Formålet med MERIT projektet har været at afprøve et beslutningsværktøj "Bayesianske netværk" til overordnet forvaltning af vandressourcen. Dette værkstøj giver mulighed for samlet at belyse hvordan forskellige faktorer har betydning i forbindelse med en given beskyttelsesindsats. Analysen kan omfatte faktorer såsom vandkredsløb, grundvandskvalitet, naturværdier, samfundsøkonomi og erhvervsmæssige aspekter. Med et Bayesiansk net kan man kombinere forhåndsviden med nye observationer og viden og dermed tilvejebringe et optimalt beslutningsgrundlag for et givent område (f.eks. et kildepladsopland), samtidig med at usikkerheden kommunikeres.

For Københavns Energi (KE) er målet at kunne planlægge og beskytte den fremtidige vandindvinding og grundvandsressource i et samarbejde med myndigheder og borgere, således at der sikres lokal forståelse og forankring af de tiltag, der konkret gennemføres, i dette tilfælde i indvindingsoplandet omkring St. Havelse kildeplads nord for Frederikssund.

Rapporten indeholder en beskrivelse af resultaterne af afprøvningen af Bayesianske net med tilhørende involvering af professionelle interessenter og borgere. Den danske case har indgået som et af fire pilotafprøvninger i et 3-årigt EU forskningsprojekt MERIT (maj 2001–maj 2004).

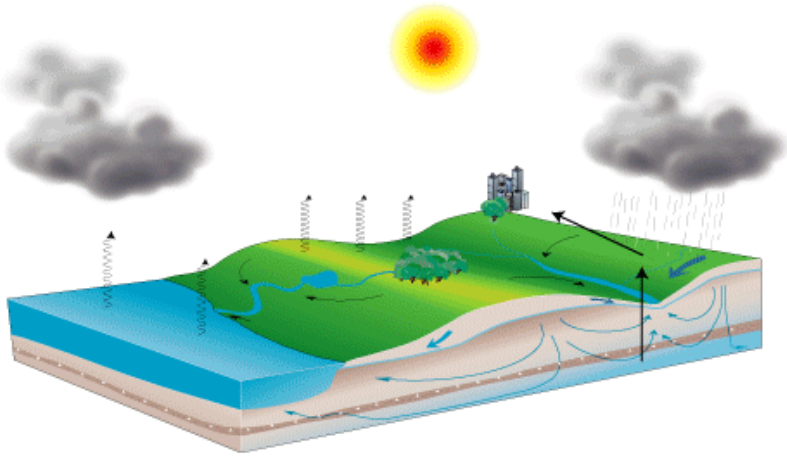
Test of Bayesian belief network and stakeholder involvement

Test of Bayesian belief network and stakeholder involvement

Groundwater management and protection at Havelse well field in Northern Zealand

EVK1-2000-00085 – MERIT
(Danish case study)

Hans Jørgen Henriksen, Per Rasmussen, Gyrite Brandt, Dorthe von Bülow, Lisbeth Flindt Jørgensen, and Per



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Test of Bayesian belief network and stakeholder involvement

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ACRONYMS

Active X	Collection of separate technologies that facilitate distribution, validation and extensibility of Internet applications
AC21	Agenda 21 Centre
AIS	The Danish Areal Information System
API	Application Programming Interface
BAM	The pesticide metabolite 2,6-dichlorobenzamide
BBN	Bayesian Belief Network
C	Programming language widely used to develop commercial applications
C++	A object-oriented superset of the C language
CD	Compact Disc
CE	Copenhagen Energy
COOF	water supply COOperation Forum
COOP	COOrdination forum for groundwater Protection
CPT	Conditional Probability Table
DAG	Directed Acyclic Graph
DANVA	The Danish Water and Waste Water Association
DB2	Dækningsbidrag II (in Danish)
DEPA	Danish Environmental Protection Agency
DN	The Danish Society for the Conservation of Nature (an NGO)
DSS	Decision Support System
EC	European Community
EDSS	Environmental Decision Support System
EM	Expectation Maximation (to learn the conditional probabilities in a network based on data)
EU	European Union
FSL	Danish Forest and Landscape Research Institute
FVD	Organisation of private waterworks in Denmark
GDP	Gross Domestic Product
GEUS	Geological Survey of Denmark and Greenland
GIS	Geographical Information System
GMO	Genetically Modified Organisms
Harmoni-CA	Harmonised modelling tools for integrated basin management (Concerted Acition)
HDE	Hugin Decision Engine
HUR	The Greater Copenhagen Authority
HUGIN	Software for intelligent solutions (www.hugin.com)
HVS	The Greater Copenhagen Area Water Association
KUPA	Concept for identifying areas where shallow aquifers are vulnerable to pesticide contamination
KVL	The Royal Veterinary and Agricultural University, Denmark
LAS	Linear Alkylbenzene Sulphonate
LØJ	The Danish Society of Organic Farmers
MAC	The Maximum Acceptable Concentration

Java	Object oriented language similar to C++
LAI	Leaf Area Index
MERIT	Management of Environment and Resources using Integrated Techniques
MVJ	An agreement supported by EC and national grants for environmentally friendly agriculture, but only in vulnerable agricultureal areas (“SFL areas”) – (In Danish: MiljøVenlige Jordbrugsforanstaltninger)
NDVI	Normalized Difference Vegetation Index
NERI	National Environmental Research Institute
NOLA	North Zealand Farmers’ Union
NO_3	Nitrate
NGO	Non Governmental Organisation
OSD	Areas of specific drinking water interest
PP	Public Participation
QA	Quality Assurance
RBMP	River Basin Management Plan
SH	Stakeholder
SJFL	Zealand Family Farmers’ Association
SNS	Danish Forest and Nature Agency
SWOT	Strengths, weaknesses, opportunities and threats
WFD	Water Framework Directive
WP5	Work Package 5

CHAPTER 0 Preamble

Hans Jørgen Henriksen, GEUS

Car start problem with a time delay: Precautionary groundwater protection

This chapter contains a brief introduction to the Danish MERIT case study. (The MERIT project: Management of the Environment and Resources using Integrated Techniques, contract number EVK1-CT-2000-00085)

At the kick-off meeting, Gyrite Brandt of Copenhagen Energy (CE) explained CE's general view: "Our drinking water supply strategy has groundwater as the main source, surface water as a buffer and artificial recharge as a supplement. We have 55 wellfields in the Copenhagen area, of which 31 are suitable, 20 that might be suitable and four unsuitable. Our effort is to restore and protect the suitable wellfields, and the Havelse wellfield belongs to this group.

"The action options CE has are afforestation, closing wells not in use, establishing monitoring wells, setting up local waterworks cooperation forums and implementing voluntary farming agreements. Because afforestation is not possible to any great extent in the area, we decided to chose farming contracts as the main issue to analyse in the case study."

Finn Jensen from the University of Ålborg introduced the audience to Bayesian belief networks by giving the example of a car that won't start [1]. "Let's say that one morning, my car won't start. I can hear the starter turn over, but nothing happens. There may be several reasons for my problem, but I can hear the starter turn over, so there must be power in the battery. Therefore, the most probable cause is either that the car's petrol was stolen during the night or that the spark plugs are dirty. It could also be due to dirt in the carburator, a leak in the ignition system, or something even more serious. To find out, I first check the fuel gauge. It shows that the tank is half-full, so I decide to clean the spark plugs.

"To have a computer perform the same kind of reasoning, we need answers to questions such as: What was it that made me conclude that stolen fuel and dirty spark plugs were the two most probable causes? What made me decide to look at the fuel gauge, and how does the observation that the tank is half full make me conclude that it must be the spark plugs? To be precise, we need ways of representing the problem and ways of performing inference in this representation so that a computer can simulate this kind of reasoning and perhaps do it better and faster than humans.

[1] Citizens' group has pointed out that the car start problem is inadequate, see chapter 9.

“We must ask ourselves questions about what affects the goal and what affects what during the process. For such a problem, it is necessary to construct a causal network, a so-called Bayesian belief network that shows causes and effects and how they are interconnected. A Bayesian belief network, or BBN, can be used to exclude causes that are improbable and to select the correct actions to be taken. In such a network, nodes are states and arrows are effects, but keep your attention on the direction of the arrows because they indicate what affects what. In a BBN, the arrow symbolises a conditional likelihood. Thus it is possible to carry out calculations of likelihood for the states of different nodes, based on ‘parent’ nodes. BBNs are especially useful for complex issues.”

Today we know a great deal about the quality of the deep groundwater from work on a national scale in the groundwater monitoring programme. However, we have little knowledge about a local area like the Havelse wellfield capture zone, and we have no information about the quality of young groundwater. Even if we did, we wouldn’t know exactly how shallow-lying contaminated groundwater would affect deep groundwater in the long run. So how can we explain and make decisions about the need for precautionary groundwater protection in an area with long groundwater residence times, when so far no nitrate and pesticides have been reported in the raw water abstracted from the wellfield?

It seems as though our Havelse wellfield case study can be compared to having trouble starting your car, but with a built-in time delay. Even if someone has “stolen the fuel’”, or “the spark plugs are dirty”, our car still starts in the morning, and will continue to do so for a number of years. Then suddenly one morning, we realise that our car will not start any more. Because there are residence times for water moving from shallow groundwater to deep groundwater, there is a delay in “feedback” in our natural system of several decades or perhaps even half a century. Our knowledge about what happens to pesticides in shallow groundwater is limited, so how can we handle this problem based on the little we do know? Can we use BBNs to encapsulate and communicate this uncertainty and agree upon sound precautionary action, and to build support and understanding in the general public and stakeholders with respect to implementation? How can a BBN be helpful for Copenhagen Energy, who has 55 wellfields? Can it provide useful input for a groundwater protection strategy?

We are dealing with a field of study that investigates the impact that individuals, groups, and projects have on the credibility of developed BBNs and the behaviour of stakeholders and the general public. The purpose was to test BBNs as a tool in water resource management, and to suggest guidelines for the use of BBNs and for improving the engagement of stakeholders.

We wanted stakeholders and citizens to express the influence they had on the development of the BBNs (variables, links and numbers). We sought an open and positive project management, which allowed discussion of the various elements and permitted suggestions to be incorporated in the construction of a BBN. We wanted to analyse whether BBNs are a good, flexible tool for integration. Do BBNs provide a clear overview, and are they a good tool in a dialogue?

There is a pressing need to develop management schemes and approaches that acknowledge the pragmatic character of these problems. We scientists should not simply

passively observe and measure, but also assist policymakers in taking better action. This requires the ability to combine, interconnect, link, and analyse information across scientific disciplines.

This report is intended as an in-depth analysis of the Havelse well field case study, which was presented to stakeholders and public for the first time in November 2002. The final joint meeting was held in March 2004. As once expressed by Danish scientist Nicolaus Steno (1638-1686), “Beautiful is what we see…more beautiful is what we understand…most beautiful is what we do not comprehend.” We have attempted to provide a thorough description in our report that is rich in detail about the BBN construction and stakeholder engagement.

The primary source of information in our case study was our own observations backed up by interviews, questionnaires, minutes of meetings and statements by stakeholders and local residents. Case studies have their drawbacks and are open to the perceptual bias and subjective interpretations of the observers, but we have tried to document everything and include as much detail as we could.

The present report is a separate report dealing with the Danish case study, which is one out of four demonstration BBNs in four catchment areas in the UK, Denmark, Spain and Italy, each having different sets of water resource problems. The report on the Danish case will provide input to the final report in the form of experience from the Danish case. Furthermore, the MERIT project will present a set of guidelines for the use of BBNs in integrated water resource management with stakeholder involvement, and these guidelines will be included on a CD with the present report and executable versions of the BBNs developed. The CD will be published in September 2004. For more information about MERIT, see www.merit-eu.net.

The Danish case study has had the following project leading steering committee:

- Senioradvisor, hydrology Hans Jørgen Henriksen, GEUS (project leader, BBN development)
- Senioradvisor Per Rasmussen, GEUS (project secretary, stakeholder engagement)
- Geologist Gyrite Brandt, Copenhagen Energy (responsible for CE inputs, BBN development)
- Anthropologist Dorthe von Bülow, Copenhagen Energy (stakeholder engagement)

Jan Poulsen, Agenda 21 Centre Frederikssund has been appointed by the steering committee as facilitator in relation to the citizen group.

Copenhagen, June 2004.

CHAPTER 1 Summary

Hans Jørgen Henriksen, GEUS

Introduction

The applicability of graphical models (Bayesian belief networks – BBNs) in water resource management regarding preventive groundwater protection was investigated in a case study for Havelse wellfield catchment in North Zealand (Figure 1.1). Geological Survey of Denmark and Greenland (GEUS) was the project leader and Copenhagen Energy (CE) the decision-maker and end-user in relation to the BBN case study.

CE is the largest water supply company in Denmark. It supplies roughly one million inhabitants in the greater Copenhagen area with drinking water each day. CE operates Havelse wellfield together with 55 other large wellfields located in northern and eastern Zealand (the island on which Copenhagen is located).

Three different types of actions have been analysed as means of protecting water resources: 1) voluntary farming contracts, 2) afforestation and 3) establishment of wetlands. For each problem a BBN have been constructed and evaluated with full stakeholder involvement of both a group of professional stakeholders and a citizens' group.

The possibilities and problems connected with voluntary five-ten-year farmer contracts prescribing no pesticide application in return for compensational payment was especially analysed. It was not a question of actually implementing such zones that was in focus in the study, only analysing what would be required in compensational payment if such zones were to be implemented at a magnitude and on a scale that allowed them to function as efficient groundwater protection. Furthermore, the aim was to clarify the impact implementation of such protection zones could have on land use, farm economics, groundwater quality, biodiversity and aquatic environment.

Information, consultation and active involvement of professional stakeholders and general public was carried out using announcements, facilitated public meeting, working group meetings, newsletters, a Web site, individual meetings and a joint working group. The facilitator of the public meeting and workshops was the Agenda 21 Centre in Frederikssund. Various subcontractors have participated in the project, e.g. Svend Rasmussen (KVL: farm economics) and Jesper Sølver Schou (NERI: value of biodiversity, land use, etc.).

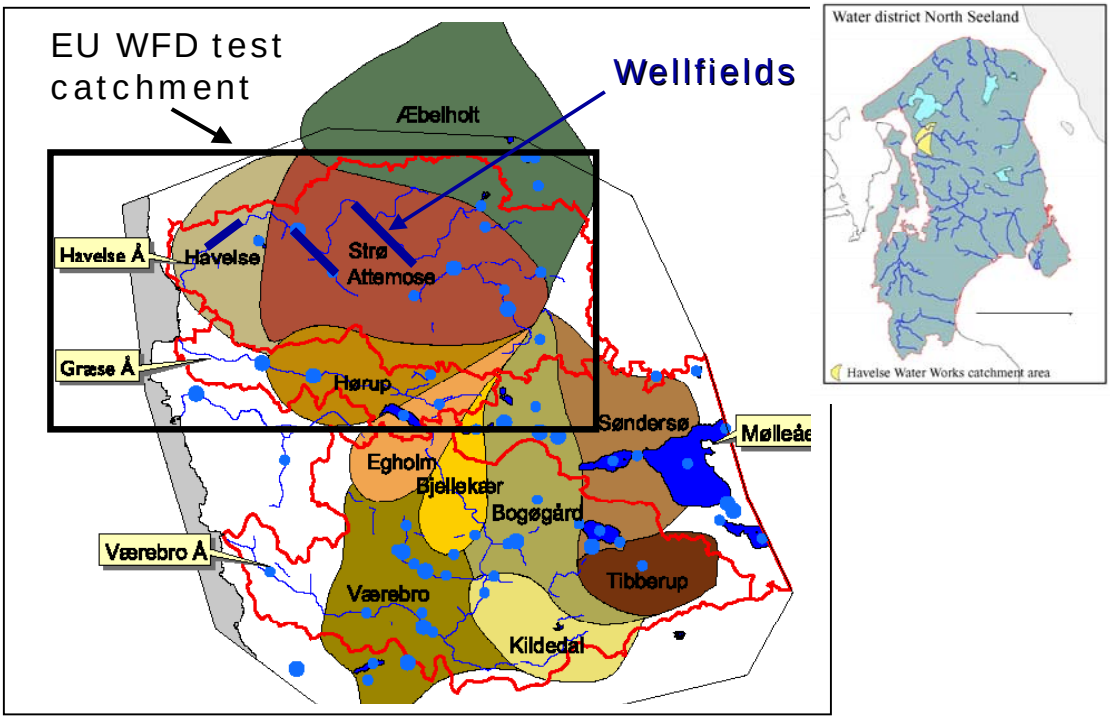


Figure 1.1 Danish case study area – Havelse river catchment (approximately 100 km^2). Havelse wellfield capture zone (35 km^2) is located in the downstream end of the river basin near Roskilde fiord. Copenhagen Energy operates two other large wellfields upstream at Strø and Attemose.

Objectives for the Danish case study

The specific objectives of the Danish case study was formulated as follows:

1. To construct a Bayesian belief network (BBN) study site in Denmark with a focus on innovative actions for precautionary groundwater protection against pesticide threats.
2. To investigate the extent to which BBNs can be used as a decision support tool for water resource management at a wellfield abstracting groundwater from the downstream part of a river basin.
3. To develop techniques to encourage and enable full stakeholder involvement in the construction of BBNs. This final but critically important component will provide an evaluation of the most effective means to involve stakeholder groups in the decision-making process.

Results of the Danish case study

Objective 1 Construction of BBN study site: The project provided clear feedback to regional authorities and the larger waterworks in Denmark that the way forward should not be based on voluntary agreements that are individually negotiated with farmers. Action planning based on voluntary agreements is a big issue, but in practice when it comes to implementation, they are not useful. It is much better for Copenhagen Energy either to look for possible afforestation areas or to buy land in the well catchment zone, where there is a certain need due to vulnerable areas (expropriation). Another option will be to auction off farming contracts, simply assigning contracts at a fixed price (e.g. EUR 200/ha) to the farmers who have the highest priority with respect to pesticide application and vulnerability.

Objective 2 Test of BBNs as decision support tool: The results of the Havelse BBN study site experience showed “a paradox”. On the one hand, Bbn’s can create space for an open and non-deterministic dialogue with stakeholders due to the flexibility of the decision support tool. This allowed factors (nodes), associations (directed links) and probabilities of the graphical model to be adjusted, reconstructed and validated throughout the process and based on inputs from all involved stakeholders and experts. This means that BBN’s were powerful for integrating data and knowledge from different domain experts and capable of handling uncertain information in a practical and easy understandable manner. Constructing the qualitative part of a belief network (nodes and links), although elaborate, seemed relatively straightforward and experts seemed comfortable doing so. This part of the net was relatively easily communicated to stakeholders.

On the other hand getting stakeholders, general public and even experts to understand and accept the idea behind BBN’s used for decision making was a demanding task. Especially the required probability assessments for the BBN’s were not easy to understand or accept by stakeholders. Even domain experts had problems to express all these probabilities numerically, something they were reluctant to do. So the quantitative part, with the probabilities over the variables, were more problematic.

However, BBN’s may still be useful in the hands of water resource scientists and water managers dealing with complex problems by permitting carefully elicited expert knowledge as a practical alternative to “hard” data, and facilitating extension of models to ecological and socio-economical endpoints.

This leads us to the following conclusions regarding BBNs as a *decision support tool*. BBNs demonstrated several advantages compared to traditional approaches. BBNs enabled locally based solutions (more than before). They provided local acceptance of decisions and solutions and improved the dialogue between the water company, local stakeholders and authorities. They encouraged diverse perspectives (and thus identified issues not thought of). They enabled a better evaluation of the issues. They made use of local and citizen knowledge not known by the authorities.

The weaknesses of BBNs as a decision support tool were the time-consuming and long-lasting process in construction and evaluation of BBNs, which had to be properly organised and conducted. This means that, if there is a lack of resources (time, money, staff), rules for participation, in-depth involvement of authorities, hands-on BBN for the stakeholders and professional supervision of the stakeholder involvement process, then the credibility of the BBNs are likely to be questioned by stakeholders and general public.

Objective 3 Techniques to encourage and enable full stakeholder involvement: Regarding involvement of stakeholders and general public in BBN development we made the following observations in the Danish case study:

- Stakeholders had an impact on the BBN development (on variables, links and CPT's, e.g. 'perception of vulnerability' variable and behaviour of farmers in relation to compensation payment)
- Evaluation of BBNs with input from stakeholders and general public was a necessary step.
- In the early, more qualitative stages, broader groups of stakeholders and the general public provided relevant input to BBN development.
- In the later, more quantitative stages, it was better to consult stakeholders and members of the general public at individual meetings or maybe in stakeholder and citizens' groups that each focused on a "domain of interest" because they were reluctant to give quantitative inputs in larger groups.
- Experts were necessary for quantitative input to BBNs. In the case study, we had two experts in farming economics and socioeconomics in addition to the geological and hydrological experts from CE and GEUS. It would have been an advantage in BBN development if the panel of experts had included an expert on biodiversity and/or pesticide-exposed aquatic environment as well.
- The results of BBNs must be followed by a detailed description of the parameters used and why, plus a description of the results and their consequences in order to make BBNs as transparent as possible. It is much to risky to allow politicians or civil servants to make decisions based on the "naked" data. So one should rather allow stakeholders and citizens to become more involved
- It was important to provide users with more easily understandable explanations of the results, for which numbers not necessarily was the best option and verbal communication are a necessary alternative. Furthermore, an expert's assessments may reflect various biases, where an expert consistently gives probability assessments that are higher or lower than the true probabilities.
- In order to provide a credible BBN it was necessary to engage stakeholder groups in the validation of BBN's. This was a crucial and demanding task.

In conclusion, the use of BBNs went beyond information and consultation and required the full involvement of stakeholders in their construction and validation. The advantage was a reduced risk of later support by stakeholders during the implementation phase of a given action plan. The benefits of BBNs were greatest when there was a high degree of interaction between researchers, users, water managers, stakeholders and general public.

Evaluation

Even though stakeholders and citizens generally expressed disappointment with participation in the project and in the working groups, including the roles played by GEUS, CE and the Agenda 21 Centre, most stakeholders and citizens also felt that they had had an influence on the development of the BBNs. Some remarks were:

- “The project management was open and positive about discussing the elements.”
- “CE and GEUS found out that farming contracts are not an applicable solution.”
- “They listened to suggestions.”

According to stakeholders and citizens, the greatest advantages of the BBNs were the following:

- “Used properly, a good, flexible tool for integration”
- “Clear overview”
- “Good tool for dialogue”
- “The citizens' group can understand a BBN just fine if it is explained properly by the specialists”.

The greatest limitations of BBNs:

- “Require insight and understanding”
- “You get the answers you want”
- “Not applicable to groundwater protection”
- “Selection of precise data required”
- “Correctness of information is questioned”
- “A complex tool whose primary strength is as a tool for dialogue”
- “Number of variables must not be too large or overview is lost and relationships less clear”

Recommendations for guidelines

Based on the Danish case study and various analysis the following inputs to guidelines was identified:

Objective 1 To construction of BBN study site in Denmark

- *A protocol for the development of a BBN is recommended. This protocol prescribes seven steps: 1) define the context, 2) identify factors, actions and indicators, 3) build a pilot network, 4) collect data, 5) define states, 6) construct conditional probability tables and 7) collect feedback from stakeholders and general public.*
- *Structural learning or EM-learning is encouraged in order to bridge data and the model developed.*

Objective 2 To investigate the extent to which BBNs can be used as a decision support tool for water resource management

- *BBNs are most powerful when integrating different domains, e.g. physical, social, economic and ecological, in the early stages of preparing a management plan with the involvement of stakeholder groups and general public*
- *A panel of experts is valuable in covering each domain included, for providing proper input and/or for reviewing the results from the BBNs developed.*

Objective 3 To develop techniques to encourage and enable full stakeholder involvement in the construction of BBNs

- *Clear rules of the game are important: it is necessary to prepare a **stakeholder involvement plan** describing how to involve stakeholders and general public which is balanced with respect to problem framing and the type of decision support system used for the planning and/or implementation.*
- *It is better to involve stakeholders and general public in "temporary" groups or in individual meetings when direct input is required, especially when collecting data for BBNs; feedback on states, links and CPTs than it is to run the process with broad, permanent working groups of stakeholders and citizens'.*
- *Don't be afraid of actively involving citizens: but be careful to inform and explain properly about the tasks and goals and do always allow feedback and comments on the BBN development process by presenting the graphical model and easily understood descriptions and results.*
- *If representatives of the general public are involved, be sure there is enough time and money to run the process according to the stakeholder involvement plan.*

CHAPTER 2 Sammenfatning

Hans Jørgen Henriksen, GEUS

Introduktion

Anvendelighed af grafiske modeller (Bayesianske belief netværker – BBNs) i vandressourceforvaltning i forbindelse med forebyggende grundvandsbeskyttelse blev undersøgt i et case studie for oplandet til Havelse kildeplads i Nordsjælland (figur 1.1). Danmark og Grønlands Geologiske Undersøgelse (GEUS) var projektleder og Københavns Energi (CE) beslutningstager og slutbruger i relation til BBN case studiet.

CE er det største vandforsynings-selskab i Danmark. CE forsyner rundt regnet en million indbyggere i det Storkøbenhavnske område med drikkevand hver dag. CE driver Havelse kildeplads sammen med 55 øvrige store kildepladser på Nordøstsjælland.

Tre forskellige indsatsområder er blevet analyseret ved opstilling af BBNs: 1) frivillige dyrkningsaftaler, 2) skovrejsning og 3) etablering af vådområder. For hver problemstilling blev der med fuld involvering af såvel en professionel interessentgruppe som en borgergruppe konstrueret og evalueret et BBN.

Muligheder og problemer tilknyttet frivillige fem-ti-årige dyrkningsaftaler der foreskriver 'nul pesticidanvendelse' til gengæld for kompensationsbetaling blev specielt analyseret. Opgaven var ikke konkret at implementere sådanne zoner, men blot at analysere hvad der krævedes i betalingsniveau, såfremt sådanne beskyttelseszoner skulle kunne implementeres med et omfang og i en skala, der kunne medføre at de bidrog effektivt til forbedret grundvandsbeskyttelse. Derudover var hensigten at klargøre, hvilke konsekvenser implementeringen af sådanne 'nul-pesticid aftaler' måtte have på arealanvendelse, driftsøkonomi (i landbruget), grundvandskvalitet, biodiversitet og det akvatiske miljø.

Information, konsultation og aktiv involvering af professionelle interessenter og offentligheden (lokale borgere) blev gennemført ved hjælp af annoncer, faciliteret offentligt møde, arbejdsgruppe møder, nyhedsbreve, hjemmeside, og en joint arbejdsgruppe. Agenda 21 Center i Frederikssund var udpeget som facilitator for det offentlige møde og arbejdsgruppemøderne (borgergruppen). Desuden deltog eksterne eksperter i driftsøkonomi (Svend Rasmussen, KVL) og værdisætning af biodiversitet mm. (Jesper Sølver Schou, NERI).

Formål

De specifikke formål med det danske MERIT case studie var:

1. At konstruere et BBN test studie område i Danmark med fokus på forebyggende grundvandsbeskyttelse (innovative løsninger) i forhold til pesticider i grundvandet
2. At undersøge i hvilket omfang bayesianske belief net (BBNs) var anvendelige som beslutningsstøttesystem i vandressourceforvaltningen for en kildeplads beliggende i nedstrøms del af et vandløbsopland
3. At udvikle metoder der opmuntrede til og gav mulighed for aktiv involvering af interessenter ved konstruktionen af BBNs. Denne sidste men kritiske komponent skulle bidrage til en evaluering af effektive værktøjer til involvering af interessentgrupper i beslutningsprocessen

Resultater af det danske MERIT case studie

Formål 1 Konstruktion af BBN test studie område. Projektet gav en utvetydig tilbagemelding til regionale myndigheder og større vandværker i Danmark om at vejen frem ikke går via frivillige dyrkningsaftaler som forhandles individuelt med landmænd. Indsatsplaner baseret på individuelle dyrkningsaftaler er et område med et betydeligt potentiale, men når det kommer til implementering af sådanne aftaler, er de ikke brugbare i praksis. Det er meget mere hensigtsmæssigt for CE enten at kigge sig om efter egnede skovrejsningsområder eller at opkøbe jord i oplandet til en kildeplads, hvor der er et særligt behov herfor som følge af særligt sårbare arealer (altså i stedet basere grundvandsbeskyttelsen på ekspropriation).

Formål 2 Test af BBNs som beslutningsstøtte system. Resultaterne af undersøgelsen af BBNs for Havelse kildepladsopland viste et paradoks. På den ene side kunne BBNs skabe et rum for en åben dialog (hvor resultatet ikke var givet på forhånd) med interessenter på grund af den fleksibilitet som dette beslutningsstøtte system har. Derved kunne styrende faktorer (knudepunkter/variable), sammenhænge (kanter/links) og sandsynlighedstabeller tilhørende den grafiske model justeres, rekonstrueres og valideres gennem hele processen og på basis an inputs fra involverede interessenter og eksperter. Det vil sige, at BBNs var stærke når det gjalt integration af data og viden fra forskellige domæne eksperter og tilmed var i stand til at håndtere usikkerhed på en praktisk og let forståelig måde. Konstruktionen af den kvalitative del af et BBN (variable og links) var, om end tidskrævende, 'lige ud af landevejen' og eksperter syntes ikke at have væsentlige problemer med denne del. Det var relativt let at kommunikere med interessenterne vedrørende denne del af BBNs.

På den anden side, var det en krævende opgave at få interessenter, borgere og eksperter til at forstå og acceptere den tilgrundliggende idé bag BBNs anvendt som beslutningsstøtte værktøj. Specielt var det svært for interessenterne at forstå og acceptere de nødvendige sandsynlighedstabeller. Selv domæne eksperter havde svært ved at formulere disse sandsynligheder numerisk, noget de ofte var tilbageholdende med at gøre. Det vil sige den kvantitative del, de betingede sandsynlighedstabellerne, gav problemer.

Men BBNs vurderedes på trods heraf fortsat at være et brugbart værktøj for såvel vandressource -forskere og –forvaltere, der står overfor komplekse problemstillinger. BBNs muliggjorde indbygning af ekspertviden som et praktisk alternativ til 'hårde data' (fra modeller eller monitering), og tillod samtidig udbygning af beslutningsstøtte systemet til også at kunne belyse økologiske og socio-økonomisk konsekvenser.

Dette førte os frem til følgende konklusion vedrørende BBNs som beslutningsstøtte værktøj. BBNs fremviste adskillige fordele sammenlignet med traditionelle metoder. BBNs gav mulighed for lokalt baserede beslutningsstøtte systemer (mere end øvrige metoder). BBNs muliggjorde bedre lokal accept af beslutninger og forbedrede dialogen mellem vandselskab, lokale interessenter og myndigheder. BBNs opmuntrede til at anskue problemstillingen udfra forskellige synsvinkler og var på den måde med til at identificere forhold og problemstillinger man ikke var opmærksom på. De tillod en bedre og mere helhedsorienteret evaluering af problemerne. De gjorde brug af lokal viden (input fra borgere) som myndighederne ikke havde kendskab til.

Svagheden ved BBNs som beslutningsstøtte system var at processen med konstruktion og evaluering tog lang tid, og at udførelsen af processen tilmed forudsatte en nøje planlægning og organisering. Det vil sige, at hvis der var mangel på ressourcer (tid, penge, bemanding), spilleregler for processen (f.eks. deltagelse og opgaver for arbejdsgrupperne), myndighedsinvolvering, instruktion i BBN værktøjet og professionel supervision af interessentinvolverings processen, så resulterede det til spørgsmål fra interessenter og borgere til troværdigheden af de konstruerede BBNs.

Formål 3 Teknikker der opmuntrede til og gav mulighed for aktiv involvering af interessenter: Med hensyn til involvering af interessenter og offentlighed (borgere) i udviklingen af BBNs gjorde vi følgende observationer i det danske case studie:

- Interessenterne havde indflydelse på udviklingen af BBNs (både på variable, links og sandsynlighedstabeller, eksempelvis 'perception af sårbarhed' og adfærd af landmænd i forhold til størrelse af kompensationsbetaling)
- Evaluering med input fra interessenter og borgere var et nødvendigt trin i brugen af BBNs i integreret vandressource forvaltning
- På de tidlige, kvalitative trin i processen, gav sammensatte professionelle interessentgrupper og borgerinvolvering relevante inputs til udviklingen af BBNs
- På de senere, mere kvantitative trin i processen, viste det sig at være mere optimalt at konsultere interessenter og repræsentanter for borgerne på individuelle møder, eller i grupper der fokuserede på en mindre del af det samlede BBN, som havde denne gruppes særlige interesse, bl.a. fordi interessenterne var tilbageholdende med at give kvantitative input når de deltog i den tværgående professionelle interessentgruppe
- Deltagelse af eksperter var en nødvendighed med henblik på kvantitative input til BBNs. I case studiet, deltog to eksperter med speciale i driftsøkonomi (landbrug) og socioøkonomi (værdisætning af miljø, skov, biodiversitet mv.) udover de geologiske og hydrologiske domæne eksperter der deltog fra såvel GEUS som CE. Det ville have været en fordel hvis der også havde været deltagelse af eksperter på områderne biodiversitet (terrestrisk økologi) samt akvatisk miljø (vandløbsøkologi) hvor specielt konsekvenser af pesticider var svagt belyst i MERIT projektet
- Præsentation af resultater af BBNs skal indeholde en detaljeret beskrivelse af parametre (variable, tilstande, links og sandsynlighedstabeller) og en dokumentation

for hvordan disse er fremkommet, samt en beskrivelse af resultaterne og konsekvenser heraf med henblik på at gøre BBNs så gennemsigtige som muligt. Det er alt for risikabelt, at lade politikere eller embedsmænd tage beslutninger ud fra de 'nøgne data'. Så lad hellere interessenter og borgere blive mere involveret.

- Det var vigtigt at præsentere let forståelige forklaringer af resultaterne for brugerne, idet tal ikke nødvendigvis gav de bedste muligheder. Her var verbal kommunikation et godt alternativ. Desuden kunne en eksperts vurderinger være 'biased', f.eks. ved at en ekspert hele tiden angav sandsynligheder som var enten systematisk højere eller lavere end de 'faktiske' sandsynligheder.
- For at opnå et troværdigt BBN var det nødvendigt at engagere interessentgrupper i valideringen af BBNs. Det var de absolut afgørende forudsætning for brugen af BBNs og kan være en ret krævende opgave.

Som konklusion, så overskred brugen af BBNs de traditionelle grænser for information og konsultation, og forudsætte aktiv involvering af interessenter både med hensyn til konstruktionen og evalueringen af BBNs. Fordelen heraf var en reduceret risiko for manglende opbakning til indsatsplanen i selve implementeringsfasen fra interessenterne. Fordelen ved brug af BBNs var størst når der var en høj grad af samarbejde og interaktion mellem forskere, brugere, vandressource forvaltere, interessenter og offentlighed / borger.

Evaluering

På trods af at interessenter og borgere generelt udtrykte skuffelse (frustration) med deltagelsen i processen og i arbejdsgrupperne, også med hensyn til GEUS's, CE's og Agenda 21 centerets roller, så gav de fleste interessenter og borgere samtidig udtryk for at de følte de havde haft indflydelse på udviklingen af BBNs. Udvalgte kommentarer hertil:

- Projektstyringen var åben og positiv overfor en diskussion af elementerne
- CE og GEUS fandt ud af at dyrkningsaftaler ikke er en anvendelig metode (i praksis)
- De lyttede til forslag

Interessenter og borgere tilkendegav at de mente at BBNs største fordele var:

- Anvendt korrekt et godt værktøj for integration
- Klart overblik
- Et godt værktøj for dialog
- Borgerne kan godt forstå BBNs hvis de forklares ordentligt af specialisterne

De største begrænsninger ved BBNs var:

- Forudsætter indsigt og forståelse (af metoden)
- Du kan få de svar som du ønsker
- Ikke brugbare for grundvandsbeskyttelse
- Udvælgelse af præcise data er en forudsætning
- Der stilles spørgsmål ved korrektheden af information
- Et komplekst værktøj hvis største styrke er som værktøj for kommunikation
- Antallet af variable må ikke være for stort så mister man overblik og sammenhænge bliver mindre tydelige

Anbefalinger til vejledning i brug af BBNs

På basis af det danske case studie og tilhørende analyser blev følgende retningslinier identificeret som input til MERIT vejledning (guidelines):

Formål 1 Konstruktion af BBN test studie område

- *En protokol for udviklingen af BBNs anbefales. En sådan protokol kunne bestå af 7 trin: 1) definer kontekst, 2) identificer faktorer, indsatser og indikatorer, 3) konstruer et pilot BBN, 4) indsaml data, 5) definer tilstande (for indgående variable i BBN), 6) konstruer betingede sandsynlighedstabeller og 7) indsaml feedback fra interessenter og offentlighed (borgere)*
- *Strukturel læring og læring af betingede sandsynlighedstabeller direkte udfra data (structural learning and EM-learning) bør så vidt muligt anvendes hvis det er muligt med henblik på at bygge bro mellem data og BBN model og øge forståelsen af BBNs.*

Formål 2 Test af BBNs som beslutningsstøtte system

- *BBNs er et stærkt værktøj til integration af forskellige domæner, f.eks. fysiske (naturvidenskabelige), sociale, økonomiske og økologiske, i de tidlige trin i arbejdet med forberedelsen af vandhandlingsplaner med involvering af interessentgrupper og offentlighed (borgere)*
- *Et ekspertpanel er værdifuldt der kan dække samtlige indgående domæner, med henblik på korrekt input/review af resultater af BBN udviklingen*

Formål 3 Teknikker der opmuntrede til og gav mulighed for aktiv involvering af interesenter:

- *Klare spilleregler for involveringen er vigtige: det er nødvendigt at udarbejde en 'interessent involveringsplan' (stakeholder involvement plan) der beskriver hvordan interessenter og offentlighed / borgere skal involveres der er afbalanceret i forhold til afgrænsning af opgave og beslutningsstøtte værktøj der anvendes til planlægning / eller implementering af opgaven*
- *Det er bedre at involvere interessenter og borgere i 'midlertidige' grupper eller på individuelle møder når der skal indsamles direkte input (kvantitative), specielt ved indsamling af data til BBNs, feedback til valgte tilstande (variable), links og betingede sandsynlighedstabeller (CPTs) end det er at køre processen med tværgående, permanente arbejdsgrupper af interessenter og borgere*
- *Vær ikke bange for at involvere borgere og offentlighed: men vær omhyggelig med at informere og give en ordentlig forklaring på hvilke opgaver og mål der sigtes på i gruppearbejdet, og sørg for at der altid er åbnet op overfor muligheder for feedback og kommentarer til BBN udviklingsprocessen gennem præsentation af den grafiske model og letforståelige beskrivelser og resultater*
- *Hvis repræsentanter for offentligheden (borgerne) er involveret, så vær sikker på at der er afsat tilstrækkelig tid og penge til at køre processen til enden i henhold til den udarbejdede interessent involveringsplan*

CHAPTER 3 Introduction

Hans Jørgen Henriksen, GEUS, Per Rasmussen,GEUS, Gyrite Brandt, CE and Dorthe von Bülow, CE

3.1 Objectives

MERIT is aimed at developing an integrated water resource management methodology suitable for use throughout Europe at the river basin scale. Integrated policies are widely accepted as the best way to achieve sustainable environmental development. The challenge is to develop a practical and effective methodology that enables managers to make multi-objective decisions, while at the same time ensuring that stakeholders become actively involved in the decision-making process: in other words, to implement integrated management.

The MERIT project will attempt to provide such a methodology through the development of a generic integrated management tool based on the concept of Bayesian belief networks (BBNs). This generic tool will be based on case studies carried out in four countries: the UK, Denmark, Italy and Spain. The sites were specifically chosen to represent four very different environmental, economic and social settings that reflect the problems that are currently facing stakeholders in many parts of northern and Mediterranean Europe.

The specific objectives of the Danish case study can be formulated as follows:

- To investigate the extent to which BBNs can be used as a decision support tool for water resource management at a wellfield abstracting groundwater from the downstream part of a river basin.
- To construct a BBN study site in Denmark with a focus on innovative actions for precautionary groundwater protection against pesticide threats.
- To develop techniques to encourage and enable full stakeholder involvement in the construction of BBNs. This final but critically important component will provide an evaluation of the most effective means to involve stakeholder groups in the decision-making process.

Copenhagen Energy (CE) not only operates Havelse wellfield and supplies drinking water to the country's capital city area from this field, but also operates 54 other large wellfields located in northern and eastern Zealand (the island on which Copenhagen is located). Thus CE is the decision-maker and end user of this BBN case study, whose results may influence CE's policy and strategy for groundwater protection.

The possibilities and problems connected with implementing groundwater protection zones using voluntary five-ten-year farmer contracts prescribing no pesticide application in return for compensational payment will especially be analysed. It is not a question of actually implementing such zones that is in focus in the present study, only analysing what would

be required in compensational payment if such zones were to be implemented at a magnitude and on a scale that allows them to function as efficient groundwater protection. Furthermore, the aim is to clarify the impact implementation of such protection zones would have on land use, farm economics, groundwater quality, biodiversity and aquatic environment.

The methodology will be generic and applicable at any scale throughout Europe. It will comprise three elements, as listed below (3.1.1, 3.1.2 and 3.1.3).

3.1.1 Decision support tool

At the heart of the approach is a decision support tool based on probability theory. Bayesian belief networks (BBNs), successfully applied in the fields of medicine and artificial intelligence for years, will provide the core of the system. BBNs offer advantages over other policy development tools in that they are able to represent the environmental system as a whole. The system is represented as a network of nodes linked in a way to represent cause and effect within the system. Each node represents a variable and can be of any type (environmental, social, economic, etc.), and the “cause and effect” links between them can be simulated using a range of analytical techniques based on whatever data is available. This may be a data set or output from a model, or it could be based simply on expert opinion.

Once a network is complete, the impact of a decision can be evaluated by entering the action into the relevant node (variable). This change will then have a knock on effect on all those nodes linked to it. In this way the impact on the entire system can be evaluated. Results are presented as bar graphs showing the state of each variable in terms of probability distributions, thus explicitly representing the degree of uncertainty in the system. The simple graphical output will help stakeholders more easily appreciate the trade-offs necessary for multi-objective management to be achieved. Furthermore, the explicit recognition of uncertainty will help decision-makers to identify more clearly the risks associated with different management strategies.

3.1.2 Quantifiable water resource indicators

Quantifiable water resource indicators are a set of indicators embedded as objective variables within the BBN. These indicators are key variables; they provide the means to monitor the success of management decisions and are used to guide the development of new strategies. The challenge was to devise a set of easily quantifiable indicators that could play this important role.

3.1.3 Framework for stakeholder participation

This is a participatory framework to enable full stakeholder involvement in the construction and analysis of the BBN. This final but critically important component provided an evaluation of the most effective means to involve stakeholder groups in the decision-making process. We wanted to define the best approaches to select suitable stakeholders,

facilitate their design of the BBN, obtain data from them for inclusion in the BBN, present the analytical results produced by the BBN, deal with conflict and, finally, select the optimal management plan. It will also investigate the best ways of combining the subjective data elicited from stakeholders with more objective measured data. No attempt to resolve all current water management issues in each catchment area will be made, but subsets will be selected to illustrate the generic way in which the technique can be applied to help facilitate planning decisions. The issues to be addressed will be identified by representative stakeholder groups at the four sites. The demonstration BBN for each catchment will thus focus on management issues considered relevant and important by local stakeholders. Widespread implementation of the approach developed by the project will lead to improved management of river basins and help Europe move towards water use which is economically optimal, socially equitable and environmentally sustainable.

3.2 Terminology for public participation under the Water Framework Directive

3.2.1 Information, consultation and active involvement

The following terminology was proposed recently for a workshop held in Brussels in February discussing public participation in modelling (the Harmoni-CA WP5 workshop):

- Information provision: providing information about management timetables, issues and management plans to the participants; considered the foundation of all further participation activities
- Consultation: encouraging written and oral responses
- Active involvement: involving people in developing and implementing plans to form the final plan decided upon
- Shared decision-making: helping to make the final decision about which plan to implement and taking responsibility for the decision

There is also a meta-level of participation termed “awareness raising and developing a learning approach”, something that will support all the other levels of participation and management, which should be remembered.

Three separate groups take part in river basin management:

- the competent authority
- stakeholders (interested parties)
- the public (general public)

Table 3.1 refers to the guidance document on public participation and illustrates involved parties at different levels of participation to meet the requirements of the Water Framework Directive (WFD). Table 3.2 details stages of participation, process outcome and methodological approach.

Table 3.1. Parties involved at the different levels of participation according to the guidance document on public participation in the Water Framework Directive.

	PUBLIC	STAKEHOLDERS	COMPETENT AUTHORITY
Information provision	Obligatory	Obligatory	the competent authority should organise the participation
Consultation	Obligatory	Obligatory	
Active Involvement	Not prescribed	Encouraged	
Shared decision making	Not prescribed	Not prescribed	Solely responsible
Awareness raising	Encouraged	Encouraged	Encouraged

Table 3.2. Characterisation of stages, degrees and methods of participation. Adapted from Mostert (2003a).

	1	2	3	4	5
Stages of Public Participa	**Information gathering/ dissemination**	**Consultation and hearings**	**Discussion**	**Co-decision making**	**Decision-making**
Process outcome	The public is provided with or has access to information	The views of the public are sought	Real interaction takes place between the public and government	The public share decision-making powers with government	The public performs public tasks independently
Methodological approach	Leaflets, brochures, mailings, briefings, use of media, Internet, etc.	Reply forms, opportunity to comment in writing, hearings, meetings, interviews, opinion polls, stakeholder analysis, Internet discussions	Small/large group meetings: workshops, roundtables, brainstorming sessions, Internet discussions	Negotiations, e.g. resulting voluntary agreement, stakeholder represented in government bodies, small/large group meetings	Water use associations and other NGOs performing public functions, popular initiative

Competent authorities are the authorities given final responsibility for deciding on and implementing the management plan. *Stakeholders* are persons, groups or organisations affected by a management plan, e.g. professional bodies, government authorities, residents' organisations, farmers' groups, individual landowners or residents. Usually stakeholders invited to participate are representatives of such groups. Unorganised groups of individuals in the community who still have a stake in the management of the river basin are termed *the general public*.

3.2.2 Public participation in relation to the case study at Havelse wellfield

Public participation can create an open and accessible decision-making process that results in decisions that reflect public concerns and are technically and economically feasible, environmentally sound, health- and safety-conscious, cost-effective, and in compliance with regulatory requirements and commitments.

When dealing with BBNs with involved economists, ecologists and hydrologists working together and communicating with stakeholders and the general public, a number of challenges can be foreseen (Moxey and White, 1998):

- Problems with academic territories: Different disciplines effectively speak different languages; defence of own territory and domains operates at fundamentally different levels of spatial and temporal aggregation.
- The illusion of the technique: BBN may provide an overview, but underlying models and datasets are rather complex for users. The effort to reflect the real world led to greater refinements, causing the models to become even more difficult to comprehend and maintain; there may also be lack of spatial and temporal data coverage and knowledge.
- Shelfware: Some practitioners and policy makers are extremely sceptical about the value of models and their usage and may not at all accept the need for a catchment approach or spatial connectivity. Can BBNs provide a meaningful alternative for such managers, or is it even harder to understand and trust BBNs?

Therefore, time and effort is necessary at the start of the project in order to build public support for the BBN development project and to define the expected outcome [2]. Developing a common understanding of problems and concerns, analysing stakeholder interests and forming working groups to deal with such issues are required if these processes are to run smoothly.

Stakeholders and the general public rarely have formal scientific training but may have considerable local knowledge and information about additional data and even data quality. This calls for a proper communication and 'hands-on' training in use of BBNs and active involvement of representatives of the general public. Other stakeholders and representatives of the general public may be easier to communicate with without having to translate too much from the language the modelling experts use.

[2] Citizens' group has suggested more hands-on training in BBNs and asked for more active involvement of general public in decision making, see chapter 9

As mentioned above, public participation can be information, consultation and active involvement. Note also that social learning is encouraged in the WFD: especially BBN development could be a tool for such social learning if stakeholders and citizens participate and understand it, or at least the qualitative part of it.

In this research study, we were working in parallel with the ongoing renovation and protection activities at Havelse wellfield carried out by Copenhagen Energy.

3.3 BBN Terminology

3.3.1 Definition of Bayesian belief networks

Bayesian belief networks, or BBNs (also known as graphical models), are a widely applicable formalism for a compact representation of uncertain relationships among parameters in a domain or across several domains (in this case, water resource management in the WFD context). They provide a natural tool for dealing with problems that occur throughout applied mathematics and engineering: uncertainty and complexity (Aitken et al., 2003; Jordan, 1999).

Fundamental to the idea of a graphical model is the combination of simpler parts. Probability theory provides the glue whereby the parts are combined, ensuring that the system as a whole is coherent and that inferences can be made. BBNs are a method for discovering valid, novel and potentially useful patterns in data where uncertainty is handled in a mathematically rigorous, but simple and logical, way (Aitken et al., 2003).

Figure 3.1 shows the BBN for the “car start problem” mentioned in Chapter 0 above. If the car won’t start, there are three different potential causes: the spark plugs, the engine or the full subsystem (see Figure 3.1). Each of these may fail for a number of reasons. The BBN helps determine the cause of the problem, based on a number of observations that can be made. Characteristic of a BBN is the following (Jensen, 2002):

- A set of *variables (nodes)* and a set of *directed edges (links)* between variables
- Each variable has a finite set of mutually exclusive states (e.g. true/false)
- The variables together with the directed edges form a directed acyclic graph
- To each variable A with parents $B_1, \ldots, B_n$, there is attached a conditional probability table $P(A \mid B_1, \ldots, B_n)$

Making decisions about how to manage environmental resources is characterised by a high level of uncertainty. The complexity of the natural world is such that it is impossible to be sure of the full consequences of any actions taken that have an impact on the environment. Nevertheless, statistics provide a formal means of identifying the optimal decision, even when we are uncertain as to the exact state of the environment and, therefore, of the consequences of the decision. BBNs have been developed which provide an accessible means of implementing the formal analytical approach described above.

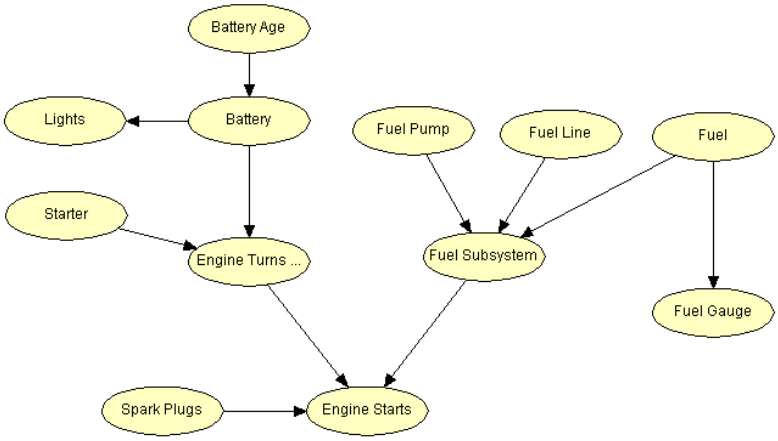


Figure 3.1. Bayesian belief network for the car start problem.

Selecting variables suitable to the decision being made and linking them together in a BBN is relatively straightforward; specifying the conditional probability tables is not. The values to be entered in the conditional probability tables can be obtained in one of three ways:

- Raw data
- Simulation modelling
- Expert opinion

3.3.2 Using HUGIN for reasoning under uncertainty

The key feature of a BBN is the fact that it provides a method for decomposing a joint probability distribution of many variables into a set of local distributions of few variables within each set. This allows an easier investigation of relationships amongst the variables in the context only of nodes of two (true/false) or more mutual independent states, e.g. groundwater quality expressed in three states: <0.01 μg/l, 0.01–0.1 μg/l and >0.1 μg/l pesticides.

Figure 3.2 shows a simple network with four variables (nodes) describing pesticide application, shallow groundwater quality (diffuse sources), point sources and deep groundwater concentration. The network in Figure 3.2 shows there is a risk of contamination above a drinking water limit value of 11.5%.

A Bayesian network package called HUGIN was used in the MERIT project to develop the networks. The results were obtained using a procedure known as propagation. In this procedure, the uncertainty in the original network is replaced with the certainty (i.e. probability 1) that matches have been reported. If in the example above we know the pesticide application for a certain area, this state can be entered into the network. After propagation, we get the results in Figure 3.3 for two different examples of entering evidence.

As can be seen from Figure 3.3, the risk of contaminated deep groundwater above 0.1 μg/l is 16.3%, assuming an application above 1.5 kg pesticides per ha, and 28% when both a high application and a high intensity of point sources is given.

The Hugin decision engine (HDE) performs reasoning on a knowledge base represented as a Bayesian network or an influence diagram. The HDE performs all data processing and storage maintenance associated with the reasoning process and allows application program interfaces for C, C++, and Java, and an Active X server.

