WATER RESOURCE ACCOUNTS AND ACCOUNTS FOR THE QUANTITY AND VALUE OF ECOSYSTEM SERVICES CONNECTED WITH THE DANISH WATER RESOURCES

Methods and Requirements

Scientific Report from DCE – Danish Centre for Environment and Energy No. 116 2015

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Abstract: The report explains how a water resource accounting system can be structured and the possibilities of making Danish freshwater resource accounts are discussed. The accounting system includes five accounts of quantities of water flows, quantities of water stocks, emissions of pollutants, water quality and the value of water resource related ecosystem services, respectively. For each account it is discussed if necessary data are available for making Danish water resource accounts. It is also discussed if and how different water resource related ecosystem services can be valued. Finally, different possible uses of the water accounting system are discussed. It is concluded that if necessary resources are available flow and stock accounts could be published within 1-3 years, while the possibilities of including emission accounts and water quality and status accounts are difficult to determine.

Keywords: National accounting, water resources, water flows, water stocks, emissions to water, water quality, ecosystem services, valuation

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Preface

This report *Water Resource Accounts and Accounts for the Quantity and Value of Ecosystem Services connected with the Danish Water Resources: Methods and Requirements* is made in collaboration between Danish Centre for Energy and Environment (DCE) and Statistics Denmark with financial support from the Ministry of the Environment. The project has also been supported from Aarhus University as part of the Ecosystem services project ECOSYS, cf. Termansen et al. (2014). The content of the report has been produced in cooperation with the EU FP7 project EPI-Water, cf. Møller et al. (2014).

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Summary

This report describes how a national account based water resource accounting system can be structured and discusses the possibilities of making Danish water resource accounts. The possibilities of making an account of the value of water resource related ecosystem services are also discussed. The approach described in the report is based on UN's guidelines for a national account based water resource accounting system, cf. *System of Environmental Economic Accounting for Water*, United Nations (2012a).

For the purpose of the present study the water resource is defined to include groundwater and surface water but not marine waters. This is in accordance with previous work on water resource accounts, which have mainly focused on groundwater and surface water. Marine waters are very different from both groundwater and surface water and are best handled within a separate accounting system.

The national account based water resource accounting system includes five separate but interconnected accounts:

- Annual water flows – annually extracted, consumed and discharged quantities of water
- Annual stocks – quantities of groundwater and surface water available
- Annual emissions of pollutants to groundwater and surface water
- Annual account of water quality and ecological status of different parts of the water resource
- Annual value of water resource related ecosystem services and the value of the total water resource.

A water resource accounting system can also include an account of the economic costs of extraction, treatment and distribution of water. The economic account indicates who pays the costs and specifies the taxes and subsidies related to the use of water. However, the economic account is not considered in this report; instead focus is on water amounts, water quality, ecological status and water related ecosystem services.

The five accounts are linked to each other. Supply, consumption and discharge of water which are stated in the water flow account determine the amount of water available (i.e. the stock account) and along with annual emissions (i.e. the emission account) the quantity of water influence water quality and the ecological status of the water resource. Finally, ecological status together with total quantity and type of use influence the provision and value of water resource related ecosystem services.

To analyse the relations between accounts it is important that all accounts are constructed similarly in terms of the breakdown of industries, demand and geographical areas into categories. As far as possible, the breakdown of emissions into different pollutant categories should correspond to the categorization used in relation to the water quality indicators and indicators of ecological status that are used in the water quality account. Also the breakdown of demand categories, emissions and water quality indicators should be closely related to the different ecosystem services. By using the same division of industries and demand categories as used in the traditional nation-

al accounts it is ensured that the water resource accounts - including the account of the value of ecosystem services – can be integrated with the national accounts. This integration of water resource accounts with traditional national accounts is a prerequisite for being able to make environmental macroeconomic analyses.

The different water resource accounts are discussed in detail in Chapter 3. In Section 3.1 water quantity accounts are discussed and it is shown how tables for water flows and water stocks can be structured, respectively. In Section 3.2 it is described how a general accounting table for emissions to water can be structured. The table can be made for every pollutant that is regarded as relevant in relation to water quality and ecological status. The construction of an accounting table for water quality and ecological status is discussed in section 3.3. This table can be structured in different ways depending on the choice of indicators for water quality and ecological status and on the geographical division used in the assessment. Finally, in Section 3.4 different water resource related ecosystem services are identified and it is discussed how the value of the services can be incorporated in a table specifying supply and demand of the services and a table specifying the value of the water resource capital, respectively.

Water resource related ecosystem services include services within the following three main categories of services - cf. the CICES classification in European Commission (2013):

- Provisioning services
- Regulating services
- Cultural services

Besides these services the CICES classification also includes supporting services. Supporting services are fundamental ecological processes, and they are a precondition for ecosystems to be able to supply the three services listed above. Although supporting services are fundamental for the functioning of ecosystems they can be disregarded in an accounting context where focus is on the value of ecosystem services to the human society. Hence, the value of these services is included in the value of provisioning, regulating and cultural services.

The provisioning services of the water resource include the extraction and consumption of groundwater as well as surface water by industries and households. The services include both the extraction of drinking water and the extraction of water for process purposes – e.g. irrigation.

The regulating services of the water resource are related to the emissions of pollutants to the water environment. Hence, to a certain degree, the water resource is capable of breaking down and assimilate pollutants. This represents a valuable service to the human society because it implies that human beings through economic activities within certain limits can pollute the water resource without inflicting welfare losses on society due to deterioration of water quality.

The cultural services of the water resource relates to the possibilities that the water resource provides households in relation to different recreational activities such as angling, hunting, swimming and sailing. In addition to this the possibility of using the water resource for scientific purposes and education also represent cultural services.

The annual value of the different services can be stated in an account where it is also stated how use of the different services is distributed across specific industries and households. The capital value of the water resource and the changes in this value can be calculated as the present value of the present and expected future services. This capital value represents a part of total nature capital and it is stated in a capital account.

Both the annual and capital accounts of the value of ecosystem services presuppose that the different services are valued. In Chapter 4 the principles and methods of economic valuation are described, and the possibilities of making accounts of ecosystem services in practice are discussed.

The provisioning services of the water resource have a direct use value, and in many cases these services can be valued on the basis of market prices associated with water use. In the cases where no market prices exist alternative valuation approaches can be adopted. Thus, the average of the existing market water prices can be used as the accounting price of water or it can be calculated on the basis of the costs of extracting water if data is available. Finally, it is possible to value the provisioning services of water on the basis of the resource rent that is generated by the use of water e.g. in the production of agricultural products.

Regulating services may give rise to indirect use value in the sense that production costs in some industries are reduced because pollutants can be discharged to the water resource without degrading water quality and ecological status of the resource. In the same way, the regulating services of the water resource may reduce households' expenses for water treatment. The saved costs of industries and households can be used as basis for valuation of regulating services.

Finally, cultural services represent use value especially for households. The value can be estimated by using a number of different direct and indirect valuation methods that have been developed. However, it is a problem that many of the methods are developed for the purpose of valuation in relation to well-defined projects. It is therefore questionable if the results from such studies are suitable for use in an accounting context.

The values of the different annual ecosystem services make up the basis for the annual accounts stating the value of services supplied by the water resource and demanded by industries and households. The values can also be used to calculate the capital value of the water resource. The capital value is calculated as the present value of present and expected future annual services. However, the present value of the annual flows of ecosystem services only represents the direct and indirect use value of the water resource. Hence, in order to calculate the total capital value of the water resource the option value and the non-use value of the resource must be added. Option and non-use values, however, are difficult to estimate with the existing valuation methods.

The five accounts of the total water resource accounting system referred to above can be used as basis for different kind of analyses which are discussed in Chapter 5. The different analyses include:

- Environmental indicator analysis
- Ex post analysis
- Input output based ex ante scenario projection
- Generation of macroeconomic water resource models, consequential analysis and forecasts
- Evaluation of sustainability on the basis of Genuine Saving

The water resource accounting system provides information that can be used in an environmental indicator context. The information on the distribution of water use across economic sectors can be linked with information about production in the same sectors from the national accounts and in this way it is possible to evaluate e.g. how the effectiveness with regard to water consumption has evolved across sectors. Similar analyses can be made for emissions of different pollutants to the water resource. The information in the water quality accounts in itself indicates how the state of the water resource evolves. Finally, the values in the accounts of ecosystem services indicate how the state of the water resource in general evolves. If the value of the annual ecosystem services increases and the capital value of the water resource is non-decreasing this means that the state of the water resource in general has improved.

Ex post analyses can be used to examine the causes of changes in emissions to water, the quality of the water resource and its ecological status and the value of the water resource related ecosystem services. If the information from the water resource accounting system is linked with economic information from national accounts it is possible to determine the extent to which the changes in the use and state of the water resource are caused by changes in production structure, consumption structure and/or emissions per produced unit. Furthermore by use of economic models it may be possible to determine to which degree the changes in structural conditions are caused by economic policy and other economic changes, respectively.

Input output based scenario projection analyses are based on the input output accounts of the national accounting system. On the basis of these accounts the direct and indirect consequences for production in all industries of a change in consumption or investments can be estimated. The production changes can be linked with the emissions accounts of the water resource accounting system to assess the consequences for emissions. However, to estimate the subsequent consequences in relation to water quality, ecological status and value of ecosystem services specific biological models are needed. The simple input output based emission projection analyses can be developed and improved by estimating proper macroeconomic water resource models. The linking of the water resource accounting system with national accounts forms a strong basis for developing such models.

Finally, information about the value of ecosystem services in the water resource accounting system can be used to calculate the genuine saving of the society. Genuine saving is an economic sustainability indicator. It is calculated as NDP + value of regulating services not included in value added + value of cultural services – value of defensive measures – depreciation of nature capital – (value of private and collective consumption and consumption of cultural services).

In the concluding chapter the possibilities of making Danish water resource accounts are discussed. In this connection the availability of data is also discussed.

There are two important data sources relevant for estimating the annually extracted and consumed quantities of water, namely the JUPITER data base from GEUS and DANVA's data base, cf. Section 6.1. Information on the quantities of water discharged to the water resource from water treatment plants and other point sources is collected as part of the NOVANA program and is available in the PULS data base from the Nature Agency. In the period 1995 – 2005 these data sources have been used by Statistics Denmark to make physical water accounts for Denmark. These accounts are presented in Section 6.5. It should be possible to recommence the publication of these accounts. In this connection, however, it is relevant to consider restructuring the accounts in terms of the underlying economic sector division and a geographical division in order to make the accounts more suitable for the analysis of water resource problems.

The data sources used for assessing annual water flows can also be used to make the annual accounts of the quantity of groundwater and of the changes in groundwater reserves. By contrast, data is not available for making similar status accounts for surface water.

Information about the annual emissions of pollutants to groundwater and surface water is also collected as a part of the NOVANA program and it is published in the PULS data base of the Nature Agency. Information about airborne emissions from foreign countries that influence the Danish water resource is collected and published by HELCOM and OSPAR. Therefore the data basis for making the emission accounts is assessed to be strong - cf. Section 6.2. However, a comprehensive work needs to be done in terms of specifying which pollutants accounts should be made for and in terms of determining the relevant sectoral and geographical levels of the accounts.

It is expected that status accounts of water quality and ecological status for different parts of the water resource can be constructed based on data on ecological status collected as a part of the NOVANA program and data about water quality available in the JUPITER data base - cf. Section 6.3. However, the existing data need to be thoroughly scrutinized in order to decide which data for water quality and ecological status is most appropriate to use in the water resource accounts. Moreover, problems with regard to geographical division of the accounts and division into different water resource types – e.g. lakes, streams, wetlands et cetera – need to be clarified before the accounts can be constructed.

Finally, in Section 6.6 it is concluded that the possibilities of making a complete account of the annual value of water resource related ecosystem services are very small. Thus, information about the size of a number of regulating and cultural services is relatively sparse and the possibilities for valuing the services are limited. In addition a number of methodological problems remain to be solved. Which valuation approach should generally be used – willingness to pay based valuation or cost based valuation? Can results from project related valuation studies be used in an accounting context? These and other problems are discussed in relation to two Danish valuation studies: valuation of cultural services supplied by Odense and Roskilde Fjord and valuation of protection of ground water. It is concluded that currently it is only the provisioning services of the water resource that can be estimated and valued.

In summary, the screening of the data available for constructing a Danish water resource accounting system indicates that except for the ecosystem services accounts the possibilities of making water resource accounts for Denmark within a small number of years are relatively good. The most important challenges seem to be related to determining which economic sector division and geographical division that should be used in the accounts. Hence, the challenge is to identify an aggregation level that is both environmentally relevant and match the possible aggregation levels in the national accounts. With regard to the ecosystem services accounts the time-horizon is likely to be significantly longer as it will take longer time not only to produce the necessary data but also to find a solution of the methodological problems related to the valuation of the services.

Sammenfatning

Med udgangspunkt i FN's retningslinjer for et nationalregnskabsbaseret vandressourceregnskab, cf. *System of Environmental Economic Accounting for Water* (United Nations, 2012a), redegør denne rapport for, hvorledes et sådant regnskab kan bygges op, og mulighederne for at opstille et dansk regnskab diskuteres. Diskussionen vedrører også mulighederne for at opstille et regnskab for værdien af vandressourcernes økosystemtjenester - en problemstilling, som i de senere år har fået stigende international opmærksomhed, og som endnu ikke har fundet sin endelige løsning i form af egentlige retningslinjer.

I rapporten omfatter vandressourcen grundvand og overfladevand, dvs. søer og åer, men ikke den marine vandressource. Baggrunden for denne begrænsning er, at det hidtidige arbejde med vandressourceregnskaber overvejende har været rettet mod grundvand og fersk overfladevand, samt at den marine vandressource på grund af forskellen til de øvrige vandressourcer formentlig bedst belyses i et selvstændigt regnskab.

Det i rapporten fremstillede samlede nationalregnskabsbaserede vandressourceregnskab består af fem delregnskaber:

- Årlige vandstrømme - årligt udvundet, forbrugt og udledt mængde af vand
- Årlig statusopgørelse over mængden af grundvand og overfladevand til rådighed
- Årlige emissioner til grundvand og overfladevand
- Statusopgørelse over vandkvalitet og økologisk status i forskellige dele af vandressourcen
- Den årlige værdi af vandressourcerelaterede økosystemtjenester samt status for værdien af vandressourcen.

Det samlede vandressourceregnskab kan også omfatte et delregnskab for de årlige økonomiske omkostninger ved udvinding, rensning og distribution af vand samt rensning af spildevand. Det økonomiske delregnskab viser også, hvem der afholder omkostningerne, og hvilke afgifter og subsidier der er knyttet til udnyttelsen af vandressourcen. Dette regnskab er dog ikke behandlet i indeværende rapport, der er koncentreret om vandmængder, vandkvalitet, økologisk status og økosystemtjenester i tilknytning hertil.

De fem angivne delregnskaber er indbyrdes forbundet. Tilførslen, forbruget og udledningen af vand, som registreres i vandstrømsregnskabet er bestemmende for statusopgørelsen over mængden af vand til rådighed, og denne har sammen med de årlige diffuse emissioner og emissioner fra punktkilder betydning for vandkvaliteten og vandressourcens økologiske status. Denne har endelig sammen med størrelsen og formålet med de forbrugte vandmængder betydning for værdien af vandressourcens økosystemtjenester. For at kunne analysere disse sammenhænge ud fra regnskabsoplysningerne er det vigtigt, at der anvendes den samme erhvervsopdeling, efterspørgselsopdeling og ikke mindst geografiske opdeling i de enkelte delregnskaber. Opdelingen på emissionstyper bør også så vidt muligt modsvare de valgte vandkvalitetsindikatorer og indikatorer for økologisk status, som benyttes i vandkvalitetsregnskabet, ligesom opdelingen på efterspørgselskategorier, emissionstyper og vandkvalitetsindikatorer så vidt muligt bør have nær relation til de forskellige typer af økosystemtjenester. Ved at anvende den samme erhvervsopdeling og opdeling på efterspørgselskategorier, som i nationalregnskabet, sikres det, at det samlede vandressource-regnskab - herunder også regnskabet for værdien af økosystemtjenester - kan integreres med dette. Dette har stor betydning for mulighederne for at gennemføre egentlige makroøkonomiske miljøanalyser - se nedenfor.

De enkelte delregnskaber omtales udførligt i rapportens Kapitel 3. I afsnit 3.1 omtales vandmængderegnskaber, og det vises hvorledes regnskabstabellerne for hhv. vandstrømme og vandbeholdninger kan opbygges. I afsnit 3.2 opstilles en generel regnskabstabel for emissioner til vand. Tabellen kan opstilles for enhver emissionstype, som anses for relevant i relation til vandressourcens kvalitet og økologiske status. Regnskabstabellen for vandkvalitet og økologisk status diskuteres i afsnit 3.3. Denne tabel kan opbygges på forskellig måde, afhængigt af hvilke indikatorer for vandkvalitet og økologisk status samt geografisk opdeling man vælger. Endelig gøres i afsnit 3.4 rede for de forskellige vandrelaterede økosystemtjenester, samt for hvorledes værdien heraf kan indarbejdes i en tabel for hhv. udbud og efterspørgsel efter tjenesterne og værdien af vandressourcekapitalen.

De vandrelaterede økosystemtjenester omfatter tjenester inden for de følgende tre hovedkategorier af tjenester - jf. CICES-klassifikationen i European Commission (2013):

- Leverende tjenester (provisioning services)
- Regulerende tjenester (regulating services)
- Kulturelle tjenester (cultural services).

Ud over disse tjenester omfatter CICES-klassifikationen også Understøttende tjenester, som omfatter de grundlæggende økologiske processer, der er en forudsætning for økosystemernes mulighed for at yde menneskeheden de tre angivne tjenester. I en regnskabskontekst, hvor fokus er på værdien af vandressourcens tjenester over for menneskeheden, kan der imidlertid ses bort fra de Understøttende tjenester, da værdien heraf er indeholdt i værdien af Leverende, Regulerende og Kulturelle tjenester.

Vandressourcens Leverende tjenester omfatter virksomheders og husholdningers udvinding og brug af grundvand og overfladevand. Tjenesterne inkluderer både udvindingen af drikkevand og udvindingen af vand til procesformål - herunder vanding.

Vandressourcens Regulerende tjenester opstår i forbindelse med udledningen af næringsstoffer og miljøfremmede stoffer til vandmiljøet. Vandressourcen er nemlig i nogen grad i stand til at nedbryde og akkumulere disse stoffer. Dette opfattes som en tjeneste med værdi for menneskeheden, fordi menneskene herved gennem produktion og forbrug kan forurene til en vis grænse uden at lide et velfærdstab herved i form af forringet vandmiljøkvalitet. Der er en Regulerende tjeneste knyttet til udledningen af hvert enkelt næringsstof og miljøfremmede stof.

Vandressourcens Kulturelle tjenester omfatter husholdningernes muligheder for at benytte ressourcen til forskellige rekreative aktiviteter såsom lystfiskeri, jagt, badning og fritidssejlads. Hertil kommer muligheden for at benytte vandressourcen til videnskabelige formål og undervisning.

Den årlige værdi af de forskellige tjenester kan opstilles i et regnskab, hvor det samtidig registreres, hvilke dele af samfundet der gør brug af den enkelte tjeneste - dvs. forskellige erhverv og husholdninger. Kapitalværdien af vandressourcen og ændringerne heri kan opgøres som nutidsværdien af de aktuelle og forventede fremtidige tjenester. Denne kapitalværdi udgør en del af naturkapitalen, og den registreres i et kapitalregnskab.

Opstillingen af begge regnskaber for værdien af vandressourcens økosystemtjenester forudsætter, at de enkelte tjenester værdisættes. I rapportens kapitel 4 gøres rede for principperne for værdisætningen og de praktiske muligheder for at gennemføre denne diskuteres.

Vandressourcens Leverende tjenester har en direkte brugsværdi, som i mange tilfælde kan værdisættes ud fra markedspriserne på vand. I de tilfælde, hvor sådanne ikke foreligger, kan man vælge forskellige alternative tilgange til værdisætningen. Man kan således enten vælge at værdisætte tjenesterne ud fra et gennemsnit af de eksisterende markedspriser, eller, såfremt der er datagrundlag herfor, basere værdisætningen på omkostningerne ved at udvinde og levere vandet. Endelig kan man værdisætte ikke-markedsomsatte leverancer af vand på grundlag af den ressourcerente, vandforbruget skaber.

De Regulerende tjenester har indirekte brugsværdi i den forstand, at produktionen i en række erhverv billiggøres, ved at der kan udledes visse mængder af næringsstoffer og miljøfremmede stoffer til vandmiljøet, uden at vandkvalitet og økologisk status forringes. Tilsvarende sparer husholdningerne renseomkostninger ved at kunne gøre det samme. De sparede omkostninger i erhverv og husholdninger kan benyttes som grundlag for værdisætningen af de regulerende tjenester.

Endelig repræsenterer de Kulturelle tjenester brugsværdi for især husholdningerne. Denne kan estimeres ved brug af de mange forskellige direkte og indirekte værdisætningsmetoder, som er udviklet. Det er dog et stort problem, at mange af metoderne er udviklet med henblik på værdisætning i relation til velafgrænsede projekter, hvorfor det er tvivlsomt, om resultaterne herfra kan anvendes i en regnskabssammenhæng.

Værdien af de løbende årlige økosystemtjenester danner som omtalt grundlag for opstillingen af et årligt regnskab for værdien af vandressourcens udbudte og forbrugte tjenester. Værdien af de årlige tjenester kan endvidere anvendes ved beregningen af vandressourcens kapitalværdi. Denne beregnes som nutidsværdien af de årlige tjenester nu og i fremtiden. Til denne nutidsværdi, der afspejler vandressourcens direkte og indirekte brugsværdi, skal imidlertid også lægges dennes optionsværdi og ikke-brugsværdi. Optionsværdien vedrører værdien af at bevare muligheden for fremtidigt direkte og indirekte brug, uanset om der viser sig at være behov herfor. Ikke-brugsværdien er uafhængig af den nuværende og fremtidige brug af vandressourcen. Den omfatter således værdien af at vide, at vandressourcen foreligger i en ønsket mængde, kvalitet og økologisk stand, samt værdien af at kunne overbringe den i denne stand til fremtidige generationer. Såvel optionsværdi som ikke-brugsværdi er dog meget vanskelige at fastsætte i praksis med de foreliggende værdisætningsmetoder.

De omtalte fem forskellige delregnskaber inden for det samlede vandressourceregnskab kan danne grundlag for flere forskellige typer analyser, som er omtalt i kapitel 5. De forskellige analysetyper omfatter

- Miljøindikatoranalyse
- Ex post analyse
- Input output baseret ex ante scenarie fremskrivning
- Udvikling af makroøkonomiske vandressourcemodeller, konsekvensanalyse og forecasts
- Vurdering af bæredygtighed ud fra ægte opsparing.

Vandressourceregnskabet indeholder en mængde information, som kan benyttes i miljøindikatorsammenhæng. Vandforbruget fordelt på økonomiske sektorer kan ved at koble vandforbrugsoplysningerne sammen med nationalregnskabets produktionsoplysninger benyttes til at belyse udviklingen i sektorernes effektivitet med hensyn til vandforbrug pr. produceret enhed. En tilsvarende analyse kan udarbejdes for emissionerne af forskellige stoffer til vandmiljøet. Derimod kan vandkvalitetsdata og data for økologisk status ikke direkte kobles til nationalregnskabets økonomiske opgørelser. Vandressourcetilstanden beskrives bedst på et passende geografisk opdelt niveau. For at kunne analysere sammenhængen mellem den økonomiske udvikling og udviklingen i vandkvalitet og økologisk tilstand er det derfor nødvendigt at de økonomiske regnskaber og emissionsregnskaberne opdeles på et tilsvarende geografisk niveau. Dette er ikke aktuelt muligt. Endelig kan oplysningerne i økosystemtjenesteregnskabet indikere, hvorledes vandressource tilstanden generelt set udvikler sig. Hvis værdien af vandressourcens økosystemtjenester stiger, indikerer det som udgangspunkt, at tilstanden generelt forbedres og omvendt. Man skal dog være forsigtig med for håndfaste fortolkninger på grundlag af værdien af de årlige økosystemtjenester alene, idet værdien af disse på kort og mellemlangt sigt udmærket kan udvikle sig positivt, samtidig med at værdien af vandressourcekapitalen udvikler sig negativt - f.eks. gennem overudnyttelse af grundvandsressourcen eller gennem stigende udledning af miljøfremmede stoffer til vandmiljøet, hvis regulerende tjenester herved på kort sigt stiger.

