actors may agree on the continuous adaptation of policy, so called adaptive management (Holling 1978). The policy makers are the persons that are formally or informally recognized as competent to decide on a policy.

Policy development involves both knowledge-related and process-related activities, which are embedded in an institutional setting (Figure 1.1). The knowledge-related activities can roughly be divided into three main groups: problem framing, analysis of alternative policies and policy design (Simon 1957, van de Riet 2003). They are paralleled by process-related activities: involvement of different stakeholders, interaction to discuss alternative policies and commitment to policy. The development of the knowledge system (Hisschemoeller et al. 2001) is the primary focus of this research, but we specifically study its close relation to actor interaction in the policy arena (Berger and Luckmann 1966).

During the policy development the actors face uncertainty. I define uncertainty as the absence of complete and shared understanding of the system subject to policy development (adapted after Brugnach et al. 2008). Uncertainty may block the progress of policy development and agreement on a handling strategy furthers the process. The system in the definition is a social-ecological system of which the actors developing the policy are specifically a part.

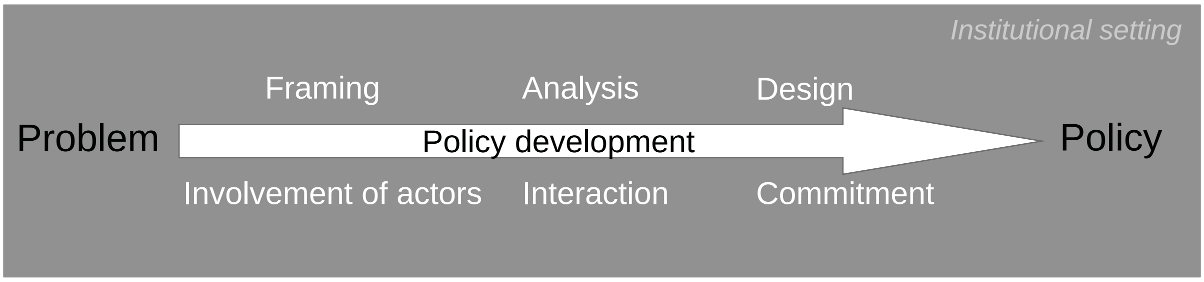

Figure 1.1 Policy development as a series of knowledge- and process-related activities embedded in an institutional setting

1.2 POLICY DEVELOPMENT AND THE VIEWS ON UNCERTAINTY

Policy sciences scholars have developed different views on the role of science, knowledge and social interaction in policy processes, reflected in different organizational models of policy processes. This is paralleled by different views on uncertainty and its handling. We discuss two main paradigms of policy development. For several centuries the dominant paradigm has been modernism, which places scientific rationality central and is therefore knowledge-oriented. Around the 1980s, influential anti-movements such as post-modernism and social-constructivism led to an increased orientation on process and actor interaction (Hoppe 1999, Van Asselt 2000).

1.2.1 Scientific rationality in policy development

Modernism in its most extreme form is based on the positivist idea that science is capable of producing true, objective and universal knowledge. By following systematic empirical-analytical procedures, scientific analysis will eventually result in conclusive evidence, in which uncertainty is considered as unscientific (Hoppe 1999, Van Asselt and Rotmans 2002, Koppenjan and Klijn 2004). This ability of science gives it superiority over other knowledge sources and domains. In the positivist view, science should be separated from other societal domains such as government and the market. Its role is to provide policy makers with objective facts as the authoritative starting point for government interventions, also referred to as ‘speaking truth to power’ (Wildavsky 1979). Values are the domain of the policy maker and normative insights should be separated from objective knowledge, also called the fact-value dichotomy (Hawkesworth 1988). The approach places the ‘expert’ policy analyst outside the system of study.

The positivist mode of thought in its pure form has lost support, but has affected several schools of scientific thought at the policy-science interface. These schools advocate the cognitive superiority of science over practice, based on scientific logic and consistency built into analytical techniques, knowledge of causal links and scientific strategies for learning (Dryzek 1993). The rational approach to policy development leads to heavy investment in analytic tools, where mathematical and quantitative methods are considered best practice for assessment of policy (Van Asselt and Rotmans 2002). A system model is put central in the understanding of the system’s behavior. Fields in scientific literature with roots in modernism are traditional policy analysis, adaptive management and resilience management.

Traditional policy analysis

Policy analysis is a field of multidisciplinary inquiry with the aim to create, assess and communicate information that is useful for understanding and improving policies (Dunn 2008). The field developed out of operations research, the techniques of which were successfully applied during the two World Wars. This led to a rapid expansion in the scope of application of these techniques (Miser and Quade 1985, Walker and Fisher 2001) and the name systems analysis was adopted. The growing interest in the political dimension of policy led to the gradual transformation of systems analysis into policy analysis (Van de Riet 2003). The role of scientific analysis in policy development has been institutionalized rapidly in the decades after World War II (Jasanoff 1990).

Policy analysts discern several phases in the policy-making process (see e.g. Brewer and deLeon 1983, Miser and Quade 1985, Walker 2000, Dunn 2008). The analysis starts with setting the objective of the policy, followed by the devising of indicators to assess alternative policies and the formulation of such policies. Policy analysis uses system modeling techniques to understand system behavior and assess the relative effectiveness of policy interventions. Finally, one or more decision-maker(s) select a preferred solution. Uncertainty hampers this procedure. The lack of understanding of the system may result in ineffective solutions or even adverse consequences. Therefore, the focus is on reducing uncertainty and, for uncertainty that cannot be reduced, assessment of the range of uncertainty to determine measures robust under this uncertainty. The analysis focuses on considering all possible impacts of the proposed policy in advance.

Adaptive management and resilience management

Adaptive management was introduced in the 1970s as an alternative to traditional policy analysis (Holling 1978, Walters 1986). Its adherents argue that independent of how many data are collected or how much we know about the system's functioning, the domain of our knowledge is small compared to that of our ignorance. In addition, policy objectives and indicators change with preferences over time. Therefore, adaptive management advocates continuous learning, based on monitoring, from the outcomes of implemented strategies, which is seen as an integral part of policy design. Walters and Holling (1990) distinguish between passive and active adaptive management. In passive adaptive management a policy is selected on the basis of expected performance and the policy is adapted when more data become available. In active adaptive management an explicit goal of a policy is to test alternative hypotheses of system behavior. Therefore, learning (policy as an experiment) is balanced by short-term performance in policy design.

The adaptive management process consists of similar phases to traditional policy analysis, but the interpretation is different. The focus of modeling techniques is on understanding key variables and causal relations of the system to illuminate the range and nature of alternative policies, as opposed to a detailed prediction of their impacts. There is special emphasis on modeling the whole system in coherence and on identifying knowledge gaps, alternative system models and extreme system behavior.

Resilience management was introduced around the same time as adaptive management (Holling 1973). System resilience reflects the magnitude of disturbance that can be absorbed or buffered without the system undergoing fundamental changes in its characteristics (called a regime shift) (Carpenter et al. 2001, Berkes et al. 2003). Resilience analysis focuses on identifying thresholds in the system that – once passed – lead to a (undesirable) shift in regime, which is mostly difficult to reverse. Scholars concentrate analysis on slowly changing variables and their interaction between scales. The aim of analysis is to identify potential pathways of system development and alternative policies to keep the system within a desirable regime (Walker and Salt 2006). Resilience management advocates approaches of adaptive management and the two fields have become highly interwoven.

Criticism of the central position of scientific rationality

The rational approach to policy processes has been criticized for an unrealistic position granted to science and scientists in policy development (Hoppe 1999). Vickers (1965) and Dunn (1993) show that empirical observation of reality is influenced by the observer's expectations and preferences, which also applies to scientists involved in policy-analytical activities such as policy framing and analysis. This observation legitimizes multiple frames (also non-scientists' frames) for policy development (Schön and Rein 1994, Van Asselt 2000) and limits the potential new insight from experiments (Dunn 1993). Furthermore, scientists are not immune to self-interested behavior (Brobow and Dryzek 1987).

Second, the creation of valid knowledge under prevailing conditions of insufficient data and slow processes of knowledge construction is questioned (Jasanoff 1990). A specific question for adaptive management is how scientific rigor is attainable in field experiments (Lee 1999). That reflexivity, i.e. humans' capacity to change behavior based on learning, may destroy the causal laws on which a policy is based (Soros 1987, Bryant 2002) applies to all approaches.

Next, the existence of (universal) criteria of validity is questioned. Kuhn (1970) shows that accepted scientific activity in any period merely conforms to the prevailing paradigm. This makes activities such as the selection of data, the choice of appropriate methods, theory building and validation a product of social convention. Equally, the choice of relevant research directions is socially driven.

Finally, the rational model is criticized for a lack of political realism. Jasanoff (1990) shows how power competes with rationality and convincingly argues that truth in science is inseparable from power. Policy development is capricious by nature and this poses a specific challenge to adaptive management, since learning from experiments is slow and success therefore depends on longer-term enthusiasm and commitment. The idea of adaptive management has therefore up to know been more influential than the actual practice (Lee 1999).

1.2.2 Process dynamics in policy development

Post-modernism and social-constructivism emphasize the socially constructed nature of scientific knowledge (Jasanoff 1990, Van Asselt 2000). The post-modern movement challenges the grounds for systematic investigation, analysis and interpretation (for an overview see Rosenau 1992). Scholars adhering to social-constructivism (Berger and Luckmann 1966) argue that the criteria for distinguishing between valid and invalid scientific statements are socially constructed. These movements induced a focus on actor interaction in policy literature. Research concentrates on forms of actor interaction (e.g. governance versus government) and the dynamics of interaction in policy development (Scharpf 1997). The scientist is considered an actor like all others and part of the social-ecological system he or she studies. I discuss network literature below as a field of special relevance for this thesis.

Network theory

Network theory scholars place actor interaction in policy networks central in the development of policy (Crozier and Friedberg 1980, Rhodes 1981, Kickert et al. 1997). A policy network is a (more or less) stable pattern of social relations between interdependent actors, which takes shape around policy problems and/or policy programs (Kickert et al. 1997). The interdependencies between actors imply that no actor is able to develop policy without the cooperation of others. The theory uses the concept of governance to reflect a more horizontal organization of policy processes. Governance is about steering without presuming the presence of hierarchy (Rosenau 1992, pp 14). The interaction on policy problems in networks has an incremental character, in which action is dependent on windows of opportunity (Kingdon 1984). This is reflected in organizational models such as the ‘garbage can’ (Cohen et al. 1972) and the ‘rounds’ models (Teisman 2002). In the network approach the role of scientists is to develop and structure arguments to serve the process.

Network theory considers uncertainty to be an inherent aspect of actor interaction. The uncertainty results from the diverse interests, positions and preferences underlying the behavior of the involved actors (Koppenjan and Klijn 2004). Actors use their power, resulting from, for example, their access to resources or legal authority, to influence the process to their advantage.

Criticism of the central position of process dynamics

Policy development based on process dynamics has relatively weak safeguards for evaluating the quality of applied knowledge and for including stakes of less powerful actors. A process that merely focuses on the approval of actors may result in negotiated nonsense (Van de Riet 2003). As Susskind and Cruikshank (1987) put it: ‘in the heat of the process, common sense is often the first victim’. Bryson and Crosby (1992) note that an organized approach of some sort is required to arrive at effective policy, which may be difficult in situations of complex actor interaction. These authors, however, argue for a procedural rationale in actor interaction instead of scientific rationality, since they encounter difficulties when applying the rigidly imposed sequence of activities of the latter.

Koppenjan and Klijn (2004) argue that the substantive aspects of policy development have been (unjustly) under-illuminated in network literature. Van Eeten (1999) shows that overly focusing on power and interaction in policy development invites deadlocks, which may be resolved by substantive arguments (compare also Kickert et al. 1997).

1.2.3 Combined approaches in policy development

The presented views on policy development provide two extremes. As Hoppe (1999) discusses, it is not necessary to choose; it is more beneficial to see the views as elaborating different emphases that mutually elicit and illuminate each other. Scientific rationality focuses on the cognitive understanding of the system, aiming at knowledge that is transferable from one individual to another. The network approach focuses on the relational aspect of policy development, where problem solving is an issue of negotiating understanding and appropriate actions and the context shapes the way a problem is understood (Bouwen and Taillieu 2004).

Process management (de Bruin et al. 2002) and *network management* literature (Klijn et al. 1997; Koppenjan and Klijn 2004) integrate the development of (scientific) knowledge in the process of policy development. The process is leading the research that is conducted and the research has a facilitating role for the process. The process manager is given a central role in the coordination of actors’ actions. The cited authors provide guidance for the design of such policy processes.

Participatory policy analysis literature focuses on the involvement of stakeholders in the development of knowledge that is accepted and considered scientifically valid, as a basis for determining preferred policy. Stakeholders are individuals and groups that are positively or negatively affected by or interested in a proposed policy intervention (Enserink et al. 2007). They may be involved at various levels of intensity (Mostert 2006), including being consulted about scientists’ proposals, having an active voice in co-design of knowledge in workshops and having a leading role in process design. The literature concentrates on development of shared knowledge of stakeholders and scientists in activities such as joint data collection and participatory forms of modeling (Vennix 1996). Von Korff et al. (2010) provide an overview of guidance for the design of participatory policy analysis. Policy analysis literature discusses participatory forms of policy development parallel to more traditional policy development. In recent *adaptive management* and *resilience management* literature, by contrast, stakeholder participation is unanimously adopted as an integral aspect of sustainable policy development of natural resources (Anderies et al. 2006, Stringer et al. 2006, Enserink et al. 2007).

In combining scientific rationality and process dynamics in policy development, the frame is an important concept. A frame reflects the collection of facts, causal relations, interests, values, social relations and one's own position within it that an actor uses as a sense-making device to interpret reality and add meaning to a situation (Schön and Rein 1995, Koppenjan and Klijn 2004, Dewulf et al. 2009). The framing research field studies both the development of individual frames and the development of frames as an 'interactional co-construction' between actors (Dewulf et al. 2009). The first line of research focuses on frames as mental knowledge structures for an actor that facilitate organizing and interpreting incoming perceptual information by fitting it into already learned schemas or frames about reality (Minsky 1975, Beratan 2007). The second focuses on frame alignments between actors. The emphasis is on the development of a 'metaframe' that facilitates communication within a group of actors, indicating their joint understanding of a situation (Putnam and Holmer 1992, Gray 2003). The influence of the individual frames on the interactively constructed frame, and vice versa, is an emerging research topic. Recent studies concentrate on how disputants with divergent individual frames interactively co-construct sufficient overlap in their sense making to reach agreement (Dewulf et al. 2009).

1.3 CLASSIFICATION OF UNCERTAINTY

The classification of uncertainty facilitates identification and discussion of uncertainty and provides clues for favorable methods of uncertainty handling. Various authors have proposed classifications, stemming from different backgrounds and perspectives. Most classifications have their roots in traditional policy analysis. These include more technically-oriented contributions (Beck 1987, Morgan and Henrion 1990, Van der Sluijs 1997) and contributions that include socio-economical aspects of policy development (Rowe 1994, National Research Council 1996). Most take (conceptual) models as a point of departure. The classification by Kwakkel et al. (2010), an elaboration of the classification of Walker et al. (2003), is consistent with most of these cited classifications. Koppenjan and Klijn (2004) have developed a different classification based on a network theory perspective, in which the authors put the process of actor interaction central.

The classifications by Kwakkel et al. (2010) and Koppenjan and Klijn (2004) are both comprehensive, in the sense that they enable the accommodation of all types of uncertainty discussed in scientific literature. However, they have a different emphasis due to being formulated from an alternative perspective. I discuss both classifications in more depth and show how they relate to each other. The two classifications complement each other and provide a useful framework for this thesis. As with the approaches to policy development, it is not necessary to choose or try to combine them. The context of the research will shift the emphasis to categories of one or other of the classifications.

The classification by Kwakkel et al. focuses on knowledge-related uncertainty and takes the perspective of the policy analyst in model-based decision support. Uncertainty is classified in a matrix along three dimensions: location, level and nature of uncertainty. The framework is applicable to decision support in a variety of contexts dealing with, for example, ecological, social and even political aspects of a policy problem.

The *location* dimension reflects where the uncertainty manifests itself (also named source of uncertainty by other authors). Kwakkel et al. focus this dimension explicitly on computerized models. The authors of the original article (Walker et al. 2003) suggest a wider applicability of the matrix for conceptual models. The general setup of the classification allows for this and Van der Keur et al. (2008) elaborated it for the context of integrated water resources management. I think the application to conceptual models in policy development is valuable, while it enables identification of uncertainties in framing and causal mapping activities independent of a technical model exercise. I have therefore slightly reformulated the explanations for the location classes compared to Kwakkel et al.. Two classes specifically focusing on computer models are not applicable in case of conceptual models.

Kwakkel et al. identify the following locations of uncertainty:

- **System boundary** refers to the demarcation of aspects of the real world that are included in the analysis from those that are not included. The system boundary is determined by the chosen framing of the problem. This location is termed context uncertainty by Walker et al. (2003).
- The **conceptual model** relates to specification of the relevant variables and relationships within the chosen boundaries.
- The **computer model** concerns the implementation of the conceptual model in computer code. This involves the choice of a model structure and model parameters to represent the variables and relationships. The model parameters may either be fixed parameters in the model, or input parameters to the model that can be changed to reflect different external developments and/ or different policies.
- **Model implementation** refers to bugs and errors arising from implementation of the model in computer code and hardware errors.
- **Input data** pertains to uncertainty in the (empirical) data underlying the model parameters and in the processing steps applied to make these data usable.
- **Processed output data** concerns the accumulation of uncertainty in the output of the analysis, including uncertainty in the post-processing of output before it is shown to users.

The *level* dimension of uncertainty gradually ranges from (the unachievable ideal of) complete deterministic understanding of the system up to total indeterminacy or total ignorance (we do not know what we do not know). Levels between these extremes:

- **Level 1** (shallow uncertainty). Being able to enumerate multiple alternatives and to provide probabilities.

- **Level 2** (medium uncertainty). The ability to enumerate multiple alternatives and provide a rank order in terms of perceived likelihood.
- **Level 3** (deep uncertainty). The capacity to enumerate multiple alternatives without being able to rank order them in terms of how likely or plausible they are judged to be.
- **Level 4** (recognized ignorance). Being unable to enumerate multiple alternatives while admitting the possibility of being surprised.

The *nature* dimension of uncertainty provides clues when choosing a strategy for handling uncertainty.

- **Epistemic uncertainty** relates to imperfection of our knowledge and may be reduced by more research.
- **Variability uncertainty** concerns the inherent variability and unpredictability of a system. Walker et al. (2003) mention the randomness of nature, human behavior and technological surprise as examples. This uncertainty may be expressed, for example in scenarios or frequency distributions, but cannot be reduced by principle.
- **Ambiguity** refers to the simultaneous presence of multiple frames of reference about a system among different actors. This uncertainty may be handled based on actor interaction to integrate different frames, negotiate a mutually acceptable frame or find a workable relation between the different views of actors.

The framework by Koppenjan and Klijn (2004) focuses on the interaction between social process- and knowledge-related uncertainty. Kwakkel et al. acknowledge the existence of different frames, but, reasoning from a system-based perspective, they do not pay explicit attention to the social process underlying framing. Process uncertainty is often strongly perceived in policy development and directly influences the knowledge and uncertainties considered in the analysis. The process, in turn, experiences increased uncertainty in case of high substantive uncertainty. Although various authors describe process uncertainty, the term is often not mentioned.

Koppenjan and Klijn describe two classes of process uncertainty and one of knowledge uncertainty that are mutually interdependent.

- **Substantive uncertainty** concerns the absence of relevant knowledge, as well as the diverse interpretations of knowledge stemming from different frames of reference. The classification by Kwakkel et al. basically further elaborates this class.
- **Strategic uncertainty** refers to the (partly) unpredictable actions of actors in articulating complex problems. Actors behave according to their unique perception of the situation (opportunities and threats), which results in a large variety of individual strategies. In formulating their strategies, actors respond to and anticipate each other’s moves. The ‘interaction’ of these strategies influences the policy development process and may introduce unexpected strategic turns.
- **Institutional uncertainty** relates to complexity resulting from the interaction of actors from different organizations and parallel developments in different policy arenas. Interactions between actors are guided by the tasks, opinions, rules and language of their own organization, their own administrative level and their own network. These institutional

frameworks develop gradually and direct influence is rarely possible. The diverse backgrounds result in ambiguity over tuning responsibilities. In combination with the parallel involvement of actors in multiple policy arenas, this leads to a complex course of events.

1.4 METHODS FOR HANDLING UNCERTAINTY IN POLICY DEVELOPMENT

The handling of uncertainty is the topic of several textbooks and guidelines. In this section I provide a short synthesis of uncertainty handling guidance and methods, while for more information I refer to the cited authors. The explicit handling of uncertainty is often aimed at finding robust policy, meaning that the effects of policy are relatively unaffected by uncertainty (Walker 1988). Rotmans and De Vries (1997) and Hoekstra (1998) use the term dystopia when a policy, optimized for a particular set of assumptions, leads to seriously adverse consequences in case of uncertain developments. Uncertainty handling may involve testing the effect of policy (ex ante) using alternative data, methods, assumptions and worldviews (IPCC 2001, Van Asselt and Rotmans 2002). Actor behavior seriously influences policy effectiveness, as actors may block policy or reduce its effects by changes in behavior (either consciously or unconsciously) (Nowotny et al. 2001).

1.4.1 Methods of scientific analysis

Van der Sluijs et al. (2003), Refsgaard et al. (2007) and Funtowicz and Ravetz (1990) provide comprehensive guidance for the scientific analysis of uncertainty. For modeling studies quality assurance documents also play a key role in guiding uncertainty handling (Refsgaard et al. 2005). The focus of the guidance is on substantive uncertainty. The general steps followed in uncertainty analysis are identification, reduction, assessment and communication of uncertainty.

Uncertainty identification results from reflecting on system understanding in a discussion between scientists and (possibly) other stakeholders. Several tools can be used to structure the identification of uncertainty and judge the importance of identified uncertainty.

- The uncertainty classification presented in the previous section.
- Sensitivity analysis (Saltelli et al. 2000). This method is relevant when a technical model is used. It identifies the parameters for which a small variation in input results in large variations in output and therefore gives an impression of the parameters it is important to include in further uncertainty handling.
- Stakeholder analysis (Bryson and Crosby 1992, Koppenjan and Klijn 2004). This method provides an inventory of stakeholders, (differences in) their problem frames and interdependencies of actors in policy development.

Uncertainty reduction may be possible for part of the epistemic uncertainty and for ambiguity (see nature of uncertainty). Epistemic uncertainty is reduced by knowledge acquisition (research or data collection). However, the improved insight may reveal further uncertainty of which the actors were unaware (Van Asselt and Rotmans 2002). Ambiguity is mostly reduced by methods of process management (see next section). Only the appearance of uncertainty may be reduced and in that case ignorance increases. This happens when knowledge is presented with more certainty than warranted or the scope of the problem frame is reduced to exclude difficult issues.

The aim of *uncertainty assessment* is to establish the (best) available knowledge for the analysis. This is either a range of alternative models or parameters, or the assumption of a single best estimate. Methods to facilitate discussion on alternatives and limitations of analysis include:

- Data analysis.
- Expert elicitation (Cooke 1991, Van der Sluijs et al. 2003). Experts may be either scientists or non-scientists.
- Discussion between scientists and other stakeholders.

Methods to structure assessment of the specific locations of uncertainty include:

- System boundary and conceptual model. Methods to structure discussion of alternative frames include mental model mapping (Kolkman et al. 2005), qualitative description of frames, surveying actors' positions (Koppenjan and Klijn 2004 pp 139), or designing a set of possible actor frames based on theoretical perspectives found in cultural theory (Rotmans and De Vries 1997, Hoekstra 1998, Van Asselt 2000). In addition, scenario analysis, the systematic reflection on future change, facilitates determining relevant processes to include in a conceptual model (Van der Heijden 1996).
- Computer model. Methods to assess alternative conceptual models or alternative model structures within one conceptual model are discussed by Refsgaard et al. (2006), Bankes et al. (1993) and Beven and Binley (1992). One method for assessing alternative input parameters is scenario analysis (Van der Heijden 1996) for level 2 and 3 uncertainty, often used for driving forces such as climate change or population growth. For level 1 and 2 uncertainty assessment defining probabilistic or Bayesian uncertainty distributions can be employed (Morgan and Henrion 1990).
- Model implementation. Quality assurance is a method to minimize the bugs and errors in computer codes.
- Input data. Methods include quality assurance and discussion between scientists and other stakeholders. Further uncertainty assessment takes place in data application.
- Processed output data. The propagation of uncertainty through the model by methods such as Monte Carlo analysis (Morgan and Henrion 1990) reveals uncertainty bandwidths. A general method to assess the uncertainty in scientific knowledge is provided by the notational system NUSAP, developed by Funtowicz and Ravetz (1990) to reflect on the quality of knowledge. This system includes a pedigree matrix to elicit expert judgment about the production process of information, by which means actors code their confidence in the strength of knowledge.

The aim of *uncertainty communication* is to safeguard a proper interpretation of uncertain knowledge. Methods include graphics, terminology applied in documents (Morgan and Henrion 1990, Wardekker et al. 2008) and involvement of stakeholders in policy analysis.

1.4.2 Methods of process management

Koppenjan and Klijn (2004) provide comprehensive guidance plus an overview of methods for uncertainty handling in process management. The focus of the guidance is on handling substantive uncertainty due to differences in actors' framing and reducing strategic and institutional uncertainty to stimulate cooperative actor behavior. The most influential uncertainties lead to impasse in the process.