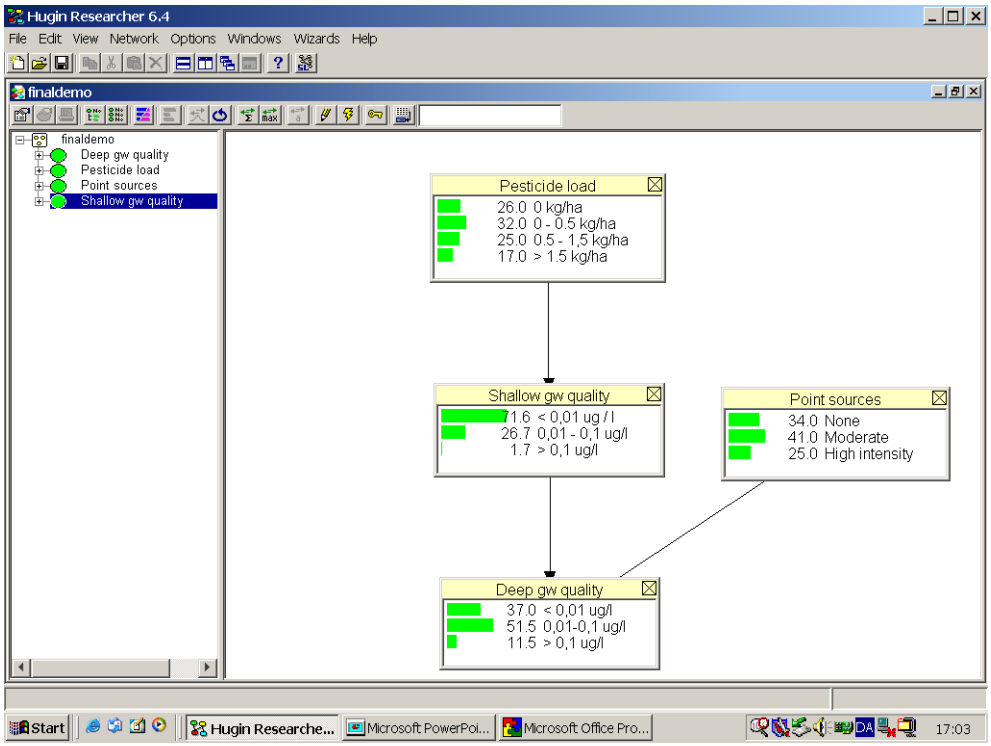


Figure 3.2. Bayesian belief network describing the relationship between pesticide load (per ha on agricultural fields), shallow groundwater quality (µg/l – diffuse sources only), frequency of point sources (three states: none, moderate or high intensity), and deep groundwater quality (µg/l). For the MERIT project we used HUGIN.

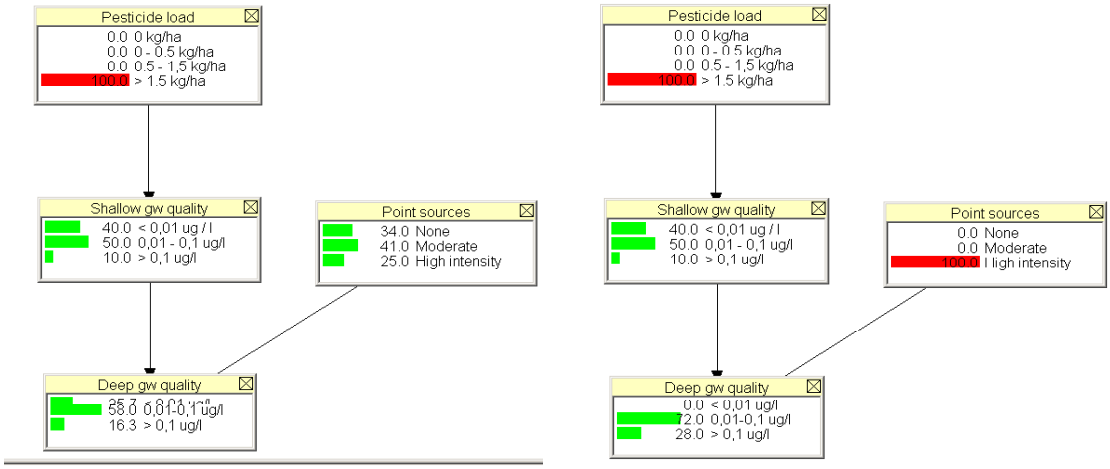


Figure 3.3. Example of analysis with a simple groundwater network, assuming that application is known to be >1.5 kg pesticides per ha (left). In the example to the right, results of the network for the application of >1.5 kg pesticides per ha and a high intensity of point sources (right).

3.3.3 Hypotheses to be tested in relation to BBNs

Most people understand the difference between a 11.5% and a 28% probability of deep groundwater pollution with pesticides above the limit value in groundwater as shown in the example above. Most people can make a decision regarding their own situation based on that information.

Probabilities offer an alternative approach to communicating data and model results which takes advantage of the ability of people to understand outcomes presented in probabilistic language. Instead of a pesticide concentration of 0.12 μg/l, simulated by a model, which is likely to be received with scepticism by stakeholders because it does not account for natural variability in the system, the information should be presented categorically in the following form: "There is a 37% probability that the concentration will be below 0.01 μg/l, a 51.5% probability that it will be between 0.01 and 0.1 μg/l, and a 11.5% probability that it will be greater than 0.1 μg/l."

One reason why probabilistic information of this form is useful is that it lends itself to evaluating the risk associated with different alternatives. Probabilities can be multiplied by the potential cost or benefit of different outcomes in order to elicit the "expected value" of a decision (Ames and Neilson, 2001). Expected values of different management alternatives can then be compared to aid decision-makers in selecting an option. Additionally, the risk of an outcome can be interpreted as a margin of safety associated with the option. In a BBN, this is done by introducing "utility nodes" that perform risk assessment by multiplying and adding total costs or benefits (in monetary value or other type of utility unit).

When applying the precautionary approach in groundwater protection, the role of uncertainty is vital: the higher it is, the lower the pressures allowed from various non-point and point pollution sources should be.

In addition, recent paradigms for risk-informed decision-making call for a participatory procedure in which the various stakeholders become involved early on in the risk assessment process to "characterise" risks even before a formal assessment of them is made. This does not diminish the role of modelling and quantification, but is aimed at eliciting the "values" and the perspectives of the community involved so that the multiple dimensions of risk can be taken into account early in the assessment (Ha et al., 2004; Amendola, 2001).

Decision-makers need to be informed not only of the available scientific knowledge but also of policy-relevant uncertainties and lacunae in the knowledge base (Levin et al., 2003). For this to be possible, uncertainties must be transparently discussed and communicated.

A key problem with the probabilistic approach is that most people feel more at ease with verbal probability expressions than with numbers. When people communicate probabilities, they frequently do so in words rather than in numbers. So when it comes to reasoning and to communicating the results of BBNs to users, the mode in which people normally represent probability must be taken into account as well (Renooij et al., 1999). This has often been considered a major obstacle, one of the reasons being that experts are reluctant to provide numerical probabilities. However, recent research activities have made some

progress in this field by developing a probability scale that contains words as well as numbers (Renooij et al., 1999; Witteman and Renooij, 2003; Gaag et al., 2002).

The objective of our study is to present and discuss the methodology adapted for the construction and validation of a Bayesian belief network for groundwater protection based on the active involvement of stakeholders and general public. Is it possible to engage stakeholders and general public in construction and validation of a BBN for preventive groundwater protection against pesticides? How should stakeholders and general public be involved most effectively using information, consultation and active involvement?

3.3.4 Impacts from individual, group and structure variables

On the Individual level, variables such as personality, emotions, perception, values, attitudes, motivation, ability and individual learning are in play, and although these variables were not studied in very great detail in our case, they certainly had an impact on testing the BBN.

Changes in the environment (both physical and socio-economical) may influence people's values and attitudes, which again have an impact on motivation and individual decision-making. Individuals are very important in groundwater protection, as consumers choosing between traditional or organic food products, as citizens using pest control measures other than pesticides in their gardens, or as farmers with a more careful attitude regarding the environmentally friendly handling of chemicals. One important variable we should most likely look out for is the perceptions of individuals. We can consult and ask people about their perceptions, and inform people and influence their perceptions using communication. However, what one perceives can be substantially different from objective reality. The problem is that we don't see things as they are; we see things as we are. A number of factors operate to shape and sometimes distort perception. These factors may reside in the perceiver, or in the object or target being perceived, or in the context of the situation in which the perception is made (Robbins, 2003).

Working groups are affected by variables at the group level, variables such as communication, group decision-making, leadership, trust and group structure. Groups offer an excellent vehicle for performing many of the steps in a decision-making process. If a group is composed of individuals with diverse backgrounds, the alternatives generated should be more extensive and the analysis more critical. When the final solution is agreed on, there are more people in a group decision to support and implement it. These plusses, however, can be more than offset by the time consumed by group decisions, the internal conflicts they may create, and the pressures they generate toward conformity (Robbins, 2003).

The construction of a BBN can be divided into three distinct components (Cowell et al., 1999). The first qualitative stage only looks at general relationships between the variables of interest in terms of the relevance of one variable to another under specified circumstances. Naturally, this leads to a graphical representation of conditional independences, but one that is not restricted to a probabilistic interpretation. The next probabilistic stage introduces the idea of a joint distribution defined in terms of the variables

in the model and relates the form of this joint distribution to the structure of the graph. The final quantitative step requires the numerical specification of the necessary conditional probability distributions.

Traditionally, all conflicts in such a process were harmful and to be avoided (Robins, 2003). In the human relation's view, the belief is that conflicts are a natural and inevitable outcome in any group. In the interactionist view of conflict, there is the belief that conflict is not only a positive force in a group but that it is absolutely necessary for a group to perform efficiently. A distinction can here be made between "task conflicts" related to the content and goal of the work, "relationship conflicts" focused on interpersonal relationships and "process conflict", which is related to how the work is done.

3.4 Concept and approaches applied for the Danish case study

3.4.1 Case study area: Havelse wellfield catchment

In the following we will present the Danish case study briefly with used concepts and approaches applied for the Danish case study area at Havelse. The applicability of graphical models (BBNs) in water resource management regarding preventive groundwater protection plans with focus on pesticides was investigated for Havelse wellfield capture zone in northern Zealand. The area provides drinking water to 50 thousand people in the greater Copenhagen area (see Figure 3.4).

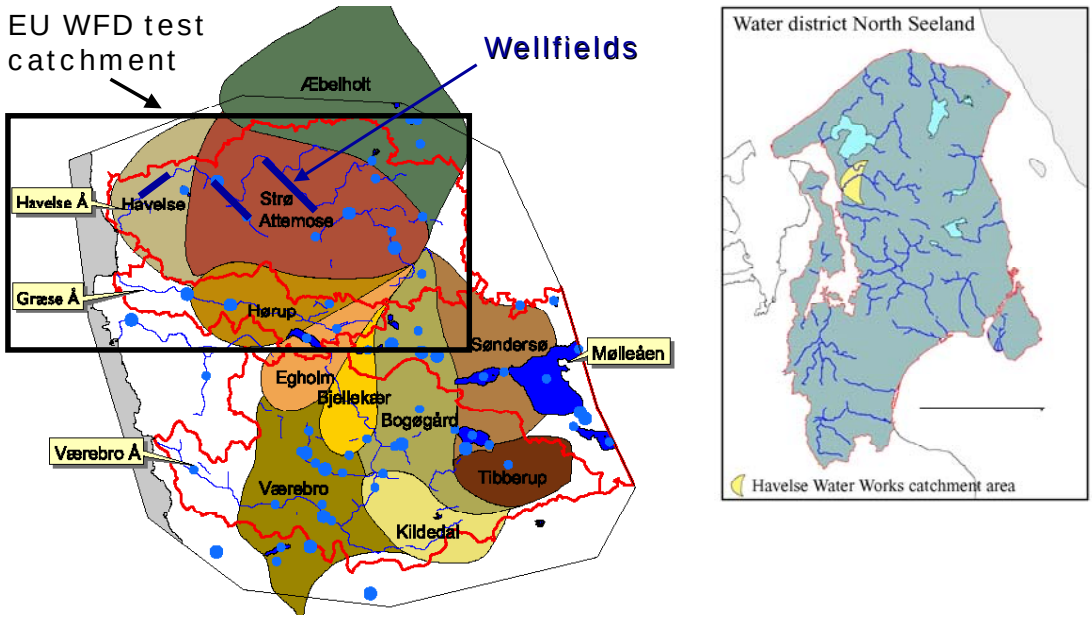


Figure 3.4. Danish case study area: Havelse river catchment (approximately 100 km^2). Havelse wellfield capture zone (35 km^2) is located on the downstream end of the river basin near the Roskilde Fjord bay. Copenhagen Energy operates two other large wellfields upstream at Strø and Attemose.

A BBN for farming contracts is to be constructed and analysed with the direct co-operation of and in dialogue with stakeholders and the general public. In the process, many different preliminary or more specific BBNs has been constructed and presented to stakeholders (e.g. preliminary BBNs for farming contract, afforestation and flooding).

Information, consultation and active involvement of professional stakeholders and general public was carried out using announcements, facilitated public meeting, working group meetings, newsletters, a Web site, individual meetings and a joint working group. The facilitator of the public meeting and workshops was the Agenda 21 Centre in Frederikssund. Various subcontractors participated, e.g. Svend Rasmussen (KVL: farm economics) and Jesper Sølver Schou (NERI: value of biodiversity, land use, etc.)

A principal task is bridging the gap between probabilistic models and human intuitive approaches to modelling uncertainty. (We used the protocol shown in Figure 3.5.)

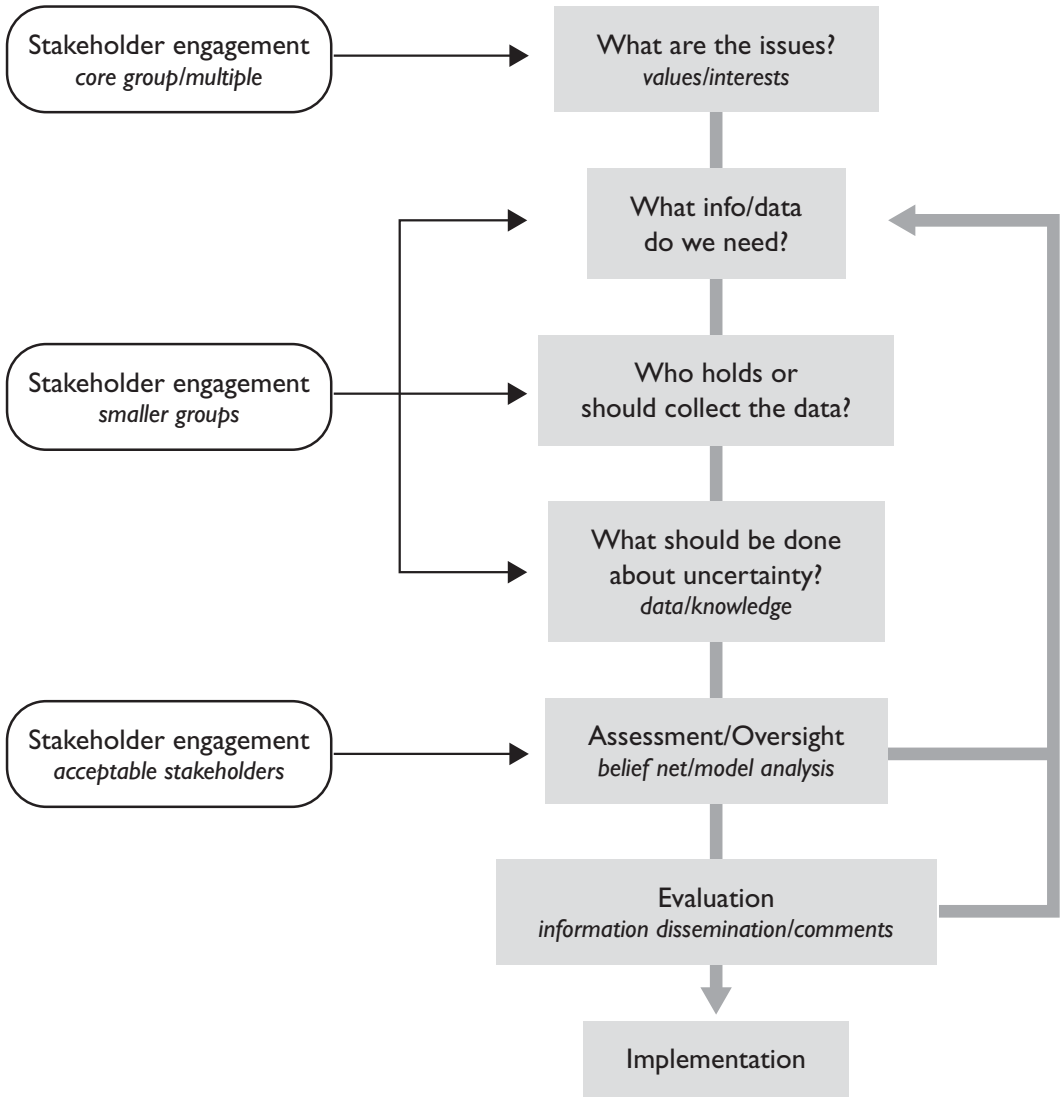


Figure 3.5. Model protocol for the MERIT stakeholder engagement process.

Stakeholder engagement might include (Petts, 2001):

- Assistance in identification of key issues (framing the problem)
- Identification of relevant data to feed into the tool
- An overview of the development of the tool (to ensure specialist input)
- Involvement in assessment and evaluation of the tool's output

Different stakeholders may be relevant to each of these elements. Each of the possible stages of engagement must be conducted in a structured way that enables information to be collected and recorded properly. In the Danish case study, this resulted in a group of professional stakeholders and citizens group.

The structure is a network that includes working groups (facilitated by the Agenda 21 Centre in Frederikssund) and Copenhagen Energy, GEUS, experts from KVL, NERI, Aalborg University and Birmingham University.

A process of active involvement requires a careful analysis of stakeholders and general public, clarified expectations, interest analysis, agreement between the parties involved, trust, resources, time, project manager flexibility, the ability to redirect the course when necessary, decision-making, courage and an open-minded attitude.

We also experienced conflicts and frustrations in the MERIT project, but we believe that we could not have gone on without them, so we very much support the interactionist view (see 3.3.4). We must remember that the things we are doing with groups of stakeholders differ from lessons learned from ordinary working groups with a number of scientists or experts or from working groups within organisations. We are dealing with stakeholders with interests, and conflicts are a necessary part of the game. It simply means that planning working group meetings has to be much more focused on behavioural organisation and organisational psychology than we are used to from the daily work in our institutions.

3.5 Existing practices at Copenhagen Energy

Copenhagen Energy is the largest water supply company in Denmark. It supplies roughly one million inhabitants in the greater Copenhagen area with drinking water each day.

Abstraction of water for drinking purposes in the greater Copenhagen area

- Regional abstraction (Copenhagen Energy):
    - Seven waterworks with a total abstraction of about 60 million m^3 per year. CE abstracts groundwater (and surface water) in four counties and about thirty municipalities.
- Local abstraction consists of:
    - Municipal waterworks
    - Private waterworks

Three-pronged abstraction strategy in Copenhagen Energy

- Groundwater wellfields can be divided into the following categories:
    - well suited (good groundwater quality, abundant resources)
    - suited (appropriate groundwater quality; wellfields located in urban areas)
    - not suited (bad water quality; closed, contaminated wellfields)
- Surface water (buffer) (abstraction of about 1 million m^3 per year)
- Artificial recharge (supplement; running as trial plants)

3.5.1 Regional abstraction

- Groundwater (backbone: 55 wellfields; abstraction of roughly 60 million m^3 per year)
    - well suited wellfields (good groundwater quality), with the following activities:
        - total renovation is continually being carried out, i.e.:
          -new boreholes
          -new pipes
          -new cables
        - groundwater protection of the catchment area, with a special levy on the price of water for this purpose of 5 (euro)cents per m^3. The funds are put into a CE "groundwater fund" and earmarked for activities which include:
            - geological mapping
            - groundwater model
            - groundwater protection plans
            - waterworks cooperation
    - concrete groundwater protection

3.5.2 Local abstraction

- groundwater only

3.5.3 Concrete groundwater protection

- afforestation
- farming contracts
- closing of unused boreholes and wells
- Stakeholders in these processes are local farmers, landowners and ordinary citizens

3.5.4 Abstraction licenses

- umbrella licence for waterworks
- new license per wellfield
- county levy on abstraction licenses

3.5.5 The test area: Havelse wellfield and catchment area

The test area is one of five wellfields under CE's Slangerup waterworks. The Havelse wellfield was established in 1955-56 and is on CE's investment plan from 2002 to 2006. Abstraction has stopped in 2001 due to water quality problems as well as inundation problems.

The wellfield's siphon system will be altered to a system based on individual centrifugal pumps in each new borehole. The wellfield will most likely be moved to a new location due to the County's plans to establish new wetlands in the area.

An umbrella license exists for all five wellfields under Slangerup Waterworks. Havelse wellfield's original license runs out in 2010.

A groundwater model was prepared in 2002-04. The model is used to evaluate abstraction in relationship to wetlands, streams and habitats in the area.

The county is working on the *establishment/re-establishment of wetlands* in the Apholm area, in which the Havelse wellfield is located. Reestablishment of wetlands involves the following:

- removal of drains
- inundation of large areas

Stakeholders are:

- the county
- farmers
- the regional abstractor (CE)

This field of work formed the basis for the flooding BBN.

A waterworks cooperation was established in 2004 in Skævinge Municipality, which is in the eastern part of Havelse's catchment area. It includes eight private waterworks as well as CE.

New abstraction (biogenetic enterprises) is being established in Hillerød Municipality, upstream from the Havelse wellfield.

3.5.6 Abstraction licence for the Havelse wellfield

An application for an abstraction license has been sent to the county authorities. Different mapping exercises, such as groundwater modelling, have been and are being carried out.

The county usually demands new examinations of existing boreholes. Afterwards, a temporary license is issued. Borehole drilling can then be carried out (the municipality is also notified).

After pumping tests, etc. are carried out and reported to the county, the county authorities issue an abstraction licence (usually a 30-year one). This is announced in the daily press, and if there are objections (by the local municipality, NGOs or neighbours) then the licence is revoked until the DEPA (Danish Environmental Protection Agency) has handled the case. Copenhagen Energy can also object to terms of the licence. Objections may also be submitted if a licence is refused or too strict, or the allowed abstraction is too small or the licence period too short.

The EPA then makes the final decision of whether or not to allow or revoke the licence. During the entire licence process, stakeholder involvement is possible only in association with the public (written) hearing of the licence.

3.5.7 Stakeholder involvement

CE has during the past ten years often been invited to lecture or give a talk on groundwater abstraction and protection. These invitations have been to conferences, farmers association member meetings and public meetings on planning processes in the counties and municipalities where CE abstracts groundwater. Over the past two years, a number of public meetings have been held concerning afforestation and opening of new forests.

Campaigns on groundwater protection have been held as well. Leaflets, brochures, posters, and two newspapers for schoolchildren on water and water problems have been produced in cooperation with one of the largest newspapers and the largest publisher in Denmark.

3.6 Introduction to BBN construction protocol

Based on our experiences with BBN construction for the Danish case study GEUS and CE has developed the following protocol described briefly in this section. It should not be considered as a final protocol, but simply as draft input for the overall guidelines for BBN development and stakeholder involvement provided by the MERIT project based on all four case study areas.

When constructing BBNs using input from stakeholders and the general public, we suggest having a protocol for the development process in order to clarify when, where and how stakeholders can provide input to the process. The flowchart we used and recommend as a rough methodology is shown in Figure 3.6, and it contains seven major steps.

In Step 1, physical and socio-economical boundaries, area of interest, alternative actions and indicators are defined. The degree of stakeholder involvement (information, consultation and active involvement of stakeholders and general public) is also determined. Afterwards, at meetings with stakeholders and general public, working groups are set up, stakeholder interests analysed and roles and responsibilities clarified [3].

In Step 2, a list of stakeholder and general public concerns is drawn up, and actions to be taken and important indicators are defined. A synopsis of data sources, reports, stakeholders and models is described and agreed upon.

In Step 3, the important variables are identified and directed edges are selected and connected. Rules for participation are also described and the platform for information decided.

In Step 4, the data from different sources (including stakeholders and general public) are collected. Data are analysed and a simple BBN prepared to illustration what to do in next step.

In Step 5, input from stakeholders and general public is important especially for indicator variables and actions. States are implemented in BBNs for all variables (indicators, actions, variables).

In Step 6 – constructing conditional probability tables (CPTs) – includes a review of the networks at individual stakeholder meetings. Structural learning is encouraged as a method of consulting stakeholders in an interactive mode. Input from models and experts for CPTs is also part of this step. BBNs should also be carefully checked for internal consistency at this stage.

In Step 7, stakeholder and general public opinions on the final network (perceptions, motivation, etc.) are collected, and a conclusion based on the final BBN is drawn. The BBN is implemented in DSS, alternative scenarios are prepared and the case reported for commenting from stakeholders and general public (e.g. citizens' group).

[3] Citizens' group has criticised the degree of involvement of general public. They feel that they could be more actively involved both in BBN development and decision making than described by the BBN protocol based on the Danish case study, which primarily involves experts and stakeholders, but not to the same extent the general public, see chapter 9.

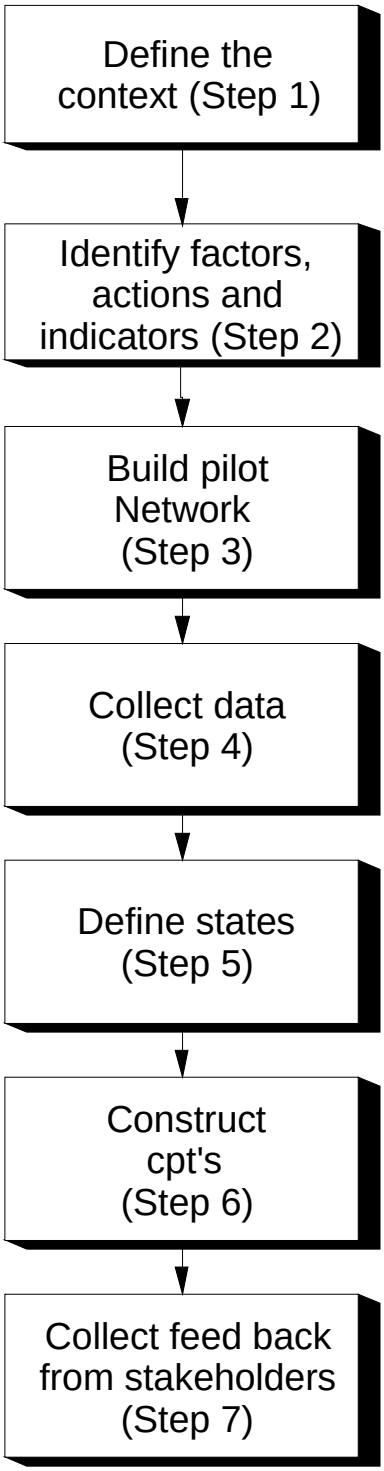
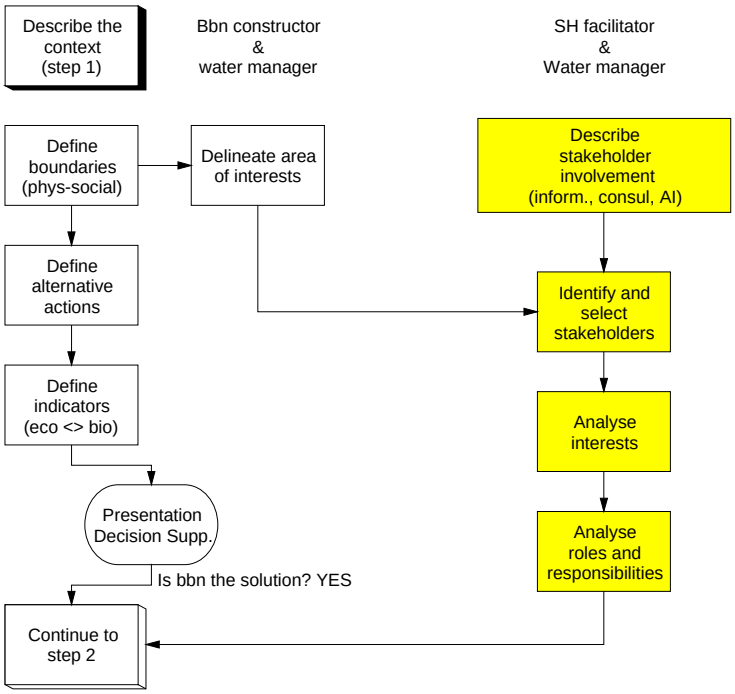
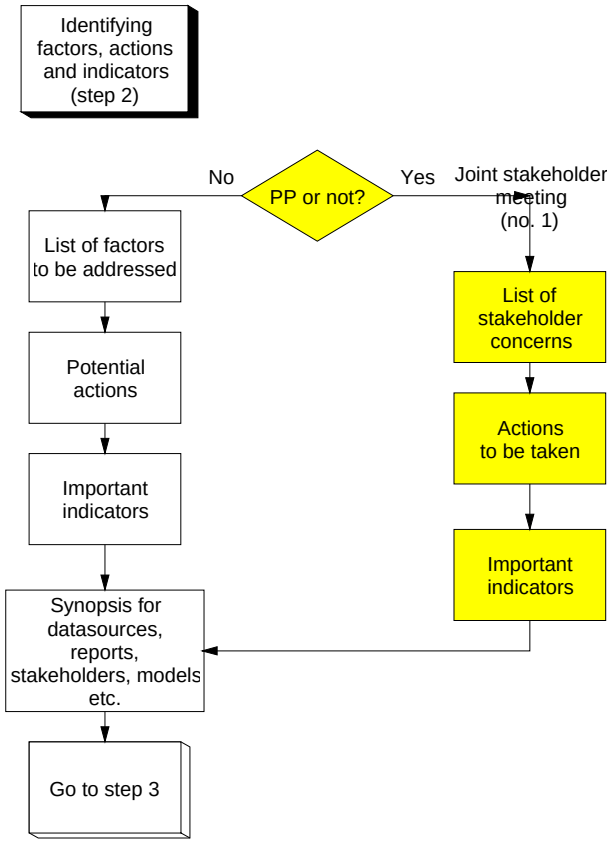


Figure 3.6. Protocol for construction of BBNs with stakeholder involvement.

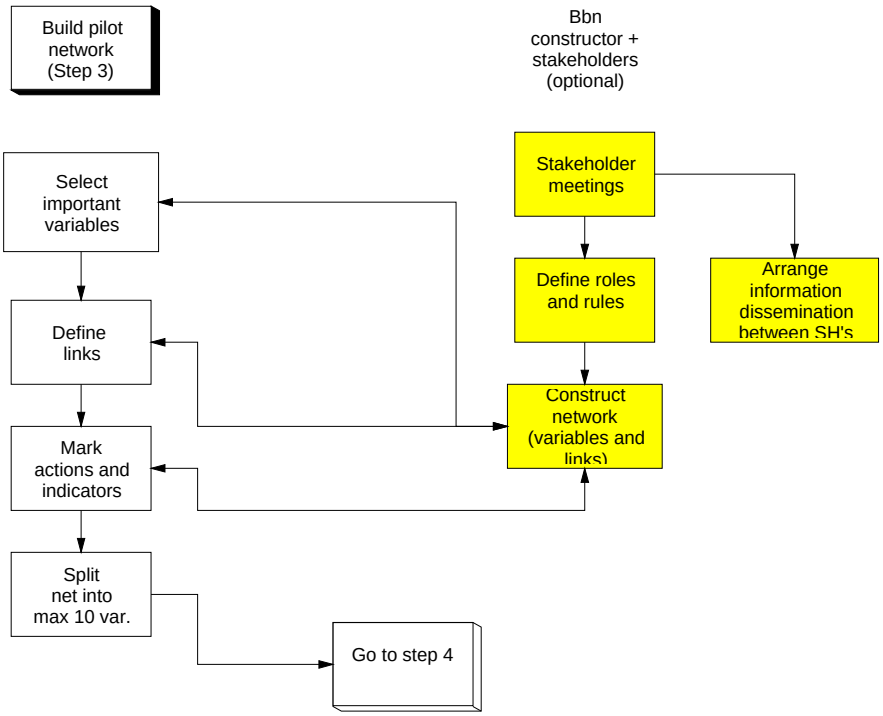
A draft decomposing of each task is shown below:



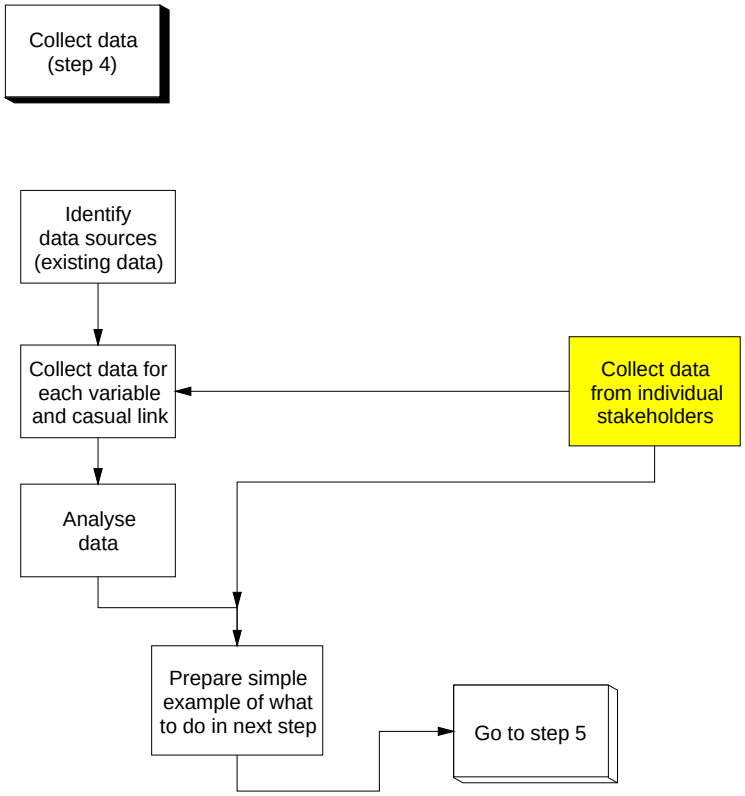
Step 1: Describe the context.



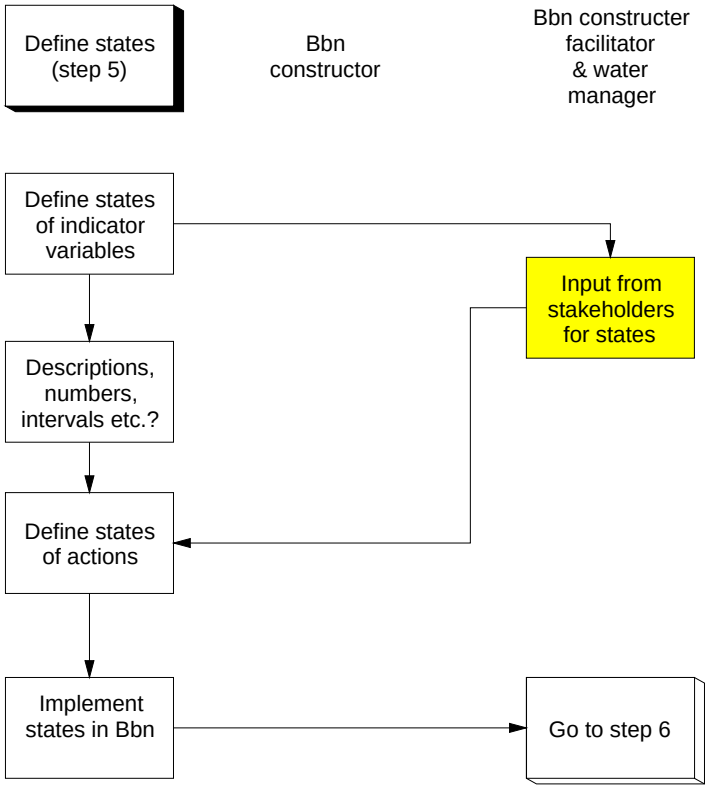
Step 2: Identify factors, actions and indicators.



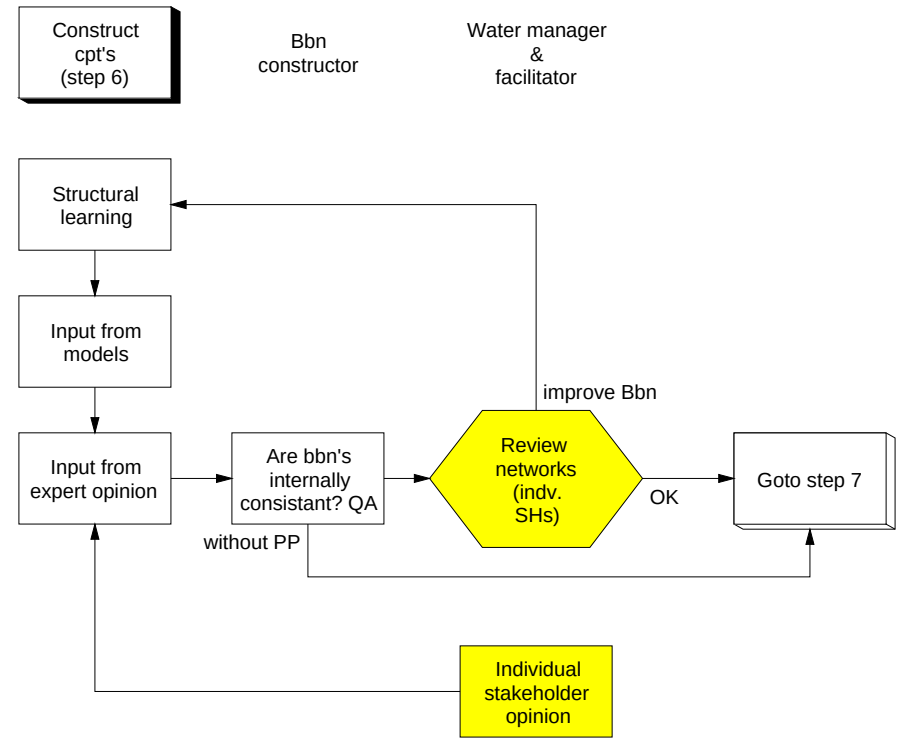
Step 3: Build pilot network.



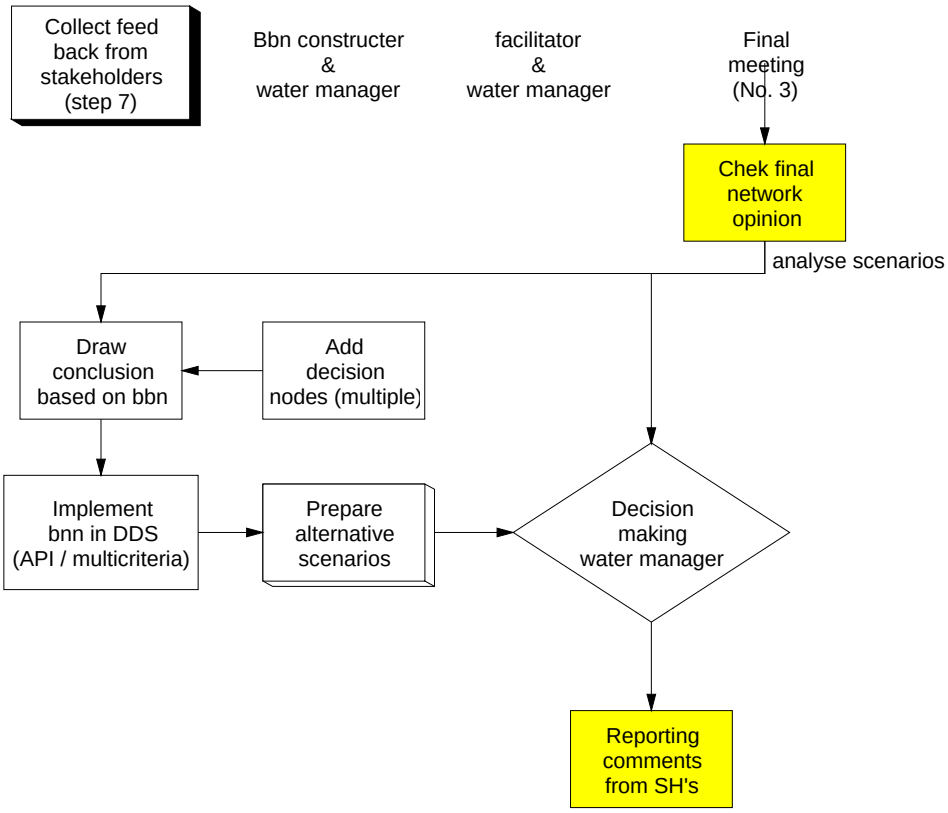
Step 4: Collect data.



Step 5: Define states of indicator variables.



Step 6: Construct CPTs.



Step 7: Collect feedback from stakeholders.

The protocol above reflects the way the BBNs were developed for the Danish case and should not be considered as a set of final guidelines for BBN construction (a set of guidelines will be developed based on all four case studies).

The significant critic raised by the citizens' group asking for a more active involvement, not only of experts and stakeholders but certainly also by non-experts from the local community, both when framing the problem, developing a common understanding, identifying uncertainty, building networks, and making decisions is not properly included in the draft protocol above, but should be incorporated in the final guidelines (see chapter 9).

3.7 References

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CHAPTER 4 Description of the wider water resources management in Denmark

Description of the current legal regulations and policy on the environment in Denmark, with an indication of the changes arising from the implementation of the Water Framework Directive

Lisbeth Flindt Jørgensen (GEUS) and Gyrite Brandt (CE)

4.1 Danish drinking water production

In Denmark, the drinking water supply is almost entirely based on groundwater of a quality enabling the water to be potable after simple treatment: oxidation and filtering through sand. The supply structure is decentralised, as there are roughly 2700 waterworks in Denmark (about 200 public and 2500 private) and an estimated number of 70,000 private drilled or dug wells, each supplying one to nine households in the countryside. The locations and production amounts of these waterworks can be seen in Figure 4.1 below. Only in a few cases has it been necessary to introduce more sophisticated water treatment. A few waterworks can also treat surface water to drinking water quality, but this is only considered as reserves to the preferred source – groundwater.

In 2002, the total Danish groundwater abstraction was 650 mill. Furthermore, 14 mill m3 of surface water was used, mainly for irrigation or as industrial process water.

4.2 The overall legal and administrative framework

There are 14 counties and 275 municipalities in Denmark, and they were established in 1972. In some areas, county borders were determined by streams or the islands characteristic for the country; in other areas they had historical origins (see Figure 1). Due to the denser population on the island of Zealand, counties are generally smaller there than in Jutland (the Danish mainland).

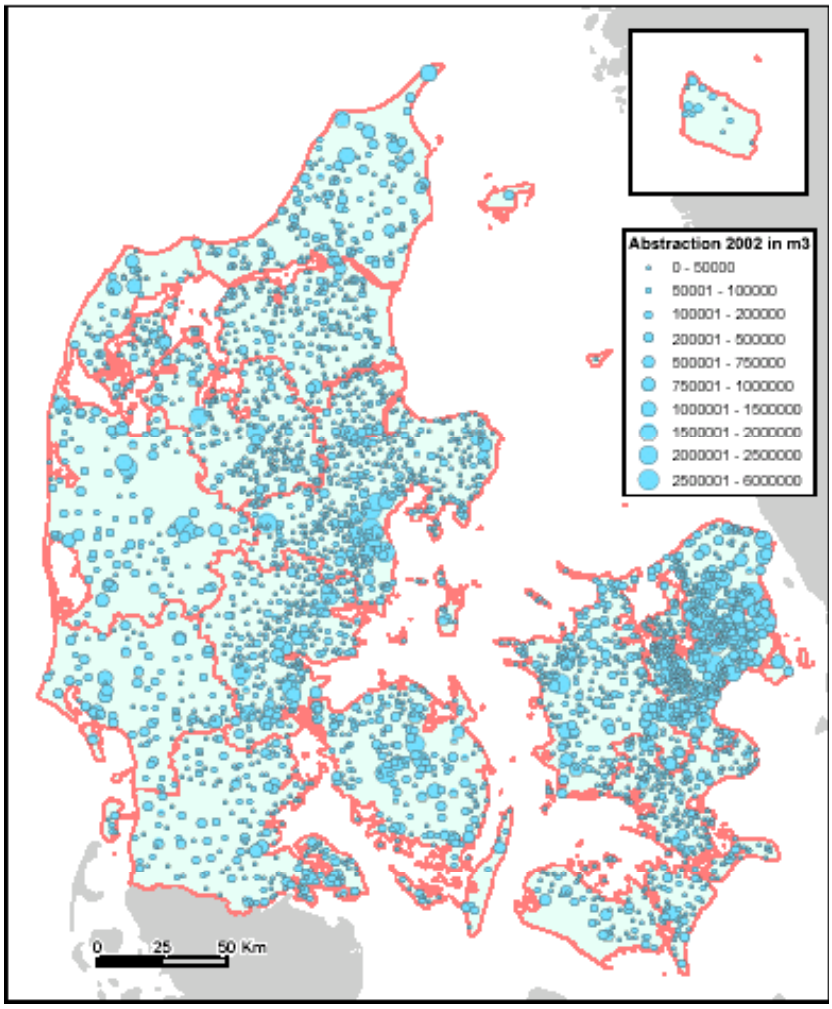

Figure 4.1. Danish counties and locations of the roughly 2700 Danish waterworks and their production amounts.

The following describes the roles of the three administrative levels in Denmark – state, county and municipality – in water resources management.

The Ministry and the Agency

At the national level, the Danish Ministry of the Environment set up the overall framework for water resources management in Denmark in line with EU directives and international conventions. The Danish Environmental Protection Agency (groundwater) and the Danish Forest and Nature Agency (surface water) prepare decisions and guidelines to ensure a uniform administration of water resources in Denmark.

County

The counties are responsible for water resources management, including planning and implementing groundwater protection within their jurisdiction. Up until now, the counties must renew their regional plan every four years for management of the water resources; this plan is subject to a public hearing. The object of this planning is to ensure that the use of land and natural resources is based on an overall assessment which aims to provide the foundation for a sound environment and contribute to the prevention of pollution: the

principles of sustainable development. Water resource plans play a vital role in the balancing of plans for the use and protection of natural resource in the open landscape.

The county has the following duties related to groundwater management and protection:

- Preparing the water resources plan
- Mapping groundwater resources
- Issuing licences for large groundwater abstractions (>3000 m^3/year)
- Determining action plan areas for groundwater protection
- Preparing and implementing action plans for groundwater protection
- Establishing a coordination forum for groundwater protection (COOP). The forum assists the county in the preparation and realisation of water resources planning. The forum consists of representatives from the county, the municipalities of the county, the water supply companies in the county, other involved authorities, agriculture, industry, and other relevant stakeholder groups in the county
- Mapping and remediation of polluted sites (point sources)

Some of the groundwater investigation conducted by the county is financed by a tax / surcharge based on the groundwater abstraction licences granted. The tax is earmarked for the investigation and establishment of protection plans, but not for their actual implementation.

Municipality

The municipalities are responsible for drinking water distribution planning and wastewater treatment, and have the following duties related to groundwater management and protection:

- Issuing licences for minor groundwater abstractions (<3000 m^3/year)
- Preparing a water supply plan
- Establishing a water supply cooperation forum (COOF) together with local waterworks with the aim of coordinating and allocating costs related to water supply safety
- Preparing additional action plans for groundwater protection where action plans prepared by the county are found to be insufficient
- Joining or forming waterworks cooperatives (possibly together with other municipalities) with private or public waterworks to implement groundwater protection measures
- Responsible for the inspection of waterworks and for the quality of drinking water

Public and private waterworks

Waterworks – public waterworks owned by municipalities and private[4] waterworks – have the following duties with respect to groundwater management and protection:

- Establishing or joining a water supply cooperation forum (COOF)
- Implementing additional groundwater protection
- Preparing additional action plans for groundwater protection where action plans prepared by the county are found to be insufficient
- Entering into farming/land-use contracts (has yet to be done)
- Buying land for groundwater protection (based on voluntary agreements)

[4] Private waterworks have boards elected at an annual general meeting for all members of the waterworks. Private waterworks in Denmark must be founded on a cooperative basis.

- Joining or forming waterworks cooperatives (possibly together with one or more other municipalities) to implement concrete groundwater protection measures
- Prepare additional action plans for groundwater protection where action plans prepared by the county are found to be insufficient

The waterworks, municipalities and waterworks cooperatives forum are permitted to add a surcharge to the water price to fund groundwater protection activities.

Stakeholders
The public/citizens can comment on the regional water resources plan prepared by the county. The water resources plan is revised every four years (every six years in the future), and then subject to a public hearing. Water supply plans and amendments to plans prepared by the municipality are also subject to public hearing. Both the county and the municipality have democratically elected councils.

NGOs and other stakeholder groups involved in groundwater protection are invited to participate in the coordination forums. The authorities or waterworks that prepare an action plan for groundwater protection are obliged to involve affected stakeholders during the preparation of the plan. The county/municipality/waterworks must send all action plans to public hearing among the members of the coordination forum, the directly affected stakeholders and the general public.

4.3 Active groundwater protection in Denmark

To summarise what can be done in Denmark in terms of active and practical groundwater protection in a specific area, it must be concluded that the effort is almost entirely directed towards point sources and very little is possible with respect to reducing the sources of diffuse pollution.

On a local and regional basis
Groundwater resources can be protected in terms of **quantity** by county regulations for issuing abstraction licences. If the need for drinking water, especially from the larger cities, make it necessary to abstract more groundwater than can be considered sustainable, then it will be done, even if connected ecological systems, wetlands and surface waters are affected.

Remediation of point sources of pollution, e.g. **polluted sites,** can be prioritised by a county if the sources are threatening an important groundwater resource. The waterworks/municipalities can establish and fund campaigns for *closing old wells* not in use to prevent surface contamination from reaching the groundwater quickly though preferential pathways.

Around every well there is a 10 m **protection zone** in which agricultural activities are banned. In addition, there is a 300 m **hygienic zon**e in which no sewage disposal or wastewater systems (e.g. septic tanks) are permitted.

Agreements on **changing farming practices** have so far only been voluntary: some agreements have been purely preventive, and some have been directly aimed at specific wellfields with groundwater aquifers with quality problems arising from pesticides or nitrate. The accepted way of solving the problem has been for waterworks to close down the well and dig a deeper one or move the wellfield/abstraction to another area.

On a regional/national basis

The counties are responsible for **planning land use**. It is possible to **delineate** areas which in future may not be used for dump sites, heavy industry or other activities which may pose a threat to the groundwater. However it is almost impossible to take measures against already established industries, etc.

On a national basis, measures has been implemented in the form of national action plans aimed at a reduction of the use of pesticides, both in terms of amount and application frequency. Some plans are aimed at a reduction in the use of nitrate by changing the rules of stocking density to meet the requirements of the Nitrate Directive, since all of Denmark has been declared nitrate-vulnerable.

4.4 After the implementation of the Water Framework Directive

After implementation of the Water Framework Directive (WFD) in Danish legislation (22 December 2003), the water resources plans will be known as river basin management plans (RBMPs) and be reviewed every six years instead of every four in line with the WFD. One designated river basin authority (a county) from each district will be responsible for preparing the first draft of input to the RBMP from their district. There are twelve designated river basin districts in Denmark (see Figure 2). Northern and mid-Zealand and the greater Copenhagen area will be united under a body called “HUR” (*Hovedstadens UdviklingsRåd*, or “The Greater Copenhagen Authority”). The Havelse catchment area is located within HUR.

For each district, the draft RBMP prepared by the designated authority will be sent to all county councils in the river basin district for approval. After approval, the draft RBMP will be sent to all the municipality councils in the river basin district for approval. A six-month public hearing of the draft RBMP is then held before the river basin district prepares a final draft of the RBMP. The final draft of the RBMP is then presented to the relevant county councils for final approval.

The overall administrative framework will generally be more or less the same for the river basin authorities as it has been for the counties in the past. In 1997, the counties defined areas within each county – or, if necessary, areas across county limits – that were important with respect to drinking water, with the intention of concentrating any groundwater protection initiative in these so-called OSD areas (*Områder med Særlige Drikkevandsinteresser*, or areas of special interest with respect to drinking water). These areas were areas of groundwater recharge which did not necessarily reflect the exact location of aquifers. Also, only areas needed to ensure present and future water demand were designated.

Water districts in Denmark

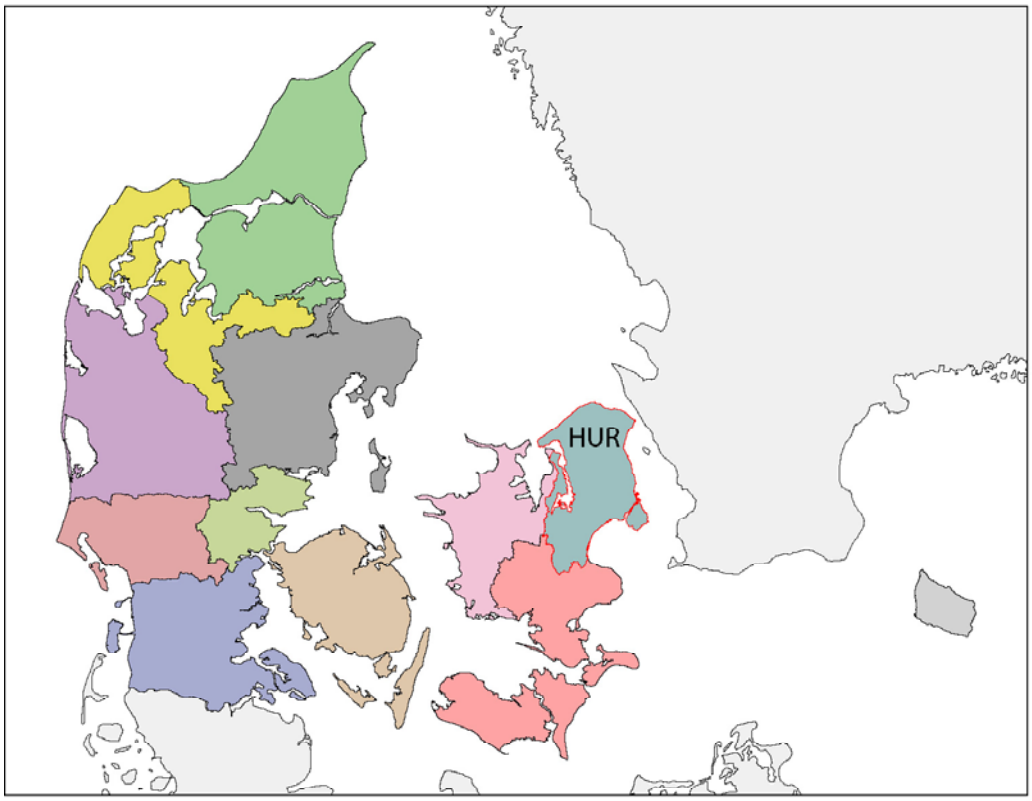

Figure 2. The 12 Danish river basins.