Ex post-analyserne vedrører analyser af årsagerne til ændringer i emissionerne til vand, vandressourcens kvalitet og økologiske status samt værdien af de vandressourcerelaterede økosystemtjenester. For at kunne gennemføre analyserne på en ideel måde, er det som antydet ovenfor nødvendigt, at der benyttes samme økonomiske sektoropdeling og geografiske opdeling i såvel de økonomiske regnskaber som i de forskellige dele af vandressourceregnskabet. Er dette krav imidlertid opfyldt, er det f.eks. muligt at belyse hvor meget af ændringen i vandmiljøets tilstand der kan forklares ud fra hhv. den generelle økonomiske vækst, ændringer i produktions- og forbrugsstrukturen og ændringer i emissionerne pr. produceret enhed. Ved inddragelse af en egentlig økonomisk model er det endvidere muligt at afgøre, i hvor høj grad de beskrevne ændringer i de økonomisk strukturelle forhold kan tilskrives hhv. den førte politik og andre økonomiske ændringer.

De input output baserede scenariefremskrivninger tager udgangspunkt i nationalregnskabets input output opgørelser. Forudsat at disse foreligger på et passende sektorfordelt og geografisk opdelt niveau er det muligt ved brug af vandressourceregnskabets forbrugs- og emissionsoplysninger at fremskrive, hvilke konsekvenser for emissionerne til vandmiljøet en ændring i efterspørgslen efter en bestemt varegruppe har. For at beskrive de videre konsekvenser for vandkvalitet, økologisk tilstand og værdien af økosystemtjenesterne af de fremskrevne emissionsændringer kræves imidlertid modeller, som bekriver sammenhængene mellem emissioner, vandkvalitet, økologisk status og værdien af økosystemtjenesterne.

De simple input output baserede emissionsfremskrivninger kan udvikles og forbedres gennem udvikling af egentlige makroøkonomiske vandressourcemodeller. Vandressourceregnskaberne udgør et solidt grundlag for et sådant udviklingsarbejde, idet de netop er opstillet med henblik på integrering med den økonomiske del af nationalregnskabet.

Endelig kan oplysningerne i vandressourceregnskabet benyttes i forbindelse med beregningen af samfundets ægte opsparing, der anvendes som økonomisk bæredygtighedsindikator. Den ægte opsparing opgøres således som NNP + værdien af reguleringstjenester der ikke er indeholdt i værditilvæksten + værdien af kulturelle tjenester - værdien af samfundets defensive foranstaltninger - afskrivning på naturkapitalen - (værdien af privat og offentligt forbrug samt forbrug af kulturelle tjenester).

I rapportens Kapitel 6 diskuteres endelig mulighederne for at opstille et dansk vandressourceregnskab, og de mange forskellige foreliggende datakilder hertil omtales.

Der foreligger to centrale kilder til opgørelsen af de årligt udvundne og forbrugte mængder af vand - nemlig JUPITER-databasen fra GEUS og DANVA's database, jf. Afsnit 6.1. Oplysninger om vandmængder udledt til vandmiljøet fra rensningsanlæg og andre punktkilder indsamles som en del af NOVANA-programmet og foreligger i Naturstyrelsens PULS-database. Disse datakilder har i perioden 1995-2005 været benyttet af Danmarks Statistik til at opstille fysiske vandregnskaber for Danmark. Disse præsenteres i afsnit 6.5. Det vurderes at være muligt at genoptage publiceringen af sådanne regnskaber. Det bør dog undersøges nærmere, om regnskaberne også kan udarbejdes med en økonomisk sektoropdeling og geografisk opdeling, som anses for mere dækkende i relation til belysningen af vandmiljøproblemer.

På grundlag af de samme datakilder, som benyttes ved opstillingen af regnskaberne for de årlige vandstrømme, er det også muligt at udarbejde årlige statusopgørelser for mængden af grundvand til rådighed og ændringerne heri. Det er derimod ikke aktuelt muligt at opstille tilsvarende statusopgørelser for overfladevand til rådighed.

Oplysninger om de årlige emissioner af næringsstoffer og miljøfremmede stoffer til grundvand og overfladevand indsamles også som en del af NOVANA-programmet og offentliggøres bl.a. i Naturstyrelsens PULS-database. Der vurderes derfor at være et solidt datamæssigt grundlag for at opstille vandressourceregnskabets emissionsregnskab - jf. Afsnit 6.2. Der udestår dog et omfattende arbejde med at specificere, hvilke stoffer der kan opstilles regnskab for, og på hvilket sektormæssigt og geografisk aggregeringsniveau dette kan ske.

Vandressourceregnskabets statusopgørelse over vandkvalitet og økologisk status i forskellige dele af vandressourcen kan formodentlig opbygges ud fra indhentede data om økologisk status under NOVANA-overvågningsprogrammet og data vedrørende grundvandskvalitet, der indgår i JUPITER-databasen - jf. afsnit 6.3. Det kræver imidlertid en grundig gennemgang af de foreliggende data nøjere at specificere, hvilke kvalitetsindikatorer og indikatorer for økologisk kvalitet, det vil være mest hensigtsmæssigt at benytte i regnskabet. Tilsvarende må problemstillingerne vedrørende geografisk opdeling af regnskaberne og opdeling på vandressourcetyper - f.eks. vandoplande, søer, åer, vådområder etc. - undersøges nærmere.

Endelig vurderes det i afsnit 6.6, at de aktuelle muligheder for at opstille et regnskab for den årlige værdi af de vandressourcerelaterede økosystemtjenester er meget små. Ikke alene er informationen om omfanget af en række reguleringstjenester og kulturelle tjenester relativt sparsomt, men grundlaget for at værdisætte tjenesterne er også yderst spinkelt. Der udestår også en række metodiske problemer, såsom hvilken værdisætningstilgang - betalingsvilligheds- eller omkostningsbaseret - der generelt bør anvendes, og om mulighederne for at anvende resultaterne fra projektrelaterede værdisætningsstudier i en regnskabsmæssig sammenhæng. Problemerne diskuteres indgående i relation til to konkrete danske værdisætningsstudier vedrørende hhv. kulturelle tjenester fra Odense og Roskilde fjorde og oplande samt værdien af grundvandsbeskyttelse. Reelt er det aktuelt kun vandressourcens Leverende tjenester, der kan opgøres og værdisættes.

Sammenfattende har den gennemførte screening af datagrundlaget for udviklingen af et dansk vandressourceregnskab vist, at, når der ses bort fra økosystemtjenesteregnskabet, er der relativt gode muligheder for at inden for en kortere årrække at opstille et sådant regnskab for Danmark. Den væsentligste udfordring er valget af et sektormæssigt og geografisk aggregeringsniveau, som på den ene side er miljømæssigt relevant og på den anden side matcher mulighederne for især geografisk opdeling af nationalregnskabet. Med hensyn til økosystemtjenesteregnskabet vil det givetvis tage længere tid at tilvejebringe de fornødne data og nå frem til de fornødne metodiske afklaringer omkring værdisætningen.

1 Introduction

In Denmark, in the EU as well as at international level, there is a considerable interest in developing national accounts that include the supply and demand of ecosystem services. The interest originates from recognizing that national accounts do not describe the interaction between the economic sphere and the environment sufficiently in their present state. Both nature's contribution to economic welfare and the consequences for nature imposed by economic activities should be included.

The work with inclusion of the values of different ecosystem services in national accounts is a continuation of a more than thirty years international work with green national accounting. This work was first summarized in Ahmad et al. (1989) and later in a Danish context by Møller (1996). In 2012 the international work resulted in the official and internationally accepted guidelines for green national accounting The System of Environmental - Economic accounting: Central Framework (SEEA) developed by UN's statistical office, cf. United Nations et al. (2014). These guidelines are summarized and discussed in a Danish context in Statistics Denmark (2013). This report on water resource accounting builds on and links to the work presented in Statistics Denmark (2013).

A vast literature exists on environmental accounting and as part of that literature the number of articles and reports dealing with water accounting are growing, e.g. Godfrey and Chalmers (2012). In an EU context Brouwer et al. (2013) have made a review of green accounting frameworks including water accounting and the MAES working group has made a pilot study on Natural Capital Accounting in the context of the EU 2020 Biodiversity Strategy, cf. European Commission (2014). The MAES approach focuses on the ecosystem component of natural capital as compared to the focus on geo-physical assets. The focus on the ecosystem component provides a direct link between the green accounting and the mapping and assessment of the state of ecosystems and their services presently being made in many countries, including Denmark. Linkages between the ecosystem services mapping and valuation initiatives and the further development of ecosystem (capital) accounts are therefore important and both the MAES and the TEEB initiatives are useful to pave the way for such linkages in the future. The work related to green accounting can be used in relation to ecosystem services mapping and valuation and vice versa.

There also exist broader initiatives to establish accounts for social welfare and sustainability as alternatives to the guidelines and the approaches that the SEEA framework represents. Since the seminal work of Daly and Cobb (1989) several attempts have been made to develop alternative national income accounting systems, referred to as "green" GDP. Two of these green GDP systems are the Index of Sustainable Economic Welfare (ISEW) and the Genuine Progress Indicator (GPI), cf. Constanza et al. (2009). These indexes aim to account for both current environmental issues and long-term sustainable use of natural ecosystems and resources.

In this report we have chosen to use the SEEA framework and the guidelines from Statistics Denmark (2013), as the present study and the study made by Statistics Denmark on Green accounting are interlinked. The general methods and possibilities in relation to a Danish green national accounting system are discussed in the Statistics Denmark report (ibid) to which interested readers are referred for a general introduction to green national accounting. The focus in the present water accounting report is on the specific part of the accounting system that is related to the water resources. The report discusses and assesses the possibilities of including the value of water related ecosystem services in the general green national accounting framework.

In line with the MAES pilot study on accounting we conclude that the descriptions and analyses on data sources etc. are useful not only for national accounting, but also for the wider perspectives of mapping and assessing ecosystem services, as agreed on in the EU Biodiversity strategy.

Nature's contribution to the economy can be described by the supply of a number of ecosystem services, which directly or indirectly is demanded by industries and households. Initially ecosystem services were divided into four types of services - supporting, provisioning, regulating and cultural services, cf. Millenium Ecosystem Assessment (2005).

Supporting services include all services that are necessary for nature to be able to "produce" the other services – e.g. photosynthesis, pollination and contributions from the micro fauna of soil. In principle, it is possible to calculate how much each supporting service contributes to the other services, but in practice it will be impossible. Therefore, in an accounting context we use the same division in service categories as the TEEB, CICES and MAES classifications i.e. provisioning regulating and cultural services – cf. TEEB (2010), Haines-Young et al. (2010) and European Commission (2014) respectively:

- Provisioning services particularly include the use of nature as a production factor - i.e. the use of e.g. land for agricultural production and the sea for commercial fishery.
- Regulating services include on the one hand nature's protection of economic activities –e.g. the protection against soil erosion by windbreaks and the protection against floods by coastal wetlands and marshes - and on the other hand nature's ability to absorb polluting substances that are emitted as a consequence of economic activities –e.g. the ability of surface and groundwater to retain and transform nutrients and to sequestrate carbon.
- Cultural services include among others the supply of recreational possibilities provided by ecosystems, but also the possibility of learning about nature and the historical development of landscapes are cultural services, cf. Mourato et al. (2010). Millenium Ecosystem Assessment (2005) also regards nature's content of cultural diversity, aesthetical values and religious values as cultural services. However, it can be discussed if such values make up real services that contribute to peoples' utility or perhaps rather should be regarded as characteristics that have values in themselves independent of peoples' utility.

Under EU's biodiversity strategy Target 2, Action 5 Denmark and other countries have ratified that "member states shall map and assess the state of ecosystems and their services in their national territory by 2014 and assess these values into national accounting and reporting systems at EU and national level by 2020", cf. European Commission (2013). In this report the focus is on water resource accounting and a part of this includes assessing the values of water related ecosystem services into national accounting systems. Therefore, the report will not meet the request of the biodiversity strategy to map and assess ecosystems, but the report could contribute to solve some of the methodological problems related to the inclusion of the values of ecosystem services into a national accounting framework.

SEEA is a useful starting point for developing a systematic account of Ecosystem services. In contrast to the national accounting framework the System of National Accounts 2008 (SNA), cf. United Nations et al. (2008), SEEA focuses specifically on the interaction between the environment and the economy and includes a number of accounts for material, energy and water flows between the economy and the environment as well as stock accounts measured in physical units of measurement. SEEA is internationally adopted as a statistical standard for environmental economic accounting systems.

In continuation of SEEA, UN's statistical office has prepared SEEA Experimental Ecosystem Accounting that directly focus on nature as the supplier of ecosystem services, including the services which are connected with some of the material flows that are included in SEEA, cf. United Nations (2012b). Finally, United Nations have prepared a special SEEA Water: System of Environmental Economic Accounting for Water which is a more detailed description of SEEA directed against the water resource, but also with elements of the ecosystem service approach that is used in SEEA Experimental Ecosystem Accounting, cf. United Nations (2012a). The SEEA Water as well as SEEA Experimental Ecosystem Accounting systems can be used both at a national and regional level. This is important because water resource accounting and environmental accounting in general in many cases need to be made at a regional level to reflect the state of the aquatic environment correctly.

The present report *Water Resource Accounts and Accounts for the Quantity and Value of Ecosystem Services connected with the Danish Water Resources: Methods and Requirements* contributes to the development of the relevant knowledge about the possibilities of drawing up of green national accounts for Denmark. The report shows how a water resource accounting system can be drawn up, and hence, the report is a methodological report. The availability and sufficiency of empirical data for Danish water resources accounts is also analysed and discussed, but no attempt has been made to draw up proper accounts for a specific year. Methodologically the suggested accounts are aligned with other parts of the national account system to allow linkage of the two. The flow accounts are drawn up in accordance with the principle of nature as supplier of a number of ecosystem services that society uses and the society as a supplier of emissions that nature uses (receives). Finally the accounts reflect the potential availability of empirical data about nature's water resources and their related ecosystem services. The practical possibilities are illustrated through a thorough description of national water related data and a discussion of how they can be used in a water accounting context.

Chapter 2 in the SEEA Water approach, cf. United Nations (2012a), deals with freshwater - not marine waters. In this report we also only deal with freshwater and suggest that marine water resources and services would be best handled in separate accounts.

The report contributes to the acquisition of knowledge by environmental authorities, statistical agencies and the scientific community about how accounts for non-traded ecosystem services can be linked to the national accounting system. At the same time the report take stock of the empirical possibilities of drawing up national accounts based accounting system for the supply of ecosystem services by Danish water resources and the demand of these services by the society.

It is important to remember that water accounts are accounts which aim to describe supply and use of water and water related services as well as the stocks of water and water quality, but they do not represent an evaluation of whether the water resources live up to requirements for good biological conditions or whether the water resources are used in a sustainable way. However, the information can be used in line with other environmental indicators to make such evaluations.

It is also important to note that water accounts do not explain causes of changes in flows, stocks and quality of water. I.e. even if a change in water quality from one period to another is registered this does not explain anything about the causes for the change. The amounts of different substances that industries and households annually discharge to the aquatic environment are also registered and of course this could be part of the reason for the registered change, but a real model is needed to give a full explanation. However, the statements in the accounts – together with coherent information from the economic national accounts - can be used as part of basis for estimating the models, i.e. national economic accounts are the main data base for estimating macro-econometric models.

As a result, water accounts can be used as basis for ex post analyses of the consequences of implemented policy measures to improve the aquatic environment. However, they cannot be used to carry out ex ante consequence analyses of considered policy measures. For this integrated environmental economic models are needed. However, the accounts can be used as basis for developing these models and the accounts can be important frameworks for presenting the results from such model-based analyses.

The report is structured as follows: In Section 2 a short description of the international work with water resource accounts is presented. In Section 3 the structure of a water accounting system is given. The various accounts in the total water accounting system, describe water amounts, emissions to water, water quality and water related ecosystem services, respectively. The description and valuation of water related ecosystem services is discussed in more detail in Section 4. The different possible uses of the water accounting system and its limitations are discussed in Section 5. After this, Section 6 is devoted to a description of which Danish water related data are available and it is discussed if and how they can be used in a water accounting context. Finally, Section 7 concludes with a summary of how a water accounting system for Denmark could be build, what is possible in practice at present and what further work is needed.

2 International work with water resource accounts

This section presents the state of the art with respect to national water accounts at international level. As mentioned in the introduction, Godfrey & Chalmers (2012) provide more information on concepts applied in other parts of the world and Brouwer et al. (2013) provides an extensive overview of different accounting systems. In Section 2.1 it is explained how water is dealt with by United Nations in different national accounting systems. The European Union co-operates very closely with the United Nations about national accounts and environmental-economic accounts and EU follows by and large their guidelines. Therefore, the methodological work with national water accounts by UN is also representative for EU's work. Therefore, Section 2.2 only presents the EU official water statistics. The Netherlands have for many years developed their water statistics into a real water accounting system National Accounting Matrix including Water Accounts (NAMWA). This system is presented in Section 2.3.

2.1 Water in UN national accounting systems

The UN national accounting systems are described in detail by Statistics Denmark (2013). Therefore, the presentation below concentrates on how water is dealt with within the system. The basic national accounting system is the economic *System of National Accounts* (SNA) which is the national accounting framework used in most countries in the world, cf. United Nations et al. (2009). As mentioned in the introduction United Nations has developed an extension of the general national account system SNA which as a part of the flow accounts includes influences of economic activities on the environment and as a part of the stock accounts assess the stock of environmental resources. As mentioned in Section 1 this extended account system is called *System of Environmental - Economic accounting 2012 - Central Framework* (SEEA), cf. United Nations et al. (2014).

Two environmental sub-systems are connected with the SEEA system - one for water *SEEA Water* (SEEAW), cf. United Nations (2012a) - and one for energy *SEEA Energy* (SEEAE) which is under preparation by the United Nations. In addition to these two sub-systems UN has published a report directed towards ecosystem service accounting *SEEA Experimental Ecosystem Accounting* (SEEA-EEA), cf. United Nations (2012b). Recently, work on a *SEEA agriculture* has been initiated which will link closely both to the SEEA Central Framework, SEEAW and the SEEA-EEA. Both SEEAW and SEEA-EEA must be regarded as the main basis for further work on national water accounting which is also reflected in this report. Below is a short description of SEEAW and SEEA-EEA respectively. The presentation here only includes the main framework and ideas of the two guidelines. The details are discussed in Section 3 and 4 where a proposal to a general water accounting system is presented.

2.1.1 SEEA Water

The extensions of SEEAW are worked out in a way which means that the whole national account system preserves its consistency - i.e. the extensions are built up around supply and use accounts, division of supply into industries is preserved as are the use categories, and the basic valuation method, based on market values, is maintained as far as possible.

As mentioned, SEEAW concerns freshwater and groundwater - not marine waters. Its accounting system includes five main parts.

- Annual supply and use of water and emissions to water measured in physical units and divided into economic sectors.
- Annual supply and use of water measured in physical units combined with economic accounts that cover costs of extraction, purification, distribution, sewers and waste water treatment as well as payments for these services including public subsidies.
- Stocks of water measured in physical units at a certain date or as an average over a certain period.
- Quality of water stocks measured in relevant physical units at a certain date or as an average over a certain period.
- Valuation of the water resources - both the value of the annual flow of water and services related to water and the value of the water resource stock.

The three first mentioned types of accounts concern water as a material input to production and consumption and as a recipient of waste water. All other services of water are meant to be covered implicitly by water quality accounting and valuation of water resources - i.e. the two last mentioned accounts. However, while the three first accounts are very thoroughly prepared and described in United Nations (2012a) the last two accounts are only in the experimental stage. So, there is a great need for more work in relation to these two types of accounts.

As mentioned above all accounts of SEEAW are designed so that the whole national account system preserves its consistency. However, with regard to geographical delimitation of the accounting statements there may be differences between the traditional administratively based delimitation - i.e. national accounts or regional accounts - and the geographical delimitation that is environmentally relevant - i.e. water resource accounts should be made on water catchment level. In certain cases where a catchment area includes more than one country this may give rise to problems in relation to drawing up a water resource account that is nationally delimitated. However, such problems only arise to a minor extent in relation Danish water resources - that is along the border to Germany in Southern Jutland.

Also the time frame of SEEAW may differ from the normally used annual or quarterly statements of economic flows and end of the year statements of economic stocks. Especially end of the year statements of environmental quality and value of the environmental resources may be misleading. The state of the environment often changes much over the year and in such cases a statement of the average quality and value for one or several years seems to be more informative.

2.1.2 SEEA Experimental Ecosystem Accounting

The SEEA-EEA report includes ecosystem services related to all the different parts of the environment and therefore also ecosystem services related to water.

Where SEEAW mainly focus on physical flows and stocks of water, emissions to water, water quality and valuation of water SEEA-EEA mainly focus on the services generated by water as an ecosystem.

There are big overlaps between the two accounting systems. For instance, the physical statements in SEEAW are also part of the description of ecosystem services in SEEA-EEA and valuation of water flows and stocks in SEEAW is highly dependent on the value of ecosystem services related to water.

Some of the important differences in approach in the two accounting systems may be summarized in the following way.

- In addition to the flows of water used for drinking water and as input in production SEEA-EEA also includes other water related services such as decomposition and sequestration of nutrients and toxic substances and use of inland waters for recreational purposes.
- SEEA-EEA considers water stocks from another perspective than SEEAW. Where SEEAW considers water and its related resources or characteristics individually (number of fish, concentration of different pollutants etc.), SEEA-EEA considers water from an ecosystem perspective where the different individual resources work together as a functional unit given the stated water characteristics. So, SEEA-EEA adopts a more holistic view on water than SEEAW.
- The ocean is excluded from the SEEAW framework because volumes of sea water cannot be meaningfully stated. However, the oceans as one or several ecosystems - e.g. open water, coastal waters and coral reefs -are included in SEEA-EEA. Still, in this report sea water is left out of account.
- The concept of environmental degradation is broader within the SEEA-EEA framework than within SEEAW. In SEEAW degradation means a decrease in water stock and/or a decrease in water quality while degradation in SEEA-EEA is related to a decrease in the aquatic environments' waters capacity to supply ecosystem services. Of course this capacity is normally related to water quantity volumes and water quality, but the relationship is not necessarily simple proportionality.
- SEEAW describes how market prices are generally used for valuation in SEEA, but since these do not reflect the broader economic values of many non-market related aspects of water flows and stocks there may be a need also use non-market valuation methods. Although this is recognised and described, SEEAW do not recommend the use or inclusion of non-market valuation methods for water, since there is still some controversy and varying views if this should be done (and how) in relation to SEEA. This is in fact also the case for SEEA-EEA, but since the number of non-marketed goods and services to be taken into account is much higher in SEEA-EEA than in SEEAW the need for a consistent and general valuation procedure is more urgent and broader in scope in relation to SEEA-EEA.

The two accounting frameworks should not be regarded as mutual exclusive but as complementary. This is the position taken in the present report where we take departure in both the SEEAW and the SEEA-EEA methodologies to outline a total water accounting system including all the physical flows, stocks, emissions and water quality elements from SEEAW and supplements this with accounts of the ecosystem services related to water. The ecosystem service accounts both include description of the amount and value of ecosystem services. Of course, the estimated values of some of the ecosystem services can also be used within the SEEAW framework alone.

2.2 EU environmental water database

In the introduction to Section 2 it was mentioned that The European Union co-operate very closely with The United Nations about national accounting systems and that it by and large follows their guidelines. Therefore, EU's methodological work will not be referred to here. Instead, a summary of the content of EU's environmental water databases is presented, cf. Eurostat (2013). Hereby is imparted a knowledge of the actual coverage of EU's water statistics which do not at present include proper water resources accounts.

Table 2.1 Information about water in Eurostat database.