Methods to facilitate identification of a deadlock include stakeholder analysis, game analysis and network analysis. These methods give information about the relevant stakeholders, their frames, interdependencies, strategies and interaction patterns within the institutional context. This provides an impression of uncertainties and their potential influence, but the actual manifestation of an impasse depends on the process dynamics that unfold.

Uncertainty is reduced on the basis of reframing, either due to cross-frame learning (Sabatier 1988) or to reformulation of the problem. Reframing reduces ambiguity between frames, as well as strategic and institutional uncertainty. However, differences in actors' frames will continue to exist. Handling the remaining uncertainty is based on finding common ground in mutually acceptable solutions or finding workable relations between different actor frames. In this case ambiguity is a favorable characteristic, as ambiguous concepts can serve as 'boundary objects' (Star and Griesemer 1989) in negotiations.

To handle uncertainty, process management concentrates on creating conditions favorable to actor learning and agreement on procedures. Methods focus on the cognitive and social dimension of policy development (Klijn et al. 1997). For the cognitive dimension these include: stimulating a variety of ideas (avoiding early selection), harmonizing actors' terminology, joint commissioning of research and finding jointly negotiated knowledge. These methods increase both transparency of the policy development and trust between actors.

Methods for the social dimension focus on the agreement on rules and procedures (De Bruijn et al. 2002), to structure actor interaction and selection of alternatives. These rules and procedures reduce strategic and institutional uncertainty, thus stimulating cooperative behavior and the commitment of actors. An additional method is to introduce new actors to create social variety and new roles, which may provide a stimulus to the process.

1.5 RATIONALES OF UNCERTAINTY HANDLING

Policy strategies influence the response of a system to uncertainty (either consciously or unconsciously). I distinguish two main rationales to guide policy development under uncertainty: system control and system resilience (following Holling and Meffe 1996 and Walker et al. 2002).

The system control rationale aims at a stable and predictable system by exerting control over uncertain variables. In this rationale the reduction of uncertainty serves to improve system functioning. The approach has been influential in traditional policy analysis (Dunn 2008) and systems engineering (Blanchard 2006). A typical system control strategy in flood management is embankment, which reduces the uncertainty over flooding in the embanked area and therefore enables a more efficient use of land. The system control rationale prepares for recognized uncertainty and increases benefits under stable conditions (Walker et al. 2002). At the same time, the approach tends to reduce the system’s potential to respond to unexpected events, while these occur more often due to alteration of the system dynamics (Beck 1999, Davidson-Hunt and Berkes 2003).

The system resilience rationale aims to mitigate the consequences of uncertainty to prevent system collapse into an undesired regime (also called basin of attraction (Holling 1973)). The rationale focuses on backup mechanisms and quick adaptation, expecting change and surprise (Walker 2006). It starts from a notion that knowledge is inevitably incomplete, with surprises more the rule than the exception, and attempts to control the system are bound to have unintended consequences. System resilience reflects the magnitude of disturbance that can be absorbed or buffered before the system undergoes fundamental change in its characteristics (Carpenter et al. 2001, Berkes et al. 2003). A resilient flood policy would include multiple complementary strategies such as evacuation plans, low-damage spatial planning and (limited) embankment. System resilience provides a safety net to avoid system collapse into a qualitatively different state, but decreases the efficiency of the performance of core activities and reaction to expected disturbances.

1.6 BASIC STRUCTURE OF THE CONCEPTUAL FRAMEWORK FOR UNCERTAINTY HANDLING

The previous sections characterize uncertainty handling based on two variables. The first variable is the method used. The methods range from those of scientific analysis to those of process management. The second variable is the rationale of uncertainty handling, ranging from system control to system resilience with intermediate rationales. These variables, represented by two axes, form the basic structure of a conceptual framework for uncertainty handling.

Figure 1.2 shows the basic structure of this framework, consisting of the methods and rationale axes. The figure also shows the position on these axes of the fields of literature discussed in this chapter. Policy development in the field of water management has traditionally been based on scientific analysis and system control (Aerts et al. 2008), something which is paralleled in other fields. Recently, there has been increased attention for participatory policy analysis and process and network management. This is stimulated by legislation such as the Water Framework Directive (EU 2000) and international agreements such as the Rio Declaration (United Nations 1992). Increasing attention is also being paid to system resilience and adaptive management, as a result of dissatisfaction over unforeseen consequences of control (Holling and Meffe 1996). To date, the uncertainty literature is lagging behind in these developments (Brugnach 2008). The proposed conceptual framework in this thesis adopts a comprehensive and interdisciplinary view of uncertainty handling in policy development by connecting the approaches of the different fields.

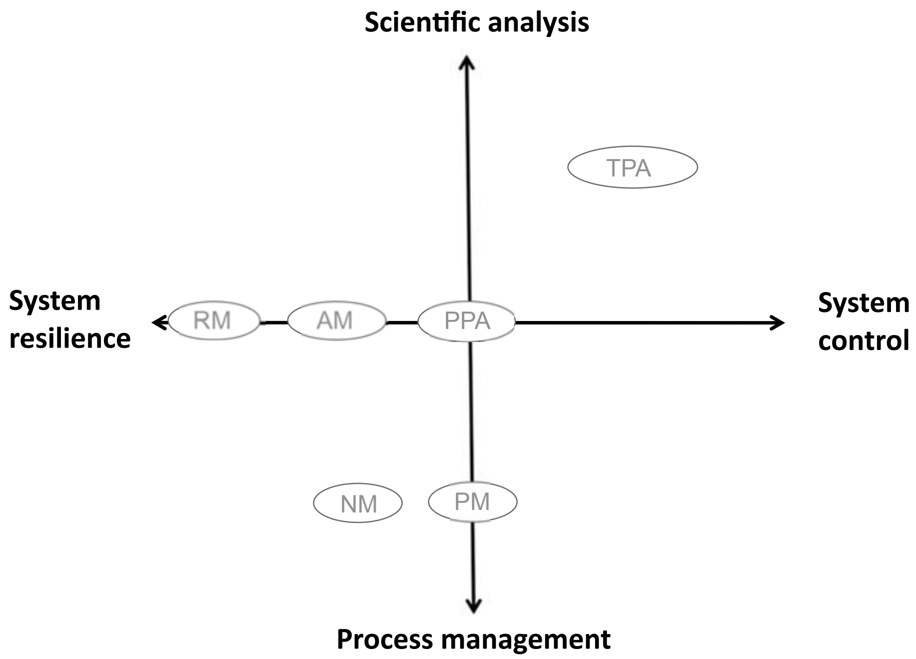

Figure 1.2 The basic structure of the conceptual framework for uncertainty handling in policy development. The vertical axis reflects methods of uncertainty handling and the horizontal axis reflects rationales. The positions of fields of literature are plotted within the framework: TPA= traditional policy analysis, RM = resilience management, AM = adaptive management, PPA= participatory policy analysis, NM= network management, PM = process management.

1.7 AIM AND OUTLINE OF THE THESIS

In this thesis I aim to elaborate the conceptual framework for policy development under uncertainty introduced in the previous section. The handling of uncertainty is often perceived as difficult and costly (Pappenberger and Beven 2005). The thesis focuses on opportunities for complementary use of the approaches in the different fields discussed. The chapters study one-sided strategies and combined approaches to visualize merits and trade-offs, thus making choices explicit. I do not aim for a coherent theory for management under uncertainty with appropriate prescriptions for all circumstances, because I think such a theory is in principle impossible (in accordance with Walters 1986).

Figure 1.3 shows the contribution of each of the chapters in this thesis. Chapter 2 focuses on uncertainty analysis based on methods of scientific analysis and mainly discusses limitations of this type of uncertainty analysis. Chapters 3 and 4 study the combined use of methods of scientific analysis and process management in policy development. Chapter 3 describes the interaction of these methods of uncertainty handling in a case of participatory policy development. To provide extra insight, the chapter compares uncertainty handling in participatory policy development to uncertainty handling in an expert-based approach. Chapter 4 discusses 'rules of the game' for actor interaction in participatory policy development that embed favorable handling of both process and substantive uncertainty. Chapter 5 focuses on the rationales of uncertainty handling. The chapter contrasts the system attributes preferred in a system resilience and a system control rationale. In doing so, it enhances the insight into merits and trade-offs of the rationales and the policy strategies typically related to them. The insight obtained in the chapters is used in the Discussion and Conclusion to further elaborate the framework. Finally, I reflect on the contribution of the framework to literature and practice.

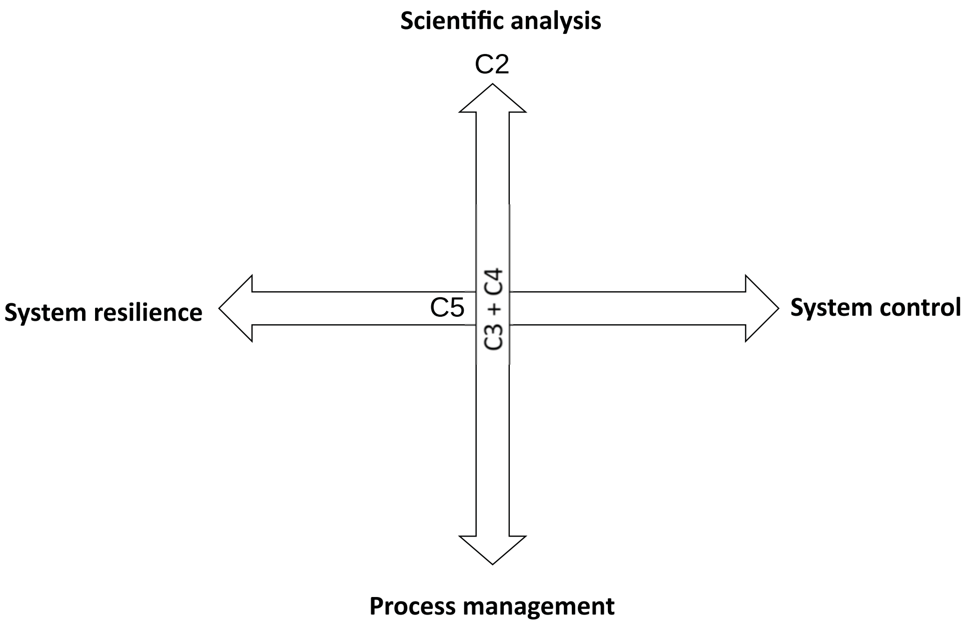

Figure 1.3 The contribution of each of the chapters in elaborating the framework.

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2 Uncertainty analysis on large scales: limitations and subjectivity of current practices - a water quality case study[1]

Abstract
Uncertainty analysis for large-scale model studies is a challenging activity that requires a different approach to uncertainty analysis on a smaller scale. However, in river basin studies the practice of uncertainty analysis on a large scale is mostly derived from practice on a small scale. The limitations and inherent subjectivity of some current practices and assumptions are identified, based on the results of a quantitative uncertainty analysis exploring the effects of input data and parameter uncertainty on surface water nutrient concentration. We show that: (i) although the results from small-scale sensitivity analysis are often applied on larger scales, this is not always valid; (ii) the current restriction of the uncertainty assessment to uncertainty types with a strong evidence base gives structurally conservative estimates; (iii) uncertainty due to bias is usually not assessed, but it may easily outweigh the effects of variability; (iv) the uncertainty bandwidth may increase for higher aggregation levels, although the opposite is the standard assumption.

2.1 INTRODUCTION

Information about uncertainty is generally held to improve the quality of decision making; it adds a useful dimension by revealing the reliability of the knowledge produced. Different methods for classification of uncertainty have been presented (see e.g. Morgan and Henrion, 1990, Van Asselt et al., 2001, Walker et al., 2003), but there is no generally agreed classification. The comprehensive classification of Walker et al. (2003), originating from model-based decision support, distinguishes four sources of uncertainty leading to model outcome uncertainty: input data, parameters, model and context. This article is restricted to considering uncertainty in input data and in parameters. Although the benefit of uncertainty analysis is widely recognized in the scientific community, in practice it is not common. One of the reasons is that uncertainty analysis is still seen as difficult to perform, partly because of a lack of clear guidance (Pappenberger and Beven 2006). Over recent decades, guidelines, methods and overviews of methods for dealing with uncertainties have been published, in particular for input data and parameter uncertainties (e.g. Yoe and Skaggs 1997, Van der Sluijs et al. 2003, Floodrisknet 2007). However, translating these methods into practical application is still a challenge in environmental science and other fields. Difficulties arise when analysis is done on a larger (e.g. catchment) scale, as often the uncertainty data are only available and model development and testing only take place on a small scale (Heuvelink and Pebesma 1999). For large-scale analysis, information on uncertainty needs to be scaled-up. Moreover, other sources and types of uncertainty may become important (Beven 1995). This involves choices about which methods to apply and which uncertainties to include

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in the analysis. In current uncertainty analysis on large scales, the following approaches are common practice: (i) the important uncertainty sources for larger scale analysis are often selected based on sensitivity analysis and expert judgment on small scales; (ii) uncertainty analysis focuses on the uncertainty sources for which clear evidence exists, following a mainly data-driven approach; (iii) uncertainty assessment is focused on uncertainty which is due to variability - often neglecting uncertainty due to bias; (iv) uncertainty bandwidths are, as a rule, assumed to reduce with an increasing aggregation level of the output variable. These common practices are mostly derived from existing practices on small scales. In this article, their validity is tested on a larger scale, using an uncertainty analysis modeling case study.

2.2 METHODS

To test the validity of the four common practices introduced in the previous section, four experiments were performed for an uncertainty analysis case study.

- The selection of uncertainty sources was based on sensitivity analysis and expert judgment on a small scale and was then used in the case study on a catchment scale. One uncertainty source is selected to test the validity of this approach.
- For one uncertainty source, uncertainty types were included for which no clear evidence of their existence or magnitude is available; expert judgment was used for their assessment. This approach is compared to an assessment restricted to evidence-based uncertainty types.
- For one uncertainty source, uncertainty due to bias was included. The effect of uncertainty due to bias is compared to the uncertainty due to variability.
- In the analysis of the results, different spatial and temporal aggregation levels of the output were collected to see the influence on the uncertainty bandwidth.

2.3 APPLICATION: A CASE STUDY

The influence of input data and parameter uncertainty related to diffuse emissions on the summer averaged phosphorus and nitrogen concentrations at the outlet of the Regge River catchment was analyzed for 1999. The analysis is methodological and was not carried out with the intention of providing direct decision support; only a selection of uncertainties was assessed. The Regge is a small river running through the east of the Netherlands and a small area in Germany; it is a subcatchment of the Vecht River catchment. In the summer months, the mean discharge at the outlet to the River Vecht is $7m^3/s$. The catchment area is about $1000km^2$. The soil type is mainly sandy and the main land use is a mixture of livestock and arable farming, with crops feeding the livestock and the livestock providing manure for the arable operations. Maximum mandatory nutrient levels are exceeded by a factor of two to three.

The model simulations were conducted using NL-CAT (Schoumans et al. 2005). The model consists of four sub-modules: (i) a soil and groundwater flow module (SWAP), simulating water discharge to groundwater and surface water; (ii) a soil nutrient cycle and leaching module (ANIMO), describing the organic matter, nitrogen and phosphorus cycle; it focuses on the following processes: nutrient addition, mineralization, volatilization, aeration and (de)nitrification, sorption and phosphate fixation, crop uptake, leaching and overland flow; (iii) a surface water flow module (SWQN) in which the main watercourses are schematized and (iv) a surface water quality module (Nuswalite), indirectly calculating nutrient retention based on dissolved organic and mineral fractions of nitrogen, phosphorus and biomass. The model is based mainly on detailed process descriptions and is pseudo-dynamic in time. The smallest model unit of the soil modules is the plot, defined as a unique combination of land cover, land management, soil, hydrological boundaries and meteorology. The smallest model unit for the surface water modules is the subcatchment. More details about the model can be found in Schoumans et al. (2005), together with a description of the setup and calibration of the model for application in the Vecht catchment. To apply it to the present study, small changes have been made to this model setup, which has minor implications for the quality of the calibration (see Bijlsma et al. 2006). To simulate the nutrient build-up for 1999, the soil modules were run for the period 1941-1999 and the surface water modules for the period 1990-1999. Uncertainty in the model was introduced from the beginning of this initialization period, setting a different equilibrium for each run. For details of the methods and results of the case study, see Bijlsma et al. (2006).

Selection of uncertainty sources for analysis. The uncertainty analysis focused on a few important uncertainty sources in ANIMO. Nevertheless, the model contains other important uncertainty sources. The selection was based on a sensitivity analysis (Groenenberg et al. 1999), analysis of critical parameters and constants (Walvoort et al. in preparation) and expert judgment. The following uncertainty sources were selected:

- fertilizer application load (fertilizer); selected to assess a wide range of uncertainty types and to assess bias;
- phosphorus background concentration of the groundwater (PBC); testing the validity of the selection of uncertainty sources on a small scale for catchment scale use;
- gas diffusion parameters in soil related to aeration and denitrification (denitrification);
- iron and aluminum content of the upper soil (Fe/Al).

Quantitative assessment of selected uncertainties. The selected uncertainties were assessed following a common data-driven approach. For the fertilizer application load, this evidence-based approach was extended by assessing a wider range of uncertainty types for which both the existence and the magnitude are uncertain. The assessment of fertilizer application load is described in detail below; for the other selected uncertainties, a summary of the method is given.

The quantitative assessment of fertilizer application covers both manure and artificial fertilizer application and is restricted to the dominant land use of grass and maize cultivation and the dominant soil type of sand. In the assessment, the following assumptions were made to deal with a lack of data: (i) a fixed relationship between the application of nitrogen and phosphorus: fixed ratios are assumed both for the content of manure and between the application of artificial nitrogen and phosphorus fertilizer; (ii) the relative uncertainty is assumed to be constant over time; the relative uncertainty bandwidth is determined for one year and is then applied to all other simulation years; furthermore, the estimate of the uncertainty for that single year is based on field observations over several years.

Based on data, uncertainty distributions were found showing variability in the field application rate (Table 2.1). The distributions on the field scale level were scaled up to the plot level through the following formula (Refsgaard et al. 2006):

$$\sigma_{plot} = \sigma_{field} / \sqrt{N} \qquad (1)$$

where σ is the standard deviation and N the number of independent fields in a plot (the number of fields divided by the autocorrelation length of a field). Based on land use maps, the average size of a field is estimated to be 2 ha. The autocorrelation length of a field is assumed to be 1.5 fields for maize and 3 fields for grass; neighboring fields are assumed to be fed with manure in the same way. The original standard deviation on the field scale is very high, but this variability is expected to average out to a large extent on the catchment scale. More data revealing the presence of uncertainty in fertilizer application loads are not available. However, other sources of uncertainty are expected to exist.

Expert judgment was brought to bear in a search for more uncertainty sources. A bias due to data processing that affects all fertilizer data was identified. Reported measurement data were processed, based on assumptions about the nutrient contents of manure, animal excretion rates and volatilization rates. To assemble the model input, additional assumptions were made about, for example, manure transport, fertilization trends over time and agricultural management. Since no data are available for these aspects, expert judgment was used to quantify this uncertainty type. A uniform distribution was defined (see Table 2.1), which has the original model's deterministic application load as its mean. In assessing the minimum of the distribution to be 75% and the maximum 125% of the mean, the less biased field application loads served as a reference for the order of magnitude.

To implement the uncertainty analysis a two-step approach was followed. The bias is for the total amount of fertilizer in the area and thus influences the mean of the uncertainty distribution. A first draw from the uniform distribution represents the total fertilizer application in the catchment. Next, the application load for each plot was sampled from a distribution with this obtained mean and the standard deviation on plot level as calculated by Equation 1.

Table 2.1 Overview of the uncertainty types and associated distributions assessed for fertilizer application (appl.) load on field scale. STD stands for standard deviation.

Uncertainty type	Distribution type	Mean(kg/ha) year 2000	STD (%)	Source and type of data
Bias for nitrogen (N) and phosphorus (P) appl.	Uniform	410 (N) 165 (P)	14	Expert judgment
Effective nitrogen appl.[1] for grass on sand	Normal	287	33	Oenema et al. (2002): nitrogen surpluses of 198 fields, 1999.
Organic manure nitrogen appl. for maize on sand	Normal	253	44	Fraters et al. (1997): non-grassland fields at 60 farms, 1991-1995.
Artificial fertilizer nitrogen appl. for maize on sand	Normal	34	91	Reijneveld et al. (2000): mean and std. of silage maize, 1997. Milk production farms 10000-12000 kg/ha.

[1] The reported surpluses for organic manure ($N_{org.man}$), artificial fertilizer (N_{fert}) and grazing cattle manure ($N_{gr.catt}$) have been converted to effective nitrogen surpluses (N_{eff}), by: $N_{eff} = N_{fert} + 0.5N_{org.man} + 0.1N_{gr.catt}$

The results of the uncertainty assessment of the other uncertainty sources are summarized in Table 2.2. For the assessments, the following assumptions were made (for justification, see Bijlsma et al. 2006): (i) no spatial variation over the catchment (except for the iron and aluminum content of the upper soil); (ii) no temporal variation; (iii) the experimental data used are representative and contain no bias.

The gas diffusion parameters in soil relating to aeration and denitrification are the variables p_1 and p_2 (-) in the oxygen diffusion relationship (Bakker et al. 1987):

$$\frac{D}{D_o} = p_1 \ \varepsilon^{p_2} \tag{2}$$

where D is the oxygen diffusion coefficient in soil relative to the oxygen coefficient D_0 in air ($L^2\ T^{-1}$) and ε is the soil air content (-). The uncertainty in the parameter values were assessed for podzolic, medium-textured sandy soils for the subsoil zone. Experimental data for the diffusion relationship were used to assess the parameters p_1 and p_2 simultaneously in a multi-variate analysis. Bootstrapping (Efron and Tibshirani 1993) was performed to estimate the joint uncertainty distribution of the parameters. For each bootstrap sample, the parameters p_1 and p_2 were estimated by means of non-linear least squares regression.
An uncertainty distribution for the phosphorus background concentration of the groundwater was assessed by aggregating point measurement concentration data. This resulted in a normal distribution representing the catchment's mean phosphorus background concentration.

The uncertainty in the iron and aluminum content of the upper soil (1-120 cm) was assessed through a geostatistical analysis on the plot scale using conditional sequential Gaussian (block) simulation (Goovaerts 1997). The mean and standard deviation of iron and aluminum concentrations were determined for each soil type and then the variogram was determined. The analysis was conducted for the horizontal spatial variations of iron and aluminum. Vertical segmentation was reflected in the original deterministic ratios.

Table 2.2 The median and 90% confidence interval (CI) for the input of each uncertainty source, represented by the median, 0.05- and 0.95-quantile for the total catchment average input. The last column gives the 90% CI as a percentage of the median value.

Uncertainty source	Median	0.05-Quantile	0.95-Quantile	% of median
Fertilizer application load	527 kg N/ha (effective N)	442 kg N/ha (effective N)	643 kg N/ha (effective N)	38%
Phosphorus background concentration in groundwater	0.00016 kg/ m^3	0.00015 kg/ m^3	0.00018 kg/ m^3	19%
Gas diffusion parameters in soil	P1: 0.65 P2: 2.46	P1: 0.34 P2: 1.95	P1: 1.59 P2: 2.94	P1: 92% P2: 40%
Iron and aluminum content of the upper soil	56.7 mmol/kg	54.4 mmol/kg	62.4 mmol/kg	14%

Assessment of the effects of the selected uncertainty sources on the results. The uncertainty distributions were propagated through the NL-CAT model by means of standard Monte Carlo analysis. The distributions were sampled independently to create 50 realizations; for this number of realizations the mean and standard deviation were sufficiently consistent.

2.4 RESULTS AND DISCUSSION

The results of the case study analysis are used in this section to show that the commonly used practices for uncertainty analysis on large scales are not always valid. In Figure 2.1, the uncertainty bandwidth for the summer averaged nitrogen and phosphorus concentration for 1999 at the Regge River outlet is shown, together with the contribution of the individual uncertainty sources for nitrogen and phosphorus to this uncertainty bandwidth.

Non applicability of small-scale sensitivity analysis to larger analysis scales. The ‘phosphorus background concentration of the groundwater’ (PBC) uncertainty source makes a very small contribution to the total uncertainty bandwidth (Figure 2.1); the 90% confidence interval (90% CI) is just 2.5% of the median value. A larger contribution was expected on the basis of the sensitivity analysis and expert judgment at the plot level. The 90% CI of the plot output loads, averaged over all plots, is 10% of the median value. At the catchment level, this effect disappears. Averaging out effects are not expected, since the input concentration is constant for the complete catchment. Saltelli et al. (2000) mention the influence of the model setting on the sources that drive output variations. Conversely, Yoe and Skaggs (1997) note that once the important sources of uncertainty have been identified, this knowledge is relevant for any future study using that model. Either way, in practical applications a sensitivity analysis is usually not performed for every model application on every scale. However, processes in the larger scale model can cause a change in the effects of uncertainty sources compared to their effect in the small-scale model.