When implementing the WFD, river basin authorities will have to determine which groundwater aquifers could possibly be used as drinking water source (if more than 10m^3 a day can be discharged) or whether the groundwater outflow from an aquifer is crucial to any connected terrestrial ecosystem. However, only aquifers from which there is an average daily abstraction of more than 100 m^3 of groundwater for drinking water purposes are to be monitored.

Other important issues from the old water resources plan system are:

- Mapping of the natural quality of the water as well as contamination and sources of contamination
- Groundwater discharge
- Natural protection (thickness of overlying [clayey] layers)
- Influence of groundwater discharge on streams and wetlands

In the context of the WFD, this will involve:

- Reviewing the environmental impact of human activity (diffuse as well as point sources, discharge and injection of groundwater)
- Natural protection in the recharge areas (overlying [clayey] layers)
- Mapping associated aquatic ecosystems or dependent terrestrial ecosystems.

4.5 Stakeholder involvement

The engagement of stakeholders and citizens has in Denmark so far been information-oriented rather than consultation and active involvement, with involvement typically limited to a public hearing at a relatively late stage of the process of adopting already politically approved and more or less finalised plans, where it seems as though only small changes can be made as a result of any response from the general public. The consultation period has typically been six months in the case of more extensive plans and as little as four weeks for smaller plans or changes to existing plans.

The WFD prescribes that “Member States shall encourage the active involvement of all interested parties in the implementation of this Directive, in particular in the production, review and updating of the river basin management plans” (RBMPs). For every river basin district, this means that the following must be published and made available for comment:

- A timetable and work programme for the production of the RBMP, including a statement on how consultation will be carried out. This must be available at least three years before the beginning of the plan period<?>.
- A provisional overview of significant water management issues identified, available at least two years before the beginning of the plan period<?>.
- Draft copies of the RBMP, available at least one year before the plan period<?>

This means that it will be possible – and compulsory – to involve stakeholders and citizens at an early stage, i.e. in the planning phase. Furthermore, citizens will have the opportunity to provide input to and comment on the overall framework of pressures, impact, etc.

How?
How to involve stakeholders and citizens is an open issue. The WFD prescribes active involvement but does not dictate how or provide the necessary tools, which the member states are free to choose on the basis of their experience and regional conditions. However, a great deal of effort is currently being put into evolving methodology, tools, guidance, etc. on public participation all over Europe and beyond, and the MERIT project is an example of this. The most appropriate methods can only be discovered by testing and trying them out.

4.6 References

Directive 200/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy

CHAPTER 5 Stakeholder involvement

Per Rasmussen, GEUS

5.1 Identification of stakeholders

The Danish MERIT case study was centred around Copenhagen Energy's (CE's) Havelse wellfield, which is located 40 kilometres north-west of Copenhagen. Havelse is one of CE's 55 wellfields supplying Copenhagen Municipality and other nearby municipalities with drinking water. The groundwater from the Havelse wellfield is of high quality, and it is an important drinking water source for CE. CE would like to protect this valuable groundwater reserve from pollution by actively implementing groundwater protection measures.

Havelse wellfield is located in three municipalities: Slangerup, Frederikssund and Frederiksværk, all in Frederiksborg County. There are smaller local waterworks within the wellfield area. Frederiksborg County is responsible for water resources planning, and the municipalities are responsible for the water supply. The land use in the area is predominantly conventional agriculture. The Havelse Creek runs through the area; it is used for angling, and the county has plans to re-establish wetlands along the creek. Copenhagen Energy's groundwater abstraction license for Havelse wellfield is due for a renewal in a few years' time, and the wellfield will have to undergo renovations in the near future.

The starting point for identifying stakeholders was trying to list categories of water users, potential groundwater pollution sources, and authorities in the area: local waterworks, water consumers, farmers, industry, anglers, county and municipalities (Table 5.1).

Table 5.1. From a stakeholder consultation point of view, a number of topics are of special interest in relation to stakeholder engagement in the Danish case study area.

Stakeholder	Sector	Level	Comments: For or against action
Counties	Public	Regional	Frederiksborg County councils: for
Greater Copenhagen Authority	Public	Regional	HUR; Tasks to work out regional plans: for
Municipalities	Public	Local	6 municipalities: for or against
Large farmers	Private	Regional and national	Danish farmers' unions (North Zealand section): generally against
Small farmers	Private	Regional and national	Danish Family Farmers' Association (Zealand section) and ecological farmers: generally for
Industry	Private	National	Confederation of Danish Industries: for or against
Conservationists and wildlife trusts	Private	Local and national	Agenda 21 groups, Danish sports fishermen's association, Danish Nature Preservation Society : for
Landowners	Private	Local and regional	For or against depending on land-use issue

Except for the authorities, it is characteristic that the same specific interests may be expressed through associations/NGOs and from local individuals. As the case study is linked to a specific area, the Havelse wellfield area, we decided not only to include institutional or professional stakeholders, but also to try to involve the local citizens in general.

We started off by sending letters to all professional stakeholder organisations that we found to have a potential or even marginal interest in groundwater protection in the specific area inviting them to a one-day workshop in October 2002. Many "green" NGOs did not show up; the industrial sector preferred to use their political contacts on groundwater issues, they told us. One result of this workshop was the formation of a professional stakeholder working group with ten institutions, including the project end user CE, the local Agenda 21 centre (facilitator in relation to citizens' group), and GEUS (project owner; see Table 5.2).

The next step was in November 2002: a public meeting in the local community hall. Invitations were distributed to more 1100 local households, and the meeting was announced in the local newspaper. About 100 people and the local TV station showed up for the meeting. At the end of the meeting, a local citizen working group of nine persons had been formed (Table 5.3).

At both meetings, stakeholders were asked to present issues and problems they found important in relation to groundwater protection.

In the following course of the project the stakeholders were organised into two different groups: the professional stakeholder group, and local citizens stakeholder group. The idea behind the split of stakeholders in two groups was the perception that the professional stakeholders are already deeply involved in groundwater management and protection, whereas local citizens might have another starting point for their involvement in groundwater management and protection.

At meetings and workshops with citizens' group, we used a facilitator from the local joint municipality Agenda 21 centre. Facilitation in relation to the group of professional stakeholders was not systematical throughout the project, but the first meeting was facilitated by Agenda 21 centre.

Table 5.2. The professional stakeholder group.

	Stakeholder	Rights	Roles	Responsibilities for water management
1	Copenhagen Energy	As municipality and water-works (water supply company owned by Copenhagen Municipality)	Main interest in protecting groundwater resources from pollution; end user in MERIT project	Water supplier for Copen-hagen Municipality and other areas in Copenhagen
2	NOLA, North Zealand Farmers' Union	Participant in coordination forums and in cooperation forums, NGO	Advisory centre and local political branch of the large farmers' association.	As more than 60% of Danish land is used for agriculture, it is strongly linked to decentralised groundwater abstraction and protection
3	SJFL, Zealand Family Farmers' Association	Participant in coordination and cooperation forums; NGO	Advisory centre and local political branch of the small farmers' association	See above …
4	Frederiksborg County	Issues water abstraction licenses. Makes water management plans	The water resources authority for both ground-water and surface water	Sustainable use of water resources, protection of groundwater resources, prepare water resources plans, conduct public hearings
5	Frederiksværk Municipality	Issues water supply plans. Issues additional action plans for groundwater protection	Owner of local public waterworks	Initiate action plans for groundwater protection
6	Skævinge Municipality	See above …	See above …	See above …
7	FVD, Organisation of private water-works in Denmark	Issues additional action plans for groundwater protection. Participant in coordination and cooperation forums; NGO	Political organisation for private waterworks; NGO	Initiate action plans for groundwater protection. NGO
8	Green Forum Slangerup	NGO?	NGO; associated with local Agenda 21 in Slangerup Municipality and umbrella organisation for local "Green NGOs"	Committed to work for an alleviation of human pressures on the environment
9	Agenda 21 Centre	Issue initiatives based on Agenda 21 principles	Agenda 21 Centre for 5 local municipalities	See above …

Table 5.3. Local Citizens stakeholder group.

	Stakeholder	Rights	Roles	Responsibilities for water management
1	Market gardener	Land owner	Concern about restrictions on land use	Land user in area with significant groundwater resources
2	Farmer	Land owner	Concern about flooding of Havelse stream	Land user in area with significant groundwater resources
3	Engineer		Member of board of local waterworks	Supply local community with sufficient drinking water of good quality
4	Farmer	Land owner	Concern about restrictions on land use and flooding	Land user in area with significant groundwater resources
5	Local citizen		Concern about flooding of Havelse stream	
6	Part-time farmer	Land owner	Concern about clean drinking water and wastewater from larger city outside the local area	Land user in area with significant groundwater resources
7	Organic farmer	Land owner	Concern about pesticide use and groundwater protection	Land user in area with significant groundwater resources
8	Local citizen		Concern about flooding of stream	
9	Local citizen		Concern about flooding of stream and the constant blaming of pollution on agriculture	

5.2 Stakeholder involvement process

The two stakeholder groups worked separately from the beginning of 2003 and until a final joint workshop in March 2004. The overall involvement process is presented in Figure 5.1.

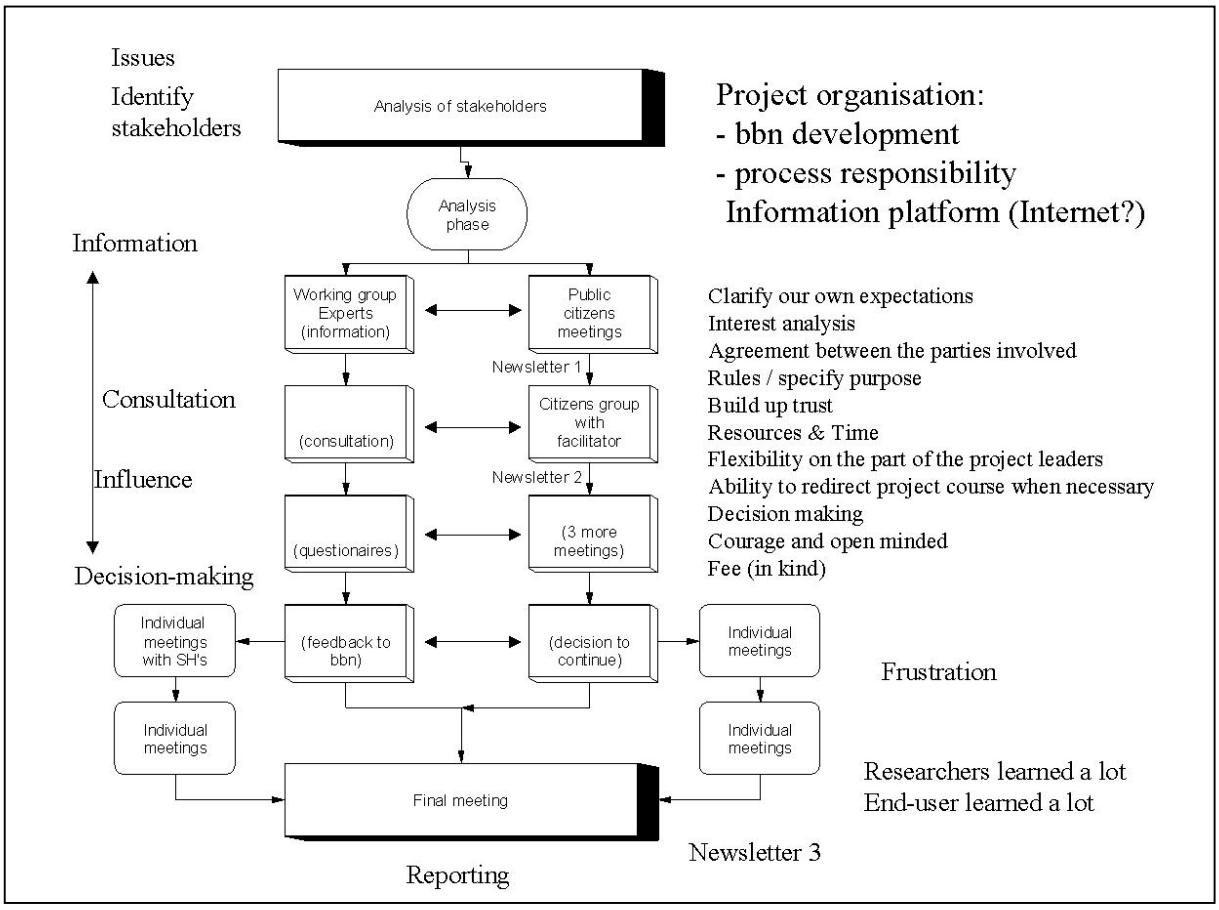

Figure 5.1. Overall stakeholder involvement process in Danish case study.

The overall idea was to begin the process as openly as possible, to get an idea of how stakeholders could contribute to an improved protection of the groundwater resources in the area.

5.2.1 The professional stakeholder group

The November 2002 workshop with the professional stakeholders was mainly a presentation of the MERIT project, including the BBN concept, end user CE's ideas and plans for groundwater protection, two experts' input on farming contracts, afforestation and social economics.

Three workshops were held with the professional stakeholder group.

At the first workshop with the formed professional stakeholder group where the main topic was to get stakeholder opinions on roles and responsibilities (Annex 1), and on consequences of different measures in active groundwater protection (Annex 2). This had the dual purpose creation a common understanding within the group of the different responsibilities and viewpoints among the stakeholders. Data collected in Annex 2 has also been used as input to the BBN construction.

Stakeholder opinions and priorities expressed at the workshop

Private Waterworks' Association:

- Clean drinking water has a high priority with people in general
- Conflict between willingness to pay and the desire for clean water
- Water surcharge difficult to explain
- Pesticide pollution from private gardens is a problem

Farmers' Association:

- GMO crops, the solution for pesticide-free agriculture
- If use of pesticides is banned in agriculture, there is a need to quantify 1) loss of income for farmers and 2) increased price of water for consumers
- Conflict between afforestation and other uses of the land
- We want the most value for money = clean drinking water for the money spent

Municipality:

- More information needed for the public about groundwater protection aspects
- More communication with the public needed

The following two workshops were used for BBN development and included input from external experts.

The three workshops were followed up with individual meetings with the Frederiksborg county council and the Zealand Family Farmers' Association to collect more data for the BBNs and to have a more in-depth discussion about the BBNs.

5.2.2 The citizens stakeholder group

At the public meeting in November 2002, participants were grouped into smaller groups and were asked the following:

1. Any suggestions on how to protect and safeguard the groundwater at Havelse wellfield (preferable ranked by priority)?
2. Who is responsible for ensuring clean drinking water? And why? Preferably several suggestions.
3. What problems do you think will affect the freshwater cycle (i.e. precipitation, creeks, inlets/bays, groundwater, irrigation and drinking water)?

Stakeholder opinions and priorities expressed at the workshop

- No problems with nitrate pollution in the area, so no need for more restrictions on agriculture.
- More restrictions on larger industries with biotech waste water. Expect both quantity and quality problems for the local steam due to new biotech companies in the neighbouring municipality.
- Better handling of wastewater from detached houses, root zone treatment plants, improved sewage systems.
- Stream maintenance, clean up of stream to avoid flooding.
- No gravel pits in the groundwater recharge area.
- More organic farming to protect the groundwater resources.
- More afforestation in the area.
- Respect the two-metre protection zones along streams.
- Private households should stop using pesticides in gardens.
- Renovation of wellfields could improve groundwater quality.

The citizen group met five times in the first half of 2003. The idea was to give the group the opportunity to develop its own identity without being influenced by professional stakeholders. The meetings were guided by the facilitator. GEUS and CE only participated in two of the five meetings to answer specific questions and to introduce and discuss the development of the BBNs. Lessons learnt from citizens' stakeholder group meetings gathered by the facilitator as shown in Table 5.4 and Appendix 3.

Table 5.4. Lessons learnt from citizens' stakeholder group (Facilitator Jan Poulsen, A21C, Abruzzo June 2003)[5].

What we expected or hoped	What we met
A varied group with different interests	A homogeneous group with common interests representing the farmers' trade
Individual opinions – out of different life experiences – will be expressed	Social relations in the neighbourhood committed people to shared opinions.
An open and friendly dialogue concerning the issues of preservation of water quality	Group had great difficulties with authorities – including Copenhagen Energy
The group will felt itself to be an equal member of the whole field of players	The members of the group felt very much like victims relative to other players
Participation in the whole range of water issues	Awareness and focus on one issue: the high level of water in Havelse creek
Suggestions to what farmers can do to save water quality	Identification of many problems to be solved by other groups: owners of private gardens or public authorities
Attitudinal openness to the problems	Attitudinal inflexibility due to own interests
Continuation of the work based on the project in the group = interests of the community in relation to water issues	Continuation possible – but on a limited basis out of individual interests

[5] The citizens' group has commented the process, see chapter 9.

The citizen group published two newsletters in the first half-year of 2003. They were distributed to 1000 households in the local area. The newsletters included mainly articles related to groundwater protection, water supply and water quality, and introduced the members of the citizen group. The production and distribution of the newsletter was financed by the MERIT project.

Due to some financial delay the series of meetings was stopped after the summer of 2003; momentum was lost and it was difficult to start the group again. But a few (three) stakeholders from the citizens' group participated in individual meetings for data collection for the BBNs, and for further discussion of the BBNs.

The citizen group has decided to continue after the end of the MERIT project as a "water group".

5.2.3 Stakeholders' evaluation of the involvement process

Before the final joint meeting in February 2004 between the citizens' and professional stakeholder groups, the stakeholders were asked to evaluate the involvement process by filling out a questionnaire. We received only six out of 19 questionnaires back: four of them were from members of the citizens' stakeholder group.

At the final joint meeting, the four stakeholder groups were asked to comment on the involvement process on the basis of four questions:

1. Is there a need for further initiatives for the protection of groundwater and the stream/bay?
2. How have you experienced the MERIT project progress (BBNs, citizens' meeting, workshops, citizen groups, newsletter, individual meetings, etc.)?
3. How should stakeholders be involved in the future in, for example, active groundwater protection and the establishment of wetlands?
4. Other comments to the process?

Two groups presented their comments: the citizens' group and the farmers' organisations.

Comments from the citizens' group

- We were a little confused about the reason for all this! The creek theme dominated our meetings too much. Not until now have we defined the objectives of the group. We will continue with a group of six or seven people under the title "clean water".
- Confusion about the expectations to the citizens' group.
- We were not aware of how important BBNs were for the project.
- The citizens of Copenhagen and Copenhagen Energy must save water. More recycling. Groundwater has to be protected against all man-made and natural threats. Better maintenance of the stream; poor waste discharge is unacceptable.
- We felt MERIT to be a politically decided project in which political groups and "experts" determined the desired result and the establishment of citizen groups, etc. was only for show. The structure of the public meetings was manipulated.
- Do not have complete information; more scenarios/solutions to the problems should have been presented. A little difficult to follow presentations of the BBNs.

- The citizens' group lost momentum because meetings were interrupted due to some financial business, and it was difficult to get the group started again.
- Better description of objections and exceptions to input/output from the citizens' group, and maybe some roles for the group. More openness from the start of the project from the County and CE.
- Too little focus on local knowledge.
- What is least expensive to purify or to protect the groundwater?

Written comments from the citizens' group are found in Appendix 4.

Comments from farmers' organisations

- If the MERIT project is a test related to the EU water framework directive, then substances other than pesticides should have been included.
- Not all relevant stakeholders were involved in the project.
- All participants in the project were stakeholders; all had their goals and agendas.
- We were hostages.
- We did not get minutes from other group.
- Look at the facts, what happens with the actual wells, focus on local and actual test results. Disagree on groundwater age of 50 years.
- Today it is only the pesticide bentazone that is actually used.
- Is the presented BBN at all useful? It was quite technical, probabilities not useful when dealing with groundwater protection.
- Maybe BBN is applicable when dealing with the water framework directive as a whole.
- It is the opinion of GEUS that only 10% of stream discharge must be abstracted.
- Who is going to pay for the stakeholder's participation in the project?
- It was frustrating that our input was not implemented in the BBN at the following meeting.
- The MERIT project should have been more anchored in the local Havelse area.
- Communication between stakeholders is important.
- Agree that voluntary farming contracts is not the way forward, but instead delineation of vulnerable groundwater areas and the waterworks should buy those vulnerable areas for groundwater protection.

The experiences gained and used in the project on stakeholder involvement in water management using BBNs are discussed in section 6.4 (Methodology of BBN development) and in Chapter 8 (Main conclusions and perspectives in relation to WFD).

In Chapter 9 comments and suggestions from the citizens's group to the draft report is presented (from heering in May 2004) and consequences for the final reporting addressed.

Annex 1. Stakeholder questionnaire and input: Distribution of tasks among stakeholders: roles in the context of groundwater protection.

Authorities

	Ongoing activities in the Havelse area	**Planned activities in the Havelse area (year)**	**Legislative basis**
County: **Frederiksborg**	- Action plans - Mapping of contaminated land - Action plans for smaller areas, catalogue of ideas	- Geological and geophysical mapping (2004) - Mapping has started in Frederikssund (2002) and Skævinge (2002)	- Water supply legislation - Contaminated land legislation (Note: Areas are appointed but not investigated) - Law on planning (regional planning)
Municipality: **Frederiksværk***	- No specific groundwater protection activities - Contribution to CE on source of contamination in the catchment of Havelse wellfield 2002	- Preparation of action plan on groundwater protection planned until 2007 - Cooperation between waterworks, county, municipality and other stakeholders	- Law on water supply
Municipality: **Frederikssund**	- None	- Injunction on better cleaning of wastewater from households at the end of 2005 - The plants must be finished in 2006	- Regulation on waste water no. 501 dated 21 June 1999
Waterworks: **CE**	- Groundwater model - Basic material - Mapping of pesticides - Geological mapping - Negotiations on renewed license for abstraction (after 2010) - MERIT	- Renovating, maybe moving wellfield (2004) - Afforestation (-> 2032)	- Law on water supply

*The Municipality of Frederiksværk prepared action plans in 2002 for the four northernmost waterworks in the municipality. Action plans for an additional three waterworks in the geographical centre of the municipality followed in 2003. Municipality and county assigned a high priority to seven waterworks in the northern and western part of the municipality (of 11 waterworks in the municipality): they were to be protected first, as they were abstracting from vulnerable sandy layers.

Distribution of tasks among stakeholders – roles in the context of groundwater protection

Other stakeholders

	Ongoing activities in the Havelse area	Planned activities in the Havelse area (year)	What should/could others do	Local interests
FVD	- Establishing a contact board - The county's coordination forum before 2005	- To activate county and municipality		- Law on water supply (water coops)
NOLA	- Members cultivating the area - Mapping of pesticides	- Wetlands - MVJ - Pesticide consultation (advising farmers)		- Around 100 members - Prepare farming agreements
SJFL	- Consultancy in the area	- MVJ - Wetlands		- Prepare farming agreements - Specific information
Green Forum Slangerup	- Organic garden demo - Urge consumers to buy sustainable goods (flyer on organic shopping options in the Municipality of Slangerup)	- Green consumers	- Agenda work in the Municipality of Slangerup - Campaigns on saving drinking water	
Agenda 21	- A21C for 5 municipalities (Slangerup, Frederikssund etc.) - Use of ecological goods, improve sale - Waterworks coops	- Members establishing waterworks coops		- Trans-municipal

Annex 2. Stakeholder questionnaire and input: What would be the consequences of different groundwater protection measures?

GW protection measure	Groundwater quantity	Groundwater-quality	Economy	Positive side-effects	Negative side-effects	Measures already started?	Measures planned	Data sources for cause-effect	Stakeholders
Afforestation	Less ground-water	Reduced pesticide and nutrient load	Expensive; Would mean lower income for the agricultural sector "Buy, plant and run"	Recreational, more nature, more animals and plants. Use by citizens; public access. Lasting initiative; permanent groundwater safe-guard; new wellfields. Would raise property prices.	Scenic views. Will stop the cultivation of arable land Less groundwater recharge Will take a long time Might enhance leaching of heavy metals	Yes, until 2032	Change in the county-designated use of the area	Axel Dubgaard, KVL[2], on valuation of wood; FSL.[3]	SNS[4], the local forest district, DN[5], local citizens, CE, county, municipality
Reduced agricultural use of pesticides	Probably no measurable effect		Expected reduced income for the agricultural sector. Reduced yield. Cheaper than the agreements on cultivation possible now.	Friendly towards nature. Improved safety. Technical discussions with the farmer. More farmers will join.	Greater use of fossil energy, e.g. for the mechanical removal of weeds. Negative economy for the agricultural sector. No total security.	Pesticide checking	Strategy towards point sources	Overview of experiments from the agricultural organisations	SJFL/NOLA/ farmers

[2] KVL: *Kongelige Veterinære Landbohøjskole*, or The Royal Danish Veterinary and Agricultural University.

[3] FSL: *Forskningscenter for Skov og Landskab*, or the Danish Forest and Landscape Research Institute.

[4] SNS: *Skov og Naturstyrelsen*, or the Danish Forest and Nature Agency.

[5] DN: *Danmarks Naturfredningsforening*, or The Danish Society for the Conservation of Nature (an NGO).

Organic agriculture	No effect	If well-run, reduced risk of contaminated groundwater. Negative effect from increased N leaching, no effect of N leaching or positive effect	Reduced income for the farmer Expensive for the farmer. Could be expensive for the farmer.	Sound agriculture. More birds. No potential point source pollution. Increased biodiversity. Less nutrient load. Health: farmers will be more healthy	Smaller yields. Risky method of cultivation.	For the time being on a volunteer basis. City/countryside project continues	Increased consumption of organic products. Awaits strategy for cultivation agreements.	SJFL/NOLA	SJFL/NOLA/ farmers, LØJ,[6] water-works
Cultivation agreements	No effect Positive effect (less irrigation)	Intensive agriculture is moved from vulnerable areas. More grass. Reduced pesticide use. Reduced N.	Expensive for the waterworks. May be expensive for the individual farmer. Should be agreed on a national basis.	Possible common interests, fallow and no pesticides. Biodiversity.	Resource-intensive. Will lock the farmer into one form of production. Must be renewed every five years.	Point sources are being addressed when farmers are consulted. Demonstration of possible agreements (MVJ[7])	More focus on MVJ. Action areas with MVJ agreements. Strategy under development.	Demonstration (MVJ) DANVA[8] Consultancy The national agreement (?) WaterTech[9]	SJFL/NOLA/ farmers, county, municipality, waterworks
Reduced use of pesticides in public areas	No effect	Reduced risk of contamination. Positive effect. No use of pesticides in areas at risk of contamination.	More expenses for municipalities/ counties. Expensive alternative, not useful.	Visual signal and good example for garden owners	Cost- and work intensive. Risk of weeds spreading from public areas to agricultural areas. Necessary to re-lay pavements.	Yes, for hogweed (1999–2003)	Stop 2003	County analysis of pesticide detection in wells; HVS[10]	SJFL/NOLA/ farmers, county, municipality, waterworks

[6] LØJ: *Landsforeningen Økologisk Jordbrug*, or The Danish Society of Organic Farmers.

[7] MVJ: *MiljøVenlige Jordbrugsforanstaltninger.* An agreement supported by EC and national grants for environmentally friendly agriculture, but only in vulnerable agricultureal areas ("SFL areas").

[8] DANVA: *Dansk Vand- og Spildevandsforening,* or the Danish Water and Waste Water Association.

[9] WaterTech: a private-sector engineering consultancy.

[10] HVS: *Hovedstadens Vandsamarbejde*, or the Greater Copenhagen Area Water Association.

No use of pesticides in private gardens	No effect	Reduced risk of contamination. Positive effect. No use of pesticides in areas at risk of contamination.	Weekend work; information and ban	Nature-friendly; more birds. Ban ONLY in private gardens. More focus on different gardening practices. Biodiversity	Especially delicate and sensitive varieties can be hard to grow – could be exchanged. No negative effects More work	Consulting of the farmer in gardening (SJFL). Information campaigns (A21C)	Future campaigns	County analysis of pesticide findings in wells; HVS	SJFL/NOLA, citizens, county, municipality, waterworks
Excavation of point sources	No effect	Reduced risk of contamination. Removal of the greatest threat to the groundwater. Positive effect.	Expensive Insurmountable	Restrictions on use of areas must be abolished. More political focus on this issue. Better indoor climate.	Expensive Contaminated soil must be moved to disposal site.	SJFL consultant. County already remediating, etc.	Priority lists COOP Hillerød, pesticide point sources	The Counties' knowledge centre for contaminated soil/sites	Public/private, county Municipality, CE
Establishing new wetlands	More groundwater recharge	Risk of leaching from former agricultural areas. Negative effect. Negative effect if established close to wells. Conflict between wetlands in stream valleys and wellfields in the same valleys. Positive effect	Expensive, also for the agricultural sector. Fewer areas for agriculture. MVJ (DKK 5850/ha maximum; average 35,000 ha)	More nature, recreation; more animals and plants. Less N leaching. Natural hydrology. Recreational area. Less flooding risk downstream. Biodiversity.	Risk if there is wastewater discharge to the wetlands. Expensive. No cultivation of some arable land. Bad dewatering means greater risk of contamination. Resource-intensive in terms of time. Hard to handle wellfields in wetlands; establish dikes	SJFL will advise if asked. The county has begun preliminary investigations into property conditions. Mapping of the areas; interview of farmers-	Agreements will be entered soon	Report from county on preliminary investigations on property conditions	County, land/property owners
Restoration of well areas	Positive effect. Reduced abstraction.	Less risk of contamination related to bad or old wells Positive effect	Expensive (DKK 13 million)	Best practice abstraction/pumping strategy. Sound abstraction.	None	Preliminary investigations	Implemented in 2004-2005	CE/county	Waterworks, CE
Treatment of wastewater outlets from scattered settlements	More wastewater = more groundwater. Positive effect. Depends on	Less risk for dangerous substances: LAS, etc. Positive effect Negative effect.	Expensive for citizens and municipality. High risk for discharge of hazardous	Better aquatic environment: streams, lakes, etc. More animals and plants.	More wastewater outlets from scattered settlements in the area. Will result in 25 ha of protection	2000	Injunction in 2005	The Danish EPA	Citizens, municipality

	method used		substances	Better water in streams and bays. Increased recrea-tional value. Cleaner water in the small local streams.	areas where wells cannot be estab-lished.				
No more wastewater	Negative effect	Positive effect	Expensive		No water in streams				Municipalities
Agricultural point sources				Focus on handling of chemicals at the farm		Already started			Municipalities Agricultural consultancy agencies
Registration of pesticide use				Focus on handling of chemicals at the farm	The agricultural sector will be mainly responsible for pesticide findings in groundwater	Already started			Agricultural consultancy agencies
Sewer renovation		Positive effect	Expensive						
Information campaigns		Better in a longer-term perspective	Cheap	No pesticides in private gardens		2002	2003-2004	HVS + CE	
Establishment of COOP			Better	Active local ground-water protection	Time-consuming to start, 1½-2 years				
Proper sealing of dug and drilled wells not in use			Dependent on wastewater to recharge ground-water; potential contamination.						

5.3 Discussion

The identification of stakeholders to participate in the MERIT project were twofold; with written invitations to all organisations with even a minor stake in water resources, and with an open invitation to a public meeting. The written invitation resulted in a weak participation from "green" NGO's (table 5.1), where as the public meeting was successful with nearly a hundred participants and the formation of a local citizen group representing a broad spectre of different opinions raised at the meeting (table 5.2).

Both the professional stakeholder group and the citizen stakeholder group clearly expressed their opinions and concerns about water resources management and the groundwater situation. This initial stage of stakeholder involvement was quite successful, probably due to the fact that the traditional Danish approach was used (information and hearing), and the fact that groundwater abstraction and wetland restoration have been hot topics in the area for some time.

The involvement of the professional stakeholders followed a path with half-day workshops with presentations and discussions. During the project it became clear that neutral facilitators are important also during traditional workshops because end users and project managers are (seen as) stakeholders as well, not least when it comes to more political sensitive issues.

Active involvement of both the professional stakeholders and the local citizens during the MERIT project has shown the importance of having clearly defined rules for participation. By clearly defining the rules e.g. for public participation in water resources planning, also the roles of the individual stakeholders and the expectations from the project (the authorities) become much more transparent.

Workshops or meetings with more than five to eight persons tended to turn more political and tactical, and not very useful for more detailed discussions of water issues and BBN's, and for data collection. Individual meetings with one or a few likeminded stakeholders showed to be much more useful in the more detailed development of BBN's.

The experiences gained and used in the project on stakeholder involvement in water management using BBNs are discussed in section 6.4 (Methodology of BBN development) and in Chapter 8 (Main conclusions and perspectives in relation to WFD).

An interpretation of the stakeholder engagement process with respect to strengths, weaknesses, opportunities and threats (SWOT) is discussed in Chapter 8, together with a suggestion for a step by step stakeholder involvement plan.

In Chapter 9 comments and suggestions from the citizens’s group to the draft report is presented (from a hearing in May 2004) and consequences for the final reporting addressed.

CHAPTER 6 Development of Bayesian belief networks

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6.1 Background

Agriculture currently accounts for two-thirds of land use in Denmark, and the farmed area covers some 2.7 million ha. More than half of the agricultural area is used to grow cereals, mainly winter cereals. These crops have a high leaching potential, because they need additional fertilisers and pesticides. Pork accounts for about a third of the country's agricultural production value, and diary products for about 20% of total production value. Denmark is one of the world's leading countries in exporting pork. Agriculture is a rather marginal activity, if measured in terms of percentage of GDP (only 2%). However, agriculture remains important economically, as it constitutes approximately 14% of national exports (Danmarks Statistik, 2000).

Before we go to our case study, first allow us to give you an introduction to cooperative farming contracts and the Danish context based on previous experiences from the Lyngby area in Denmark, which is in many ways similar to our case study area at Havelse in northern Zealand. A recent review of occurrence and feasibility of cooperative agreements in agriculture in Denmark (Brouwer, 2003) observed only a limited number of agreements. Pesticides in groundwater resources was the key threat addressed in the first cooperative agreement finalised for Lyngby (in Jutland) in the year 2000, which was intended to stabilise concentrations and prevent future pressures on the environment. The main objective of this Lyngby cooperative agreement was to demonstrate strengths and weaknesses in the achievement of environmental policy targets through voluntary arrangements among the actors involved. This agreement can be classified as preventive and compensatory, and it involved water supply companies and farmers. The water catchment area in Lyngby included three waterworks, with the water supply company from Aarhus the largest one, supplying about 1 million m^3 of water per annum. The water is abstracted from a depth of 20 to 50 metres. The preventive actions were taken to reduce potential pesticide pollution problems in the future. The size of the catchment was about 1,500 ha, with about 1,000 ha farmland mainly featuring mixed agricultural production systems with an emphasis on crop production. There are no problems regarding nitrates, which remains below 1 mg per litre. Options considered were farming without the use of pesticides, afforestation and a shift to organic farming methods.

A national programme to monitor pesticide content of groundwater was initiated in the late 1980s; several pesticides were detected. In the first half of the 1990s, the monitoring programme included eight pesticides, which were detected in 12% of the cases. The MAC level for pesticides in drinking water was exceeded in 3.5% of the cases. Pesticides, which have been found commonly in groundwater, are currently prohibited or strongly regulated

by the Danish Environmental Protection Agency (DEPA). More recently, the programme was extended to monitor about 50 pesticides and metabolites. Pesticides were detected in more than 30% of the monitored wells, and 10% exceeded the MAC level.

An action programme for the protection of groundwater and drinking water required a reduction of pesticide use by 50% over the ten years up to 1996. This reduction was not achieved. Application frequency also was supposed to be halved, but this is more difficult to achieve without the provision of legal instruments or strong economic incentives. The reduction in application frequency was not achieved, either. The so-called Pesticide Action Plan II was published in March 2000; it built upon the strategies to reduce pesticide use, reduce the exposure of biotopes and increase restructuring to organic production. Pesticide Action Plan III was adopted in 2003 and prescribes that the application frequency of pesticides must be reduced from 2.04 to 1.7 between 2004 and 2009, and the existing 8000 ha protected zones near streams and rivers should be extended to 25,000 ha. Also with the recent Action Plan for the Aquatic Environment III (adopted in April 2004), the indirect focus is on:

- Reducing treatment frequency of using pesticides
- Protecting certain areas, including the provision of a buffer zone along watercourses and lakes, and a reduction of pesticide use in areas that are particularly sensitive (e.g. the KUPA project)
- Increasing the area in which organic products are grown
- Revising the pesticide approval scheme

Several instruments in the pesticide action plans could stimulate the feasibility of cooperative agreements. The usage of pesticides could be regulated in the sensitive areas, and the approval of pesticides revised in case they prove to be a major threat to the groundwater.

The cooperative agreements in the Lyngby programme were established with farmers in individual negotiation processes. Farmers negotiated their commitment with the other partners involved, including the Danish Water Supply Association and the Municipality of Aarhus. Farmers that joined the scheme were not allowed to use pesticides. They could do so by choosing between entering an afforestation scheme, moving into organic farming or maintaining conventional farming practice without making use of pesticides. Some 15 landowners were included in the agreement, out of a total of 40 farmers working in the region, and the agreements established so far include only farmers who agreed to change to farming without the use of pesticides. No farmers have taken up organic farming.

The basic source for compensation payments is the Danish state (under the afforestation and organic farming schemes). In addition, the water suppliers provide compensatory payments as part of the cooperative agreement. If an agreement is reached, the contract applies for a period between five and 20 years. The contract expires or conditions can be renegotiated if legal requirements change (e.g. conditions for payment become mandatory) or there are major changes in international market conditions (e.g. a drastic increase in market prices of agricultural products).

In the Lyngby case (250 ha), the scheme involves the following total costs per year:

- Water supplier: EUR 30,000 (EUR 60 per ha/year)
- Farmers: cost recovery
- Public resources: EUR 40,000 (EUR 140 per ha/year)

There are also costs for negotiation and administration.

The Lyngby example above, which is in some ways similar to our Havelse case, shows that drinking water companies can promote cooperative agreements (farming contracts) by stimulating farmers to join agri-environmental programmes under EU Regulation 2078/92. Such programmes could be applicable across the country (e.g. shifting to organic farming) or, alternatively, focus on environmentally sensitive areas (e.g. regions vulnerable to nitrate and pesticide leaching). The question now is whether this is also the case for the areas from which Copenhagen Energy (CE) abstracts its drinking water in northern Zealand, north of the capital city of Copenhagen? As concluded in Brouwer (2003), "The current agri-environmental programmes are rather complicated to fulfil, and the compensation (for Lyngby 200 euro per ha/year) might be too small relative to the efforts required to join the programme. Also, the administrative efforts required are rather demanding for farmers, which reduces their motivation to join."

However, it is not correct, as stated in Brouwer (2003), that "the cooperative agreements made between farmers and drinking water supply companies need to be approved by the county councils (e.g. Frederiksborg council in our case study example)." The waterworks are allowed to make their own agreements with farmers without county approval. Furthermore, according to new Danish farming legislation (28 April 2004), waterworks are now also permitted to buy farming land for the purpose of groundwater protection.

Brouwer (2003) also concluded that "farmers tend to be fully compensated for joining the cooperative agreements, either by the provision of compensatory payment or through the provision of advice".

There seems to be another mistake in the Brouwer (2003) report regarding the compensation offered to farmers joining a cooperative agreement. According to the report, "payments from the water supply company on top of the agri-environmental programmes stimulate farmers to change their practice." This is **not** the case. Simply to add onto on EU agri-environmental programmes is not allowed.

The question in relation to CE now is, how useful are agri-environmental agreements for large-scale groundwater protection in northern Zealand, where conditions may be different from those in Lyngby in Jutland. CE operates 55 large wellfields with thousands of farmers, and the Havelse case study could provide important input for CE's strategy and policy in this area.

6.2 What is a BBN?

A Bayesian belief network (BBN), also called a belief network, is a type of decision support system based on probability theory which implements Bayes' rule of probability. This rule shows mathematically how existing beliefs can be modified with the input of new evidence. Devised by Thomas Bayes, an eighteenth-century English clergyman (Osman and Jensen, 2004), BBNs organise the body of knowledge in any given area by mapping out cause-and-effect relationships among key variables and encoding them with numbers that represent the extent to which one variable is likely to affect another.

BBNs have become a highly successful technique in medical diagnostic systems, analysis, artificial intelligence, and decision-making in real-world domains. They have been applied for many years in practice in a variety of fields, including engineering, science, and medicine (Charniak, 1991). BBNs have gained a reputation of being powerful techniques for modelling complex problems involving uncertain knowledge and uncertain impacts of causes. They can be used simply to provide a mathematically optimal decision on the basis of the information provided, or they can be used in a way that promotes an improved understanding of the environmental system, leaving decision-makers to reach their own conclusions on the basis of that understanding. The second approach is more highly recommended, as it supports the decision-makers rather than making the belief itself (Osman et al., 2004). Ideally, BBNs are a technique to assist decision-making that is especially helpful when there is a scarcity and uncertainty in the data used in taking the decision and the factors are highly interlinked, all of which makes the problem highly complex.

BBNs can help to formulate environmental management strategies by (Osman and Jensen, 2004):

- Allowing users to build their own environmental decision support system (EDSS). By building it themselves, users can ensure that the decision support system meets their needs.
- Helping users to understand the nature of their decisions better. An EDSS should help users make a better decision, not an easier one. It should not make the decision for the user. Instead, it should encourage the user to identify all the relevant information and analyse it more in depth.
- Encouraging users to deal with uncertainty. It is impossible to be certain about the consequences of any environmental management decision. This fact must be recognised together with the effect of that uncertainty of the decision.
- Encouraging consultation with stakeholders. Without stakeholder consultation, it is unlikely that an environmental management decision can be implemented.

A more thorough explanation of technical aspects and construction of BBNs for water resource management can be found in Osman and Jensen (2004); Jensen (2002) and Cowell et al. (1999). In the following, we will attempt to explain the methodology using examples from our own case study.

6.3 An example of a BBN for farming contracts

BBNs provide a natural tool for dealing with two problems that occur throughout applied mathematics and engineering: uncertainty and complexity (Aitken et al., 2003; Jordan, 1999). Fundamental to the idea of a graphical model is the combination of simpler parts. Probability theory provides the glue whereby the parts are combined, ensuring that the system as a whole is coherent and that inferences can be made. BBNs are a method for discovering valid, novel and potentially useful patterns in data where uncertainty is handled in a mathematically rigorous yet simple and logical way (Aitken et al., 2003). A relatively simple example from the construction of BBNs in this study is the intermediate BBN for farming contracts shown in Figure 6.1.

The general idea with this BBN was to analyse the effects of compensation payments to farmers for not using pesticides on agricultural fields. The higher the compensation level, the more farmers will join such a voluntary contract. However, farmers signing a contract will also try to optimise land use by growing crops more suitable for farming without pesticides, and this means that contracts will also affect crop rotation. Farming contract restrictions and crop rotation affect the farmers' bottom line, so to speak, and this, together with the compensation payment, has an impact on farm economics as a whole. All the relationships in this part of the farming contract BBN were initially provided by subcontractor Svend Rasmussen from the Royal Veterinarian and Agricultural University (KVL), which also collected the data for pesticide application for different crop rotations. The other part of the BBN in Figure 6.1 shows variables concerning environmental impacts of pesticide application. These variables were based on information from monitoring programmes at GEUS and CE. It was assumed that a wet climate increases the leaching of pesticides into shallow-lying groundwater and that research from the USA had shown that high concentrations of herbicides in surface water impacts the reproductive capability of leopard frogs (expressed by the variable "biological abnormality").

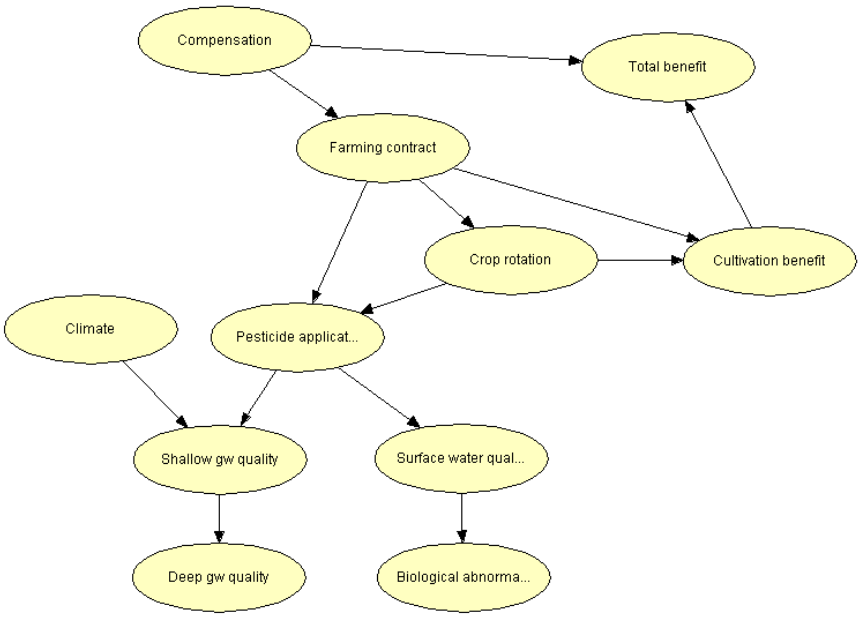


Figure 6.1. Bayesian belief network for farming contracts (Intermediate network constructed 8 May 2003).

The BBN in Figure 6.1 represents relationships amongst uncertain events. Look at the directed edge linking the nodes “shallow groundwater quality” and “deep groundwater quality”. Shallow groundwater quality and deep groundwater quality represent events; the edge running from the shallow groundwater quality node to the deep groundwater quality node expresses a causal relationship between the two events. Probabilities are specified in the form of conditional probability tables.

For the edge running from “shallow groundwater quality” to “deep groundwater quality”, there is a table expressing the probability that specifies, for each state of shallow groundwater quality (parent node with three states: <0.01 μg/l, 0.01-0.1 μg/l and >0.1 μg/l), the probability of each state of deep groundwater quality (the so-called *child* node here having states defined at the same intervals as shallow groundwater quality). Probabilities for nodes with no parents are unconditional (e.g. “Climate” and “Compensation”). These nodes are also called *root* nodes (Jensen, 2002; Aitken et al., 2003).

Each node represents a random variable that can assume either discrete values or continuous values, although only discrete nodes are considered in this example from our case study dated 8 May 2003. There are three basic types of connections among nodes in a BBN: serial, diverging and converging connections. We have a *serial connection* linking three nodes A, B and C when there is an edge from A to B, another one from B to C and no arcs from A to C (as is the case in the network in Figure 6.1 for the three variables “pesticide application”, “‘surface water quality” and “biological abnormality”).

A diverging connection linking A, B, and C is one where there are two or more edges originating from A and pointing to B and C (or additional nodes), and no edges between B and C. A diverging connection is the graphical representation of what statisticians call a “spurious correlation” (Aitken et al., 2003). In Figure 6.1, there are diverging connections between the variables “pesticide application”, “shallow groundwater quality” and “surface water quality”.

An example of a converging connection linking A, B and C is when there is an edge running from A pointing to C and another one from B pointing to C, and no edges between A and B; A and B are conditionally dependent given the value of C (Jensen, 2002). There is an example of a converging connection in Figure 6.1, between “climate”, “pesticide application” and “shallow groundwater quality”.

The conditional probability tables (CPTs) for the BBN in Figure 6.1 were initially based on expert input (Rasmussen, 2003) and monitoring data from Denmark at GEUS. We provided tables including explanations in text for the discussions at the workshops where we went through each conditionally probability table. Afterwards we consulted some of the stakeholders at individually meetings in order to collect more additional feedback and suggestions for additionally variables and edges. It turned out that stakeholders actually questioned the expert knowledge both regarding farm economics and groundwater contamination with pesticides, and influenced the development of the BBN with additional variables or adjustments of CPTs according to local conditions and knowledge. This is one of the most powerful abilities of BBNs: that they can be adjusted easily to include evidence and local data and that they are flexible, allowing adjustment not only of the CPTs but also

the model structure itself (variables and edges). In fact, there are built-in tools for *structural learning* in Hugin which can be used to construct a BBN from existing data, thus facilitating interactive approaches and decision-making in the construction phase.

BBNs allow researchers, managers, stakeholders and the general public to learn (Aitken et al, 2003):

- A way of thinking about a problem involving uncertain information
- How to apply these methods to draw inference about the world of interest
- How to act rationally under uncertainty
- How to induce a model from data
- An natural way of combining domain knowledge and data within a single model

From a practical point of view, scientists are forced to cope with uncertainty. Certain factors must be taken into account:

- Incomplete theory, because no complete theory is known about a problem domain
- Resource limitations, because the number of relevant factors is potentially very large and it would be impractical to make a complete list
- The problem of decision-making under uncertainty, because it is necessary to make rational decisions even when there is not enough information to prove that a particular action will work.

Briefly, to summarise, a BBN is a series of nodes representing states in nature and the casual dependencies among them (Marcot et al., 2001). The probabilities representing those linkages can be developed empirically or through expert judgement (Reckhow, 1999; Rieman, 2001; and Borsuk, 2003). A distinct advantage of this approach is that BBNs do not have to incorporate the complete mechanistic detail of more process-based models. Uncertainty about the fate of pesticides in groundwater and surface water and about ecological and socio-economic impacts or limited information is reflected in the vector of conditional probabilities for linkages that are defined.

6.4 Methodology of BBN development

6.4.1 Informing stakeholders and general public about precautionary groundwater protection issues and BBN development

GEUS and CE developed the first presentable BBN for the purpose of informing stakeholders and the general public about different precautionary actions, which could be directed against both urban and rural pollution sources. This BBN was developed in September 2002 after consultation with both Professor Finn V. Jensen of Aalborg University and Centre of Ecology and Hydrology (CEH) at Wallingford (see Figure 6.2). A number of early BBNs had been developed prior to this one so that we could become familiar with the capacity and functionality of BBNs (Henriksen, 2002).

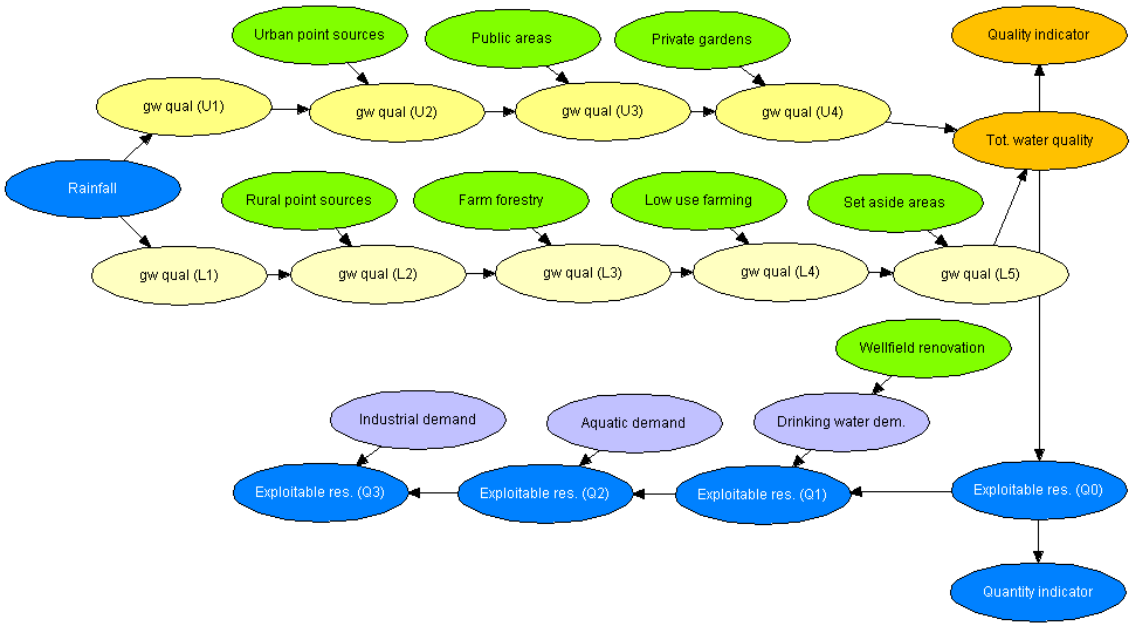


Figure 6.2. Pilot network for informing stakeholders (October 2002).

The BBN in Figure 6.2 deals with the management of groundwater protection issues for a regional groundwater wellfield catchment area (Havelse catchment), where different actions can be considered in order to reduce the total load of pesticides from urban and rural areas.

The preliminary network consisted of 28 nodes. At the time, they were to be broken down into additional nodes based on input from various stakeholder meetings. Data were also collected in the area, both basic mapping of pesticide applications and other theme maps, and a numerical groundwater modelling study was started to provide data on exploitable resources and solute transport in groundwater.

The preliminary network was made up of three main branches:

- Action against urban pesticide sources (unit: pesticide concentration in groundwater from "urban pesticides", μg/l)
- Action against rural pesticide sources (unit: pesticide concentration in groundwater from "rural pesticides", μg/l)
- Action related to management of groundwater resources allocation (unit: million M^3/year)

The Havelse wellfield catchment area is a rural area with only minor loads of urban origin.

The 28 nodes are described in greater detail in Table 6.1.

Table 6.1. Description of initial BBN used for informing stakeholders and the general public at kick-off meetings in November 2002.