Database	Number of countries		Denmark
	At least one year	Three out of last five years	
1. Water resources: long-term annual average (million m^3)	26		All years
2. Total fresh water abstraction - 2000 - 2011 (million m^3)	20	17	2000 - 2010
3. Total fresh water abstraction per capita - 1998 - 2009 (m^3 per capita)	22	17	1998 - 2009
4. Groundwater abstraction, volume - 1990 - 1996 (million m^3)	23	15	1990, 1991, 1995, 1996
5. Surface water abstraction, volume - 1990 - 1996 (million m^3)	21	13	1996
6. Water abstracted for public water supply - 1990 - 1996 (million m^3)	21	13	1990, 1991, 1995, 1996
7. Water abstracted for agriculture - 1990 - 1996 (million m^3)	21	13	1990, 1991, 1995, 1996
8. Water abstract. for electricity prod. and distrib: cooling - 1990 - 1996 (million m^3)	18	11	-
9. Water abstracted for manufacturing industry - 1990 - 1996 (million m^3)	20	12	1990, 1991, 1995, 1996
10. Water abstracted by manufacturing industry: for cooling - 1990-1996 (million m^3)	8	5	-
11. Population connected to public water supply - 1998 - 2009 (thousands)	19	16	2001, 2002
12. Use of water from public water supply: total - 1998 - 2009 (million m^3)	27	21	1998 - 2008
13. Use water pub. water sup. by serv. and priv.househ. - 1998 - 2009 (million m^3)	22	17	2001 - 2004
14. Use water pub. water sup. by the manufact. industry - 1998 - 2009 (million m^3)	16	13	-
15. Use of water from self supply: total - 1998 - 2009 (million m^3)	17	12	1998 - 2009
16. Use of water from self sup. by the manufact. industry - 1998 - 2009 (million m^3)	18	12	2005 - 2009
17. Use of water from self sup. by agric. for irrigate.purp. - 1998 - 2009 (million m^3)	15	12	1999 - 2009
18. Use of water from self supply for production and distribution of electricity (including cooling water) - 1998 - 2009 (million m^3)	15	9	2002 - 2009
19. Populat. connec. tourb.wastewater collect. syst: total - 1998 - 2009 (pct.)	25	12	1998
20. Populat. connec. to wastewater collect. and treat. syst. - 1998 - 2009 (pct.)	27	14	1998
21. Population connected to wastewater collection and treatment systems by NUTS 2 regions - 2000 - 2009 (pct.)			
22. Populat. connec. tourb. wastew.treat: prim. treat. - 1998 - 2009 (pct.)	25	12	1998
23. Populat. connec. tourb. wastew. treat: second.treat. - 1998 - 2009 (pct.)	25	13	1998
24. Populat.connec. tourb. wastew. treat: least second.treat. - 1990 - 2009 (pct.)	25	11	1990 - 1998
25. Populat. connec. tourb. wastew. treat: tertiary treat. - 1998 - 2009 (pct.)	25	11	1998
26. Populat. connec. tourb. wastew. collect. syst: without treat. - 1998 - 2009 (pct.)	25	14	1998
27. Populat. connec. to indepen. wastew. collect. syst: total - 1996 - 2007 (pct.)	21	12	1996 - 1998
28. Populat. connec.to indepen. wastew. collect. syst: with treat. - 1998 - 2009 (pct.)	20	9	1998
29. Design capac. ofurb. wastew. treat. plant (BOD) - 1998 - 2009 (1,000 kg O_2/day)	21	9	1998

Continued			
30. Design capac. of urb. wastew. treat. plant with advan. treat. (BOD) - 1998 - 2009 (1,000 kg O_2/day)	22	8	1998
31. Total sewage sludge production from urban wastewater - 1998 - 2009 (kg/capita)	26	17	1998, 2007 - 2009
32. Agricult. use of sewage sludge from urban wastewater - 1998 - 2009 (kg/capita)	27	18	1998, 2007 - 2009
33. Composting of sewage sludge from urban wastewater - 1998 - 2009 (kg/capita)	26	15	1998
34. Landfill of sewage sludge from urban wastewater - 1998 - 2009 (kg/capita)	27	16	1998, 2007 - 2009
35. Incineration of sewage sludge from urban wastewater - 1998 - 2009 (kg/capita)	26	16	1998, 2007 - 2009
36. Other meth. of dispos. of sew. sludge from urb. wastew. - 1998 - 2009 (kg/capita)	27	14	1998, 2007
37. Biochemical oxygen demand in rivers - 1990 - 2008 (mg O_2/litre)	24	21	1990 - 2008

Table 2.1 describes the different water databases. It is also stated how many countries have provided data for each database at least one year in the specified period, how many countries have provided data for each data base in at least three out the last five years of the stated period and for which years Denmark has provided data.

For Denmark other sources such as DANVA and GEUS (JUPITER) exists and these data sources entail more updated information, cf. Chapter 6. But Eurostat is the only source where these data are presented together.

It can be seen from the table that none of the data bases cover all 28 EU countries. The data base with most records is number *12. Use of water from public water supply: total*. 27 countries have provided data for this data base at least one time and 21 countries have provided data for at least three out of the five latest years of the period. Information about the population’s connections to wastewater treatment plants and use of sludge from urban wastewater is found at least for one year for almost all countries. However, for the last five years of the specifically stated periods, the information is more scattered and sporadic with only 11 to 18 countries having provided data at least three times.

It can also be seen from the table that the reporting of most Danish water statistics stopped with the reference year 1998. Since 1998, Denmark has only provided data for the EU water database on the following subjects *2. Total fresh water abstraction, 3. Total fresh water abstraction per capita, 12. Use of water from public water supply: total,15. Use of water from self supply: total, 16. Use of water from self sup. by the manufact. industry, 17. Use of water from self sup. by agric. for irrigate. purp., 18. Use of water from self supply for production and distribution of electricity (including cooling water) and 37. Biochemical oxygen demand in rivers.* Since 2007 Denmark has also provided data on use of sewage sludge from urban waste water.

Only a part of the databases is directly relevant to water accounting systems. Of course information about abstraction of water (database 2 - 10) and use of water from public supply as well as self-supply (data base 12 - 18) is relevant, but information about percentage of population connected with different waste water plant (data base 19 - 28) and information on sewage sludge usage (database 31 - 36) is not directly relevant for the water accounts per se.

What is needed, is information about amounts of waste water treated and amounts of emissions of different pollutants to the environment.

The overview given in the table shows that European water statistics is very sporadic and that many accounting subjects are not well covered. For many countries the data seems too sparse to draw up a proper water accounting system. However, data which are not indicated in the EU water database may be available in the member countries and therefore, the empirical basis for water accounting may be much better than reflected in Table 2.1. This is the case for Denmark, cf. Chapter 6. Finally, it should be noticed that only one database, number 37. *Biochemical oxygen demand in rivers* is related to water quality, which must be regarded as an important part of a water account system especially if it is meant to measure amounts and values of ecosystem services.

2.3 The Netherlands' water accounts NAMWA

The Netherlands was among the first to develop on integrated water accounting system. Thus, in the Netherlands the Central Bureau of Statistics (CBS) and the National Institute for Integrated Water Management and Wastewater Treatment (RIZA) have developed an integrated river basin information system, National Accounting Matrix including Water Accounts (NAMWA), cf. Veeren et al. (2004) and Graveland (2006). In this system national environmental accounts are extended to include water flows (e.g. water extraction, waste water discharge) and emissions of substances to water (e.g. nutrients, metals, other chemical) linked to economic activities. The data and information is further disaggregated to the level of seven river basins.

NAMWA follows the principles of the more general NAMEA (National Accounting Matrix including Environmental Accounts), which on the other hand can be regarded as part of SEEA. The principles of NAMEA and the term was originally developed by Statistics Netherlands, and later on used by many countries especially in Europe. Now the principles and accounts of NAMEA and SEEA have converged, and the term NAMEA is not used as often. When it comes to the water accounts NAMWA can be regarded as being more or less equivalent to the water accounts of SEEA.

2.3.1 Economic accounts in NAMWA

The economic account of NAMWA includes several sub-accounts and all information is reported in euros. Only a minor part of the information in the economic account is related to water. This is information about:

- Supply and demand of tap water
- Sewage rights; taxes received by municipalities for use of sewage
- Internal environmental services related to water treatment; water related self-services
- Water extraction and distribution by drinking water companies (production)
- Environmental services, including waste water treatment (production)
- Construction and miscellaneous, including water boards (production)
- Water related revenues by central government, provinces, regional water boards and municipalities respectively (income)
- Water related taxes - water board levies, water pollution levies, sewerage levies, levies on wastewater discharged into large state-owned rivers and levies on groundwater extraction

This is information that is mostly already included in SNA, but in NAMWA it is shown explicitly.

2.3.2 Emission accounts in NAMWA

The emissions accounts describe the emissions of 78 substances to the aquatic environment originating from households, 36 industries and import of trans-boundary pollution from abroad. All emissions are expressed in kg. Emissions to water through the air (atmospheric deposition) and through runoff from soils are attributed to the sources which originally caused the emissions.

The accounts show the sources (supply) of the emissions and their destination (use) - i.e. the part of emissions that is absorbed by producers through the production process, by environmental services as waste water treatment, by the environment and by foreign countries as trans-boundary pollution, respectively.

By combining the information about the amount of different substances emitted with the information about their destination it is possible in another account to show the contribution of the sub-stances emitted to various environmental themes - i.e. eutrophication, wastewater, heavy metals and dispersion. However, as it is only the pressure from different substances emitted and received that is shown it is not possible from the data to make conclusions about the final environmental impact of the emissions. To do this environmental dose response models are needed.

2.3.3 Physical water flow accounts in NAMWA

The water flow accounts are expressed in millions of m^3. One account describes the extraction from five different water sources - fresh groundwater, brackish groundwater, fresh surface water, salt surface water and tap water - and the consumption of the extracted water by households, different branches of industries and other consumers including water losses. Water consumption is further broken down into consumption for cooling purposes and for other purposes. Total use of water is equal to total consumption minus consumption for cooling purposes as cooling water is recycled to the water stock after use.

Another account describes the changes in the stocks of groundwater and fresh water. The changes are the result of annual extraction from the sources and annual addition through replenishment by rivers or rainfall.

2.3.4 Water accounts and environmental statistics using NAMWA

Information from NAMWA is included as a part of the environmental accounts published by Statistics Netherlands. The latest publication Part 3 about Water includes the following information, cf. Statistics Netherlands (2011).

Water use

- Tap water use by household 1990 - 2010 (index 1990 = 100)
  - total tap water use
  - tap water use per capita
- Tap water use by industries 1990 - 2010 (index 1990 = 100)
- Water used in livestock production (million m3)
  - tap water use for livestock drinking

  - tap water use for other purposes
  - ground- and surface water to water livestock
  - ground- and surface water for other purposes
- Tap water use intensity by 11 industries 2003 and 2009 (litre / euro value added)
- Abstraction of fresh surface water per (sub-)River Basin and divided on 17 production activities 2008 (million m3)
- Abstraction of groundwater per (sub-)River Basin and divided on 17 production activities 2008 (million m3)
- Abstraction of water by water supply companies and final supply of tap water 2008 (million m3).

Emissions to water

- Emissions of heavy metals to water 1995 - 2009 (index 1995 = 100, expressed in heavy metal equivalents)
- Emissions of nutrients to water 1995 - 2009 (index 1995 = 100, expressed in heavy metal equivalents)
- Change in emissions of phosphorus, nitrogen and eight heavy metals to water from 2008 to 2009 (% change)
- Change in emissions of heavy metals to water by primary industries, manufacturing and waste management and recycling from 2008 to 2009 (% change)
- Change in emissions of nutrients to water by primary industries, manufacturing and waste management and recycling from 2008 to 2009 (% change).

Regional water accounts

- Emissions of heavy metals to seven river basins (% share of total emissions to each river basin)
- Emissions of seven different heavy metals for each of seven river basins (% share that each metal make up of total heavy metal emissions to each river basin)
- Emission intensity of heavy metals and nutrients for each of seven river basins (heavy metal equivalents and nutrient equivalents respectively per million euro GDP for each river basin).

This example from the Netherlands shows how information from the water accounts (NAMWA) can be used together with water statistics to draw up different water related environmental information and indicators, which are of big relevance for economic and environmental policy.

3 The water accounting system

In this section the different parts of a potential total Danish water accounting system is outlined. The system presented reflects the recommendation by United Nations, cf. United Nations (2012a) and (2012b), but is also on certain points inspired by the Dutch NAMWA system, cf. Veeren (2004). As also stressed by the United Nations a very important consideration in building up the system is that it should be easy to integrate it with the rest of the national accounting system. The focus of a water resource accounting system is flows of water, pollutants, quality of water, amount and value of ecosystem services and stocks of water. However, it is also important that the accounting system is consistent with the way the economic activities are described in the economic system of national accounts. This is necessary to allow further analysis of causes of observed changes and of impacts of policy measures.

The system is meant as a frame of reference for the further work with water resource accounts for Denmark. In Section 6 about water resource accounting for Denmark, the data availability useful for an accounting system is investigated. The results have implications for how the final accounting system could benefit from existing data and they can help to give an overview of further work needed to complete the methodological and empirical work to develop the system.

The potential water resource accounting system includes four different types of accounts:

- Water amount accounts where flows and stocks of fresh water are measured in m^3
- Emission to water-accounts where different pollutants emitted to fresh water by industries and households are measured in kg or litre
- Water quality accounts where quality of different fresh water resources is stated in relevant natural units of measurement - e.g. concentrations of different pollutants or ordinal measures such as good, medium and bad quality
- Ecosystem services account where the amount and value of different ecosystem services supplied by different fresh water areas are stated.

The SEEAW system also includes so-called hybrid accounts where supply and use of water measured in physical units are combined with economic accounts. These accounts are not included in the presented accounting system, but they can be drawn up by combining information from the system with economic information from the national accounting system.

The four types of accounts which are described in more detail below reflect how the quantity and quality of the water resource develops and how water is used by society. This is illustrated in Figure 3.1.

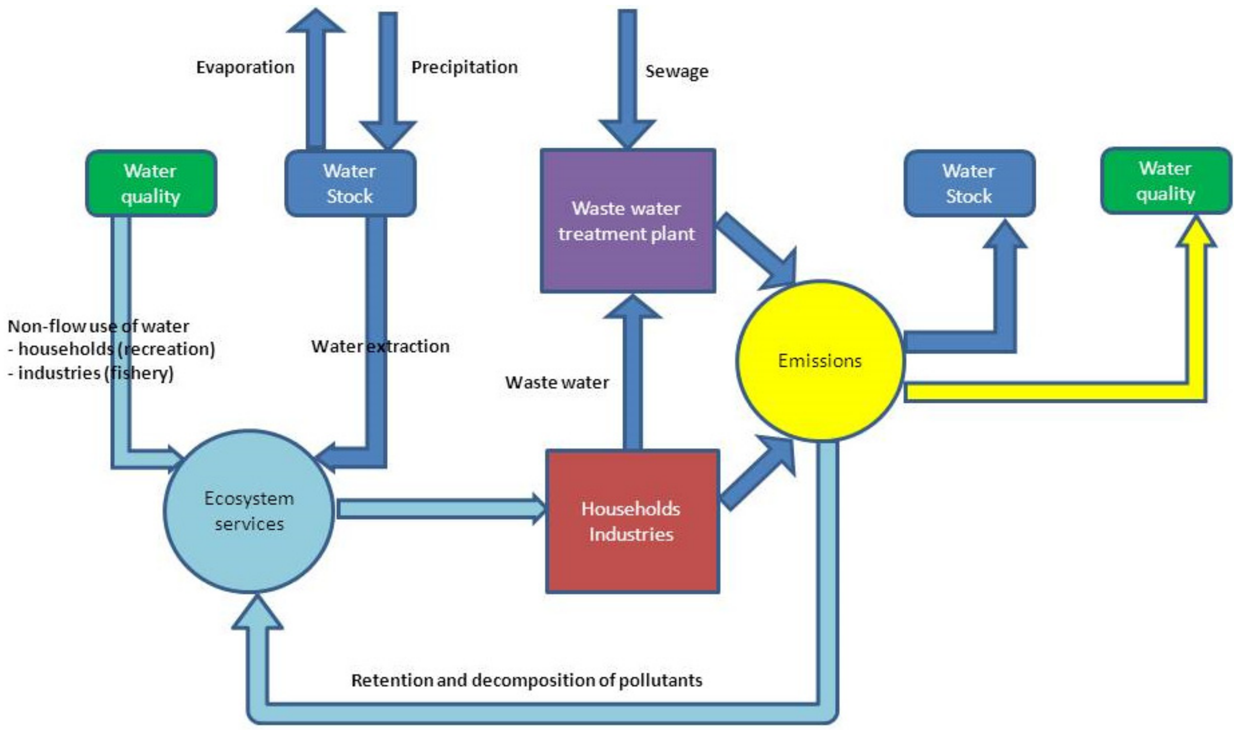

Figure 3.1. The system of accounts for water flows, water stock, water quality, emissions to water and water related ecosystem services. Note: The five main account types of the total water accounting system are illustrated using five different colors. The water flows included in the water flow accounts are shown with dark blue arrows. The stock accounts are represented with dark blue boxes. The emission accounts are represented as a yellow circle, and the water quality accounts with green boxes. Finally the ecosystem services accounts are represented with a light blue circle and light blue arrows. (Water extraction is also an ecosystem service, but it is shown with a dark blue color because it is also included in the water flow accounts).

The freshwater resource includes both groundwater and surface water. In the beginning of a year there are certain stocks of water of different quality. In the course of the year the stocks are increased by precipitation while they are decreased because of evaporation outflow to the sea and net use by the society. The society extracts water for different purposes and leads a part of the extracted water back to the water resource after use. As a result of these water flows the water stocks in the end of the year have changed relative to the stocks in the beginning of the year. These connections measured in m^3 are stated in the water amount accounts described in Section 3.1. Part of the water flows stated in these accounts - i.e. the part extracted and used by households and industries - represents a provisioning service supplied by the water resources.

Society's use of the water resource leads to emissions of different substances, including nutrients, hazardous substances, heavy metals etc., back into the water resource. The emissions originate from different sources including diffuse sources and point sources among which waste water treatment plants are the most important. Nutrient and other substances are transported from diffuse sources (mainly agriculture) either to groundwater or directly to streams and waterways. Diffuse sources also include run-off from roads, buildings and plants, which are lead to surface- and groundwater. Some of these emissions are lead directly to surface- or groundwater, while others go through waste water treatment plants that receive rain water from sewers. The second main source of emissions is industries which discharge polluted water after its use in production. Also in this case a part of the polluted water is lead directly into the aquatic environment while the other part are lead to waste water treatment plants that cause the final emissions. The third main emission source is households that also discharge polluted water to the environment and waste water treatment plants, respectively. The emissions to the water resource measured in kilo or litre are stated in emission accounts described in Section 3.2. The emissions might be reduced by retention and other regulation processes supplied by the resources. However, these services are not specified in the emission accounts, but only in the ecosystem services accounts.

As a result of the emissions of different pollutants in the course of the year the water quality of the different waters stocks will change. Of course the change in water quality is also affected by the ability of the water resource to decompose and transform the emitted pollutants when loaded or deposited to the water bodies - i.e. its supply of regulating services. The final result is stated in the water quality accounts described in Section 3.3. The water quality of surface water (streams, lakes and coastal areas / fjords) is, according to the WFD – cf. Miljøministeriet (2014) – described using five quality classes; high, good, moderate, bad and poor. If the water bodies are classified as heavy modified the water quality is classified as maximum, good, moderate, bad or poor ecological potential. There are quality indicators for the quality classes and these are used in the monitoring of the water quality of the water bodies – cf. the NOVANA programme. Good ecological status includes both ecological and chemical conditions. The water quality accounts do not comprise flows of ecosystem services, but of course water quality is important for the value of ecosystem services supplied by the water resources, cf. the discussion of ecosystem services accounts below.

There is expected to be links between the emission levels indicated in the emission accounts and the observed changes in water quality indicated in the water quality accounts. To be aware of these links and to be able to analyse the relations between emissions and water quality changes it is important that the same geographical delimitations are used in the two types of accounts.

Society uses the water resource in different ways, which can be expressed as the water resource supplies a number of water related ecosystem services. These services include the provisioning services where ground– and surface water resources are used for the provision of drinking water and water for production of crops; the regulating services where water related ecosystems such as wetlands are used to transform nitrogen from NO_3 to N_2O, and also as phosphorus sinks, although to a much lower extent. Thus wetlands prevent nutrients from agriculture and households to be transported to inland lakes and waterways as well as marine recipients. Add to this that fresh water systems are used for a number of recreational purposes. The amount and value of these different services both depend on the amount of water used and the quality of water. So, there are several links between the information stated in the three accounts described above and the value of water related ecosystem services specified in ecosystem service accounts described in Section 3.4 and Chapter 4. The values of ecosystem services stated in these accounts are measured in DKK.

The value of provisioning services depends on water amounts used, the value of regulating services depends on the amounts of emissions stated in the emission accounts and the value of recreational services depends among other things on water quality stated in the water quality accounts. To be aware of these links and be able to analyse the relations between water use, emissions, water quality and the value of different ecosystem services it is important that the same geographical delimitations are used in all types of accounts.

The way that the water account system is built up makes it very suitable as a basis for several kinds of analyses of the interaction between the economic activities in society and the development of the water resource. Economic activities use water and also discharge pollutants into the aquatic environment. This has consequences for the stock of water and water quality which further affect the supply of water related ecosystem services. The different kind of analyses based on the water accounting system is described in Chapter 5.

3.1 Physical Water accounts

Physical water accounts contain information about flows and stock of water measured in physical units - most often m^3. The accounts concern groundwater and surface water and should include traded as well as non-traded freshwater. In a Danish context surface water primarily includes lakes, rivers and streams, but in a wider geographical context of course also artificial reservoirs, glaciers, snow and ice are included. Also soil contains water and in fact SEEAW suggests that water in soil should be included in water asset accounts, but here it is left out of account.

Water-flows between different parts of the freshwater environment are very difficult to cover statistically, but they are important because the different parts are mutually interdependent. E.g. too heavy use of groundwater resources will have consequences for the amounts of surface water available. Indirectly such interdependencies are registered in the development of the stock of groundwater and surface water, respectively. Therefore, it is proposed to draw up accounts for both groundwater and surface water resources. To make the information in the two accounts comparable their formal setup and aggregation level - geographically as well as on economic sectors - should be similar.

The information in the water flow accounts forms an important part of the basis for estimating the value of provisioning services stated in the ecosystem service accounts, cf. Section 3.4. Provisioning services supplied by the water resource include use of water for drinking purposes and as input in production processes. The water stock accounts are the basis for calculation of the value of the water resource stated in capital accounts related to the ecosystem service accounts, cf. Section 3.4.

The following sections describe in more detail how the flow accounts covering supply and use of water, the asset accounts showing the development in the stocks of water, the emission and water quality accounts can be organized. The suggestions cover both the accounts for groundwater and surface water.

3.1.1 Flow accounts - supply and use of water

The annual supply and use of water measured in physical units are stated in tables that include

- Water-flows from the environment into the economy - divided in different economic sectors (industries and households)

- Water-flows between different economic sectors
- Water-flows from the different economic sectors back into the environment

A physical flow account including a supply and use account for groundwater is outlined in Table 3.1.

Table 3.1 Flow account - supply and use water.

Supply (origin) of water		Water works	Sewage plants	Other industries	Households	Environment	Total
	Type of water:			Million m^3			
Environment	1. Groundwater					1050	1050
	2. Surface water					50	50
	3. Rain water					25	25
Economy	4. Tap water	900					900
	5. Waste water for discharge		800	150	175		1125
	6. Waste water for treatment		25	500	275		800
	Total supply of water	900	825	650	450	1125	3950
Use (destination) of water		**Water works**	**Sewage plants**	**Other industries**	**Households**	**Environment**	**Total**
	Type of water:			Million m^3			
Environment	7. Groundwater	900		100	50		1050
	8. Surface water			50			50
	9. Rain water		25				25
Economy	10. Tap water			500	400		900
	11. Waste water for discharge					1125	1125
	12. Waste water for treatment		800				800
	Total use of water	900	825	650	450	1125	3950

Note: The size of water flows is calculated as net-flows, i.e. recirculation of water is not shown in the account.

As stated in the note to the table it shows net-flows of water and therefore, recirculation of water is not stated in the table. An increased rate of recirculation will, everything being equal, over time appear either as a decrease in use of water per produced unit in the economy or decreased consumption of water per inhabitant.

The table should be read like this:

Supply:
Rows 1-3. Amounts of water originating and abstracted from different parts of the environment - groundwater, surface water and rain water. *1,050 Million m^3* comes from groundwater, while *50 and 25 Million m^3*, are surface water and rainwater, respectively.

Rows 4-6. Amounts of water supplied by economic sector. *900 Million m^3* of tap water is supplied by water works while *1,125 Million m^3* of waste water for discharge and *800 Million m^3* for treatment come from sewage plants, other industries and households.

Observe that in a sense the water is stated twice in the supply account. *1,125 Million m^3* is supplied by the environment and after use the same amount of water is supplied as waste water for discharge.

Use:
Rows 7-9. The use in the economy of the groundwater, surface water and rain water abstracted from the environment. E.g. water works, other industries and households use *900 Million m^3*, *100 Million m^3* and *50 Million m^3* of ground water, respectively.

Rows 10-12. The use of tap water by economic sectors and the quantity of waste water discharged from economic sectors. Row 10 shows how much tap water is used by industries and households, and row 12 shows how much waste water is treated by the sewage plants. Finally row 11 shows how much water that is discharged to the environment.

A very important characteristic of the supply and use table for water is that the total supply and use of a specific type of water should always be equal. Thus, from the example in Table 3.1 it can be seen, for instance, that the total supply of *1,050 Million m^3* of groundwater supplied from the environment (row 1) is exactly equal to the total use of groundwater by economic sectors (row 7). Similar balances are found for the other types of water represented in the account.

Observe also that in this simple account the total amount of groundwater, surface water and rain water supplied by the environment is equal to *1,125 Million m^3* (1050+50+25), which is exactly the same as the total amount of water finally discharged to the environment. In more sophisticated accounts it would in principle be possible also to include changes in stocks of water within the economy, which could mean that there would not be an exact balance between inflows from and outflows to the environment within the period in focus.

The main idea with the supply and use table is a distinction between different types of water (the first column of the table) which are supplied and used by economic sectors and the environment (the head of the table). The water changes characteristics as it flows through the economy and therefore, the same amount of water will occur several times in the table. Thus, the stated total supply of water counts the same amount of water more than one time and the same is true with regard to the total use of water. However, from the table it becomes clear how water flows between the environment and economic sectors and between economic sectors and on its way changes type.