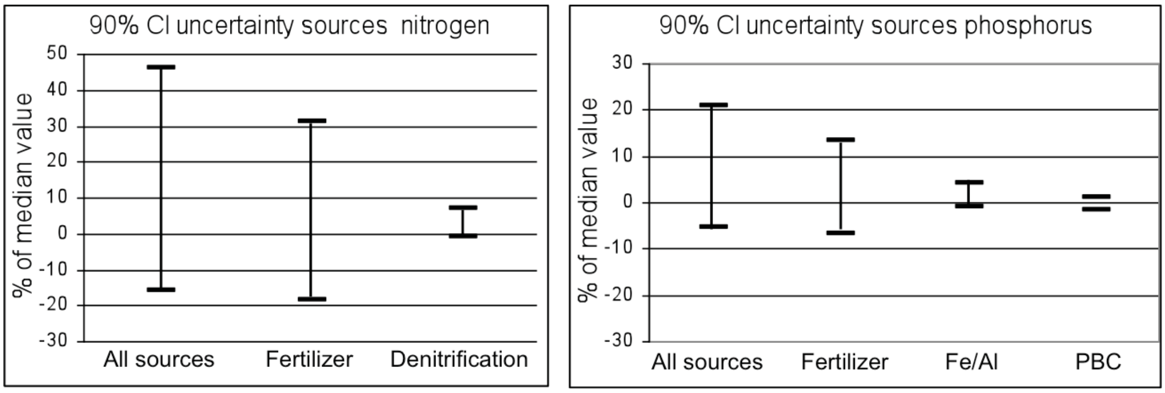

Figure 2.1 The 90% CI of the uncertainty bandwidth for 1999 at the Regge River outlet for nitrogen (left) and phosphorus (right) as a percentage of the median value, shown together with the contribution of the individual uncertainty sources to the uncertainty bandwidth characterized by the output of the simulation runs with 0.05- and 0.95-quantile input.

Restricting the assessment to uncertainty types with a strong evidence base gives conservative estimates. The contribution of the variability in fertilizer application load, as assessed using a data-driven approach, is very small compared to the contribution of the bias (25%) in the application load (Figure 2.2). The existence and magnitude of this bias were assessed based on expert judgment. The consulted experts agreed that the uncertainty due to variability alone is much too insignificant to represent the uncertainty in fertilizer application load. Several authors suggest that uncertainty analysis could - and should - be extended to those aspects of scientific enquiry that are beyond empirical testing (e.g. Brown 2004, Saltelli et al. 2004). The difficulty is that this introduces a large amount of uncertainty about the extent of uncertainty. Assessment of these types of uncertainty by expert judgment is inevitably subjective (Cooke 1991). However, not assessing such uncertainty types is a subjective choice as well, which has a very large impact on the results of the uncertainty analysis, as shown by Figure 2.2, namely a large structural underestimation of the uncertainty bandwidth.

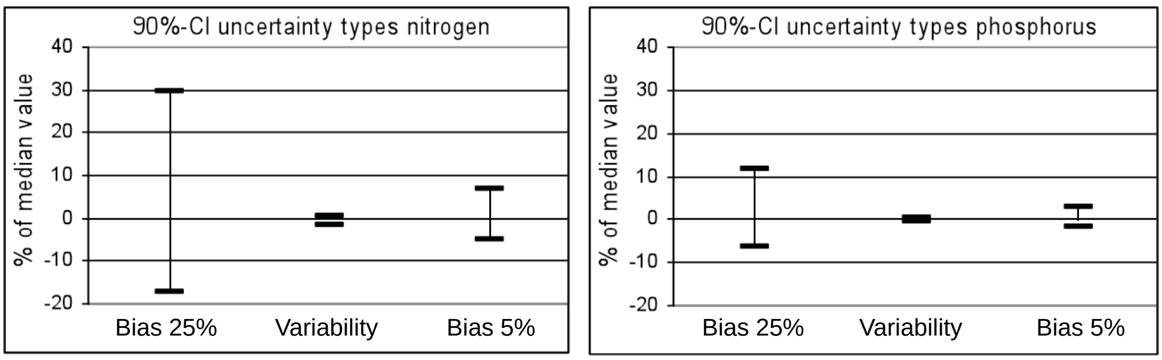

Figure 2.2 Comparison of the 90%-CI of the variability and the bias as quantitatively assessed for fertilizer application load. The contribution of a bias in the data of 5% is also shown.

Small degrees of bias may easily outweigh variability. Figure 2.2 also shows the contribution of a bias of only 5% in fertilization application load data, in comparison to the variability. The conventional data-driven approach usually focuses on uncertainty due to variability and often fails to explore structural uncertainties such as bias (Brown 2004). The figure shows that, on large scales, the impacts of a small degree of bias may greatly outweigh the effect of variability. A similar notion can be found in, for example, Oreskes and Belitz (2001) and Brown (2004).

Uncertainty bandwidth may increase for higher aggregation levels. The choice of an output variable with a different spatial or temporal aggregation greatly influences the median and uncertainty bandwidth of the results of a study (see Figure 2.3). When a higher aggregation level of the output variable is chosen, it is generally assumed that the uncertainty bandwidth decreases due to effects of averaging out (e.g. Heuvelink and Pebesma 1999). However, Figure 2.3 shows that it can also increase when, for this higher level, the spatial or temporal variability patterns in the variable concerned become larger.

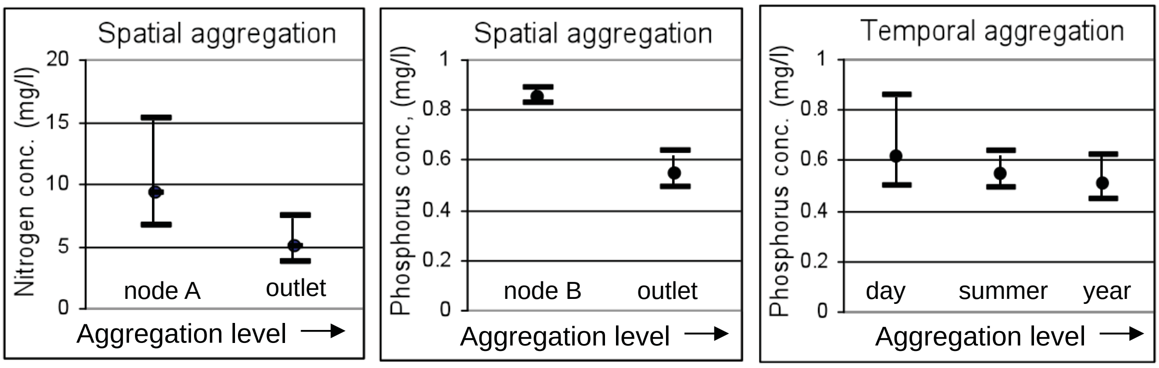

Figure 2.3 The effects of spatial and temporal aggregation on the nitrogen and/or phosphorus concentration. The nodes are situated halfway along the catchment.

2.5 CONCLUSIONS

This article demonstrates that the following common current approaches and assumptions in uncertainty analysis are not always valid in large-scale uncertainty analysis.

- The most relevant uncertainty sources are often selected - as in our case - based on sensitivity analysis and expert judgment on a small (in our case, plot) scale. The results may differ from the effects on a large (in our case, catchment) scale.
- The assessment of an uncertainty source is usually restricted to the uncertainty types for which clear evidence exists (usually data-driven). Uncertainty types for which the nature and magnitude are largely unknown (uncertain) are left out. This leads systematically to a conservative estimate of the uncertainty bandwidth. Since these uncertainty types can be highly influential, including them gives a more realistic uncertainty estimate. The disadvantage is a less precise and probably subjective uncertainty distribution. However, the choice not to assess these uncertainty types is itself subjective and is also very influential.
- The focus of current uncertainty analysis is mostly on data variability. In large- scale analysis, small biases in the data may easily outweigh the effect of great variability; the correlation length scale of biases is mostly much greater than that of variability.
- When a higher aggregation level of the output variable is chosen, the uncertainty bandwidth can decrease due to the effects of averaging out, but it can also increase. This is in response to the spatial or temporal variability patterns in the variable concerned.

Our conclusions imply a need for change in current common practice and conceptions in large-scale uncertainty analysis. The first and fourth points do not imply major changes in current practice, but practitioners need to be made aware of the implications of their approach. The second and third points suggest a necessary change in paradigm in which uncertainty analysis becomes an actual reflection of what we are uncertain about and not just a reflection of the uncertainties we understand.

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3 An empirical analysis of stakeholders' influence on policy development: the role of uncertainty handling[2]

Abstract

Stakeholder participation is advocated widely, but there is little structured, empirical research into its influence on policy development. We aim to further the insight into the characteristics of participatory policy development by comparing it to expert-based policy development for the same case. We describe the process of problem framing and analysis, as well as the knowledge base used. We apply an uncertainty perspective to reveal differences between the approaches and speculate about possible explanations. Viewing policy development as a continuous handling of substantive uncertainty and process uncertainty, we investigate how the methods of handling uncertainty of actors influence the policy development. Our findings suggest that the wider frame that was adopted in the participatory approach was the result of a more active handling of process uncertainty. The stakeholders handled institutional uncertainty by broadening the problem frame and they handled strategic uncertainty by negotiating commitment and by including all important stakeholder criteria in the frame. In the expert-based approach, we observed a more passive handling of uncertainty, apparently to avoid complexity. The experts handled institutional uncertainty by reducing the scope and by anticipating windows of opportunity in other policy arenas. Strategic uncertainty was handled by assuming stakeholders' acceptance of non-controversial measures that balanced benefits and sacrifices. Three other observations are of interest to the scientific debate on participatory policy processes. Firstly, the participatory policy was less adaptive than the expert-based policy. The observed low tolerance for process uncertainty of participants made them opt for a rigorous 'once and for all' settling of the conflict. Secondly, in the participatory approach actors preferred procedures of traceable knowledge acquisition to handle substantive uncertainty over controversial topics. This excluded the use of expert judgment only, whereas the experts relied on their judgment in the absence of a satisfactory model. Thirdly, our study provides empirical evidence for the frequent claim that stakeholder involvement increases the quality of the knowledge base for a policy development process. As these findings were obtained in a case featuring good process management and a guiding general policy framework from higher authorities, they may not generalize beyond such conditions.

3.1 INTRODUCTION

European legislation such as the Water Framework Directive (EU 2000, Article 14) encourages the involvement of affected parties in the management of natural resources. This can be seen as a break with the approach in which stakeholder needs are taken care of by public agencies and experts (De Marchi 2003). In the latter 'expert-based approach', the competent authority frames the problem, performs the policy analysis (or outsources it to experts) and balances the stakes. An expert-based approach may include some interaction with stakeholders, but not to the extent that characterizes a 'participatory approach'. In a participatory approach stakeholders are at least consulted in a structured way, so that they can

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influence problem framing, policy analysis and/or decision-making (Arnstein 1969, Biggs 1989).

Stakeholder participation in environmental policy development is associated with benefits for the substantive quality of policy, its legitimacy, its implementation and the development of social capital for involved parties (Fiorino 1990, Laird 1993, Smith Korfmacher 2001, Beierle and Cayford 2002). In this article, we focus mainly on the influence of stakeholder involvement on the development of substance in policy development, notably the framing of the policy problem, the policy analysis and design and the creation and use of knowledge.

We view participatory policy development as a complex, path-dependent process in which actors, not knowing exactly how their interests will be affected by future developments, seek to reach an understanding about the policy situation and the possible options and their consequences, in order to coordinate their actions through agreement. When actors have potentially conflicting interests and asymmetric access to resources, this process will comprise communicative action based on reason and argument, as well as self-centered action based on strategic calculation. Baccaro (2006) convincingly argues that what happens in a successful participatory process is probably some form of 'mixed-motive' bargaining (Walton and McKersie 1965, Elster 1989, Scharpf 1997) in which actors try to increase the total benefit by creatively combining issues and options (integrative bargaining to 'enlarge the pie'), but also try to frame the situation in a way that will maximize their own advantage when it comes to bargaining about the final policy decision (distributive bargaining to 'make sure we get a big piece'). The integrative mode involves open and truthful communication, whereas the distributive mode entails intentional misinformation.

Following this line of thought, we conceptualize participatory policy development as an ongoing multi-actor search for a frame that gives all actors sufficient certainty that within this frame they will be able to promote, or at least protect, their own interests. The term frame here denotes an 'interactional co-construction' (Dewulf et al. 2009) that gives meaning to a situation. A joint frame is constructed from the individual frames of actors, which reflect their ideas about facts, interests, norms, values, rules and responsibilities and their own position within it (Schön and Rein 1994). This joint frame constructing occurs in a process of social interaction that Putnam and Holmer (1992) refer to as 'issue development'. It entails agenda setting, because the frame highlights some problems while obscuring others (Entman 1993, Fischer 2003). Actors feeling comfortable with the frame (e.g. because it reflects their interests and offers good bargaining prospects) will push towards closure, whereas actors feeling unsure (e.g. because consequences of options are uncertain or procedures are ambiguous) will endeavor to defer closure in the hope of change towards a more favorable frame. Frame development thus is a dynamic process: as the frame establishes pertinent aspects (causes, options, effects, constraints – social, technical, financial, ...), it drives the collection of new knowledge; this may raise new issues which prompt frame changes; actors who become doubtful about whether the frame is still advantageous for them will try to redress this, and so on.

On these assumptions, we describe and analyze the development of the frame in two policy development processes – a participatory approach and an expert-based approach – for the same case: the development of a local water management plan. Since the perception and resolution of uncertainties is an important dynamic driving the process (Koppenjan and Klijn 2004, Abbott 2005), we try to identify and characterize the uncertainties that were the cause of reframing and the methods that actors used to handle these uncertainties. We expect that comparing the participatory process to the process without direct stakeholder involvement will help us understand the process of framing and analysis. The ‘one case, two processes’ comparison also allows us to look in more detail at the substantive knowledge that stakeholders contributed to the policy development process and to elaborate on the claim that stakeholders participation may improve the knowledge base (Beierle and Konisky 2001).

In the Method section below, we will first present the conceptual framework that we used in our analysis and comparison of the two policy development processes and then outline the setup of our study. In the Results section we describe the essential events for both processes and identify and categorize the uncertainties that played a role and the uncertainty handling methods that were used to resolve them. In the Discussion section we compare the obtained results to those reported in other empirical case studies addressing the influence of stakeholder involvement (Stern and Fineberg 1996, Wynne 1996, Clark and Murdoch 1997, Beierle and Konisky 2001, Maxim and Van der Sluijs 2007). Although our study is mainly descriptive, we do venture some tentative explanations for the observed behaviors and outcomes. We also reflect on the advantages and limitations of our analysis, notably our focus on uncertainty and uncertainty handling methods. We conclude with a summary of our main findings.

3.2 METHOD

3.2.1 Analytic framework

We assume that joint frame construction occurs in a continuous process of scoping and sense-making, in which actors seek to incorporate relevant parts of their individual frame into the joint frame to create opportunities for themselves and/or others. In this process establishing the nature, scope and relevant aspects of the problem and collecting, analyzing and synthesizing knowledge on these aspects (ranging from physical processes to actor preferences to socio-political institutions) are so tightly connected, that we do not distinguish between framing activities or policy analysis and design activities. We do make a conceptual distinction between the process and the knowledge that is used and produced in the process. From now on, we will refer to the former as ‘framing and analysis’ and to the latter as ‘the knowledge base’. There is a constant interaction between the two, as the framing and analysis determine the relevant knowledge, while the availability of knowledge influences the actors’ strategies in framing and analysis. We assume that actors will especially attempt reframing when they believe that the present frame contains uncertainties that pose the risk of a loss (Kahneman and Tversky 2000). This leads us to focus on the perception and resolution of uncertainties during framing and analysis.

Types of uncertainty

Following Koppenjan and Klijn (2004), we distinguish between substantive, strategic and institutional uncertainty:

- *Substantive uncertainty* refers to a lack of knowledge about the substance (content, subject matter) of the policy problem, e.g. the relation between soil properties and vegetation, the volatility of market prices, or the effect of land use on groundwater. This lack may be experienced because there is indeed no information on the subject, but also because the available information is too abundant, or is ambiguous or conflicting.
- *Strategic uncertainty* refers to a lack of knowledge on how actors will anticipate and respond to each other's actions. This is inevitable as actors, because of their own frames, will perceive the risks and opportunities (their own and those of other actors) in a given situation differently and develop different strategies, while second-guessing those of other actors. The outcomes of these strategies when played out are highly unpredictable.
- *Institutional uncertainty* refers to a lack of knowledge about formal competences, procedures and conventions. It is the result of actors belonging to different organizations, administrative levels and networks, and hence being guided by different concepts, tasks and opinions and respecting different rules. This makes the organization of the policy development process very unpredictable, even more so when actors are involved in multiple policy arenas.

When analyzing a policy development process, we infer the occurrence of uncertainty from the actors' behavior. Direct indications are the explicit mentioning of uncertainty and the performance of an uncertainty analysis. Indirect indicators are disagreement, an attitude of sit and wait for the other actors to move first (paralysis in the process), the exploration of alternative modes of action, or a search for information.

Uncertainty handling methods

To handle the uncertainties actors may opt for several methods. The overview in Table 3.1 is inspired by Termeer and Koppenjan (1997), Walker and Marchau (2003), and Van Asselt (2005). As the handling methods for strategic uncertainty and institutional uncertainty are quite similar (they deal with unpredictable actor behavior), we have grouped these under the term 'process uncertainty'. Abbott (2005) uses this term when making a similar distinction. Substantive uncertainty handling methods focus on the cognitive dimension, while process uncertainty handling methods focus on the social dimension. We further distinguish between passive and active methods. Passive methods preclude the need for more active handling of uncertainty. Each method is identified with a mnemonic, which we will use to code our observations in the Results section.

Table 3.1 Methods for handling uncertainty

Passive methods	
(p-I)	*Ignorance:* the policy development process proceeds without an observable choice regarding the handling of an uncertain aspect
(p-RI)	*Recognized Ignorance:* the uncertain aspect is identified and expressed, but a decision is taken without considering other options
(p-A)	*Avoidance:* uncertainty is avoided by restricting the scope of the joint frame, e.g. by leaving out or deferring measures of which the effectiveness and/or feasibility (technical and/or political) are uncertain
Active methods	
Increase uncertainty tolerance	
Substantive uncertainty	
(ts-T)	*Transparency:* share information about the origin and quality of available knowledge and make the acquisition of new knowledge traceable, e.g. by involving actors in modeling and data collection activities
(ts-S)	*Safeguards:* work with bandwidths in calculations and communicate results using orders of magnitude, rather than precise figures
Process uncertainty	
(tp-TB)	*Trust Building:* increase trust among actors by furthering social interaction, encouraging information sharing and emphasizing interdependencies
Reduce uncertainty	
Substantive uncertainty	
(rs-KA)	*Knowledge Acquisition:* consult experts, study scientific literature, collect empirical data, perform model-based simulations, analyze and interpret findings, etc.
(rs-EBAK)	*Establishing Best Available Knowledge:* discuss rivaling knowledge and knowledge limitations (qualitative), analyze uncertainty (quantitative) and make assumptions
Process uncertainty	
rp-P	*Procedures:* develop formal rules and procedures that reduce the actors' room for unexpected strategic behavior
rp-C	*Commitment:* involve influential actors who can assume decision-making authority and emphasize the benefits of reaching an agreement

Note that we can observe the passive strategy ignorance (p-I) only through comparison of the participatory and the expert-based process. When an uncertainty is observed in one approach but not in the other, we identify this as ignorance on the part of the actors in the latter approach.

The knowledge base

Stakeholders often contribute detailed knowledge about specific aspects to the knowledge base, indicate omissions and flaws and criticize analysis methods and model predictions of the effects of policies (Stern and Fineberg 1996, Wynne 1996, Clark and Murdoch 1997, Beierle and Konisky 2001). To assess whether this also occurred in our case study, we compare the knowledge base jointly developed by experts and stakeholders with the knowledge applied by the experts only. We look for substantive (e.g. relevant hydrological models, ecological expertise, local system knowledge) as well as process content (e.g. knowledge of actor preferences, formal competences, pertinent rules and regulations). We use the expert knowledge base as the point of reference and then look for additions and corrections to and omissions from this knowledge in the participatory approach. An addition is defined as supplementary knowledge accepted by all actors, a correction as the replacement or deliberate rejection of knowledge with the support of all actors and an omission as relevant knowledge overlooked due to process dynamics. Knowledge that is applied but is unacceptable to one or more actors will be labeled as non-validated knowledge. We do not consider superfluous knowledge (Van de Riet 2003), i.e. knowledge brought in that was not relevant to policy development.

3.2.2 Case study

In 2005 the Dutch national government required the formulation of local water management plans (*Gewenst Grond- en Oppervlaktewater Regime*, or GGOR for short) for all Natura 2000 areas by the end of 2007. Our case study concerns the Natura 2000 area Bargerveen and its surrounding agricultural land, situated in the province of Drenthe in the northeast of the Netherlands. The most important objective set for this area by the Dutch ministry of Agriculture, Nature and Food is the development of high peat. High peat growth requires a rise in the water table, whereas the agriculture on the adjoining land requires lower water levels. This divergence between stakes constituted the core of a long-drawn-out local water management conflict. We focus our study on the conflict between actors at the south side of Bargerveen. An earlier negotiation process in 2001 had ended without result and the Natura 2000 objectives only reinforced the clash of interests. The water board initiated a participatory process to develop the GGOR. We will outline the setup of this process and then describe why and how we conducted a second process, this time applying an expert-based approach to the same case.

The participatory approach

This approach involved a 'sounding board group' whose members were selected in such a way that all stakes were represented. The level of control for this group can be characterized as consultation with some collaborative elements (Biggs 1989, Barreteau et al. 2010), or as placation on Arnstein's (1969) ladder of participation. The actors collaborated closely through an exchange of knowledge and advice on decisions, but the key decisions remained with the water board. The water board devolved the policy development process to a project team consisting of an external process manager, several water board employees and an external consultant for hydrological modeling. Throughout the entire process, the first three authors of this article were involved as co-designers, facilitators and evaluators.

The most important stakeholders were the nature conservationists and the farmers. Others were the residents of surrounding villages and a few entrepreneurs. The GGOR plan had to be formally approved, first by the board of directors of the water board, then by the province of Drenthe and ultimately by the ministry. The sounding board group consisted in total of 30 delegates. The group first convened in October 2006 and agreed on the objective of determining a GGOR for Bargerveen and the surrounding area. The group met twice a year in its complete configuration (four meetings in total). Between meetings the project team bilaterally interacted up to three times with both the farmers and the nature conservationists (sometimes in combination with the province). The GGOR was established in April 2008. We refer to Bots et al. (forthcoming) for more details.

The expert-based approach

We were curious to know how framing and analysis might have taken place if no stakeholders had been involved. We presumed that even a simulated expert-based approach to the Bargerveen case could provide us with data on frames, uncertainties and uncertainty handling methods that, when compared to those observed in the participatory process, would improve our understanding of this process.

The design of a realistic expert-based process needed some consideration. The involvement of the experts from the participatory approach would be problematic. Involving these same experts before or parallel to the participatory process might give stakeholders the impression that the competent authority had already determined the policy to be implemented, irrespective of the outcome of their participation. This impression needed definitely to be avoided, as it would deter stakeholders taking an active part in the process. Conversely, an ex post development would suffer from expert ‘contamination’ because of the joint frame developed in the participatory process.

These considerations led us to invite a team of three professionals from a neighboring water board: recognized experts in the area of hydrology and spatial planning, familiar with the overall process of defining a GGOR, not familiar with Bargerveen but knowledgeable about similar areas. We did not have the resources to allow this second team to perform a full-scale policy development with its own data collection and modeling activities. During the simulation, we therefore let them use the knowledge developed during the participatory process, but only upon request: the experts had to precisely formulate their specific knowledge need and were given only what they asked for (insofar available). In this way, we not only traced the use of knowledge, but also avoided contaminating the experts with a problem frame from the participatory process. We observed stakeholders’ additions to and correction of the knowledge base directly in the participatory process, analyzing the changes stakeholders proposed to knowledge brought in by the project team in this approach. We observed omissions of knowledge in the participatory approach by comparing knowledge use in both approaches

The simulation was organized shortly before the stakeholder participation process came to a decision and was led by the first two authors and the process manager of the stakeholder process. The expert team received a very brief introduction to the problem. We took special care not to give more information than had been available at the start of the stakeholder process.

3.2.3 Data collection

We analyzed the participatory approach using minutes of the meetings and records of project team discussions aimed at interpreting the process dynamics. The first author performed the analysis and the second author and the process manager verified the findings. Additional insight was obtained through direct observation of all meetings and through questionnaires and interviews that the first author conducted after both the first and third sounding board group meeting (see Appendix 3.1). The questionnaires asked for the participants' view on the context in which the process started and on the process management. The semi-structured interviews were based on the questions in the questionnaires and served to deepen the insight. We selected four members of the sounding board group for both interview rounds, each round inviting a different delegate from both the nature conservationist and the farmer group. The other interviews explored the views of stakeholders that attracted attention during the relevant meeting.

We analyzed the expert-based approach using a transcript of the workshop. We urged the experts to think out loud, which enabled us to follow their arguments during policy development. In the debriefing afterwards we asked them to elaborate further on the assessment criteria they applied, the assumptions they made regarding funding, what further steps they saw as being required and the future as they foresaw it for the area. Finally, we asked for their reaction on the GGOR that had been developed in the participatory approach.

3.3 RESULTS

3.3.1 Framing and analysis

The activities are discussed first for the participatory approach, then for the expert-based approach. For each approach we first outline the process and the resulting preferred policy and then discuss the identified institutional, strategic and substantive uncertainties, when they occurred in the process, how this affected framing and how they were handled.

Participatory policy development

From the first meeting onwards, the participants were deeply aware of the conflicting stakes of farming and nature conservation. The existing water regime was advantageous for neither stake: it threatened the high peat and was suboptimal for agricultural production. The nature conservationists, strengthened by the Natura 2000 legislation, aimed for preservation of the peat vegetation and where possible further growth. The farmers' aim was good economic conditions for farming. In particular this meant clarity concerning the long-term prospects for agriculture in the area, since the ongoing conflict kept them from investing in their farms.

The sounding board group considered technical and spatial planning measures to improve the water levels for both parties. The technical measures were found either to contribute only little to peat development or their effects were uncertain. Therefore, these measures were unfavorable not only to the nature conservationists but also to the farmers, who feared that the conservationists would continue calling for additional measures, which would keep the prospects for agriculture in the area uncertain. An option that emerged later in the process was the creation of a large hydrological buffer zone. This spatial planning measure would require the full cooperation of the province and the ministry, both in endorsement and in co-funding. No less important, it would also require cooperation by the farmers, as they would have to sell some of their land.