Variable	Node type	States	Definition
Rainfall	Labelled	Dry, normal, wet	A wet climate is assumed to increase the leaching of both urban and rural pesticides compared to a dry climate, due to more frequent heavy rain events with subsequent leaching
gw qual (U1) [sequential list: U2, U3 and U4 depending on the urban action taken]	Interval	0 – 0.01 0.01 – 0.05 0.05 - 0.075 0.075 – 0.1 0.1 – 0.15 0.15 – 0.2 0.2 – 0.5 0.5 – 1	Assumed long-term groundwater quality of water abstracted from wellfield at different urban loads; quality based on monitoring data and expert assessments. [μg/l]
gw qual (L1) [sequential list: L2, L3, L4 and L5 depending on the rural actions]	Interval	0 – 0.01 0.01– 0.05 0.05 - 0.075 0.075 – 0.1 0.1– 0.15 0.15 – 0.2 0.2– 0.5 0.5– 1	Assumed long-term groundwater quality of water abstracted from wellfield at different rural loads. [μg/l]
Urban point sources	Boolean	False/True	Action: Remove urban point sources. When the variable is true, it is assumed that the loads from all urban point sources have been completely removed
Public areas	Boolean	False/True	Action: Stop pesticide application to public urban areas
Private gardens	Boolean	False/True	Action: Stop pesticide application to private gardens
Rural point sources	Boolean	False/True	Action: Remove pesticide rural point sources
Farm forestry	Boolean	False/True	Action: Convert rural areas with leaching into forest
Low use farming	Boolean	False/True	Action: Agreements with farmers about reduced pesticide use or organic farming. This variable is dependent on application (use) of pesticides (not yet represented in BBN for Havelse).
Fallow land and protection zones	Boolean	False/True	Action: Establish wetlands on cultivated land, or other measures to take agricultural areas out of production

Total water quality	Interval	0 – 0.01 0.01– 0.05 0.05 - 0.075 0.075 – 0.1 0.1 – 0.15 0.15 – 0.2 0.2 – 0.5 0.5 – 2	Based on states of urban and rural concentration (U4 and L5). It is assumed that both concentrations can be added to a total groundwater quality, reflecting both urban and rural pesticides. [μg/l]
Water quality indicator	Labelled	Very good Acceptable Poor	"Very good" is the total fraction below detection limit (< 0.01), and "poor" is above MAC > 0.1 μg/l
Exploitable res. (Q0) [sequential variables: Q1, Q2 and Q3 after different water uses]	Interval	0-1, 1-2, 2-3, 3-4, 4-5, 5-6, 6-7, 7-8, 8-9 and 9-10 (million m^3/year)	All exploitable groundwater resources of "good quality groundwater". If groundwater quality is poor, there are less exploitable groundwater resources than if quality is acceptable/very good. (It is assumed that a maximum of 10 million m^3/year is available.)
Quantity indicator	Labelled	Not sufficient Acceptable Favourable	Below 4 million m^3/year Between 4 and 7 million m^3/year Above 7 million m^3/year.
Well field renovation	Boolean	False/true	Action: New pipes, cables and wells at the wellfield can affect the likelihood of Havelse wellfield operating
Drinking water demand	Boolean	False/true	Drinking water demand: If the regional abstraction and the local drinking water abstraction from private and municipal waterworks are in operation, the exploitable resource is reduced by this amount.
Aquatic demand	Boolean	False/true	Operator that reduces the exploitable resource by an amount corresponding to the one which is assumed necessary in order to supply the aquatic environment
Industrial demand	Boolean	False/true	Water for irrigation of crops, industrial supply, etc.

The sequential variables U2-U4, L2-L5 and Q1-Q3 are designed as expressions in the network. If "true", the concentration is reduced by an amount based on the assessed concentration from that specific load type in the catchment area.

So far, the relationships between climate and exploitable resources have not been included in the network. It is assumed that climate change will result in the same annual recharge, but that the heavy rainfalls merely will increase the pesticide leaching, and not have an impact on total recharge.

The socioeconomic variables have not yet been introduced into the preliminary belief network.

Table 6.2 shows the expected utility variables that have been considered so far. Some may be economic in nature; others may not.

As shown above, the first BBN was rather ambitious, and many different issues were addressed. Both groundwater quality and quantity issues were represented. In order to assure an open process, nearly all types of actions that could be imagined (taken by GEUS and CE) were represented. The idea was to present a "neutral" BBN and then to let stakeholders provide their input on which issues the focus should be on in the subsequent BBN development.

Table 6.2. Socioeconomic variables considered for the BBN presented at kick-off meetings.

Type of socioeconomic variable	Description
Cost estimates	Must be incorporated for each of the actions categorised as "removal of urban and rural sources". A cost estimate also has to be included for the wellfield renovation variable.
Environmental benefits	Must be incorporated for abstracted and excess resources that have not been utilised yet (but still valuable for the Roskilde Fjord bay aquatic environment, future generations etc.): • Regional abstraction • Aquatic demand • Local abstraction • Excess exploitable resource (Q3)
Agricultural production / changed land use benefits or drawbacks	Must be evaluated for the following variables: • Afforestation • Farmers' contracts (productivity upon shift from traditional to organic farming or upon reduced pesticide application) • Establish wetlands (gains for public and wildlife)

Only Figure 6.2 was presented at the meetings, not Table 6.1 or Table 6.2. The tables were primarily prepared in order to develop an understanding of which states could be relevant and to get some hands-on experience with Hugin about the functioning of the software, use of expressions, implementation of states, etc.

The structure of the BBN in Figure 6.2 resulted in a high number of states for groundwater quality. This was a drawback due to the many issues the first BBN was supposed to include (both quality and quantity issues).

The kick-off workshop on 29 October 2002 resulted in a group of professional stakeholders with representatives from private waterworks (FVD), Frederiksborg County, Frederiksværk Municipality, farmers' organisations (NOLA and *Sjællandske Familielandbrug [*"Zealand Family Farms"]), Green Forum in Slangerup (an NGO), the Agenda 21 Centre in Frederikssund (facilitator), Copenhagen Energy (end user) and GEUS (responsible for the project). Also Professor Svend Rasmussen from the Royal Veterinary and Agricultural University (farm economics input), Jesper Sølver Schou from the Danish National Environment Research Institute (economic value of the environment) and Professor Finn V. Jensen from the University of Aalborg (BBNs) participated in the kick-off workshop with the professional stakeholders.

One hundred citizens attended the public meeting in Sigerslevøster a week later, on 5 November 2002. The first BBN was not presented at the public meeting. Instead, a small multi-choice test had been created that tested the knowledge of the locals. A sheet containing 15 questions and answers was to be filled in and returned before the correct answers were shown using an overhead projector and various charts. After a short collaboration in small work groups, the various groups displayed their different suggestions for groundwater protection at the Havelse wellfield catchment area:

- “There are no problems with nitrate in the area, so it’s not necessary to reduce the intensive agricultural activities in the area.”
- “*Tighter restrictions on the discharge of waste water are required as far as industries are concerned.”
- “We need better handling of wastewater from single households out in the country.”
- “The maintenance of the stream is too poor: too many weeds and too much sediment causes flooding of the agricultural areas.”
- “More organic farming and subsidies for raising forest should be introduced.”
- “Pesticide use in private gardens should be prohibited.”
- “Farmers should respect the two-metre protection zones along the creek.”
- “The wellfield should be restored.”

After a short while, and after the facilitator had applied a little pressure, a citizen group of 11 persons were formed. At the end of the session, there was an open debate and the local television broadcast company “Fjord TV” covered the whole session and debate. Among the participants were the mayor of Skævinge, members from the local town council and municipal colleagues from Frederikssund and Frederiksværk.

In the citizens’ group, there were part-time traditional and organic farmers, a public school teacher, a representative from a small private waterworks, landowners, a full-time potato farmer, a market gardener and a full-time dairy cattle farmer. The perceptions and motivations behind participation in the citizens’ group were manifold:

- “The purity of drinking water has a high priority for me, and I believe that the various stakeholders involved must try to improve their communication.”
- “There is a problem In my local area with a possible future gravel quarry that will threaten groundwater preservation.”
- “I would like to focus on the fact that also citizens from towns and cities have a responsibility to preserve pure drinking water.”
- “I want to influence coming decisions/strategies in preserving drinking water and nature in the area.”
- “I have carried out measurements and comparisons of water levels in and precipitation near Havelse Creek for the last ten years.”
- “I have experienced how little a single landowner can influence decisions….I would like to use this opportunity to contact the people involved.”
- “I support the preservation of drinking water….the high water level in the creek is a serious problem for the local area.”
- “It’s a problem that everybody passes the buck so that nobody actually solves the problem...I have a clear interest in the water level in Havelse Creek being kept low.”
- “It is necessary to gain an overview of the consequences of different chemical substances before they are brought into use.”
- “I am nervous that the future restrictions imposed in this area can force me to retire in the longer term.”

It was decided for a start to let the citizens' group "have its own life"[6] so that the group could go through the necessary stages of group teamwork. It was a rather non-homogeneous group, and members had joined the group for various reasons. According to a five-stage group development model, the group would pass the stages: 1) forming (uncertainty about the group's purposes), 2) storming (intragroup conflict), 3) norming (close relationship and cohesiveness), 4) performing (fully functional group) and 5) adjourning. At least the two first stages were anticipated. It was a necessary that the group of citizens first find their own foundation.

We did not expect the same problems with the group of professional stakeholders, but on the other hand (looking back), many of the same phases should probably be considered for a group of professional stakeholders as well. This mistake could eventually be one of the main reasons why, in the final questionnaires, stakeholders responded rather negatively about the participation in the working groups.

It was clear after feedback from stakeholders that farming contracts, afforestation and flooding were issues that we should pay some attention to. One of the reasons for this was the threat from new wastewater discharges upstream, from biotech companies in the town of Hillerød, which could increase problems with flooding in the local area, but another reason was the plan to establish wetland areas along Havelse Creek in the local area, which would likely also increase problems with flooding in the area. Frederiksborg County was responsible for the new wetlands (which were aimed at reducing nitrate transport to the Roskilde Fjord bay) through voluntary agreements with local farmers. However, it would be interesting to somehow include the establishment of wetlands, because it could provide some relevant input for our farming contract BBN about what level of compensation would be necessary in order to get the farmers on board. The feedback from the kick-off meetings showed that especially farmers in general were against the environmental action.

Thus We decided to work with three different BBNs in the next phase of the project, with the following ownership (Brandt and Henriksen, 2003):

- BBN for farming contracts (ownership: the group of professional stakeholders)
- BBN for afforestation (ownership: CE)
- BBN for flooding (ownership: citizens' group)

6.4.2 Construction of BBNs with stakeholder involvement (Steps 1 – 3)

A first version of the flooding network developed in the consultation process with the group of professional stakeholders at workshop meetings in the spring of 2003 is shown in Figure 6.3.

This first network was focused on the problems with flooding (see Figures 6.5 and 6.6) and genetically modified organisms (GMO). Input from the County about the plans for establishing wetlands was not included yet. The plans for establishing wetlands were rather critical to future wellfield operation, so CE and Frederiksborg county were negotiating

[6] The citizens' group has commented this decision, which they found inappropriate, see chapter 9.

possible alternative locations based on the numerical groundwater model developed. These negotiations resulted in four potential wellfield locations both north and south of Havelse Creek, for which numerical simulations were run that showed the impact on low flow, groundwater table and risk of saltwater intrusion for each potential wellfield location.

However, the presentation of the BBN shown in Figure 6.3 gave useful feedback from both the group of professional stakeholders and the citizens' group about how they perceived the problems with flooding and what causes we should focus on in the subsequent work. A BBN for farming contracts was also presented (shown in Figure 6.4).

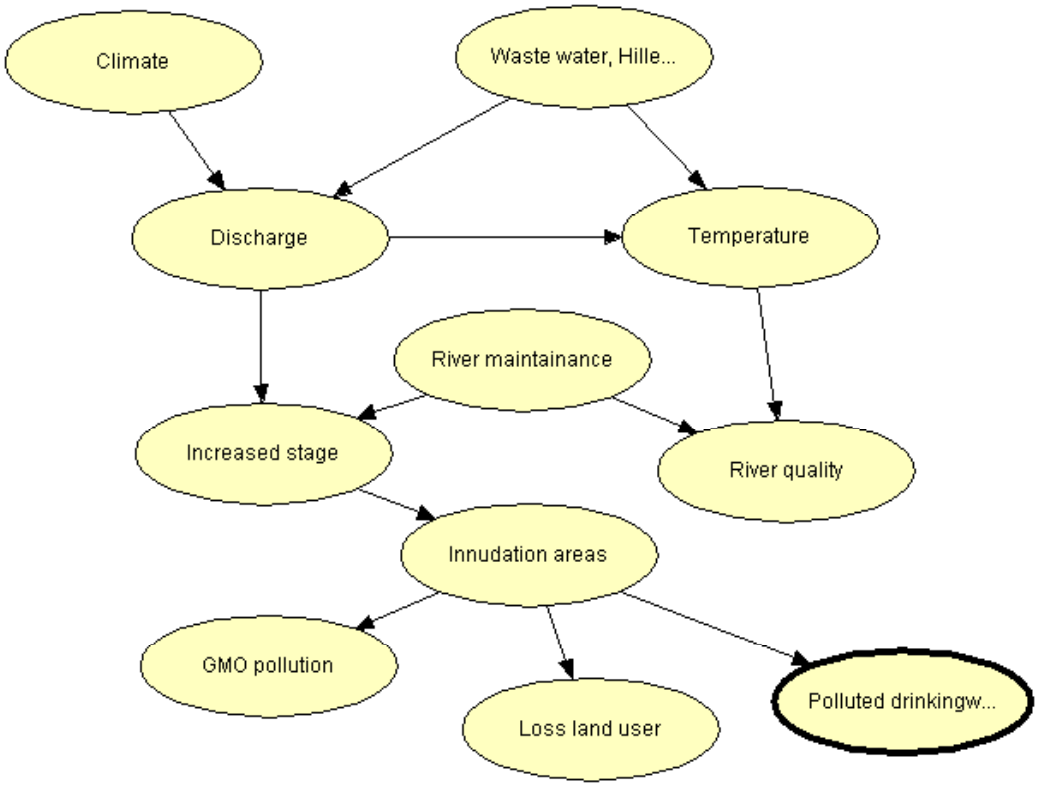


Figure 6.3. First version of BBN for flooding (19 March 2003).

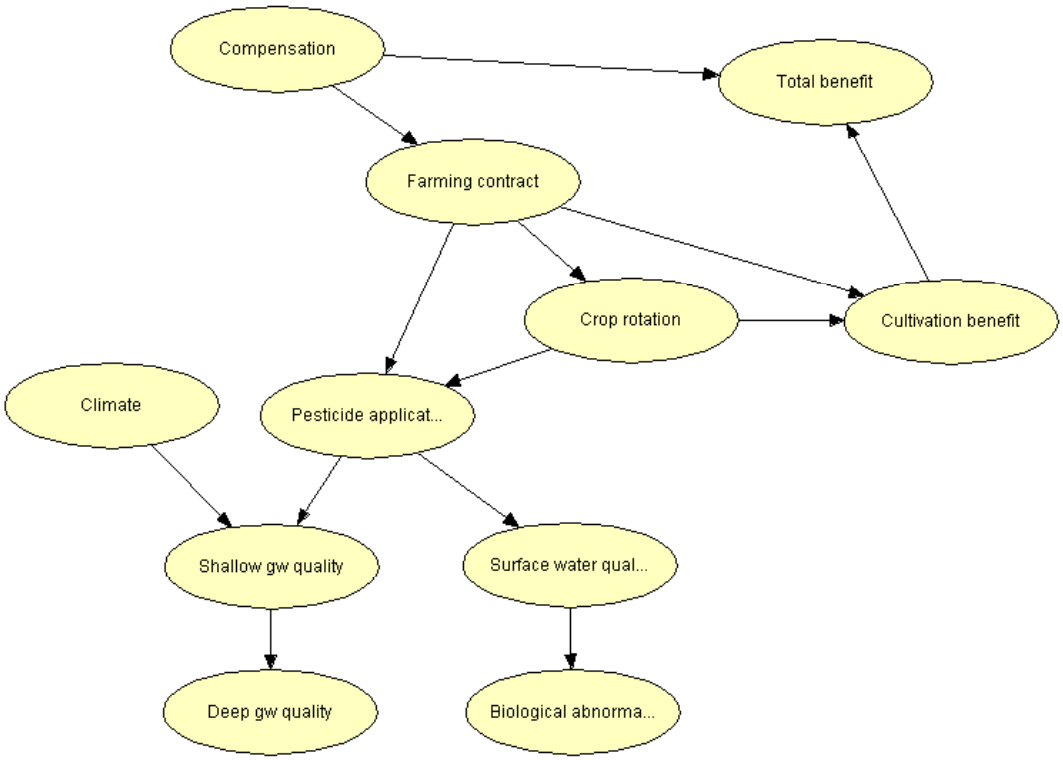


Figure 6.4. Early version of BBN for farming contracts (8 May 2003). First version presented at second working group meeting did not include the "total benefit" variable, and had slightly different names for the variables compared to this version.

Figure 6.5. Havelse Creek valley and flooding on 5 February 2004 (river stage 1.52 m). (Photo Bjørn Hansen, member of the citizens' group in the MERIT project)

Figure 6.6. Havelse Creek valley after flooding 18 February 2004 (river stage 0.64 m). The building in the middle is Copenhagen Energy's wellfield pumping station. (Photo Bjørn Hansen, member of the citizens. group in the MERIT project)

The first MERIT project working group meeting with the professional stakeholders was held on 5 February 2003, before the two initial networks shown above in Figures 6.3 and 6.4. Focus was directed on follow-up from the kick-off meetings in October-November 2002 and discussion of tasks among stakeholders and roles in the context of groundwater protection.

There was also a questionnaire completed at and after the first workshop in February 2003 describing consequences of various methods of groundwater protection when dealing with afforestation, the reduced agricultural use of pesticides, organic farming and cultivation agreements.

The idea behind the first meeting was to develop a common understanding of the problem and define the context, which was Step 1 in the protocol for the construction of BBNs with stakeholder involvement (see Chapter 3). Furthermore, Step 2 – identify factors, actions and indicators – was discussed in detail at this first workshop meeting. Thus the objective of the first workshop in relation to BBN development (Steps 1 and 2) was to:

- To reach a common understanding of roles, responsibilities and activities of the individual stakeholder groups in the context of groundwater protection in the area around Havelse wellfield
- To elicit which elements are considered as the most important when it comes to groundwater protection in the area
- To look into consequences and direct/indirect consequences of different measures. What is the interrelation between causes and effects?

- Where to find data for qualification and quantification of cause-effect interaction for use in the building of the BBNs
- Determine which indicators for effects and consequences of groundwater protection would be relevant

GEUS promised to include the information from the forms in the further development of the BBNs and to present examples of BBNs at the next meeting, which was scheduled for 26 March 2003.

At the second working group meeting on 26 March 2003, two BBNs were presented:
- Flooding (see Figure 6.3)
- Farming contracts (see Figure 6.4)

The network for farming contracts was roughly designed and based on input from an expert in farming economics (Rasmussen, 2003; Schou, 2003).

Each of the variables in both pilot networks (Step 3 in the BBN construction protocol) were presented and discussed individually; a draft on likelihood tables and explanations on each variable was distributed. Afterwards, the BBNs were demonstrated with different scenarios.

There were various comments on the BBN for flooding: abstraction missing, about maintenance of the creek, missing link from flow to quality, temperature, which GMOs were we talking about, more parameters from wastewater required, etc.

Of the suggestions to the pilot BBNs, the following was considered relevant for use in further development, and incorporated in later BBNs for farming contracts:
- A good idea is to look at the agri-environmental agreements; no farmers have yet been interested in them because the DKK 1000/ha grant (EUR 140/ha) is too small (variable compensation).
- The farmers in northern Zealand must produce grain/fodder for livestock (variable crop rotation)
- Could be interesting to see a list of possible crops prioritised in relation to groundwater protection (variable crop rotation)
- For the time being, no differentiation between different pesticides, e.g. division into “absolute undesirable” pesticides and “undesirable” pesticides (variable pesticide application). It is necessary to have this distinction. Fungicides and insecticides are a minor problem.
- Handling of places where machines are filled up and washed could be part of an agreement between the farmer and the waterworks (variable pesticide application).
- Where do the numbers come from? There are no data from the actual area, the Havelse area, which means that data from the national groundwater monitoring programme and from a specific project on pesticides, etc. in small private wells are used on a general basis (variable shallow groundwater quality)
- The reduction of pesticides from shallow to deep groundwater seems to be somewhat underestimated; especially in relation to the Havelse area (variable deep groundwater quality). The relation is largely based on old and now-banned pesticides.

Based on these comments, development of the BBNs continued; they were presented at the third meeting held 22 August 2003. BBN development focused on the networks for farming contracts, afforestation and flooding (see Figures 6.7, 6.8 and 6.9 below).

At the third meeting, a presentation and discussion of the report "Financial loss for farmers who cultivate without pesticides near Havelse wellfield" was given (Svend Rasmussen participated and gave an oral presentation). Jesper Sølver Schou (Danish National Environmental Research Institute) presented his ideas and thoughts behind a draft report entitled "Socioeconomic analysis on different groundwater abstraction strategies in the Havelse Creek catchment areas". Professor Finn V. Jensen of Aalborg University participated in this working group meeting and commented on the BBNs developed.

6.4.3 Quantitative BBN construction, data collection and definition of states and CPTs (Steps 4-6)

After this third working group meeting, it was decided to arrange some individual meetings in order to collect data from individual stakeholders, define states and construct CPTs, Steps 4, 5 and 6 in the proposed protocol for BBN construction introduced in Chapter 3. It was decided to skip the afforestation BBN because this measure was not realistic in the future wellfield locations negotiated by CE and Frederiksborg County. Only farming contracts were possible due to "open landscape" zoning, and flooding was still an issue and used to demonstrate the BBNs and address issues relevant for the citizens' group.

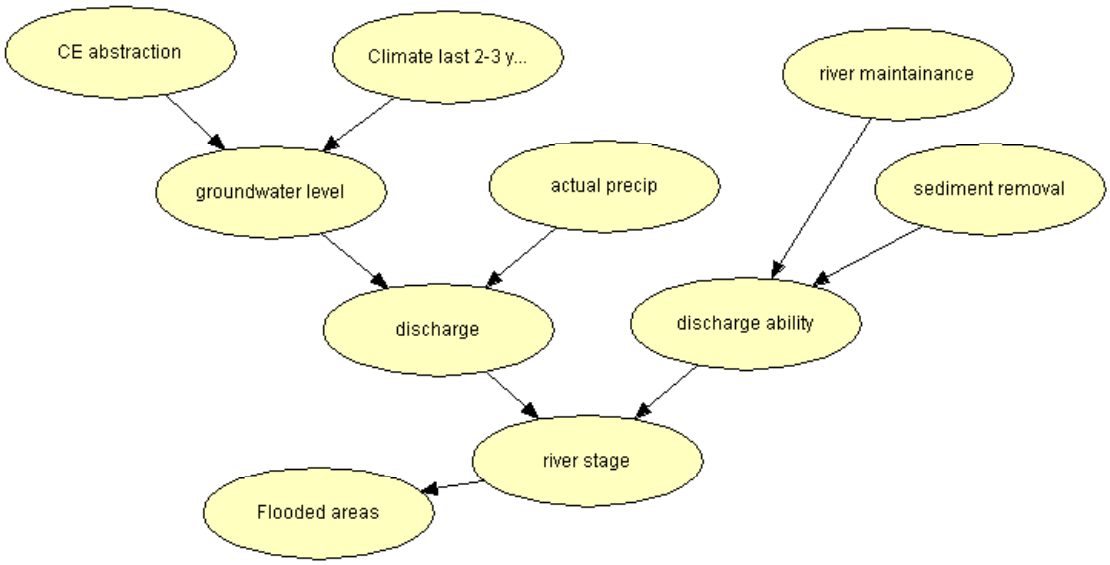


Figure 6.7. Second version of BBN for flooding (25 June 2003).

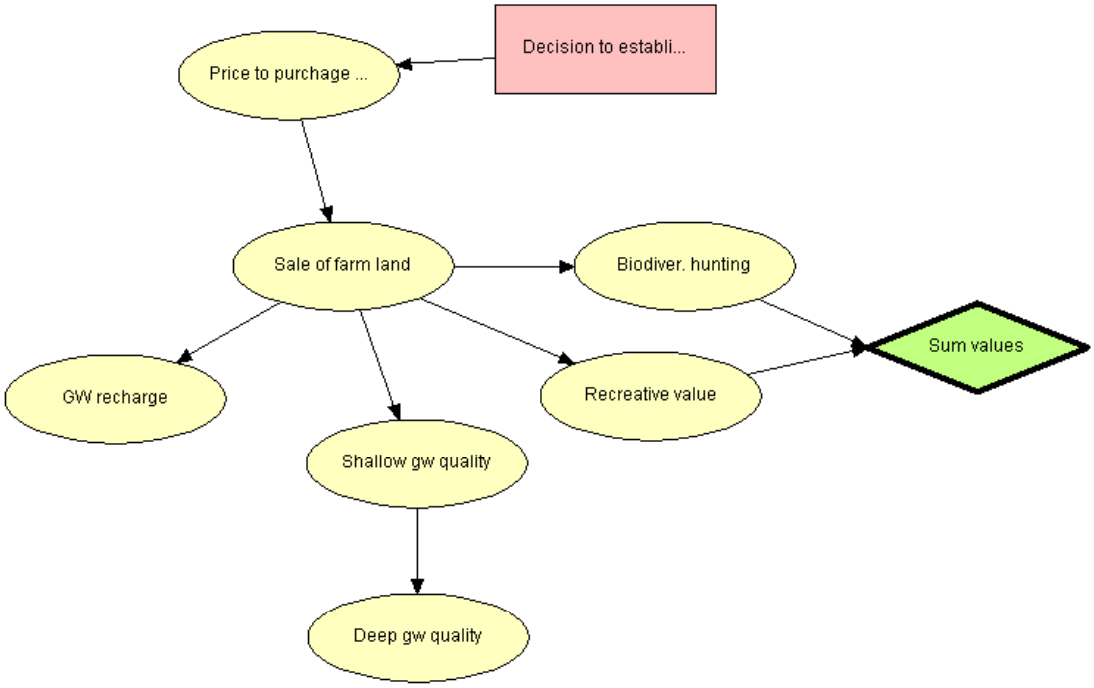


Figure 6.8. First network for afforestation (22 August 2003).

The first citizens' group meetings were held on 26 February 2003, 19 March 2003, 8 April 2003 and 6 May 2003 (attending the May meeting were Hans Jørgen Henriksen from GEUS and Gyrite Brandt from CE).

There were suggestions from the citizens' group that data from Bjørn Hansen, who had collected daily creek water level and climate data for ten years, be incorporated in the BBN for flooding. The citizens also suggested agri-environmental farming agreements that could provide a higher grant to farmers. The farmers attending the meeting were of the opinion that farming contracts would require grants up to DKK 5000/ha (EUR 700/ha/year). Another option could be putting an encumbrance on the property (e.g. no pesticide use); this could be done parallel to various grant arrangements). Figures 6.9, 6.10 and 6.11 show how the BBNs were developed further between September 2002 and February 2003.

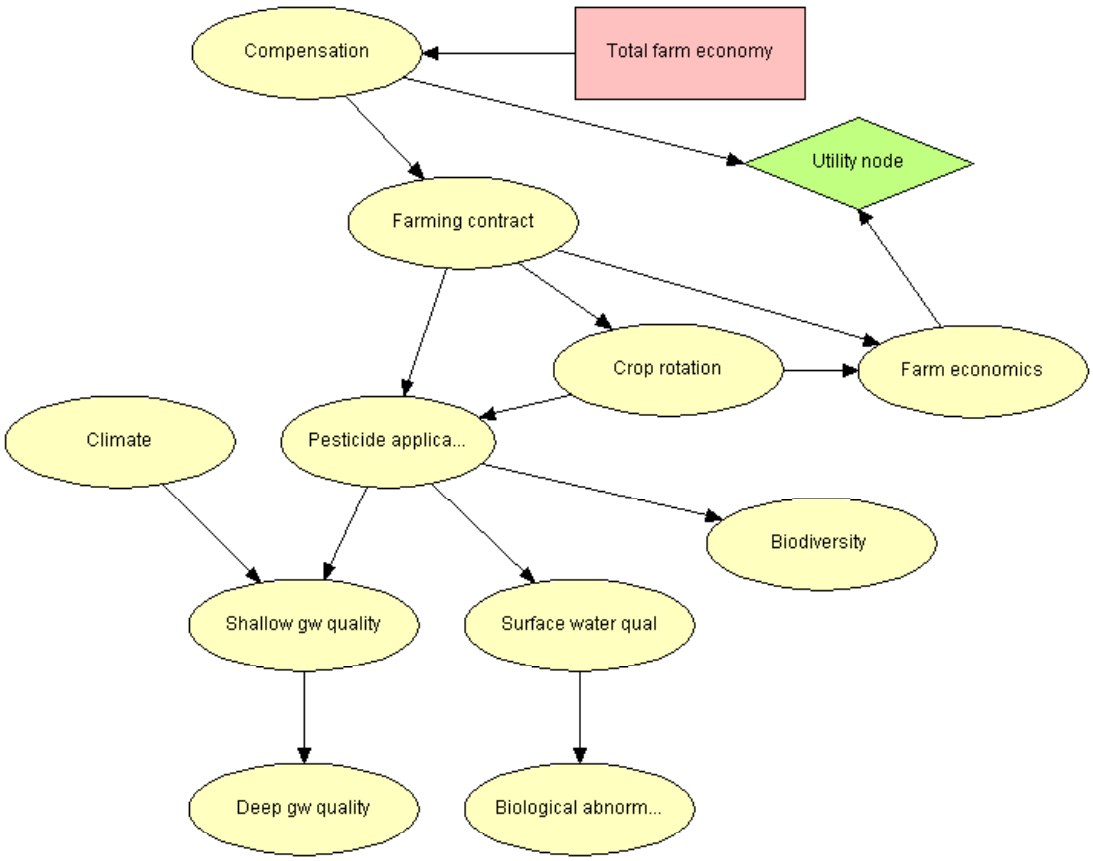


Figure 6.9. Second network for farming contracts (16 September 2003).

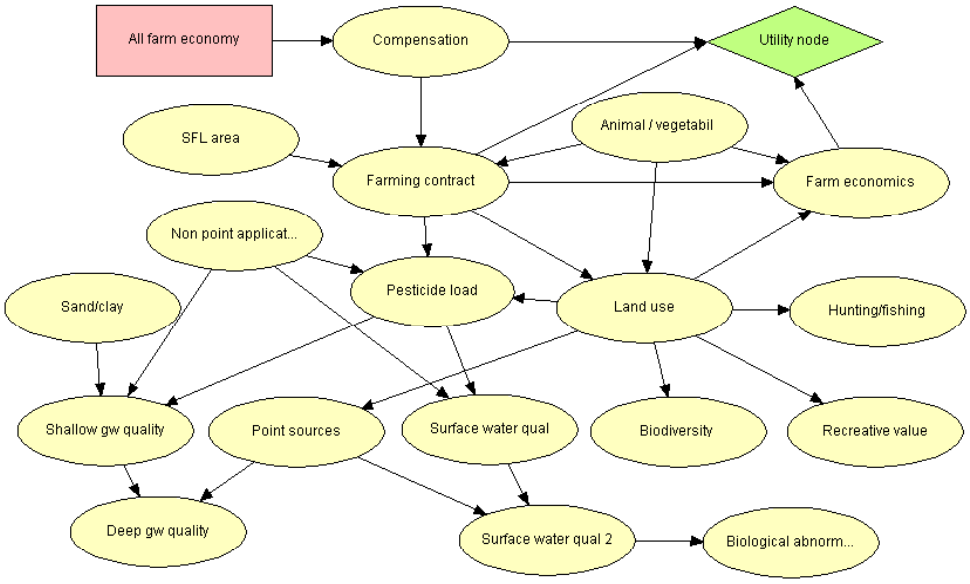


Figure 6.10. Third BBN for farming contracts (17 February 2004).

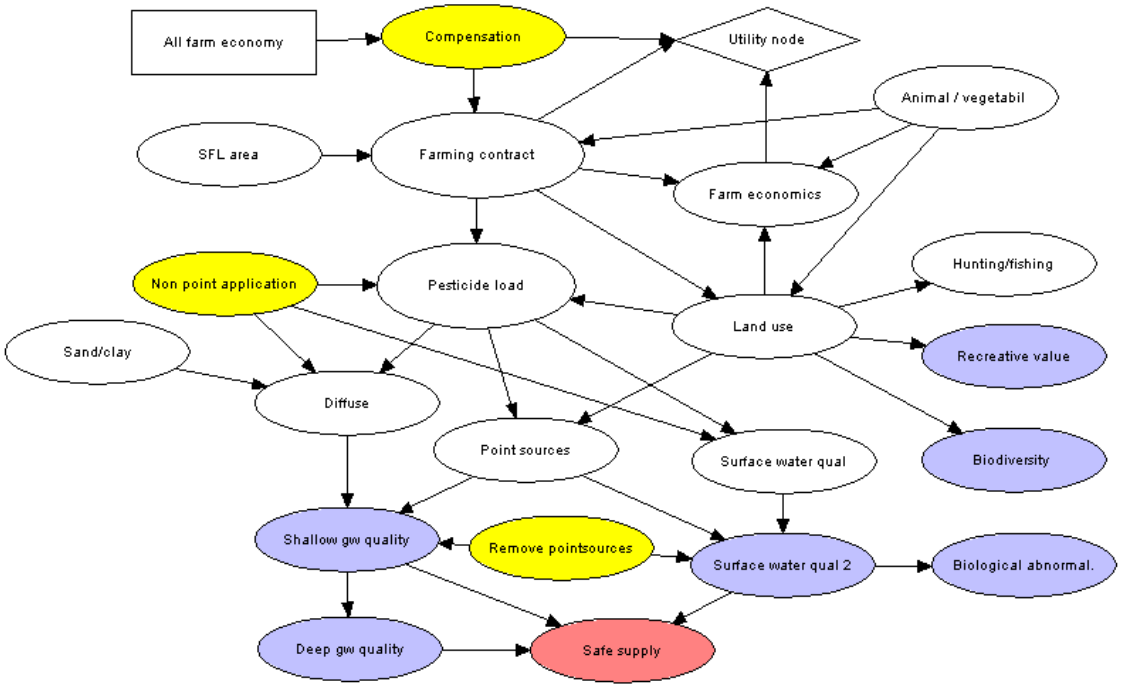


Figure 6.11. Fourth BBN for farming contracts.

The final BBNs for farming contracts (precautionary groundwater protection) and flooding are described in more detail in sections 6.3 and 6.4 below.

6.4.4 Collection of feedback from stakeholders (Step 7)

The seventh and last step in the BBN construction protocol (collecting feedback from stakeholders) was taken on a second workshop on 3 March 2004 to which members of both the professional stakeholder group and the citizens' group were invited. Written feedback was also collected in the form of questionnaires that had been sent to all stakeholders and members of the citizens' group. Finally, all participants were requested to comment on the draft report, and here the citizens' group provided a significant input (see chapter 9).

Even though stakeholders and citizens generally expressed disappointment with participation in the project and in the working groups, including the roles played by GEUS, CE and the Agenda 21 Centre, most stakeholders and citizens also felt that they had had an influence on the development of the BBNs. Some remarks were:

- "The project management was open and positive about discussing the elements."
- "CE and GEUS found out that farming contracts are not an applicable solution."
- "They listened to suggestions."

According to stakeholders and citizens, the greatest advantages of the BBNs were the following:

- "Used properly, a good, flexible tool for integration"

- “Clear overview”
- “Good tool for dialogue”

The greatest limitations of BBNs:

- “Require insight and understanding”
- “You get the answers you want”
- “Not applicable to groundwater protection”
- “Selection of precise data required”
- “Correctness of information is questioned”
- “A complex tool whose primary strength is as a tool for dialogue”
- “Number of variables must not be too large or overview is lost and relationships less clear”

There was some disagreement at the workshop about how representative newly collected data for shallow and deep groundwater quality were (see section 6.7 below, where these data are discussed).

The citizens’ group said they had difficulty following the presentation of BBNs. The County of Frederiksborg could not see much use for BBNs when it came to actual groundwater protection. The farmers’ organisation (NOLA), also on behalf of their sister organisation *Sjællandske Familielandbrug*, made the following comments on the BBNs:

- If the project was testing under the WFD, it should not only focus on pesticides, which the agricultural organisations felt to be the case
- “We do not believe that the water [abstracted at the wellfield] is 50 years old.”
- Only the pesticide Bentazone represented the current situation; other findings of pesticides were due to years-ago use of currently banned pesticides
- Was using probabilities in connection with groundwater protection a good idea?
- “But maybe BBNs are useful when looking at the WFD as a whole.”
- “The project should be more anchored in data from the local Havelse area.”

The farmers’ organisations had the attitude that the deep groundwater will not be polluted above the MAC level, that the main source of uncertainty in the BBN is the relationship between shallow and deep groundwater.

In the case study, we based the BBN on expert opinion and monitoring data (proxy basin). Local people and stakeholders did not like this approach; they thought we should have based the BBNs on local input. In general it seems as though stakeholders misunderstood the aim and purpose of the project, which was to analyse a policy, to investigate whether cooperation agreements were an option, and what level of compensation, if any, should be implemented in the real world, i.e. in northern Zealand on a larger scale. Expectations about what was going on were not clear, which is, of course, another argument for using written documents to clearly express the work to be carried out (some kind of stakeholder involvement plan).

The disappointment expressed about participation was probably to a great extent due to this lack of clear rules for the game. If the rules, time schedule and terms of reference for the work in the groups had been more clear, then a higher satisfaction would likely have

been the result. On the other hand, the lack of satisfaction could also be due to disappointment with the working group meetings, simply because they malfunctioned in the later stages (during Steps 4-6 of the BBN protocol) and did not produce much constructive input for the BBN development any longer.

Perhaps the working group was too inclusive, with too many "conflicting" stakeholders. Splitting the working group into smaller and more specific "task forces" covering different domains (e.g. farm economics, groundwater impact, biodiversity, etc.) may have been a more efficient way of finalising the BBNs.

Instead, we decided to arrange individual meetings with Frederiksborg County, *Sjællandske Familielandbrug* and members of the citizen group (organic farmers and Bjørn Hansen) that turned out to provide highly useful input for the final development of the BBNs. At individual meetings, it is clear that disappointment from the "overruled" working group is a very likely outcome.

This leads us to the following conclusions about stakeholder involvement in BBN development:

- In the early, more qualitative stages (Steps 1 – 3), broader groups of stakeholders and the general public can provide relevant input to BBN development.
- In the later, more quantitative stages (Steps 4 – 6), it is better to consult stakeholders at individual meetings or maybe in stakeholder groups that each focus on a "domain of interest".
- Experts are necessary for quantitative input to BBNs (Steps 4 – 6). In the case study, we had two experts in farming economics and socioeconomics in addition to the geological and hydrological experts from CE and GEUS. It would have been an advantage in BBN development if the panel of experts had included an expert on biodiversity and/or pesticide-exposed aquatic environment as well
- Evaluation of BBNs with input from stakeholders is a necessary step (Step 7). The experts did not come to the final workshop meeting in 2004; a review of the final BBNs by domain experts at a separate meeting is recommended.

After the evaluation we decided to include a new uncertainty variable. The new variable, "perception of vulnerability", refers to the great deal of uncertainty and disagreement between the farmers' organisations and project leadership (GEUS and CE) regarding the relationship between shallow and deep groundwater. Also, the variable "safe supply", which describes the future possible supply of clean groundwater (in fifty years) depends on "perception of vulnerability".

The following section describes the final BBN for farming contracts in a bit more detail.

6.5 BBN for groundwater protection

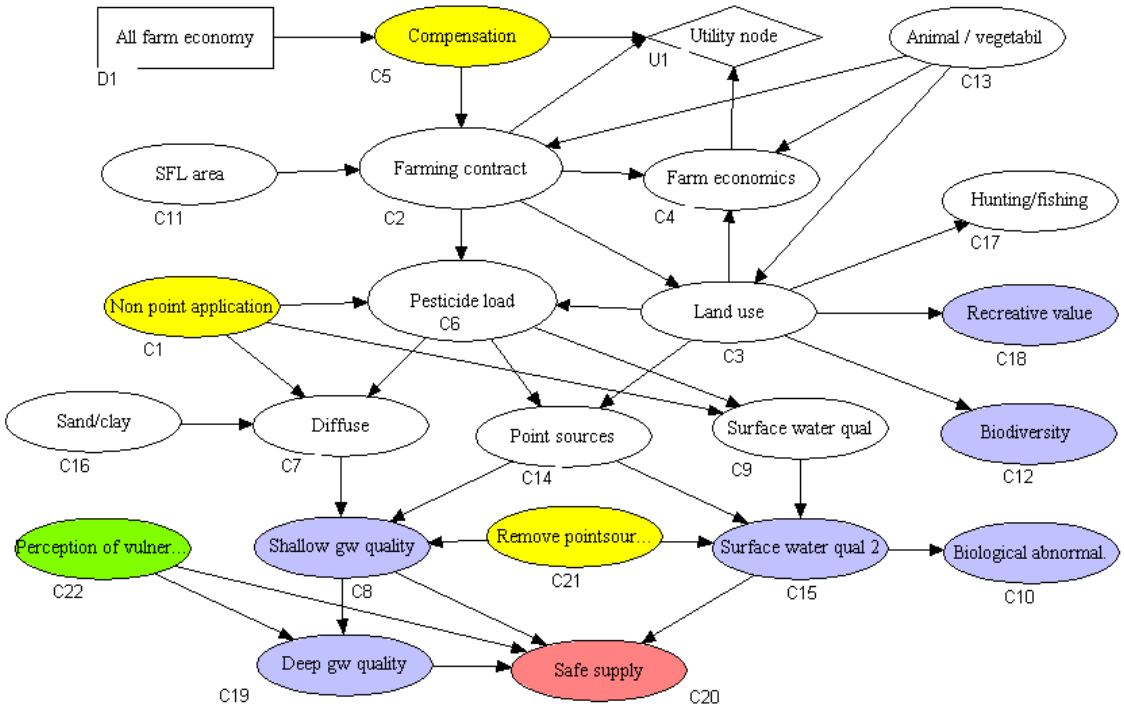


Figure 6.12. Fifth BBN for voluntary farming contracts (29 March 2004). The final network had one decision variable (D1) and one corresponding utility variable which calculate total yield for farmers in the area (U1) and 22 variables (C1 – C22).

We were attempting to deal with the effects of farming contracts in a situation where causality plays a role but where our understanding of what is actually going on is incomplete. We needed to describe things probabilistically because casual connections are not absolute. Even if we pay a fairly high amount of money, not all farmers will sign farming contracts. We know that there is a relationship between pesticide application and pesticide content in shallow groundwater, but this relationship is uncertain; still, we need to represent this uncertainty. The BBN in Figure 6.12 is a directed acyclic graph (DAG) in which the nodes are random variables – which can be thought of as states of affairs – and variables have two (e.g. true/false) or more possible values (e.g. <0.01 μg/l, 0.01-0.1 μg/l or >0.1 μg/l). The arcs in the BBN in Figure 6.12 specify the probability information required to specify the probability distribution among the random variables of the network.

To specify the probability distribution of the BBN, one must give the prior probabilities of all root nodes (nodes with no predecessors) and the conditional probabilities of all non-root nodes, given all possible combinations of their direct predecessors. BBNs allow one to calculate the conditional probabilities of the nodes in the network, given that the values of some of the nodes have been observed. As evidence comes in, it is tempting to think of the probabilities of the nodes changing, but, of course, what is changing is the conditional probability of the nodes to which the changing evidence is assigned.

The BBN in Figure 6.12 may be used in different applications. The idea was to find the action (or plan) that maximised the expected utility minus costs. The BBN incorporates a decision node describing action to establish voluntary compensational payment contracts and the utility (for the farmer), which means that the BBN is also a influence diagram. The idea was to focus the BBN on this purpose and to include variables describing groundwater quality, effects on biodiversity, values related to land use, etc. in order to provide a "holistic picture" for CE's decision-making regarding groundwater management and protection at Havelse and other wellfields, and thus provide input to CE's policy for groundwater protection in the greater Copenhagen area.

Another application of the BBN developed was to use it for diagnosis problems. Stakeholders were important in this connection, because the BBN development process incorporated feedback from stakeholders regarding the realistic "willingness" to enter into voluntary farming agreements on pesticide application restrictions in return for a certain level of compensation. Willingness did not only depend on economical factors, but is also very much related to deeper values, traditions, etc. and the politics of farmers' organisations in a certain region. Another possible use could be to identify any pesticide sources or vulnerabilities.

The BBN developed for voluntary farming contracts is shown in Figure 6.12. The following is a technical description of the BBN with respect to:

- The directed acyclic graph (qualitative part: nodes and links)
- Conditional probability tables (quantitative part: variables and states selection, conditionally probability tables [CPTs] and data collection)
- Using the model in decision-making (structure and CPT considerations)
- The construction of BBNs and/or CPTs from data (structural and EM learning)

6.5.1 Description of the directed acyclic graph for voluntary farming contracts

The types of variables in the BBN in Figure 6.12 can be grouped into five categories:

1. *Objectives.* Things that are affected. (Objective variables are **blue**: C8 Shallow groundwater quality, C10 Biological abnormality, C12 biodiversity, C15 Surface water quality, C18 Recreational value and C19 Deep groundwater quality. Overall objective variable is **red**: C20 Safe supply.)
2. *Interventions.* Things which must be implemented or included in CE policy. (intervention variables are **yellow**: C5 compensation, C1 non-point application and C21 remove point sources.)
3. *Intermediate factors.* Variables which link objective variables with intervention variables. (Intermediate factors are **white**: C2 Farming contracts, C3 Land use, C4 Farm economics, C6 Pesticide load, C7 Diffuse, C9 Surface water quality, C14 Point sources and C17 Hunting/fishing.)
4. *Controlling factors.* Factors that control the environmental system. (Controlling factors are **white**: C16 Sand/clay, C13 Animal/vegetation., C11 SFL area. Uncertain controlling factors are **green**: C22 Perception of vulnerability – stakeholders do not agree about this factor.)

5. *Decision and utility variables.* Variables that are included in order to calculate and visualise a certain utility. (Decision/utility variable rectangles/rhombi are white: D1 All-farm economy and U1 Utility node.)

The green variable C22 (perception of vulnerability) was included in order to communicate disagreement and a special uncertainty regarding the controlling factor "vulnerability of the subsurface with respect to pesticide leaching". This variable implies that some stakeholders and/or experts have the perception that pesticides in shallow groundwater will never spread to deeper groundwater aquifers, and other experts or stakeholders argue that the opposite is most likely to be the case: that it is more a matter of time.

Two variables are aimed at balancing the overall BBN and function as focal points to allow a better understanding of the outcome of the BBN. These variables are the indicator "safe supply of drinking water" and the utility variable "total farm economy" (*dækningsbidrag 2* in Danish) of farmers:

1. Safe supply of drinking water to 20 thousand inhabitants in the capital city area (Boolean variable which can be true or false: true means that future clean groundwater with a content of pesticides below the maximum allowed concentration can be abstracted from the wellfield, also after 50 years
2. The utility variable "total farm economy", which is the sum of agricultural production yield (economic benefit exclusive machinery and other fixed costs) and compensational payment

Including the variables D1 and U1 limits the functionality of the BBN in terms of updating with additional data because it limits the option of updating the BBN with additional data using the "generate cases" function. Hugin can generate (simulated) cases based on the current conditional probability distributions (CPTs) using the "Case Generator Button". However, we tried to develop a BBN, which shows the farmers' financial situation in our case, and updating using the EM wizard would require a substantial amount of data. However, it is not difficult to delete the decision and utility nodes (D1 and U1), hereby changing the network from an influence diagram into a BBN, if limitations related to handling of influence diagrams are to be avoided. Some parts of the BBN developed have many parent variables. Table 6.2 shows the calculated complexity of the BBN for farming contracts (seven variables do not have any parents, requiring seven numbers for CPTs):

Table 6.2. Number of parent variables for BBN for farming contracts (total of 24 variables).

4 parent variables	3 parent variables	2 parent variables	1 parent variable
C20 Safe supply	C2 Farming contracts C4 Farm economics C6 Pesticide load C7 Diffuse C8 Shallow gw quality C15 Surface water qual 2 U1 Utility node	C3 Land use C14 Point sources C9 Surface water quality C19 Deep gw quality	C5 Compensation C10 Biological abnormal. C12 Biodiversity C17 Hunting/fishing C18 Recreational value
>= 16 numbers for CPTs	>= 56 numbers for CPTs	>= 16 number for CPTs	>= 10 numbers for CPTs

Some of the links and variables generate more numbers for the conditional tables than others. If variables or parent variables are all of the Boolean type (true/false) and the number of parents is low, then the total number of values for the CPTs is much smaller compared to very complex networks (which have a relatively large number of parents and a large number of states).

One objection to the use of probability theory is that the complete specification of a probability distribution requires an absurd number of numbers. For example, if there are n binary random variables, the complete distribution is specified by 2^n-1 joint probabilities. Thus, the complete distribution for the BBN in Figure 6.12 would require 16.8 x 10^6 values, yet we only would need to specify 105 values required for CPTs when using a BBN (assuming binary values, e.g. a Boolean true/false network which as can be shown below is not the case, but this was included simply to provide an example of the reduction in necessary numbers using BBNs results in, compared to a complete specification of probability distributions) (Winter, 1991).

6.5.2 Description of conditional probability tables for BBN for farming contracts

The states for the farming contracts BBN were defined as shown below in Figure 6.13. The probability distributions shown are for the final network, assuming that there is no compensation, that the probabilities deal with herbicides, that point sources are not removed, and that a proxy basin assumption for the perception of vulnerability has been made based on groundwater monitoring results for Denmark.

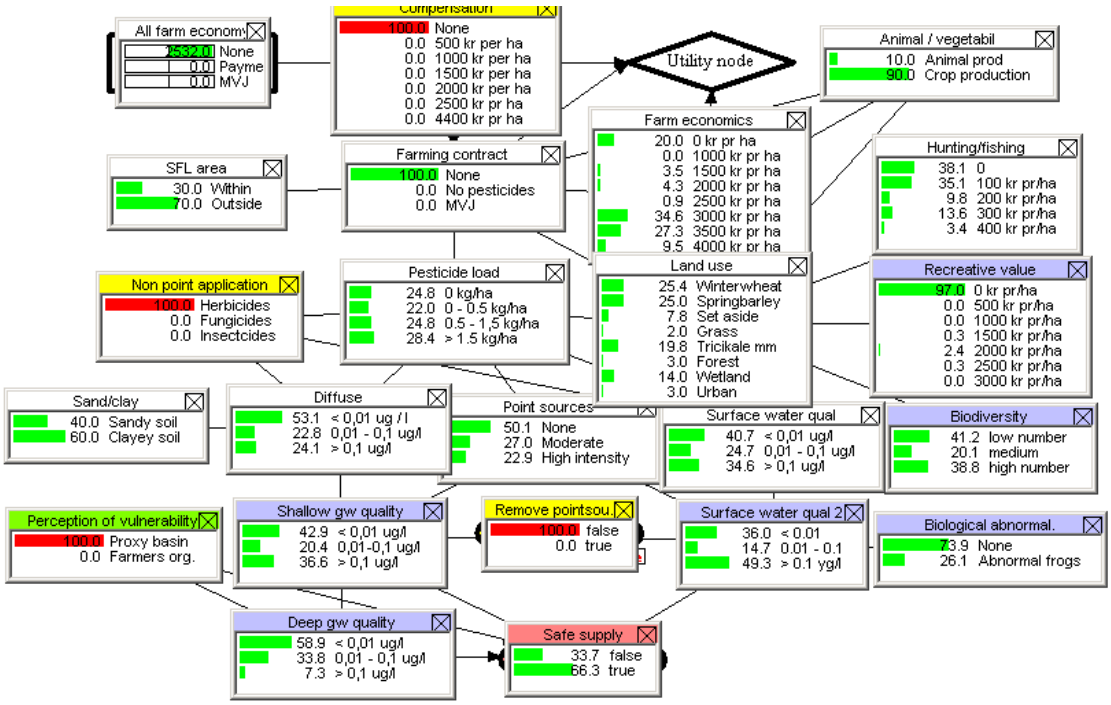


Figure 6.13. Initial conditions for BBN (proxy basin assumption about vulnerability).

Data collection for the quantitative part of the BBN is based on sources listed in Table 6.3.

Table 6.3. Description of data collection for CPTs.