The supply and use table only include water flows that are related to the use of water as an input into production and as a consumption good by households. Flows of waste water and sewage are also shown in the tables, but all other uses of water are not. Thus, use of water for recreational purposes, fishing waters, water for ship traffic etc. is not included. Of course, this will generally not be meaningful either. Supply and use tables concern water flows measured in physical units and when water is used for recreational purposes, fishing water or water for ship traffic it is not a water flow or a certain amount of water that is used. The use of water for these purposes which are ecosystem services - see Section 3.4 and Chapter 4 - cannot be measured in physical units related to amounts of water.

However, recreational use and use of water for fishing are important services that are supplied by surface water in general. Therefore, as they are not easily registered in a water flow account where flows are measured in physical unit it is important that the services are included in ecosystem accounts and especially in the value accounts.

3.1.2 Physical water asset accounts - water stock beginning of year, change during year, stock end of year

Physical water asset accounts state the amount of water that is disposable for the society at the start and at the end of the year, respectively. The accounts state the size of stocks measured in physical units, and the changes in the stocks between start and end of the year. The size of these flows forms part of the water asset accounts, which include the main entries stated in Table 3.2.

Table 3.2 Water asset account (overview without data).

	Groundwater	Surface water	Total
		Million m^3	
Opening stock			
Increase in stock because of natural processes			
Precipitation			
Other inflow			
Increase in stock because of human activities			
Waste water			
Draining			
Decrease in stock because of natural processes			
Evaporation			
Outflow to sea			
Other outflow			
Decrease in stock because of human activities			
Water abstraction			
Closing stock			

Table 3.2 shows how the relationships between the amount of water at the start of the year, the increases and decreases during the year and the amount of water at the end of the year. The water amount is increased by natural processes - primarily precipitation - and human activities among which discharge of waste water is the most important, but also building of new draining facilities, although not common in Denmark, may mean that more water will be lead from soil to surface water. The water stock is decreased by evaporation and outflow to the sea which are natural processes and by water abstraction which are human activities.

So, the information in Table 3.2 can be used to explain changes in the observed water stock during the year. As the table is drawn up for both groundwater and surface water it also becomes feasible to analyse possible connections between observed changes in stocks of surface water and groundwater.

As mentioned earlier the accounts only include groundwater and surface water - i.e. like for water flow accounts one sub-account for each. Therefore, water in soil, seawater and water in the atmosphere is not explicitly included in the accounts, but of course water flows between these media and the media included in the accounts will affect the stated stocks of water.

It may be useful to introduce subcategories of the groundwater and surface water, for instance the volume of annually exploitable groundwater. By this is meant the amount of groundwater that can be extracted annually without harmful consequences for surface waters. Of course the volume of annually exploitable water is not a real account figure because it is a hypothetical figure. But, if it is compared to the actual volume of extracted water it is indicated if actual extraction is sustainable. An overconsumption of groundwater is also stated in the stock accounts for surface water. The volume of surface water will decrease.

Wetland areas are an important asset related to surface water. These areas are important suppliers of regulating ecosystem services because they detain nutrients that flow from cultivated areas. Therefore, it would be useful to establish a supplementary stock account that states the development in the size of wetland areas. This will be an important basis for estimating the value of ecosystems services related to nutrient fixing.

It is generally not taken into account that the quality of water might have changed in course of the year and that the value of water might have changed. The problems of bringing water quality measures into national accounts have not been solved satisfactorily yet and neither have the problems in relation to valuation of water, cf. Section 4 and 5.

3.2 Emissions to water

The water flows described in Table 3.1 and especially the flows back to the environment cause the emissions of different pollutants to water. Emissions of the various pollutants are measured in physical units.

There are a very large number of substances that are emitted to the aquatic environment and for a water account system the substances that are monitored on a regular basis must be the basis for the accounting. The monitoring of emissions to the aquatic environment is performed in the NOVANA programme (the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environment) which consist of monitoring subprogrammes for groundwater, streams/rivers, lakes and marine water bodies, including the emissions to these aquatic ecosystems and the water quality of the water bodies which is described in water quality accounts, cf. Section 3.3. The emissions are regulated according to the Law of Environmental Protection (“Miljøbeskyttelsesloven”) and the Law of Environmental objectives (“Miljømålsloven”) as regards the specific requirements set by the implementation of the Water Framework Directive.

For streams and rivers the concentrations of environmental hazardous substances in the streams /rivers are monitored. Both ecological and chemical status are also monitored. For groundwater a large number of compounds are monitored; nitrate, pesticides, chloride, different metals, organic matter, phosphorus, chlorinated compounds, cf. the River Basin Management Plans (RBMPs), Miljøministeriet (2014).

Table 3.3 Emission account for one type of pollutant.

	From					
	Industries[1] except sewage	Sewage industry	House-holds	Rain[2] (urban runoff)	Foreign countries	Total
	Tonnes					
A. Direct emissions to water	30	270	3		12	315
A.1.1 Without treatment to freshwater	*2*		*2*		*12*	*16*
A.1.2 Without treatment to sea	*8*	*45*	*1*			*54*
A.2.1 After treatment to freshwater		*20*				*20*
A.2.2 After treatment to sea	*20*	*205*				*225*
B. To waste water treatment industry	400		310	50		760
C. Actual emissions by source (gross emissions) (A+B)	430	270	313	50	12	1,075
D. Reallocations of gross emissions from sewage industry	144	- 270	105	17	4	0
E. Emissions to water by estimated original source (net emissions) A+D=(C-B+D)	174		108	17	16	315
Emissions removed by sewage industry by estimated original source (B-D)	256		205	33		494

Notes: 1. Including agriculture. 2. Including pollutants that flow with rainwater directly into freshwater and sea or to sewage industries through sewers.

An account of the emissions of one type of pollutant can include the entries stated in Table 3.3. It is important that the sub-division of emissions on different industries (including agriculture) is the same as the industry sub-division used in the remaining part of the national accounting system. This is to allow linking of the changes in emissions with changes in production and input use from industries. The emission should also be sub-divided geographically in the same way as water quality accounts, cf. Section 3.3, and ecosystem service accounts, cf. Section 3.4, to make it possible to analyze links between emission levels, water quality and supply of water related ecosystem services. This may be a problem in practice because economic activities are not always sub-divided geographically, cf. Chapter 6.

It is seen from Table 3.3 (row A 1.1, A 1.2, A 2.1 and A 2.2) that the emission account distinguishes between emissions that flow directly to freshwater and sea respectively. It is also stated if the waste water has been treated or not by industries and households themselves before it is drained off directly into the environment. Finally, in row B the part of gross emissions that is drained off to the sewage industry is stated. Thus, gross emissions by different industries, households and foreign countries (row C = A + B) include emissions drained off directly to freshwater, directly to sea and to the sewage industry.

The total gross emissions also include emissions from sewage industries. These emissions stem from other industries and households that have conducted waste water to the sewage industries. Therefore, the emissions can be re-allocated proportionally to their original source (row D). Finally, total net-emissions from industries and households can be calculated as the sum of direct emissions to water and re-allocated gross emissions from sewage industries (row E = A + D). In the last row is indicated how much of total gross emissions emission has been removed by the sewage industry (i.e. row B - row D)

Pollutants contained in rain water which flow directly into freshwater and sea or flow to the sewage industries, freshwater or sea through sewers are included in the emission accounts. Also pollutants which are transported into national water by streams from foreign countries are included. The accounts only include pollutants contained in water that is emitted to water and therefore, atmospheric depositions directly to water are not included in the accounts. This means that the emissions stated in the national emission accounts cannot explain all changes registered in the national water quality accounts, cf. Section 3.3.

The emission accounts only include the extra pollution generated in different industries (among these agriculture) and households. So, if an industry uses water for cooling that is already polluted, the account only includes the additional pollution from the industry.

3.3 Water quality and status of ground water and surface water

The water quality and status of Danish ground water and surface water are regulated according to the Water Framework Directive (WFD). Good ecological status of the water bodies has been defined as part of the implementation of the directive. Excluded from the definition are the water bodies that are classified as heavily modified water bodies. These water bodies are regulated to achieve good ecological potential. Water bodies are monitored and their water quality and status are evaluated according to the Danish Stream Fauna Index. Following EU 2013, the subsequent "inter calibration exercise envisages a harmonised approach to define one of the main environmental objectives of Directive 2000/60/EC, namely good ecological status". The inter-calibration process involves harmonisation of the monitoring results from different countries so that similar ecological status of water bodies in different countries leads to the same environmental quality evaluation for these bodies. However, the inter-calibration process does not include heavily modified water bodies.

In order to carry out the inter-calibration exercise Member States are organised in Geographical Inter-calibration Groups consisting of Member States sharing particular surface water body types. The objectives for good ecological status are set by Directive, but some of the ecological status indicators are specific for member states to meet individual member state priorities. The inter-calibration exercise is meant to make the national results comparable and transform them into a common EU Environmental Quality Ratio (EQR) as required by the WDF.

The use of EQRs is prescribed in Annex V, 1.4.1 of the WFD: "In order to ensure comparability of such monitoring systems, the results of the systems operated by each Member State shall be expressed as ecological quality ratios for the purposes of classification of ecological status. These ratios shall represent the relationship between the values of the biological parameters observed for a given body of surface water and the values for these parameters in the reference conditions applicable to that body. The ratio shall be expressed as a numerical value between zero and one, with high ecological status represented by values close to one and bad ecological status by values close to zero".

The emissions described in accounts like Table 3.3 for each pollutant affect water quality and status. In Denmark monitoring of groundwater and freshwater quality as well as marine water quality has been conducted for many years as part of the NOVANA program and earlier monitoring programs. The monitoring has been directed towards specific pollutants in groundwater or surface water - e.g. pesticides and nitrate in groundwater and organic compounds, nutrients and heavy metals in surface water. The results have been reported in the NOVANA programme.

However, water quality statistics have not until now been set into a water accounting context. Therefore, proper water quality or water status accounts will represent a very important extension of the standard water accounts as those described for water flows and assets in Section 3.1. The extension is especially important in relation to the possibilities of drawing up accounts for ecosystem services, cf. Section 3.4. Thus, the amount and value of many water related ecosystem services both depend on amounts of water, water quality and ecological status of water.

The water quality of river/streams and lakes are monitored according to chemical and ecological status indicators set forward in the Water Plans. Groundwater is monitored according to quantitative and chemical status, where the abstraction of water over long term horizons must not exceed the long term aquifer recharge. The groundwater abstraction is not allowed either are the water flow in streams required to fulfil good ecological status, by more than 10-25 %. The chemical status is assessed with regard to the content of both natural and hazardous compounds – cf. Miljøministeriet (2014). This means that the subsequent monitoring in the NOVANA programme deliver a significant data source for the accounts. The current challenge is to connect the water quality indicators such as the content of chlorophyll in lakes to ecosystem services and to the value of these. Also with regard to water quality and ecological status accounts it may be best to work with separate accounts for groundwater and surface water, respectively.

The accounting system should include both flow accounts of annual water flows of different ecological status and quality and asset accounts of water stocks of different quality. Flow accounts are the primary basis for calculating the annual quantity and value of water related ecosystem services. However, in practice these accounts may be very difficult to draw up - especially for surface water. Therefore, it seems more realistic only to draw up asset accounts that show annual amounts of groundwater and surface water with different water status and quality or number of water wells-/streams/lakes with different water status and quality. Such asset accounts may be good indicators of how the state of the aquatic environment develops. Based on these indicators it is still possible to estimate how the supply of different water related ecosystem services has developed. The data for such asset accounts are to a large extent already available from the NOVANA monitoring reports.

Even if water quality and ecological status accounts are restricted to asset accounts there are still several theoretical and practical challenges. So far, no acceptable solutions have been identified for these challenges, which include

- measuring quality and ecological status
- aggregation problems - aggregation of different quality indicators and choice of geographical aggregation level
- causal relationships to explain changes in water quality and ecological status

3.3.1 Measuring quality and ecological status

Water quality and ecological status depend on several water characteristics - i.e. chemical, physical, hydro morphological and biological conditions. This means that measurement of water quality and ecological status is directed against different pollutants and conditions depending on the water body observed. It also means that the relevant measure of quality and ecological status varies between different types of water stocks. The typology developed for the Water Framework Directive is useful, as the water bodies are classified in terms of ecological status on a five step scale from bad to high / very good (high- good - moderate – poor – bad) where this classification can be tied back to the status of the specific physical and quality conditions of the specific water body. The ecological status in streams and rivers, lakes and coastal waters / lakes is classified according to the EQR scale. The ratio varies between 1 and 0, where 1 indicates the best possible ecological status and 0 the worst status.

- For groundwater, the chemical status classification for nitrate and pesticides follows the quality standards according to the Groundwater Directive. The quantity targets are set to regulate groundwater abstraction levels in order not to influence surface water levels negatively (different levels are measured).
- For streams and rivers, the indicator of ecological status is measured by the conditions for the small water-fauna-species, measured by the Danish Fauna Index. The objective of good ecological status can be obtained by hydrological and other technical measures as planned in the current River Basin plans. One measure changes the maintenance of water courses by reducing the removal of plant biomass from the bottom and edges. This measure will improve the retention of nutrients as well as the conditions for flora and fauna in the water courses. Another measure is changing of the hydrological conditions in the streams and rivers by adding stone and gravel to the bottom. This measure will improve the habitat-quality of the creeks and water courses. At the same time this measure improves the oxygen conditions at the bottom. Re-opening closed, excavated water courses and creeks and removal of barriers for fish are other measures to improve the quality of these habitats, i.e. improving the recreational value for angling as well as the provisional value, but the latter is negligible.
- For lakes the present indicator of good ecological status is the content of chlorophyll. The objective of good ecological status can be obtained by hydrological and technical measures within the lakes and by reducing nutrient loads to the lakes, especially phosphorus. The phosphorus loads to lakes can be reduced by measures implemented on fields under risk of phosphorus losses and by restoration and construction of wetlands with the aim to retain phosphorus in the area draining to the lakes. Buffer zones along rivers, streams and lakes are another measure aiming at retaining phosphorus.

The classification is described in Table 3.4 below.

Table 3.4 Water quality and ecological status classes for surface water measurement according to the Water Framework Directive.

Water bodies and objectives	Indicator					 [1]
		High	Good	Moderate		Poor and bad
Streams/rivers: Better conditions by improvement of physical/hydrological conditions	Chlorophyl a concentrations	7-6, dependent on the bottom conditions	5, dependent on the bottom conditions	4 and		Lower
Lakes: Better conditions by reduced Phosphorus loads.	Danish lake phytoplankton- index (DF), macrophyt-index	Limited values depend on the type of lake[2]	Limited values depend on the type of lake[2]	Limited values depend on the type of lake[2]		

Notes: 1. Icons from Water Information System for Europe (WISE) 2008. 2. Status for the water bodies.
2. Miljøministeriet (2014).

One important issue is to link the classification of water quality and ecological status in Table 3.4 to the status and value of the different ecosystem services. This is discussed in the section about ecosystem services accounts.

Table 3.5 Ecological status account. (Overview without data).

	Surface water status 1. High	Surface water status 2. Good	Surface water status 3. Moderate	Surface water status 4. Poor	Surface water status 5. Bad
			Km		
Opening stock river and streams					
Change rivers and streams					
Closing stock rivers and streams					

The ecological status account in Table 3.5 describes the distribution of river and stream stretches measured in km on the five different classes of ecological status. The stretches are stated in the beginning and the end of the observation so that it is possible to see how the ecological status of these water courses has developed over the period. Table 3.5 indicates ecological status at a national level, but of course, it is also possible to draw up tables at a regional level. A similar table can be outlined for lakes, coastal zones and ground water. The size of water bodies within the different status or quality classes should just be stated in km^2 and m^3 respectively.

3.3.2 Aggregation problems - aggregation of different quality indicators and choice of geographical aggregation level

It is not without problems to draw up status tables like Table 3.5. The water planning process related to the Water Framework Directive illustrates the problems of aggregating different measurements into an aggregate measure of quality and ecological status for all water bodies. These problems still remain to be solved, but there is information about average water quality and ecological status for the different water bodies in the River Basin Management Plans (RBMP). However, this information does not provide a link between the water quality and ecological status assessment and the expected services of water - i.e. if water is used for drinking, swimming, angling, irrigation etc. A water body may be evaluated as low quality for drinking purposes, but as satisfactory quality for bathing water.

It is possible to measure and record the content of many different pollutants to give a detailed description of the state of the water body and water resource. However, this does not provide an overall evaluation of water quality and ecological status. In the work on environmental indicators many solutions to this aggregation problem have been proposed. The proposals include suggestions to measure a single pollutant, plant or animal as a representative indicator for the quality or ecological status of a specific water resource. Advanced aggregated quality and status indices based on weighting of different indicators have also been proposed. The weights used may reflect human evaluation of the importance of the different indicators with respect to a given use of water or relative degrees of meeting target values set up for the different indicators. However, there are still plenty of possibilities for development of water quality indices.

In many cases water quality and ecological status varies over time because of seasonal weather conditions. Therefore, it is necessary both to choose a suitable period for measurement and a methodology to identify a representative quality. Finally, it is possible to examine the development in water quality and ecological status by comparing quality and status indicators over many periods.

The choice of measuring period should make it possible to compare quality and ecological status indicators between periods in a meaningful way. As natural variations can last for more than a year annual quality and status estimation is not always the most suitable estimation frequency. Two or even five years periods may give more correct information about the water quality and status. A simple mean of the measured quality indicators in the chosen period may not give the right picture of quality and status either. E.g. if quality is measured by the concentration of a pollutant, the highest concentration may be more important for the evaluation of quality in the period than the mean. The average concentration may look satisfactory even when the highest concentration have had damaging consequences for the environment, cf. United Nations (2012a) Chapter 7.

Finally, water quality and ecological status also have a geographical dimension. Water quality and status in one part of a stream or river might be good and in another part bad and if the quality information is aggregated, e.g. by weighting according to the size of the different parts of the stream or river, a lot of information is lost. However, this will always be the case when indicators are aggregated. So, the challenge with regard to aggregation of spatial differentiated quality and ecological status numbers is to find a suitable geographical delimitation of the information presented. This can be quality and status measures related to specific freshwater courses, aquifers or geographical areas. However, these solutions may still result in too much information which may not be manageable within an accounting system. SEEAW proposes an account which subdivides a well-defined water resource into different quality or status classes in the beginning and the end of the chosen period, see Table 3.5.

The advantage of this account is that it sub-divides the water resource into different parts determined by their water quality or ecological status. This provides a more nuanced picture of the water quality or status and at the same time preserves the possibility of estimating the average water quality or status. It is also possible to relate changes in average water quality or ecological status to specific changes in the amount of water within each quality or status class.

The water quality classes in Table 3.5 describe the average water quality or ecological status at a national level. However, the ecological status is monitored for the 23 river basins for each water body type. The actual regional ecological status for these 23 basins is presented in Table 3.6, for the opening stock.

Table 3.6 Regional ecological status account.

	Streams	Lakes
Kattegat and Skagerrak	Moderate	Good
Limfjorden	Moderate	Poor
Mariager	Good	Poor
Nissum	Good	Good
Randers	Good	Moderate
Djursland	Good	Moderate
Bay of Aarhus	Moderate	Poor
Ringkoebing	Good	Good
Horsens	Good	Poor
Wadden sea	Moderate	Moderate
Belt sea, Lillebaelt, Jutland	Good	Moderate
Belt sea, Lillebaelt, Funen	Moderate	Poor
Odense Fjord	Moderate	Poor
Belt sea, Storebaelt, Funen	Moderate	Poor
The sea south of Funen (Smaalandsfarvandet)	Moderate	Moderate
Kalundborg	Moderate	Poor
Isefjord and Roskilde	Moderate	Poor
Oresund	Moderate	Good
The Bay of Koege	Moderate	Moderate
The sea south-west of Zealand	Moderate	Moderate
The Baltic Sea (Baltic Proper)	Moderate	Moderate
Bornholm	Good	Good
Krusaa/Vidaa	Good	Moderate

Reference: Adapted from Jensen et al. (2013). Water quality classifications based on the River Basin Management Plans (RBMP).

Table 3.6 shows a very aggregated statement, which reflects large variations within each water basin, cf. Miljøstyrelsen (2014).

3.3.3 Possibilities of relating quality and ecological status changes to different causes

It is important to be aware that the accounts only give information about the water quality and ecological status in two periods and the change in quality and status between the periods. It is not possible to distinguish between changes in quality and status caused by human activities and natural processes. This is clearly a weakness in the accounts because the main purpose of setting up the quality and status account is to be able to react on observed quality and status deteriorations in an efficient way. Models that describe the interaction between human and natural influences on water quality and ecological status are a prerequisite for efficient water management. This presupposes knowledge of the causes of quality and status changes.

However, linking information from water quality and ecological status accounts with information from the emission accounts and information on abiotic conditions, such as weather records makes it possible to estimate models that explain quality and status changes. Of course, a prerequisite for making this link between emissions and water resource status is that the same demarcations of water stocks are used in emission accounts and water quality and ecological status accounts. Therefore, it is important that emission accounts and water status accounts is geographically specific.

3.4 Water resource related ecosystem services

The final water accounts suggested by SEEAW are accounts in which water flows and stocks are valued in economic terms. This is considered an essential component of sustainable water management, including optimisation of the economic value obtained from the use of the water resources along with equity and environmental sustainability; cf. United Nations (2012a). The ecosystem services accounts are similar to the traditional national accounts which state money flows related to economic activity and value of economic assets respectively.

In fact the value of water flows that are traded on a market is already included in the traditional accounts, cf. Section 2.4.3. Thus, the costs of supplying water to industries and households as well as the expenses by industries and households to buy water are included in national accounts. Furthermore, the costs of cleaning and protecting water stocks are included and to a certain degree the recreational values attached to freshwater stock are reflected in house prices and tourist revenues. It should also be noted, that the value of provisioning services delivered by the water related ecosystems are to some extent included in the conventional national accounts through the values of the products which are produced with water as an input - e.g. crops, timber and fish. It is important to be aware of this if the specific water accounts are to be integrated with the traditional accounts, so that double-counting is avoided.

SEEAW do not propose real value accounts for water because there are still many unsolved problems connected with this. The objective is to be able to set up such accounts, but as long as the solutions to the problems have not been identified, it may be advisable not to decide on one particular solution. However, one very promising solution is to value water flows and stocks on the basis of the ecosystem services they provide.

Below, the different ecosystem services related to water are presented. This is followed by suggestions for flow and stock tables for ecosystem services supplied by water. The possibilities and problems of estimating quantities and values of the different ecosystem services are discussed in Chapter 4.

3.4.1 Ecosystem services related to water

The European Commission (2013) uses the CICES classification for ecosystem services version 4.3 as a basis for mapping of ecosystems and their services. The focus of The European Commission is mapping and hereby is also stressed the importance of the geographical dimension in describing ecosystem services. In this report the classification is used as a basis for a discussion of the problems related to assessment of ecosystems and their services in an accounting context.

From the CICES classification the ecosystem services related to water can be separated into different services for use in water resource accounting. The water related ecosystem services are described in Table 3.7. It can be seen from the table that ecosystem services related to water include provisioning services, regulation & maintenance services and cultural services.

Provisioning services only include surface water and groundwater used for drinking and non-drinking purposes. Non-drinking purposes are domestic use, irrigation, livestock consumption and industrial use. The use of water for power production is not mentioned explicitly, but might be included in industrial use which both includes water used for cooling and water used as raw material in products.

The distinction between drinking and non-drinking purposes or water used as nutrient and material respectively is of course meaningful, but it can be discussed if it is useful in a practical accounting context. The problem is that - at best - households and different industries record how much water they use in total, but it may be very difficult for them to state how much of the total use has been for drinking and other domestic use, respectively. Therefore, in an accounting context the distinction between surface- and groundwater should be maintained on the supply side, but on the demand side total water use should be distributed between households and different industries. This suggestion is reflected in the ecosystem service accounts that are drawn up in Section 3.4.2.

Regulation & Maintenance services include many different biological, physical and chemical processes that are very difficult to separate in an accounting context. Common to almost all of them is that they are related to the use of the water resource as recipient of pollution that is degraded or accumulated. However, in practice it is not possible to identify how much of this total service is related to detoxification, decomposition, mineralisation, degradation, biological and bio-physico-chemical filtration, sequestration, storage, accumulation, adsorption, binding, dilution or mineralisation.

Table 3.7 CICES classification of ecosystem services related to water.