The actors finally agreed on a GGOR comprising a large buffer zone south of Bargerveen, plus filling in a few ditches within the area. The farmers would be financially compensated for the land and the relocation of several farms, while the drainage system of the remaining agricultural area would be optimized for farming.

Uncertainties in the participatory policy development

Several uncertainties played a role in the participatory process. Some were handled causally, while others became very important and were handled at crucial decision points. The actors showed institutional uncertainty about the roles and responsibilities of actors, about a threat to the long-term prospect of agriculture by developments in the policy arena of another nature area nearby and about the exact nature objectives to be established by the ministry. The interaction between actors caused strategic uncertainty. Throughout the process, substantive uncertainty about the most suitable locations for peat development, the required hydrological conditions and the effects and costs of measures was handled actively. We discuss the uncertainties approximately in their sequence of appearance in the process, together with their handling.

At the start of the process, the influence on the agricultural outlook of developments in another policy arena was recognized. Although the farmers demanded clarity regarding their future prospects, they urged ignoring these developments. The other actors acquiesced (p-RI).

Early in the process the process manager asked the farmers and nature conservationists to specify what regime would be optimal from their perspective. This caused strategic uncertainty, as the actors might demand higher (nature conservationists) or lower (farmers) groundwater levels than they actually wanted, anticipating a process of bargaining towards a compromise. This uncertainty was recognized, but ignored (p-RI).

Establishing the optimal groundwater regime also required specification of the preferred locations for peat development. The nature conservationists and project team jointly (ts-T) handled the uncertainty relating to this exercise. They collected information on area characteristics (rs-KA) by consulting both experts and an earlier area plan, thus developing a map of ecological targets per location. Data discrepancies were discussed and could be resolved by establishing single best estimates (rs-EBAK). The process manager handled the uncertainty over the required hydrological conditions for peat by consulting a group of external peat experts (rs-KA), who used scientific literature as the basis.

The optimal regimes, presented during the second sounding board meeting, were such that the water board concluded that the differences could not be reconciled in a feasible water management plan. The water board then framed the problem as a political choice between nature and agriculture that was beyond their jurisdiction and should be made by the province. The board suggested that, pending this decision, they would declare the existing regime (possibly with minor changes) to be the GGOR. Wishing to avoid (p-A) the strategic uncertainty of deferral, both farmers and nature conservationists strongly opposed this frame, arguing that the option of a hydrological buffer zone had not been investigated in sufficient depth to warrant such a move. The other sounding board group members concurred (p-A) and the water board was asked to commission a model study to establish the effectiveness of this option. Lacking a good hydrological model, the water board was reluctant to commit to such a (costly!) modeling study.

To implement a buffer zone the water board needed the commitment of and funding by two other government bodies. The participants indicated ambiguity over roles and responsibilities of the different governmental bodies. The relatively new GGOR legislative framework was equivocal and the procedure it outlined cut through the established consultative structures. During the first two sounding board group meetings, with their primary focus on open exchange of information (p-TB), this institutional uncertainty was acceptable to the participants. However, it stalled the process after the second sounding board group meeting, when the buffer zone option appeared.

There was uncertainty over whether the province and the ministry would both commit to the GGOR process, but without their funds the buffer zone option would not be feasible. The province had the authority to change the spatial plan for the area and controlled certain funds earmarked for agricultural reform and nature development. The ministry could still decide on the precise nature objectives for the area and also controlled some earmarked funds. The farmers insisted on clarity, arguing that further discussion about a buffer zone was meaningless without commitment to funding. They emphasized that a lack of financial support from the governmental authorities demonstrated that the objectives were overly ambitious and argued that the ministry should use its authority to moderate the nature objectives for the area. The nature conservationists refused to agree to this frame, arguing that it was pointless to press for a decision in the absence of knowledge about the effectiveness of a buffer zone.

The substantive uncertainty about the effectiveness of a buffer zone combined with the institutional uncertainty over the commitment of province and ministry to the GGOR process resulted in a complex strategic game. If the model study were to show a buffer zone to be ineffective, the nature conservationists could still block the process by contesting the model. If shown effective, implementing a buffer zone would succeed only with the support of the ministry and the province. These actors could either commit to the process, or not. The risk for them of commitment was getting trapped into making a big financial contribution, but an inconclusive GGOR process would require them to make a precarious political choice between forfeiting agriculture in the area or moderating the nature objectives, with the risk of losing face at EU level.

The impasse was resolved in a face-to-face meeting between principals of the water board and the province before the third sounding board meeting, in which the province agreed to finance a buffer zone if it was shown to be effective (rp-C). Given this opening, the farmers consented to sell land provided they were sufficiently compensated (rp-C). These conditional commitments sufficed for the water board principal, who then approved a modest modeling study to provide rough estimates of the buffer zone's effectiveness. The idea of a quick modeling study to elicit the best available knowledge (rs-EBAK) was discussed in the sounding board group. The nature conservationists were reluctant, but provisionally accepted the procedure (rp-P). The project team involved the nature conservationists and the province in the modeling activity to stimulate acceptance (ts-T) and invited them to reflect on data, methods, intermediate results and model limitations.

The stakeholders assessed the effects and societal impact of the measures both in the bilateral meetings before and also during the fourth sounding board group meeting (rs-KA). In the communication to the province and the ministry the results were presented as orders of magnitude, indicating their uncertain nature (ts-S). Once the feasibility of the plan became more apparent, the ministry was taken onboard by pointing at the unique window of opportunity (rp-C). In the fourth meeting, the group agreed on monitoring (rs-KA) of groundwater levels after implementation of the buffer zone. Uncertainty over the costs of the measures was explicitly mentioned and was handled by using a bandwidth (ts-S). During this fourth sounding board group meeting the actors tentatively agreed on the policy.

During the framing and analysis, we observed several games that caused strategic uncertainty. A permanent concern was that all actors had the option of participating actively in the sounding board group, or staying away, or not speaking their minds. Active participation would allow them to bring in and defend their interests. On the other hand, raising a new issue near the closure of the process (end of game behavior) might give them an advantage in the negotiations. To reduce strategic uncertainty for the participants, the process manager acted as mediator. She arranged face-to-face encounters for participants to meet and exchange considerations (tp-TB), stimulated agreement on procedures (rp-P, see Bots et al. (forthcoming) for details) and time and again emphasized the actors' stakes in participating (rp-C). The uncertainty regarding opportunistic end of game behavior was handled by two procedural agreements (rp-P): firstly, the group would be entitled to ignore strategically withheld information and secondly, if the scope of measures was to widen and affect additional stakeholders, these would be invited to join the sounding board group.

The expert-based approach
The expert team focused on satisfying the Natura 2000 objectives with the least sacrifices. Their objective was to keep the solution affordable for the water board and to avoid resistance by stakeholders in its implementation. They interpreted the ambition of the nature objectives flexibly and searched for locations in the Bargerveen area for which the hydrological situation could be improved easily. The solutions considered were essentially the same as those in the participatory approach. The team first considered technical measures and then opted for a buffer zone. They indicated the need to contact the province for authorization and funding of this zone. The team asked for the farmers' preferences and discovered their reluctance to give up activities. This was taken as a boundary condition for the further process. The experts built their plan on the premise that all parties would accept making small sacrifices.

In addition to filling in a few ditches inside Bargerveen, the resulting GGOR featured a small buffer zone southeast of it, for which the land would be acquired via land consolidation based on attrition of the farming population. The farmers would be compensated through an improvement in the water regime for the agricultural land. The process manager of the participatory approach judged that this policy could have been acceptable to all stakeholders and if not, that it would probably have been upheld in court, as it met the procedural and substantive criteria for this kind of planning.

<u>Uncertainties in the expert-based policy development</u>
The experts barely discussed institutional uncertainty. Being aware of policy developments in other arenas, the team had doubts about the long-term prospects for agriculture in the Bargerveen area and they did not rule out that their formulated policy might be modified in future policy rounds. Furthermore, they expressed strategic uncertainty about the behavior of stakeholder in ex post acceptance (or non-acceptance) of the policy. The experts voiced substantive uncertainty over good locations for peat development, the effect of measures on the hydrological conditions, and the societal impact of measures.

As a first step in the workshop, the experts requested (and received) information on required hydrological conditions for peat development (rs-KA). They appeared to interpret these conditions more loosely than was done in the participatory process. Looking for locations with peat growth potential, the team relied on their expert judgment to interpret the various ecological, geological and hydrological maps (rs-KA). To handle strategic uncertainty, the team requested (and received) the preferences of the farmers (rs-KA). They made assumptions about the preferences and behavior of the other actors (rs-EBAK). They searched for non-controversial measures that could be implemented by the water board (p-A) and extended the implementation of measures over a long time frame so as to benefit from windows of opportunity, such as the retirement of farmers (p-A). The team made assumptions for the societal impacts (rs-EBAK).

The experts stated the need to communicate the uncertainty over the long-term prospects for agriculture to the province (ts-S). The uncertainty of whether their plan would endure was discussed but not handled and the policy time frame was left implicit (p-RI). They overlooked the interest of the farmers in obtaining clarity on this point (p-I). To handle uncertainty about the effect of measures the team would have preferred model calculations, but lacking a detailed model they relied on expert knowledge (rs-KA). Uncertainty was communicated less explicitly than in the participatory process (p-RI).

3.3.2 The knowledge base

In the participatory approach, the stakeholders added to and corrected the knowledge of the project team. We did not observe discarding or ignorance of knowledge considered relevant in the expert-based approach, nor inclusion of non-validated knowledge. We discern several categories of stakeholders' contributions and corrections:

- *Background information.* The farmers contributed knowledge of earlier research into drainage possibilities and bottlenecks for agriculture, while the conservationist added that of a historical hydrological study. Additionally, the participants shared the ins and outs of sensitivities of the conflict, such as the distrust between farmers and conservationists.
- *Area characteristics.* The nature conservationists contributed information about favorable locations for peat development and necessary hydrological conditions. The farmers gave information about wet spots of land and their management practices, such as their crop rotation system, as a basis for determining the optimal groundwater regime. The conservationists corrected the model calculations by pointing out that a ditch in the model had actually been filled in.
- *Model application and interpretation.* The stakeholders contributed to the interpretation of peculiar model outcomes, such as excessive seepage, sharing their knowledge of area characteristics. The conservationists corrected the application of model extrapolation, pointing out the many uncertainties involved.
- *Stakeholder preferences.* The farmers and conservationists amended the knowledge about their main concerns. The conservationists valued the health of the overall ecosystem over peat development at specific locations. The farmers set great store by clarity about the long-term prospects for agriculture in the area rather than preserving as many farms as possible. The farmers also indicated a preference for local drainage control.
- *Local developments.* A few farmers shared – off the record – the fact that they would be willing to sell their property. A resident knew that a road that would need to be elevated in the GGOR plan was already due for reconstruction.
- *Creative policy design.* The farmers contributed the idea of raising farms on artificial mounds in the buffer zone to limit the number of farmers having to leave the area.
- *Competences and procedures.* The province and ministry shared their interpretation of procedures, for example the ministry representative stated the intention to leave the tentative nature objectives unchanged. The principals of these organizations also exchanged ideas about their roles.

3.4 DISCUSSION

3.4.1 The influence of uncertainty handling on framing and analysis

Compared to the policy developed by experts, that developed with stakeholder participation involved more resources, had a larger scope and required the cooperation of more stakeholders. We will discuss the differences in the two policy development processes, consider mechanisms that might explain our observations, and compare the findings to our reference case studies, by which we mean other empirical case studies addressing the influence of stakeholder involvement (Stern and Fineberg 1996, Wynne 1996, Clark and Murdoch 1997, Beierle and Konisky 2001, Maxim and Van der Sluijs 2007).

The dominant institutional uncertainty identified in the participatory process was uncertainty about actors' roles, which the group handled by arranging active commitment. Strategic uncertainty was handled through trust-building, commitment and procedures. The participants used what power they had to try to influence the frame to their advantage, mostly widening it. Since the participants did not want the decision to be moved beyond their influence, a logical reaction to this process uncertainty was to enlarge the frame so as to internalize it. We suggest that the low tolerance of process uncertainty was driven by the stakes: the farmers needed a firm long-term agreement that would warrant new investments in their farms and the nature conservationists wanted to maximally exploit the window of opportunity opened by the acquired Natura 2000 status. Interestingly, we see two proposals to narrow the frame, which may also be explained by intolerance of process uncertainty. The farmers' (successful) urging to exclude developments in surrounding nature areas reduced the risk of actors emphasizing the precarious position of agriculture in the region. We suggest that the (unsuccessful) proposal of the water board to narrow the frame and defer the actual choice to higher authorities was rejected because it would increase, rather than decrease, process uncertainty for most stakeholders.

The dominant institutional uncertainty identified in the expert-based approach was uncertainty about developments in other arenas, which the experts avoided by anticipating future windows of opportunity. By aiming for measures within the reach of the water board, they avoided uncertainty about roles and responsibilities. The experts reduced strategic and substantive uncertainties by making assumptions, collecting knowledge on preferences and measure feasibility, while balancing benefits and sacrifices for stakeholders. In this process they ignored some assessment criteria important to the stakeholders in the participatory process.

Looking at our reference case studies we equally see a broader frame in participatory policy development (Stern and Fineberg 1996, Beierle and Konisky 2001), and a tendency to reduce the frame in an expert-based approach (Wynne 1992a), a phenomenon also discerned by Kickert et al. (1997). Fritsch and Newig (2006) address frame reduction in participatory policy development, and offer as explanation that the interest of local actors tends to focus on time horizons not large enough to internalize the negative externalities. Such temporal myopia seemed to play no role in our case.

An interesting observation is that the expert-based policy is more adaptive, whereas the participatory approach fixed the policy for the next 25 years. This is at odds with the expected urge of stakeholders to reach agreement despite uncertain information by making adaptation part of the preferred policy (Ehrmann and Stinson 1999). We again find the low tolerance of (future) process uncertainty at the base of this difference; adaptive management sustains process uncertainty. The context of the case, a persisting conflict, decreased the tolerance of process uncertainty even further, since farmers had experienced the disadvantage of process uncertainty over a long time.

The two approaches identified similar substantive uncertainties and applied similar handling methods, except for the measure effect uncertainty. The experts relied on their judgment in the absence of a detailed model, whereas in the participatory approach this method was rejected in favor of model calculations. The model became a decisive factor in determining the width of the buffer zone. The calculations were favored because they would make information collection traceable and formal, so developing trust. This finding supports the proposition by Kickert et al. (1997) that formalizing procedures in complex processes overcomes process uncertainty. Our reference case studies do not show this in action.

Finally, we noticed that the participatory approach paid explicit attention to communicating uncertainty in analysis results, while the expert-based approach did this less. Case studies by Wynne (1992b) and Stern and Fineberg (1996) show similar observations. We tentatively offer two explanations: (1) the experts felt less need to communicate uncertainty because the impact of the measures they proposed was smaller and the effects were presented qualitatively; and/or (2) the experts felt more confident, because of their prior experience with the measures and the absence of stakeholders' critique and insistence on transparency.

3.4.2 The knowledge base

Like all of our reference case studies, we found that the stakeholders contributed to the knowledge base. Being more detailed, our analysis enables us to distinguish categories for stakeholders' contributions: background information, area characteristics, model application and interpretation, stakeholder preferences, knowledge of local developments, creative policy design and competences and procedures. The knowledge had a substantial influence on the policy development:

- The background information and knowledge of local developments saved on costs of both the analysis and the measures.
- The knowledge of area characteristics made the analysis more accurate and better tailored to the local situation.
- The stakeholder preferences diverged considerably from those initially assumed by the project team and this changed the policy assessment criteria.
- The discussion of competences and procedures and the information that some farmers would be willing to sell their property provided a crucial opening for the process.

As we found no discarded knowledge, our study provides additional empirical evidence for the frequent claim that stakeholder involvement increases the quality of the knowledge base for a policy development process. Viewing the process as one of mixed motive bargaining, we find it difficult to differentiate between the motives of stakeholders to share specific knowledge. We see more strategic contributions to the optimal groundwater regime, stakeholder preferences and the correction of model extrapolation. We also find more neutral contributions in the interpretation of model outcomes and mentioning the plan for road elevation. None of the actors contributed information that directly harmed their stake.

3.4.3 Focus on uncertainty handling

The focus on uncertainty necessarily highlights decision points in the process and helps to clarify and characterize the actions that further the process. This aided our comparison of the two processes. Differentiating between types of uncertainty makes the interaction between substance and process more apparent: in the participatory process, we could see how establishing the optimal groundwater regime for peat development and for agriculture led to a strategic move by the water board and we elucidated the complex negotiation process that preceded the decision to perform model calculations. We could also see interaction between methods to handle process and substantive uncertainty, for example combining the search for best available knowledge with seeking commitment to accept the results. Reviewing the literature, however, we found that substantive uncertainty has been a topic mainly in policy analysis and operational research (Morgan and Henrion 1990, Walker et al. 2003), while process uncertainty is discussed mainly in the field of policy networks and process management (Kickert et al. 1997, Rhodes 1997). Studies that explicitly address both process and substantive uncertainty (Wynne 1992a, Koppenjan and Klijn 2004, Brugnach et al. 2008) are rare. We suggest that more research into the interaction between the handling of different types of uncertainty is warranted.

In some policy science literature discussing decision making under uncertainty (Scharpf 1997, Walker et al. 2003) uncertainty is a given, stemming from the policy context. In our perspective, uncertainty is a dynamic variable, dependent on perception and influenced by framing, analysis and the interaction of actors in the process. Uncertainty provides a motive for reframing until all actors feel sufficiently comfortable with the frame. We further elaborated this view of uncertainty as an important dynamic driving the process, driven by the work of Koppenjan and Klijn (2004) and Abbott (2005). The uncertainty perspective, we speculate, may provide valuable insight when considering alternative process management interventions in a participatory approach. In our case, the process manager stimulated firm commitment to handle process uncertainty. An alternative method (see Table 3.1) would have been to put increased emphasis on trust building. This in turn could have enabled a more adaptive policy. To give another example, the team of experts avoided institutional uncertainty about roles and responsibilities by frame reduction. They might also have opted for handling it actively, for example by involving the province and the ministry in policy design to seek their commitment. This could have made the resulting policy more robust in case of change in future policy rounds, but would also have involved complexity due to strategic behavior of these actors. Focusing on decision points and uncertainties and comparing the potential of methods in Table 3.1 will enhance reflection on alternative methods to advance the policy development process. We would therefore posit the perception of uncertainty as a variable that should be studied in its own right, seeing uncertainty tolerance and uncertainty reduction as steering variables and uncertainty handling methods as a mechanism for intervention.

Identifying uncertainties and handling methods facilitated our comparison of the participatory and the expert-based processes. We believe that it would equally facilitate the comparison of different participatory processes and support process evaluation by providing additional information on evaluation criteria such as the influence of stakeholders and the transparency of decisions (see Rowe and Frewer 2004). This information complements traditional data collection on individual actor experiences and motivations through questionnaires and mapping of actor frames.

3.4.4 Limitations of the study

Given the available resources, the level of detail of the expert-based approach was limited. It was a simulation in which the experts had restricted time, tapped from the knowledge base of the participatory approach and eventually outlined preferred measures and subsequent steps. Even so, we contend that these limitations cannot explain the observed differences in framing and analysis. We left the experts completely free in their choice of scope and encouraged them to request whatever information they considered relevant.

Another consideration is that the stakeholders had limited influence over the objectives and institutions laid down by higher authorities – although they frequently challenged them – and this depoliticized the process to some extent. It is possible that our findings are limited to such contexts, which we can expect to find often in the future, for example in relation to the implementation of the Water Framework Directive and the Natura 2000 agenda.

3.5 CONCLUSION

By comparing two policy development processes for the same case – one using a participatory approach and the other using an expert-based approach – we hoped to improve our understanding of the influence of stakeholders on framing and analysis and on the knowledge base used. Not surprisingly, we found large differences in both process and outcome. Active participation of stakeholders in policy development on a controversial issue is bound to show a wider variety of frames and generate a more passionate and dynamic discourse. In the participatory process, reframing occurred more often and involved more radical proposals (giving up nature objectives, leaving the decision to politicians, buying out several farms and relocating others). Our analysis of both processes in terms of uncertainties and the way they were handled was effective in articulating the important episodes and elucidating the differences in the framing and analysis and the use of knowledge during policy development.

Our study confirmed several findings from previous empirical research. Firstly, stakeholder involvement in policy development increased the quality of the knowledge base. Secondly, it widened the frame to include important stakeholder criteria and additional options. In the expert-based process the frame was limited to what the water board would be able to achieve. We see this as avoidance of process uncertainty. The involvement of stakeholders made process uncertainty much more prominent and the effort to resolve the institutional and strategic uncertainty resulted in the adoption of a broader frame. We see the wish for a 'once and for all' settlement of the prolonged conflict as an important driver for the differences in uncertainty handling. The low tolerance of process uncertainty eventually led to a policy that was not adaptive. An interesting observation is the rejection in the participatory process of relying on expert judgment as the main method to handle substantive uncertainty on a controversial topic. Instead the stakeholders opted for a more formalized modeling procedure to make knowledge acquisition traceable, combined with explicit communication of uncertainty.

The explanations we offer for the observed phenomena are tentative. More research is needed to establish whether they can be generalized beyond this case study. Having established the practical feasibility of a 'one case, two processes' comparison, we believe that this research design merits further development and replication, because it allows scrutiny of framing and analysis while case-specific conditions are (more) controlled. We speculate that the applied focus on uncertainty enhances insight into alternative choices for process management in a policy development process and we envisage its application not only in case comparison, but also in process design and evaluation. Finally, our study suggests that more research into the interaction between the handling of different types of uncertainty is warranted.

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APPENDIX 3.1: QUESTIONNAIRES USED TO EVALUATE THE PARTICIPATORY APPROACH

We asked the participants' view on the context and process management of the participatory process. Presenting statements, we asked them to choose one of the following responses: strongly agree, agree, neither agree nor disagree, disagree or strongly disagree.

Questionnaire to evaluate the context of the participatory approach

Statements:

1. At the beginning of the process, there was no or only a little conflict between the goals/objectives of the various participants.

2. At the beginning of the process, personal relationships between the participants were good.

3. At the beginning of the process, participants trusted the water board.

4. At the beginning of the process, participants were interested not only in reaching their own objectives but also the objectives of the group.

5. At the beginning of the process, participants were confident that the approach would help reach the group's objectives.

6. At the beginning of the process there were only very few problems to be addressed.

7. At the beginning of the process, water managers and other decision makers involved were open to the opinion of others.

8. At the beginning of the process, participants were used to speaking up in a group and to frankly sharing their opinions.

9. At the beginning of the process the geographical and legal boundaries of the problem were clearly defined.

10. Enough time and funds are available to meet the targets of the process.

Questionnaire to evaluate the process management of the participatory approach

Statements:
1. In my opinion, the participants in this process fairly represent the members of the public who will be affected by the issues raised in it.

2. In my opinion, the process has been run in an unbiased way (i.e. without undue influence from process organizers).

3. In my opinion, this process has taken place at a sufficiently early stage in the policy formulation procedure to allow participants to have some genuine influence (i.e. not at a stage where most of the important decisions have already been made).

4. In my opinion, the recommendations that originate from participants in this process will be implemented by the organizers of the exercise.

5. In my opinion, the activity's process has been transparent (i.e. all interested parties are readily able to see what is going on if they want).

6. In my opinion, the process provided me with sufficient resources (financial, number of meetings and information) to take part in it effectively.

7. In my opinion, the nature and scope of the task was well defined (i.e. I understood precisely what was required from me in the process).

8. In my opinion, the process was well organized and managed on a practical level (i.e. the understanding of key concepts by participants was ensured during the process, discussion and decision-making procedures were appropriate and kept on track and the process was skillfully adapted to unforeseen developments when this was necessary).

9. In my opinion, this process would seem to be cost effective (i.e. the outcome of the activity could not be achieved in a more cost-effective way).

4 Supporting the constructive use of existing hydrological models in participatory settings: a set of 'rules of the game'[3]

Abstract
When hydrological models are used in support of water management decisions, stakeholders often contest these models because they perceive certain aspects to be inadequately addressed. A strongly contested model may be abandoned completely, even if stakeholders could potentially agree on the validity of part of the information it can produce. The development of a new model is costly and the results might be contested again. In this article we consider how existing hydrological models can be used in a policy process so as to benefit from both hydrological knowledge and the perspectives and local knowledge of stakeholders. We define a code of conduct as a set of 'rules of the game', which is based on a case study of developing a water management plan for a Natura 2000 site in the Netherlands. We propose general rules for agenda management and information sharing and more specific rules for model use and option development. These rules structure the interaction between actors, help them to explicitly acknowledge uncertainties and prevent expertise being neglected or overlooked. We designed the rules to favor openness, protection of core stakeholder values, the use of relevant substantive knowledge and the momentum of the process. We expect that these rules, although developed on the basis of a water management issue, can also be applied to support the use of existing computer models in other policy domains. As rules will shape actions only when they are constantly affirmed by actors, we expect that the rules will become less useful in an 'unruly' social environment where stakeholders continually challenge the proceedings.