Variable	Description	References
C1 Non point application	Variable C1 controls which issue the BBN focuses on: herbicides, fungicides or insecticides. Herbicide application is more frequent than that of fungicides and insecticides and leaching to groundwater subsequently more likely; effects on groundwater, aquatic environment, health and socioeconomics related to farming may be rather different for herbicides, fungicides and insecticides.	CPTs: treatment index estimates for different crops; see Rasmussen (2003) Other sources: www.geus.dk www.mst.dk www.dmu.dk
C2 Farming contracts	Variable C2 describes the type of voluntary farming contract. Distinction has been made between "None", "No pesticides" and the more restrictive "MVJ agreement"	CPTs: Rasmussen (2003) and *stakeholder feedback* MVJ: www.fba.dk
C3 Land use	Variable C3 describes the crop rotation and land use pattern (likelihood) for a given area. The following states are incorporated: winter wheat, spring barley, set aside fallow/protection zone, grass, forest, wetland and urban.	CPTs: Changes in land use under farming contracts or animal/vegetable production. Rasmussen (2003)
C4 Farm economics	Variable C4 describes the farmers' financial situations *(dækningsbidrag 2*) with different land uses and farming contract agreements. States: DKK 0, 1000, 1500, 2000, 2500, 3000, 3500 and 4000 per ha/year	CPTs: Based on Rasmussen (2003)
C5 Compensation	Variable C5 describes level of compensation. States: DKK 0, 500, 1000, 1500, 2000, 2500 and 4400 per ha/year	States based on input from end user and stakeholders (Brouwer, 2003)
C6 Pesticide load	Variable C6 describes pesticide application (kg per year) given the state of farming contracts, land use and crop rotation and the type of pesticide used (e.g. herbicides, fungicides or insecticides).	CPTs based on Rasmussen (2003)
C7 Diffuse	Content C7 describes pesticides in shallow groundwater from leaching of non-point application from agricultural fields. Knowledge of used pesticides by farmers in the area from interviews for last 10 years of application and expert knowledge from GEUS: "Varslingssystemet" (early warning system for pesticides). States: "<0.01 μg/l" or "0.01-0.1 μg/l" or ">0.1 μg/l"	Sources: www.geus.dk Www.agrsci.dk Www.dmu.dk VAP: http://pesticidvarsling.dk/index.shtml
C8 Shallow gw quality	Variable C8 describes the content of pesticides in shallow groundwater (from both point and non-point sources). States: "<0.01 μg/l" or "0.01-0.1 μg/l" or ">0.1 μg/l"	Sources: Brüsch et al. (2004) GEUS (2003)
C9 Surface water quality	Variable C9 describes the content of pesticides in surface water from non-point sources: States: "<0.01 μg/l" or "0.01-0.1 μg/l" or ">0.1 μg/l"	Sources: www.dmu.dk

C10 Biological abnormal.	Variable C10 describes the sexual development of frogs based on investigation from the US, where atrazine is the most commonly used herbicide. Results have shown that 10-92% of wild leopard frogs have gonad abnormalities such as retarded development and hermaphrodism. States: “None” or “Abnormal frogs”.	Sources for CPTs: Nature (2002a,b) Other sources: www.dmu.dk www.mst.dk
C11 SFL area	Variable C11 characterises the likelihood of the agricultural area being classified as vulnerable (an SFL area) by Frederiksborg County in terms of groundwater or surface water or for another reason.	www.fba.dk See Chapter 7.
C12 Biodiversity	Variable C12 describes biodiversity as a function of land use. It is assumed that the number of animals is increased when land use changes from winter wheat or barley to fallow land, forest and wetlands. States: “low number”, “medium” and “high number”.	Source: Schou (2003) www.dmu.dk
C13 Animal/vegetable	Variable C13 describe whether an agricultural area is used for animal production (diary products, pigs/ livestock) or to grow cereal/crops (vegetables). States: “Animal production” or “Crop production”.	Rasmussen (2003)
C14 Point sources	Variable C14 describes the number of point sources that impact the content of pesticides in groundwater and surface water. Depends on both pesticide load (C6) and land use (C3), especially urban areas and wither cereals are assumed to give higher intensity of point sources due to both urban sources and accidents during winter period with higher/faster leaching to groundwater. Very uncertain (calculated “backwards” from other input/evidence: C7, C8, C15) States: “none” , “moderate” or “high intensity”	Pesticide point sources have been identified by Frederiksborg County (report not available) www.fba.dk
C15 Surface water qual2	Variable C15 describes the content of pesticides in surface runoff in streams and rivers (from both non-point pollution, wastewater discharges to the creek, wind-driven sources to the creek, etc.) States: “<0.01 μg/l” or “0.01-0.1 μg/l” or “>0.1 μg/l”	Monitoring programme for surface water (rivers): www.dmu.dk
C16 Sand/clay	Variable C16 describes soil conditions which may affect leaching (simplified on the basis of digital soil map). An operational concept for identifying areas where shallow aquifers are vulnerable to pesticide contamination has been developed in a comprehensive project (not ready until the end of May 2004; not implemented in the present BBN for farming contracts). States: Sand or clay.	Soil type (Chapter 7): Danmarks Digitale Jordartskort 1:25.000: www.geus.dk www.kupa.dk
C17 Hunting/fishing	Variable C17 describes the socioeconomical benefit to farmers of hunting/fishing as a result of no pesticide application (proxy willingness to pay per ha: approximately DKK 300 per ha/year). States: DKK 0, 100, 200, 300, 400 per ha/year.	Source: Schou (2003)
C18 Recreational value	Variable C18 describes the socio-economic recreational benefits of land use (e.g. forest assumed to result in a recreational value of DKK 2000 per ha/year based on a benefit transfer analyse with input from house pricing). States: DKK 0, 500, 1000, 1500, 2000, 2500, 3000 per ha/year.	Source: Schou (2003)

C19 Deep gw quality	Variable C19 describes the content of pesticides in deep groundwater of the main aquifer system located 30-50 meter below surface (chalk and sand aquifer with a cover of till and clay). See Chapter 7. States: "<0.01 μg/l" or "0.01-0.1 μg/l" or ">0.1 μg/l"	Source: Monitoring data from Copenhagen Energy and GEUS: GEUS (2003). Brüsch et al. (2004) www.geus.dk
C20 Safe supply	Variable C20 describes the likelihood of being able to abstract clean groundwater (<0.1 μg/l) for the Havelse catchment area in the future (30-50 years). This overall Boolean indicator variable provides an overall estimate based on content of pesticides in groundwater, shallow groundwater and surface water. The first is weighted highest for the total "score". The risk of pollution from surface water can eventually be minimised significantly by moving the wellfield away from the present location in the creek valley. Perception of vulnerability impacts this variable significantly. States: "false" (must be stopped) or "true" (safe drinking can be abstracted).	The variable is based on stakeholder involvement. May be used for benchmarking several of CE's wellfields (55 in northern Zealand).
C21 Remove point sources	Variable C21 describes a possible action for CE focus: a removal of point sources both in urban and rural areas. The action to remove may involve other stakeholders (Frederiksborg County and municipalities or even farmers' organisations): States: "false" (not removed) or "true" (remove).	The variable is based on stakeholder involvement www.fba.dk
C22 Perception of vulnerability	Variable C22 is a new controlling factor that was included after the collection of feedback from stakeholders (Step 7 in the protocol). The farmers' organisations have the attitude that the deep groundwater will not be polluted above the MAC value because the deep aquifer is less vulnerable (compared to average Danish vulnerabilities). Maybe the KUPA project can help clarify this major uncertainty; the limited number of samples is not enough to show which party has the most correct "perceptual model" of this problem. States: "proxy basin" (e.g. based on monitoring data from Denmark) or farmers' organisation (NOLA).	The variable is based on stakeholder feedback. Sources: - GEUS (2003) - Brüsch (2004) - Henriksen and Sonnenborg (2003) www.geus.dk www.kupa.dk www.vandmodel.dk

With the same control variables as in Figure 6.13 the figure below (6.14) shows the effect of "perception of vulnerability".

The farmers' organisation (NOLA) believes that the deep groundwater will not be polluted above the maximum limit value (probability of pesticides >0.1 μg/l = 0%). Also, supply is regarded rather safe for present conditions (probability of safe supply = true is 90%). On the other hand, GEUS experts and CE (based on proxy basin perception) believe that with the current application of pesticides, the deep groundwater probably will be polluted above maximum limit value (probability = 7%). Also, supply is at risk because the probability for safe supply is only 66%. See Figure 6.13.

Stakeholders usually understand but do not necessarily agree with groundwater protection plans. Most stakeholders agree with the idea of groundwater protection, but do not necessarily understand the hydrological cycle, e.g. the connection between surface land use and groundwater quality. Data from existing CE, AIS and GEUS were collected and displayed on various theme maps using GIS (see Chapter 7).

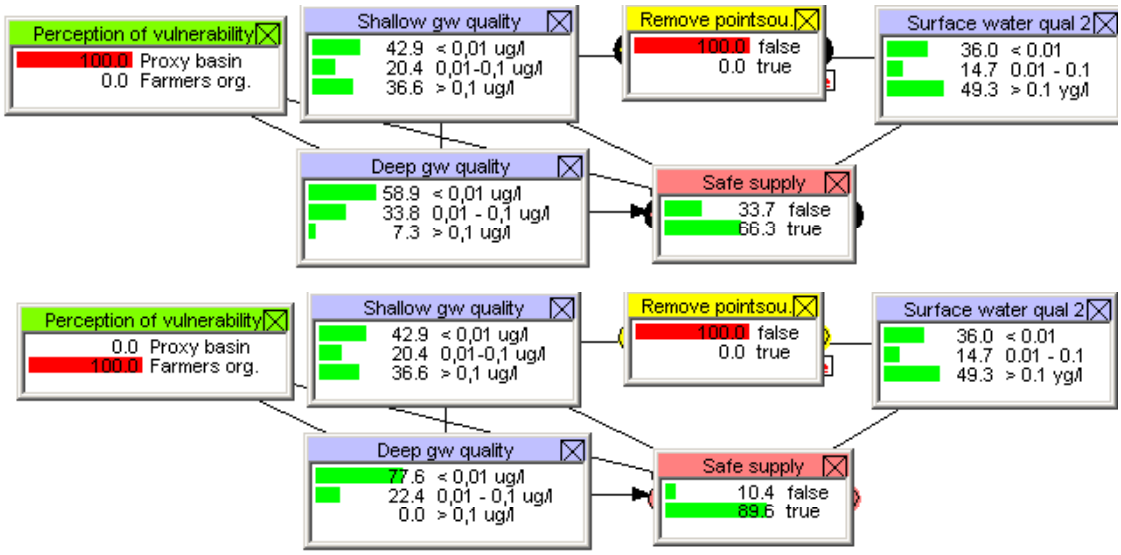


Figure 6.14. Effect of "perception of vulnerability" on "deep groundwater quality" and "safe supply" (upper perception by GEUS "proxy basin", below perception by "farmers' org.").

Groundwater is the "backbone" for drinking water supply, industrial supplies and supply for aquatic environment in the greater Copenhagen area. In Denmark, 99% of the water supply is groundwater. Furthermore, most Danes agree that clean groundwater and drinking water has the highest priority of all environmental issues. Chemical treatment of groundwater is rarely accepted before it is supplied to the consumers.

This raises the question, at which goal should CE aim with respect to the overall variable "safe supply" of groundwater? Since that variable has only two states (Boolean variable), it can be translated into words using the scale in Table 6.2 (Renooij and Witteman, 1999).

Table 6.4. Scale with seven categories of probability expressions plus probability points (Renooij and Witteman, 1999). Two more states have been added to the scale: almost certain (95%) and almost impossible (5%).

	Expression	Probability (%)
I	Certain Almost certain	100 95
II	Probable	85
III	Expected	75
IV	Fifty-fifty	50
V	Uncertain	25
VI	Improbable	15
VII	Almost impossible Impossible	5 0

If there is a 75% probability of a safe supply (based on three parent variables: water quality of deep groundwater, shallow groundwater and surface water) it can be said that it is *expected* that there will be clean groundwater abstracted from the area also in thirty or fifty years. A 95% probability of safe supply is termed *almost certain*. On the other hand, if there is only a 25% probability of a truely safe supply, then the abstraction at Havelse wellfield is *uncertain*.

We saw a 66-90% probability (proxy basin; farmers' org. perception), which according to the probability scale above means the current situation at Havelse wellfield is better than *fifty-fifty* but less than *expected*, and between *probable* and *almost certain* based on the perception of vulnerability taken by the farmers' organisation (NOLA).

From a preventive groundwater protection point of view, the goal should be no pesticides in the groundwater above the maximum limit value (*certain*). However, a more pragmatic goal in most cases could be to aim at *almost certain* (a 95% probability of a future clean groundwater).

Perhaps the vulnerability of the area with respect to the deeper aquifers is less than for other Danish aquifers, but we do not know in detail which parameters or factors we should base such an assessment on when dealing with pesticides. In fact, we know very little about the vulnerability of the deep groundwater in the Havelse area at the depths from which groundwater is abstracted. We do know that pesticides have a very low degradation rate (nearly none) once they reach the anaerobic parts of the aquifer, which in this case is located a few meters below the surface. However, the results presented above, taking the viewpoint of the farmers' organisations, are important in describing the sensitivity of an important controlling factor.

We do not know the results of the KUPA project yet, but they will be published in the near future. Perhaps they will provide additional input so that we can better determine the specific areas which are important in reducing the pesticide levels in both groundwater and surface water.

In the following, we will focus on using the model in decision-making that is based on the "proxy basin" assumption regarding vulnerability. We will analyse effects on voluntary

farming contracts for different “levels of compensation” to see if these agreements could be attractive as part of CE’s policy of groundwater protection.

Later we will demonstrate an example of “structural learning” using a BBN dealing with “depth to anoxic groundwater”, which is of importance in groundwater protection.

6.5.3 Using the BBN model in farming contract decision-making

In this example, all the controlling factors are the same as in Figure 6.13. The only difference is the assumption for the following use of the BBN is that soil conditions are clayey. This results in a slight reduction in “safe supply” from 66.3% to 64.4%.

Two scenarios are analysed:

1. Farming contracts: voluntary farming contracts (different compensation level)
2. Both actions: voluntary farming contracts (different compensation level plus removal of point sources; it is assumed that all point sources are simply removed)

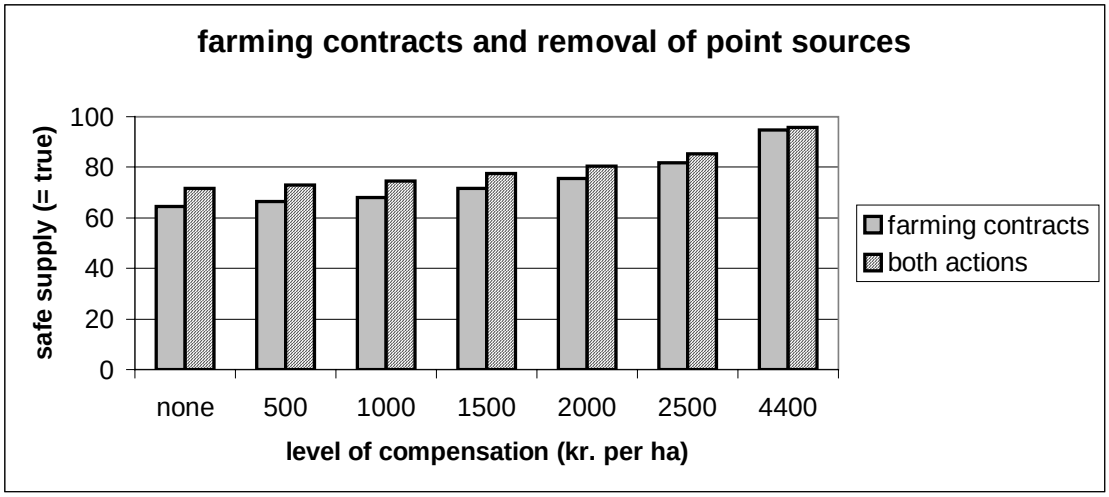


Figure 6.15. Comparison of overall indicator (safe supply) for the two alternative scenarios: “Scenario 1: farming contracts” and “Scenario 2: both actions” for different levels of compensation.

Figure 6.15 illustrates that the compensation payment must be MVJ agreements (with a compensation of DKK 4400 per ha/year, of this up to 60% financed by the EU) if the “preventive goal” is to be achieved (minimum a 95% probability for the state “true” of the safe supply).

Even if both actions are taken, with an additional cost for removing all the point sources, the result is the same.

We have not included the move of the wellfield away from the creek in the present analysis. This could both increase the probability of the “safe supply” being in the state of “true”, but other effects could also adversely decrease this probability (intrusion of salt water closer to the Roskilde Fjord bay or unknown point sources close to the new wellfield location).

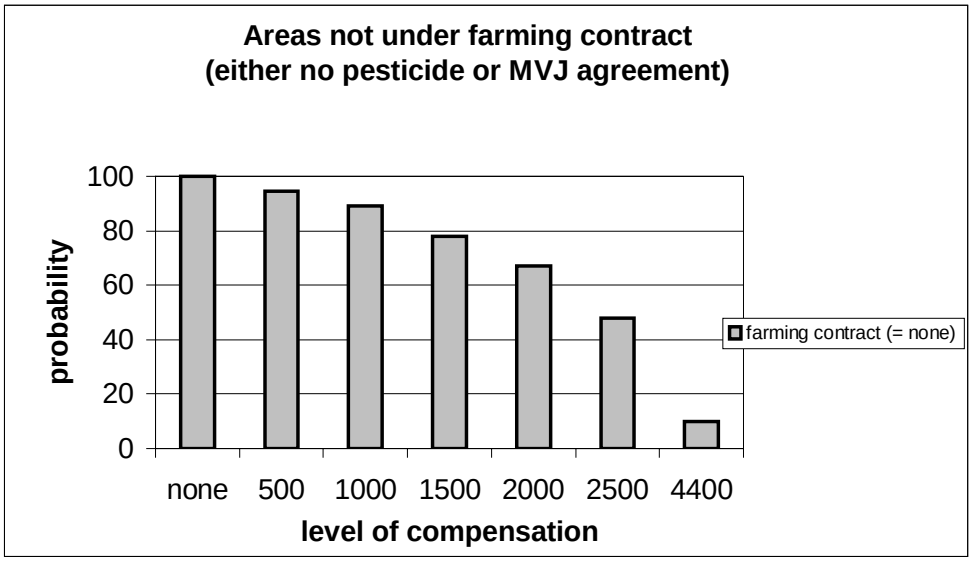


Figure 6.16 shows the evaluated "commitment of farmers" to go into voluntary farming contracts with CE.

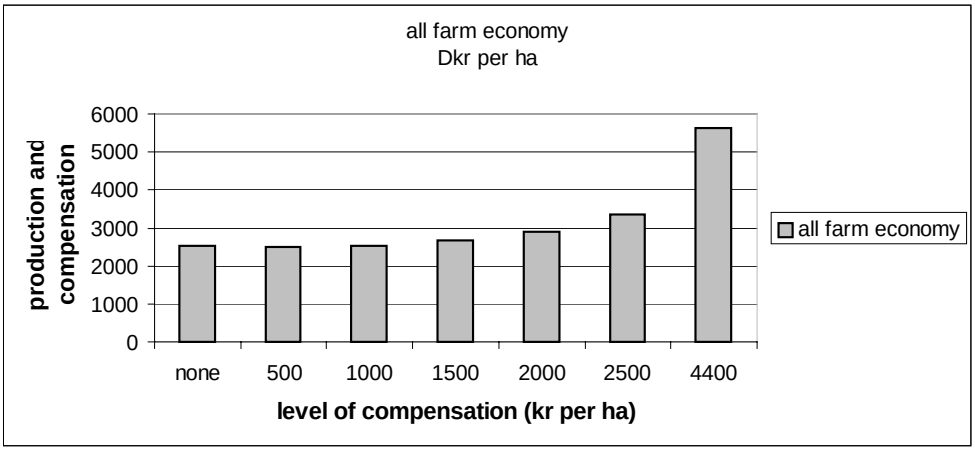


Figure 6.17. Areas which are not likely to be part of voluntary farming contracts.

For a compensation of DKK 500 per ha/year, few farmers (4.1%) would join voluntary farming agreements prescribing no pesticide application. For DKK 1000 per ha/year, a slightly larger fraction would join (11%). At DKK 2500 per ha, nearly 50% would join, but their willingness to sign voluntary preventive farming contracts (no pesticides) is much less than the input from the expert indicated (Rasmussen, 2003), which indicated a break-even point of below DKK 1500 per ha/year.

Thus the main problem is related to a lack of commitment to realistic levels of compensation. Farmers in the area have suggested compensation payment levels of about DKK 5000 per year. Farmers' organisations (NOLA and *Sjællands Familielandbrug*) have indicated that such agreements should either offer a very high compensation (up to DKK 7000 per ha/year) or not be part of groundwater protection at all (expropriation may be necessary and a more feasible method). Figure 6.18 shows the variable "all farm economy" (U1 utility variable).

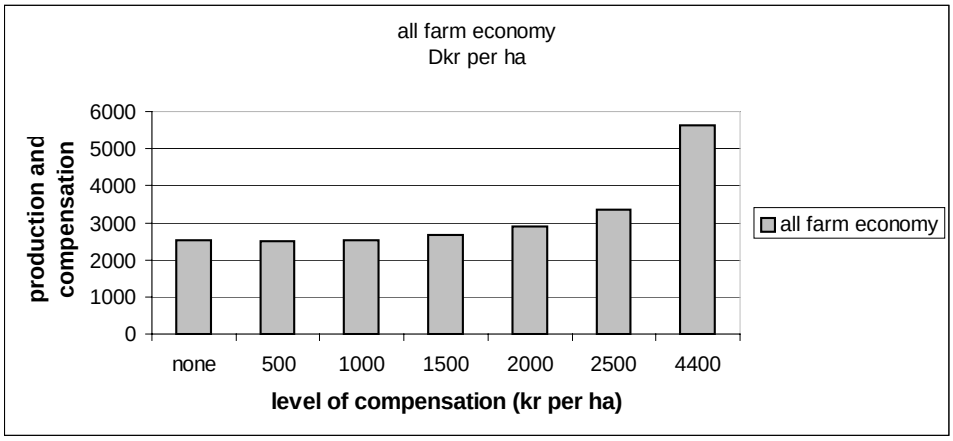


Figure 6.18. Total yield for farmers (U1 utility: total/all farm economy) for both compensation and agricultural production ("dækningsbidrag 2" plus compensation) as a function of level of compensation.

In Figures 6.19 and 6.20 are shown the water quality indicators and biodiversity indicators for different levels of compensation.

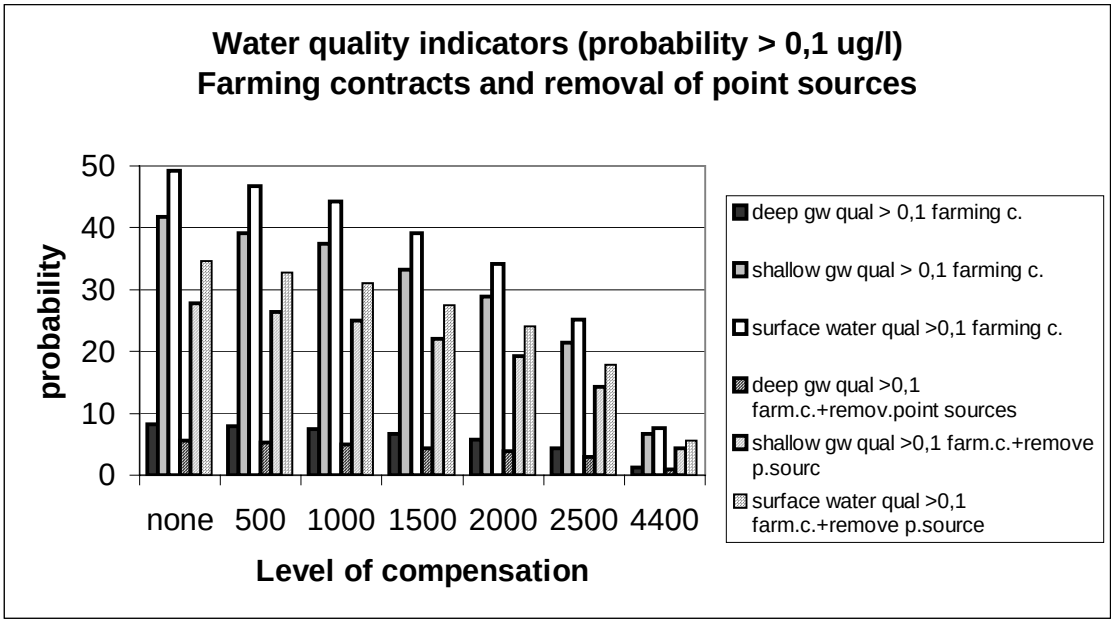


Figure 6.19. Water quality indicators for deep groundwater, shallow groundwater and surface water as a function of level of compensation.

The Scenario 1 indicators for water quality show that the probability of polluted deep groundwater drops to below 5% at a compensation level of DKK 2500 per ha/year. This probability varies for the different compensation level from 8.3% (none) to 7.3% (500), 7.5% (1000), 6.6% (1500), 5.8% (2000), 4.3% (2500) to 1.3% (DKK 44 per ha/year), according to Figure 6.19. Scenario 2 reaches the 5% level at DKK 1000 per ha/year, signifying that

action directed at point sources (removal) may be a necessary element of groundwater protection policy.

In Scenario 1, shallow groundwater has a probability of pesticide content of between 41.7% (none) and 33.2% (DKK 1500 per ha/year). Not until DKK 4400 per ha/year does the probability drop below 10% for clean groundwater (6.6% probability). Scenario 2 results in an achieved goal of a 5% level at DKK 4400 per ha/year including removal of point sources. Similar results were found for surface water.

Conclusions for farming contract evaluation

Active groundwater protection from pesticides requires innovative solutions, coordination of actions by various authorities and commitment to implementation from the different stakeholder groups. Lack of knowledge about different sources of pesticide pollution, vulnerability and spreading of pesticides to drinking water requires precautionary management and sound decisions about preventive groundwater protection. The application of pesticides to agricultural fields according to regulative guidelines, accidents, point sources, past mistakes, and the spread of pesticides (e.g. BAM) all contribute to a high frequency of findings both in shallow and deep groundwater, as well as in surface water.

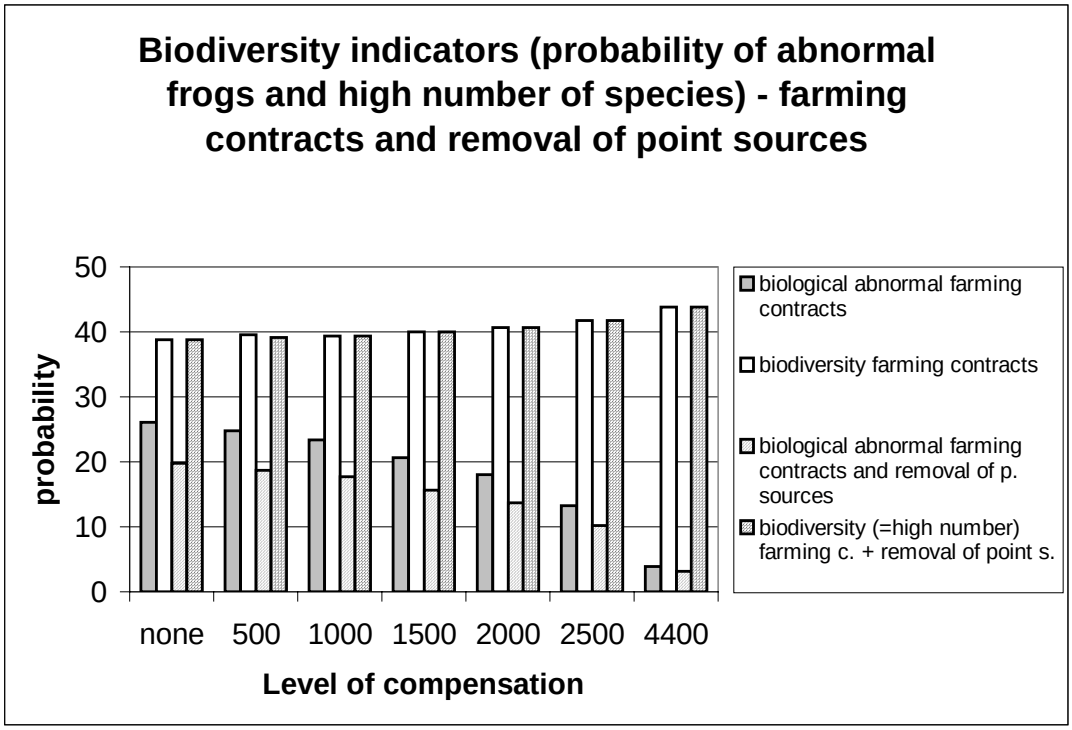


Figure 6.20. Biodiversity indicators as a function of level of compensation.

The aim of the farming contracts BBN was to analyse a complex problem in order to develop a decision support tool that would provide a transparent, flexible and holistic basis for decision-making that included environmental issues, socioeconomics and physical conditions.

The final results have shown that BBNs are powerful in integrating, visualising, structure and setting the scene for a dialogue with stakeholders about a difficult problem: groundwater protection against pesticides. It was not possible to reach an agreement about the results of the final decision support tools, but it was possible to identify the variables and causal relationships where the disagreement was strongest and explicitly incorporate this uncertainty in a single node: the vulnerability of the deep groundwater aquifer system.

Furthermore, the exercise demonstrated that cost/benefit issues and especially the implementation of management action plans are associated with by many more issues than expert knowledge normally takes into consideration. In our case, a barrier for voluntary farming contracts is not data or information on economic conditions in farming, but, to a much greater extent, perception among stakeholders of the soundness of the action. Attitudes, beliefs and group behaviour among farmers and their organisations, and the uncertainty and lack of data, play a more important role than a possible financial benefit in the short run. Since farming contracts also are rather difficult to manage, at least as voluntary agreements negotiated within a wellfield catchment area as part of a groundwater protection plan, the entire approach is both costly and difficult to implement.

Instead, auctions on a larger scale could be a more appropriate approach, assuring agreements at a much lower cost for CE, the water company (Rasmussen, 2003).

At the final meeting, there was support from farmers' organisations for expropriation instead of voluntary agreements, if further groundwater protection action was necessary to combat pesticide contamination. This would require a methodology to determine vulnerable areas (such as KUPA, if it turns out to be a success with both sand and clay) in order to establish accurate and effective protection zones.

The results have also shown that action against point sources is necessary, as well as appropriate action aimed at both shallow groundwater and surface water.

6.5.4 Use of structural learning for assessment of sandy soils vulnerable to pesticide leaching

The overall objective of the KUPA project (www.kupa.dk) is to develop an operational concept for identifying areas where aquifers were vulnerable to pesticide contamination. In the part I of KUPA, the focus has been on a concept for sandy soils.

Studies had shown that pesticide degradation occur predominately in the presence of oxygen (aerobic conditions) (Albrechtsen et al., 2001). Throughout Denmark aerobic conditions occur mainly in the unsaturated zone above the groundwater table. Therefore, understanding of the fate of pesticides in the unsaturated zone is crucial for determining the risk of underlying aquifers to pesticide contamination.

The transport of pesticides through the unsaturated zone is largely controlled by the residence time in the aerobic zone, and the degradation and sorption characteristics of the soil. Residence times are a direct reflection of the hydraulic properties of the soil (hydraulic conductivity and porosity) and the thickness of the unsaturated zone together with the sorption capacity of the soil. Degradation rates are represented by the half-life (DT50) and sorptive characteristics of the pesticide and soil.

The focus in the KUPA study was to quantify the magnitude of the parameters controlling the transport of pesticides through the unsaturated zone. In order to develop a meaningfull classification scheme, the variability in the magnitude of individual parameters and correlation between parameters were investigated. Ideally, if all parameters important to pesticide leaching were known everywhere, the mass flux of pesticides through the unsaturated zone could be quantified. Obviously this is not the case and therefore, it is necessary to focus on determination of dominating parameters and generalization of results.

The results of KUPA for sandy soils showed that it was possible to identify areas vulnerable to pesticide leaching based on a limited number of soil parameters. Subsequently in second phase it is possible to further evaluate which soils are the most vulnerable based on modelling and/or correlation, again based on simple and easy collectable data. The analysis in KUPA show that three parameters are important in the first phase: ‘organic content’, ‘clay’ and ‘silt’. These parameters were accumulated for the A-, B- and C-horizon from the surface to 1 meter’s depth.

The example in this section illustrate an analysis of a nationwide dataset (‘kvadratnets data’ approximately 150 cases) which was used in KUPA to establish multi-variant correlations between ‘organic content’, ‘clay’ and ‘silt’ with predicted ‘relative pesticide leaching’ using the MACRO unsaturated zone solute transport pesticide model.

In the present example structural learning has been applied in order to analyse the 150 cases to identify ‘structure’ (variables and links) and CPT’s. The example includes:

1. Structural learning in order to construct BBNs based on data (from 150 cases)

2. Examples of use of BBNs for decision support system for groundwater management

6.5.4.1 Structural learning based on KUPA dataset

Structure learning can be performed via the Hugin Learning Wizard which allows data to be read from databases, to be preprocessed, etc or by activating one of the structural learning algorithms directly. Two algorithms are available for structural learning: The *PC algorithm* and the *NPC algorithm*. In this example we have used the PC algorithm.

The Hugin PC algorithm, which is a variant of the original PC algorithm due to Spirtes, Glymour & Scheines (2000), belongs to the class of constraint-based learning algorithms. The basic idea of these algorithms is to derive a set of conditional independence and dependence statements by statistical tests.

The algorithm performs the following steps:

- Statistical tests for conditional independence are performed for all pairs of variables (except for those pairs for which a structural constraint has been specified)
- An undirected link is added between each pair of variables for which no conditional independences were found. The resulting undirected graph is referred to as the *skeleton* of the learned structure.
- Colliders are then identified, ensuring that no directed cycles occur. (A *collider* is a pair of links directed such that they meet in a node.)
- Next, directions are enforced for those links whose direction can be derived from the conditional independences found and the colliders identified.
- Finally, the remaining undirected links are directed randomly, ensuring that no directed cycles occur.

One important thing to note about the PC algorithm is that, in general, it will not be able to derive the direction of all the links from data, and thus some links will be directed randomly. This means that the learned structure should be inspected, and if any links seem counterintuitive, one might consider using the Learning Wizard which provides a means of specifying structural domain knowledge.

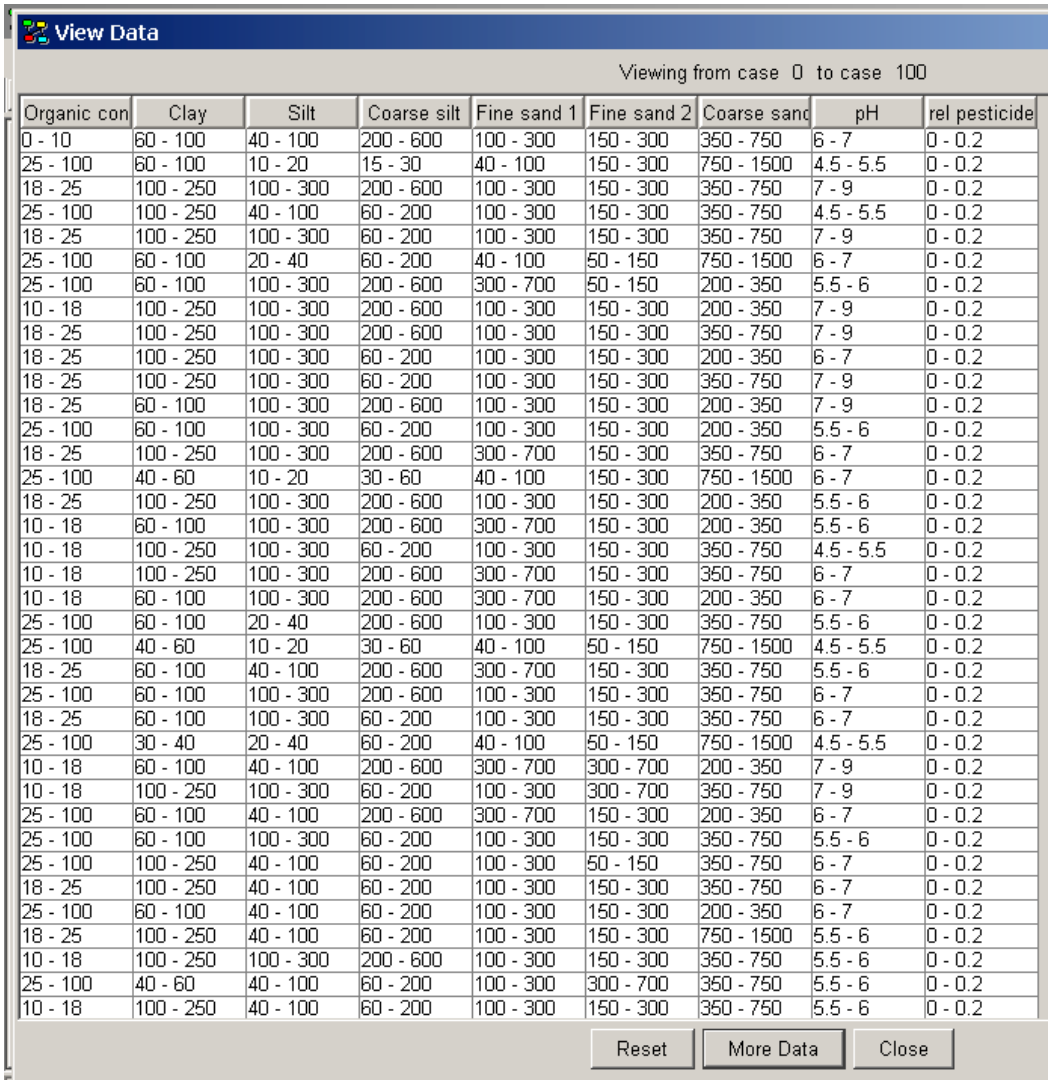
Traditional constraint-based learning algorithms produce provably correct structures under the assumptions of infinite data sets, perfect tests, and directed acyclic graph (DAG) faithfulness i.e., that the data can be assumed to be simulated from a probability distribution that factorizes according to a DAG. In the case of limited data sets, however, these algorithms often derive too many conditional independence statements. Also, they may in some cases leave out important dependence relations.

Generally, it is recommended to use the NPC algorithm, as the resulting graph will be a better map of the conditional independence relations represented in the data. In particular, when the data set is small, the NPC algorithm should be the one preferred. The NPC algorithm, however, has longer running times than the PC algorithm.

The initial steps in structural learning are the following:

- select which variable should be included in the test
- define states for the problem and pre-process raw data into aggregated datasets (see Figure 6.21)

- analyse relationships (links and CPT's, see Figure 6.22, 6.33 and 6.24)



Organic con	Clay	Silt	Coarse silt	Fine sand 1	Fine sand 2	Coarse sand	pH	rel pesticide
0 - 10	60 - 100	40 - 100	200 - 600	100 - 300	150 - 300	350 - 750	6 - 7	0 - 0.2
25 - 100	60 - 100	10 - 20	15 - 30	40 - 100	150 - 300	750 - 1500	4.5 - 5.5	0 - 0.2
18 - 25	100 - 250	100 - 300	200 - 600	100 - 300	150 - 300	350 - 750	7 - 9	0 - 0.2
25 - 100	100 - 250	40 - 100	60 - 200	100 - 300	150 - 300	350 - 750	4.5 - 5.5	0 - 0.2
18 - 25	100 - 250	100 - 300	60 - 200	100 - 300	150 - 300	350 - 750	7 - 9	0 - 0.2
25 - 100	60 - 100	20 - 40	60 - 200	40 - 100	50 - 150	750 - 1500	6 - 7	0 - 0.2
25 - 100	60 - 100	100 - 300	200 - 600	300 - 700	50 - 150	200 - 350	5.5 - 6	0 - 0.2
10 - 18	100 - 250	100 - 300	200 - 600	100 - 300	150 - 300	200 - 350	7 - 9	0 - 0.2
18 - 25	100 - 250	100 - 300	200 - 600	100 - 300	150 - 300	350 - 750	7 - 9	0 - 0.2
18 - 25	100 - 250	100 - 300	60 - 200	100 - 300	150 - 300	200 - 350	6 - 7	0 - 0.2
18 - 25	100 - 250	100 - 300	60 - 200	100 - 300	150 - 300	350 - 750	7 - 9	0 - 0.2
18 - 25	60 - 100	100 - 300	200 - 600	100 - 300	150 - 300	200 - 350	7 - 9	0 - 0.2
25 - 100	60 - 100	100 - 300	60 - 200	100 - 300	150 - 300	200 - 350	5.5 - 6	0 - 0.2
18 - 25	100 - 250	100 - 300	200 - 600	300 - 700	150 - 300	350 - 750	6 - 7	0 - 0.2
25 - 100	40 - 60	10 - 20	30 - 60	40 - 100	150 - 300	750 - 1500	6 - 7	0 - 0.2
18 - 25	100 - 250	100 - 300	200 - 600	100 - 300	150 - 300	200 - 350	5.5 - 6	0 - 0.2
10 - 18	60 - 100	100 - 300	200 - 600	300 - 700	150 - 300	200 - 350	5.5 - 6	0 - 0.2
10 - 18	100 - 250	100 - 300	60 - 200	100 - 300	150 - 300	350 - 750	4.5 - 5.5	0 - 0.2
10 - 18	100 - 250	100 - 300	200 - 600	300 - 700	150 - 300	350 - 750	6 - 7	0 - 0.2
10 - 18	60 - 100	100 - 300	200 - 600	300 - 700	150 - 300	200 - 350	6 - 7	0 - 0.2
25 - 100	60 - 100	20 - 40	200 - 600	100 - 300	150 - 300	350 - 750	5.5 - 6	0 - 0.2
25 - 100	40 - 60	10 - 20	30 - 60	40 - 100	50 - 150	750 - 1500	4.5 - 5.5	0 - 0.2
18 - 25	60 - 100	40 - 100	200 - 600	300 - 700	150 - 300	350 - 750	5.5 - 6	0 - 0.2
25 - 100	60 - 100	100 - 300	200 - 600	100 - 300	150 - 300	350 - 750	6 - 7	0 - 0.2
18 - 25	60 - 100	100 - 300	60 - 200	100 - 300	150 - 300	350 - 750	6 - 7	0 - 0.2
25 - 100	30 - 40	20 - 40	60 - 200	40 - 100	50 - 150	750 - 1500	4.5 - 5.5	0 - 0.2
10 - 18	60 - 100	40 - 100	200 - 600	300 - 700	300 - 700	200 - 350	7 - 9	0 - 0.2
10 - 18	100 - 250	100 - 300	60 - 200	100 - 300	300 - 700	350 - 750	7 - 9	0 - 0.2
25 - 100	60 - 100	40 - 100	200 - 600	300 - 700	150 - 300	200 - 350	6 - 7	0 - 0.2
25 - 100	60 - 100	100 - 300	60 - 200	100 - 300	150 - 300	350 - 750	5.5 - 6	0 - 0.2
25 - 100	100 - 250	40 - 100	60 - 200	100 - 300	50 - 150	350 - 750	6 - 7	0 - 0.2
18 - 25	100 - 250	40 - 100	60 - 200	100 - 300	150 - 300	350 - 750	6 - 7	0 - 0.2
25 - 100	60 - 100	40 - 100	60 - 200	100 - 300	150 - 300	200 - 350	6 - 7	0 - 0.2
18 - 25	100 - 250	40 - 100	60 - 200	100 - 300	150 - 300	750 - 1500	5.5 - 6	0 - 0.2
10 - 18	100 - 250	100 - 300	200 - 600	100 - 300	150 - 300	350 - 750	5.5 - 6	0 - 0.2
25 - 100	40 - 60	40 - 100	60 - 200	100 - 300	300 - 700	350 - 750	5.5 - 6	0 - 0.2
10 - 18	100 - 250	40 - 100	60 - 200	100 - 300	150 - 300	350 - 750	5.5 - 6	0 - 0.2

Figure 6.21.The first step in structural learning is analyse the data and to define states. In the example with the KUPA data set each variable is assigned one of four states. This can be done interactively using the Learning Wizzard in Hugin giving the results shown above.

First the variables are simply shown (Figure 6.22). The user are allowed to define any known dependencies or known independencies. Depending on the selected states Hugin may suggest relationship between clay and silt which the expert don't want, and in that case, the user should define such independencies. Alternatively, the user could want a certain structure at least for a small number of governing parameters, e.g. 'organic content', 'silt' and 'clay' with a given relationship to 'relative pesticide leaching' and analyse the other relationships given this predefinition.

When working with a limited number of cases, in our example approximately 150, the statistical analysis could easily result in coincidental structures rather than physical correct or logical structures. So the user should always be critical about what is produced, and eventually go a step back and repeat the structural learning process with other

dependencies/independencies (the step shown in Figure 6.23). For the example below we used the PC algoritm, alternatively the NPC algoritm could have been selected.

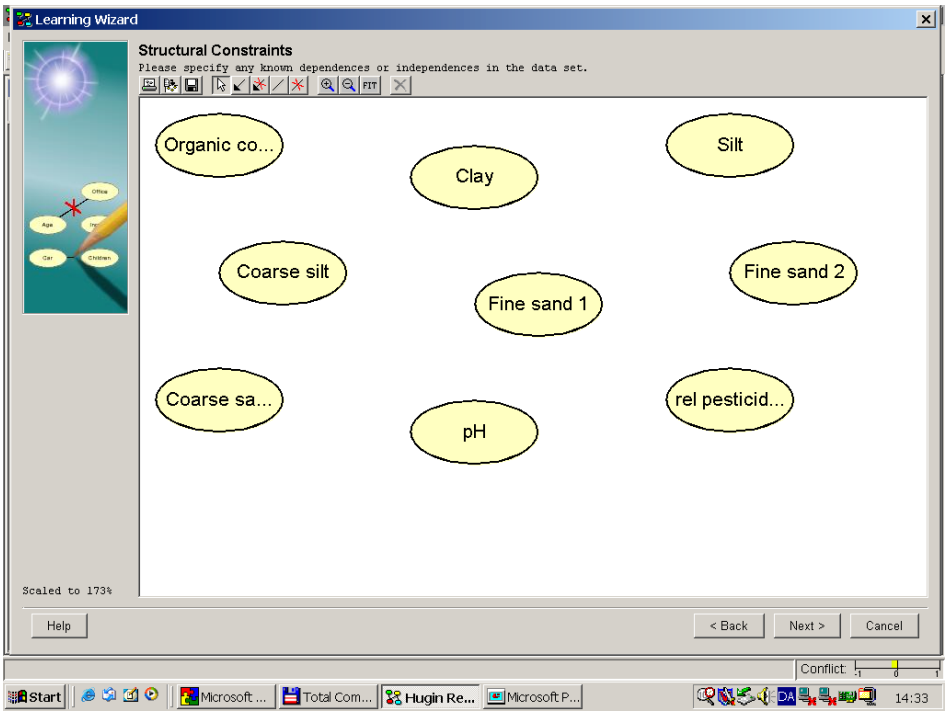


Figure 6.22.The Learning Wizzard ask for known dependencies or independencies between variable. In this example we didn't define any dependencies/independencies

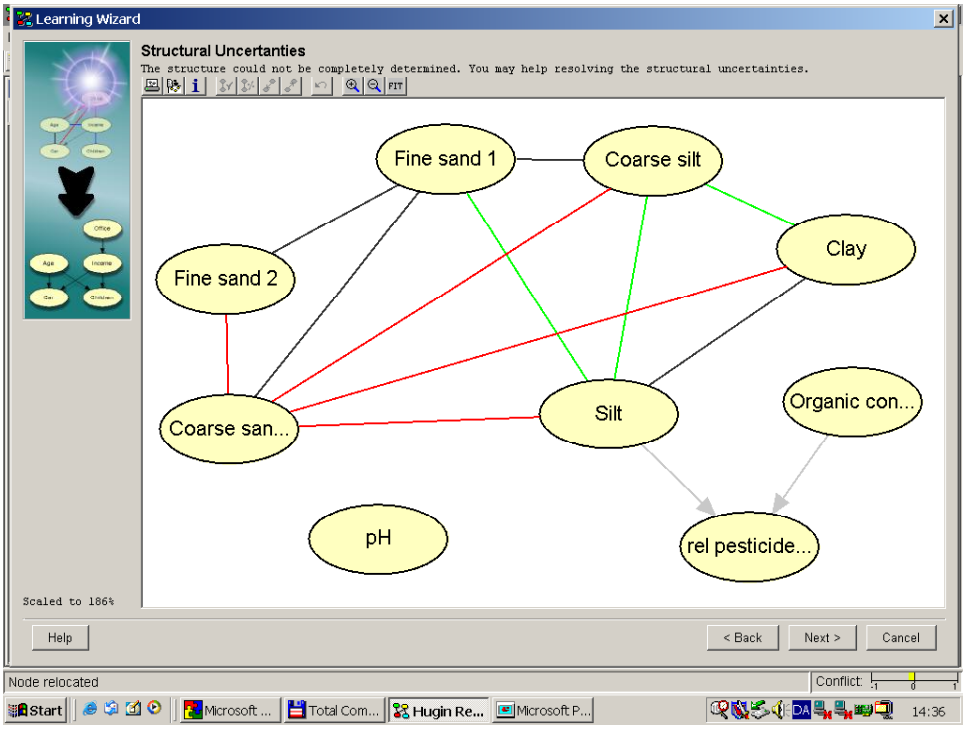


Figure 6.23. The Learning Wizzard defined 'strong' links between some variables shown with *arrow. Other links had to be defined by the user*

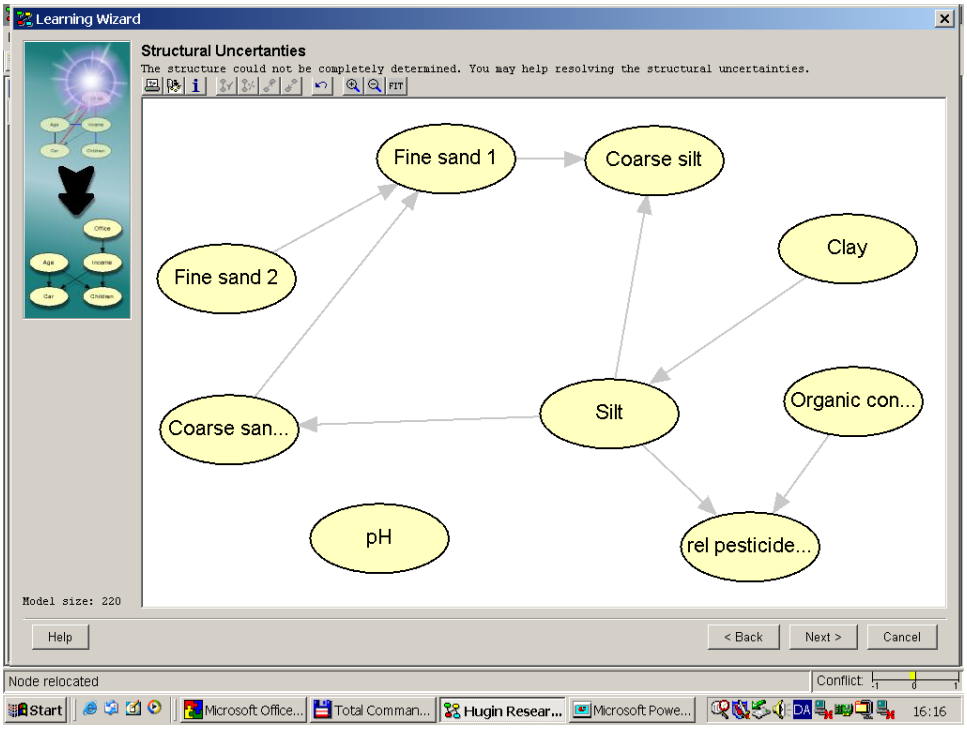
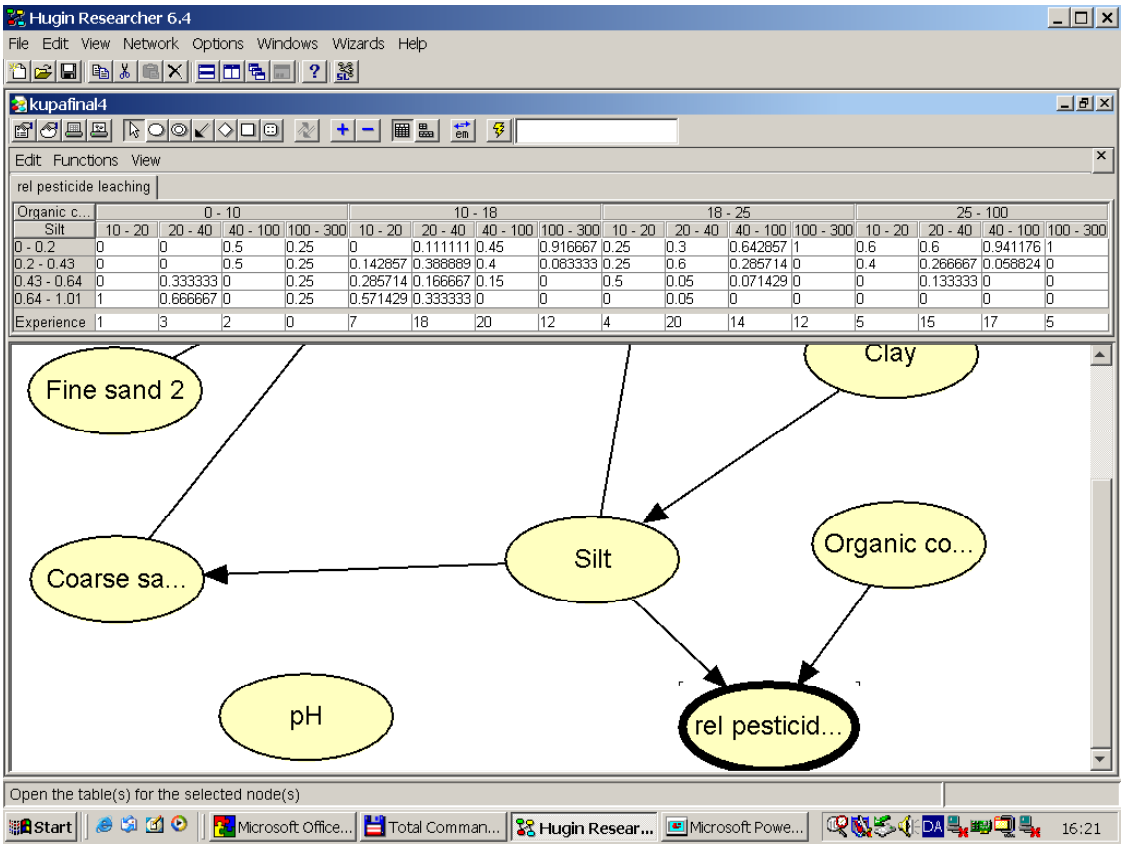


Figure 6.24. Final BBN after definition of all links. There is not a relationship between pH and any other variables in the BBN because pH.