Section	Division	Class	Examples
Provisioning	Nutrient	Surface water for drinking	Collected precipitation or abstracted from rivers, lakes etc.
		Groundwater for drinking	Abstracted directly from aquifers or by desalination
	Materials	Surface water for non-drinking	Collected precipitation or abstracted from rivers, lakes etc. and demanded for domestic use, irrigation, livestock consumption and industrial use
		Groundwater for non-drinking	Abstracted directly from aquifers or by desalination and demanded for domestic use, irrigation, livestock consumption and industrial use
Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Bioremediation by micro-organisms, algae, plants and animals	Detoxification, decomposition, mineralisation and degradation
		Filtration, sequestration, storage and accumulation by microorganisms, algae, plants and animals or by ecosystems	Biological and bio-physicochemical filtration, sequestration, storage and accumulation of pollution in freshwater biota and ecosystems, including sediments. Adsorption and binding of heavy metals and organic compounds in freshwater biota and ecosystems
		Dilution by freshwater	Bio-physicochemical dilution of fluids and waste water in lakes and rivers, including sediments
	Maintenance of physical, chemical and biological conditions	Maintaining nursery populations and habitats	Freshwater habitats for plant and animal nursery and reproduction
		Decomposition and fixing processes	Maintenance of bio-geo-chemical conditions of soils by decomposition-/mineralisation of dead organic material, nitrification, denitrification, N-fixing and other biogeochemical processes
		Chemical conditions of freshwater	Maintenance/buffering of chemical composition of freshwater column and sediment to ensure favourable living conditions for biota etc. by denitrification, re-mobilisation/remineralisation of phosphorous etc.
		Global climate regulation by reduction of climate gas concentrations	Global climate regulation by greenhouse gas/carbon sequestration by freshwater columns and sediments and their biota
Cutural	Physical and intellectual interactions with biota, ecosystems and landscapes	Physical use of landscapes in different environmental settings	Walking and hiking along rivers and lakes, boating, angling, hunting and swimming
		Experiential use of plants, animals and landscapes in different environmental settings	Bird watching, botanizing, and diving
		Scientific use (intellectual)	Subject matter for research both on location and via other media
		Educational use (intellectual)	Subject matter for education both on location and via other media
		Heritage, cultural use (intellectual)	Historic records and cultural heritage preserved in freshwater bodies
		Entertainment use (intellectual)	Ex-situ experience of natural world through different media
		Aesthetic use (intellectual)	Sense of place, artistic representation of nature

Continued			
	Spiritual, symbolic and other interactions with biota, ecosystems and landscapes	Symbolic	Emblematic plants and animals and national symbols
		Sacred and religious	Spiritual and ritual identity such as holy places, sacred plants and animals
		Existence	Enjoyment provided by existence of wild species, wilderness, ecosystems and landscapes
		Bequest	Willingness to preserve plants, animals, ecosystems and landscapes for the experience and use of future generations. Ethical perspective or belief.

Source: After CICES classification version 4.3 in European Commission (2013).

Therefore, in an accounting context it is suggested only to work with one class of regulation services which includes the CICES division *Mediation of waste, toxics and other nuisances* and the two CICES classes *Decomposition and fixing processes* and *Global climate regulation by reduction of climate gas concentrations*. Thus, the total regulation services class includes all services by the water resources that in one way or another contribute to protect human beings from the harmful consequences of damages caused by human activities and nature. The regulation class could be subdivided not according to the processes involved but according to the pollutants involved - e.g. nutrients like nitrogen and phosphorous, heavy metals and other toxic substances. This subdivision of the services on the supply side makes it possible to relate the services to households and different industries on the demand side because it is known from the emission accounts which pollutants and amounts of pollutants are emitted by households and industries.

The maintenance services in Table 3.7 - i.e. the two classes maintaining nursery populations and habitats and chemical conditions of freshwater - should not be included in the ecosystem service accounts. Of course, these services are important prerequisites for the other services, but as these are already included indirectly in the accounts, it will be double-counting also to include maintenance or supporting services. This could be handled within the accounts by measuring the contribution from maintenance services in generating provisioning services. But, as the focus in the accounts is the services supplied by the water resources to the economy, and not services supplied and demanded within the environment, it is decided in this report to leave maintenance services out of account and only state regulation services in the ecosystem services accounts. Therefore, in the accounts this total class of services is named *Regulating services* instead of *Regulation and Maintenance Services*.

Cultural services include two divisions of services - physical and intellectual interactions with biota, ecosystems and landscapes and spiritual, symbolic and other interactions with biota, ecosystems and landscapes, respectively. Physical use of the water resource encompasses direct physical use such as walking and hiking along rivers and lakes, boating, angling, hunting and swimming as well as experiential use such as bird watching, botanizing, and diving. In a practical accounting context it may be very difficult to keep these different activities separate from each other. E.g. you normally walk along a lake shore while bird watching and often you angle or hunt from a boat. Therefore, the CICES distinction between physical and experiential use is very difficult to uphold. Instead one division for recreational use could be formed and perhaps it could be further subdivided in different activities determined by the primary purpose of the activity – hunting, angling, swimming et cetera.

Symbolic use of the water resource includes different so-called intellectual uses such as scientific and educational use. It also includes heritage and cultural use (historic records and cultural heritage preserved in freshwater bodies), entertainment use (ex-situ experience of natural world through different media) and aesthetic use (sense of place and artistic representation of nature). Some of these activities have much in common with recreational use described above and therefore, could be included among these.

In contrast it can be discussed if preservation of cultural heritage in freshwater bodies can be regarded as a utility generating activity. Thus, it can be argued that preservation of cultural heritage has value in itself and therefore, should not be included among all the other utility generating ecosystem services.

The same argument could be put forward with regard to the ecosystem service division designated spiritual, symbolic and other interactions with biota, ecosystems and landscapes. All the religious, ethical and symbolic values included in this division can be argued to have value in themselves. It is not their utility for people that make them valuable. Therefore, they should not be included among the utility generating ecosystem services that are valued because of the utility they convey to people.

The discussion above can be summed up in the following way.

- Provisioning services include groundwater and surface water used by different industries and households.
- Regulating services are related to the use of the water resource as recipient of pollution that is degraded or accumulated and the services should be subdivided not according to the processes involved but the pollutants involved - e.g. nutrients like nitrogen and phosphorous, heavy metals and other toxic substances.
- Cultural services include different recreational activities and if possible these could be subdivided according to the main activity involved - walking, angling, swimming, boating etc. Also included in this section are scientific and educational uses of the water resource.

These ecosystem services are supplied by the water resource and should enter into the national water resource accounting system on the supply side of the system. Industries and households demand the different services and therefore, they are also stated on the demand side of the system. Section 3.4.2 below suggests a flow account which is in accordance with this recommendation.

3.4.2 Flow accounts

A flow account for the ecosystem services that are related to the water resource is presented in Table 3.8. The account includes both services related to groundwater and surface water, but in principle it can be split up into two tables one for each of the two water media. In this case an account can be made both for each relevant aquifer or water catchment areas and at a national level. It may be difficult to relate some of the regulating services to either surface water or groundwater because these services are also supplied by water in soils. Therefore, it is suggested that one account including groundwater as well as surface water is preferable.

The flow account can be made for quantities as well as values of ecosystem services. With regard to quantities of ecosystem services the account will be directly related to the water flow accounts of Section 3.1 (the provisioning services) and the emission accounts of Section 3.2 (the regulating services) while the quantities of cultural services have no direct relation to any of the earlier described accounts. However, none of the values of ecosystem services that are stated in the account has direct relation to the other accounts of the water accounting system either.

The main idea with the ecosystem services accounts is that they should form the basis for sustainable water resource management. This means that both narrow market-economic efficiency considerations and more general regard for the environment should be taken into account. Therefore, the accounts should provide the economic value of all the different ecosystem services related to the water resources regardless if they have market-economical relevance or not. This is a precondition for being able to weigh different services against each other. Quantities of ecosystem services - i.e. the quantity of fresh water extracted and used as provisioning service - form part of the basis for estimating the value of the services.

Table 3.8 Supply and demand of ecosystem services related to the water resource.

Ecosystem services		Industry 1	Industry n	Water	Water	Households
Provisioning						
Direct supply from water resource	Groundwater	+	+	+	+	+
	Surface water	+	+	+	+	+
Supply from water catchment industry	Groundwater	+	+	-	+	+
	Surface water	+	+	-	+	+
Regulating services						
N-retention, fixation, denitrification		+	+	+	+	+
P-retention, P fixing,		+	+	+	+	+
Detoxification		+	+	+	+	+
Accumulation of heavy metals		+	+	+	+	+
Cultural services						
Walking, birdwatching etc.						+
Angling						+
Boating						+
Swimming						+
Hunting						+
Educational and scientific use		+	+	+	+	+

Note: +positive value and service demanded / -value of service supplies by water catchment industry 1.

Table 3.8 includes all ecosystem services related to the water resource. The supply side of the ecosystem service account (the rows) includes all the different services discussed above and the demand side of the account (the columns) relates the different services to industries and household. Of course, the same classification of industries used in the general national accounting system should be used on the demand side of the ecosystem service account. It also includes services that are already a part of the SNA and SEEA national accounting system. The overlap concerns particularly the value of provisioning services, but also the value of some of the regulating services may indirectly be included in the production value and / or value added of industries. If these were not allowed to emit substances into the water resource perhaps they would have been forced to reduce their production or the costs of production would have been higher.

The point is that the values of ecosystem services cannot be directly added to the value added stated in the economic part of the national accounting system to get the total value of human and environmental production of society. To calculate this value it is necessary to make corrections to the ecosystem service values stated in the ecosystem service account so that double-counting is prevented.

Presumably there is both a need for an account of the value of ecosystem services related to water and a need for an account of the total value added of goods and services provided jointly by industries and the water resource. Therefore, two accounts have to be made, one like Table 3.8 showing the total value of all ecosystem services related to water and one showing the value added of goods and services provided jointly by the society and the water resource. This account could be drawn up like traditional national accounts of value added distributed on economic production sector, but with the water resources sector added. This main sector supplies the different water related ecosystem services. In this way, the contributions of these services become clearly associated with the water resource. By contrast, the value added of the economic sectors will be reduced by the value of ecosystem services earlier included in their value added.

In Chapter 4 below the possibilities of measuring and estimating the amount of the different ecosystem services is discussed in more detail. The possibilities and problems in relation to valuation of the services are also discussed.

3.4.3 Stock accounts

The concept of an ecosystem service is by definition a flow variable and therefore it can be discussed if stock accounts of these services can be meaningfully put forward. However, the annual value of these services now and in the future determines the stock value of the water related part of the nature capital. It is important to estimate this value - or at least the change in the value - for two reasons.

Deterioration of the quality of the aquatic environment that cannot be observed in the current year, but is expected in future years should be stated in the water account as a depreciation of the stock value of the water resource. The value of future ecosystem services has decreased.

To obtain the annual value of depreciations of the value of the water resource is necessary to calculate the value of the Green Net Domestic Product and the value of Genuine Saving.

Many impacts on the aquatic environment - e.g. different emissions –have long term impacts and perhaps the full effects on quality and services are only experienced several years after the emission to the water body. In such cases it is important that the value of the total effects of the impacts is stated in the water accounts in the year where the impacts take place. This is done as a reduction of the value of the water resource - i.e. as depreciation. Of course, an improvement of the water quality now and in the future should be stated in the account as an appreciation of the value of the water resource.

Table 3.9 Opening and closing asset value of a water resource determined by value of expected annual ecosystem services in actual and future years - DKK. (Overview without data).

Asset value of water resource dependent on expected annual flow value of ecosystem services	Opening value of water resource	Increase in value	Decrease in value	Closing value of water resource
Provisioning				
Direct supply from water resource				
- Ground water				
- Surface water				
Supply from water catchment industry				
- Ground water				
- Surface water				
Regulating services				
N-retention, fixation, denitrification				
P-retention, P fixing,				
Detoxification				
Accumulation of heavy metals				
Cultural services				
Walking, bird watching etc.				
Angling				
Boating				
Swimming				
Hunting				
Educational and scientific use				

The Green Net Domestic Product and especially Genuine Saving are important economic indicators of economic and environmental sustainability, cf. Section 5.5. An important part of the calculation of these measures is the calculation of the depreciation of the value of Natural Capital including the depreciation of the value of the water resource.

The stock value of the water resource is determined by the actual and expected future value of ecosystem services supplied by the aquatic environment. Thus, the stock value is calculated as the present value of these services. Calculation of the stock value of the water resource involves huge practical difficulties related to estimation of expected future amounts and values of ecosystem services. The stock value is also highly dependent on the chosen discount rate.

These are challenging issues. However, if they were solved, a stock value account, as the one presented in Table 3.9, could be developed. Like the flow account in Table 3.9 for the annual value of ecosystem services, the stock account can be drawn up for both each water catchment area and at a national level, dependent on data availability.

The asset values and the changes in these values are determined by

- the use of water amounts stated in the flow accounts of Section 3.1.1 and expected future use
- the emissions to water stated in the emission accounts of Section 3.2 and expected future emissions
- the quality of the water resource stated in the water quality accounts of Section 3.3 and expected future changes in water quality
- the use of cultural services stated in the ecosystem service account of Section 3.4.1 and expected future use of cultural services
- changes in relative prices of the different ecosystem services.

All these conditions are mutually dependent and determine the amount and value of different ecosystem services supplied and demanded. Therefore, the information in the stock value account is central for analyzing the relations between use of the aquatic environment and the development in the value of natural capital. The aquatic environment is used for consumption and production purposes as well as a recipient of emission, and this affect the value of natural capital.

4 Valuation of Water Resource Related Ecosystem Services

This chapter gives an overview of how different ecosystem services, described in Section 3.4, can be valued. The presentation follows the classification of ecosystem services in Table 3.8. Economic valuation of provisioning services, regulation services and cultural services are discussed in Section 4.1, 4.2 and 4.3 respectively.

In this report the annual flows of ecosystem services are only assigned direct or indirect use value. Therefore, the services should only be valued by methods that estimate use value. This approach is not in accordance with current practice which also assigns non-use values to ecosystem services and regards them as flows - cf. UK National Ecosystem Assessment (2011) and Bateman et al. (2011a). However, in this report it is argued that in accordance with national accounting principles, services are flows that are supplied and used and therefore they can only be assigned use value.

However, water resources do also have an asset value - the water resource is part of the natural capital which first of all depends on the direct and indirect use value of its expected future supply of ecosystem services, but the asset value may also reflect option value and non-use values. The valuation of these is discussed in Section 4.4. Finally, Section 4.5 addresses issues specifically related to valuation of ecosystem services in water resource accounts.

4.1 Provisioning services

Provisioning services supplied by the water resource include groundwater and surface water used by industries as input in production and by household for drinking water. This use of water resources generates direct use value.

4.1.1 Water resource provisioning services traded on the market

Water provisioning services traded in the market include water as input into intermediary or final products and consumers purchase of water, which they may use for drinking water or non-drinking water purposes. In Denmark, these services primarily originate from ground water resources. The amounts of traded water are recorded in the water flow accounts as discussed in Section 3.1.

Valuing traded water resource services is relatively straightforward. The marginal value of water sold to consumers or producers is given by the actual consumer/producer prices. If the market price includes taxes and subsidies, it is termed “purchase price” and if the price does not include taxes and subsidies it is called “factor price”. Although water prices may vary across the country it is possible to estimate the total value of water consumption from data about total sale and purchase. This is in accordance with general practice in national accounts. An average marginal value of traded water can be estimated based on the total value and total use of water.

4.1.2 Water resource provisioning services not traded on the market

Water resource services may be obtained for direct use through private extraction, e.g. private boreholes established by industry and agriculture. The annual use of non-traded water is included in the water flow accounts of Section 3.1. Often, this resource is not sold directly on the market, and no market price exists for this quantity of the water resource. Different methods exist to attribute a marginal value to non-traded water resource services:

- Average resource rent – this is calculated by subtracting the value of all other input uses than water (i.e. labour, real capital, land and produced inputs) from the value of the product in which water is used. Therefore, the resource rent necessarily depends on how the other inputs are valued. In particular, if the value of land is affected by water availability, it is not clear how the average resource rent should be adjusted. In theory marginal and not average resource rent should be used in national accounts - cf. the principle of marginal valuation. However, this requires a correction for how the production value changes as a consequence of changes in water consumption. This correction is difficult to make in practice and therefore, average resource rent without any corrections is used in national accounts.
- Marginal productivity – this is calculated based on a production function. Marginal productivity of different inputs can be estimated, including the marginal productivity of water.
- Cost based approaches – this is calculated based on the costs of extracting, distributing and cleansing the water.

Several values of water services result when applying average resource rent or marginal productivity approaches. The values are dependent on the production context where water is used.

Cost based approaches are in accordance with current methods in national accounts when valuing the supply of public services such as police, national health system, and defence. These services are not traded and therefore do not have a market price nor a known marginal value. As an approximation, national accounts define the value of public services as the cost of service provision.

A similar approach could be used for estimating the value of the non-traded provisioning services. The costs of water extraction could be calculated for a number of water extractions and although these costs may vary across the country, it is possible to calculate a representative cost based price. This price could be used as basis for valuing the non-traded provisioning services of water.

In theory, the productivity based approach to valuing marketed ecosystem services is preferable in the cases where data for calculating resource rent or marginal productivity is available. If productivity based approaches prove disproportionally costly or difficult to implement, cost based valuation approaches can be considered.

If none of these valuation methods can be used because of lack of information, non-traded water resource provisioning services may be valued as the average marginal value of traded water, cf. Section 4.1.1.

4.2 Regulating services

Regulating services of the water resource include N-retention, denitrification and N fixation, P-fixing and retention, detoxification, accumulation of heavy metals etc., cf. Section 3.4.2. The amounts of these different services are not stated in any of the existing water accounts described in Section 3.1 - 3.3. They have to be estimated as a part of the total valuation of regulating services.

One important basis for valuation of regulating services is the emission accounts of Section 3.2. This is because the value of the water related regulating services is related to the part of total emissions that are fixed or decomposed by the aquatic environment. This part depends on total emissions and can be estimated on the basis of these and knowledge of the receiving water resource.

The other part of the emissions which is not fixed or decomposed flows into the aquatic environment where it has negative consequences for the water quality. Some of these consequences may be registered in the same year as the emissions take place, but other consequences may first show up in later years. However, in both cases the negative consequences should be stated in the water asset account as depreciations in the value of the water resource.

Two valuation problems are related to valuation of water resource regulating services - one related to valuation of the regulating service as such (fixing and decomposition of substances) and another related to valuation of water quality deterioration. The problems will be discussed in Section 4.2.1 and 4.2.2, respectively.

4.2.1 Valuation of water resource regulating services

As mentioned above the amount of different regulating services may be calculated on the basis of the amounts of different emissions stated in the emission accounts of Section 3.2. E.g. on the basis of the amount of N leached from agricultural land it is possible for each water catchment area to calculate the amount of N fixed or decomposed on its way from farm land to the sea. The same kind of calculations may be done for other substances. The fixed or decomposed amounts of different substances indicate the amount or quantity of the regulating service supplied by the aquatic environment.

Water resource regulation services have indirect use value. This means that the value of these services is not directly captured by the market, but only implicitly through the value of marketed and non-marketed products. Therefore, regulation services must be valued by non-market valuation methods. Hein (2011) and Gascoigne et al. (2011) suggest two methods:

- Alternative costs of pollution mitigation
- Avoided damage costs

If water resources did not supply the different regulating services, emissions would have had to be neutralized in other ways to make sure that the aquatic environment is not deteriorated. Alternative neutralization measures include reduced production, use of other types or other amounts of input in production and different purification measures. All measures represent costs to society and it is these saved costs that can be used as indicators of the value of regulating services.

Valuation of regulating services needs information about first the amount of each substance fixed or decomposed by the water resource and second about the marginal cost of reducing the load of the aquatic environment with each the different substances. This assumes that cost effectiveness analyses of alternative reduction measures have been made. In cost effectiveness analysis the marginal costs of reducing the load to the same extent as the ecosystem provides through regulating service is calculated. This marginal cost is a measure of the economic value of the regulating services. The total value of ecosystem services is the marginal cost multiplied with the estimated amount of the service.

Regulating services may also be valued in an alternative way based on the value of prevented decreases in the value of other ecosystem services. If the water resource has not supplied the different regulating services the aquatic environment would have been deteriorated and this would have meant a decrease in the value of supplied provisioning and cultural services. The prevented decrease reflects the value of regulating services. However, this valuation method is not in accordance with the method used in other parts of the national accounting system. Normally non-trade production and consumption are valued on the basis of the production costs - e.g. this is true for public production and consumption. Therefore, the outlined alternative valuation method cannot be recommended in a national accounting context.

4.2.2 Valuation of pollution that leads to water quality deteriorations

The emissions that are not absorbed through regulating processes in ecosystems leads to pollution. Water pollution both includes pollution of drinking water and pollution of fresh water used by the fishery sector and for recreational purposes. Pollution affects both the quantity and quality of drinking water available. The quantity is affected if the pollution is severe. When water is polluted the value of its input and use services decreases. Therefore, it is important to decide if the value of the effects of pollution should be stated as either a negative value of each type of pollution or as a decrease in the value of the different water services.

By valuing each of the different pollution substances a direct link to the emission accounts of Section 3.2 is established. However, the problem with this approach is that the negative value of a polluting substance very rarely can be represented by one price. The effects of each substance often depend on both where it is emitted and when it is emitted and in some cases also on other concurrent emissions.

These problems mean that preferably pollution should be valued for each pollutant and each drainage area. Again the valuation can be based on alternative mitigation costs or damage costs - cf. Section 4.2.1.

The damage cost approach assumes that the dose response relationship between emissions and final consequences for water quality, and even better for the supply of water related services, is known. The approach also presupposes that the value of the different affected water related services is known. Especially the value of cultural services may be affected, but also provisioning services supplied to e.g. fish farms may be affected. Valuation of cultural services is discussed in Section 4.3. The value of the water stock will also be changed as it reflects the expected value of all future services, cf. Section 4.4.

For most fresh water systems the values of their services depend continuously on the amount and quality of the services. However, polluted drinking water might represent a problem. Does it have a zero value - it cannot be consumed directly any more - or does it have a value reflecting that it is possible to purify the water? This may depend on whether it is water flows or water stocks that are valued. If the necessary amount of pure drinking water can be supplied just by extracting until now unused water resources and this does not generate extra costs, the value of drinking water flow services is unaffected by the pollution. However, the value of the total drinking water stock is affected as a part of it is not available for drinking purposes any longer. The question is if the lost water resources should be valued as of zero value or it still has value because it can be used for irrigation purposes or be used as drinking water if it is purified.

In fact, the same question can be raised in relation to the flow of drinking water services. If these cannot be sustained without purifying the polluted water either the total value of services decreases equal to the value of the lost flow of pure drinking water or the value of services is sustained while extra costs of purification are put on the society.

Caution should be taken, if other provisioning and cultural services are valued and the values reflect the deterioration of the aquatic environment caused by pollution in the same year pollution should not be valued on the basis of the costs of reducing the pollution. This would lead to double-counting.

4.3 Cultural Services

Cultural services include recreational activities like walking, bird watching, angling, boating swimming and hunting, but also educational and scientific use of the water resource, cf. Section 3.4. The supply of these services represents direct use values to the users. However, these values fall outside the realm of the market and non-market valuation techniques are needed to attribute economic values - see Figure 4.1.

Recreational activities refer to services provided by freshwater resources which in most cases include several recreational services at the same time. The individual values of the different services may influence each other. E.g. if a lake is used for sailing and swimming the value of these services may be high, but the values of its angling and bird watching services may be low because of the disturbance from the sailing activities. Thus, valuation of these services individually is not a trivial task. Therefore, many valuation studies focus on estimating the consumer surplus of recreational value of improving the quality of a habitat from the present level to a future hypothetical level, leaving it open for interpretation for which recreational purpose. However, other studies seek to value a particular use of a site - e.g. angling, bird watching, mountain climbing, boating etc., etc.

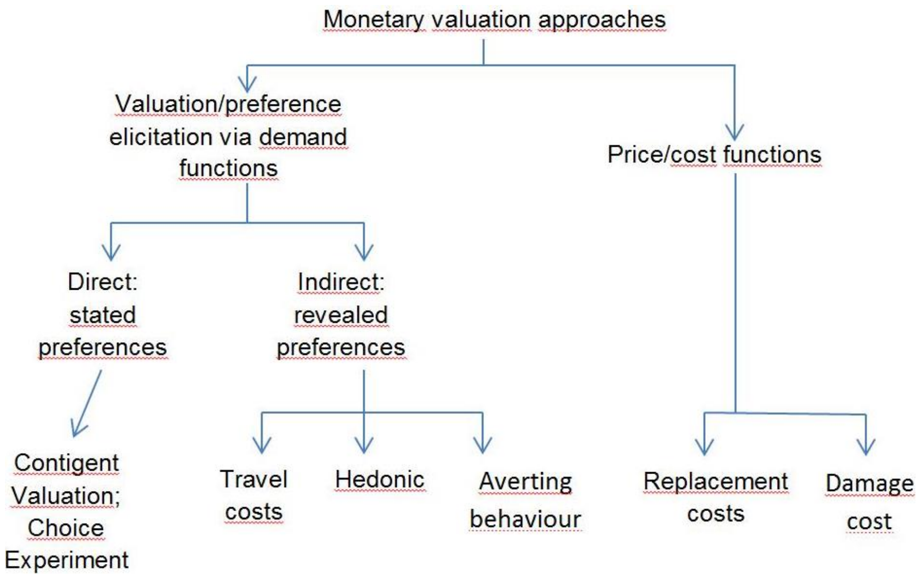

Figure 4.1 Overview valuation of non-market goods and services.