4.1 INTRODUCTION

4.1.1. Background

Article 14 of the European Water Framework Directive (WFD) encourages stakeholder participation and the use of expert knowledge in water management decision processes (EU 2000). While the benefits of stakeholder participation for a policy process are advocated on theoretical grounds in the literature (Fiorino 1990, Laird 1993, Webler 1995), with regard to empirical findings Delli Carpini et al. (2004) note that 'Although the research … demonstrates numerous positive effects of deliberation it also suggests deliberation under less optimal circumstances can be ineffective at best or counterproductive at worst.' The policy literature makes clear that the use of expert knowledge likewise may be problematic. When scientific expertise is solicited by policy makers to legitimize decisions, it loses its authority in situations where: science fails in predicting policy outcomes (because of uncertain knowledge); different scientists can be found to support different policies (because competing theories means there is no single 'truth') (Weingart 1999); and stakeholders perceive aspects to be inadequately addressed (Hoppe 1999, Van Buuren and Edelenbos 2004). Despite these

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difficulties, the policy literature also makes clear that participatory processes are essential in linking science and policy (De Bruijn and Ten Heuvelhof 1999, Munnichs 2004).

Implementing the WFD therefore poses a real challenge to water managers. Water systems are physically complex and expert knowledge, to a large extent embodied in computer models, is often partial and rife with uncertainties (Walters 1997). Moreover, water systems are intricately linked to virtually all types of human activity. This means that water-related decision processes must deal with the competing values, preferences and perspectives of many different stakeholders (Blomquist and Schlager 2005, Blackmore et al. 2007). As water is a vital resource, the stakes are high. Meanwhile, the knowledge about the socio-economic system is distributed over different scientific disciplines, as well as locally over the actors concerned by a particular water-related issue. As a consequence, the available knowledge, physical and socio-economical, is often contested by stakeholders (Van Latesteijn 1998, Fischer 2003).

4.1.2 Focus

In this article, we focus specifically on the role of knowledge of physical water systems that is embodied in hydrological computer models. Van Daalen et al. (2002) show that in environmental policy development computer models can play different roles: they can serve as eye-openers (drawing attention to a specific issue), as arguments in dissent (advocating a particular world view), as vehicles in creating consensus (accommodating alternative perspectives) and as management tools (assessing the effects of policy measures). The hydrological models that we have observed in the case featured in this article performed the last role.

Although hydrological models represent but a limited range of aspects of the physical world, they are nevertheless mostly ‘black boxes’, in the sense that the decision makers and stakeholders cannot easily verify whether the predictions these models make are realistic. They will have to rely largely on the competence of the modelers to produce reliable images of future states of the world. This makes *trust* in models a key factor in policy processes (Shackley 1997, Saunders-Newton and Scott 2001). Lack of such trust can hamper the process. When the validity of a model is contested it may be discarded in its entirety, even when stakeholders could potentially agree on the validity of part of the information that it produces. This information is then lost to the process. Developing (new) models so that they are proof against the objections made is costly in both time and resources and even when these are available (which often is not the case) the results obtained with the improved model may eventually be contested as well.

One strategy to avoid such stalemate is to involve decision makers and stakeholders in the process of model development, with the aim of increasing trust by making the black box transparent (Pahl-Wostl 2002, Van Eeten et al. 2002, Barreteau 2003, Etienne et al. 2003, Jackson 2006, Pahl-Wostl 2006, Howick et al. 2007, Bots and Van Daalen 2008). When guidelines are provided (Smith Korfmacher 2001, Caminiti 2004, Karas 2004, Voinov and Brown Gaddis 2008), these typically set objectives (e.g. the modeling process should be transparent, the public should participate continuously and have influence on modeling decisions) and suggest tactics (such as make modelers document and present their assumptions and the model’s uncertainties and limitations or manage the expectations of stakeholders from the start). They do not, however, make clear how these objectives can be reached or how these tactics can be implemented procedurally.

A second strategy is to determine in interaction with decision makers and stakeholders for what purposes the model could still be used. This strategy differs from the first in that the objective is not to develop a model that meets the information need for a given scope of decision making for all parties, but to develop the parties’ understanding of the capabilities and limitations of a given model and adapt the decision scope to these. This strategy will require fewer resources, but it may resolve only part of the issue and/or still require new model development. Which strategy is to be preferred will depend on the decision context.

The second strategy, which to our knowledge has not received attention in the literature, was adopted in the case we studied. Therefore, the question we focus on in this article is how existing hydrological models can be used effectively in a multi-stakeholder setting, even when their validity is questioned. Ehrmann and Stinson (1999) emphasize that processes to deal with policy situations in which the level of trust among parties is low must be firmly embedded in the larger policy decision-making process by defining a set of ‘ground rules’. Taking this to heart, our aim is to define ‘rules of the game’ that set a standard for actors with particular roles in the process on how to behave insofar as existing hydrological models are concerned.

4.1.3 Case study

The set of rules that we propose is inspired by a participatory process in the Netherlands. It concerns the water management issue of defining a so-called ‘desired groundwater and surface water regime’ (*Gewenst Grond- en Oppervlaktewater Regime*, or GGOR for short) for Bargerveen, a nature area in the province of Drenthe in the northeast of the Netherlands. Bargerveen has been designated a Natura 2000 area and the Dutch national government required that a GGOR was formulated for all such areas by the end of 2007, as part of a fully-fledged Natura 2000 management plan to be developed by the provinces before 2010. The Bargerveen GGOR should strike a balance between the competing water interests of the nature area and its surroundings, mainly agricultural land.

The Dutch local water authorities (water boards) and the national authorities responsible for rural development have agreed a general procedure to formulate a GGOR for a given geographical area (Gehrels 2003, NBW 2003, Vlotman and Jansen 2003). This procedure first establishes reference water regimes: the *actual* regime that is currently in practice (AGOR) and for each land use function in the area (agriculture, housing, industry, nature, etc.) a theoretical *optimal* water regime (OGOR). To determine what is ‘optimal’ the relation between groundwater regime, soil type and land use performance has been established for a broad range of functions (Gehrels et al. 2003). The performance indicator is a percentage, where 0% indicates the worst case (e.g. maximum crop loss due to drought for agricultural functions, or local disappearance of a species for nature functions) and 100% indicates the best case (e.g. optimal crop yield or optimal ecological conditions). This indicator has been calculated for the most important crop and nature types (on the basis of best available knowledge) for a comprehensive set of soil type/groundwater regime combinations.

Once AGOR and OGORs are known, alternative water regimes are defined and assessed in an iterative process until a regime is found that realizes a certain percentage (typically > 70%) of the optimal performance. If this criterion cannot be met for the existing land use functions using the available means for operational water management, changing land use and/or taking more radical hydrological measures may be considered. The GGOR procedure presupposes the use of hydrological models for ex ante assessment of such measures.

In line with the WFD, the Dutch national administrative water agreement (NBW 2003, Article 5) necessitates close cooperation with stakeholders in the development of a GGOR. The water board Velt en Vecht, being the responsible authority for the formulation of the GGOR Bargerveen, wanted to achieve a widely supported GGOR, to avoid its rejection in the future provincial planning process. The water board opted for an approach that reflects what Laird (1993) calls pluralism (as opposed to direct participation) as it involves a ‘sounding board group’ whose members have been selected in such a way that all stakes are represented. The water board employed the fourth author of this article – a private consultant with experience in participatory decision-making processes on regional water management issues – to lead the process, supported by a team of water board employees and an external consultant for hydrological modeling. The water board invited the other authors to take part in the stakeholder participation process design, implementation and evaluation.

4.1.4 Outline of this article

The rules of the game that we focus on were *not* defined ex ante and then ‘imposed’ on the GGOR process, but were elicited ex post. Our research aim was to make explicit the rules of the game that from our perspective have implicitly been steering the cooperative behavior of participants in the GGOR process that we were involved in as researchers and practitioners. In the Methods section that follows this introduction we will present the conceptual model that we used as the basis for formulating rules of the game. In the subsequent Results section we present the rules of the game that we derived and then show where we observed them as ‘rules in action’ in the GGOR process. In the Discussion section we reflect on local conditions that may influence the efficacy of the proposed code of conduct.

4.2 METHODS

The work we present here is what Schön (1983) calls ‘reflection on action’. Intrigued by the particular way in which existing hydrological models were challenged but nevertheless used in the Bargerveen GGOR process, we decided to analyze this process by looking at the underlying institutions (North 1990, Ostrom 1990, 1999). The GGOR procedure is embedded in legislation and therefore what North (1990) calls a formal institution. It provides a rational framework for decision making. The participatory implementation of the GGOR procedure by the water board Velt en Vecht builds on informal institutions: conventions and norms of behavior. Our aim was to elicit these as procedural rules that describe what actions are considered appropriate for, and expected from, participants. Our rules of the game should specifically address the use of computational models and preferably be capable of generalization beyond the GGOR context.

The term 'rules of the game' has several aspects. Rules are social constructs that shape social action, while they at the same time are reaffirmed through being used by social actors (Giddens 1984, Ostrom et al. 1984, North 1990). Rules will be continuously interpreted and contested (because they constrain) by actors. Social interaction *about* rules will typically be structured by additional rules. The general GGOR procedure, for example, was enacted following a well-established formal legislative procedure. By contrast, the GGOR itself provided no clear rules for being implemented in a participatory way. We investigated how this 'institutional void' (Hajer 2003) was filled, focusing on the rules; we did not examine the mechanisms by which these rules were adopted, such as policy learning (Grin and Loeber 2006) or negotiation (Fiorino 1990).

We articulated the rules *after* the process; they were not used overtly (in the sense of 'made explicit to participants') in designing the process. However, many of the ideas that we now identify as rules were brought to the fore by project team members during team meetings in which the next steps of the process (sounding board group meetings and other interactions with stakeholder groups, experts or modelers) were discussed.

Crawford and Ostrom (1995) provide a general syntax for rules. This has the acronym ADICO, where **A** stands for the *attributes* that identify specific participants to which the rule applies, **D** for the *deontic* operator that defines whether the rule permits, forbids or obliges participants to take some action, **I** for the particular *aim* (action or outcome) to which the rule refers, **C** for the *conditions* that specify when, where and how the rule applies, and **O** for the *or else* part of the rule that details the consequences for a participant who does not comply with the rule. As an example, we structure a rule of the game for a joint fact-finding process proposed by Ehrman and Stinson (1999) according to the ADICO syntax:

Participants in a joint fact-finding process (A) must not (D) distribute any information they receive (I) until the group as a whole agrees on the timing and method of its distribution (C).

This example shows that not all parts need to be present. The following example illustrates what an 'or else' part could look like:

When a participant has information that pertains to the policy decision (C) this participant (A) must (D) share this information with other participants (I) or else this information may be ignored by the decision makers (O).

We use the ADICO model to designate our rules of the game. The **A** part of these rules is either 'all participants', i.e. the set of actors who take an active part in the policy process, or one of the five subsets of participants that we define below by giving their characteristic role attributes:

- *stakeholders*: actors whose interests may be affected by the policy decisions that will result from the policy process that is being investigated;
- *decision makers*: actors with the authority to make these policy decisions;
- *modelers*: actors who have the technical competence to develop and operate computational models;
- *experts*: actors whose knowledge on a particular topic is acknowledged by all participants;
- *process manager*: actor responsible for managing the policy process by planning and facilitating the interaction between participants; and
- *process sponsor*: actor who has delegated the management of the policy process to the process manager and who can decide on the resources that are allocated for this process; this role is also referred to as lead agency (Beierle and Konisky 2000, Ryan 2001).

These actor roles need not be mutually exclusive. Modelers, for example, usually also are (or become) experts, stakeholders may also be experts on particular aspects of the socio-ecological system (local knowledge) while experts may also be stakeholders (e.g. ecologists who champion a particular species) and process sponsors often also are decision makers. Moreover, the term actor may refer to multiple people so, despite use of the singular form the roles of process sponsor and process manager may be assumed by several individuals.

In the rules of the game we distinguish the following entities:

- *socio-ecological system*: the part of the real world that is the object of the policy process for which the rules are defined;
- *measure*: a course of action that is expected to produce desirable changes in the state of the socio-ecological system;
- *option*: a particular course of action that might be implemented;
- *decision*: a choice between several alternative options; a decision may be substantive, i.e. part of the policy (for example what measures to take or budget limits), as well as procedural, in other words the way to proceed with the policy process (such as what model to use or who to invite to and what to discuss during the next meeting);
- *agenda*: an overview that shows all decisions that are relevant to the policy process and specifies for each decision whether it is still open (no choice has been made between alternative options and new options can still be proposed), near closure (no choice has been made but sufficient information on options and consequences is available to choose), or closed (the choice of a particular option has been made);
- *model*: a representation of the socio-ecological system that can predict (with some degree of accuracy) the consequences of implementing a particular measure; the set of variables and their computational relationships constitute the *structure* of the model; we distinguish between *input variables* – variables to which values (inputs) are assigned to represent

measures (e.g. digging ditches) and exogenous factors (such as precipitation levels); *parameters* – variables whose constant values represent invariable system characteristics (for instance the geometry and hydraulic conductivity of soil layers); and *output variables* – variables whose values (outputs) are computed when the model is executed and which are of interest to participants (for example minimum, maximum and average groundwater levels); and

- *scenario*: a set of inputs that, when the model is executed, is expected to produce outputs that predict the effects of a measure as accurately as is possible, given the model's structure and parameters.

The diagram in Figure 4.1 highlights some of the assumptions we make with regard to the relative position of some of these actor roles and entities:

- The agenda is determined by stakeholders, decision makers, process manager and process sponsor. The open decisions on the agenda correspond to a need for information.
- These same actors can provide local knowledge, while experts furnish expertise. The distinction between these two types of knowledge hinges on the recognition of the source as an expert.
- Modelers develop the model by modifying its structure and/or parameters and 'translate' proposed measures into scenarios.
- Local knowledge, expertise and model output are expected to satisfy the information need to some extent (the match between supply and demand of information). The term surplus refers to information that is considered irrelevant to the decisions on the agenda, while information that is lacking is called uncertainties.
- Uncertainties inform agenda setting and model development.

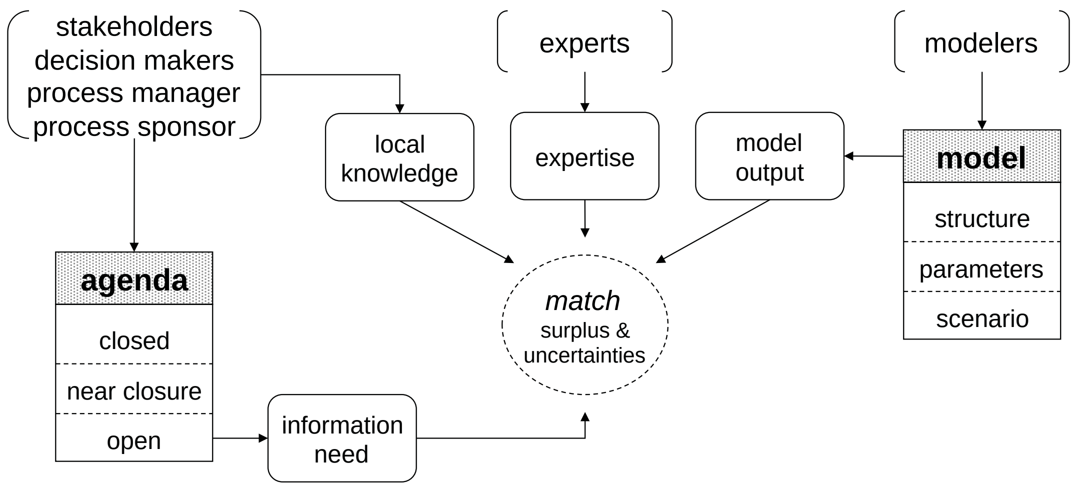

Figure 4.1 Elements of a model-informed participatory policy process.

This diagram does not identify actions and thus does not reflect the dynamics of the policy process. The implicit assumption is that the actors will affect the agenda either directly by their own actions or indirectly by provoking other actors' actions . If we make the assumption that *all* actions are governed by (implicit) rules, then the set of rules we define should be a closed system that covers all process activities in such a way that actions triggered by one rule produce changes that trigger new rules (or the process terminates).

To assess whether the set of rules as a whole can produce the type of participatory process that we observed, we chose the framework proposed by De Bruijn et al. (2002). The four core elements of this framework are compatible with the general criteria of fairness and competence put forward by Webler (1995), but also make explicit the time aspect of a participatory process:

1. *Openness*: the process is open in terms of participation (all stakeholders have access to the process), problem definition (broad in scope, flexible) and solution space (no pre-set restrictions as to what constitutes a good solution).
2. *Protection of core values*: the process does not lead participants to act against their own interests.
3. *Substance*: the process makes use of relevant substantive knowledge, drawing on the expertise within the stakeholder network to generate variety as well as to make selections.
4. *Speed*: the process gains and maintains sufficient momentum to achieve significant results in the end.

Obviously, tensions exist between these elements. For example, if (new) stakeholders may at any moment bring up new considerations, the process might not converge to a conclusion (*openness* versus *speed*). If decisions are based on a particular model, some stakeholders may opt out because of fear that it may produce unfavorable results for them (*substance* versus *protection of core values*). While defining our rules of the game we therefore checked if they would allow the process manager to strike a balance between all four elements.

Our *post hoc* rule defining process was essentially heuristic. Using the elements in Figure 4.1, the first author drew up a skeleton set of rules that, when 'executed' would produce a very general 'fair and competent process' (Webler 1995). He then gradually extended this set, aiming to include as much as possible of the activities and decisions observed in the Bargerveen GGOR process in rules that specify what is proper behavior for participants in this process. In this way, the deontic operator **D** in the ADICO syntax always obliged participant **A** to do **I** given condition **C**. The or else part **O** of the rules was left implicit, since no concrete sanctions for rule breaking were observed (we will come back to this in the discussion section). The rule set was then scrutinized by the second author, modified and reviewed again. Next the set was validated by the other authors, notably the manager of the GGOR process herself. Finally, to check relevance and completeness, the second author used the rule set as a coding scheme to label the occurrence of rules in action in the condensed process description that is part of the following section.

4.3 RESULTS

Having explained the methods by which we have identified rules of the game that we consider to be favorable in model-informed participatory policy processes, we will present the results of our analysis as four sets of rules:

- *agenda management* rules (AM) that regulate the decision making process
- *information transparency* rules (IT) that guide the development of a shared information set
- *model transparency* rules (MT) that direct the communication about models and model output
- *measure proposal* rules (MP) that govern how participants can put forward measures for resolving the policy issue

The first two sets apply to the overall process. They provide the context for the other two sets, which specifically address the use of models to assess policy measures. We did not examine the rules that guided the selection of participants, but the general principle was that all relevant stakeholders should be represented. Being very familiar with the Bargerveen area and the interests at stake, the process sponsor and process manager drew up a first list of delegates. During its first meeting, this sounding board group (see Appendix 4.1) worked on identifying interests and stakeholders that were not yet represented, and people who should be included.

We specify the rules using a syntax that is based on ADICO but allows some shorthand. The attribute part **A** of a rule will always be one of the participant roles. We can leave the deontic operator **D** implicit, because all our rules define appropriate behavior. This means that all verb phrases denote aims (**I**). When the condition part **C** is omitted, this should be read as at all times. Such rules expect constant vigilance from the participants it concerns. When rules logically occur in sequence because one rule creates the condition for another, we present these rules together to further improve clarity.

4.3.1 Agenda management rules

AM-1 The process manager prioritizes the decisions on the agenda, provides motivation for why the decisions need to be made, and why in the proposed order, for progress towards the final policy decision and determines which actors are decision maker for which decision.

AM-2 For each decision on the agenda, the stakeholders indicate either near closure (when they find the available information sufficiently complete and reliable to make the decision), or they indicate what uncertainties exist that prevent closure.

AM-3 When a decision on the agenda is near closure, the associated decision makers choose an option and clarify their deliberation with reference to the available information. The process manager then marks these decisions as closed.

AM-4 When uncertainties prohibit progress (i.e. no high priority decisions are near closure), the process manager consults with the process sponsor on the availability of resources and with the modelers and experts on possible additional analysis. The process manager then develops alternative options to deal with the uncertainties and places this procedural decision on the agenda.

Rule AM-1 constitutes the process manager as the ‘procedure maker’. It is a crucial rule: if the process manager fails to establish and maintain a legitimate agenda, all other rules fail automatically. The rule states that the process manager determines (rather than decides) who is decision maker for which decision. Thus, if the choice of decision maker becomes an issue, it can be put on the agenda as a procedural decision in which the process manager can propose decision makers.

The agenda management rules mainly favor speed, but rule AM-2 allows stakeholders to protect their interests. Rule AM-4 ensures that the process cannot block, allowing the process manager to diagnose the lack of decisiveness and frame the problem as a procedural decision. The alternative options for this decision will be either to accept uncertainty (the decision makers take their responsibility and accept the risk that may be involved), to reduce uncertainty (additional information is sought – see the information transparency rules below), or to reduce the decision scope (alternative decision options that produce less uncertainty are looked for – see the measure proposal rules below). Rules AM-1 and AM-2 ensure that the information that is needed to make this procedural decision will be sought before a choice is made. The obvious problem is that it may be difficult to identify a legitimate decision maker for this procedural decision. It is typically at this point that the process manager will have to make a trade-off between the previously mentioned four core elements of de Bruijn et al., and powerful actors (e.g. the process sponsor or decision makers) are likely to exert their influence.

4.3.2 Information transparency rules

IT-1 The participants communicate whatever information they consider to be relevant, specifying the decision(s) that should be based on this information.

IT-2 The participants report when they obtain new information that may be relevant to decision making.

IT-3 The process manager maintains and shares with all participants an overview of the information that has been identified as relevant and/or available.

IT-4 The participants take notice of the information that is available and notify the process manager of information that appears to be contradictory or missing. The process manager notes this in the overview as uncertainties.

IT-5 The participants identify people they consider to be knowledgeable on a subject that has been denoted uncertain. The process manager verifies with these people whether they can indeed contribute relevant information. If so, they are invited to participate in the process as experts.

IT-6 If different experts are proposed for the same subject, they determine whether their views conflict. If this is the case they clarify their differences of opinion. These differences are noted as uncertainties.

The decisions referred to by these rules may be substantive as well as procedural. Similarly, the information may be substantive or can be meta-information (e.g. information on where other information can be found, or information on the quality of other information). The information transparency rules mainly favor openness and substance, but rules IT-1, IT-5 and IT-6 also allow stakeholders to protect their interests. Rule IT-5 is an entry rule in the sense that it allows new actors to become participants. Under rule IT-2, those persons who accept the invitation to participate as experts on a subject share their knowledge on this subject with all participants.

4.3.3 Model transparency rules

MT-1 The stakeholders explain which phenomena in the socio-ecological system are of particular interest to them in such a manner that the modelers can assess whether, or to what degree of accuracy, these phenomena can be predicted by the model.

MT-2 The modelers explain the structure and parameters of the model, as well as the scenarios that are evaluated, in such a wat that the stakeholders can assess which phenomena in the system are represented in what detail and what this means for the uncertainties in the model output.

MT-3 The process manager maintains and shares an overview of the aspects that are known to be (not) represented by the model and clearly relates this to the information that has been identified (by rule IT-1) as relevant to some decision(s) on the agenda.

MT-4 When there are alternative models or alternative ways of representing an aspect in the model, the modelers communicate the options and their consequences in terms of what the model can and cannot do to the process manager. The process manager then adds choosing between these alternatives to the agenda as a procedural decision.

The model transparency rules follow the same principles as the information transparency rules, but expand them by making explicit the joint responsibility of modelers and stakeholders to make black box models more transparent.

4.3.4 Measure proposal rules

MP-1 The participants propose a measure first as a generic option, i.e. as a class of possible options, leaving design parameters and implementation details unspecified.

MP-2 When the effects of a generic option have been noted as uncertain, the modelers calculate these effects, using different scenarios to reveal the range of impacts of this class of options.

MP-3 The process manager communicates the results of this impact assessment to all participants. The stakeholders then express their opinion with regard to the option's desirability and feasibility. Under rule IT-2 and IT-3, the impact assessment results together with the stakeholder opinions are added to the information set.

MP-4 During formal meetings, participants refrain from discussing options for which the impacts are still being assessed.

The measure proposal rules mainly favor openness, substance and speed. From rule AM-2 (in combination with rule IT-2) it follows that participants can propose a new policy measure at any time in the process. Rule MP-2 mitigates the risk of losing time and resources on model exercises that are unlikely to produce relevant new information, while rule MP-4 aims to avoid losing time on premature discussions. The interaction between measure proposal rules and information transparency rules ensures the protection of core values (IT-4 provides guidance in the event that actors disagree on the option's effects). The agenda management rules give direction in case the impact assessment requires additional model development. They also guide the process of developing generic measures into more specific measures, because actors will not indicate near closure until information on the impacts of sufficiently detailed option variants is available.

4.3.5 The Bargerveen case study

As we explained earlier, the four sets of rules that we have just presented are the result of our reflection on the Bargerveen GGOR process in which we were involved as researchers and practitioners. In this subsection we present the water management issue and the stakeholders. In the following subsection we describe the process in sufficient detail to indicate where we observed the rules in action.

The Bargerveen area is situated at the border with Germany in the Dutch province of Drenthe. Its recent Natura 2000 status makes it a priority nature conservation area. The Dutch Ministry for Agriculture, Nature and Food Quality (*Landbouw, Natuurbeheer en Voedselkwaliteit*, or LNV for short) has formulated nature development objectives for the area (LNV 2006, LNV 2007), which contains a type of living high peat that is unique in Europe. The main objective is to increase the total area of high peat, which is currently declining. This requires the raising of the groundwater level, which will affect the water regime in the surrounding area.

The stakeholders in the area share a long history of negotiating over the water regime; they are collectively well organized. The last attempt to settle the water regime conflict, in 2001, resulted in an agreement for the north and west sides of Bargerveen, but failed for the south side. The German side (east) was not included. The Natura 2000 status of Bargerveen reopened the negotiations. The water board decided to restrict these new negotiations to the south and east sides, leaving the existing agreements in place.