Organic c...	0 - 10				10 - 18				18 - 25				25 - 100			
Silt	10 - 20	20 - 40	40 - 100	100 - 300	10 - 20	20 - 40	40 - 100	100 - 300	10 - 20	20 - 40	40 - 100	100 - 300	10 - 20	20 - 40	40 - 100	100 - 300
0 - 0.2	0	0	0.5	0.25	0	0.111111	0.45	0.916667	0.25	0.3	0.642857	1	0.6	0.6	0.941176	1
0.2 - 0.43	0	0	0.5	0.25	0.142857	0.388889	0.4	0.083333	0.25	0.6	0.285714	0	0.4	0.266667	0.058824	0
0.43 - 0.64	0	0.333333	0	0.25	0.285714	0.166667	0.15	0	0.5	0.05	0.071429	0	0	0.133333	0	0
0.64 - 1.01	1	0.666667	0	0.25	0.571429	0.333333	0	0	0	0.05	0	0	0	0	0	0
Experience	1	3	2	0	7	18	20	12	4	20	14	12	5	15	17	5

Figure 6.25. The variable 'rel pesticid…' (relative pesticide leaching) has two parent variables: 'Silt' and 'Organic co…' (organic content, in Danish: humus). Note that some of the relationships are rather weak (shown by the indentifier: "Experience" in the CPT). A more reliable CPT could be developed if also expert knowledge were incorporated.

6.5.4.2 Examples of use of BBNs for decision support system for groundwater management

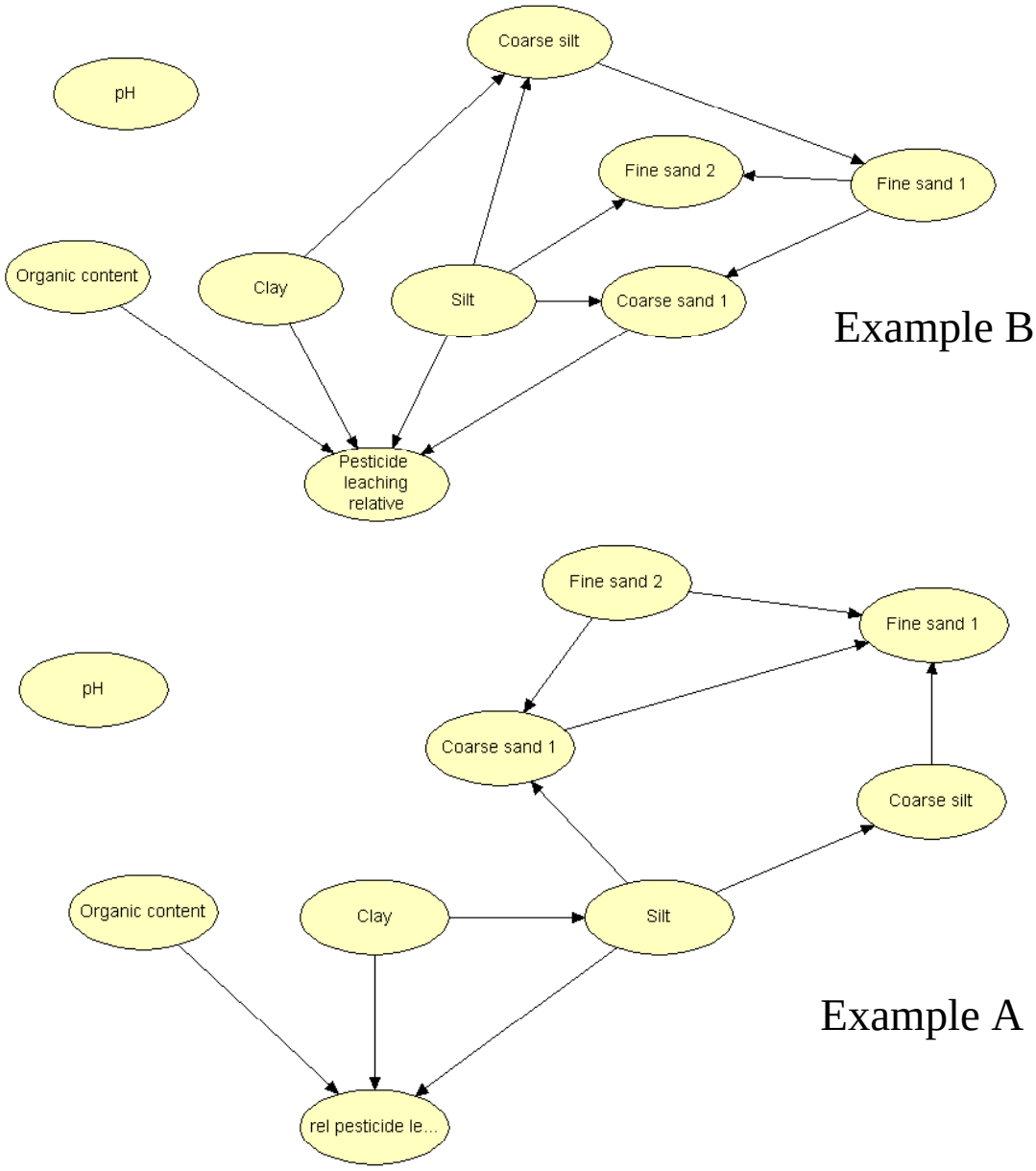


Figure 6.26. Two alternative results of structural learning based on the KUPA dataset. In the example A below three parameters had influence on relative pesticide leaching, whereas in the example B above, four parameters had influence on relative pesticide leaching. In none of the examples pH had direct influence (only hydraulics and sorption is described not degradation, and that is probably the reason why pH do not influence on relative pesticide leaching.

In the first example A the BBN was generated using structural learning and assuming dependencies between 'Organic content', 'Clay' and 'Silt' to 'Relative pesticide leaching'. All other links were estimated interactively by Hugin and additional expert inputs. In the second example B the BBN was generated assuming independencies between 'silt' and 'clay' and with additional expert inputs in process of defining the which links should be included and direction.

The example A in figure 6.26 illustrates that only the three parameters have direct influence on relative pesticide leaching: ‘Organic content’, ‘Clay’ and ‘Silt’. However, ‘Clay’ and ‘Silt’ are interrelated which is indicated by the link between these variables. The more easily measured parameters ‘Fine sand 1 & 2’, ‘Coarse silt’, ‘Coarse sand 1’ influences the ‘Silt’ variable. Hence, instead of collecting data on ‘Silt’, it could be possible to collect data on ‘coarse sand’ or ‘coarse silt’ or even ‘Fine sand 1 & 2’. The latter data are easier to measure compared to clay, silt and organic content.

In the example in Figure B the structural learning resulted in another calculated structure which is a bit more complex with a total of four variables influencing relative pesticide leaching as parent variables. Again the test with Hugin confirm that results from KUPA regarding ‘Silt’, ‘Clay’ and ‘Organic Content’ as useful parameters for phase I vulnerability mapping for pesticides on sandy soils. But here the structural learning result in an additional parameter: ‘Coarse sand 1’ that has to been included, when the learning is based on the assumed independencies between ‘Clay’ and ‘Silt’.

A variable like ‘Coarse silt’ in example B has both ‘Clay’ and ‘Silt’ as parent variables and ‘Fine sand 1’ as a child variable. Below in Figure 6.27 is shown the result of structural learning and CPT’s calculated based on KUPA dataset for example A and B.

Note that evidence on ‘Silt’ in Figure 6.28 resulting in this variable in the lowest interval (10-20) and evidence on ‘Organic content’ in second lowest interval (10-18) brings the relative pesticide leaching indicator in a state of ‘alarm’. Under these conditions there is a 61,8 % chance of most vulnerable soil type and 23,5 % chance of second highest vulnerability interval. Note also that the evidence for ‘Silt’ has altered the ‘Clay’ probabilities and probabilities for ‘Fine sand 1’, ‘Coarse sand 1’ and ‘Coarse silt’. Only ‘Fine sand 2’ is not changed.

An alternative way of using the BBN in example A could have been to measure some of the easy observable sand and silt parameters (‘Fine sand 1 & 2’, ‘Coarse sand 1’ and ‘Coarse silt’) and simply analyse the ‘knock on’ effect of that evidence on the other variables. This is shown in Figure 6.29.

The only variable that was not influenced by the entered evidence in Figure 6.29 is the ‘Organic content’.

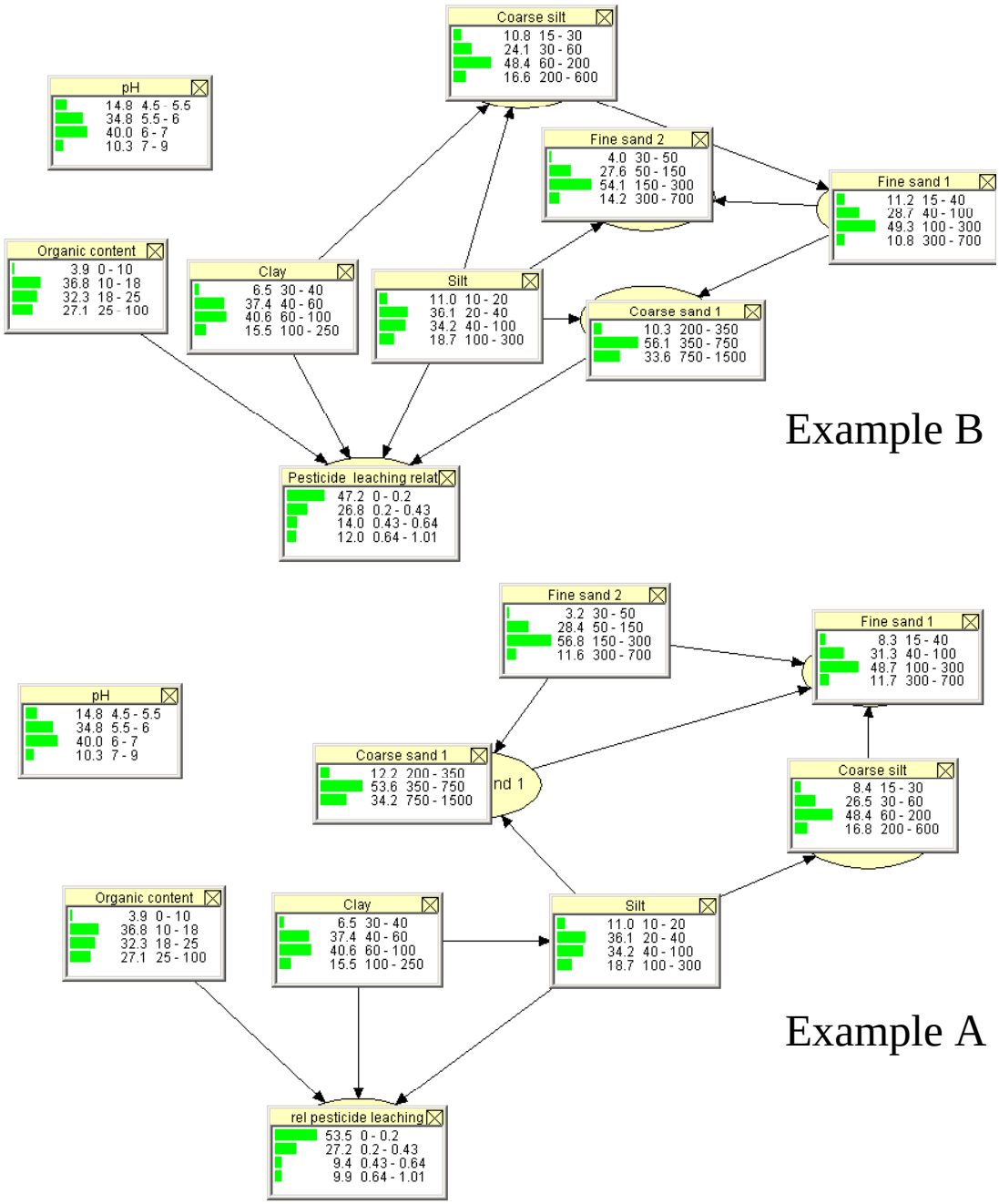


Figure 6.27. The most pesticide vulnerable areas belong to the interval 0.64-1.01 (9,9 % in example A). Vulnerable, but a bit less, are also soils belonging to the interval 0.43-0.64 (9.4 % in example A). Thus a total of 18 % belongs are relative pesticide leaching vulnerable.

Note that the 'Relative pesticide leaching' indicator based on the entered evidence now show a result of only a very little chance that the soil is vulnerable to leaching (= 1 % only). Depending on socio-economic framing conditions it could be decided to accept a low risk of pesticide leaching or to collect additional data on either 'Clay' or 'Organic content' in order to determine more precisely the risk of 'vulnerability to pesticide leaching'.

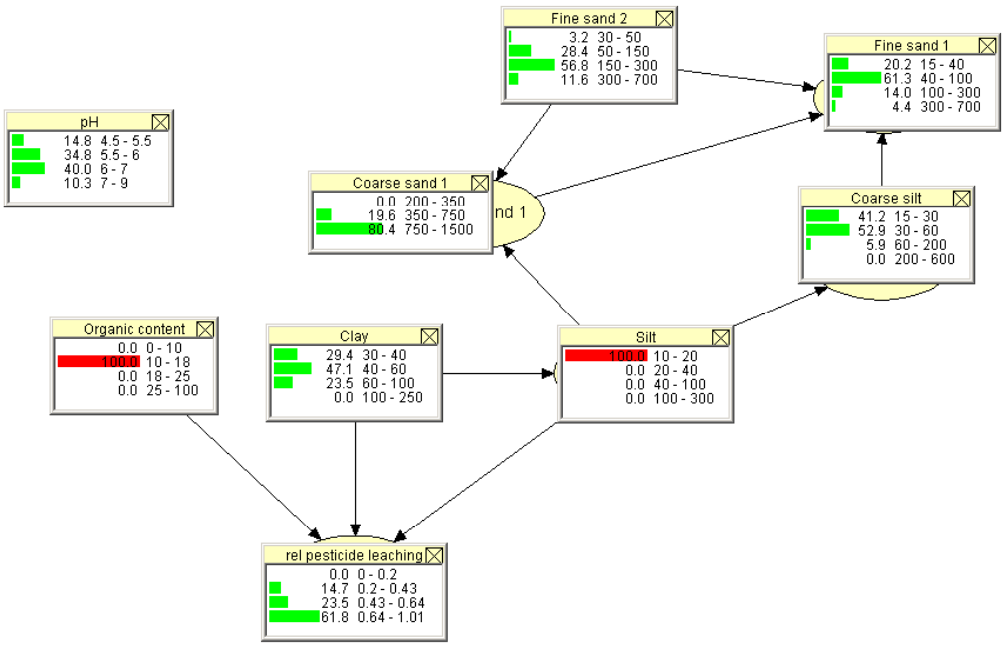


Figure 6.28. Example of adding evidence (red bars) to selected variables and updating the prognosis for pesticide leaching vulnerability for BBN example A.

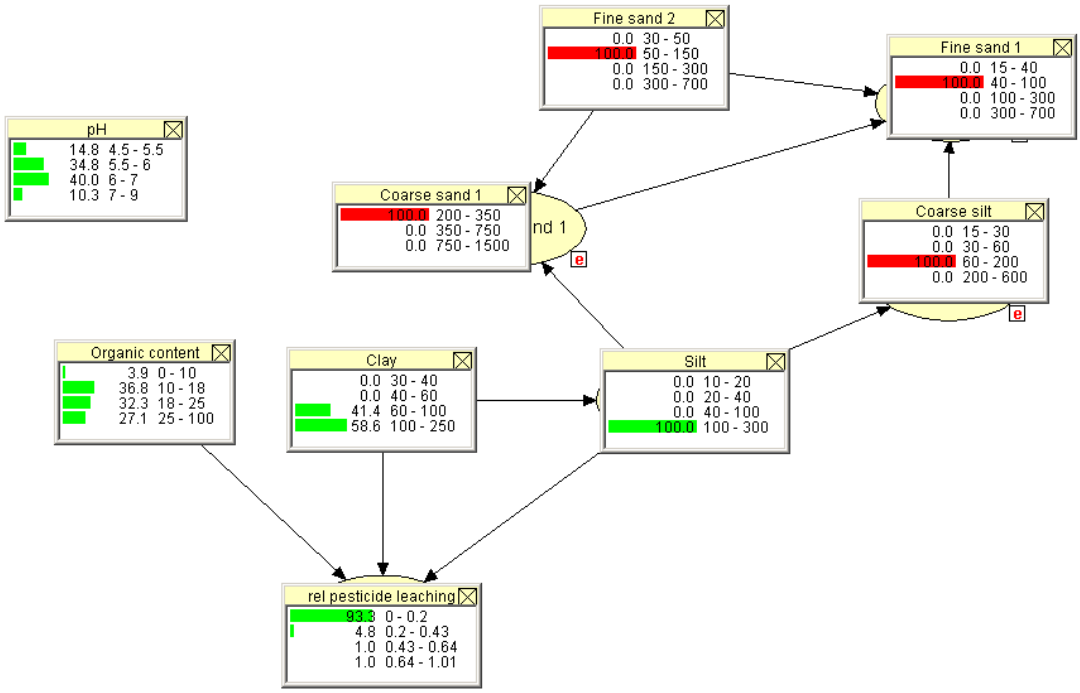


Figure 6.29. BBN example A with collected data for 'Coarse sand 1', 'Fine sand 2', 'Fine sand 1' and 'Coarse silt'. There is a 41,4 % chance for 'Clay' in the interval 80-100 and a 58,6 % chance of 'Clay' in the interval 100-250. Low risk of pesticide leaching in this case.

Another capability of a BBN, is the possibility of entering likelihood and analysing influence on other variables, given this assumption (likelihood). In figure 6.30 an example of entering likelihood for BBN example A, assuming highest or second highest relative pesticide leaching (either 0.43-0.64 or 0.84-1).

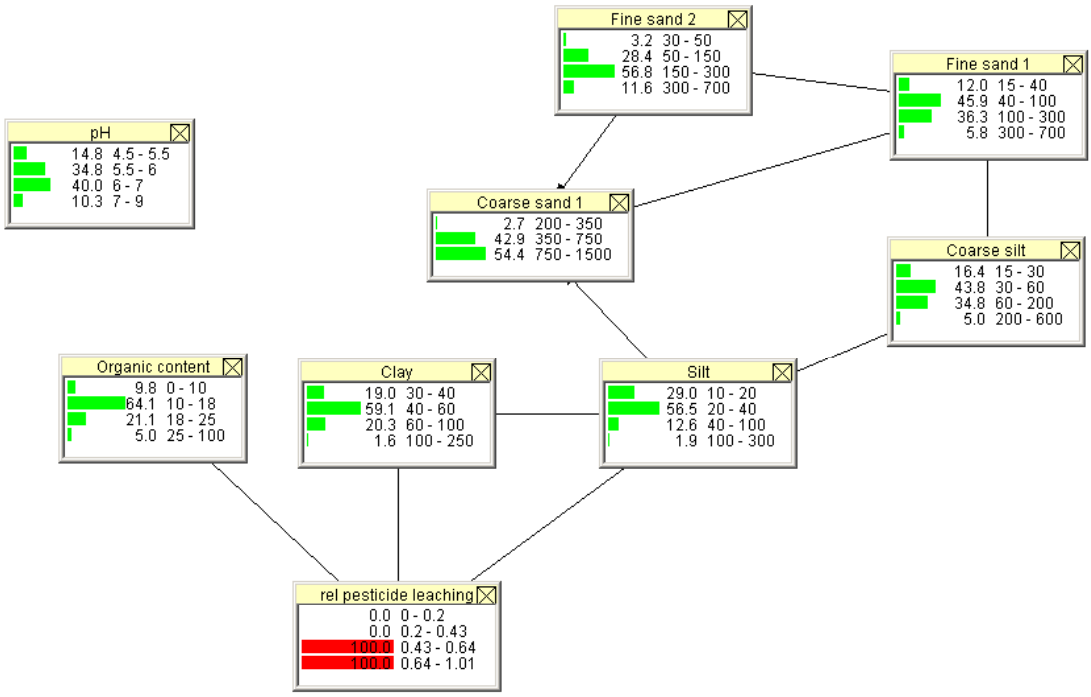


Figure 6.30. Example of entering likelihood of highest/high leaching risk in BBN example A

6.5.4.3 Summary of structural learning based on KUPA data set

The test of BBN development using structural learning algorithm on the KUPA dataset is only for demonstration purposes. Two alternative example BBNs: A and B was developed with different dependencies/independencies however many other structures was tested in the process. When no dependencies were defined, some structures resulted in two parameters: 'Silt' and 'Organic content' as parent variables to 'Relative pesticide leaching' others in three parameters: 'Silt', 'Clay' and 'Organic content' depending on which states were defined and which decisions were made when including/excluding other links or choice of direction of different links in the BBN. For examples the PC algorithm was used, even though the NPC algorithm may have been a better choice. The developed BBNs should be further evaluated before they are used in the real world because some of the CPT's for some of the relationships are rather weak (experiences < 5). However, BBNs are a flexible tool for analysing a dataset and combined with expert judgement useful for understanding and communication.

A main advantage of the BBNs, is the explicit quantification of uncertainty, which is useful in relation to groundwater management and protection. Furthermore, the possibility of assessing the 'Relative pesticide leaching' based on all available data for a given area and in addition, to combine this assessment with other datasets (e.g. degradation, pesticide application, groundwater monitoring and socio-economic conditions) is promising and should be further investigated. The example BBNs demonstrated in this section is limited to sandy soil conditions. Relative pesticide leaching for clay conditions should also be incorporated before the example BBNs are included in the more general BBN for groundwater protection described in earlier sections of this chapter.

6.6 A BBN for flooding

The BBN for flooding deals with the problem of flooding in the downstream part of Havelse Creek (see Figure 6.31).

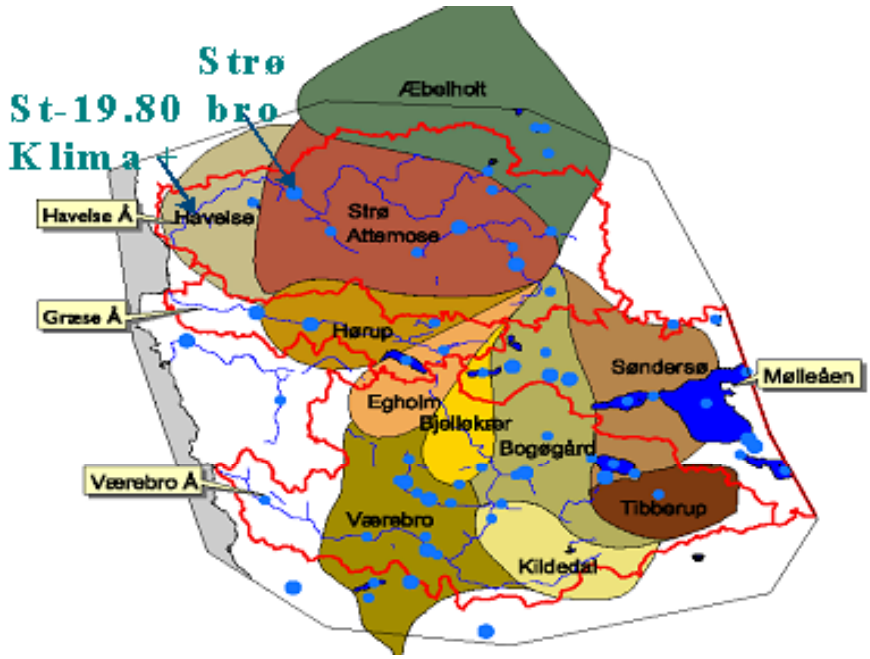


Figure 6.31. Flow and water level in the creek is recorded at the gauging station at Strø Bro (Frederiksborg county). A member of the citizens' group, Bjørn Hansen, has recorded daily data for climate and water level in the creek at a downstream location (St-19.80) since 1993.

With the aim of establishing wetlands in the downstream part of the creek, Frederiksborg County investigated and negotiated with local farmers a proposal to cutting the drainpipes and flood the areas in the creek valley with the drainage water to reduce the nitrate flow into Roskilde Fjord bay (Frederiksborg Amt, 2001).

The constructed BBN has ten nodes (Figure 6.33) which describe creek runoff upstream, water level downstream and conditions of various areas with respect to depth to shallow groundwater, thus combining three different sources of data:

- Havelse Creek flow and level at Strø Bro (52.08, daily data for April 1990-April 2002) available from www.dmu.dk (station part of national station network).
- Observation of wind speed and water level at Station 19.80 (daily at the same time)
- VMP II wetland project (Frederiksborg Amt, 2001).

Figure 6.32 illustrates the relationship between flow and discharge at 52.08 Havelse å, Strø Bro.

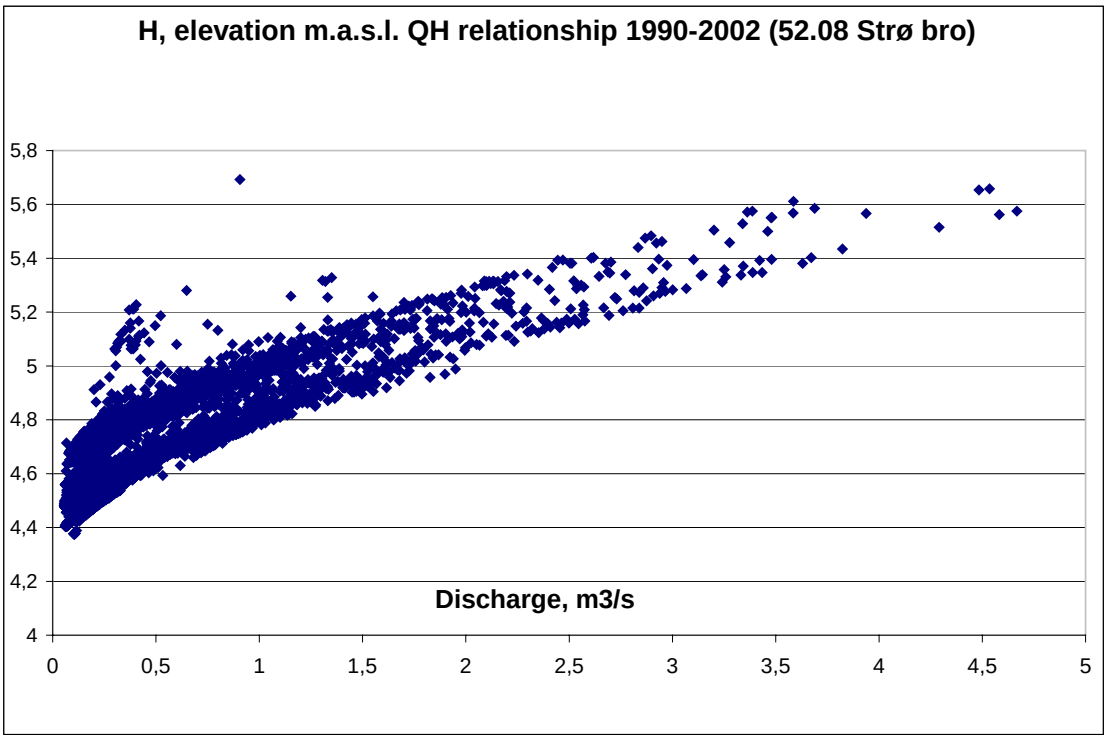


Figure 6.32. Relationship between flow and discharge in Havelse Creek, upstream at Strø Bro.

The relationship is clearly biased, with a variation of 40 cm for the same creek discharge runoff . The water level is measured in m.a.s.l.

Bjørn Hansen's dataset goes back to 1995 (daily water level, barometric pressure, precipitation, minimum and maximum temperatures, wind direction and speed at Station 19.80 [Apholm]). Additional recording of data on flora and fauna was also collected by Mr Hansen (also flooding). An analysis of the water level with the flow upstream is shown in Figure 6.32.

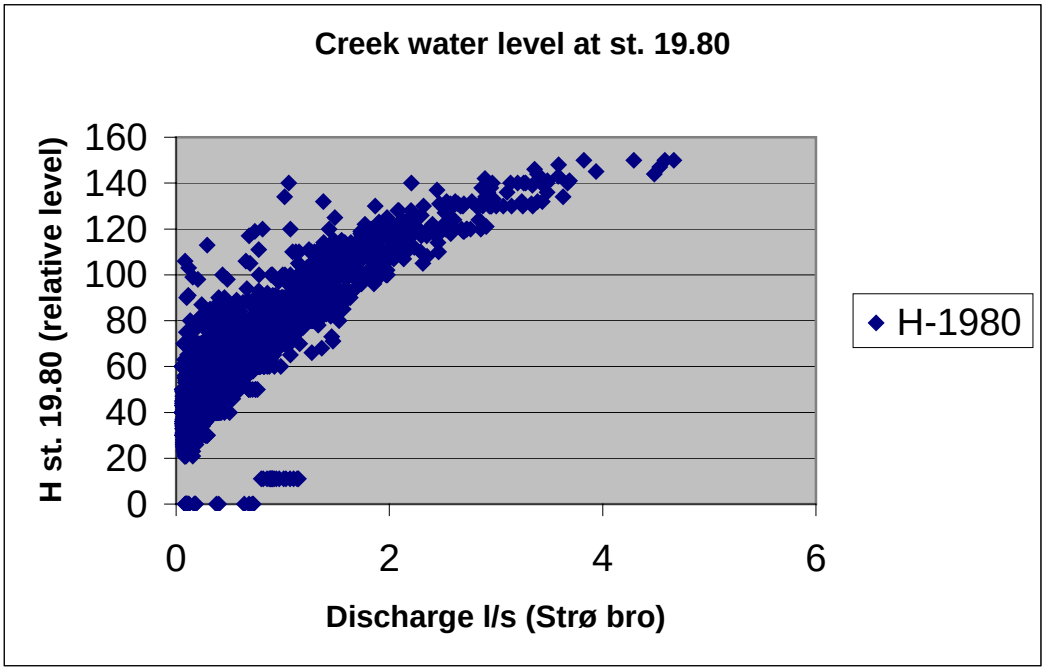


Figure 6.33. Relationship between creek runoff and water level downstream.

These data were analysed to provide input for the BBN shown in Figures 6.24 and 6.25.

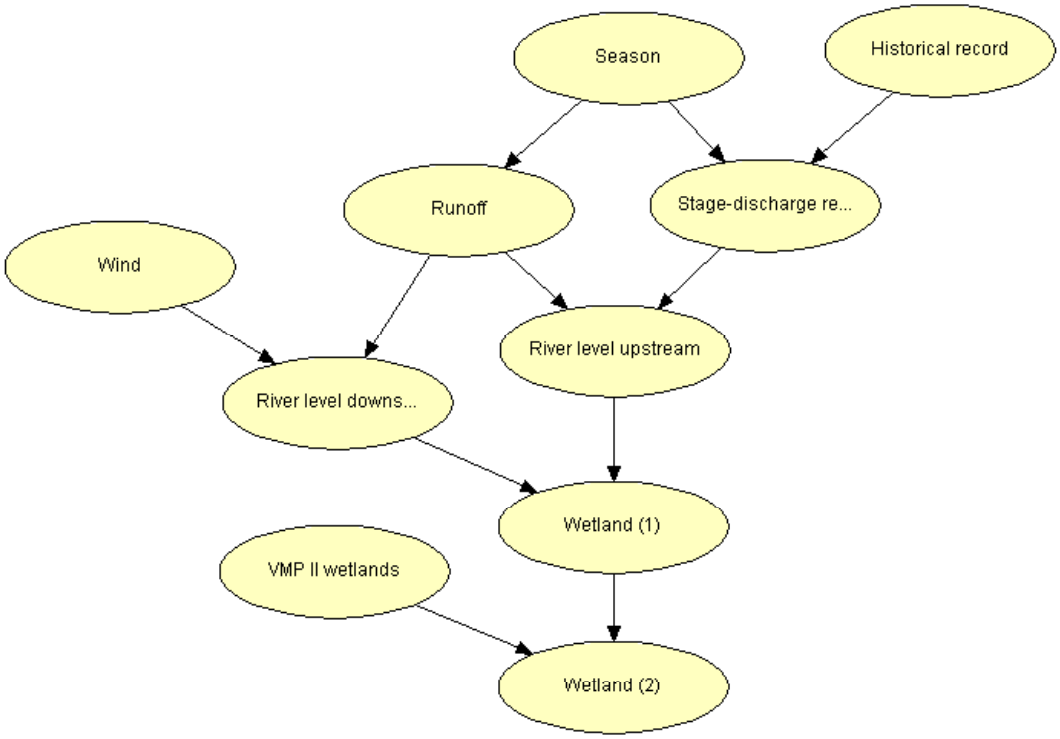


Figure 6.34. Third and final BBN for flooding (4 February 2004).

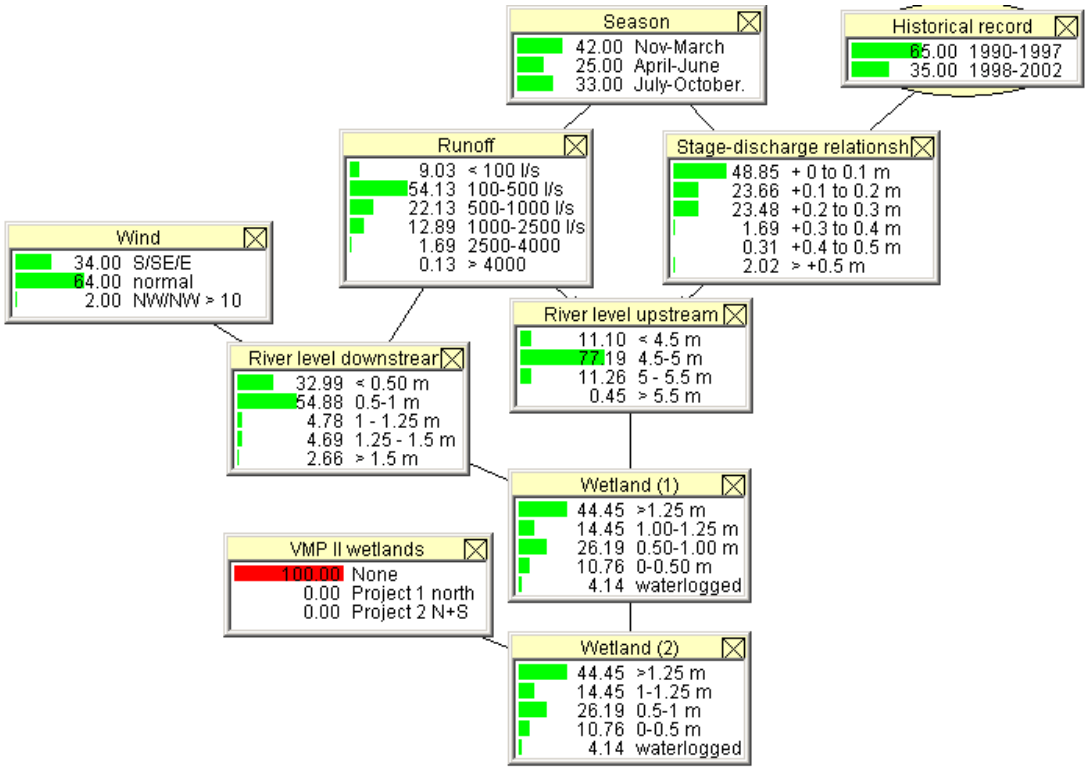


Figure 6.35. Example of results of the BBN.

Table 6.6. Description of variables.

Variable	States	Description
Season	November-March April-June July-October	Seasonality in both discharge and water level in creek (weed and sediments).
Historical period	1990-1998 1998-2002	There is a significant shift in runoff capacity in the creek around 1998 at Strø bro for the upstream part of Havelse creek (not near the outlet in fiord)
Runoff	< 100 l/s 100-500 l/s 500-1000 l/s 1000-2500 l/s 2500-4000 l/s > 4000 l/s	Discharge at Strø bro (52.08) used as parent / control variable in the BBN. Small discharges < 100 l/s are only seen less than 10% of the time, whereas large discharges > 4000 l/s are only frequent 5 times in total in the period 1990-2002
Stage-discharge (QH relationship)	+ 0 – 0.1 m +0.1-0.2 m +0.2-0.3 m +0.3-0.4 m +0.4-0.5 m > 0.5 m	Decrease in discharge capability measured as an increase in water level compared to a winter QH relationship. Analysed based on water level recordings and discharges for 1990-98 and 1998-2002.
Creek water level upstream (Strø bro)	< 4.5 m 4.5-5 m 5-5.5 m > 5.5 m	Water level in creek at Strø bro, m.a.s.l. Normal level around 4.5 – 5 meter. Water levels in creek > 5.5 m.a.s.l occur rarely (daily data from gauging station 52.08, DMU)
Wind (vindhastighed og retning)	S/SE/E (south, southeast, east) Normal (all other directions) N/W/NW (west, north, northwest > 10 m/s)	Observed windspeed and direction (source Bjørn Hansen) from period May 1992 – April 2002. Daily observations. Significant effect of strong winds from N,W,NW > 10 m/s (flooding).
River water level downstream (St.19.80 Apholm, m.a.s.l)	< 0.5 m 0.5-1 m 1 – 1.25 m 1.25 – 1.5 m > 1.5 m	Water level at Apholm observed by Bjørn Hansen from period May 1992 – April 2002. Daily observations of winddirection and speed. Various other datatypes are available in Bjørn's database.
Wetland (1) Existing conditions	➢ 1.25 m 1-1.25 m 0.5-1 m 0- 0.5 m waterlogged	Based on report by COWI for Frederiksborg county. Areas along creek is characterized by depth to groundwater table. Data from VMP II delineated areas amount 62 ha + areas outside these (up to 100-120 ha in total).
VMP II wetlands	None (existing conditions) North (26,2 ha) North+South (61,7 ha)	Cutting of drainage pipes in creek valey and surface runoff over meadow areas. Changes in water level in creek is not included in project.
Wetland (2) After establishment of wetland project	Samme as Wetland (1)	Assumed that both water level upstream and downstream influence wetlands and depth to groundwater table for areas along Havelse creek.

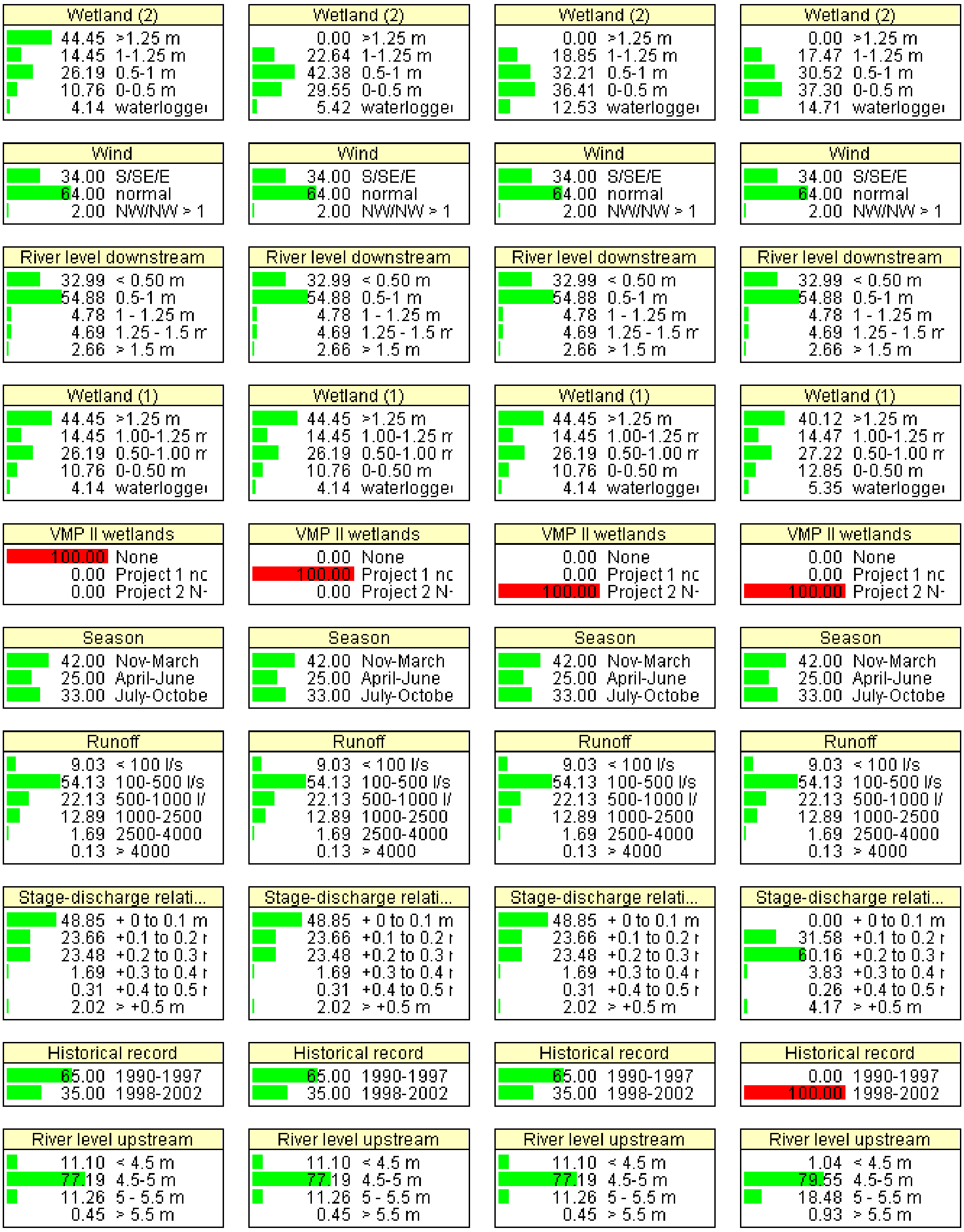


Figure 6.36. Analysis of different scenarios for possible future wetlands using flooding BBN.

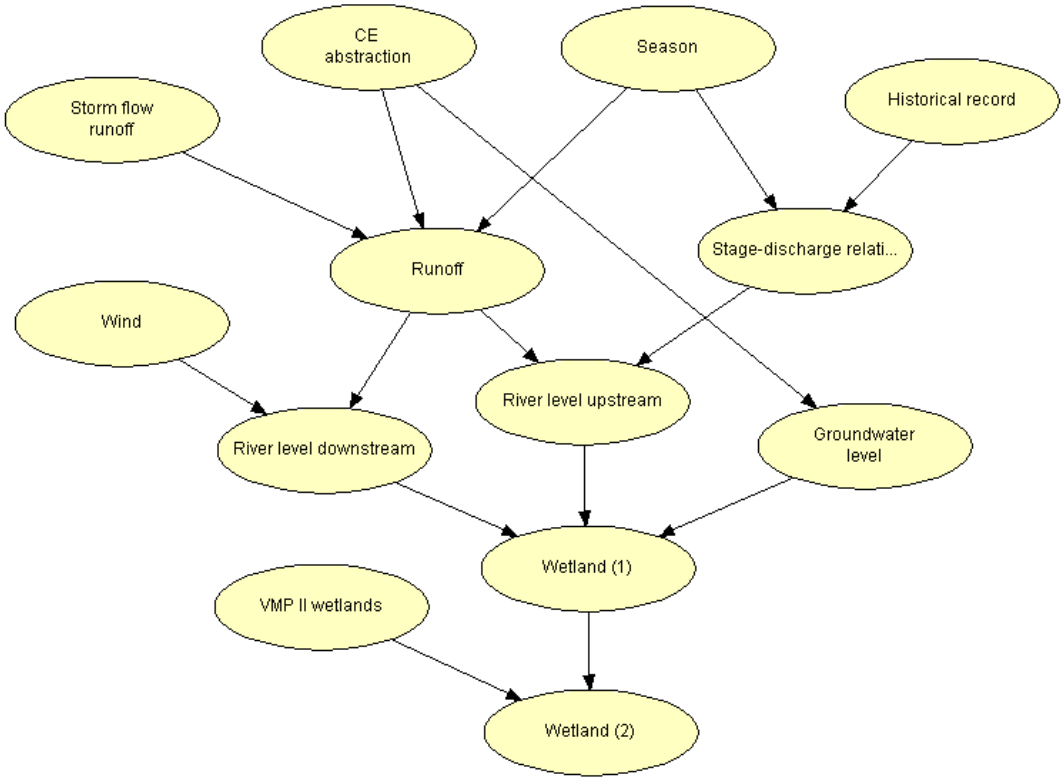


Figure 6.37. Proposal for BBN with extended parameters

As pointed out by the citizens group (see chapter 9) additional work is very much necessary if the BBN for flooding shall describe influence on water level on areas along Havelse creek and groundwater – surface water interaction related to the significant groundwater abstraction from CE's wellfields in the area.

In figure 6.37, a proposal for such an extended BBN is shown by introducing three new variables:

- CE abstraction (Havelse, Strø and Attemose wellfields which all influence the runoff in Havelse river especially in the dry summerperiod), but also cause a decreased regional groundwater level in the area (the influence and CPTs can be evaluated based on CE modelleling and the National water resource model)
- Groundwater level is decreased by several meters in the deep chalk aquifer 30-40 meter below the surface due to abstraction. However, influence on shallow groundwater level hasn't so far been established (more numerical modelling are required if CPTs shall be evaluated)
- Storm flow runoff (both waster water discharges upstream near Hillerød and from smaller villages and especially storm water runoff from paved areas impact the max flow rates in the creek; CPTs may be evaluated based on MOUSE simulations or similar)

The citizens' group find the BBN for flooding as the most important one with respect to the history and future of the entire area. It shall be recalled, that the information in the May 2004 newsletter from Frederiksborg County brought the news, that the establishment of wetlands along the creek has been given up temporarily.

6.7 Validation of BBNs

6.7.1 Validation of the BBN for farming contracts

Split-sample validation

Data observations not used for construction can be used for a validation of the final BBNs (or at least of the initial condition). The following data could be considered:

- Additional sampling of water quality for shallow, deep and creek according to a voluntary sampling programme offered by CE for private wells and boreholes (Københavns Energy, 2004). This is an ongoing sampling program; more data may become available within the next few months.
- A more thorough analysis of all existing data, especially a comparison of land use data by remote sensing (see Figure 6.38), samplings of water quality and results of pesticide interviews (application over past ten years). The same data are also available for other wellfields, and at the least, a sufficient amount of data is required in order to test the BBNs.

Proxy basin validation

- Using another area (wellfield) to test the entire BBN and especially the CPTs describing willingness to join a farming contract (level of compensation) might be a good idea.

6.7.1 Validation of BBN for flooding

Split-sample validation

- Additional creek and flooding observation data (citizen group member Bjørn Hansen has collected additional 2004 data not used in the construction of the BBN for flooding, including photos). It is not possible to complete this validation before data from the creek measurement station upstream has been finally calculated, even though a part of the network can be evaluated based on the new observations (data recordings in Figure 6.39 and photos in Figure 6.40).
- Independent data sets not used for the construction of BBNs (e.g. data from numerical hydrological model from Havelse Creek catchment developed by CE, data from the national water resource model and remote sensing data). Figure 6.41 below shows an example of vegetation cover based on remote sensing data; other methods could be used to provide input about water content, especially near the creek). A combined use of data from numerical models and remote sensing would be ideal; we recommended to consider on which scale such a test should be carried out.

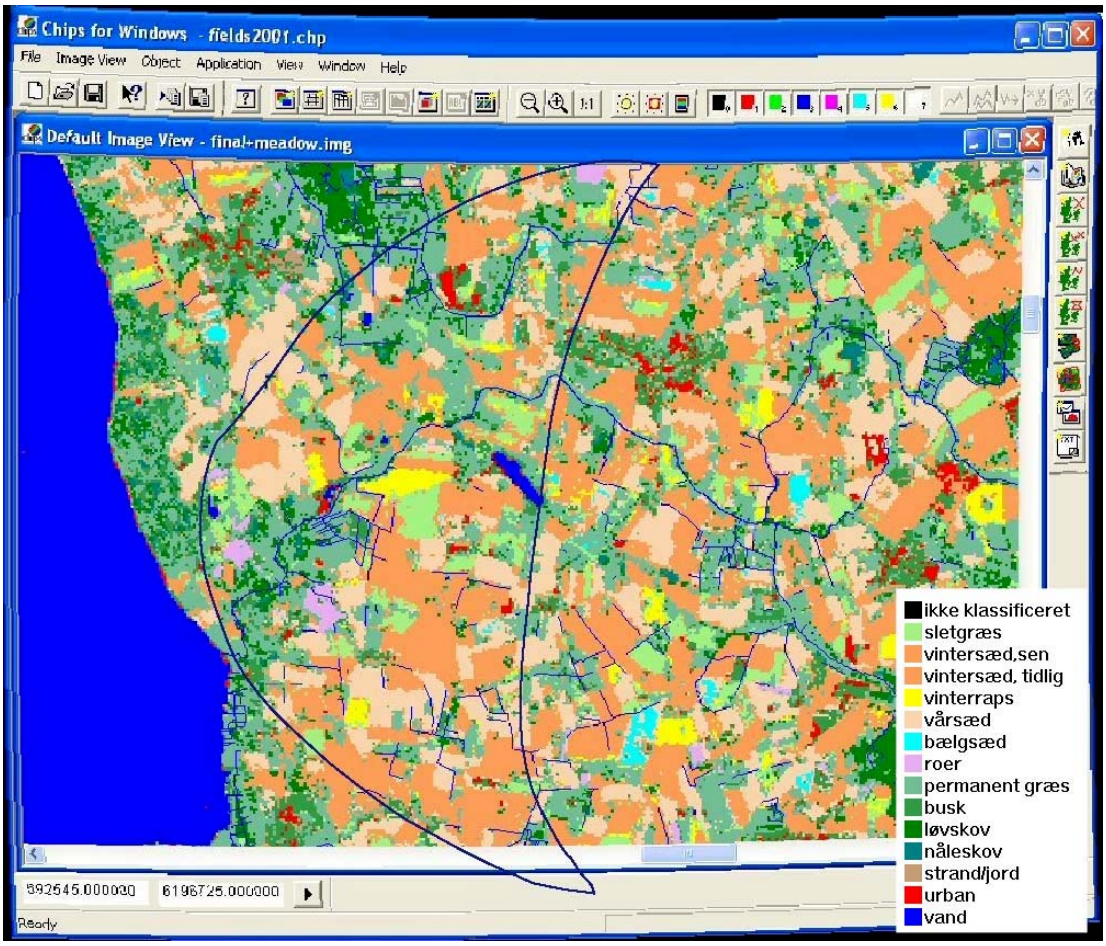


Figure 6.38. Remote sensing interpretation of land use based on Landsat (TM 30 meter). Source: Eva Bøgh (Copenhagen University). The map shows different crops and could be combined with results of water sampling and interviews revealing farmers' pesticide use over the past ten years.

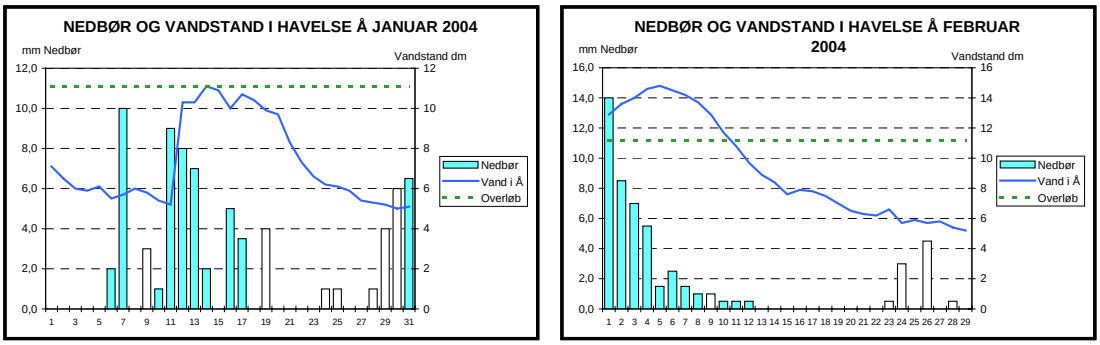


Figure 6.39. Observations of precipitation (nedbør) and creek water level (vandstand) January-February 2004 (source: Bjørn Hansen).

Figure 6.40. Photos from flooding 2004 (source: Bjørn Hansen).