Valuation techniques for measuring non-market values are based either on direct or indirect preference elicitation or on price/cost functions. A brief overview is given below:

- **Contingent valuation** – uses direct preference elicitation by asking respondents for the willingness to pay WTP for a quality or quantity improvement or for a willingness to accept WTP a decrease in quality or quantity of the specific ecosystem service. This method can be applied to both use and non-use values.
- **Choice experiment** – uses direct preference elicitation by asking respondents to trade off among a pre-specified set of characteristics of the ecosystem service through a number of choice occasions (typically 6-12 choice occasions). A cost factor (for WTP measures) or a subsidy factor (for WTA measures) is included in the characteristics. Results of choice experiments can reveal i) how much the average individual would be willing to pay for any of the options and ii) how much the average individual would be willing to pay (accept) to obtain (to avoid) specific levels of characteristics. This method can be applied to both use and non-use values.
- **Travel cost** – estimates the value of access to a specific site using the observed relationship between frequency of visit and costs of visiting to derive a demand function for accessing the site. This method can only be used for use-values and can be defined as one of the hedonic approaches, cf. Brown and Mendelsohn (1984).
- **Hedonic –** estimates the value of an ecosystem service using the observed relationship between the market price of a good and a number of attributes or characteristics of the good. From the relationship can be derived the marginal value of each attribute. E.g. differences in house prices can be used as basis for valuing vicinity to habitat sites, parks, level of air quality, noise levels, isolating etc.
- **Averting behaviour** – estimates the value of an ecosystem service by observing costs inferred by consumers to purchase market goods as a substitute for environmental quality and deriving the demand function. Examples are fire alarms, indoor air cleaning systems, sound insulation etc.
- **Replacement costs** – estimates the value of protecting an ecosystem service via the costs of re-establishing the quality/quantity of the ecosystem service at the same site or at a different location.

- **Damage costs** – estimates the value of an ecosystem service on the basis of the production value cost if the supply of the service is decreased.

These different valuation techniques can all be used to value the use value of cultural services. However, if the general valuation method in national accounting should be followed, valuation of non-traded goods - e.g. public consumption - should be based on the costs of producing the goods. This means that the alternative costs and replacement costs methods should be preferred when valuing cultural services in a water resource accounting context.

4.4 Asset value of the water resource

Water resources are part of natural capital and as such they also have an asset value. This value depends on the expected future use value of ecosystem services supplied by the water resource. The expected annual value of these services can be calculated in the same way as the value of the present year's services is calculated, cf. Section 4.1 - 4.3.

The asset value is calculated as the present value of expected future ecosystem services. This means that a social discount has to be used for the calculation. The official social discount rate in Denmark is 5 percent, but of course it can be discussed if this rate which is used in a project evaluation context also should be used in a national accounting context - cf. Møller (2009). In national accounting, market prices are used and it could be argued that a market interest rate should be used for discounting in this context. However, the question is not yet clarified.

In addition to the use values of the water resource, the water resource may also have a so-called option value and different non-use values. Option value is related to possible but yet not exploited known and unknown uses of the water resource. It has a value to society to preserve these possibilities. Non-use values include existence value and bequest value of water of the highest possible quality. This means that the water resource may have value to people living today either because they value the existence of clean water resources, even in places where they do not use the water or because future people' welfare has a value to people living today.

Fresh water and especially clean water may have existence value because people think that clean water as an environmental good has to exist. It is an absolutely necessary part of a natural environment. The possibility that groundwater or drinking water has such a value to persons cannot be excluded. However, it is very difficult to distinguish existence value from a bequest value. People may primarily assign non-use value to fresh water out of regard for future people's welfare - cf. Hasler et al. (2005).

Valuation methods for estimating option value and non-use values include:

- Contingent valuation
- Choice Experiment
- Replacement costs

However, in practice, it has proven very difficult to value option value and non-use values independently. Direct valuation methods are often directed either at use values or total values, which include both use and non-use values.

One important aspect of calculating the asset value of the water resource is to include expected future deteriorations of the aquatic environment in the water resource accounts. These may be caused by actual emissions with consequences which first show up in later years. Such expected changes in the future deteriorations should be stated in the accounts as depreciation of the value of the water resource - i.e. in the stock accounts of Section 3.4.3. Depreciation may include both decrease in use, option and non-use values of the water resource.

4.5 Special issues in valuing ecosystem services in water resource accounts

A number of issues related to valuation of water resources services are discussed below, these include:

- The value of water – marginal versus total value;
- Stocks and flows - valuation of water stocks or services;
- Moving from specific site valuation to generalised values.

4.5.1 The value of water – marginal versus total value

In a national accounting context valuation of services connected with the use of water should be based on marginal values and not total value including consumers and producers surplus. This would be in accordance with other parts of the national account system where flows and stocks of goods and services are valued by use of market prices. Market prices reflect the relative marginal value to users of the different goods and services. In practice it may be very difficult to meet this methodological claim especially for water related services that are not traded on a market. For some of these services valuation studies that estimate peoples' willingness to pay have been carried out, but in many cases it is not marginal willingness to pay that have been estimated. Many valuation studies either state average or total willingness to pay. This means that caution has to be shown when considering the use of results from valuation studies. Only marginal willingness to pay estimates or for lack of anything better average willingness to pay estimates should be used in valuing ecosystem services.

Luisetti et al. (2013, p.7) discusses this question and they conclude: "While it is appropriate to consider, as far as is feasible, economic value in terms of marginal changes, a review of the existing empirical literature suggests that in fact very few studies do so. Mahan et al. (2000), for example, produce marginal value estimates of the value of wetland amenities to properties in Portland, Oregon. The results indicate a property's value increases by $24.39 per *one acre* increase in the size of the nearest wetland. Maler et al. (2008) explicitly undertakes marginal analysis in estimating the accounting price for the habitat service provided by a mangrove ecosystem to a shrimp population. Their model evaluates changes to fisherman wellbeing for a *10 hectare* change in the stock of a mangrove forest of *4000 hectares* in size, obtaining an accounting price of $200 / hectare.

In most cases, the ecosystem valuation literature has focused on valuing the stock or the actual service flow. Normally, the analyses are placed in a context of "change" by drawing comparisons between alternative land and water use options. Therefore, the estimated values are marginal values relative to a specific use of land or water.

4.5.2 Stocks and Flows - Valuation of Water Services and Water Stocks

Valuation of fresh water comprises both valuation of supply and demand of different services generated by water, as well as valuation of the stock of water based on the value of different services that water is expected to supply. Valuation of service flows and stocks should be consistent - i.e. the flow and stock values should be based on the same valuation methods and prices. This means that if the expected annual marginal values of the different water services have been estimated the value of the corresponding stocks should be calculated as the present value of each of the expected flows.

As mentioned above, the present value calculation presupposes choice of a discount rate. This rate may heavily influence the stock values calculated. However, the discount rate problem has not yet been solved.

If good solutions of these problems can be found, this may also solve some of the problems related to quality statements - cf. Section 3.3. Valuation of the use value of the stock of water should reflect quality and by weighing water of different qualities by their value, a measure of total value is achieved which can be used as an indicator of aggregated water quality.

4.5.3 Specific site valuation and generalised values

Many valuation studies have been made for specific fresh water bodies and services. Both indirect and direct valuation methods have been used. However, it is questionable if the results from these studies can be used in a national account context. Firstly, nearly all non-market valuation studies are site specific and in case of stated preference methods, the hypothetical scenarios may vary across studies and sites (as opposed to the revealed preference method travel cost method, which always values the access to the site). It is not a trivial endeavour to transfer values from one site to another if transfer errors are to be kept below say +/-20%. Benefit transfer studies have resulted in very divergent results. Secondly, valuation studies are generally partial studies. This means that results cannot be added up. This aggregation problem has not been solved yet. Thirdly, in many cases valuation studies estimate the total value of a nature area or environmental service - i.e. the value includes consumers and producers surplus (equivalent variation or compensation variation). These values cannot be used in a national account context where marginal values should be used as far as possible.

4.6 Summary

Table 4.1 summarizes the valuation methods that should be used in relation to each of the main water related ecosystem services.

Table 4.1 Valuation of Ecosystem Services – Overview.

ES Class	Economic value	Ecosystem Service	Valuation Methods
Provisioning	Direct use value	Use of groundwater for drinking and non-drinking purposes (e.g. process water and irrigation) Use of surface water for drinking and non-drinking purposes (e.g. process water, irrigation and aqua culture)	Market prices Average resource rent Marginal value productivity Cost based valuation
Regulation	Indirect use value	Mediation of waste, toxic and other nuisances (e.g. bio-remediation, filtration sequestration, dilution) Maintenance of physical, chemical and biological conditions (nursery and habitats, decomposition and fixing processes, retention, climate regulation, chemical conditions) Recharge of groundwater	Cost based valuation (avoided costs) Value of avoided decreases in value of other ecosystem services
Cultural	Direct use value	Recreation (e.g. boating, swimming, hunting, education, angling, walking) Intellectual use (scientific, education, heritage, entertainment, aesthetic)	Replacement cost Averting behaviour Contingent valuation Choice experiment Travel Cost Method Hedonic pricing Benefit transfer
Asset value	Direct and indirect future use value	Actual and future input to production and use for consumption Actual and future indirect use of regulation services Actual and future recreational and intellectual use	Present value of actual and future ecosystem services
	Option value	Value of maintaining the possibility of future direct and indirect use of groundwater and surface water related ecosystem services	Contingent valuation Choice experiment Damage cost method Replacement cost method Benefit transfer
	Non-use values	Existence value – value of knowledge of continued high level of quantity and quality of groundwater and surface water related ecosystem services Bequest value - value of leaving a certain quality and quantity of groundwater and surface water related ecosystem services for future generations	Contingent valuation Choice experiment Hedonic pricing Damage cost method Replacement cost method Benefit transfer

5 The use of water resource accounts

As mentioned in the introduction to chapter 3 the water resource accounting system is build up in such a way that it is very suitable for different kind of analyses of the actual development of the water resource and its expected future development. The different analyses include

- Environmental indicator analysis
- Ex post analysis
- Input-output based ex ante scenario projection
- Estimation of macroeconomic water resource models, consequence calculation and forecasts
- Evaluation of sustainability based on Genuine Saving

These different analyses are described and discussed below. All analyses except evaluation of sustainability based on Genuine Saving, can be made on the basis of information from the SEEA accounting system. This system includes use of water accounts, water asset accounts and emission accounts where emissions are related to different economic activity. However, if the analyses are supposed to include consequences for water quality and supply of water related ecosystem services, the full SEEA Water framework has to be brought into use - cf. Chapter 3. Description of consequences for the supply of ecosystem services assumes that these are valued by use of the valuation methods discussed in Chapter 4. Valuation is also needed to calculate Genuine Saving.

5.1 Environmental indicator analysis

The water resource accounting system contains several types of information that can be used together with other environmental indicators to evaluate the state of environment in relation to water.

The water flow accounts directly show how the use of water changes over the years. As the water flows are divided between economic sectors, the accounts show which sectors are the main users and if their use is increasing or decreasing. If the information from the stock accounts is also included in the analysis, it can be evaluated if the actual water use is within the limits set by the total amount of water available for use each year. If water stocks are decreasing, the water use is too big. However, water availability depends among other thing on climatic condition and therefore, it may change over time independently of annual use.

The information about water flows can also be combined with economic and demographic statistics to evaluate if industries and households have become more effective in their water use. It is one of the advantages of the integration of water accounts with the general national accounting system that through their common sector division there is a direct link between production and input use in different economic sectors and their use of water. This makes it possible to calculate a water use coefficients for each of the sectors (water use per production value) and evaluate the development in water use effectiveness.

The same advantage applies to *the emission accounts,* which either shows the emissions of each compound distributed on different industries and the households or the emissions of different pollutants from one industry or household. In this case emission coefficients - i.e. emission per production value or per use of different inputs - for the different pollutants and industries can be calculated. Changes in coefficients over time indicate if production in each industry sector and households' consumption has been less polluting or not. As the sectors are divided in the same way as in the rest of the national accounting system, the information can be used for further analyses of the underlying reasons for the observed development in total emissions - cf. Section 5.2.

As described in Section 3.2 emission accounts should be divided geographically to be suitable for further environmental analysis of the impacts of the emissions. The deposition of the emitted pollutants will have different consequences in different catchments. The hydrological movements inside catchments / drainage basins and between the catchments, the air and the sea are important for the transport of water and pollutants and for the regulating, provisional and cultural services in general. The drainage basin's boundaries and the groundwater aquifer boundaries can be seen in Figure 5.1a and b.

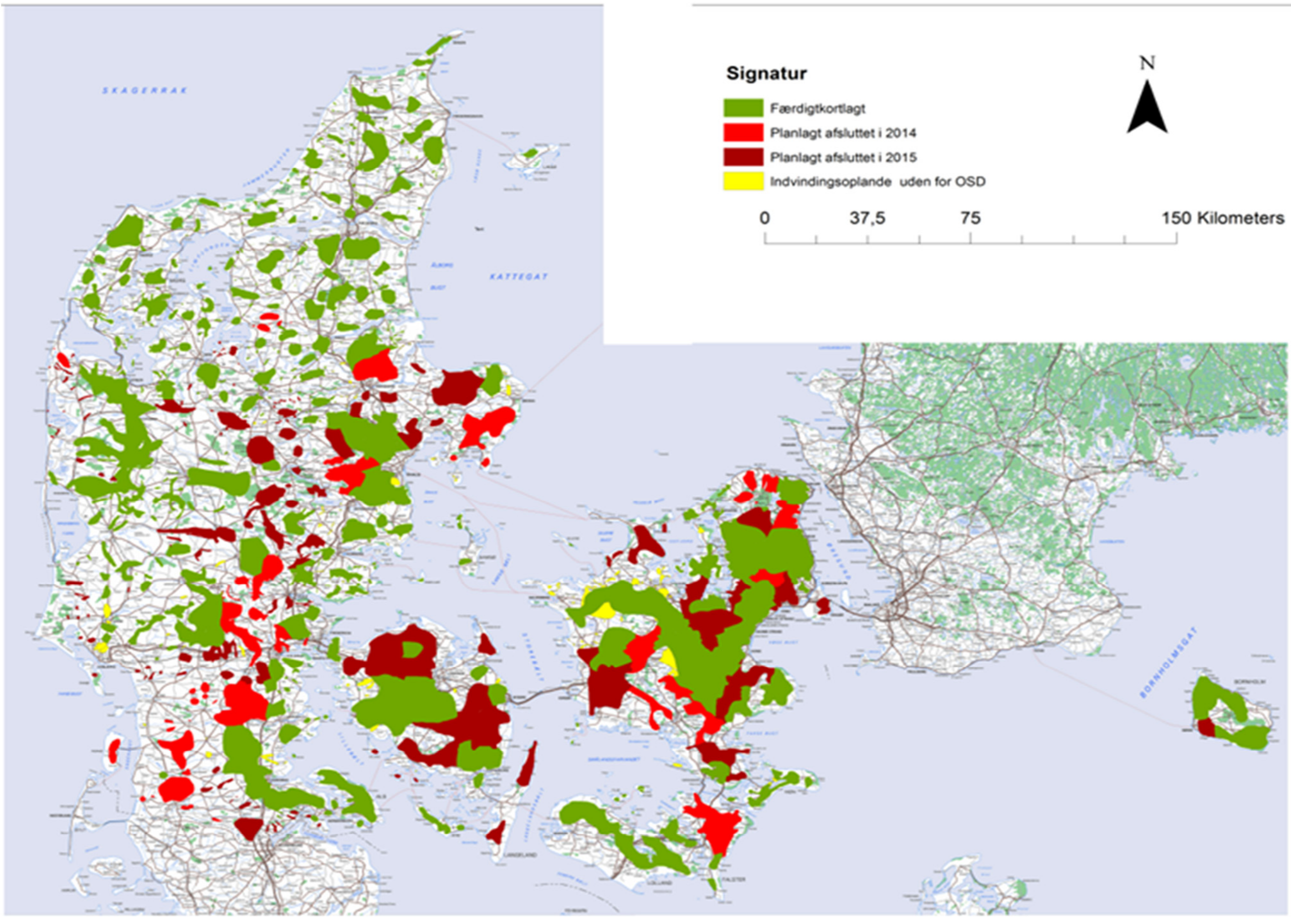

Figure 5.1a Example of mapping: Groundwater abstraction map.

Figure 5.1b Example of mapping: Main River Basins.

The geographical hydrological units complicate integration with the other parts of the national accounting system, which normally are not geographically subdivided. Without this subdivision of economic activities it is not possible on the basis of the national accounting system to explain geographically specific changes in water quality and supply of ecosystem services. However, the geographically subdivided emission accounts indicate which water resource systems may be threatened by pollution.

Water quality accounts indicate if there are water resource systems that have unsatisfactory water quality and if water quality is improving or deteriorating. The accounts are not directly linked with the economic part of the national accounting system. The link goes through the emission accounts which of course imply that the same geographical subdivision of water resource systems should be chosen in water quality as well as emission accounts. As described above the emission accounts are linked with the economic accounts and in this way the total economic cause / environmental effect chain has been established. It can be used as basis for explanation of observed changes in water quality, cf. Section 5.2 below.

Finally, *the ecosystem services accounts* indicate the economic value of the water resource for the society. As explained in Section 3.4 the water resource provides services which are used by different parts of the society. The value of some of these services - especially the provisioning services - are already included in the economic accounts, but the value of the services that have not until now been included in these accounts increases the total production value and value added generated jointly by humans and nature. Correspondingly, non-marketed ecosystem services are included on the demand side of the national accounting system and increase the value of total demand.

The value of ecosystem services related to the water resource and the measured stock value may be used as aggregated state of the environment indicators. It may be referred to these in argumentation for protection and preservation of the water resource. Of course referral to economic value should not be the only argument for protection - also ethical and aesthetical considerations are important - but as economic value can be regarded as an aggregated indicator of the consequences of society’s use of the water resource, it is highly relevant.

However, it is important to be careful when interpreting the development in the total value of ecosystem services. An increase in the value of ecosystem services related to water is not necessarily an expression of an improvement in the state of the water resource. Thus, the value both depends on the quality of the water resource and the amount of water used (or how many uses the water resource). It should be added that the relative prices of ecosystem services may change over time, e.g. because peoples’ preferences for the services can change.

An increase in the amount of water resource used, in many cases increases the value of ecosystem services, but it may also mean a deterioration of the resource. Some examples show this:

- An increase in the annual amount of groundwater extracted increases the provisioning ecosystem service related to groundwater, but if the amount of water extracted exceeds the natural growth in the ground water resource the increase in the ecosystem service value cannot be interpreted as an indicator of an environmental improvement. This will also be stated in the extended national accounts as a decrease in the value of the groundwater stock - i.e. a depreciation. So generally the annual value of provisioning services should be stated together with any depreciations of the resource to give a correct picture of the value of the service.

- An increase in the area of farm land cultivated will be stated as an increase in the provisioning ecosystem service related to farm land, but if the increase in farm land area has been achieved by draining wetlands the value of regulating and cultural ecosystem service provided by these may have decreased. However, if this decrease is less than the increase in farm lands provisioning services, the result will still be an increase in the total value of ecosystem services. From an economic point of view this can be interpreted as an environmental improvement, but from a broader environmental point of view this interpretation may not be correct.
- If annually more pollutants are released to the aquatic environment and the water resource is able to degrade or absorb the pollutants without any immediate consequences for water quality the value of the regulating ecosystem service will increase. However, even if water in this case supplies more services it can be discussed if this also can be interpreted as an environmental improvement. It is also possible that the ability of the water resource to degrade and absorb pollution gradually will decrease in the future if the emissions of pollutants go on for several years. It can be difficult to foresee these consequences and even if it is possible they will not appear before several years later. These consequences may be stated in the actual year as a depreciation of the water resource, but because of discounting of the value of future ecosystem services the depreciation may not be as big as the stated increase in the actual value of regulating services.

These examples clearly shows that caution should be taken when interpreting changes in the value of water related ecosystem services as an expression of similar changes in the state of the aquatic environment, but in most cases there will be such a direct connection. In summary it is important to be aware that economic accounts stating the value of water resource related ecosystem services do not give an adequate picture of water resource conditions. The accounts have to be complemented with the physical accounts of the total water resource accounting system.

5.2 Explanation of environmental changes - ex post analysis

If the different water accounts are fully integrated with the economic part of the national accounting system and not least if the economic part can be subdivided geographically in line with the subdivision suitable for water resource accounting the total accounting system can be used for a number of analytical purposes. One of these is ex post analysis.

Ex post analysis is an analysis that focus on explanation of observed economic or environmental changes that have taken place and on uncovering effects of earlier incidents such as implementation of policy measures. Thus, the analysis gives knowledge of the reasons for observed changes in emissions to water, water quality or value of water related ecosystem services and it can also give valuable experience about the effects of different policy measures.

An accounting system is very useful for ex post analysis. The total national accounting system including the water accounts form one big input output system that is a good basis for analysing the different causes of observed environmental changes. In accordance with the way that the accounting system is structured, the analysis is best carried out by going through three different analyses:

- Analysis of the causes of changes in emissions
- Analysis of the causes of changes in water quality
- Analysis of the causes of changes in the value of ecosystem services supplied

The *emission accounts* are directly linked to the economic accounts and therefore, it is possible on the basis of input output tables to separate which part of the emission changes that is due to:

- General growth in the economy
- Changes in the composition of consumption and other demand
- Changes in industry structure
- Changes in emission coefficients caused by either changes in input use or resource effectiveness

The result of such an input output based decomposition analysis makes up a very good basis for an explanation of observed emission changes, but of course, the result does neither explain the size of general growth nor the changes in demand composition, industry structure and emission coefficients. To explain these changes further analysis is needed.

One such analysis could focus on the effects of policy measures put in action. E.g. if the price elasticity of demand for a certain polluting input is known it is possible to estimate how much the demand of this input has changed due to a tax on the input. Subsequently, this estimate can be used to determine how much of the observed changes in the input related emission coefficients can be explained by changes in the use of input. Finally, the change in emission coefficients can be used to calculate the total change in emissions caused by the tax. Of course, this effect is only the direct effect of the tax on emissions. There may also be several indirect effects caused by substitution of the taxed input with other input and by changes in final demand caused by relative price changes triggered by the input tax. These indirect effects are not included in the outlined simple partial analysis. A proper general equilibrium model is needed for this kind of general analysis, cf. Section 5.4.

The next kind of analysis focuses on the causes of the observed changes in water quality stated in the *water quality accounts*. In most cases the main reason is the changes in emissions related to changes in human economic activity described above. But, also other causes like pollution accidents, trans-boundary pollution and natural incidents may be part of the explanation. Changes in trans-boundary pollution are stated in the emission accounts, but the reasons for the changes cannot be deduced from information in the national accounting system. The same is true for pollution accidents and natural incidents like flooding.

The final type of ex post analysis concerns the reasons for changes in the *value of ecosystem services*. Each change has different reasons depending on the ecosystem service in question.

Changes in the value of provisioning services in most cases have economic reasons related to changes in demand for water for production and consumption purposes. These changes are stated in the economic accounts and the underlying causes can be found by the input output based analysis described above. In some cases also changes in water quality affect the value of provisioning services - e.g. catches in the fishery sector and provision of drinking water - and of course, the reason for these value changes should be found among the explanations for water quality changes stated in water quality accounts.

As explained in Section 5.1 changes in the value of regulating services are related to emission changes and the capacity of the water resource to degrade and absorb the pollutants. Actual emission changes can be explained on the basis of information in the actual national accounts as described above, but changes in degradation and absorbing capacity have causes related to emissions in earlier years. Therefore, a complete explanation of stated changes in the value of water related regulating services has to incorporate earlier year's economic activities and emissions related to these activities.

Finally, changes in the value of cultural services are caused by changes in people's use of the aquatic environment and their willingness to pay for the services. Of course, these two elements are related. Most cultural services (except hunting and angling) are public goods which are free for the users. So the higher they value the services the more they will use them, and their contingent marginal willingness to pay for the services may also be higher. It is difficult on the basis of the information in the national accounting system alone to determine which are the underlying causes of a change in the value of cultural services. Changes in water quality may be part of the explanation, but probably also socio-economic and demographic factors such as income changes, changes in age distribution and preference changes are important determinants. Real statistical analysis is needed to settle these questions.

5.3 Input output based ex ante scenario projection

Just as the national accounting system can be used as basis for retrospective and explanatory ex post analysis, it can also be used as basis for forward looking ex ante scenario analysis. This analysis shows the consequences of an assumed change in economic activity for other economic activities and the aquatic environment. In its most simple form the ex-ante scenario analysis is based on the input output accounts that are part of the national accounting system. As such an analysis is based on input output relations stated by fixed coefficients and not real demand and supply functions the analysis is in the nature of a projection and not a forecast. A real forecast must be based on a macroeconomic model, cf. Section 5.4.