Key actors in these new negotiations – the GGOR process – are the water board, the national nature conservation agency responsible for the operational management of Bargerveen (*Staatsbosbeheer*, or SBB for short) and the farmers whose lands will be affected by a change in water regime. These farmers are organized in a local chapter of the national agriculture and horticulture organization. The farms are mostly family businesses and the land is alternately used for intensive crop growing and dairy farming. The current water regime is already quite wet for this land use. The water regime conflict causes uncertainty for farm management and the farmers want clarity and action. They are apprehensive about getting involved in yet another indecisive negotiation process.

Additional stakeholders are the local residents and entrepreneurs, the neighboring municipalities and the German local water authorities. The GGOR is to be approved first by the board of directors of the water board, then by the province of Drenthe and ultimately by the LNV. All stakes are represented in the sounding board group (see Appendix 4.1).

4.3.6 Rules in action: the Bargerveen process, focusing on models and expertise

The GGOR project team (process manager, modelers and support staff) started the GGOR process in June 2006. We distinguish four phases in our description of this process. The first was the preparation phase, which ended with the establishment of the sounding board group in October 2006. The second phase, until April 2007, was aimed at the development of a joint knowledge base. During this phase the participants agreed on the reference water regimes AGOR (actual water regime) and OGOR (optimal water regime) for the primary interests of agriculture and nature. The remainder of the process, directed at defining the GGOR, can be roughly divided into two phases: selection of a model and identification of possible measures until November 2007 and assessment of these measures and the definition of a GGOR until April 2008.

During the preparation phase, the project team performed a stakeholder analysis (Bryson 2004) and developed a plan of approach for defining the GGOR for Bargerveen. The process manager presented this plan at the first sounding board group meeting (IT-3). She urged the participants to comment on the plan and on the composition of the sounding board group and to share any other information they considered relevant (IT-2). The farmers observed that the plan did not include defining the OGOR for the surrounding agricultural land and stressed the relevance of knowing the current deviation from the optimal water regime in order to realistically judge the consequences of new measures for agriculture (IT-1). The process manager proposed to let the project sponsor decide on this (AM-1) and the water board agreed to include this task in the plan (AM-3).

To develop a complete information base and determine the reference water regimes for nature and agriculture, the process manager organized bilateral meetings. The OGOR for an area depends on the land use. The project team suggested basing the land use in the agricultural area on satellite data from 2003 (IT-3). The farmers did not agree to this (IT-4), arguing that the land use varies each year and that the satellite data provided a random snapshot. They proposed basing the OGOR for agriculture on the most demanding land use instead (IT-1). This looked like a strategic move. When the water board professionals judged the resuling optimal water regime as too dry for agricultural purposes, the farmers appeared vague. In a second meeting they explained that they do have possibilities for local water buffering, but no means of coping with wet regimes. The project team accepted this argument (AM-1) and decided to follow the farmers' proposal (AM-3).

The definition of the OGOR for nature was hampered by many uncertainties (IT-4). The Natura 2000 objectives did not specify *where* in Bargerveen high peat growth should be realized and the optimal conditions for high peat development had not been determined (IT-4). The process manager consulted a team of experts identified by the SBB (IT-5). Despite differences of opinion, this team agreed on a best available expert opinion for the OGOR for nature (IT-6). They stressed that high peat is very particular and needs near optimal conditions to develop.

In the second sounding board meeting in April 2007 the process manager first shared the results of the bilateral meetings with the farmers and the SBB (IT-3). The optimal regimes for nature and agriculture differed widely: the OGOR for nature entailed an expected highest groundwater level (in winter and spring) for the agricultural area that was several meters above the 1.2m below ground surface that was considered optimal by the farmers. Neither OGOR came close to the water regime then in practice (AGOR). The process manager then opened the discussion, by pointing out that Bargerveen's nature would only benefit from a drastic change in water regime – too drastic for the water board to decide upon, because the options were either to do nothing and accept a degradation of the peat vegetation or to create a hydrological buffer zone around Bargerveen at the expense of agricultural activities. The process manager proposed to leave this decision to the province and the LNV (AM-1), since they have the ability to either change the nature objectives or authorize a change in land use and finance a buffer zone. The participants did not agree with this strategy, arguing that the available information did not warrant this step (AM-2). The farmers feared that decisions would be taken without sufficient consideration for their stake. The SBB wanted more information about the effects of measures and there was no consensus about the effect of a buffer zone (IT-1).

This conclusion of the sounding board group meeting called for a decision about additional analysis (AM-4). The executive board of the water board did not want a costly modeling exercise. They felt that sufficient information was available from past studies and aimed for a fundamental political decision by the province and LNV. The farmers were not interested in another model study; they just wanted clarity on the prospect of the continuation of their farms. The SBB, however, was keen on accurate model calculations, as they feared ending up with a buffer zone that would not produce the conditions for high peat growth.

The available models were MIPWA (Berendrecht et al. 2007) and Microfem (Hemker et al. 2004). The modelers suggested using MIPWA to explore the effects of measures. This model was especially designed to support GGOR processes in the northern part of the Netherlands and was co-financed by the water board. The Microfem model, tailored for the Bargerveen area but for a different type of calculations, was considered inadequate (MT-4). The project team started to prepare MIPWA for calculations – without the explicit approval of the project sponsor – to produce quick results and show the benefit of the calculations to the project sponsor and participants. However, the modelers soon identified serious shortcomings in the model. Enhancement would take at least a year.

At that moment the project sponsor stalled the process for strategic and financial reasons (seizing the role of process manager in AM-1). Before allocating money for model enhancement and calculations, the water board wanted to know whether the province was willing to support and finance a buffer zone at all. Its principal contacted the provincial executive in October 2007, which then requested information about whether a buffer zone would be effective enough to warrant the significant costs of this type of measure (IT-1). Sensitive to the argument that time and resources for obtaining detailed information were lacking, the provincial executive agreed to base the decision on the best possible prediction using the available models (MT-1). As MIPWA's shortcomings precluded calculations of any accuracy, the hydrologists re-evaluated the Microfem model and concluded that it could give a rough indication of the effectiveness of the buffer zone (MT-4). The executive board of the water board decided to finance the application of this model (AM-3).

This initiated a series of model-related activities and decisions. The process manager and modelers discussed with the stakeholders how best to develop information for the provincial executive. The process manager decided to evaluate the effects of buffer zones of various types and sizes (MP-1). She argued that information about the possible range of impacts of the buffer zone would give more direction to the discussion about its feasibility and desirability (MP-2). The stakeholders found it odd to spend resources on the exploration of a measure without first discussing the feasibility and desirability of the implementation details, but went along (MP-4).

The process manager organized meetings with each of the key stakeholders and with the provincial representative in the sounding board group to discuss the intermediate model results (MP-3). During these meetings the modelers explained the structure and parameters of the model, as well as the scenarios evaluated. They presented the model outputs visually, with maps that showed the predicted groundwater level related to the two OGORs (MT-2). During these meetings, the process manager stressed the limitations of the model and urged the participants to make clear what in their opinion could be decided on the basis of the Microfem model (MT-3). The SBB initially opposed using the rough Microfem model. They critically assessed the model and the scenarios evaluated, proposed some changes, but then agreed to its use to determine the order of magnitude of the effects of a buffer zone. The farmers proposed additional scenarios to evaluate the effects of the agriculture OGOR on Bargerveen, to which the process manager agreed. Furthermore, they communicated that they were not only interested in water levels, but also in the drainage possibilities for wet parcels (MT-1). Both the SBB and the farmers insisted that the process manager should explain to the province not only the calculated effects, but also the opinions that they, as stakeholders, had given on these effects (MP-3).

The farmers also proposed to evaluating an alternative option: putting an impervious screen in the subsoil between Bargerveen and the agricultural land (MP-1). The hydrologists explained that the effectiveness of this measure could not really be evaluated ex ante. Such a screen must be placed on a entirely impervious boulder clay layer. Complete knowledge of the boulder clay layer is impossible to obtain, which implies a high risk that the measure would be ineffective. However, the farmers had found an expert with a different opinion (IT-4, IT-5). The process manager asked the experts to discuss their difference of opinion, after which they agreed that the effectiveness of an impervious screen was very uncertain (IT-6).

The Microfem model calculations showed that a buffer zone on the south side of the Bargerveen of at least 500 meters wide would be reasonably effective. Based on this information, the province gave the green light for negotiations about a buffer zone to start in February 2008 (AM-3). A final sounding board group meeting was called in April 2008 to in principle agree on a GGOR. This GGOR – in principle because the funding had not been confired yet – comprised a 500-meter-wide buffer zone along two-thirds of the south border of Bargerveen plus measures to compensate the other stakes. Prior to the meeting the director of the SBB had personally given his approval for this GGOR and both the province and the LNV had committed themselves to finding the financial resources.

During this final meeting the farmers restated their willingness to consolidate and sell land, in return for complete financial compensation and near-optimal circumstances for the remaining agricultural land (MP-3). The participants were about to declare near closure (AM-2) for the GGOR on condition that funding would be found, but then an influential expert of the SBB mentioned that the SBB still had objections to the GGOR, which they would put forward after the meeting (MP-3). The farmers instantly flew into a rage and voiced their distrust of the SBB; in the earlier negotiating round in 2001 the SBB had made a similar move, rejecting an agreement at the last moment. The process manager reacted firmly, recalling the approval of the SBB director, and emphasizing that the expert had to share any new information or considerations during the meeting and not afterwards (IT-2). It appeared that, possibly due to poor internal communication within the SBB, the expert was still looking for negotiation space. The SBB manager present at the meeting hastened to confirm that the SBB agreed to the GGOR and no new information was brought forward.

The water board, LNV, the province of Drenthe and the SBB signed a formal agreement on the GGOR-in-principle (pending the funding) for Bargerveen and its surrounding area in October 2008. Subsequently the GGOR was formally approved by the provincial council and in May 2009 the complete plan, with a total budget of 20 million euros, was ratified by the general board of Velt en Vecht (Velt en Vecht 2009). As a first step towards its implementation a detailed water management plan is presently being elaborated for the agricultural area south of Bargerveen.

4.4 DISCUSSION

Having presented the ‘rules of the game’ for a model-informed participatory policy process and having shown how we observed these rules in action in the Bargerveen GGOR process, we will address the following questions:

- What is new, or more specifically, how do our rules of the games differ from guidelines and rules that have been reported previously on this topic?
- What factors ensure that these rules will effectively steer participant behavior?
- Related to the previous question, will these rules work in other contexts?

- What is the contribution of this research to the management of water resources and associated socio-ecological systems?

4.4.1 Comparison with other guidelines and rules

Guidelines for model development and use in policy processes (Smith Korfmacher 2001, Caminiti 2004, Karas 2004, Voinov and Brown Gaddis 2008) emphasize good and continuous communication between modelers and other participants about what the model preferably should be able to do (from the participants' perspectives) and what it actually can do (from the modelers' perspective). Our rules of the game that relate specifically to the use of models (the sets MT and MP) do not go far beyond this norm. But guidelines per se are difficult to put into practice. What we see as a distinctive feature of our model transparency and measure proposal rules is that they become meaningful and practical because they are imbedded in other, more general, rules for agenda management and information transparency. Thus our rules of the game are more than guidelines; the set as a whole constitutes a coherent system that covers the use of information and models in a participatory policy process.

Our rules of the game are conceptually similar to the rules in the Institutional Analysis and Development (IAD) framework (Ostrom 1999). Nevertheless, they do not easily fit within the seven broad types of rule of this framework. Although the participant roles we defined can be seen as *position* rules that describe the positions or roles that actors can take, we do not specify *boundary* rules that determine how actors can change their position. When our rules of the game set out by whom decisions are made, these can be seen as *authority* rules, but we define no *aggregation* rules that, for example, say that a majority of participants suffices when determining whether a decision on the agenda is near closure. We do not indicate *scope* rules that establish the set of outcomes that can be affected by decisions, nor do we list *payoff* rules that detail how costs and benefits are allocated when a final decision has been made. Finally, we do not give *information* rules that define the information available to actors in specific positions. Instead, all of our rules of the game are based on a single, implicit information rule: all information is to be available to all participants, regardless of their position.

We see the incongruence between the seven IAD rule types and our rules of the game as the result of a difference in focus. Within the IAD framework the rules pertain to the utilization and management of a common pool resource, whereas our rules of the game concern the organization of a policy process. Ostrom et al. (1994) point out that a set of rules will always be nested in another set of rules that details how and by whom rules can be changed, so our rules of the game could be seen as this other set. Still, the relation between these sets is elusive and merits analysis.

4.4.2 Conditions for effectiveness

Clearly, rules will be effective only when the actors concerned know the rules and are capable of applying them. In the Bargerveen case the decision-making responsibilities of the government agencies at different levels were formally established in planning procedures. Nevertheless, the process manager put continuous effort into clarifying these formal institutions to the participants. Although the participants were already familiar with the informal institution of a sounding board group, the purpose of such a group and the roles of its members were also made explicit. This essentially corresponded to what we have identified as information transparency rules (IT-1 through IT-6).

To fulfill her pivotal role in the process, the process manager must have a clear mandate from the process sponsor and also from the other participants (Webler 1995; Reuzel et al. 2007). The role requires special abilities: some knowledge of the topic under discussion (in our case hydrology and modeling), the capacity to synthesize and summarize information and track down external information referred to by participants and above all the ability to proceed firmly and consistently by the rules, explaining and providing motivation for decisions, and to call out of order those who do not observe the rules, regardless of their position.

The process sponsor should commit to the process, but preferably have and retain the formal authority to decide unilaterally in case of process failure (De Bruijn et al. 2002). Such an overruling decision then becomes the default or else for the rules of the game and the process manager can make this explicit if participants cannot be held to the rules by reasoning. The process sponsor should also be open about time and budget constraints, as otherwise the process manager cannot properly apply rule AM-1.

Our model transparency rules focus on establishing what part of the information need the model can satisfy. Similar to the guidelines proposed by Karas (2004) and Caminiti (2004), our rules implicitly assume that the modelers have adequate knowledge and skills, adhere to professional standards (Refgaard et al. 2005, Jakeman et al. 2006) and – even more importantly – are aware of their limitations in these respects.

To sum up, the effectiveness of our rules of the game largely depends on whether participants have the competencies their role(s) require.

4.4.3 ‘Transplantability’

We expect that in model-informed participatory policy processes our explicit set of rules of the game can help to structure the interaction between actors and thereby enable effective participation. How much it will help will depend on scale and context. The Bargerveen GGOR had a local character, but even so the sounding board group had more than 30 members. Adequate stakeholder representation for controversial water management issues on a regional or national scale will lead to several times this number. The information processing capacity required will rise with the number of participants. The capability of the process manager may be increased by forming a project team, but participants may soon find rules AM-2 and IT-4 too demanding to comply with. To avoid this, special support is needed (Enserink and Monnikhof 2003).

Formal and informal institutions are closely related to national culture (De Jong et al. 2002). Hofstede (1983) has shown how national cultures and the related formal and informal institutions that embody them differ along four dimensions: individualism, power distance, uncertainty avoidance, and masculinity. The existence of different national cultures implies that the rules of the game that we have defined may be tailored to the Dutch institutional context. The Dutch tradition of collaborative decision making reflects its culture, with high individualism, short power distance, weak uncertainty avoidance and low masculinity index values. The same rules may not function in a culture with different index values for Hofstede's dimensions. The agenda management and information transparency rules favor an egalitarian process (short power distance) in which participants must feel free to defend their opinions (high individualism) without trying to stand out or dominate (low masculinity). Such rules may be difficult to implement in countries with great power distance (e.g. Belgium or France) or high masculinity (e.g. Germany or the US). Moreover, De Jong (2004) makes clear that transplantation of institutions from one context to another is difficult, even when the contexts have very similar institutional characteristics.

The effectiveness of rules of the game will also depend on the stability of the institutional context. As Klijn (2001) puts it, rules "only continue to exist if they are continually (re)affirmed by actors either overtly or tacitly". Our rules worked well in a policy process that was legitimized by a formal institution (the GGOR procedure), with participants who were very familiar with policy negotiations. The rules of the game we have defined were effective in the Bargerveen GGOR process because most were already part of the informal institutions and hence implicitly known to, and accepted by, the participants. In less stable institutional contexts (for example without a formal procedure embedded in legislation, or when informal institutions for policy negotiations are lacking or favor confrontational behavior), rules need to be negotiated by the actors themselves (Ostrom 1990, Webler 1995, Ehrmann and Stinson 1999, Hajer 2003).

4.4.4 Contribution to the field

The Bargerveen case has shown the value of a deliberate implementation of an institutional design such as the GGOR procedure in finding ways to protect a vulnerable ecosystem while respecting the socio-economic interests of the stakeholders. We believe that the results of our reflection on this case may help to improve the management of water resources and their associated socio-ecological systems on two levels.

On a practical level, the rules of the game that we propose provide a detailed and yet general description of a code of conduct that may serve as a model for future participatory processes – not as a prescription to be followed indiscriminately, but as a 'boundary object' (Star and Griesemer 1989): the rules and their vocabulary (the concepts presented in the Methods section and depicted in Figure 4.1) may serve as an ideal type of a model-informed participatory policy process. Presenting them as a template in the process design phase will stimulate discussion about what is 'proper behavior' for each actor role and also about the competences required for each role. This discussion will heighten the participants' awareness of the important role of these soft institutions in establishing a fair and transparent process and in determining the quality of information and the capabilities and limitations of models. This same discussion will help the process manager take into account the caveats concerning conditions for effectiveness and transplantability.

On a methodological level, we have shown how the ADICO syntax for rules proposed by Crawford and Ostrom (1995) can be used, in combination with a conceptual model of a participatory process, to represent on a detailed level the informal institutions that underlie such a process. Model and rules may help structure future research. We speculate that the rules we have defined for agenda management and information transparency will apply to a wide range of cases and may be used as a coding scheme for qualitative analysis and cross-case comparison of process designs and their implementation. One aspect that could be investigated in more detail would be the relative importance of process design and the level of competence of participants in the role(s) they perform.

4.5 CONCLUSION

The particular way in which existing hydrological models were challenged and nevertheless used in the successful participatory development of a water management plan in the Netherlands drove us to analyze the code of conduct of participants' interaction. This has resulted in a coherent system of 'rules of the game' to guide the interaction in model-informed participatory policy processes. Compared to the situation-specific rules (i.e. plans, policies, institutions) for collaborative resource management that are more commonly discussed in the literature, the rules of the game we propose are meta-rules, as they address the *organization of a process* for developing such plans, policies or institutions.

We have structured our rules of the game in four sets. The first two sets comprise general rules for agenda management and information sharing, based on the notion of 'fair and competent process' as reported in the literature. The other two sets comprise more specific rules for using models and proposing policy measures. The rules complement existing (modeling) guidelines, because they define how to integrate models and information procedurally in the process. They make explicit a framework of informal institutions favorable to the joint development of 'best' knowledge and to a constructive discussion on model limitations. The focus on fair process and transparency of model-based analysis enhances the trust-building mechanism that is needed to compensate for the intrinsic black box character of an existing model.

We recognize that the applicability and effectiveness of the proposed rules will depend on the context of formal and informal institutions already in place. Nevertheless, we contend that the rules provide a useful reference model to support discussion while designing and managing model-informed participatory policy processes. As our set of rules of the game also proved useful as a coding scheme for ex post analysis of a water management policy process, we speculate that the rule-centered language and approach taken in this research will facilitate detailed cross-case comparison of process designs.

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APPENDIX 4.1: COMPOSITION OF THE ‘SOUNDING BOARD GROUP’ FOR THE BARGERVEEN GGOR PROCESS

The sounding board group consisted in total of 30 delegates. The represented organizations are listed below, the figures in parentheses indicating the number of delegates from an organization.

Governmental organizations

Ministry of Agriculture, Nature and Food Quality
- Directorate of Regional Affairs North (2)
- Agency for Rural Development (1)

Province of Drenthe (2)

Municipality of Emmen (1)

Municipality of Twist, Germany (1)

Water board Velt en Vecht (1 board member + 2 staff members not on the project team)

Non-governmental organizations

SBB – Staatsbosbeheer, region North (4)

LTO – National agriculture and horticulture organization
- region North (3)
- local chapters (of region North) for Schoonebeek and Emmen-Oost (3)

Land division advisory committees for Schoonebeek and Emmen-Zuid (3)

Village council of Zwartemeer (1)

Village council of Weiteveen (1)

Farm owners on the south border of Bargerveen (3)

Commercial enterprises

Firma Griendtsveen – trader in soil (1)

NAM – subsidiary of Shell (1)

5 Managing systems under uncertainty: an elaboration of the contrast between a resilience and a control rationale with application to flood management[4]

Abstract
We contrast two policy rationales to manage uncertainty: system control and system resilience. The first focuses on predictability of the system in times of stability, the second on avoiding system collapse in times of change and surprise. These rationales support different system attributes. The two related schools of thought promote their own legitimacy, but provide little effort to connect to each other. We argue that such a connection, showing merits and trade-offs, is essential for a well founded choice by policy analysts and decision makers. Based on a literature review, we developed a list of contrasting system attributes for control and resilience. Next, we applied the list to a case of flood management in the Netherlands to test its usability in evaluating policy strategies and visualizing trade-offs. The analysis revealed typical policy strategies for resilience and for control, but also provided the subtle distinction making it possible to uncover strategies with elements of both rationales. Current Dutch flood management aims at developing resilience without relinquishing control, by allowing variability between strictly controlled boundaries. This development of resilience in a dominant control rationale is limited to a maximum. We see experiments and discussion in the Dutch policy arena which focus on increasing both control and resilience. We argue that it is difficult, if not impossible, to make these two trends compatible. The framework developed in this article facilitates discussion on the type of uncertainty management desired and its related policy strategies.

5.1 INTRODUCTION

The policy strategies used to manage a social-ecological system influence the response of that system to uncertainty. In this article we contrast two policy rationales that differ in their approach towards uncertainty: system control and system resilience (cf. Walker and Salt 2006, Wardekker et al. 2009). Uncertainty refers to the absence of complete and shared understanding of a system to be managed (definition adapted from Brugnach et al. 2008). Actors may be aware of uncertainty, having an approximate or relatively precise idea of the range of uncertain conditions, or system behavior may surprise them (Holling 1986).

The system control rationale aims at increased system predictability by exerting control over uncertain variables. In this rationale the reduction of uncertainty serves to improve the functioning of the system (Blanchard 2006). This approach became popular after successful interventions in military operations in the World Wars based on operations research theory, which was paralleled by the development of management science in economics (Simon 1978). The scope of application rapidly expanded to all types of systems (Miser and Quade 1988). The approach has matured in fields such as policy or decision analysis (Dunn 2008)

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and systems engineering (Blanchard 2006). A typical system control strategy in flood management is embankment, which reduces the uncertainty of flooding in the embanked area and therefore enables a more efficient use of land. The system control rationale prepares for recognized uncertainty and increases benefits under stable conditions (Walker et al. 2002). At the same time, the approach tends to reduce the system's potential to respond to unexpected events, while these occur more often due to alteration of system dynamics (Beck 1999, Davidson-Hunt and Berkes 2003).

The system resilience rationale aims to mitigate consequences of uncertainty to prevent system collapse into an undesired state (also called basin of attraction (Holling 1973)). The rationale focuses on backup mechanisms and quick adaptation, in the expectation of change and surprise (Walker 2006). It starts with the notion that knowledge is inevitably incomplete, surprises are more rule than exception, and attempts to control the system are bound to have unintended consequences. System resilience reflects the magnitude of disturbance that can be absorbed or buffered without the system undergoing fundamental changes in its characteristics (Carpenter et al. 2001, Berkes et al. 2003). Holling (1973) introduced the concept in ecology. Walker and Salt (2006) distinguish between specified and general resilience. Specified resilience relates to key variables, the resilience 'of what, to what' (e.g. the resilience of an area to flooding). General resilience does not consider any particular kind of shock or any particular aspect of the system that might be affected. In our spectrum of dealing with uncertainty, system control and general system resilience are opposites. A resilient flood policy would include multiple complementary strategies, such as evacuation plans, low-damage spatial planning and (limited) embankment. System resilience provides a safety net for the possibility of the system collapsing into a qualitatively different state, but decreases the efficiency of the performance of core activities and the reaction to expected disturbances.

The system requirements for resilience and control differ. The necessity of managing the system both for unforeseeable change and for performance in time of stability is explicitly discussed by Walker et al. (2002) and Aerts et al. (2008). At the same time, resilience scholars refer to system control mainly to point out failure of its practices (Holling and Meffe 1996, Berkes et al. 2003). Conversely, the mainstream policy and uncertainty analysis literature pays limited attention to concepts of resilience (Morgan and Henrion 1990, Dunn 2008). The aim of this article is to explicitly contrast the preferred system attributes for both rationales, to facilitate the discussion and provide a tool for the evaluation of policy strategies. To do this, we develop a list of contrasting system attributes in the next section. We apply this list to a case of flood management in the Netherlands to reflect on the usability of the contrast and take it to the level of policy strategies and their trade-offs.

5.2 SYSTEM ATTRIBUTES OF RESILIENCE AND CONTROL

5.2.1 List of contrasting system attributes

The resilience literature discusses several system attributes that are beneficial to resilience. The insight is based on a growing number of case studies. There is no agreed list of attributes, since understanding is still being developed and authors emphasize different aspects based on their own perspective. Walker and Salt (2006), Levin (1999) and the Resilience Alliance (‘Assessing resilience in social-ecological systems – A workbook for scientists’ and the module on ‘Specified and General Resilience’, see http://www.resalliance.org, January 2010) seek to present attributes that make sense to both natural and social scientists. Their lists have three attributes in common that play an important role in maintaining general resilience (Walker and Salt 2006): diversity, modularity and tightness of feedbacks. We find a different list of six system design principles ecological and systems dynamics literature (Wildavsky 1988, Barnett 2003). On closer inspection, however, this list differs mainly in terminology and the principles are similar to the ones incorporated in the references above.