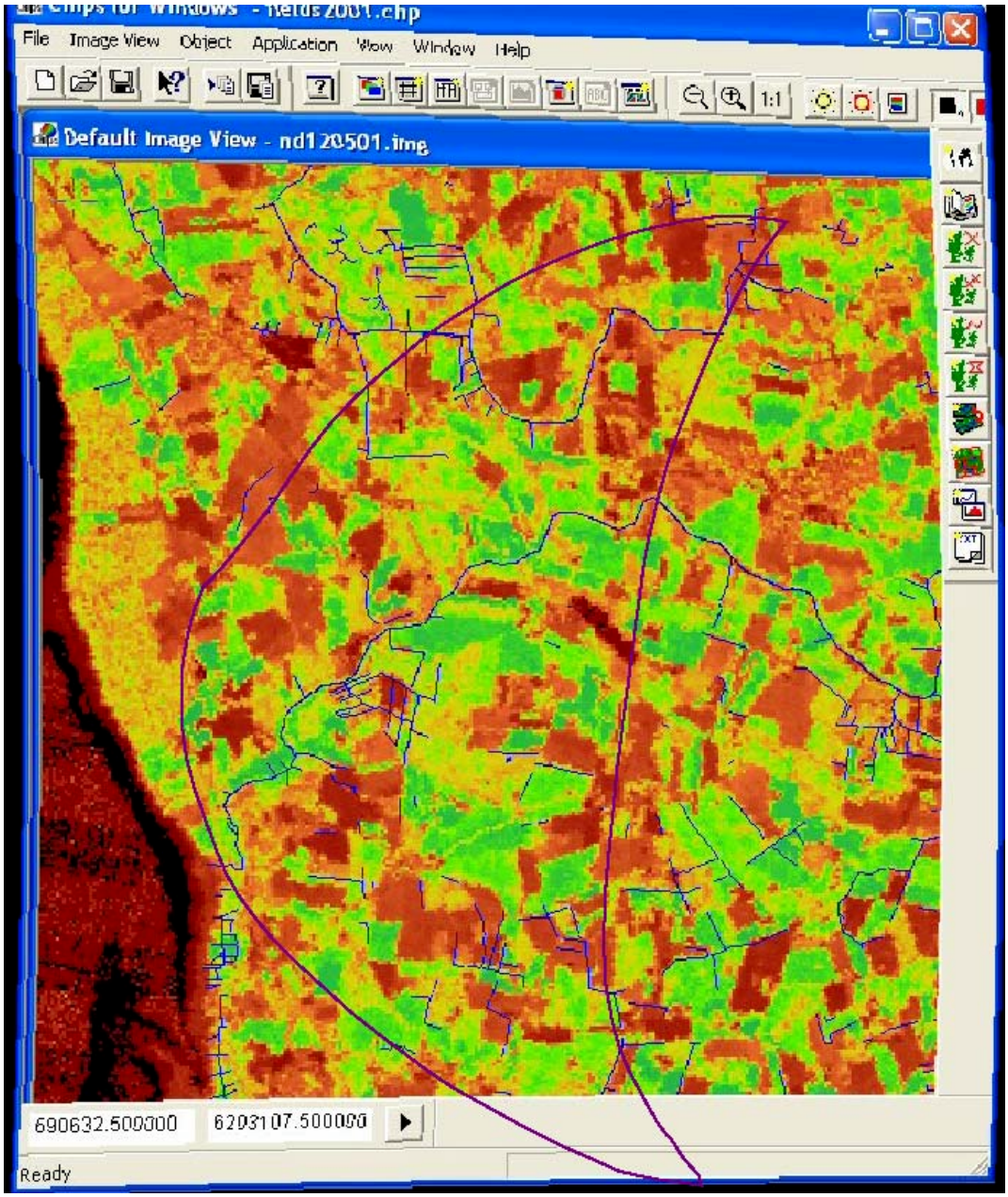


Figure 6.41. Vegetation index (NDVI & LAI) from 12 May 2001. Landsat TM 30 m. Green colours are dense vegetation; red colours limited vegetation. Interpretation of colours for the Roskilde Fjord bay has not been analysed and compared to other field-based data. (Does it indicate problems with sedimentation of the outlet into the bay?)

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CHAPTER 7 Data collection for groundwater protection management

Per Nyegaard, GEUS

7.1 Basic hydrogeological data

Basic hydrological data and land coverage maps were collected from several sources, and geochemical data from groundwater was extracted from databases at the Geological Survey of Denmark and Greenland (GEUS). Many GIS maps have been obtained from the GEUS's GIS system and from the Frederiksborg County Web site that contains area information (Frederiksborg County, 2003). Data were also obtained from reports made available by Copenhagen Energy (Copenhagen Energy 2003a and Copenhagen Energy 2003b).

The Havelse waterworks wellfield catchment area covers an area of 26 km^2 with a wellfield zone of about 3.7 km^2 with 21 bore holes (Figure 7.1). The land use is mostly agricultural, with small villages. The Havelse waterworks catchment area covers the lower part of the Havelse Creek catchment area and comes close the shoreline of the Roskilde Fjord bay. The northern part of the waterworks catchment area includes part of the Lyngby Creek catchment area (Frederiksborg County, 2003).

Until 1994, 1.4-1.6 million m^3/year was abstracted; then about 1.2 million m^3/year was abstracted until 2001, when the waterworks were shut down due to borehole flooding. Within the Havelse waterworks catchment area, there are several small local waterworks with a total abstraction of about 49,000 m^3/year (Copenhagen Energy 2003a).

Figure 7.1. Map of the Havelse waterworks catchment area with boreholes and wellfield zone. Proposed new wellfields are shown in red.

The geology at the depth of one meter below the surface is shown in Figure 7.2. The southern part of the areas is covered with a clayey till; the northern part is meltwater sand. Stretched SE-NW across the area is a large sand and gravel esker. Along the streams are postglacial freshwater deposits, and saltwater sand deposits from the Stone Age period are located downstream along Havelse Creek (GEUS 1998).

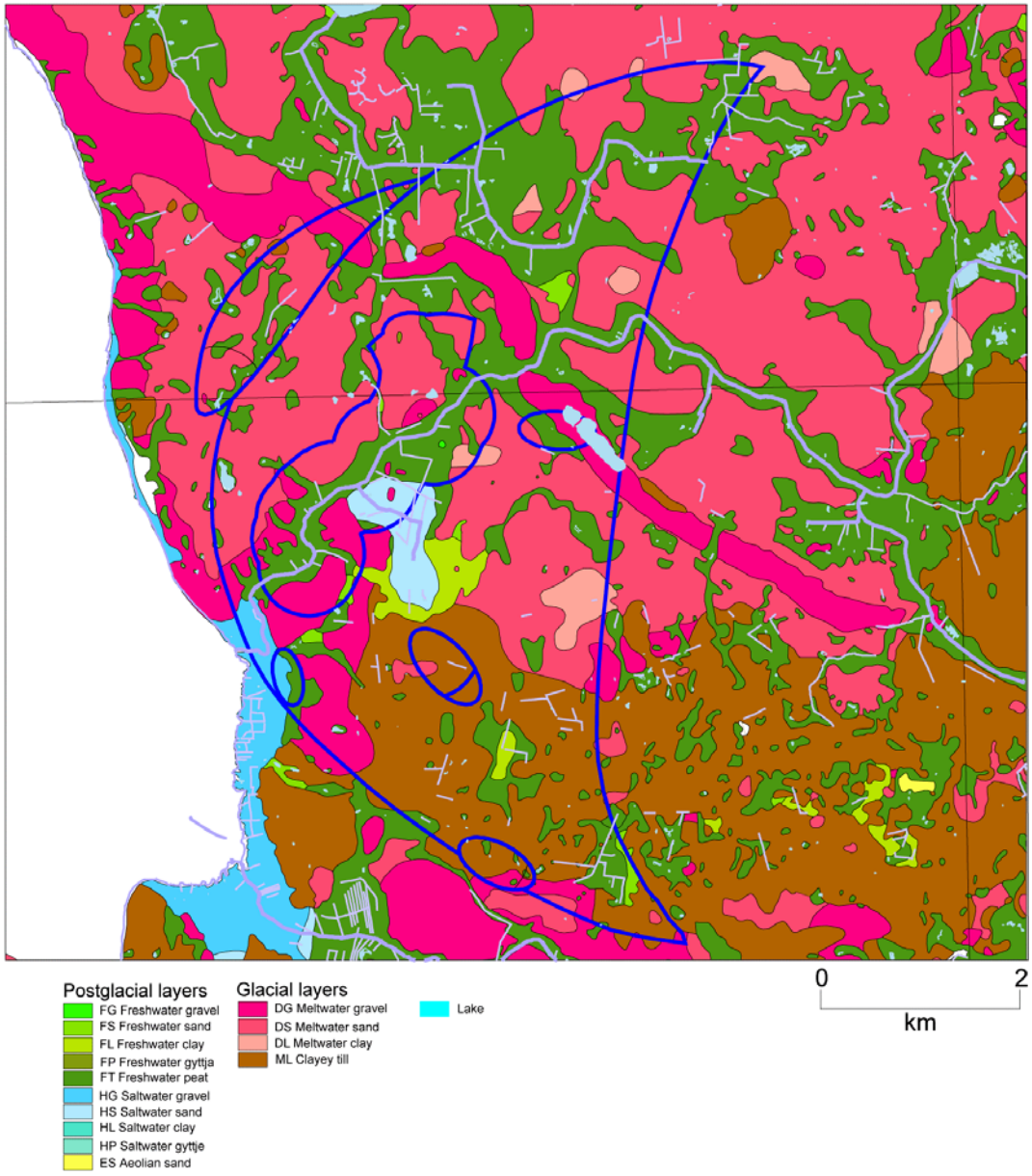

Figure 7.2. Geological basic data map. Red indicates sandy meltwater deposits, brown clayey till, green freshwater deposits and blue saltwater deposits.

The primary groundwater reservoir in the area is limestone and chalk deposits from the Danien period. The limestone may be in hydraulic contact with overlaying meltwater sand. The surface of the limestone is located at about 20 metres below sea level. The reservoir is generally well protected by the overlying clayey till, which is from 15 to 30 metres thick in large regions of the catchment area (Figure 7.3). Running through the area along a N-S direction is an area where the thickness of the clay is less than five meters, and it may be totally lacking in some spots. This area may represent a 500-metres-wide and buried valley filled with meltwater sand. The clay thickness is also reduced along the esker, to a layer five to ten metres thick in a 250-metre-wide zone (Frederiksborg County 2001).

The primary reason for selecting the Havelse waterworks catchment area for testing BBNs was that there is a threat of pesticide contamination of the groundwater. There are no pesticides in the groundwater in the catchment area at present, but to the south-east, in an

area with thin clay layers above the primary reservoir, there have been a few findings (Figure 7.4). In this area, the primary reservoir is meltwater sand overlaying limestone and covered by 4-16 meters of clayey deposits. The pesticide found is BAM – 2.6 dichlorbenzamide, which is a metabolite of the herbicide dichlobenil or chlorthiamide. BAM is the greatest threat to groundwater quality at the moment. The use of these herbicides is now prohibited. The pesticide findings were made in a village, and it is probably more point-source pollution than diffuse pollution. Similar vulnerable or very vulnerable areas are also found inside the catchment area and in the present wellfield zone. The vulnerability is here an expression of the thickness of the clay layer above the primary reservoir and whether the aquifers are unconfined or confined.

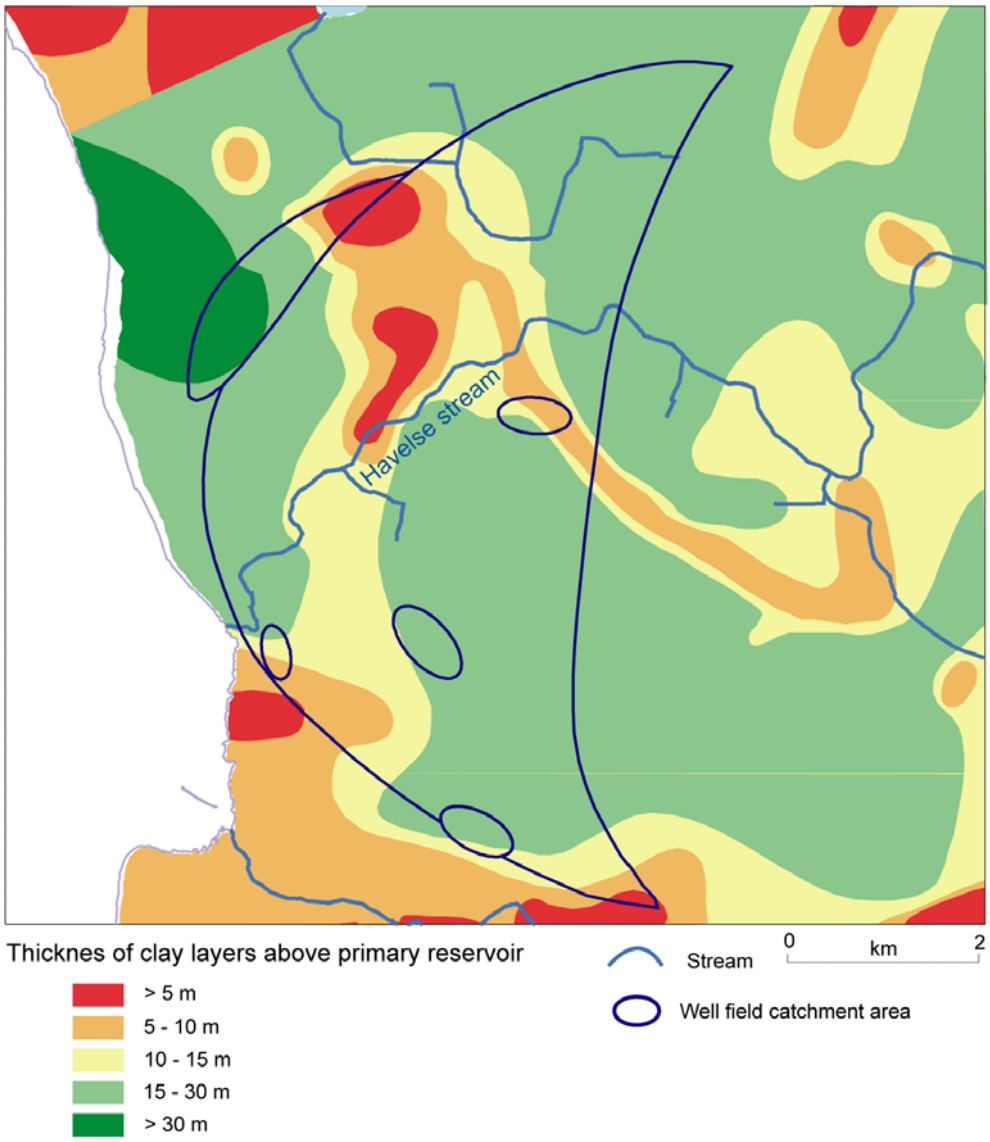

Figure 7.3. Thickness of the clayey till.

New pesticide analyses from five drilled wells, four dug wells and Havelse Creek show pesticides in two dug wells and one drilled well, but also in Havelse Creek, with all findings above the MAC value[7].

Other naturally occurring substances may also be a threat to groundwater abstraction for drinking water: nitrate, chloride, sulphate, potassium and several others. Nitrate above the MAC value of 50 mg/l NO_3 is found in the area north-west of Havelse wellfield (Figure 7.5). Here, the primary reservoir is meltwater sand and limestone with 4-16 metres of clay on top. The often very high nitrate levels are found in shallow dug wells located close to farmhouses. The nitrate content in Havelse Creek in January 2004 is also rather high – 28 mg/l nitrate. Chloride and sulphate cause no problems, but at few high findings of potassium are found (Figure 7.6). The groundwater has also been analysed for other elements – e.g. sodium, fluorine, phosphorous and nickel, but all values are below the MAC value or even the limits of detection.

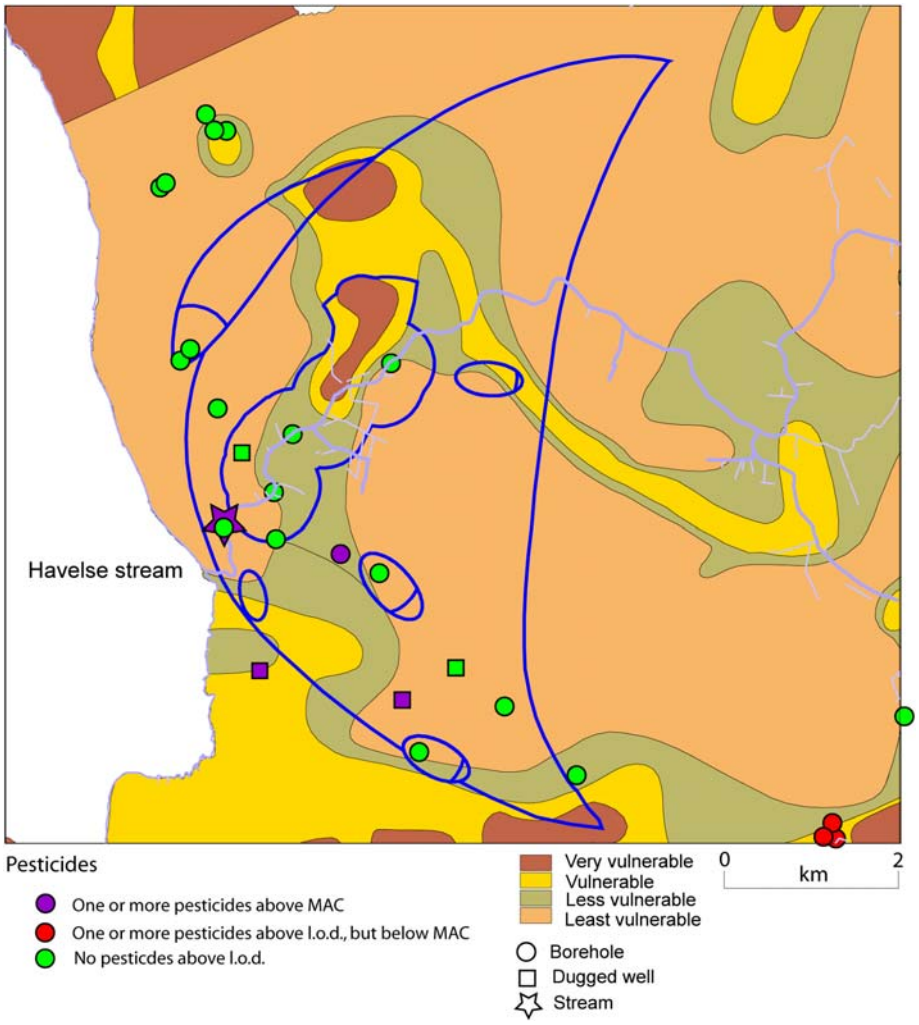

Figure 7.4. Findings of one or more pesticides in groundwater.

[7] Citizens' group has commented the groundwater monitoring data, see chapter 9.

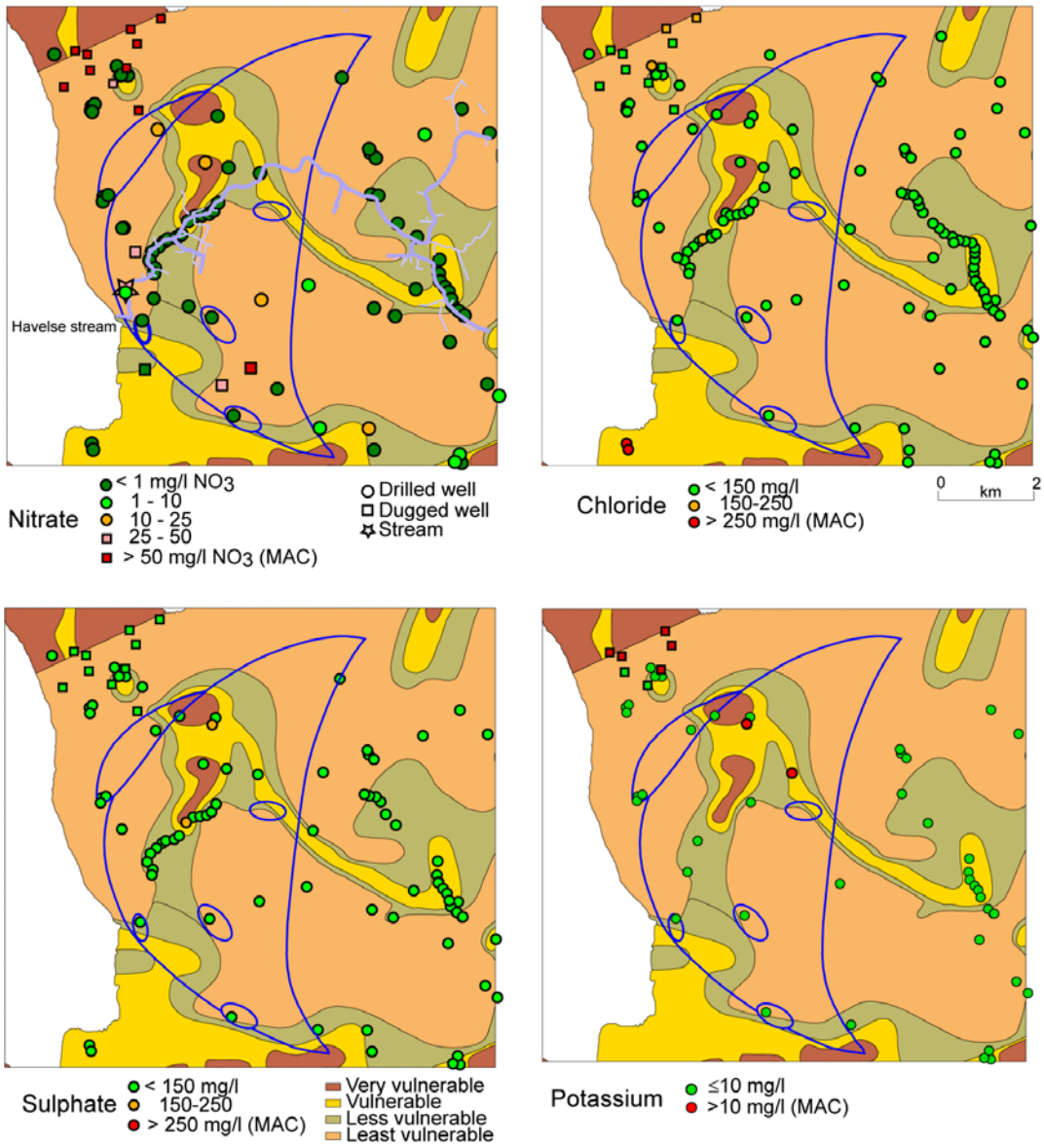

Figure 7.5. Findings of nitrate, chloride, sulphate and potassium in the catchment area.

7.1.1 Pesticide mapping at field level

10 years of pesticide use have been mapped on 1,624 fields in all within 5 catchment areas (Figure 7.6). The focus has been on the agricultural use of pesticides. The agricultural use far surpasses the urban use in total usage. The pesticides' active substances have been grouped into "vulnerabily" classes defined by the active substances' solubility.

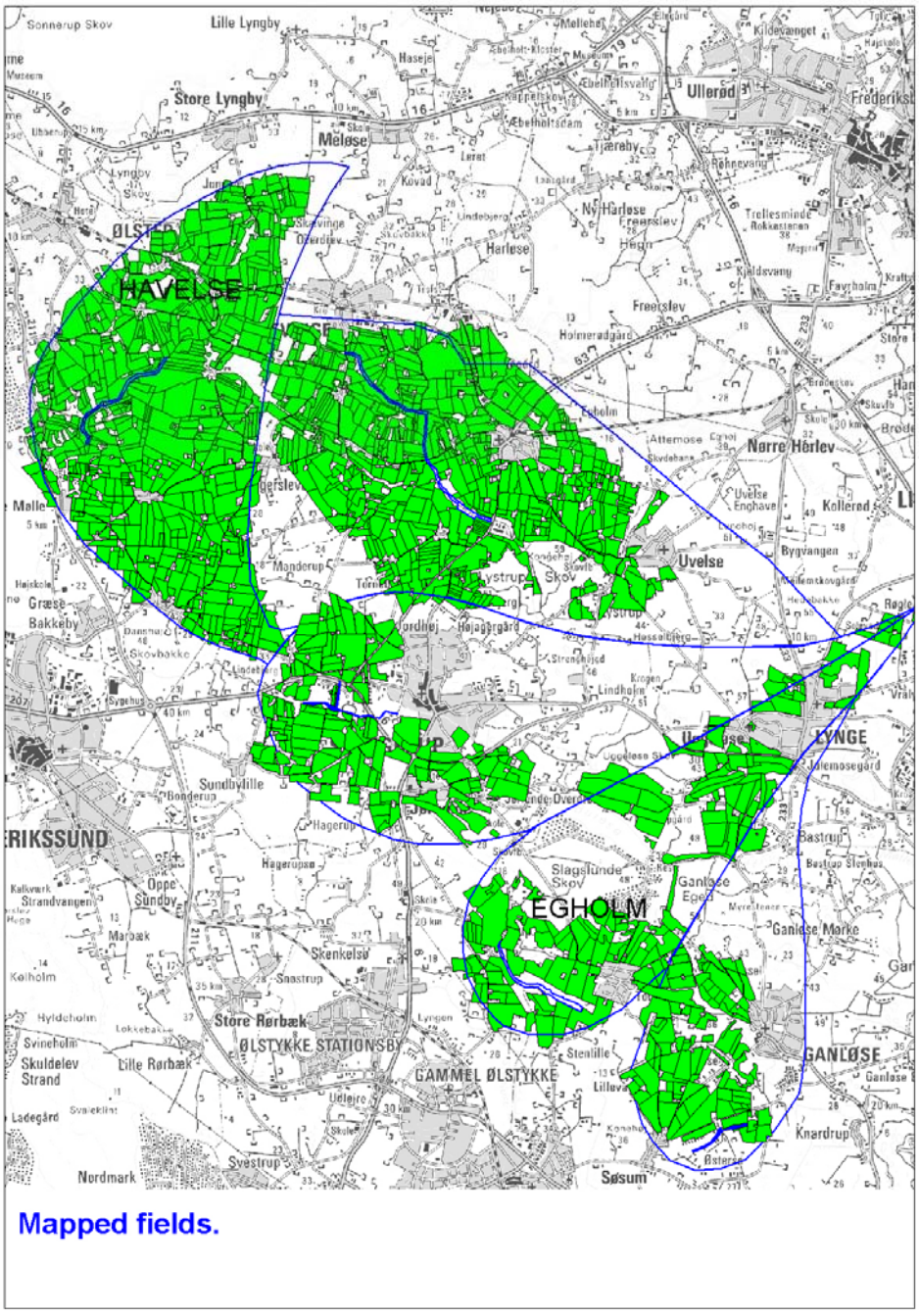

Figure 7.6. Pesticide mapping at field level

Pesticide data are presented at field level as regards total loading, pesticide type and pesticide category for the whole mapping period. It can be seen that the loading varies

between different fields and for different crops. There is a large variation in the used pesticide types and categories.

In the survey it was noted that 38 pesticides used in the catchments are not included in CE's pesticides analysis programme (CE analyses for 59 pesticides and their degradation products).

7.1.2 Sampling of individual (shallow wells) and Havelse creek for pesticides

To get an idea of the water quality in the shallow groundwater CE offered local citizens a free sampling and analysis of their water in individual wells within the Havelse catchment.

Groundwater from 9 boreholes and wells were analysed for 53 pesticides and degradation products and for nitrate. Seven were analysed for 6 PAH's. A water sample from Havelse Stream was tested for the same substances. Results are shown in Table 7.1.

Table 7.1 Sampling of pesticides in shallow wells and creek

1 : Apholm 5* Frederikssund (Irrigation well)
2 : Fjeldhøjvej 2* Frederikssund (Supply well for animals/other uses)
3 : Havelse Mølle 32* Frederikssund (Drinking water supply well)
4 : Sigerslevøstervej 8* Frederikssund (Drinking water supply well)
5 : St. Havelsevej 145* Ølsted, Frederikssværk (Drinking water supply well)
6 : Præstemarken 1* Frederikssund (Supply well for animals/other uses)
7 : Sigersslevøstervej 1* Frederikssund (Supply well for animals/other uses)
8 : St. Havelsevej 215** Ølsted, Frederiksværk (Drinking water supply well)
9 : Havelse creek, Havelse Mølle 32* (River)

Sampling point:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Pesticide / metabolite	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**
4-chlor-2-methylphenol	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
2,4-dichlorphenol	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Atrazin	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
2,6-dichlorbenzamid (BAM)	<0,02	<0,01	<0,01	<0,01	<0,01	**0,37**	<0,01	<0,01	**0,017**
Bentazon	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Bromoxynil	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Carbofuran	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	<0,01	<0,01
Chloridazon	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Chlorsulfuron	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
4-CPP	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01		<0,01
2,6-DCPP	<0,02	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01		<0,01
Cyanazin	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
2,4-D	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Desethylatrazin	<0,02	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Desethylterbutylazin	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	<0,01	<0,01
Desisopropylatrazin	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Dichlobenil	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Dichlorprop	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01		<0,01
Dichlorvos	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Dimethoat	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Ethofumesat	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Fenpropimorph	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Fluazifop-(p)-butyl	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Sampling point:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

Pesticide / metabolite	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**
Hexazinon	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
3-Hydroxycarbofuran	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Ioxynil	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Isoproturon	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	**0,010**
Lenacil	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Malathion	<0,02	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
MCPA	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Mechlorprop	**0,26**	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Methabenzthiazuron	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	<0,01	<0,01
Metazachlor	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Metribuzin	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Metsulfuron-methyl	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Parathion-ethyl	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Pendimethalin	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Pirimicarb	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Propyzamid	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	**0,040**
Simazin	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Terbutylazin	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Trifluralin	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	<0,01	<0,01
DNOC	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Dinoseb	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Diuron	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	**0,022**
Metamitron	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Linuron	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
2-hydroxysimazin	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
2-hydroxyatrazin	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Esfenvalerat [1)]	<0,02	<0,02	<0,02	<0,02	i.a.	<0,02	<0,02	i.a.	<0,02
Propiconazol	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Hydroxyterbutylazin	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	<0,01	<0,01
Metoxuron	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Prochloraz	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Propachlor	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Thifensulfuron-methyl	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
Triadimenol	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	<0,01
AMPA	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	**0,12**
Glyphosat	<0,01	<0,01	<0,01	<0,01	i.a.	<0,01	<0,01	i.a.	**0,054**
4-chlorprop								<0,01	
2,6 – Dichlorprop								<0,01	
Dichlorprop(2,4-DP)								<0,01	
Dicamba								<0,01	
2,4,5-T								<0,01	
Propyzamid								<0,01	
Pentachlorphenol								<0,01	
PAH's									
Fluoranthene	<0,2	<0,2	<0,2	<0,2	i.a.	<0,2	<0,2	i.a.	<0,2
Benzo(b+j)fluoranthene	<0,2	<0,2	<0,2	<0,2	i.a.	<0,2	<0,2	i.a.	<0,2
Benzo(k)fluoranthene	<0,2	<0,2	<0,2	<0,2	i.a.	<0,2	<0,2	i.a.	<0,2
Benzo(a)pyrene	<0,2	<0,2	<0,2	<0,2	i.a.	<0,2	<0,2	i.a.	<0,2
Indeno(1,2,3-cd)pyrene	<0,2	<0,2	<0,2	<0,2	i.a.	<0,2	<0,2	i.a.	<0,2
Benzo(g,h,i)pyrylene	<0,2	<0,2	<0,2	<0,2	i.a.	<0,2	<0,2	i.a.	<0,2
Benzo(g,h,i)pyrylene	<0,2	<0,2	<0,2	<0,2	i.a.	<0,2	<0,2	i.a.	<0,2
Fluoranthene	<0,2	<0,2	<0,2	<0,2	i.a.	<0,2	<0,2	i.a.	<0,2
Benzo(b+j)fluoranthene	<0,2	<0,2	<0,2	<0,2	i.a.	<0,2	<0,2	i.a.	<0,2

Benzo(k)fluoranthene	<0,2	<0,2	<0,2	<0,2	i.a.	<0,2	<0,2	i.a.	<0,2
Benzo(a)pyrene	<0,2	<0,2	<0,2	<0,2	i.a.	<0,2	<0,2	i.a.	<0,2
Indeno(1,2,3-cd)pyrene	<0,2	<0,2	<0,2	<0,2	i.a.	<0,2	<0,2	i.a.	<0,2
Benzo(g,h,i)pyrylene	<0,2	<0,2	<0,2	<0,2	i.a.	<0,2	<0,2	i.a.	<0,2
Benzo(g,h,i)pyrylene	<0,2	<0,2	<0,2	<0,2	i.a.	<0,2	<0,2	i.a.	<0,2
Nitrate (NO3) – mg/l	<0,01	<0,01	2,3	0,72	0,54	33	81	40	28

The results from this investigation have been used for the cpt't for groundwater quality for shallow (upper) groundwater.

7.2 Land use data and restrictions

The whole groundwater catchment area is designated as an area particularly valuable for drinking water. Such areas are referred to by their Danish abbreviation: "OSD" areas (Figure 7.7). Because this catchment area is an OSD area, the groundwater should be protected against contamination with nitrate and/or pesticides or other harmful pollutants (Frederiksborg County, 2003).

The function of creeks also has a great deal of influence on water abstraction, since lowering the groundwater level will cause less water to flow in the creeks. Most of Havelse Creek is designated a B2 creek (salmonid waters) and a part of the upstream watercourse is designated as a B1 steam (salmonid spawning and nursery waters) (Figure 7.7). All of Lyngby Creek in the northern part of the area is designated as a B3 stream (cyprinid waters). A few minor tributaries are designated as C creeks, which are watercourses to be used for drainage purposes (Frederiksborg County, 2003).

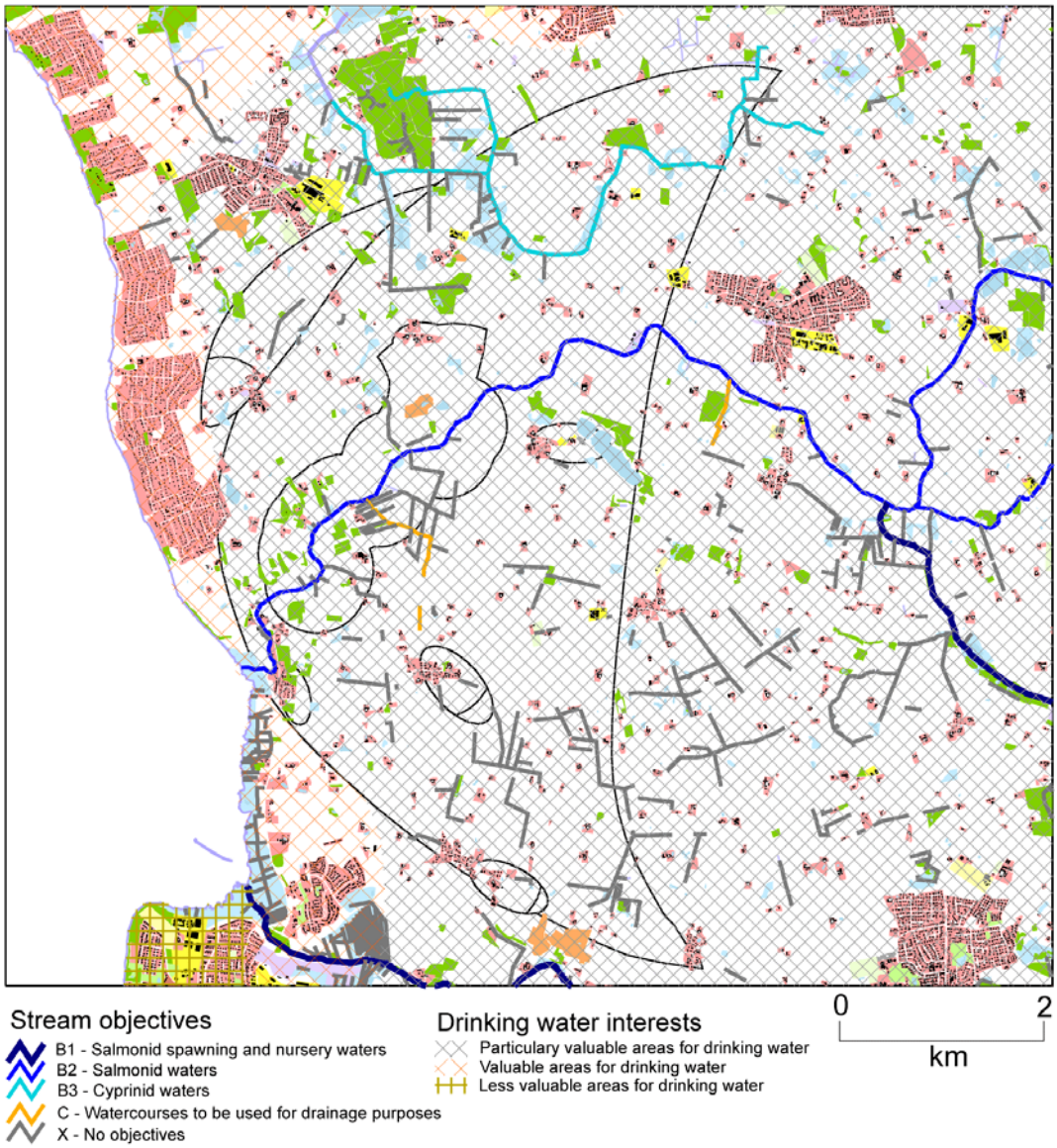

Figure 7.7. Drinking water interests and stream objectives.

Some parts of the catchment area are zones protected against groundwater abstraction: the areas along all of Lyngby Creek and the upstream part of Havelse Creek. Also a small low-lying area just south-west of what is today the Havelse waterworks (Figure 7.8) is an area protected against groundwater abstraction (Frederiksborg County, 2003).

The esker and its surrounding area is laid out as a “geologically interesting area”: sand and gravel excavation is not allowed, as it is a protected landscape (Figure 7.8). Some small parts of the catchment area are reserved for clay and sand/gravel production. Previously, sand and gravel were excavated from several pits along the esker (Frederiksborg County, 2003).

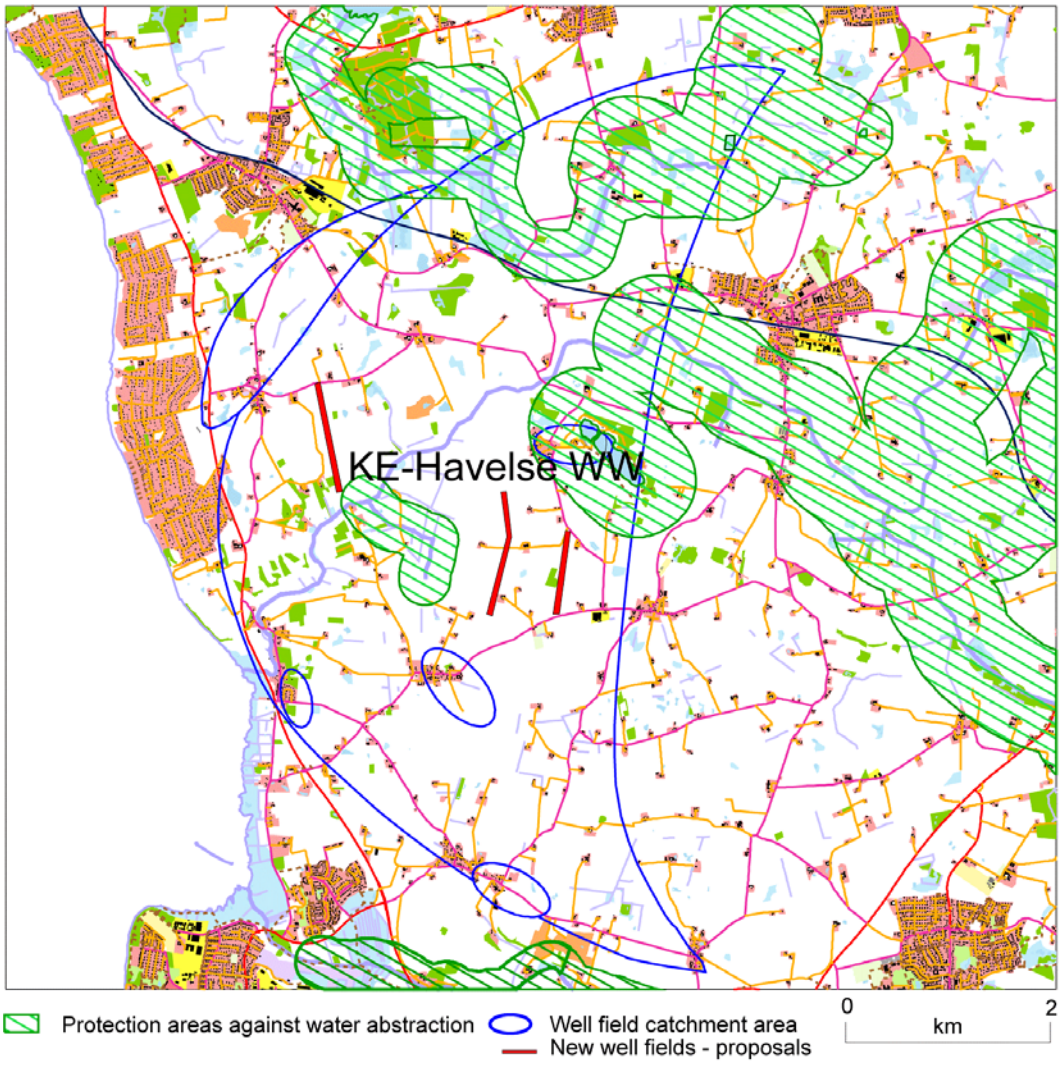

Figure 7.8. Protection against water abstraction.

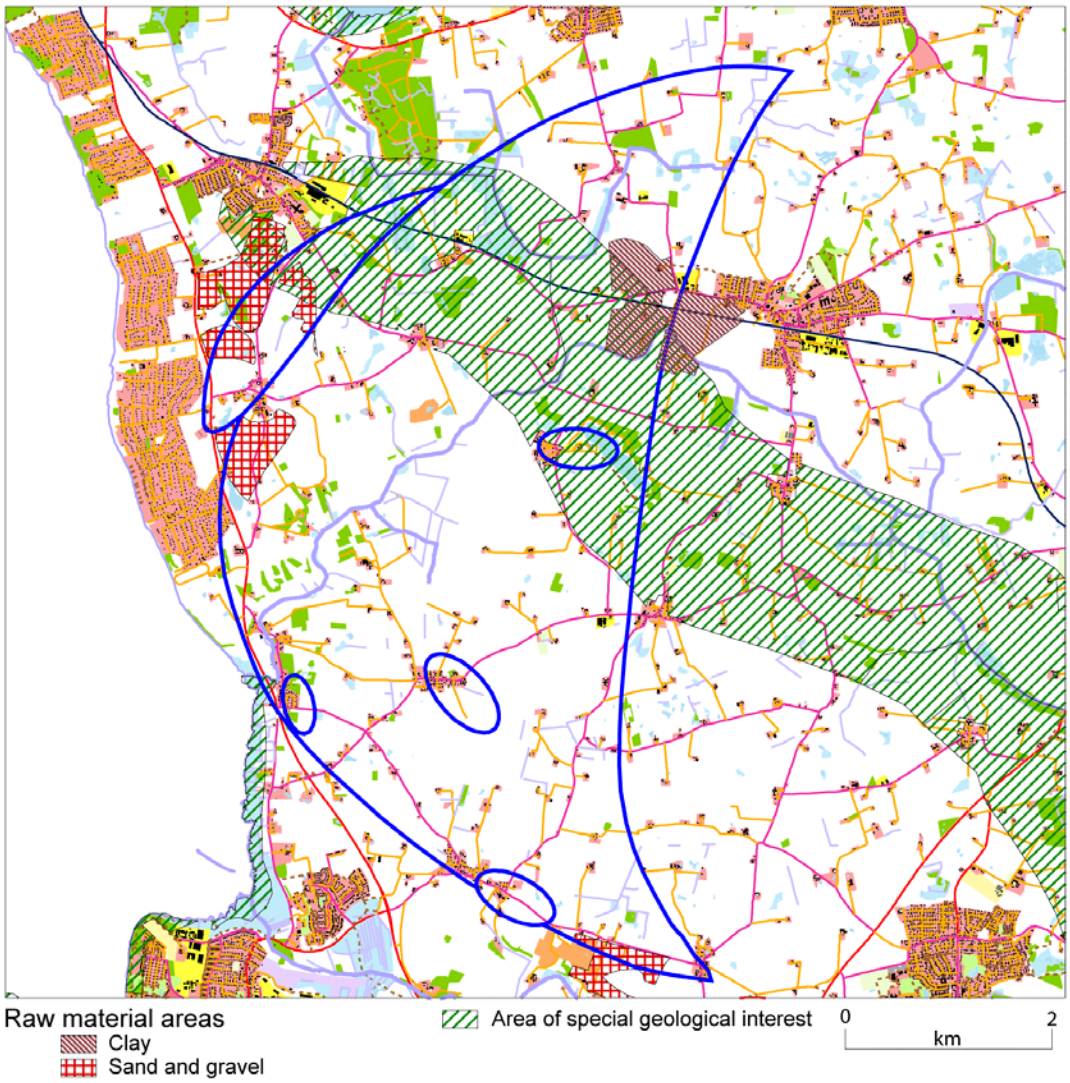

Figure 7.9. Areas reserved for raw material production and special geological interest.

Some farming areas are especially sensitive with respect to pollution of wetlands, surface water and groundwater (Figure 7.10; Frederiksborg County, 2003).

Another type of zone is “Valuable Landscape and Forest” (Figure 7.11), which almost completely overlaps the so-called “SFL” areas (Frederiksborg County, 2003).

The Roskilde Fjord bay area is an EU bird protection and habitats area (Figure 7.12), and the areas surrounding the creeks in the catchment area are designated ecological passages (Frederiksborg County, 2003).

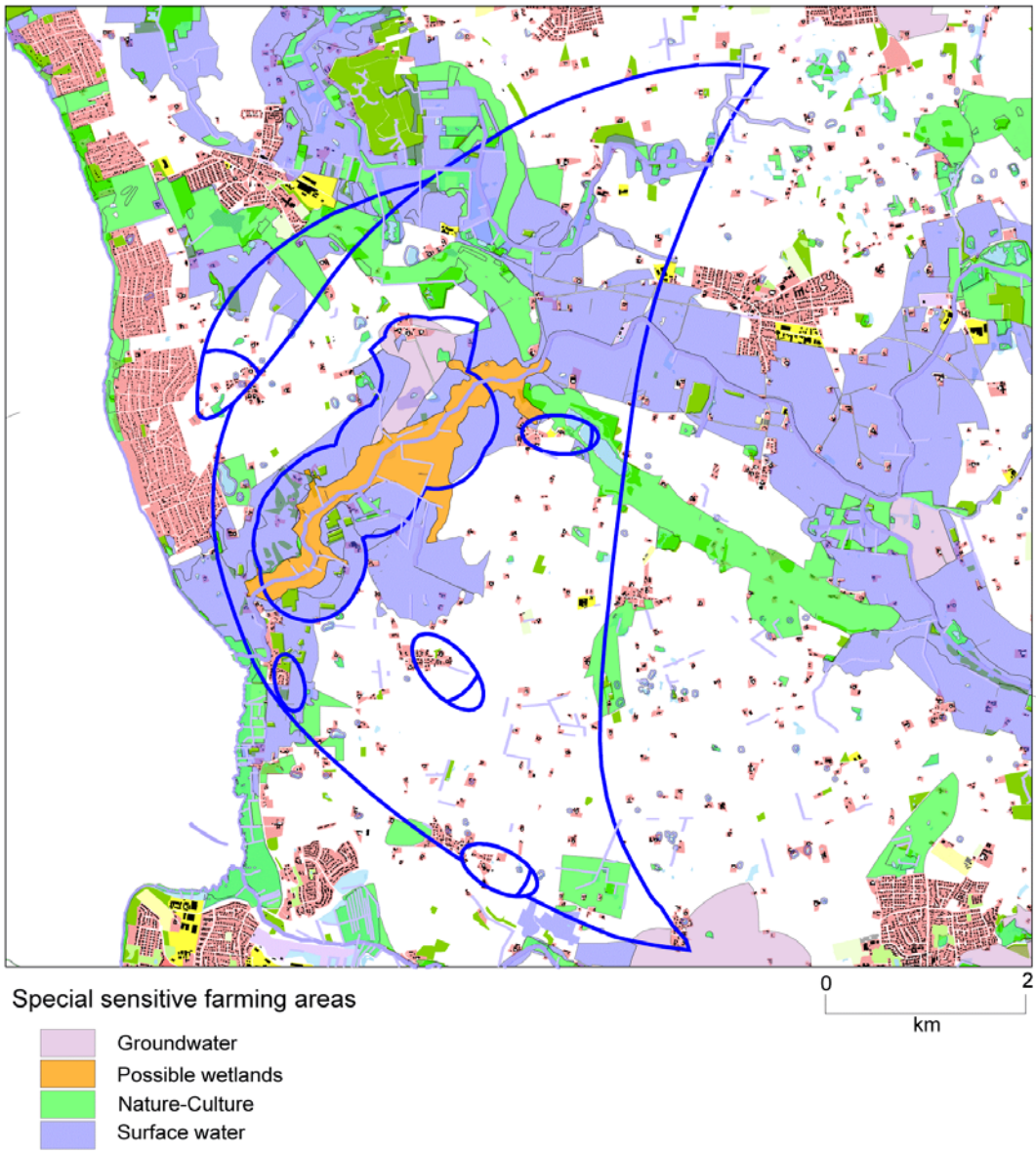

Figure 7.10. Special sensitive farming areas.

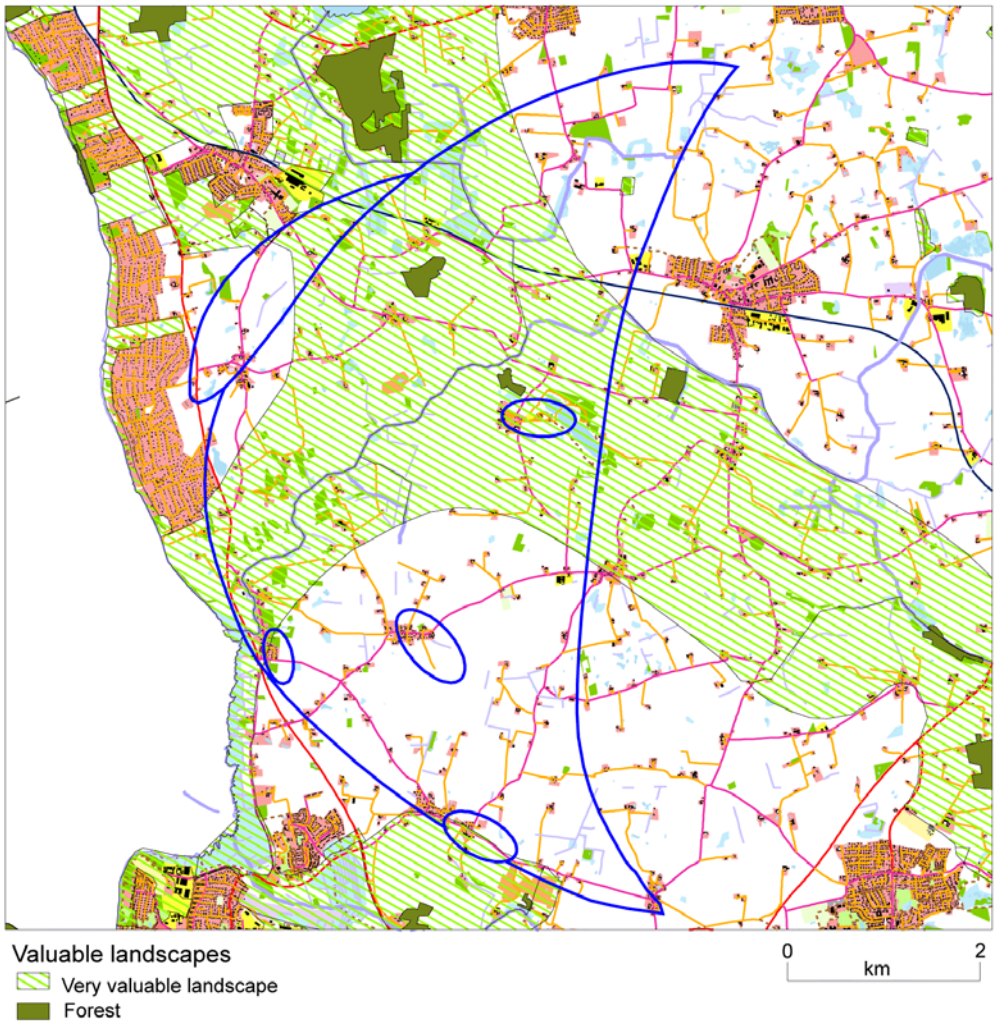

Figure 7.11. Valuable landscapes.

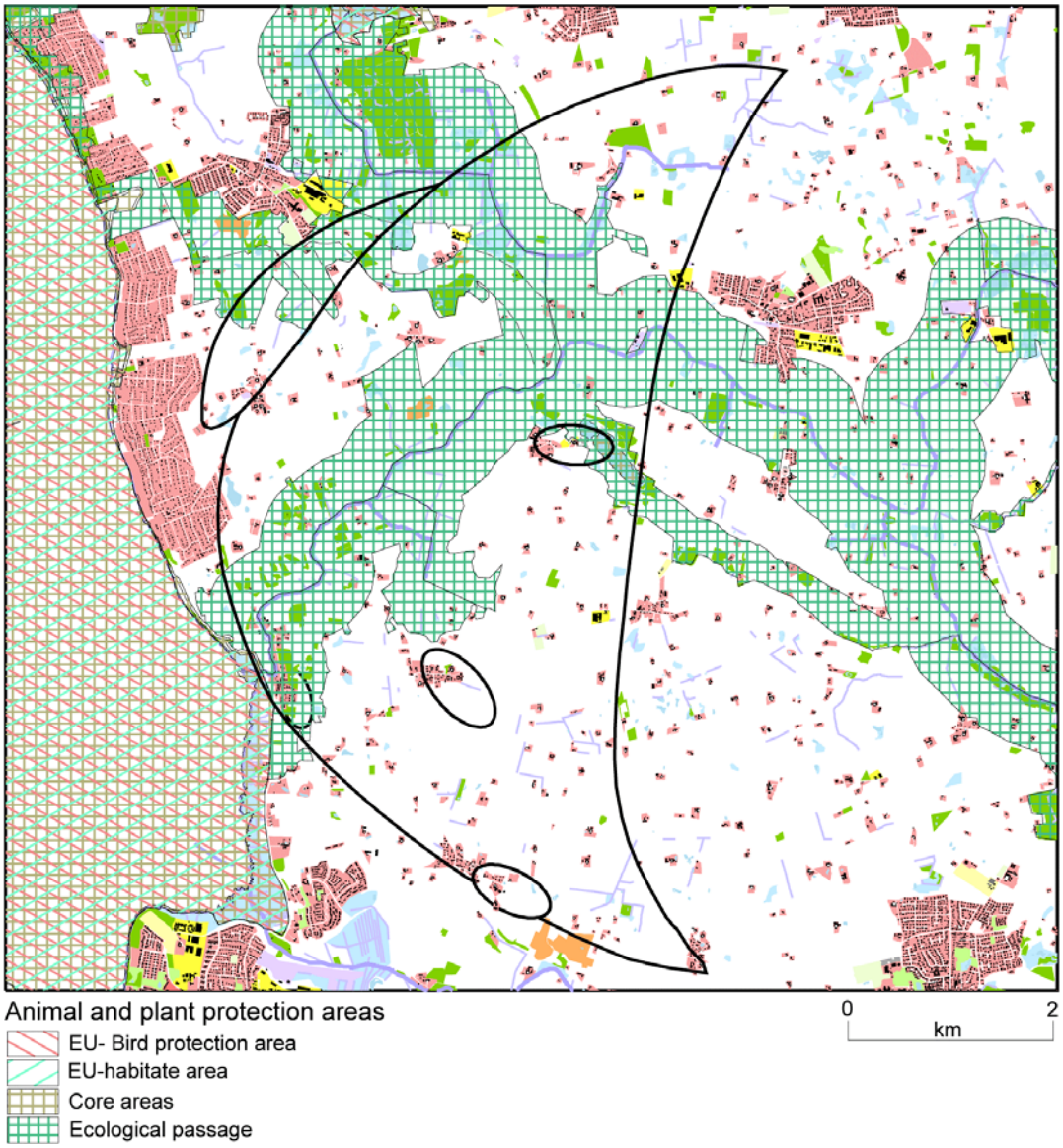

Figure 7.12. Animal and plant protection areas.