An input output based scenario analysis of an increase in a private consumption category makes use of the following direct and indirect relations between demand and supply of goods. Increase in consumption of a good leads to an increase in the supply of the good. Some part of the supply comes from an inland production sector and another part may come from import. These are the direct effects of the consumption increase. However, it also leads to indirect effects because to increase production in one economic sector, more inputs from other sectors are needed and they should also be produced or imported etcetera, etcetera. All these relations are stated by input output coefficients in the input output account. Based on these, the total direct and indirect consequences for production in different sectors and for import of an increase in a consumption category can be calculated.

On the basis of the projected production changes and the emission coefficients calculated on the basis of the water emission accounts, the consequences for different emissions to water of the increase in consumption can be calculated. However, the calculated emission changes only include emissions generated by Danish production sectors. The import of consumption goods and inputs for production generate emissions in foreign countries, but these emissions are not included in the national accounting system. Separate information about production conditions and the related emissions in foreign countries has to be obtained before emission consequences for foreign countries can be projected.

So, the national accounting system with its input output accounts and emission accounts makes it possible to make simple projections of the national emissions to water of assumed changes in consumption of different consumption categories. Of course the same kind of analysis can be made for assumed changes in the production in different economic sectors.

The use of input output coefficients and emission coefficients to make simple projections of emissions can be defended because the coefficients reflect real average relations between demand and supply of goods and between production and emissions. The relations do not have general validity, but they are valid for the specific accounting year that they are calculated for. However, this is not the case for the relations between emissions and water quality and between water quality and value of ecosystem services. These relations might not be linear, even not within a single year. This means that the consequences for water quality and the supply of ecosystem services cannot be directly projected on the basis of the information stated in the water accounts. This information has to be supplemented with real knowledge about how emissions will affect water quality and what changes in water quality will mean for the value of different ecosystem services. Such knowledge will in some cases be available in form of so-called dose-response or dose-effect functions.

The input output based projection described above is initialised by a change in final demand or production, but projections of assumed change in input use or water treatment can also be made. However, first this calls for an independent analysis of how emission coefficients are affected by changed input use or water treatment. It may not always be easy to estimate this, but if it is possible, the consequences for total emissions can easily be projected - moreover assuming unchanged economic activity.

The projections described in this section are calculated on the basis of assumed partial effect of changes in consumption or production activity. This means that basic economic interaction mechanisms have not been taken into account in the analysis - more consumption of one good means less consumption of another and changes in demand affect relative prices which again will affect relative demand et cetera. Such economic interaction can only be handled within economic models and in fact information from the national accounting system constitutes a good basis for estimating such models.

5.4 Estimation of macroeconomic water resource models, consequence calculation and forecasts

The integrated national accounting and water accounting system can be used to estimate integrated economic and water resource models. Such models can either take the form of a main macroeconomic model with a water resource satellite model linked with it as e.g. the Danish ADAM macroeconomic model and its energy satellite EMMA model for supply and demand of energy products. Alternatively the model can be a fully integrated macroeconomic and water resource model. For now, such models do not exist in Denmark.

The strength of the integrated national economic and water resource accounting system in relation to model estimation is the possibility of estimating a fully integrated economic and water resource model based on coherent and statistically consistent information. Such model also includes feed-back effects from the aquatic environment on the economic activity and value of ecosystem services - e.g. feed-back effects from emissions and water quality on value added in the fishery sector (a provisioning water ecosystem services) or value of water related cultural services.

Estimation of the fully integrated macroeconomic and water resource model is based on time series for all the relevant data in the economic and water resource accounting system. In addition to the economic demand and supply function, the time series of the accounting system makes it possible to estimate functional connections (not necessarily linear) between environmental investments of industries and emissions to water, between emissions and water quality and between income, water quality and economic activity and value of ecosystem services. First of all the functions represent statistical regularities and not a deeper insight in and description of the economic and natural scientific mechanisms behind the functions - cf. McKinney et al. (1999). Therefore, it is important they are in accordance with what should be expected of their form and parameter sizes from knowledge of these mechanisms. Examples of such models are presented in California - cf. Jenkins et al. (2004) - in the Adra river in Spain - cf. Pulido-Velazquez et al. (2009) - in the Nilufer river basin in Turkey - cf. Gurluk and Ward (2009) - and in the Yass river basin in Australia - cf. Letcher et al. (2007).

It may be possible to construct similar models on the basis of information from many different sources - e.g. by linking independently estimated dose-response relations with economic models as mentioned above. Such models are often based on thorough natural scientific knowledge of the interaction between the society and nature. However, the problem with these models is that they are based on data collected in many different contexts and therefore, data are not necessarily consistent with regard to time scale, economic sector division and geographical scale, etc. But, even if the consistency and coherence of the models can be questioned they should be used and their results compared with the results from the models estimated on the basis of information from the integrated national economic and water accounting system. These comparisons may lead to a deeper insight into the complex interaction between the economy and the aquatic environment.

The integrated macroeconomic and water resource models can be used for different analytical purposes which comprise two main groups of analyses:

- Impact analysis of policy measures
- Forecasts of expected economic and environmental development

The advantage of integrated models in relation to impact analysis is that the models include demand and supply functions that describe how economic agents react on taxes and cost increases caused by environmental regulation. The agents' direct reaction on the regulation may have consequences for demand, supply and prices on other goods than the regulated good which cause further adaption and so on. The economic adaptation behaviour has consequences for the aquatic environment and the value of ecosystem services which again may affect economic activities. The total economic and environmental adaptation to the policy measure is described by the integrated model and the final consequences of the measures appear as differences between the former and the new economic and water resource equilibrium.

Compared to the input output based scenario projections the use of integrated models may lead to forecasts of the expected development of the economy and the water resource. This is because the models are build up around functions that as well as possible describe real economic behaviour and adaptation to changed economic and environmental conditions as well as functions that describe how the water resource develops as a consequence of changed economic use of the resource's ecosystem services. The functions are not necessarily linear as in the input output model and therefore, they represent a more realistic picture of the economy and the water resource.

5.5 Evaluation of sustainability based on Genuine Saving

Section 5.1 described how the integrated national economic and water resource accounting system includes information about resource effectiveness, emissions to water, water quality and value of ecosystem services that can form part of a complete environmental indicator system. In addition to this, the system also includes information that can be used to evaluate if the economic and environmental development is sustainable. In fact already from the beginning of the development of green national accounting evaluation of sustainability has been an important focus and reason for developing the accounting system, cf. Ahmad et al. (ed.) (1989).

To begin with focus was on the concept of Net Domestic Product (NDP) and the necessity of making corrections to this measure so that it would give a more correct picture of the development of pure income and wealth of the society than traditional NDP. The fundamental theoretical work was done by Mähler (1991) and Dasgupta (1995). They showed that a real Net Welfare Measure (NWM) could be formed from NDP by decreasing this measure with the value of defensive measures and increasing it with the value of non-market environmental services. Besides depreciation of physical capital total depreciations should now include depreciation of all renewable and non-renewable environmental resources.

This insight could be expressed by use of the concept of ecosystem services in the formula for Genuine NDP below

$$\begin{aligned}&Genuine\ NDP\\&= NDP\ +\ value\ of\ regulating\ services\ not\ reflected\ in\ value\ added\\&+\ value\ of\ cultural\ services\ -\ value\ of\ defensive\ measures\\&-\ depreciation\ of\ natural\ capital\end{aligned}$$

The concept of Genuine Saving is derived from Genuine NDP by subtracting the value of private and public consumption as well as the value of cultural services. Its relevance as an indicator of sustainability is based on the so-called Harwick's Rule according to which the economic and environmental development is sustainable if investments in real capital (including knowledge) at least correspond with depreciation of natural capital, that is Genuine Saving is zero or positive, cf. Hartwick (1977).

Genuine Saving is now accepted by many as an economic indicator of weak sustainability, but to make it practicable a complete integrated national economic and environmental accounting system has to be drawn up. The water accounts and especially the accounts of the value of water related ecosystem services and changes in the value of the water resource constitute an important contribution to this system.

It should also be remembered that Genuine Saving has very serious weaknesses as an indicator of sustainability of which the two most important are:

- If the value of total capital already in the present situation is too low for sustainability then the economic and environmental development may still be unsustainable even if Genuine Saving is positive.
- Some parts of nature may have infinite value or we are not allowed to destroy it and therefore, it may not be possible to replace all parts of natural capital with real capital as assumed in Hartwick's rule.

In the light of these weaknesses Genuine Saving should not be the main focus when drawing up integrated national economic and water resource accounts.

6 Data available for a Danish water resource accounting system

This section presents existing data sources for a Danish water resource accounting system. The available data are discussed with respect to how these data can be used for water resource accounting. In Section 6.1 data sources on water quantities - flows and stock - are presented and discussed. Section 6.2 presents data sources of emissions to Danish inland water and in Section 6.3 sources of water quality data are described. Most of the data sources referred to in Section 6.1 - 6.3 can be found in the Danish Natural Environment Portal ("Miljøportalen") which is presented in Section 6.4. This is followed by Section 6.5 which presents Danish water accounts that have been published by Statistics Denmark until 2010. This is to give an idea of which kind of water accounts have been published until recently and which data sources are available for use in water accounting. After this, in Section 6.6 the empirical possibilities of establishing ecosystem services accounts for Danish water resources are discussed - including presentation of two Danish economic valuation studies for water resources and one study assessing the regulating ecosystem services of retention in a Danish catchment. Finally, Section 6.7 concludes on the data availability for Danish water resources accounting.

6.1 Data sources of water quantities – flows and stocks

Data for the physical water accounts described in Section 3.1 are available mainly from three principal sources: GEUS (Geological Survey of Denmark and Greenland), DANVA (Danish Water and Waste Water Association) and the NOVANA program (Danish Water Monitoring System). Water flows from point sources such as waste water treatment plants are registered in the PULS data base which is basis for annual reports on water flows and emissions from point sources, cf. Naturstyrelsen (2012). The two sections below present these data sources and discuss how data from these two sources can be used for the accounts of water flows and stocks, respectively.

6.1.1 Important sources of data on the physical water flows

In Section 3.1.1 it was explained that the annual supply and use of water measured in physical units should be stated in water flow accounts that include

- water flows from the environment into the economy - divided in different economic sectors (industries and households)
- water flows between different economic sectors
- water flows from the different economic sectors back into the environment.

Data on water flows from the environment into the economy originate from two sources - groundwater and surface water. Information about extractions from these two sources can be obtained from the JUPITER database (www.geus.dk/jupiter) and DANVA (Danish Water and Wastewater Association, www.danva.dk).

The Jupiter database forms the basis for GEUS' estimations of the total water extractions in Denmark and follow-up on the objectives laid down in the Danish performance measurement act (Consolidated act no. 932 of

24/09/2009 act on performance measurements, etc. for water deposits and international protected natural areas). According to the Danish Data Responsibility Agreement ("Dataansvarsaftalen") the JUPITER database ensures that data is of well-defined quality, and that all confidential data are handled correctly, cf. Thorling et al. (2013).

As a result of the Danish act on water supply (Consolidated act no. 635 of 07/06/2010 on water supply, etc.), all extractions of water must be reported to the municipalities, which are charged with the task of checking data and subsequently entering the data in the JUPITER database. The database contains data on amounts of water extraction from 1989 up to and including 2011, which have been reported by the municipalities (until 2006 by the counties), as well as information on the geographical location, permissions granted for water extraction (amount), and tests and analyses of chemicals in drinking water as well as administrative information.

The data reported by the municipalities make it possible to construct regional accounts distributed by the geographical location of the water extraction plants. It is also possible to distribute extraction by user types (waterworks, household, irrigation of fields, etc.).

The database also contains information from more than 240,000 drillings with information on e.g. the technical structure of the drilling, geological description, water level, chemical tests and analyses of groundwater.

Previously, GEUS received data from the counties including estimates of the size of the missing data from the extractors. Following the Danish local government reform in 2007, the 98 municipalities are charged with the task of supervising the extraction of water, and estimates of missing data from the extractors are no longer made. The statistics on water amounts pumped up by the waterworks now provide more or less full coverage, whereas data for the first years after the Danish local government reform 2007-2011 must be considered incomplete.

An overview of the number of waterworks and extractions of groundwater at national level is still not available, cf. Thorling et al. (2013), and this delimits the access to a full data description of both groundwater quality and quantity. According to the Ministry of Environment (2012), it is however now required to provide information for all water delivering services, and this point towards more precise data about both quantity and quality of the groundwater from all groundwater extractions.

Another source to data about water flows is DANVA (Danish Water and Wastewater Association, www.danva.dk) which annually publishes an estimate of the consumption of water distributed by households, industries and institutions in its annual publication "Vand i tal" (Figures on water) (http://www.e-pages.dk/danva/120/) conducted on the basis of information from water suppliers throughout Denmark. DANVA also collects information on prices from the different water suppliers that are members of the DANVA association.

Finally, most data for descriptions and accounts of the *water flows from waste water treatment plants* etc. to the environment and the water flows from the environment – from surface water – to industries, households, agriculture etc. are sampled as part of the NOVANA-program. Sampled data for water flows from and between point sources - waste water treatment, industries etc. - are available from the Danish Natural Environment Portal - se Section 6.4. The Nature Protection Agency also publishes these data in annual reports on point sources, cf. Naturstyrelsen (2012) p. 86-89, based on an underlying database on point sources sampled in PULS. This report, and other NOVANA reports, also includes data on water flows from point and non-point sources to marine recipients.

Table 6.1 Flow account - supply and use of groundwater.

Supply (origin) of water		Water works	Sewage plants	Other industries	Households	Environment	Total
	Type of water:						Million m^3
Environment	Groundwater					JUPITER	
	Surface water					JUPITER	
	Rain water					NOVANA	
Economy	Tap water	JUPITER DANVA					
	Waste water for discharge		NOVANA PULS	NOVANA PULS	NOVANA PULS		
	Waste water for treatment		NOVANA PULS	NOVANA PULS	NOVANA PULS		
	Total supply of water						

Use (destination) of water		Water works	Sewageplants	Other industries	Households	Environment	Total
	Type of water:						Million m^3
Environment	Groundwater	JUPITER		JUPITER	JUPITER		
	Surface water			JUPITER			
	Rain water		NOVANA				
Economy	Tap water			DANVA	DANVA		
	Waste water for discharge					NOVANA PULS	
	Waste water for treatment		NOVANA PULS				
	Total use of water						

Note: The size of water flows is calculated as net-flows, i.e. re-circulation of water is not shown in the account.

The data sources for the assessment and accounting of water flows from the environment into the economy, as far as possible divided on sectors, are presented in Table 6.1, using the same format as in Table 3.1. In the table, DANVA means benchmarking data from DANVA, and NOVANA means the ODA data base from this monitoring programme.

It can be seen from Table 6.1 that all necessary data for drawing up a water flow account of quantities supplied and used by the environment and the economy is available from the three data sources referred to above. This will also appear in Section 6.6, which presents an account of the Danish water quantity accounts that were published by Statistics Denmark until 2010.

6.1.2 Important sources of data on the physical water stocks

A National Ground Water Level Monitoring Program (Det Nationale Pejleprogram) was established in 2007 with the aim to monitor the stock, changes in the stock because of climate change, changes in land use as well as changes in water abstraction. Before 2007 this type of monitoring was done on a regional basis and a data-series of 40 years is therefore available.

The groundwater stock data are collected by GEUS and they are published in the JUPITER database. A similar program is not established for surface water because this is not required by the Environmental Legal Act, cf. Miljøministeriet (2009), and therefore, stock data for this water asset are not available.

As described in Section 3.1.2 and Table 3.2 changes in water stocks can be attributed to natural as well as human processes and the effects of these processes should be included in the accounts. As mentioned above changes in groundwater stocks because of climate change, changes in land use and changes in water abstraction are monitored, and there are data available, but there are no data at national level about e.g. draining. This also appears from Table 6.2 where data availability is described in a stock account similar to Table 3.2.

The data available for stocks and flows of groundwater satisfies most of the demands of a national accounting system. Thus, data are partly sufficient to account for changes in stocks between years – i.e. in the start of the year and the end of the year - but information about fluctuations within years, which is required to explain changes in the observed surface water stock during the year, is not available. Still, the effects of dry summers which can affect the groundwater table up to 1-2 meters, can be seen from the data, cf. Thorling et al. (2013).

As mentioned in Section 3.1.2 a certain stock category is the size of wetland areas that are important for the regulation of nutrient flows. The wetland area is monitored as part of NOVANA, and wetland restoration is an important measure in the River Basin Management Plans. This applies to the current plans and also as a measure in upcoming plans that are required to fulfil the Danish implementation of the objectives in the Water Framework Directive.

Table 6.2 Water asset account.

	Groundwater	Surface water	Total
		Million m^3	
Opening stock	A	NA	
Increase in stock because of natural processes			
Precipitation	A	NA	
Other inflow			
Increase in stock because of human activities			
Waste water	-	A	
Draining	NA	NA	
Decrease in stock because of natural processes			
Evaporation	A	NA	
Outflow to sea			
Other outflow			
Decrease in stock because of human activities			
Water abstraction	A	A	
Closing stock	A	NA	

Note: A: Available; NA: Not Available.

Information from the ongoing groundwater stock monitoring program in connection with mathematical water models is used by GEUS to estimate the quantity of the water resources that are available in the future. In this way, it is possible to assess changes in stocks and water level as a consequence of changes in precipitation and water extraction. It is also possible to evaluate how much groundwater can be expected to be available for sustainable extraction in the future. The most recent nationwide statistics on groundwater sources in Denmark were compiled in 2003 (http://vandmodel.dk/vm/index.html).

6.2 Data sources on emissions

The data on emissions to water is extensive, and covers both data on groundwater pollution and emission sources as well as surface water pollution and emission sources. In this section is given an account of emission data sources while data for pollution levels are referred to in Section 6.3 about water quality.

As presented in Table 6.3, data on emissions of different pollutants to groundwater and surface water bodies (lakes, watercourses and rivers) can be retrieved from reports about emissions from point sources, cf. Naturstyrelsen (2012), and the underlying database on point sources sampled in PULS as well as from the NOVANA reports. The industrial sources of wastewater emissions are partly divided into separate industries, but not directly according to the industry division used in national accounts. Emissions from aquaculture are also monitored and there are separate data for aquaculture which is relevant as freshwater aquaculture is widespread. The point-source database includes data on wastewater quantities and the wastewater treatment, the content of organic matter and nutrients, heavy metals and hazardous substances. The nonpoint data from NOVANA monitored in the LOOP-areas (Land use monitoring program) report nonpoint emissions to the root zone from agriculture being estimated using monitoring data and modelled data. The NOVANA reports for surface water and marine areas are published by DCE (www.dce.au.dk) - see e.g. Blicher-Mathiesen et al. (2012) - and by GEUS for ground water. Much data are available at the Danish Environmental Portal (Miljøportalen).

In contrast to water flow accounts where only one account is needed, there is a need for several accounts to account for the emissions to groundwater and surface water bodies, as there are a large number of different pollutants (nutrients, organic matter, hazardous substances and heavy metals). It is also important to state emissions in a geographical scale relevant for the aquatic environment.

It is seen from Table 6.3 that most of the entries of the emission account can be derived from the above mentioned data sources. Further analyses are needed to determine which specific pollutants emission accounts can be drawn up. These analyses will also uncover the need for adjusting the industrial division used in the data sources to the industrial division used in national accounts. Finally, the possible geographical scale of the emission accounts should be analyzed. Emissions from both point and non-point sources are distributed regionally, and the emissions are monitored for the respective water bodies within the 23 Main River Basins, according to the Water Framework Directive and NOVANA. Therefore, it may be possible to find a common geographical scale for emissions into the aquatic environment.

Table 6.3 Data for accounting emissions to ground- and surface water.

	Industries, aquaculture	Households	Agriculture	Rain[1]	Foreign countries
1. Direct and diffuse emissions from industries, agriculture, households, rain and foreign countries into freshwater	PULS	PULS	NOVANA	PULS	-
1a. Without treatment	PULS	PULS	NA	-	-
1b. After treatment	PULS	PULS	NA	-	-
2. From industries, households and rain to wastewater treatment plants	PULS	PULS	Not relevant	PULS	Not relevant
Gross emissions (total emissions from industries, households, rain and foreign countries - except wastewater treatment plants) 1+2					
3. From wastewater treatment plants into freshwater					
3a. Without treatment	PULS	PULS			
3b. After treatment	PULS	PULS			
Net emissions (direct emissions from all industries - including waste water treatment industry - households and foreign countries) 1+2+3					
4. Net emissions into freshwater	PULS	PULS	NOVANA		
4a. Without treatment	PULS	PULS			
4b. After treatment	PULS	PULS			

[1] Including pollutants that flow with rainwater directly into freshwater and sea or to waste water treatment plants.
NA: Not Available.

6.3 Data sources of water quality and status

The water quality of groundwater and surface water, including both freshwater/inland water sources (lakes and waterways) and marine water bodies (fjords, coastal areas and open marine areas), is monitored in NOVANA, and data are available from the Danish Natural Environment Portal - see Section 6.4.

NOVANA reports on status of the *groundwater quality*, cf. Thorling et al. (2013) and groundwater pollution data are also accessible from the DAI (Danish Areal DataBase) and JUPITER (GEUS). In DAI groundwater pollution sites are indicated on maps and JUPITER contains data for groundwater areas with respect to data on the content of nitrate, phosphorus, inorganic trace elements (arsenic, nickel, aluminium and boron), organic micropollutants and pesticides (different substances that are approved and regulated, but also banned), cf. Thorling et al. (2013).

The National Monitoring Program NOVANA reports data on the *ecological status of water courses and rivers, of lakes and of coastal areas and fjords*, cf. Jensen et al. (2013). The ecological status is monitored with respect to the objectives of the Water Framework Directive (WFD) where the indicators of rivers/water courses, lakes, coastal areas and fjords are inter-calibrated across EU, cf. EU Commission (2009). For water courses the ecological status is described and classified according to the implementation of the WFD, primarily for biological quality elements, cf. Wiberg Larsen et al. (2013). These quality elements comprise plankton (phytoplankton), bottom algae and larger macrophytes as well as macro-invertebrates and fish. At the moment only macro-invertebrates/fauna is used as the indicator for good ecological status in Denmark, using the Danish fauna-index for watercourses. The NOVANA program monitors the development in this indicator and the results are published in annual reports, cf. Wiberg Larsen et al. (2013). Data are available at the Danish Environment Nature Portal.

Furthermore, for lakes the total-phosphor (Mg P/l) and total-nitrogen content (Mg N/l) as well as the Chlorophyll A, sight depth and color scale are monitored and reported as part of the NOVANA program. The main indicator for the reporting of the good ecological status under the WFD is Chlorophyll A.

The data on water quality of the water bodies in each river basin district (watercourses, rivers, lakes, coastal and marine water bodies) are also compiled in the European WISE database (Water Information System for Europe). DG Environment liaises with Member States, especially on official reporting requirements of EU water legislation
(cf. http://ec.europa.eu/environment/water/index.html) and the European Environment Agency hosts the Water Data Centre and the thematic WISE webpages
(cf. http://www.eea.europa.eu/themes/water/dc,
http://www.eea.europa.eu/themes/water).

In WISE the following information relevant for the accounting of water quality is available for each River Basin District:

- *Area of each water body* can be relevant for the assessment and these data are available from WISE as well as from the River Basin Management Plans. Data available include:
  - The total number of water bodies including artificial water bodies
  - Water body surface area (km^2) - the size of the water body is calculated at the scale of 1:250 000.
  - Total area of transitional water bodies (km^2)
  - Total number of HMWBs (Heavy Modified Water Bodies) and AWBs (Artificial Water Bodies).

- For each *category of water body* (water courses, rivers, lake, transitional and coastal waters) the following data are available:
  - Number of types per water category - national or river basin district (RBD)
  - A list of types and a short description of each type (<300 characters).

- For each *pollutant/monitoring program and for each surface water category* (rivers, lakes, coastal and transitional), the following data are available:
  - Start and end of monitoring
  - Number of monitoring sites and monitoring frequency
  - Priority Substances and other substances discharged, quantities and exceeding.

To sum up there is a large data material available which can be used to make water quality accounts both for groundwater resources and surface water. It seems best to account groundwater and surface water quality separately as environmental problems related to these two resources are different. This is also reflected in the monitoring programs and data bases described above.

Further analyses are needed to determine the preferable geographical scale of the water quality accounts and the indicators used to express water quality. Water quality accounts for groundwater could be drawn up either at aquifer or national level and similarly quality accounts for surface water could be drawn up at water catchment or national level. From an environmental point of view aquifer and catchment levels have to be preferred, but of course, this also means many separate accounts that may seem chaotic. Some form of data aggregation may be expected to be necessary to get a clear picture of the state of the aquatic environment - e.g. at river basin or water district level.