We favor a relatively short list in which similar attributes are clustered, to facilitate the contrast of rationales and the analysis of policy strategies. The three attributes diversity, modularity and tightness of feedbacks provide the basis, but we feel these do not cover some essential attributes we found in the other references. Therefore, we have added the attributes reserves and innovation. An overview of the clusters is provided in Table 5.1. We give our motivation and an explanation in the next subsection. We do not claim that our interpretation is the only one possible, but we think it largely covers the important attributes discussed in the literature.

We did not find a list of preferred attributes for system control and many authors implicitly take its preferred attributes as a point of departure. The resilience scholars Anderies et al. (2006) provide considerable detail on the background and features of control and mention the attributes top-down management and optimization. The control of systems was originally based on the positivist idea of a predictable system and rational actors. These ideas have been replaced in most contemporary literature, but optimization (in some form) remains at the core of the rationale, which makes it different from the resilience rationale (Anderies et al. 2006, Walker and Salt 2006). The systems engineering literature explicitly discusses system optimization (also for natural systems) as a method to minimize disturbance by its environment (Blanchard and Fabrycky 2006). In policy analysis and optimal resource management literature, a range of optimization techniques is discussed based on the fields of optimal control, management science and economics (Clark 1976, Simon 1978, Dunn 2008). Weber (1949) discusses optimization in governance in the form of bureaucracy: centralization of government (top-down), high formalization of jobs and clear regulations.

We formulate the control attributes to represent counterparts of those of resilience. The main attributes we define are optimization, connected systems and focused feedback. Secondary features, which appear more as a consequence of the main attributes, are intensification and improvement. An overview is provided in Table 5.1 and we give an explanation of these concepts in the next subsection.

The list of attributes in Table 5.1 is meant as a tool to identify changes in system resilience or control as a consequence of policy. We do not intend to assess the state of the system with respect to its resilience or control, which (for resilience) is the aim of a large part of resilience literature (Carpenter et al. 2001, Walker et al. 2009). Assessment of resilience of a specific system to a specific disturbance requires detailed insight into thresholds for a system shift to another basin of attraction and the position of the system in relation to these thresholds. Another part of resilience literature aims at determining research requirements to assess resilience, such as covering different scales and an emphasis on trends for slow variables. Such preferences affect policy on monitoring and research and are therefore indirectly reflected in our system attributes.

Table 5.1 Preferred system attributes in a resilience and a control rationale

	RESILIENCE	**CONTROL**
	Diversification	**Optimization**
Response strategy	Complementary strategies	Best strategy
Governmental responsibility	Overlap in tasks	Sharp division of tasks
Attitude towards variability	Value variability	Reduce variability
Natural variability	'Living with' dynamics	Restrict dynamics
Social variability	Regulation fit to context	Limit actor behavior
	Reserves	**Intensification**
Resource allocation	Over-dimensioning	Economical allocation
System exploitation	Extensive use	Multifunctional use
	Modular-connected system	**Connected system**
Physical connectedness	Loosely connected areas	Single scale intervention
System coordination	Decentralized responsibilities	Central regulation
	Adaptive feedback	**Focused feedback**
Consultative structures	Context-dependent structures	Established structures
Social capital	Stakeholder involvement	Small circle engagement
Information	Monitoring change	Monitoring states
	Innovation	**Improvement**
Policy adjustment	Revision of policy	Refinement of policy
Attitude towards flexibility	Flexibility essential	Efficiency-oriented
Function of experiments	Find alternative strategies	Increase yield

5.2.2 Elaboration of the list of attributes

Diversification versus optimization

In a diversified system multiple elements contribute to the same function, while these elements respond to change and disturbance in a different way (Walker and Salt 2006). Diversity enables the system to function under a wider range of conditions. We found several forms of diversification discussed in resilience literature. Walker and Salt (2006) discuss diversification of response strategies in general, whereas Aerts et al. (2008) specifically discuss complementarity of policy strategies. For governmental responsibility, Low et al. (2003) and Walker and Salt (2006) argue that an overlap facilitates response to a wider range of disturbances. A large part of the discussion focuses on variability, which we see as diversity in occurring events. The presence of variability has a stimulating effect on diversity in system response. Therefore, natural and social variability is highly appreciated in a resilience rationale (King 1995, Holling and Meffe 1996).

An optimized system carries out the system functions in the best (or most efficient) way. Optimization targets a single strategy or a limited set of strategies to work cost-effectively based on detailed system knowledge. The focus on a limited set of strategies increases surveyability and therefore control. For government, the sharp division of responsibilities facilitates control (Weber 1949). This sharp division does not necessarily exclude the overlap advocated in a resilience rationale. Variability is seen as a disturbance of control and should preferably be reduced (Holling and Meffe 1996, Blanchard and Fabrycky 2006).

Reserves versus intensification

Reserves are identical system elements that are redundant under expected conditions and therefore create buffer capacity to cope with change and surprise. We distinguish these identical system elements from diversity (or similar system elements, see also Low et al. 2003 and Resilience Alliance 2010 online), based on their different functions in case of surprises. We discern between reserves in use and reserves not in use during expected circumstances (Low et al. 2003). Reserves in use are the result of extensive use of resources, such as limited use of flood zones for other functions, for example agriculture. Reserves not in use point to over-dimensioning, such as reserving ample land for flood management.

An intensified system has limited reserves to benefit maximally from system resources. Reserves are limited to situations where reliability of elements is critically important (Blanchard and Fabrycky 2006). The efficiency of resource use is high in case of economical and multifunctional use of resources. For flood policy we find examples such as sophisticated dike constructions and the use of dikes for the production of other benefits, such as power generation. System intensification is a logical step after system optimization has removed disturbances and it leads to the concentration of resources (Davidson-Hunt and Berkes 2003).

Modular-connected versus connected systems

A modular system consists of subcomponents that are (partly) independent, while a connected system has strong links between areas. Over-connected systems rapidly transmit shocks through the system, making them susceptible to disturbances with considerable consequences. On the other hand, highly modular systems become isolated, which means a trade-off for feedbacks, innovation and possibility for migration in case of surprise. Therefore modularity needs to be balanced with connectedness (or openness) to contribute to resilience (Resilience Alliance 2010 online). Levin (2008) discusses modularity in space and organization. Modularity in space includes the presence of physical compartments and refuge possibilities. Modularity in organization refers to decentralization and self-organization. Important elements for connectedness are the physical links between areas, actor mobility (Adger 2000) and having overlapping units of governance in place (Low et al. 2003).

A control rationale prefers a connected system, to enable direct influence on the whole system. The focus is on larger-scale structures as a barrier against outside forces, due to their surveyability and optimal cost-benefit ratio (Fiering 1982). Furthermore, the focus on disturbance control decreases the importance assigned to modularity. Centralization is favored for efficiency of control (Weber 1949, Janssen et al. 2006), while standardization and formalization mean fewer errors will be made (Weber 1949), although it is more susceptible to larger errors (Gunderson et al. 1995).

Adaptive versus focused feedback structures

Adaptive feedback structures easily adjust to the context and therefore allow a quick notification of and response to disturbances and change, limiting adverse consequences and increasing resilience (Walker and Salt 2006). At least three factors influence the system feedback, the first being the consultative structures. Adaptive feedback benefits from decentralization (see modularity), which increases connectedness within modules and shortens and strengthens feedback in case of surprise (Davidson-Hunt and Berkes 2003, Wardekker et al. 2009). For the system as a whole, the availability of (sleeper) connections between modules promotes adaptive feedback (Nahapiet and Ghoshal 1998, Janssen et al. 2006). These connections develop with consultation into changing, context-dependent configurations. Second, actor involvement influences feedback. A resilience rationale prefers inclusion of stakeholders and their social capital in the network, which facilitates the response to disturbances and change (Lebel et al. 2006). To benefit from a network linkage there has to be some trust, development of leadership and shared systems of meaning (Nahapiet and Ghoshal 1998, Adger 2003). These evolve through actor interaction and require effort for large networks. A downside of stakeholder involvement is the difficulty of generating action in larger groups. Third, feedback is influenced by the available information. A resilience rationale focuses on detecting change and disturbance, such as sea level rise, by monitoring so-called slow variables (Walker and Salt 2006).

Focused feedback structures are tuned to work very efficiently under specific conditions. This type of feedback benefits from established consultation between a limited number of actors, which exerts a positive influence on group performance (Weber 1949, Nahapiet and Ghoshal 1998). On the other hand, it limits openness to social capital from outside the network addressed, in terms of information and other ways of doing things. Just as with the resilience rationale, the control rationale values a good information infrastructure within the system.

The difference is the actor involvement in information development and sharing and the type of information aimed for in monitoring. For control, monitoring is often concerned with goal achievement and guarding current system functioning (Holling and Meffe 1996).

Innovation versus improvement
Innovation refers to developing new ways of doing things (Walker and Salt 2006). This cluster of attributes specifically focuses on the capacity to create a fundamentally new system when change and surprise result in an undesirable regime. This focus on longer-term adaptation is referred to as transformability in Walker et al. (2004). The innovation in a system is stimulated by revision of policy objectives, research aimed at second order learning and experimenting to test alternative strategies. In addition, a preference for policy strategies flexible enough for future revision facilitates innovation (Holling 1978).

Improvement refers to enhancement of existing strategies. The aim of improvement is to refine policy, mostly by intensifying resource use and/or a specialization in actors' tasks, in order to compensate for a changing environments or further increase a system's yield (Larkin 1977). The incentive to innovate in a control rationale has been largely removed because of the best strategies and reduction of disturbance mindset (Thompson 1965, Walker and Salt 2006). Therefore, the rationale is not concerned with flexibility regarding policy revision, while Weber (1949) already recognized the difficulty of reversing implemented control.

5.3 CASE STUDY

The conceptual contrast between attributes of resilience and control is interesting in itself, but a second step is to test the applicability of the list and the potential insight it provides on the level of policy strategies. We analyze two policy documents of Dutch flood policy. Historically Dutch flood policy has been dominated by control, while more recently it has adopted elements of resilience (Aerts et al. 2008, Wardekker et al. 2009). We analyze a more control-oriented and a more resilience-oriented policy.

The control-oriented Deltaplan (Maris 1961) was developed as a reaction to a large flood event in 1953 that inundated the southwest Netherlands and caused many casualties. After the flood, there was a general feeling of inadequacy regarding flood management. The government made considerable resources available and set up a 'Delta Commission' to advise on a new policy. The commission recommended improving embankment. First, tidal inlets in the southwest of the Netherlands were to be closed to reduce the length of primary defense system required. Second, the dikes along the remainder of the coastline should be heightened. The national government approved the report as an official policy document. The suggested defense structures were built between 1955 and 1986. This line of policy has been dominant until the 1990s.

The National Water Plan (Stumpe 2009) draws on the report of a second Delta Commission (Deltacommissie 2008) and is somewhat more resilience oriented. The commission was set up to advise on long-term sustainable water management in the Netherlands under climate change. It made recommendations on preferred system design and governmental embedding of the water policy. The government agreed to the recommendations and incorporated them in the National Water Plan (NWP) for the period 2009-2015. The NWP continues the line of policy initiated in the 1990s, when policy documents began to recognize the importance of 'going with the flow' of natural dynamics.

5.3.1 Data collection

The two policy documents discuss several aspects of water management, but we focus our analysis on policy strategies related to flood management. First we studied the points of departure formulated and the underlying arguments used in the documents. Second, we coded the complete documents in a search for policy strategies that influence one or more of the system attributes in Table 5.1. The first author carried out the initial coding, after which all authors discussed the results.

5.4 RESULTS

Tables 5.2 and 5.3 provide an overview of the analysis of the policy documents. In this section we present the line of reasoning in each document, followed by a summary of the analysis and specific observations.

5.4.1 Deltaplan

Further flooding was judged 'unacceptable' in the Deltaplan and the focus is on preventing it. On the other hand, the commission realized that absolute safety regarding a natural phenomenon cannot be achieved. The main question in the document is the dike height required to offer a sufficiently high degree of safety. The commission prescribed safety norms and designed guidelines for the coastal defenses. The norms were based on a worst case scenario of the conditions that occurred in 1953. Statistical extrapolation of historical floods showed that this scenario would occur approximately once every 10,000 years. The commission demonstrated that the costs of defenses required to withstand such a flood are justifiable. For more scarcely populated areas the safety norm was lowered to defenses able to withstand a flood such as might occur every 4000 years. The commission recognized the uncertain character of the analysis. However, they assumed that the constructions themselves would not fail and would suffice until the year 2000. The line of reasoning shows the dominance of the control rationale.

The analysis in Table 5.2 confirms this dominance. The Deltaplan strongly reduces natural dynamics and focuses on a single best policy strategy. Flexibility to revise the strategy was not considered. The commission foresaw unfavorable erosion caused by changes in sediment transport after tidal basin closure. This was accepted and compensating for it was anticipated. Other unfavorable side effects were expected, but were not known at the time (the greatest surprise was the algal bloom in the former tidal basins). Monitoring in the Deltaplan is largely focused on improvement of the strategy. The plan has only a few recommendations for the way the government should organize the water management. It advocates uniformity of water management and strict regulation of the defense systems.

The Deltaplan also shows elements of resilience for three attributes. To start with, the commission argued for reserves. They preferred relatively extensive use of the water system and defenses, emphasizing their primary flood function. Also, the safety norm for coastal defenses – which is chosen on the cautious side – arguably provides over-dimensioning. Second, the policy balances modularity and connectedness. On the one hand the introduced defense system interconnects the coastal area and so reduces resilience, but this is compensated for by increased compartmentalization of the hinterland. Also, flood safety coordination is transferred to the national level, while most of the management remains at the regional and local levels as before the flood of 1953. Finally, the monitoring includes several slowly changing variables.

5.4.2 National Water Plan

The line of reasoning of the NWP has changed compared to the Deltaplan, but the document keeps the safety norms as the point of departure for flood policy. The NWP recognizes the importance of facilitating natural processes, rather than adapting the water system to our needs. "Natural processes have a built-in resistance to disturbance and a certain extent of resilience." The break in trends is meant to decrease dependence on technique and vulnerability to changing circumstances. The plan explores change in the form of scenarios and trends, where climate change especially is recognized as a large uncertainty. The recognition that embankment will never offer absolute safety initiated a search for complementary strategies to mitigate the consequences of flooding, such as spatial planning and disaster control.

The analysis in Table 5.3 confirms the balance between resilience and control. We see a continuation of the control initiated in the Deltaplan, but also an appreciation of strategies allowing dynamics and flexibility to adaptation. To start with, the NWP prefers flexible dunes to hard defenses. Dynamics in dune growth are allowed within strict limits. Next, the plan reserves land for future flood management, justified by the specific threat of climate change. On the other hand, advocating multifunctional land use and win-win situations for water management plans reduces reserves. Furthermore, the Deltaplan's trend towards centralization is changed to one towards decentralization. We see a stimulation of regional responsibility, bottom-up policy development and local planning. The flood policy is the responsibility of local, regional and national government, in which the national framework is leading. Stakeholders are involved in planning and information exchange, consultation between actors takes place on multiple levels and consortia and forums stimulate new network contacts. In addition we see experiments and research focused on alternative strategies. However, the main focus of research is on improvement of strategies. Finally, the plan argues for a revision of existing land use at locations where maintenance of the status quo is costly.

Table 5.2 Policy strategies contributing to resilience and control in the Deltaplan. The table indicates the dominant rationale for each system attribute (control, resilience or a balance between control and resilience) and specifies the relevant policy strategies.

DELTAPLAN		**General**	**Resilience**	**Control**
Diversification-optimization	Response strategy	Control dominant	Complementary strategies of minor importance	Best strategy o embankment
	Governmental responsibility	Only a few recommendations, the focus is on technical aspects	Overlap in responsibility o national responsibility primary dikes, regional maintenance o regional crisis management supported by national army	Sharp division of tasks o clarity on responsibilities of water authorities advocated o water management arranged on a regional scale
	Natural variability	Control dominant	'Living with' dynamics o dune management based on natural sand drift o some buildings constructed to withstand flood	Restrict dynamics o structural works reduce tidal dynamics, manipulate river discharge and fight beach erosion o canalization of river sections o breaking up of ice in winter to protect structural works
	Social variability	Control dominant	Regulation fit to context o regional differentiation safety norms o details of dike design adapted to context	Limit actor behavior o prescription of safety norms for all primary dikes o uniform water authorities and flood defense maintenance advocated o good practice for dike design
Reserves-intensification	Resource allocation	Control dominant	Over-dimensioning o safety norms based on worst case scenario o original dikes kept in place after closure of tidal inlets	Economical allocation o structural works based on arguments of cost-efffectiveness and surveyable maintenance o optimal river discharge regimes o lower safety norms in case of double defenses at tidal inlets
	System exploitation	Resilience dominant	Extensive use o primary safety function of defense systems	Multifunctional use o exploitation of former tidal inlets allowed to a certain extent

Modular connected-connected system	Physical connectedness	Balance control and resilience	Loosely connected areas o dike compartmentalization improved for central Holland	Single scale intervention o joint defenses for the coastal area o extreme isolation of a few water bodies in southwest Netherlands
	System coordination	Balance control and resilience	Decentralized coordination o most responsibilities decentralized o match between physical catchments and administration advocated	Central regulation o national coordination of flood safety and dike legislation
Adaptive-focused feedback	Consultative structures	Not discussed		
	Actors involved	Control	Stakeholder involvement o involvement in two decisions not important to flood safety	Small circle engagement o commission plus external experts developed the strategies based on cost benefit optimization
	Information	Balance control and resilience	Monitoring change o sea level rise, subsidence, change in sediment transport due to structural works	Monitoring states to improve strategy o wave behavior, flood levels, wind effects, state of structures
Innovation-improvement	Policy evaluation	Control		Refinement of policy o compensate for unfavorable erosion o research aimed at first order learning: physical processes, policy effectiveness and dike construction
	Flexibility	Control		Efficiency-oriented o high flood safety, agricultural revenue, land reclamation and easy future dike heightening
	Experiments	Only one experiment		Experiments for increased yield o fine-tuning operational management regimes

Table 5.3 Policy strategies contributing to resilience and control in the National Water Plan. The table indicates the dominant rationale for each system attribute (control, resilience or a balance between control and resilience) and specifies the relevant policy strategies.

NATIONAL WATER PLAN		**General**	**Resilience**	**Control**
Diversification-optimization	Response strategy	Balance control and resilience	Complementary strategies o embankment o spatial planning o disaster control	Dominant (best) strategy o embankment
	Governmental responsibility	Balance control and resilience	Overlap in tasks o regional (local) water management with national supervision o regional crisis management taken over nationally for severe crises	Sharp division of tasks o national agreement on water government (NBW)
	Natural variability	Balance control and resilience	‘Living with’ natural dynamics… o maintain biodiversity, restore natural watercourses and tidal marshes, protect tidal dynamics in the Waddenzee o dunes preferred as coastal defenses o temporary water nuisance accepted in cities after heavy rainfall o land reclamation is reversed when maintenance becomes too costly	… but within strict limits o strong control of inland water levels and river discharge o strategic sand replenishment for dune growth and coastline extension o selection of nature locations and artificial simulation of water level dynamics
	Social variability	Balance control and resilience	Regulation fit to context o area-tailored planning approach o quality team-based approval of building at river foreland and beaches o water test procedure adaptable to local needs (test meant to ensure water stake in area planning)	Limit actor behavior o national legislation for design of defenses o strict national framework for regional planning

Reserves-intensification	Resource allocation	Balance control and resilience	Over-dimensioning o land reserves for future adaptation of defenses to climate change o more water and nature in the landscape o restoration of secondary dikes	Economical allocation o land reserves are compromised after the coastline is extended for extra safety o no re-allocation of retention areas compromised for housing
	System exploitation	Balance control and resilience	Extensive use o emphasis on primary safety function of defense systems and of inland water management	Multifunctional use o win-win solutions advocated, e.g. power generation in defenses and building in river foreland
Modular connected-connected system	Physical connectedness	Resilience	Loosely connected areas o flood risk management based on dike compartments and function zones (e.g. ICT, business) o decoupling IJsselmeer's water level from adjacent lakes (for flood buffering) o flood evacuation routes evaluated o reconnecting isolated water bodies in southwest Netherlands	
	System coordination	Balance control and resilience	A trend of decentralization o regional and local planning o regional responsibility for water storage and crisis management o facilitation of bottom-up policy in the administrative agreement on water policy	Rooted in central coordination o strong national framework for policy o national government is end-responsibility for water and crisis management
Adaptive-focused feedback	Consultative structures	Balance control and resilience	Context-dependent structures o consultation on multiple levels (catchment, administrative units, area plans) for normal and crisis management o stimulation of consortia, forums, networks o exchange of governmental employees within the organization	Established structures o discussed optimization of knowledge exchange structures to stimulate efficiency

Table 5.3 (continued)

Adaptive-focused feedback	Actors involved	Balance control and resilience	Stakeholder involvement o decentralized authorities and societal actors involved in development of NWP o stakeholders involved in policy process o public involved in crisis management through local networks o information on flood prone areas and land characteristics supplied to public o water in education, campaigns and increased water visibility in the landscape o area plan initiative with various actors	Small circle engagement o flood training excludes stakeholders
	Information	Balance control and resilience	Monitoring of change o sea level, river discharge, demography, economy, subsidence, public awareness	Monitoring states to improve strategy o state of defense structures
Innovation-improvement	Policy evaluation	Balance control and resilience	Revision of policy o revision of costly polder maintenance o research into alternative system design o research into innovation barriers for administration	Refinement of policy o research agenda largely focused on improvement of strategies such as sand replenishment and dike constructions
	Attitude towards flexibility	Balance control and resilience	Flexible policies o coastal protection based on dunes and sand replenishment o open estuary defense structures that close in case of flood	Efficiency resulting in reduced flexibility o over-dimensioning of structures in the face of climate change o building in floodplains, multifunctional dike design, wider dikes
	Experiments	Balance control and resilience	Finding alternative strategies o innovative building o housing on mounds pilot in southwest Netherlands o innovative defense structures o adaptations in the agricultural sector o nature development experiments o building with nature program: exploiting natural dynamics	Experiments for increased yield o sand replenishment regimes o dike failure conditions o flood training

In the balance between modularity and connectedness the NWP strategies point at resilience, at least on paper. The decisive factor is the way of implementation.

A number of strategies in the NWP show elements of both resilience and control. An example is the Deltadike, the idea of building very wide dikes integrated into the landscape and accommodating functions such as housing or garage parking. Such dikes create considerable reserves in dike strength (over-dimensioning), but the constructions are very inflexible as regards revision of policy. Another example is the win-win solutions advocated in water management plans. This way of working heavily involves stakeholders, but a complex combination of different stakes in area plans means inflexibility regarding adaptation.

5.5 DISCUSSION

The list of contrasting attributes offers a framework for reflecting on policy strategies and facilitating discussion. This framework provides considerable distinctions to evaluate policy strategies. The analysis discerned policy strategies that typically contribute to either system resilience or control, but also strategies associated with elements of both.

In the analysis of the control-focused Deltaplan the framework revealed several elements of resilience. In addition, we (unexpectedly) saw an explicit acceptance of unexpected events regarding the remaining flood risk and undesirable consequences of the embankment strategy used. Dutch society in 1953 had already avoided flooding through the use of embankment for quite some time and the flood took them by surprise. As a response, the Deltaplan focused on improvement of the existing policy with the aim of lowering the risk of new surprises. The plans were (and still are) seen as advantageous to Dutch society.

Analysis of the NWP shows that the plan develops all attributes of resilience, but not at the cost of relinquishing control. The development of resilience is meant to lower the consequences of surprises, which are no longer acceptable in current Dutch society. The stakes in flood management have increased since the Deltaplan, due to intensification of land use in areas prone to flooding. We note that on paper our analysis reflects the advocated policy, but the actual balance will show in the implementation.

The NWP allows variability within strictly controlled boundaries. This limits the development of resilience to a maximum. We argue that further resilience development requires decreasing the level of control, allowing more variability and even some small-scale surprises. We speculate that a relatively small release of control in a dominant control rationale offers the potential for substantial development of resilience, based on increased actor awareness. We see an aim to increase both control and resilience in the Dutch policy arena. The NWP discusses a pilot scheme in the southwest of the Netherlands for lessening control by building smaller dikes and placing housing on mounds. On the other hand, the second Delta Commission recommends higher safety norms for the dikes and therefore greater control; this is not yet reflected in NWP's shorter-term policy outline. We argue that it is difficult, if not impossible, to make the two trends compatible. As Table 5.1 clearly illustrates, the typical characteristics of resilient versus highly controlled systems are often antagonistic. In the context of flood policy, resilience implies the regular occurrence of flood events that are coped with, but are not controlled in the sense of being prevented or fully regulated.

5.5.1 Reflection on the list of attributes and case study analysis

The list of attributes worked well in evaluating policy strategies and satisfies the main aim of facilitating discussion. As far as the control attributes are concerned, the exact allocation of policy strategies may be subject to interpretation. These attributes have been defined as a counterpart of the resilience attributes, with the consequence that intensification and improvement are not a goals in themselves, but are more a consequence of the other attributes.

We note that the attributes governmental responsibility, regulation and system coordination show a strong correlation. For example, when there is no overlap in governmental responsibilities, this automatically implies a strong connectedness or modularity of the system. The resilience attribute modular-connected system is special in the sense that it reflects a balance, which makes the distinction between control and resilience more difficult.

The case study analysis was based on textual analysis of policy documents. From the argumentation in these documents it was difficult to interpret the nature of the monitoring, the balance between modularity and connectedness of strategies and the innovative character of the strategies. To assess the innovative character of the policy strategies we made use of additional background information on historical policy.