A possible way of protect the groundwater is afforestation, but afforestation is not considered desirable in much of the catchment area (Figure 7.13). Only small areas are laid out for new forests (Frederiksborg County, 2003).

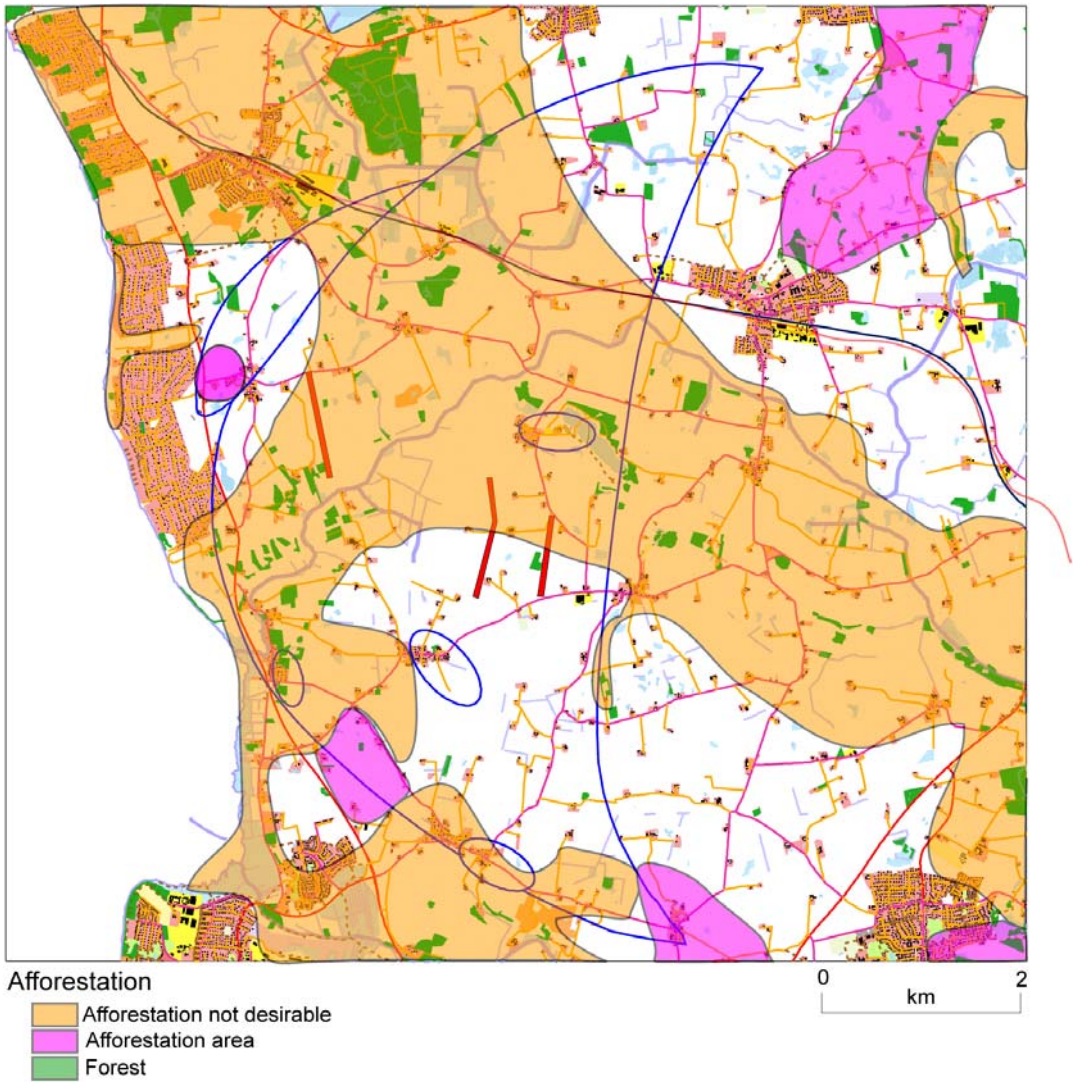

Figure 7.13. Afforestation areas.

7.3 References

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CHAPTER 8 Main conclusions and perspectives in relation to WFD

Hans Jørgen Henriksen, GEUS, Per Rasmussen, GEUS, Gyrite Brandt, CE and Dorthe von Bülow, CE

8.1 Stakeholder engagement

We experienced both successes and barriers in the Danish case study:

Successes

- Many people showed up at the public meeting.
- The citizen group wants to continue beyond the MERIT project.
- Increased level of knowledge on both sides of the table.
- A deeper understanding of pesticide sources and precautionary actions.
- Implementation of cooperative farming contracts is not only a question of money.
- There are new opportunities to establish waterworks cooperation projects in the area.
- There is now cooperation with selected stakeholders about groundwater protection.

Barriers / Problems encountered

- One of the key players in groundwater management did not go wholeheartedly into the project (Frederiksborg County).
- NGOs/environmentalists were weakly represented and had little voice.
- GEUS and CE defended to some extent the role of NGOs/environmentalists.
- The workshops were not the open forum for dialogue we expected.
- Stakeholders in working groups tended to switch to "political mode" very quickly.
- Stakeholders (also) had their own agenda.
- A vocal minority dominated workshops.
- The importance of facilitation at professional workshops was neglected.
- Facilitator costs were high if facilitators were used extensively.

Table 8.1 lists an interpretation of the stakeholder engagement process in the case study with respect to strengths, weaknesses, opportunities and threats (SWOT).

Table 8.1. SWOT analysis of stakeholder engagement in the Danish MERIT case study.

STRENGTHS	WEAKNESSES
Public participation can…	Public participation can be weakened by…
▪ Make use of local and citizen knowledge not known by the authorities ▪ Encourage diverse perspectives (and thus identify issues not thought of) ▪ Enable a better evaluation of the issues	▪ A lack of resources (time, money, staff) ▪ A lack of rules for participation ▪ A lack of in-depth involvement of authorities ▪ A lack of hands-on BBN for the stakeholders ▪ A lack of professional supervision of the stakeholder involvement process
OPPORTUNITIES	**THREATS**
Public participation offers the opportunity to…	Public participation processes can be threatened if…
▪ Build trust and capacity ▪ Empower people by starting a dialogue and improving openness ▪ Expand the limits of understanding (working together to solve problems) ▪ Improve the accountability of stakeholders	▪ The public thinks that the process is a formality (that minds are already made up) ▪ A vocal minority dominates public meetings

If we compare our results with ordinary SWOT analysis for public participation, then we did not experience particular strengths such as “Brings out technical knowledge from the public and others” or “Allows the public to understand the system better”. However, we obtained data not known by the authorities or experts, e.g. in relation to the flooding BBN: a citizen had collected daily climate and river level data and various observations of flooding over a ten-year period. We have also identified issues not thought of such as the barriers to voluntary farmer contracts which we would not have expected if we had based the work solely on expert assessments (e.g. the report prepared by Svend Rasmussen of KVL). Certainly, stakeholder engagement has given CE and GEUS a great deal of valuable experience, both about how to run such processes more efficiently and transparently and how to plan the entire stakeholder involvement process more carefully[8].

An important statement about stakeholder engagement based on our Danish case study experience is as follows:

[8] The citizens’ group gave significant feedback to the draft version of this chapter, see chapter 9.

Statement 1: Stakeholder involvement

*Clear rules of the game are important: it is necessary to prepare a **stakeholder involvement plan** describing how to involve stakeholders and general public which is balanced with respect to problem framing and the type of decision support system used for the planning and/or implementation.*

A stakeholder involvement plan should include the following:

1. Developing a common understanding of problems or concerns
2. Defining goals and objectives, principles and the character of public participation
3. Defining team roles and responsibilities
4. Making a list of stakeholders
5. Evaluating the group's interest and responsibilities (if different authorities are involved)
6. Forming working groups (professional stakeholders and/or group of citizens) and planning public meetings and individual meetings
7. Selecting facilitator(s) for different public and professional stakeholder groups
8. Creating mission statements (terms of reference, rules and responsibilities) for all groups
9. Outlining a time schedule for work in groups/meetings about reviewing milestones
10. Describing resources for implementation of the stakeholder involvement plan
11. Describing initiatives for informing the general public and stakeholders

8.2 Use of BBN

The use of BBNs goes beyond information and consultation and requires the full involvement of stakeholders in their construction and validation. The advantage is a reduced risk of later support by stakeholders during the implementation phase of a given action plan. The benefits of BBNs are greatest when there is a high degree of interaction between researchers, users, water managers and stakeholders (Figure 8.1).

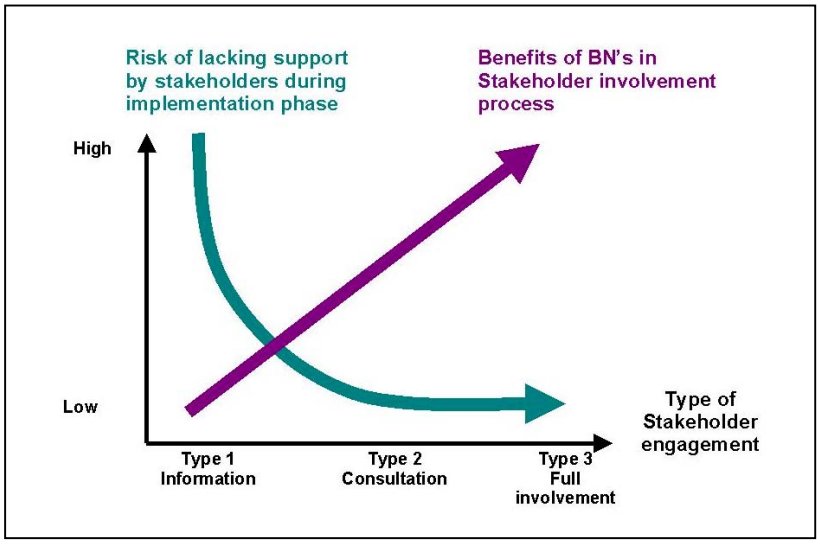

Figure 8.1. Type of stakeholder engagement compared to risk of lack of support and the benefits of BBNs in the stakeholder involvement process.

Problems encountered in BBN development:

- Stakeholder input to networks and probability tables (numbers) required individual meetings. (Workshops were not enough, even if tables were presented carefully.)
- It was not that easy to understand the networks (a way of thinking that requires a little practice), if not properly explained
- Farmers tend to easily understand decisions in which risk plays a role (everyday case).
- Difficult to motivate stakeholders to become involved in BBN development: "BBN is a toy for researchers." "Water managers without hands-on experience with the BBN won't easily understand it."
- Problems with conditional probability tables in different stakeholder groups.
- We did not receive as much input to the BBNs as expected from stakeholders.

BBNs can help formulate environmental management strategies by allowing users to build their own decision support system that meets their needs, helping users to understand the nature of their decisions better, and encouraging users to deal with uncertainty and to consult stakeholders and members of the general public. Without consultation of stakeholders and general public, it is unlikely that you will be able to implement your decision.

Table 8.2 contains an interpretation of BBNs with respect to strengths, weaknesses, opportunities and threats (SWOT) based on experience from the Danish case study dealing with precautionary groundwater protection from pesticide contamination.

Table 8.2. SWOT analysis of use of Bayesian belief networks in water resources planning and management.

Strengths	Weaknesses	Opportunities	Threats
Excellent for structural learning, elegant statistical approach and data mining for analysis of complex systems	Difficult to understand for non-experts	Possible to understand for representatives of general public if explained properly by the specialists	Not easily understood if not properly explained
Easy to develop a BBN with nodes and directed links and update it with input from stakeholders	Feedback nodes are not allowed; some problems in the real world cause strong feedback		
Social and ecological issues can be incorporated and coupled with hydrology	The interdisciplinary approach raises problems with organising knowledge input and data input (academic territories, illusion of techniques)	The opportunity to work with more disciplines	Over-expectations with respect to modelling capabilities
Excellent for strategic considerations (indicators, actions and additional data requirements)			
Expert knowledge and data can be combined and modified/balanced through stakeholder involvement	Requires panel of expert input for all domains => resources and time (equivalent to numerical models)		
Improves conversation/ dialogue with stakeholders	Too much ”hot air”/soft discussion (difficult to govern the process; ”focused stakeholders”)	New problems can be structured and analysed quickly	
Very useful for complex systems	There is a danger that use of BBNs causes ignoring of real data and knowledge		Political manipulation
Excellent for integration and breakdown of barriers between different domains, e.g. economy, hydrology, ecology, social (different time and spatial aggregation)	Not useful for implementation of specific protection zones (physical-based model required)	Holistic approach	BBNs describe an understanding of the system and processes that are not physically based (more information flow than mass flow). Non-linearity not incorporated.
Can be used even if data sets are incomplete	The BBN hides the complexity of the system from the users (underlying conditional probability tables are rather complex!)		
Ability to predict future state of systems based on simplified assumptions	Data manipulation is possible (it is easy to get carried away)	A possible tool when dealing with water managers sceptical about comprehensive models and questioning the need for catchment modelling	Experts do not want to provide input for the conditional probability tables (numbers): defending academic territories!
It is possible to “validate” the importance of value and belief when consulting stakeholders.	BBNs work on “aggregated data” (probabilities). Not possible to utilise all collected data (temporal and spatial variation/information in data)		
Inferences allow fast assess-ment of changes conditions/ evidence etc. => quick tool			

An important characteristic of BBNs is that the tool can be used "interactively" for uncertainty assessment and communication with the stakeholders involved. However, it is important to apply a kind of a "protocol" for BBN construction in order to explain to stakeholders, experts, users, etc. what input is required at different stages of the development. This leads us to our second statement and input for guidelines regarding BBN construction with stakeholder involvement:

Statement 2: Building the BBN model

A protocol for the development of a BBN is recommended. This protocol prescribes seven steps: 1) define the context, 2) identify factors, actions and indicators, 3) build a pilot network, 4) collect data, 5) define states, 6) construct conditional probability tables and 7) collect feedback from stakeholders and general public.

Such a protocol makes it easier for all parties to "play the game" and be aware of when different types of input is required in the construction of the BBNs and how to approach conflict in framing the problem and uncertainties. BBNs may be powerful for this kind of early and useful exercises in relation to preparing a WFD management plan for later implementation.

An example of guidance in uncertainty assessment and communication is found in (Petersen et al., 2003), where attention is paid to the following parts of environmental assessments:

1. Problem-framing
2. Involvement of stakeholders
3. Selection of indicators
4. Appraisal of knowledge base
5. Mapping and assessment of relevant uncertainties
6. Reporting of uncertainty information

Usually uncertainty is only addressed in the last two parts (items 5 and 6). However, the choices and judgements made in items 1-4 are crucial to ascertaining the most relevant uncertainties and communicating about them. According to Petersen et al. (2003), problem-framing includes (i) existing views on the problem other than the client's, (ii) how the problem is interwoven with other problems, (iii) possibly relevant aspects of the problem that are not dealt with in the research questions, (iv) the role the study is expected to play in the policy process, and (v) the way the study is related to previous studies on the subject.

Involvement of stakeholders and general public should provide a clear picture of (a) the relevant stakeholders, (b) their views and roles with respect to the problem, and (c) the problem aspects about which they disagree. On the basis of all this, it is then decided *if*, *how*, and *when* (in the beginning, during or after) and *which* stakeholders and members of general public are to be involved in the assessment.

The most successful part of BBN construction and stakeholder engagement and public participation in our case study – announcements, the public meeting and working groups with professional stakeholders and citizens' group – were in fact the early steps in BBN construction. This included Steps 1 to 4 in our BBN and public participation 'protocol', which was:

Step 1: Define context
Step 2: Identify factors, actions and indicators
Step 3: Build a pilot network
Step 4: Collect data

This more or less corresponds to the four first steps in the Guidance suggested by Petersen et al. (2003).

When we reached Step 5 (define states) and Step 6 (construct CPTs), our approach for stakeholder engagement was malfunctioning until we realised that we had to arrange individual meetings in order to provide the input for the BBN development that was required for the more quantitative part. Again, we believe that a protocol for the seven steps makes it easier to define which steps we should use working groups for and which we should not. This leads to our third statement:

Statement 3: Quantitative input to the BBNs by stakeholders and general public

It is better to involve stakeholders and general public in "temporary" groups or in individual meetings when quantitative input is required, especially when collecting data for BBNs; feedback on states, links and CPTs than it is to run the process with broad, permanent working groups of stakeholders. Structural- and EM learning is encouraged in this process in order to bridge data and the model developed (Steps 4-6 in the BBN construction protocol; see Statement 2 above).

In general BBNs are easy to communicate to stakeholders and the general public, but the quantitative part that has to do with CPTs has to be explained properly. It is, however, possible to show the CPTs and to collect feedback from citizens about the need for adjustments. The fourth statement is therefore:

Statement 4: Don't be afraid of public participation

Don't be afraid of actively involving citizens: but be careful to inform and explain properly about the tasks and goals and do always allow feedback and comments on the BBN development process by presenting the graphical model and easily understood descriptions and results. If representatives of the general public are involved, be sure there is enough time and money to run the process according to the stakeholder involvement plan.

8.3 Problems to look out for

On the one hand, BBNs can create space for an open dialogue with stakeholders due to the flexibility of this decision support tool. This allows an adjustment, reconstruction and validation of factors (nodes), associations (edges) and probabilities (CPTs) in the graphical model throughout the process based on interactive communication with involved stakeholders and domain experts. This means that BBNs are powerful when it comes to integrating data and knowledge from different domains, and they are capable of handling uncertainty in a practical and easily understandable manner. Although the entire stakeholder involvement process may be elaborate, constructing the qualitative part of a BBN seems relatively straightforward. Experts seem to be comfortable with participating in this part of the process.

On the other hand, it is difficult to ensure that stakeholders and general public understand and accept the idea behind BBNs. Especially the probability assessment required for BBNs is not easy for stakeholders and general public to understand or accept without proper explanation. Even domain experts may have problems expressing all these probabilities numerically, and it is something they are often reluctant to do. Thus the quantitative part, the part with the probabilities (numbers), is more problematic.

BBNs are useful for scientists and water managers dealing with complex problems (where there is a lack of process understanding or where it is important to focus on the most important issues and the uncertainty aspects). BBNs permit carefully elicited expert knowledge to be used in developing holistic decision support tools, including ecological and socio-economical endpoints (utilities expressed in monetary units or other types of units). This leads to Statement 5 below:

Statement 5: Applications of BBNs in water management

BBNs are most powerful when integrating different domains, e.g. physical, social, economic and ecological, in the early stages of preparing a management plan with the involvement of stakeholder groups and general public.

The use of BBNs as a dialogue tool in framing the problem, getting the right stakeholders on board as early as possible, selecting indicators, evaluating the knowledge base, and mapping and assessing relevant uncertainties should be encouraged. Planning and implementation of novel actions and regulations for WFD, especially when dealing with interdisciplinary environmental catchment modelling, would be facilitated by such an exercise. Relevant input for the design of the model structure, performance criteria, and data for the calibration and validation of more sophisticated physically based distributed models could be addressed by such BBN pilot studies. In this case, the use of BBNs is more an implementation support system or an action identification system.

As the Danish case study has shown, cooperative farming contracts are not realistic in practice on a large scale, or they are so costly for the waterworks in both compensation and administration that they are out of scope. If we had only asked the expert in farm

economics, this result would never have been the immediate outcome, not because the economic analysis was not correct, but merely because of "social factors" (farmer traditions, values and motivations, and the fact that the farmers' organisations are against farming contracts for various reasons, especially in northern Zealand). The BBN case study provided clearer information on the practical barriers for voluntary precautionary farmers' agreements, information that is essential for CE when the company is forming an optimal policy for groundwater protection for all its 55 wellfields.

The project provides clear feedback to regional authorities and the larger waterworks in Denmark that the way forward should not be based on voluntary agreements that are individually negotiated with farmers. Action planning based on voluntary agreements is a big issue, but in practice when it comes to implementation, they are not useful. It is much better for Copenhagen Energy either to look for possible afforestation areas or to buy land in the well catchment zone, where there is a certain need due to vulnerable areas (expropriation). Another option will be to auction off farming contracts, simply assigning contracts at a fixed price (e.g. EUR 200/ha) to the farmers who have the highest priority with respect to pesticide application and vulnerability.

The results of the Danish case showed that experts are necessary in the process of developing a BBN. Even though things are complex and better tools cannot be implemented (e.g. process-oriented, physically based hydrological models), there certainly is a need for a panel of experts dealing with the issues included in the BBN. In the Danish case this was the case for farm economics, socio-economics and groundwater, but there was a lack of expertise when dealing with biodiversity and aquatic environment issues dealing with impacts of pesticides. This gives our last statement:

Statement 6: Applying BBNs to water management

A panel of experts is valuable in covering each domain included, for providing proper input and/or for reviewing the results from the BBNs developed.

8.4 Future research needs

It was recommended at the last evaluation meeting with stakeholders that the BBNs should cover a broader range of issues. Also incorporated in the BBNs should be more economic issues and issues such as biodiversity and other pollutants (nitrate and phosphorous) that are important in the context of the WFD. A future research project could be to test the proposed guidelines for a larger area, e.g. the entire "HUR" WFD district in northern Zealand), and to investigate the involvement of stakeholders against experience from the Havelse study, which was carried out on a smaller scale. A combined use of numerical modelling, habitat models, economic models and BBNs for analysing the development and implementation of a pilot WFD water management plan would be relevant.

8.5 MERIT concept compared to traditional approaches

Pros

- Locally based solutions (more than before)
- Local acceptance of decisions and solutions
- Improved dialogue between the water company, local stakeholders and authorities

Cons

- Time-consuming and long-lasting process
- Requires experts in stakeholder involvement and in BBNs
- Requires facilitator(s)
- Difficult to define stakeholder roles and influence in decision-making

8.6 Main ongoing CE activities related to the Water Framework Directive

Current waterworks-established cooperation projects : six (involving local authorities [municipalities] and local waterworks [privately and publicly owned]). ***The waterworks cooperation projects include the following activities:***

- Implementing additional groundwater protection
- Preparing additional action plans for groundwater protection where action plans prepared by the county are found to be insufficient
- Entering into farming/land use contracts (has yet to happen)
- Buying land for groundwater protection (based on voluntary agreements)

Waterworks cooperation projects being started up: three (involving local authorities [municipalities] and local waterworks [private and publicly owned waterworks]). The activities listed above under current waterworks cooperation projects will be included in the new ones. The waterworks cooperations have rules and the amount of money paid into the cooperative is dependent on the amount of water each member abstracts yearly. The usual levy is one cent pr. cubic meter abstracted within the cooperation area.

Afforestation areas: eight (cooperation with the Danish Forest and Nature Agency and local municipalities). The Danish state and local municipalities have plans to establish eight afforestation areas for groundwater protection. All the eight areas are situated in the catchment areas for CE's wellfields. The agreement will run until 2032; a sum of roughly EUR 1 million has been allocated to the project per year by CE. Public meetings have been held for each of the areas.

Hydrological modelling: catchment versus wetlands, rivers and streams. CE is constantly running hydrological modelling projects. The modelling is usually performed in connection with wellfield renovations and for risk assessment. During implementation of the WFD, modelling will be focused on the connection between surface and groundwater, especially the effect of groundwater abstraction on creek and river flow. A GEUS thematic report on the entire freshwater cycle points out that water resources are being over-exploited in several areas of the country, resulting in excessive creek and river flow depletion.

Groundwater is apparently being over-exploited in the greater Copenhagen area as well, which may result in the degradation of the quality of groundwater and surface water. Further investigations based on model scenarios of these subjects will be carried out in the near future by CE.

Other initiatives. Monitoring of groundwater quality (a collaboration between CE and local waterworks): monitoring of raw water quality and water quality in the catchment areas are carried out. Monitoring especially wells strategically located as far as groundwater flow and known pollution are concerned is important for early warning systems.

Mapping of pesticide sources (CE, sometimes in cooperation with the local farmers' association): m*apping on a field scale the pesticides used over a ten-year period.* This should be seen in connection with groundwater monitoring (what substances are monitored and what substances should be). The mapping is also used in combination with vulnerability mapping to localise the areas/farms which should be covered by farming contracts to reduce pesticide use.

Closing of old wells and boreholes (waterworks collaboration). Old wells and boreholes that are not in use are threats to groundwater quality. They are often used as rubbish bins or for storing farm chemicals. It is thus of paramount importance that they are closed in the prescribed manner.

Campaigns (about not using pesticides in gardens, etc. have been carried out in the Municipality of Copenhagen and local catchment areas). Campaigns are run in local areas in order to keep homeowners from using pesticides in their private gardens. These campaigns have their origins in the fact that several wellfields in urban areas have been closed due to the use of pesticides on paths, driveways, etc. It is also impossible to convince farmers to stop using pesticides (or at least reduce the use of these chemicals) if homeowners are permitted to use them freely.

Cooperation concerning EU-financed fallow land: CE, the local county, and the farmers' associations). The counties select especially vulnerable farming areas (SFL areas) for which farmers can apply for funds for employing Agri-Environmental Measures (AEM subsidies). The areas are usually vulnerable groundwater areas or denitrification areas. Marginal zones along steams and lakes as well as natural areas with marshy ground are also included in the scheme.

AEM subsidies are a whole series of subsidies to promote natural and environmental farming. Farmers who own land within the assigned areas (SFL) and wish to make an effort to protect natural habitats and the environment can apply for and receive AEM subsidies.

8.7 References

Petersen, AC, Janssen, PHM, Sluijs, JP, Risbey, JS and Ravetz, JR. (2003). RIVM/MNP Guidance for uncertainty assessment and communication. Mini-checklist & Quickscan questionnaire. RIVM – Netherlands Environmental Assessment Agency. www.rivm.nl

CHAPTER 9 Comments from the Havelse Creek Citizens' Group on draft GEUS report entitled "Test of Bayesian belief network and stakeholder involvement"

Hans Jørgen Henriksen, GEUS

The comments are dated 25 May 2004 and marked with '*cursive*'. Answers in 'normal'. This chapter is a translation of answers in Danish to citizens' group 21 June 2004 (GEUS, 2004)

9.1 Re Chapter 0: Preamble

It is a good idea to use "Bayesian belief networks" (BBNs) to process the analogue and digital information collected. The "car start" problem was too simplified for the use it was put to, but the model idea is fine if the necessary model is structured correctly and the various scenarios prepared on the basis of the model provide an adequate explanation of the reasons for selecting the parameters and a comprehensible description of the resultant calculated values and consequences.

It must be remembered that not only researchers and scientists have to be able to understand the consequences, but also politicians and people such as those in the Citizen's Group.

ANSWER
The preamble is thought of like as a kind of appetizer. The 'car' problem was actually used by professor Finn Jensen, University of Aalborg on the first meeting in the professional stakeholder group. That is the reason why it has been used in the preamble. On the other hand we agree about the criticism brought forward by the citizens' group, that the example is not so relevant for the Havelse wellfield case study. Hopefully, we can find better and more relevant examples on the guideline CD, which is a deliverable from the MERIT project. Thus we have incorporated a footnote in the preamble with a link to chapter 9, mentioning the critics by the citizens' group in relation to the 'car' problem.

9.2 Re Chapters 1 and 2

The Citizens' Group would also very much appreciate the opportunity to review these chapters before the report is published so we can see the total work in which we are participating.

We would also suggest, for the sake of readability, that the report start with an explanatory list of the abbreviations and acronyms used. We also hope that the report is carefully proofread for language, grammar and spelling before it is published.

We recommend that the project's steering committee step forward and be mentioned by name in a description of the project's organisation, responsibility and competencies.

Moreover, we ask that the individual authors of the various chapters be introduced by name, with their affiliations and reasons for participation listed as well.

ANSWER
GEUS will write the summary of the report and it is GEUS's responsibility as a research institution that the summary covers the content of the entire report. That is assured through internal quality assurance procedures at GEUS.

The suggestion to include a list of acronyms and careful proofreading of the report is accepted. The report has been proofread using an external specialist for language, grammar and spelling.

The suggestion to let the steering committee step forward and be mentioned by name has been incorporated with description of organisation, responsibility and competencies (included in preamble).

Authors will be introduced by name with their affiliations.

9.3 Re Chapter 3: Introduction

The intention behind the work on and in connection with the BBN model and its results is fine, but it should not be the experts that choose "the best" result. They should present several scenarios with descriptions of the consequences and allow politicians and citizens to choose. As is apparent, unfortunately, several places in the report, some of the experts do not have any great belief in the ability of the citizens' group to understand, provide information and make decisions, and, similarly, we do not believe that some of the "experts" possess it, either.

*You must be very careful that the model doesn't fascinate you so much that you forget that it cannot be used in all situations, and that the model and its results have to be "humanised" **before** its results are used in decision-making. This is especially true with respect to the basis for farming contracts.*

There is a good description of how the work should be done and what should be taken into consideration. We just hope that this does not all come from the references, but from recognised insight.

It is all right for Copenhagen Energy to get some of its water supply for the greater Copenhagen area from Frederiksborg County, but we believe that the effects on the local

area should be taken more into consideration and the greater Copenhagen area should learn to conserve water better.

The chapter does a good job explaining the problems that can arise in the communication between specialists and citizens, but it is the responsibility of the specialist to adjust the information and communication, not the other way around. There are indications that not all the specialists had read and understood what was said in the publications used as references for the report.

The short presentation of the BBN is acceptable, also together with the statements about how it is used and how the results should be communicated with respect to contact with "the non-specialists". A great deal of it was taken from the reference literature, and we will just have to hope that the specialists understand the meaning of the words that were written. It does, however, give one a bit of food for thought that the specialists had decided in advance how much the "non-specialists" should be involved, asked for advice and informed, and how much they should be co-responsible. We hope that the drawing up of the BBN models and collaboration procedures in the three other cases can help make the final model more acceptable than the Danish one.

In general, however, we think that Chapter 3 was fine work, but it seemed to be inclined too much towards study of the literature and contained too little actual contact with the everyday world of the citizens' group.

ANSWER

The project is based on the EU Water Framework Directive guidance documents for public participation, which prescribes different levels of involvement of stakeholders and general public. According to WFD active involvement is encouraged. Information is obligatory both regarding general public and stakeholders, allowing feedback to the basis of decisions. Furthermore, stakeholders must be consulted in relation to water management plans. General public and stakeholders can give input to the basis for decisions, but the actual decision making is in the hand of the water district authority, eg. the responsible regional authority.

We understand that some of the comments to chapter 3 are a result of a mixture of theory (state of the art) and pratice (the actual Havelse case) in the draft report. We welcome the critics from the citizens' group as a constructive input. The chapter has been restructured, allowing theory to be handled first, followed by the practical case study and CE's activities. The protocol is our own product and based on experiences from the Danish case study, not something that we have copied from the literature.

It has never been the intention that non-experts in any way should be kept outside the project arena, or shouldn't be consulted properly when asking for suggestions, information, comments etc. On the contrary, we did what we was able to do by involving members of the general public though the public meeting in Sigerslevøster and the subsequent establishment of the citizens' group.

We later realised that it had been a mistake that the citizens' group had 'their own life'. Next time we will use BBNs, both citizens' and stakeholder groups should definitely be directly

involved in the development of BBNs from the very beginning of the process. Eventually with some hands on training which probably is necessary in order to introduce the groups to the 'magic' of BBNs. Therefore, we have included a footnote in chapter 3 with a link to the comments by the citizens' group (chapter 9).

Water saving is still necessary in Copenhagen. Consumption today is 125 liter pro person per day in Copenhagen (= the average consumption on a national scale). The goal is 110 liter pro person per day. In buildings with water consumption 'meters' installed for trade (pizzarias etc.) the consumption today is as low as 90 liter pro person per day. CE has a 'grant' arrangement for installation of meters in flats. This grant arrangement will continue until 2010.

Water spills (losses) in the supply system (network) in Copenhagen is around 4 % (3.8 %), one of the lowest in the country. The abstraction has decreased from 100 mio. m^3/year (in mid seventies) to 60 mio. m^3/year today.

Copenhagen Energy supplies 19 other municipalities beside Copenhagen municipality.

Water saving campaigns under the HUR water cooperation (where CE is a member) is coming up and will be conducted in autumn 2004.

9.4 Re Chapter 4: Description of the wider water resources management in Denmark

The description of the distribution of responsibility and of water supply activities in connection with, among other things, the registration of abstraction areas seems to adequately covered.

With respect to the involvement of citizens in water abstraction projects and water protection projects, we hope that the authorities will become better at living up to the requirements of the Water Directive. Copenhagen Energy tried in connection with the Havelse Creek matter, but it was a somewhat weak effort which probably should be followed up by a serious informing of each household in the area.

ANSWER
We refer to the letters, which has been send out concerning investigations of location of the new wellfields. The new locations are still negotiated. A groundwater model has been constructed. In the proposal for new field locations four alternatives has been considered, within a polygon delineated by Frederiksborg County.

Issues related to groundwater abstraction and drawdown of groundwater table below sea level (problems with saltwater near coastline) are also discussed with Frederiksborg county.

It is not the case that there has been an agreement between the authorities and Copenhagen Energy, which has caused the flooding of the farmlands. Groundwater

abstraction at Havelse wellfield was stopped due to water quality problems partly related to the flooding of the wellfield area.

The constructed BBNs for the flooding case illustrate a possible coupling of data from Frederiksborg county collected at the gauging station upstream at Strø, from citizen Bjørn Hansen collected downstream and assessments made by COWI consult in relation to the pilot project of establishment of wetlands along Havelse creek.

We agree that this BBN should be further developed to include a number of factors which also play a role like relationship between groundwater abstraction and flooding of farmlands, storm water discharges, farm economics and socio-economics. We didn't go so far within the frame of the present MERIT case study (of various reasons).

We will include a footnote in the chapter with a link to the comments by the citizens' group included in this chapter 9.

9.5 Re Chapter 5: Stakeholder involvement

It was a shame that more didn't come out of those activities. A different, professional management and consultancy before, during and after the meetings could have provided substantially better results. Our first impression was that the specialists did not wish to involve themselves with the citizens.

The chapter has many lists and diagrams that were not discussed but will presumably be dealt with later. It is a too bad for Jan Poulsen that he does not quite manage to describe what he got out of chairing the Citizens' Group meetings.

The origins of Annexes 1 and 2 should be stated.

ANSWER
We have taken the comments from the citizens' group 'ad notam'. We agree, that the process and the meetings should have been better anchored to the steering committee (GEUS and CE) next time, and that the idea to let the citizens' group 'have their own life' wasn't an optimal decision.

There has been included a footnote about this in chapter 5 with at link to this chapter and this comment will also be considered in the recommendations for the use of BBNs.

There will also be included a discussion in chapter 5 which describes the results of the analysis (tables).

9.6 Re Chapter 6: Development of Bayesian belief networks

There is an interesting description of a case in Lyngby (the Lyngby near Aarhus) that describes the means that can be used to reduce groundwater pollution from agriculture, although doubt is expressed that it would be possible to use the same model in the Havelse case.

There is another explanatory introduction to BBNs – a good one – and there are even cited readable references about the model, and it tells you what you should be careful about and how you can use the results in decision-making, and recommends that you remember to consult the stakeholders. So remember to ask the citizens as well.

It says that BBNs are instruments that can be used to deal with theoretical and practical problems with a built-in degree of uncertainty and complexity, and in dealing with the problems achieve results that can be used and can make a decision-making process easier. As an example, it is used to look at the problems in connection with farming contracts aimed at stopping the use of pesticides in groundwater abstraction areas that need to be protected against pollution.

The first draft model for farming contracts is stated as a result of generalised paperwork [literally, “desk work” –translator].

In the presentations for "the professional stakeholders", only one model was provided, and there was no description of parameters; for the citizens' group, the model was not shown: they probably thought no one would be able to understand it.

This has been an overall flaw in the contact with stakeholders: that the specialists underestimated the ability of "the citizens'" to comprehend the significance of the models.

You are going to have to try to agree on whether the "citizens' group" consisted of nine or eleven people. Have a single editor look at the entire report.

Unfortunately, the description of the groups' work and results shows the problems the specialists had communicating with the citizens’ group and even "the professionals".

As described, information from the groups was built into the altered BBN models and presented to "the professionals", but not to the citizens' group – a big mistake that shows a lapse in judgement [literally, “lack of assessment ability to evaluate” –trans.] on the part of the project management.

The results from several of the meetings were poor because information was not provided far enough in advance of the meetings. For example, the BBN models plus the parameters and assessments used should have been sent to each of the participants for their comments before the meeting, and if, for example, the specialists were in possession of data necessary to understand the results, then the data should have been given to the

groups as well. The model can presumably also be handled on a home computer of a reasonable size: a copy on CD would be of great interest.

Actually, it is odd that no feedback situation was used in the model with an optimisation as a result.

Against a backdrop of the comments on clean drinking water, the models should also consider what qualities of water are necessary for human intake, toilet flushing, field irrigation, industrial process water, etc.: water quality is much more complex than it appears from the description in the report.

The comments on results also show that it would be advantageous if more of an effort was made to collect the necessary relevant water-quality data before taking drastic decisions about farming contracts, expropriations or the like.

Moreover, one should know the actual crop cultivation in the Havelse area in detail and be ready to make individual contract calculations.

Where several bars appear in diagrams, they should be coloured.

It is correct that BBNs are a good support tool, but the results must be followed by a detailed description of the parameters used and why, plus a description of the results and their consequences. It is much to risky to allow politicians or civil servants to make decisions based on the "naked" data. So one should rather allow citizens to become more involved (farmers are citizens, too).

It is probably correct that, in certain cases, expropriation is the only realistic solution if the pesticide load is to be reduced.

Using a BBN on Havelse Creek flooding is fine, but the section in the report is messy; the stated units for data must be adjusted (the water current cannot be different by a factor of a thousand at stations 19.80 and 52.08). The figures must be labelled correctly and the Danish text should be removed. Additional work is very much necessary: this chapter may be the most important one with respect to the history and future of the entire area. Also, the information in the May 2004 newsletter from Frederiksborg County about temporarily giving up on wetlands should be included in the report.

We very much agree that more data on water quality, water flow and flooding should be collected and processed. Perhaps it would be a good idea to include Copenhagen Energy's existing data on water abstraction, upstream emissions from Hillerød, for example, and precipitation quantities should be included in the model for flooding. The section numbering should be adjusted.

ANSWER

The citizens' group have provided many good and constructive comments to chapter 6 which we will try to include in the final chapter, by softening and adjusting some of the conclusions and also changing some of the recommendations in chapter 8 for guidelines.

We agree that the citizens' group in principle should have the same weight when it comes to influence and involvement as the professional group of stakeholders. In stead of the warning in the draft report regarding involving members of the general public, we have decided in stead to recommend as much involvement as possible of general public in order to give input to BBN development formulated in the following way:
"Don't be afraid of actively involving citizens: but be careful to inform and explain properly about the tasks and goals and do always allow feedback and comments on the BBN development process by representing the graphical model and easily understood descriptions and results".

It is not correct that the professional stakeholder group only were presented for a single model without parameter descriptions. What happened was, that 'hand-outs' describing CPT's was distributed and discussed for variables and links at the meeting. The BBN was also briefly presented for the citizens' group on one of their meetings, which resulted in comments to the necessary level of compensation payment. We welcome that the citizens' groups express, that they do understand BBNs, and even ask for a closer communication in the construction phase. We have added a bullet in the list of advantages of BBNs:

- "The citizens' group can understand BBN just fine if it is explained properly by the specialists"

Furthermore, we have added an additional bullit in the recommendations / conclusions about the need for involvement of stakeholders and general public (local citizens) in the BBN development:

- "The results of BBNs must be followed by a detailed description of the parameters used and why, plus a description of the results and their consequences in order to make BBNs as transparent as possible. It is much to risky to allow politicians or civil servants to make decisions based on the 'naked' data. So one should rather allow stakeholders and citizens to become more involved"

To the complain raised by the citizens' group that changes in the BBNs were not presented for the citizens' group I can only feel sorry that the timing in the project wasn't optimal and that the delay related to the ask for financial changes to EU, didn't allow time for a proper involvement of the citizens' group in the development of the final BBNs. I agree, it was a mistake, and it was also a mistake that the information before the meetings in the citizens' group was not sufficient for the group work.

I am glad that the citizens' group asks for access to BBNs so that it is easier to participate in the process (from a home computer via Internet or CD-rom).

We can inform you, that we used 100.000 DKR for extra pesticide analysis of groundwater (pesticides) in the Havelse wellfield capture zone.

Your comments regarding actual crop rotation in details and individual contract calculations are relevant and we agree that BBNs only should be used as a tool in the decision making process (not to take the actual decisions directly from the results of BBNs but rather to take better decision based a better understanding of consequences). Furthermore, it is of critical importance that stakeholders and citizens are involved when BBN's are used.

We have included a footnote in chapter 6 with a link to the comments by the citizens' group. Vi note, that the citizens' group recognises, that expropriation in some cases is the only realistic solution to reduction in pesticide application.

The comments to the flooding case are relevant and will be incorporated in the final report. We won't finalise the BBN for flooding, but the suggestions for further development will be described in the report, so that they can be considered in future projects dealing with this topic and action planning in general.

9.7 Re Chapter 7: Data collection for groundwater protection management

Shouldn't "clayey till" be "clayey tilth"? What does "esker" mean?

It is a good idea to include this section, but it seems a bit thin and quickly prepared when you consider how important the pollution data are in the report as a whole.

We would like to hear the reasons why some areas are protected against water abstraction.

Someone should proofread the chapter.

ANSWER
Clayey till is clayey till (in Danish: moræneler). Its ok!

Esker is the English terminology (in Danish: ås). Its ok!

The groundwater pollution data is not included in details, only on a map. The argument for this is that we are dealing with a test of BBNs, which focus on policy, not implementation of groundwater protection zones, thus a more general purpose, aiming to give an overview in stead of giving too many details.

On the other hand, we have decided to extent the description of both existing investigations (both interviews regarding pesticide use and also the voluntarily collected pesticide analysis from groundwater from wells within the area.

For addressing your question regarding protection against groundwater abstraction we refer to Frederiksborg County.

9.8 Re Chapter 8: Main conclusions and perspectives in relation to WFD

Next time the project group addresses this subject, they must be more aware of the fact that the citizens' group is often much more interested than expected (and much better qualified – in some areas perhaps even better and more broadly orientated out of interest than the specialists). For this reason, the project group should do better preparatory work with better information; the citizens' group does not wish to be put off with cursory information. And it sounds as though the work has led to somewhat of an understanding of this.

It is correct that it is best to include interest groups in the BBN model construction phase, but it should be done openly, objectively and from the beginning. Don't keep the citizens' group outside the door because you don't think they understand the topic. Be aware of the fact that the citizens' group is willing to contribute much more volunteer work than you apparently think; you only have to include and engage them. They know that the result of the work will have an impact on their own situation, and the specialists should not forget that many members of the general public are extremely well qualified when it comes to finding information on the Internet. The old specialist world is changing.

The citizens' group can understand a BBN just fine if it is explained properly by the specialists.

Yes, it is true that BBN models in which no feedback is used have a problem, but that is something that simply can be changed in the model. (See how it was used in the "Limits for Growth" model.)

Unfortunately, it is correct that decision-makers and others have a tendency to use the results from models without understanding their background and consequences, which is why models can be dangerous. Just look at how politicians misused or ignored the "Limits for Growth" warnings.

Overall, however, we believe that BBN models are necessary tools in many complicated decisions.

The project group statements are a good thing, but a few of the essential considerations of making parameter input and the results comprehensible to and useable for decision-makers and the citizens [the Danish phrase can also mean “the general public” or “the citizens’ group –trans.] were lacking. Also, it is not only the interest group participants that should be "selected" with care: the participating specialists should be screened as well. It would especially be a good idea if the specialists were to describe the model, background and structure on the basis of their own understanding and not so much on the basis of quotes from references. A little more respect for the citizens [see above –trans.] would be becoming.

It is correct that specialists are essential in preparing the BBN models, but it is an absolute necessity that the citizens take part as well – and this is where the project group has to get a handle on the expression of its statements rather than shifting from participation-is-essential to participation-is-not-desirable. There is no doubt that the project group and the report authors need to have one or more critical voices read through the report before it is published.

Although the northern-Zealand countryfolk will not come to heel voluntarily, the BBN model does, however, show some of the way and shows a little of what can be achieved and what has not been taken into consideration. For example, what do you do if earnings per hectare from speciality crops exceeds the compensation granted twentyfold?

It is interesting to read about Copenhagen Energy's activity plans. We of the citizens' group expect that we will be kept informed, and we hope that the local residents in the affected water abstraction areas will be kept informed through the local press, door-to-door handouts or the like.

ANSWER

I think that many of the comments raised by the citizens' group about conclusions in chapter 8 are relevant. Conclusions will be adjusted in order to incorporate comments by the citizens' group in the final report:

- The citizens group ask for a better structured information and wants to take a role as an active player in the process also when it comes to construction of BBNs
- The citizens can understand BBNs, if properly explained
- BBN-models are in general necessary tools for many complicated problems (but they can eventually be misused if results are used uncritical)
- It is important to make parameter input and results understandable for stakeholders and citizens

In addition a footnote has been incorporated in chapter 8 with a link to the comments by the citizens' group.

9.9 Re Appendix 1: Economic loss on conversion to pesticide-free crop cultivation in the Havelse abstraction area

It is great that the Appendix states that the basic data must illustrate the use of BBN models and not show the actual situation. For this reason, it is also acceptable that all data are based on average figures that do not have their origins in the actual area itself. There is some text missing at the top of page 4. We recommend proofreading.

Where crop prices are stated, it is worth noting that they are now DKK 1.10 per kilo. It would also be worth the trouble to adjust to match the changes/pending changes in EU agricultural policies.

When reading Tables 1a, 1b and 1c, it would be nice to have a description of what "treatment index" is defined as, and not just have a reference be cited.

Where the DB2 in the case of "pesticide-free" cultivation is stated, there is a perfectly good reference to the loss figures, but this is where the chain really falls off the bicycle: when these figures are then subsequently used to illustrate the actual situation of financial loss in the conversion to pesticide-free cultivation in the Havelse wellfield. The beautiful thoughts expressed in the introduction have fallen away.

There should be consistency in the numbers used. It is wrong to state in this report figures for losses that would be suffered by crop farmers and cattle farmers if they convert to pesticide-free farming, since the statistics behind these figures are not relevant to the field. Such numbers are always misused by decision-makers, and the article itself is used as a reference (just look at Appendix 2).

Setting up the various compensation and contract models is fine, but, for example, the effect on the market value of the property is forgotten, as is the loss of the option of converting from standard crops to speciality crops. Perhaps the changed work situation of the individual farmer should be considered more as well, and the changes in his daily activities when his cultivated area is reduced in size or used for different purposes.

The calculation examples are highly theoretical and do not, for example, take into consideration the changed values of the different crops, inflation, etc., which happens in actuality, but, well, it is a purely theoretical chapter.

The conclusions about variations between the different farms, their losses and their motivation are very daring and uncertain. It should be rewritten.

Farmers' desire to take upon themselves a change in the work they do must also be included in the assessment of farmers' willingness to convert to pesticide-free cultivation.

It may sound acceptable that society, Copenhagen Energy or the county buys the properties, but it is a political question whether this land should be converted from private to public-sector ownership.

Table 10 must be set up correctly. It is wrong to state exact, seven-digit numbers in the examples shown: the material does not permit that degree of precision. This degree of exactitude will always be taken for the truth. It is frivolous to juggle numbers this way in a certain area and make it look like a solution to an actual situation, since a field investigation would show that farmers are not motivated at all to sign the contracts described under the conditions described.

The afterword is fine, but could contain an extra remark that the entire chapter should be considered a theoretical case and has no actual value in relation to the Havelse wellfield situation.

By the way, Appendix 1 should be translated into English if it is to be part of the report.

ANSWER

We don’t have the required resources in the project to translate Appendix 1 nor to adjust the input. It would have been an advantage if the comments to the appendix had arrived a

bit earlier. It was finalised for nearly a year ago. So we simply have to include the appendix as it is (in Danish) in the final report for the CD.

Comments with relevance for BBNs and the report will be incorporated in the final report (the same will be the case for Appendix 2), and the comments by the citizens' group will also be mentioned in chapter 9.

Most of the comments are welcomed, because they can help the reader to understand why the level of compensation payment has to be so high in order to implement such voluntary agreements.

Since the data used are the official data from Denmarks Statistik we believe that they covers the real world in relation to the work done by Svend Rasmussen in the project.

If GEUS can find the time for it we shall try to translate to English over the summer period, at include Appendix 1 (and 2) in English in the printed version available in August.

9.10 Re Appendix 2: Economic analysis of abstraction strategies for groundwater in the Havelse Creek catchment area

The introduction to the analysis seems serious, proper and well-considered. It should be proofread.

Unfortunately, we note that the analysis makes use of the faulty data in Appendix 2, which means that the "exact" numerical values of the work are irrelevant in practice. However, the estimates could be used in the comments.

The remarks on farming contracts and set-aside programmes are fine and the most serious ones in the report, but, as mentioned above, the figures cannot be used in practice.

Afforestation is no longer relevant for farmers as an alternative occupation today.

The section on economic analysis, with its pricing of environmental effects, is excellent and adds some comments to the report that should be included, with a bit of politics added, in the decision of where the next wellfield should be, but it does not solve the issue of generally ensuring clean drinking water. However, afforestation at Græse Bakkeby sounds like the best solution for locating a new wellfield while establishing a new wellfield. This is a high-lying area as well, and thus one able to avoid pollution by surface water.

Appendix 2 should also be translated into English.

ANSWER
Same answer as for Appendix 1 (regarding translation).

The mentioned afforestation is financed by public sources (state/municipality). The groundwater modelling has shown that it is not feasible to locate the new wellfield in the delineated are for afforestation (risk of saltwater intrusion). This is the reason why

afforestation no longer is a relevant cooperation project between Danish Forest- and Nature Agency and CE.

9.11 Re Appendix 3: When citizens are to be involved: From water in the basement to Bayesian networks

The issue of how much the general public should be involved in public-sector tasks in which "professionals" and specialists are also involved receives an excellent treatment in this appendix. We are very strong advocates of citizens being involved much more than normally is the case, but such involvement should involve open and adequate information, acceptance of the fact that it takes time to get people to become actively involved, and respect for the fact that citizens can contribute valuable knowledge or evaluations.

Thank you for the quote.

Appendix 3 should also be translated into English – after proofreading.

ANSWER
Fine comment. We will include it in the new chapter 9 and in the conclusions. Appendix 3 will be translated into English, because we consider this Appendix as an important contribution to the understanding of the Danish case (all contributions regarding the citizens' group e.g. Appendix 3, 4 and chapter 7 will be translated into English). The reason for this is that we want to communicate the results to EU.

9.12 Re Appendix 4: Contribution from the Havelse wellfield citizens' group

We have no comments: it is our own contribution.

We hope that the comments above on the draft report we received will be taken seriously and utilised.

We also believe that the project participants may not have been ready until now to set up the right BBN model, and that the values achieved and ideas about the contract model are unsuitable for solving the task at hand. Only with individual agreements will it be possible to ensure clean water.

We are very sure that there is a risk that the report will be misused.

Allow us also to draw your attention to the fact that citizens with a minimum of schooling might need an explanation of foreign loan words used by "professionals" and specialists, but that the same citizens may still possess a knowledge and understanding that could result in valuable and necessary modifications in the comments and models derived from studies of the trade literature.

The citizens' group is interested in learning how much in subsidies the EU has contributed to the Danish MERIT project and who has received these subsidies.

We expect to receive feedback on the comments above and information on the use to which they will be put.

ANSWER
Appendix 4 (from the citizens' group) will be translated into English.

In principle we agree that the participants in the project now are ready to develop the correct BBN model or rather, capable of planning the work in doing so including a proper involvement of stakeholders and citizens in the process in structured way for the purpose of developing BBNs (compensation payments).

In reality, it is not simply a deskwork. The final BBNs reflect the feedback from the field, both from citizens and stakeholders.

The steering committee does not understand the comment that there is a risk that the report will be misused.

When it comes to financing then EU has contributed with about the half of the costs, GEUS contribute the another half as an applied research institute (sektorforskningsinstitution). In addition Copenhagen Energy has made a significant contribution for their part both in form of used time for staff persons and also for travel costs for meetings (in EU), and costs for pesticide investigations in groundwater and reporting these data (DKR 100.000).

The contribution from EU was in total 200 K. EURO (1.5 mio DKR).

Hans Jørgen Henriksen
21 June 2004

9.13 References

GEUS (2004) Svar på kommentarer fra Havelse å borgergruppe. Miljøministeriet. GEUS. 21. Juni 2004 (in Danish).