5.6 CONCLUSION

We contrasted the attributes of system control and system resilience to facilitate discussion on policy strategies. The list of attributes was useful in the analysis of the Dutch flood policy and revealed policy strategies that typically contribute to either system resilience or control, but also strategies associated with elements of both. Current flood management in the Netherlands aims at developing resilience without releasing control, allowing variability within strictly controlled limits. The policy documents show a desire to increase resilience alongside a discussion on increasing control. It is difficult to make these two paths compatible. The framework in this article connects the schools of thought on resilience and on control to stimulate thinking about trade-offs.

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6 Discussion and conclusion

In this thesis I aimed to connect disciplinary-based approaches to uncertainty handling in a comprehensive framework for policy development under uncertainty. The framework includes methods of uncertainty handling based on scientific analysis and process management, as well as rationales of uncertainty handling focused on system resilience and control. In Chapters 2 to 5 I studied merits and trade-offs of one-sided and combined approaches and visualized choices and opportunities.

6.1 DISCUSSION OF THE CHAPTERS

Chapter 2 discusses uncertainty handling based on methods of scientific analysis. The chapter focuses on the quantification of parameter uncertainty in a model-based study and the propagation of this uncertainty to output variables. This is one possible approach, but it illustrates some of the merits and shortcomings that apply to scientific uncertainty assessment in general. The main strength of scientific uncertainty assessment is the clear visualization of the effects of identified uncertainty sources on the expected outcomes of policy measures. However, assessment is difficult when data or insights are lacking to make uncertainty explicit, which in the case study was most obvious for the uncertainty assessment of the fertilizer application load. The strategy therefore works best for shallow and medium uncertainty, but is not well equipped to handle ignorance. In many cases, however, these deeper uncertainties are the most influential (Kwakkel et al. 2010). Although qualitative uncertainty assessment is better able to cope with deeper uncertainties (Refsgaard et al. 2007), ignorance is not very suitable for assessment in general. A focus on ex ante scientific uncertainty assessment, and on probabilistic techniques in particular, is prone to create a false sense of safety. In addition the chapter describes the subjectivity of assumptions in identifying and assessing uncertainty. This is a general issue in the scientific analysis of uncertainty also noted by other authors (see Funtowicz and Ravetz 1993).

The limitations and subjectivity of scientific uncertainty assessment triggered my in-depth study of complementary approaches in the following chapters. Policy analytical literature discusses handling ignorance through the development of adaptive policy (Walker et al. forthcoming). I see this as an attribute of the resilience rationale and discuss it in Chapter 5. First, Chapter 3 describes the role of process management in handling uncertainty, based on a case study of stakeholder participation. It is argued that stakeholder participation, among other things, makes additional information available (substantive benefits) and increases the legitimacy of policy analysis (Fiorino 1990).

Chapter 3 shows that stakeholder participation emphasizes alternative methods of uncertainty handling, such as trust building and commitment, based on process management. In the participative approach used in the case study, the sounding board group employs these methods in interaction with methods of scientific analysis. As an illustration I relate the handling of uncertainty over the effect of a hydrological buffer zone. The sounding board group chose approximate modeling in combination with transparency of the activities and clear communication of uncertainty. The group of experts, in contrast, focused on information collection and expert judgment to make reasonable assumptions. In the case study we saw that different ways of uncertainty handling, especially in relation to framing, enables consideration of other measures. I do not argue which is a 'better' strategy. Process management enlarges the scope of methods of uncertainty handling, which provides opportunities.

The expert group and the sounding board group in the case study prioritized and handled uncertainties in different ways (compare Van Assselt and Rotmans 2002). This clearly shows the subjectivity of – and the stakes involved in – these choices. A merit of stakeholder involvement is, in case of joint commitment, the wider support of the chosen strategy. A case study by Maxim and Van der Sluijs (2007) shows that stakeholders identify uncertainty sources ignored by experts. Our two groups did not identify different uncertainties, but stakeholders did contribute additional information.

In the case study the process-related uncertainty handling in the participatory approach increased uncertainty tolerance, active knowledge of the system and its uncertainties and commitment to intervene on the side of stakeholders. These factors enable adaptation in case of adverse consequences (due to ignorance), as I discuss in Chapter 5. However, a proliferation of conflict over stakes and power play introduced complexity (see also Kickert et al. 1997). Persisting conflict between actors (not limited by process management) may achieve exactly the opposite and reduce uncertainty tolerance, obstruct learning and block finding (simple) solutions, thus severely reducing the adaptive capacity. In the case study we saw that conflict (and the stake in settling it) induced an agreement on long-term static policy.

In the expert-based approach process-related uncertainty handling was less prominent. The trust between experts was high, their frames showed considerable overlap and interaction relied on standard procedures that none of the experts challenged. For the implementation of policy, the experts relied on formal regulations and procedures (see also Scharpf 1997). These procedures limit the behavior of actors affected by the policy and therefore enabled experts' assessment of the acceptability of policy. Nevertheless, a lack of support and conflict over procedures may undermine this approach.

Figure 6.1 shows the uncertainty handling methods observed in Chapter 3 arranged according to their focus on scientific analysis and process management.

Figure 6.1 The range of available uncertainty handling methods, from scientific analysis to process management.

Chapter 4 discusses the successful simultaneous management of process and substance in policy development. The set of ‘rules of the game’ makes explicit informal institutions favorable to embedding the handling of uncertainty. The process management set down in the rules stimulates a transparent and constructive discussion on substance among actors. The aim is to create a ‘fair process’ and transparent model-based analysis to enhance the trust between actors and so exploit the merits of process management discussed in Chapter 3. Chapters 3 and 4 clearly show that uncertainty handling is inherent in all activities in policy development and is not a separate activity. Choices regarding uncertainty handling are made continuously throughout the activities, but often remain implicit.

Chapter 5 discusses the resilience and control rationales for system intervention, which influence the ability of the system to cope with uncertainty in a different way. A system control rationale aims at stability of the system and low variability or day-to-day uncertainty by reducing disturbance. It depends on a high-quality uncertainty assessment to foresee these disturbances. The dominant uncertainty for system control is ignorance, which may lead to surprises with considerable adverse consequences. The resilience rationale focuses on mitigating the consequences of uncertainty through backup mechanisms and quick adaptation. At its core is allowing day-to-day uncertainty over disturbances and accepting the related adverse consequences, since this stimulates the development of favorable mechanisms for handling ignorance. This strategy decreases the dependency on detailed uncertainty assessment in policy development, which makes the rationale interesting in light of the limitations of uncertainty assessment discussed in Chapter 2. The downside is a lessening in efficiency under expected circumstances, which is a merit of system control.

Figure 6.2 shows the system attributes related to resilience and control as discussed in Chapter 5. Management may focus on stimulating system attributes related to both rationales, although high levels of both control and resilience are mutually exclusive.

Figure 6.2 System attributes related to resilience and control.

6.2 THE CONCEPTUAL FRAMEWORK FOR UNCERTAINTY HANDLING

The conceptual framework for policy development under uncertainty structures methods and rationales of uncertainty handling along two axes. The far ends of the axes reflect one-sided approaches, with each having merits and trade-offs. Uncertainty handling based on scientific analysis provides clear insight, but suffers from subjectivity and ignorance. Uncertainty handling based on methods of process management limits actor behavior, increases uncertainty tolerance and develops capacity to deal with uncertainty, but persisting conflict in actor interaction may seriously damage, and even reverse, these merits. Uncertainty handling based on a control rationale provides low everyday uncertainty with a high risk of ignorance, while uncertainty handling based on a resilience rationale offers an increased capability of handling surprise combined with greater everyday uncertainty. Figures 6.1 and 6.2 further elaborate the individual axes.

The quadrants in the framework characterize the combination of a type of method and a particular rationale. The policy development activities in each quadrant have a dominant focus, which leads to a specific framing of uncertainty handling. I discuss the uncertainty handling related to each quadrant and provide an illustration based on the cases in Chapters 3 and 5. Figure 6.3 shows the complete framework for policy development under uncertainty.

In the combination of methods of scientific analysis and a rationale of system control, the emphasis is on understanding the system’s key steering variables in order to design interventions that improve system functioning. The analysis of uncertainty concentrates on the risk of being wrong, i.e. that interventions have no or adverse consequences. The uncertainty handling methods focus on disclosing alternative ways of system behavior in order to determine robustness of interventions. The analysis aims at *optimization of interventions* given the available knowledge and defining measures that reduce disturbances in the system. In the case study in Chapter 3 we saw the optimization of water management in the Bargerveen area and the aim of precise control over water levels.

Where methods of scientific analysis and a rationale of system resilience are combined, the focus is on understanding system vulnerability to avoid undesirable system regimes. Uncertainty management concentrates on monitoring the attributes in Figure 6.2, furthering understanding of system thresholds and exploring alternative pathways for system development. The analysis aims at *exploring vulnerabilities*, for instance through exploratory modeling to understand the interaction of critical system variables between scales, and defining measures that enable response to surprise. The Dutch flood management described in Chapter 5 analyzes system thresholds and alternative pathways for development under climate change uncertainty. The flood management focuses on resilience attributes such as diversity in ecology and flexibility in the defense system.

In the combination of methods of process management and a rationale of system control, the focus is on top-down policy development to improve system functioning. Uncertainty is managed by *formulating strict procedures*. Regulations and procedures aim at restricting actor behavior, thus reducing variability, and they structure the contribution of scientists and other actors. The top-down policy development in the quadrant includes low-level interaction with stakeholders, such as informing and consulting, to create support and enrich preferred policy. The approach focuses on measures for which the government can direct implementation. We saw this clearly in the expert-based policy developed in the case study in Chapter 3. The experts relied on regulation and awaited opportunities to implement the preferred policy.

A combination of methods of process management and a rationale of system resilience focuses on decentralized policy development to improve adaptive capacity. Uncertainty is managed through *organizing learning*. The aim is to increase uncertainty tolerance, commitment and actors' capacity to change practices in case of surprise. The quadrant targets network-based policy development with great stakeholder involvement, managed by a process manager. The approach focuses on measures for which there is sufficient commitment. The stakeholder participation in Chapter 3 combined elements of both lower quadrants. The stakeholders were closely involved in the analysis and co-determined objectives and solutions. On the other hand, their contributions were to a high degree structured by the competent authority.

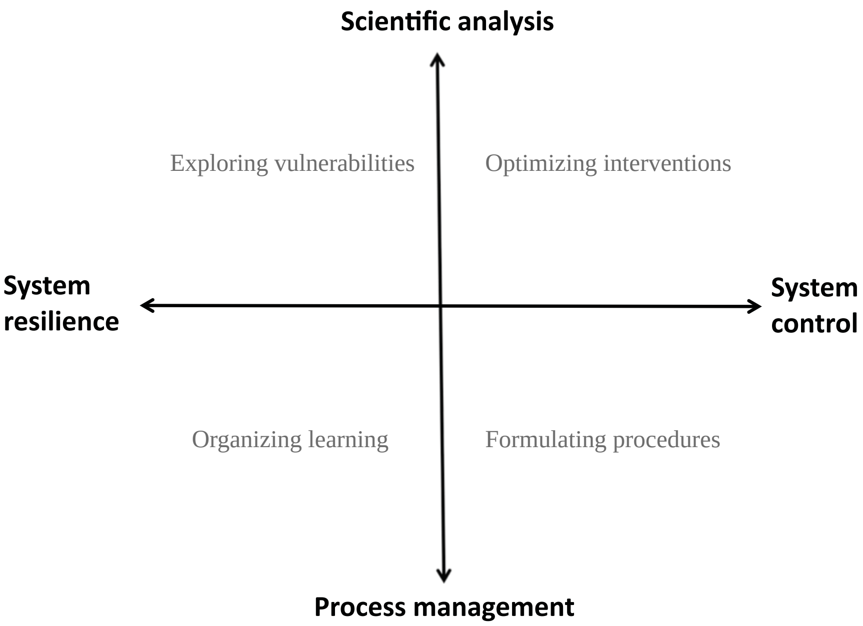

Figure 6.3 The conceptual framework for policy development under uncertainty. The vertical axis reflects methods of uncertainty handling and the horizontal axis shows rationales. The figure characterizes the dominant focus of uncertainty handling in each quadrant.

Application of the framework

The framework facilitates a more explicit choice of the preferred uncertainty handling strategy in a policy development process, a choice that is currently often made implicitly. A complementary use of methods and rationales offers opportunities, since combined approaches mitigate the trade-offs related to one-sided approaches. An appropriate strategy for complex policy development probably combines methods from all four quadrants. For policy development processes with low complexity a one-sided strategy may offer sufficient tools, although this comes with limitations. The framework is truly a framework and does not aim to replace the different pieces of existing literature. It merely guides the choice between the disciplinary-based approaches outlined in Chapter 1.

The guidance provided by the framework is primarily aimed at actors involved in the design and facilitation of policy processes – such as policy analysts, process managers and researchers – and researchers concerned with evaluation of these processes.

The development of the conceptual framework has been inspired by the tradition of uncertainty handling in water management. However, based on the highly conceptual character of the framework and its embedding in more general policy literature, I would argue it is more widely applicable, including in fields such as natural resources and environmental management, transport policy and spatial planning. For the same reasons I argue for its applicability in policy development on different spatial and temporal scales. However, the process management on larger scales becomes more complex than that illustrated in Chapters 3 and 4.

6.3 CONTRIBUTION TO THE LITERATURE AND PRACTICE

The idea of uncertainty management as a resource-intensive activity is frequently considered a hurdle in considering thoroughly what uncertainty strategy to adopt (Pappenberger and Beven 2006). I have shown that uncertainty is implicitly handled anyway: the design of the policy development activities and the rationale of system intervention contribute strongly to uncertainty management, leaving the system with a different type of risk. I argue for a more explicit choice. With this research, I aim to provide an impetus for thinking about uncertainty handling strategies.

A frequently discussed issue in policy analytic uncertainty literature is the inability to communicate uncertainties to policy makers (and stakeholders). The problem is often framed as policy makers not liking or accepting uncertainty. Personally I think policy makers are used to managing uncertainty in their daily jobs and realize the uncertain nature of knowledge. The problem is rather in the communication between actors, where policy makers, scientists and stakeholders may have different ideas about appropriate uncertainty handling. I speculate that policy makers consider the wider perspective on uncertainty handling in this thesis more realistic, compared to the more narrow view in disciplinary literature. However, the barriers to communication will never completely dissolve. The actors' own interests continue to play a role in the framing of uncertainty, which may induce actors to ignore some and emphasize other uncertainties, while using research as intellectual ammunition.

The framework for uncertainty handling presented in this thesis broadens the perspective on uncertainty management for complex problems, also called unstructured problems (Hisschemoeller and Hoppe 1995), wicked problems (Rittel 1973) or post-normal problems (Funtowicz and Ravetz 1993). Firstly, I expand the role of stakeholder participation in uncertainty handling. Funtowicz and Ravetz (1993), for example, discuss the role of stakeholder participation in the quality assurance of a policy analysis and in obtaining support. However, participation also introduces additional methods of uncertainty handling. Secondly, the presented framework shows the potential of the resilience rationale in the management of risk due to uncertainty. This wider conceptual framework is expected to be beneficial under complexity.

Finally, I connected the resilience literature to the more prevailing literature on uncertainty management in policy sciences.

6.4 FURTHER RESEARCH

In my opinion, the wider perspective on uncertainty handling presented in this thesis is the way forward for uncertainty research. The more realistic view of uncertainty handling is a condition for its serious application in practice. The urgency to find new classifications of uncertainty or new assessment methods has been reduced; much good work has been done. The research into deep uncertainty and the increased focus on qualitative uncertainty assessment should be continued. Further research should be aimed at insight into the complementary application of the approaches represented in the framework. To develop the framework further, I see the need for case studies in which uncertainty handling is based on all four quadrants of the framework and where choices are made explicit.

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Samenvatting

Een weloverwogen strategie om met onzekerheid om te gaan in beleidsontwikkeling biedt voordeel in het beheren van sociaalecologische systemen. Onzekerheid is inherent aan beleidsontwikkeling en brengt een risico met zich mee op nadelige consequenties van beleid en blokkade van het beleidsontwikkelingsproces. Wetenschappers en mensen in de beleidspraktijk vinden het omgaan met onzekerheid vaak lastig. De bijdrage van deze dissertatie ligt in het verbinden van de opvattingen over onzekerheid en bijbehorende methoden en principes voor de omgang met onzekerheid uit verschillende wetenschapsvelden: (participatieve) beleidsanalyse, netwerk- en procesmanagement en adaptief en veerkracht management.

Deze dissertatie biedt een breed en interdisciplinair conceptueel raamwerk voor het omgaan met onzekerheid in beleidsontwikkeling. Het raamwerk is geïnspireerd vanuit de praktijk van het waterbeheer maar is naar verwachting breder toepasbaar in vakgebieden gericht op het beheer van natuurlijke hulpbronnen, milieubeheer, vervoer en ruimtelijke ordening. Onzekerheid in beleidsontwikkeling is gedefinieerd als de afwezigheid van complete en gedeelde kennis over het systeem waarover beleid wordt ontwikkeld. Deze definitie relateert onzekerheid aan zowel inhoudelijke als procesmatige aspecten van beleidsontwikkeling. De focus van het proefschrift ligt op inhoudelijke aspecten van beleidsontwikkeling en gerelateerde inhoudelijke onzekerheid, maar het proces van interactie van actoren en de bijbehorende strategische en institutionele onzekerheid worden specifiek meegenomen.

Het conceptuele raamwerk bestaat in essentie uit twee variabelen die het omgaan met onzekerheid in beleidsontwikkeling karakteriseren, weergegeven door twee elkaar kruisende assen. De eerste variabele is de methode toegepast in het omgaan met onzekerheid, welke methoden kunnen variëren van wetenschappelijke analyse tot procesmanagement. De tweede variabele is het principe waarop de omgang met onzekerheid is gebaseerd, variërend van een streven naar systeem controle tot streven naar systeem veerkracht. De hoofdstukken in het proefschrift geven inzicht in de voor- en nadelen van eenzijdige gebruik van een bepaald type methode of principe, en kansen voor complementaire aanpakken.

Hoofdstuk 2 gaat dieper in op de wetenschappelijke analyse van onzekerheid in een modelstudie. De methode die wordt toegepast is de kwantificering van onzekerheid met behulp van een onzekerheidsverdeling en vervolgens de voortplanting van deze onzekerheid door het model. Het voornaamste voordeel van deze methode is dat helder inzicht wordt verkregen in de effecten van geïdentificeerde onzekerheden op het gekozen beleid. Het hoofdstuk toont ook duidelijk de nadelen. De gebruikte methode is niet toegerust op het omgaan met dieper liggende bronnen van onzekerheid en bovendien is er inherente subjectiviteit in de aannamen van de onzekerheidsanalyse, met een aanzienlijk effect op de resultaten. De discussie en conclusie sectie laat zien dat deze voor- en nadelen meer algemeen gelden voor methoden gericht op wetenschappelijk analyse van onzekerheid.

Hoofdstuk 3 en 4 gaan dieper in op het combineren van methoden voor omgang met onzekerheid vanuit wetenschappelijke analyse en proces management. Hoofdstuk 3 laat de interactie tussen deze methoden zien in beleidsontwikkeling. Het hoofdstuk beschrijft de omgang met onzekerheid in participatieve beleidsontwikkeling en vergelijkt het met de omgang met onzekerheid door een team experts tijdens de beleidsontwikkeling voor hetzelfde probleem. De omgang met onzekerheid in de participatieve aanpak berust in toenemende mate op methoden vanuit proces management zoals ontwikkeling van vertrouwen en committent, in interactie met methoden vanuit wetenschappelijke analyse. In het expert team beperken de methoden voor de omgang met onzekerheid vanuit proces management zich tot het inzetten van vastgelegde procedures. Het hoofdstuk laat zien dat een verschil in toegepaste methoden de overweging van andere beleidsmaatregelen mogelijk maakt. De omgang met onzekerheid vanuit procesmanagement maakt het gedrag van actoren meer voorspelbaar, vergroot de tolerantie voor onzekerheid en ontwikkelt capaciteit om met onzekerheden om te gaan. Aanhoudende conflicten (niet ingeperkt door procesmanagement) kunnen leiden tot de omgekeerde situatie.

Hoofdstuk 4 presenteert een set ‘spelregels’ voor interactie tussen actoren in participatieve beleidsontwikkeling waarin een gunstige omgang met inhoudelijke en procesmatige onzekerheid is ingebed. De besproken gedragscode dient als leidraad voor procesmanagement in het bevorderen van een constructieve inhoudelijke discussie. Het hoofdstuk expliciteert informele instituties die de complexiteit en het conflict tussen actoren in beleidsontwikkeling beteugelen. De regels zijn onderverdeeld in vier subsets gericht op agendabeheer, delen van informatie, modelgebruik en ontwikkelen van maatregelen. De regels richten zich op een “eerlijk proces” en transparantie in modeltoepassing om het vertrouwen tussen partijen te stimuleren en zo de voordelen van procesmanagement besproken in hoofdstuk 3 te benutten. Hoofdstuk 3 en 4 laten allebei zien dat omgang met onzekerheid inherent is aan alle activiteiten van beleidsontwikkeling en niet een afzonderlijke activiteit. Keuzes in de omgang met onzekerheid worden voortdurend gemaakt alhoewel ze vaak impliciet blijven.

Hoofdstuk 5 vergelijkt de systeemveerkracht en systeemcontrole principes. Beide stellen het systeem in staat met onzekerheid om te gaan, maar op een andere manier. Het systeemcontrole principe richt zich op stabiliteit van het systeem en een lage dagelijkse onzekerheid door middel van het reduceren van verstoringen. Een voordeel van dit principe is de systeemefficiëntie onder verwachte omstandigheden. Echter, het voorzien van verstoringen vereist gedetailleerde analyse en verassingen hebben waarschijnlijk grote nadelige consequenties. Het systeemveerkracht principe richt zich op het ontwikkelen van back-up mechanismen en mogelijkheden tot snelle aanpassing om consequenties van onzekerheid te verzachten. Dagelijkse onzekerheid wordt gewaardeerd omdat het de ontwikkeling van back-up mechanismen stimuleert. Het principe is minder afhankelijk van gedetailleerde analyse en het risico van verassingen is lager. Een nadeel is de verminderde systeemefficiency. Het hoofdstuk contrasteert de gewenste systeemeigenschappen vanuit beide principes, om discussie in beleidsontwikkeling te ondersteunen. Het illustreert dit contrast met beleidsmaatregelen vanuit het historische en huidige overstromingsbeleid. Systeemeigenschappen die veerkracht vergroten zijn diversiteit, reserves, modulaire connectiviteit, adaptieve feedback en innovatie. Systeemeigenschappen die controle vergroten zijn optimalisatie, intensivering, connectiviteit, gerichte feedback en verbetering.

Het laatste hoofdstuk duidt de betekenis van de kwadranten van het raamwerk, die elk een type methode en specifiek principe combineren. Wanneer wetenschappelijke analyse methoden worden gecombineerd met een systeemcontrole principe ligt de focus van de omgang met onzekerheid op het optimaliseren van interventies. Wanneer wetenschappelijke analyse methoden worden gecombineerd met een systeemveerkracht principe ligt de focus op verkenning van kwetsbaarheden. Wanneer procesmanagement methoden worden gecombineerd met een systeemcontrole principe ligt de focus op het opstellen van procedures. Tenslotte, wanneer procesmanagement methoden worden gecombineerd met een systeemveerkracht principe ligt de focus op het organiseren van leren.

Het gepresenteerde raamwerk biedt structuur voor het kiezen van een strategie in het omgaan met onzekerheid, een keuze die nu vaak impliciet wordt gemaakt. Het complementair toepassen van methoden en principes biedt mogelijkheden, omdat het de nadelen van eenzijdige aanpakken verminderd. Een geschikte strategie voor het omgaan met onzekerheid voor complexe beleidsontwikkeling combineert waarschijnlijk aanpakken uit alle vier de kwadranten. Het gepresenteerde bredere perspectief op het omgaan met onzekerheid wordt gezien als een manier om de onzekerheidsliteratuur gelijk te schakelen met het bredere perspectief op beleidsontwikkeling zoals zich dat in waterbeleid en andere vakgebieden ontwikkelt. Het wordt daarom bepleit als de toekomst voor onzekerheidsonderzoek. Het raamwerk is complementair aan bestaande onzekerheidsliteratuur en probeert deze niet te vervangen.

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About the author

Rianne Bredenhoff-Bijlsma was born on 18 October 1980 in the Netherlands. She started her studies in Civil Engineering & Management at the University of Twente in 1999, out of a desire to study both the natural and the social sciences. Rianne graduated in water engineering and management in 2005. During her internship at the UPC in Barcelona she studied the model-based simulation of wave processes near shore. Her Masters thesis focused on operational flood management at the regional water authority Wetterskip Fryslân in the Netherlands.

In 2005 Rianne started her PhD at the Water Engineering and Management department of the University of Twente, studying uncertainty handling in policy analysis. She soon reframed her research to include the wider field of policy sciences. During the first three years of her PhD studies, Rianne was based partly at the National Institute for Inland Water Management and Waste Water Treatment, RIZA, and Deltares.[5] She worked with national and international colleagues on case studies of the European research projects HarmoniRiB and Aquastress and took part in several workshops on uncertainty and evaluation of stakeholder participation.

While working on her dissertation, Rianne published several articles in international journals and co-edited a special feature for *Ecology and Society* on participatory water management. Rianne is currently working for the Dutch consultancy firm Witteveen + Bos, to apply and further develop her insight into policy development in practice.

[5] RIZA was reorganized and transformed into the Waterdienst, while part of RIZA and other research institutes merged into the knowledge institute Deltares.