With regard to choice of water quality indicators two considerations have to be taken into account. On the one hand it should be possible to relate the quality indicators to the emissions stated in the emission accounts, cf. Section 6.2, and on the other hand as far as possible they should also be related to the supply of water related ecosystem services and their value. Thus, also with respect to water quality indicators a form of aggregation over pollutants may be needed.

6.4 The Danish Natural Environment Portal

Most of the data referred to in the sections above are available from the Danish Natural Environment Portal. The portal gather environmental data concerning for instance water resources and water quality for monitoring, managing and safeguarding the natural and environmental resources, cf. the portals homepage www.miljoeportal.dk, downloaded December 18, 2013. The Danish Natural Environment Portal gives access to data, web services, a user administration system and access to legacy archives with data from the former counties. The data portal also provide access to data across administrative units, sectors and geographical areas and it is used by Governmental institutions to gather environmental data for national surveillance as well as reports to the Danish Parliament and the EU, cf. the homepage of the portal. Since 2007 it has been possible to download environmental data directly from the site www.miljoeportal.dk, either through “Area information” or through a number of web services that have been developed since 2007. All users are granted access to the databases from the portal.

- *Area Information* represents natural environment data graphically on a map, e.g. data on groundwater.

- *Web services* are software which enables access to the databases of The Danish Natural Environment Portal. Some of these databases are:
  - AquaBase: Marine vegetation data
  - FiskBase: Data from fish monitoring in lakes and fjords
  - FS-base: Data on environmental hazardous substances in biota and sediments
  - STOQ FAGSYSTEM STOQ: Data in water courses, streams, rivers, lakes and marine areas, including a module for detection of sources
  - WinBio: Danish fauna index for water courses (DVFI). Fauna, small fauna in water courses and streams, water vegetation in lakes, fish in streams and rivers, vegetation along streams and rivers, physiological conditions in rivers and streams (index)
  - WinRambi: Bottom fauna in lakes and fjords.

Data about water quality are now also available from the PULS database which as mentioned above covers data from point sources (“punktkildeudledningssystem”). Until recently these data were available only from the closed data sources WinRIS, WinSPV and Magic Dambrug that were used until 2012/13. Now the data are available in PULS which covers data on water use and abstraction as well as emissions from different point sources - among others aquaculture, industries and waste water treatment plants. The data cover amongst others chemical content and nutrient content in waste water, data on water flows and data from monitoring programs, cf. “Fagsystemoversigt” downloaded from miljoeportal.dk 02.12.2013. Use of the webservices at the portal requires access permission by a user’s license, but the portal and the data are freely accessible for both professionals and private citizens.

6.5 Danish water accounts

In this section is given an account of Danish water resources accounts that are either published or have been published until recently. The presentation gives an idea of the practical possibilities of drawing up such accounts and it includes physical water accounts that are described in Section 6.5.1, waste water balances presented in Section 6.5.2 and finally water supply and waste water treatment in the national accounts described in Section 6.5.3.

The accounts are based on data from the sources referred to in the sections above. To this is added a number of statistics and information from Statistics Denmark, which were used to give estimates of the distribution of water consumption by industries and households. The data sources for the monetary water accounts and national accounts are derived from economic statistics (accounts statistics for public utilities, etc.) supplemented by calculations using the physical water accounts, etc.

Since the most recent physical water accounts for the reference year 2005 were compiled a couple of years ago, some changes have taken place with regard to the organization of the collection of data on extraction of water. This is, among other reasons, due to a change in the distribution of tasks between the regional and municipal authorities in conjunction with the Danish local government reform. This is also one of the reasons that Statistics Denmark has stopped publishing physical water accounts for Denmark.

6.5.1 Statistics Denmark’s physical water accounts for Denmark

Until 2010 Statistics Denmark published annually accounts for Denmark’s physical (m^3) extraction and use of water. The water accounts were published in the series Statistical News ”Environmental Accounts for Denmark”, cf. Statistics Denmark (2010). The water accounts were published for the reference years 1995 to 2005. Data are available from the database StatBank Denmark at: www.statistikbanken.dk/mreg5V.

The water accounts were constructed as satellite accounts to the Danish national accounts in accordance with the principles described in the System of Environmental-Economic Accounting (SEEA). Subsequently, data in the water accounts complied with the definitions and classifications used at that time in the Danish national accounts and the water accounts were applicable for purposes of analysis, together with the national accounts and input-output tables.

The physical water accounts showed the general extraction and use of water in Denmark broken down by the following elements:

- Extraction of groundwater (1000 m^3)
- Extraction of surface water (1000 m^3)
- Consumption of piped water (1000 m^3)
- Final consumption of water (1000 m^3)

The 2005 water accounts are summarized in Table 6.4 below.

The first part of the accounts shows the extraction of groundwater and surface water broken down by industries and households. From this part it appears partly which amount of water is extracted by the water supply industry (general water supply) and partly the own extraction of water by other industries and households. The total amount of extracted groundwater and surface water can be seen in the third column of the table. It appears that groundwater accounts for the dominant part of water extraction.

Table 6.4 Water accounts, 2005.

		Extraction					
		Ground water	Surface water	Total ground and surface water	Supplied by the water supply industry	Received by the water supply industry	Final consumption of water
		(1)	(2)	(3)	(4)	(5)	(3)-(4)+(5)=(6)
		million m3					
	Total industries and households	639.8	18.1	657.9	373.8	373.8	657.9
	Households	9.8	0.0	9.8	0.0	251.8	261.7
	Total industries	630.0	18.1	648.0	373.8	122.0	396.2
1	Agriculture, fishing and quarrying	172.0	3.7	175.7	0.0	35.6	211.3
2	Manufacturing	32.1	8.4	40.5	0.0	34.9	75.4
3	Electricity, gas and water supply	423.0	5.9	428.9	373.8	3.6	58.7
	of which water supply	*420.4*	*4.7*	*425.1*	*373.8*	*0.0*	*51.3*
4	Construction	0.0	0.0	0.0	0.0	0.5	0.5
5	Wholesale/retail trade, hotels, restaurants	0.2	0.0	0.2	0.0	12.7	12.9
6	Transport, storage and communication	0.0	0.0	0.0	0.0	3.2	3.2
7	Financial intermediation, business activities	0.0	0.0	0.0	0.0	3.8	3.8
8	Public and personal services	2.7	0.1	2.7	0.0	27.6	30.4

As presented in Table 6.4 groundwater is abstracted and used by different sources. The largest share of the extracted water is used for drinking water purposes by the waterworks (in all approximately 3000), but groundwater is also extracted and used for irrigation in agriculture, which is the second largest usage. The amount of water extracted for irrigation is varying between years because of variations in weather conditions. Groundwater is also extracted for industrial usage, as well as for use by different institutions, aquaculture and greenhouses.

The water supply industry accounts for the greatest part of the extraction, but a considerable own extraction can also be attributed to agriculture. Moreover, some households and business enterprises extract groundwater from their own drillings.

The fourth column of the water accounts shows the total amount of water that was supplied by the water supply industry to other industries and households. In the fifth column, this amount of piped water is broken down by the industries and households that have received the piped water. It can be seen that 251.8 million m^3 piped water have been received by the households out of the total amount of 373.8 million m^3 piped water supplied by the water supply industry.

The sixth column shows for each industry and for households the total amount of water that was used in the form of water from own extraction as well as water from the water supply industry. This so-called final consumption of water appears, especially for the water supply industry, as the aggregate sum of extracted water less than the water supplied to other industries and households. For the water supply industry the final consumption of water was 51.3 million m^3 water. This corresponds to the industry's loss, etc. in the water pipe lines, consumption of filter backwashing and protective drillings.

As an example of how the water accounts can be applied in conjunction with the national accounts and input-output tables, Table 6.5 shows the industries' final consumption of water broken down by final demand, which ultimately underlies the consumption of water. The final demand denotes in the national accounts private consumption, government consumption, gross fixed capital formation, etc. and exports of goods and services, i.e. the demands that are not made up by input in the industries (intermediate consumption).

It appears, e.g. from the table that the water consumption by agriculture is predominantly attributed to private consumption and especially exports, because it is in these demand categories that the agricultural products ultimately end up. The great export orientation of agriculture and manufacturing implies that a total of 232.8 million m^3 of the industries' total water consumption of 396.2 million m^3, i.e. almost 60 pct., is related to exports of goods and services.

Table 6.5 Industries' final consumption of water broken down by final demand. 2005.

		Private consumption	Government consumption	Gross fixed capital formation, etc.	Exports of goods and services	Total
				million m^3		
	Total industries	112.5	35.1	15.8	232.8	396.2
1	Agriculture, fishing and quarrying	39.5	3.0	4.4	164.4	211.3
2	Manufacturing	14.5	2.1	6.6	52.3	75.4
3	Electricity, gas and water supply	45.4	3.5	1.7	8.2	58.7
	of which water supply	*41.1*	*2.8*	*1.3*	*6.1*	*51.3*
4	Construction	0.1	0.0	0.4	0.0	0.5
5	Wholes./retail trade, hotels, restaurants	5.5	0.8	1.6	4.9	12.9
6	Transport, storage and communication	1.3	0.3	0.2	1.4	3.2
7	Financial intermediation, business activities	1.5	0.6	0.7	1.1	3.8
8	Public and personal services	4.8	24.8	0.3	0.5	30.4

Note: The estimation is based on model calculations on the basis of the input-output table for 2005.

For the sake of simplicity, the water accounts are here presented with disaggregated industries to eight industry groups. The water accounts included at the most detailed aggregation level 117 industries and one single group for the households.

6.5.2 Waste water balance

The waste water balance has not, unlike the above-mentioned water accounts, been compiled in conjunction with Statistics Denmark's current publication of environmental accounts, but has on a trial basis been constructed for the reference years 2002 and 2003 as part of a pilot project conducted for Eurostat.

The principal aim of the waste water balance was, together with the water accounts, to provide a cohesive description of the flows of water, from when the water is extracted until it is discharged to nature again.

The waste water balance was compiled on the basis of the final water consumption as it appears from the physical water accounts above. The balance shows how the amount of water, which is not incorporated in the products or evaporates, is either purified by the industries and is from here discharged to nature, or collected as waste water and treated by a sewage disposal plant and is then ultimately discharged. The balance does not contain information about rain water and melt water.

Table 6.6 shows the physical amounts of waste water discharged, together with the payments made by the different industries and households related to purification of waste water in the years 2002 and 2003. Information about these payments is derived from the information in the national accounts' industry *Sewerage and sewage disposal plants (business number 370000)* sales of services to other industries and households (see also below).

Table 6.6 Waste water discharges and payment of waste water taxes 2002 and 2003.

		2002	2003	2002	2003
		1.000 m^3		1.000 DKK	
	Total industries and households	**397 115**	**375 317**	**4 841 204**	**5 137 393**
	Households	230 706	228 627	3 395 175	3 589 133
	Total industries	**166 409**	**146 690**	**1 446 029**	**1 548 260**
1	Agriculture, fishing and quarrying	13 855	12 810	149 873	168 938
2	Manufacturing	72 710	59 861	663 304	643 901
3	Electricity, gas and water supply	25 080	21 780	15 791	21 744
4	Construction	571	512	5 568	6 482
5	Wholesale/retail trade; hotels, restaurants	14 625	13 404	130 936	146 409
6	Transport, storage and communication	3 317	3 285	30 194	36 071
7	Financial intermediation, business activities	3 973	3 750	36 737	41 741
8	Public and personal services	32 277	31 288	413 627	482 975

For the purpose of the waste water balance, the discharge of waste water by industries and households was compiled on the basis of the final consumption of water (from the water accounts above) with deductions of the amounts of water used for irrigation, evaporated or added to the products. Information about these "demands" of water was, e.g. obtained from the Danish Environmental Protection Agency and the green accounts of some business enterprises. Moreover, data from the Danish Environmental Protection Agency on the amounts of water, which were received by the sewage disposal plant from manufacturing industries and households, were used in establishing the waste water balance.

Figure 6.1 below illustrates how the water accounts and the waste water balance together provide a picture of the flows of water from when the water is extracted by the different industries and households until added to the products, etc. or discharged either from the industries and households themselves or via the public sewerage disposal plants.

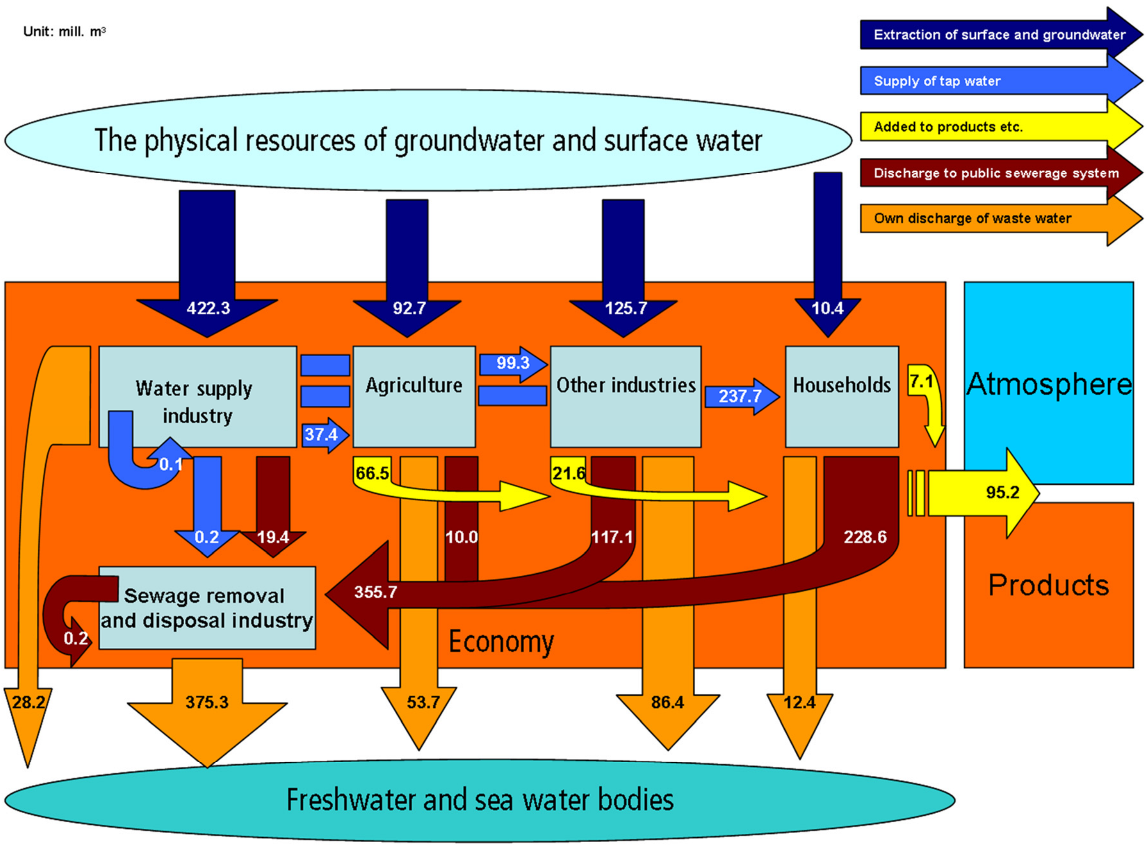

Figure 6.1 Primary flows of water and waste water in Denmark.
Source: Olsen (2005).

6.5.3 Water supply and waste water treatment in the national accounts

The Danish national accounts contain two industries, business number 360000 and 370000 (out of a total of 117 industries) that are of special interest in connection with the description of the role of water in the economy.

360000 Water supply
This industry comprises activities related to extraction, sewerage disposal and distribution of water to industries and households. The industry also comprises operation and maintenance of irrigation canals, whereas irrigation by means of sprinkler systems and similar services intended for agriculture are excluded. The latter services are recorded instead together with agricultural activities by the agricultural sector.

370000 Sewerage and sewerage disposal plants
This industry comprises operation and maintenance of sewerage systems and sewerage disposal plants, including collection and transport of household waste water as well as rainwater, emptying of cesspools and septic tanks, sludge boxes and drainage, maintenance of chemical toilets, purification of waste water (including household and industrial waste water, water from swimming pools, etc.).

The production value and the expenditures are compiled for the two industries on the basis of Statistics Denmark's accounts statistics for utilities. Information on revenue and expenditure, etc. of public and private utilities is collected via the accounts statistics. The production values of the two industries are distributed to the demand side for the 117 industries and households that are paying for the supplies of water, etc. purification of water, etc. It must be noted that the payments made by the industries and households to *360000 Water supply* do not only cover payments for the water itself, but also the different services involved in the form of distribution, etc. related to water supply.

While the total value of the services supplied in the form of water supply and waste water treatment is based on an overall estimation of the revenue, etc. of the two industries, the distribution of this amount on the demand side (i.e. who is paying for the services) is estimated on the basis of the most recently available water accounts, i.e. for the reference year 2005.

The payments for the water supply are made up by three services:

- Payment for water: Payments for water can be calculated on the basis of the physical amounts of water received by the different industries and households as well as the price per cubic meter water supplied.
- Payment of a fixed water rate to the water supply industry: Payments of a fixed water rate to the water supply industry (i.e. subscription payment) can be calculated on the basis of the ratio between the sizes of meter readings (water consumption broken down by households, industries, etc.) and subscription payments. For this purpose, information on type of building and installation is collected from the Register of Building and Dwelling Statistics. Moreover, information on subscription prices from major Danish cities is also used.
- Payment of a connection fee to the water supply industry: The connection fee paid to the water supply industry can generally be calculated on the basis of information on the number of new buildings distributed by types of dwelling as well as building investments distributed by industry. In calculating the connection fee, the connection of older dwellings, which have not previously been connected to the water supply industry, is also taken into.

For the three types of payments the calculations are conducted at the level of municipality as the water price, etc. varies, to a great extent, among municipalities. The detailed calculation is possible due to the circumstance that the information on water consumption and the other types of services are compiled at the level of municipality, although the water accounts, etc. are not published at the same detailed level.

For payments to the industry *370000 Sewerage and sewerage disposal plants* a similar calculation is conducted at municipal level based on a distribution of payments for water discharge (on the basis of information from DANVA, Danish Water and Wastewater Association) as well as tax on water discharge. The tax levied on water discharge accounts for the major part of the production value of the industry. It is characteristic of the water discharge tax that it is generally linked to the amount of water that is purchased. In connection with the accounts, it is taken into account that some industries are completely or partially exempted from payment of the water discharge tax as the water purchased is not discharged to the sewerage system and a sewerage disposal plant, but the water are instead added to the products produced by the industry. Furthermore, other information is used when the accounts are established, e.g. information from the Household Budget Survey of household expenditure on waste water management.

Applying the above-mentioned method, an estimate is created of the payments made by each individual industry and the households to the *water supply* and *sewerage and sewerage disposal plants.* These estimates are used in distributing the directly calculated production values for the two industries.

Table 6.7 Payments to the water supply and waste water disposal, etc. 2009.

	360000 Water supply	370000 Sewerage and disposal plants
	DKK million	
Total	**3 946**	**8 635**
Households	**2 560**	**6 509**
Total industries	**1 386**	**2 126**
A Agriculture, forestry and fishing	185	97
B Quarryíng	1	2
C Manufacturing	286	697
D-E Electricity, gas and water supply	170	74
F Construction	33	18
G-I Wholesale and retail trade, transport, etc.	199	389
J Information and communications	17	20
K Financial intermediation and insurance	5	12
LA Real estate activities and renting of business properties	23	35
LB Housing	215	4
M_N Business activities	29	71
O_Q Public administration, education and health	174	619
R-S Culture, leisure, and other service activities	49	89

Note: The classification of industries in this table is different from the classifications presented in the above tables due to a shift in the national accounts classification.

Table 6.7 shows that the production value in the industries for the water supply, respectively, sewerage and waste water disposal plants accounted for DKK 3.9 bn. and DKK 8.6 bn. in 2009. The table also shows that the major part, respectively, 64 pct. and 75 pct. of this was accounted for by payments of the households for the services in question.

6.6 Ecosystem services accounts - valuation studies

Ecosystem services related to the water resources include three main categories of services: provisioning services, regulating services and cultural services, see Section 4.6 for a discussion of the quantification and valuation of services that can be included in the accounts. In this section data of potential relevance for Danish ecosystem services accounts are described. The description follows the classification used in Section 4.6. In Section 6.7 quantification and valuation of provisioning services are discussed and this is followed by a discussion about regulating services in Section 6.8. Section 6.9 is about valuation of selected cultural services and in Section 6.9.1-6.9.3 the possibilities of estimating the value of Danish water resources are appraised.

6.7 Provisioning services

Provisioning services include use of groundwater and surface water for drinking and non-drinking purposes. The annually supplied quantity of these services is measured in the water flow accounts referred to in Section 6.1.1, where the conclusion was that the data sources available are sufficient for quantification. With regard to valuation of the services prices of water exist, even though these prices are not real market prices but partly cost based and politically determined prices for both drinking water and waste water treatment. Prices from a stated preference valuation study also exist, cf. Section 6.6.3. Bottled water for drinking purposes have a market price, however, but much higher than the price for tap-water. Where no prices exist - e.g. for industries own extractions - either average prices or average extraction costs can be used for valuation. However, it should be mentioned that the value of this non-marketed use of water is not included in actual national accounts.

6.8 Regulating services

Regulating services include mediation of pollutants emitted into the aquatic environment and maintenance of physical, chemical and biological conditions of the aquatic environment. As referred to in Section 4.6 the most important water resources related regulating ecosystem service may be retention of nutrients such as nitrogen (N) and phosphorous (P), but also other polluting matter may be mediated by water resources.

In addition to these regulating services the aquatic environment also function as a nursery habitat for fish, amphibians and other aquatic. These services are important for biodiversity conservation which is essential for the aquatic environment as a supplier of several cultural services, cf. Section 4.3. They may also have option value and existence value that are stated in asset accounts, cf. Section 4.4. Therefore, in an account of the total value of ecosystem services related to the water resources the value of these services should not be stated separately. In principle they should be included in the value of cultural services and the asset value of water resources respectively. This requires that the value of cultural services is estimated in a way that ensures that the value of nursery services is included.

These habitats and services could also be described as supply of regulating services which are used within the aquatic environment and afterwards supplied to society as cultural services and as option and existence values. This will increase the production value supplied by the aquatic environment, but the value added will not be affected, and to avoid double counting we therefore conclude that the value of the regulating services mentioned will be reflected in the value of cultural services and asset values.

The same argumentation can be put forward in relation to the regulating service recharge of groundwater. Precipitation can be seen as an ecosystem service supplied by nature and it contributes to recharge of groundwater - precipitation is used by the groundwater resource. Afterwards the groundwater resource supply provisioning services used by the economic sectors. Therefore, the value of recharge of groundwater is reflected in the value of provision services supplied by this resource and of course, could be valued in the same way, cf. Section 6.6.1.

The most important regulating ecosystem services are the regulation of nutrients and other substances supplied by the ability of the aquatic environment to retain and transform nutrients and other pollutants. The basis for quantification and valuation of these regulating services is an estimate of the quantity of nutrients and other pollutants that the water resources can receive without harmful consequences for the water quality and an estimate of the saved cost for the society compared to a situation where the pollutants were reduced by other measures.

For most point and non-point sources the pollutants and the polluting level are measured or monitored and the geographical scale and localisation are also measured, cf. the description of emission accounts in Section 6.2. It is also in many cases known how much of the different pollutants the aquatic environment can receive without harmful effects - tolerance levels are measured in accordance with the water quality indicators described in Section 6.3. These two quantities can be used as basis for estimation of the costs of reducing the emissions to the tolerance level and the costs of reducing the emissions completely (which is very difficult). The difference in these reduction costs equals the value of regulating services supplied by the aquatic environment.

For point sources the emitted quantities of pollutants equal the quantities that are directly discharged into the aquatic environment and there are no retention in soil and groundwater. By contrast, for non-point sources - e.g. nutrients from agricultural production - the emissions are the leaching from the root zone that is reduced through retention in soil, ground and surface waters. So, for non-point sources the regulating service also include the retention, as described in previous sections.

The costs of reducing emissions should be calculated as the costs of the most cost-effective reduction measures, according to the Water Framework Directive. These measures include technological changes in e.g. waste water treatment plants and the utilisation of animal manure (handling and timing), reduced use of polluting inputs as well as reduced production and nature restoration - e.g. wetland restoration to reduce nutrient loads to lakes and marine recipients.

Several cost-effectiveness analyses of reduction of nutrient loads exist, cf. Jensen et al. (2009), Jacobsen (2013) and Jensen et al. (2013), and the results from these studies can be used to value the regulating services related to retention of nutrients. Further studies are underway measuring the value of the retention accounted as saved costs for agricultural measures necessary to achieve the same level of nutrient load reduction to aquatic recipients, cf. Termansen et al. (2014). Maes et al. (2013) have measured the value of the retention in a scenario setting in Odense Fjord Catchment using the stated preference study of the willingness to pay for good ecological quality of the Odense fjord as the measurement of the value, cf. Section 6.9.1. Termansen et al. (2014) use this approach to address the value of this ecosystem service (retention) in a scenario setting where changes in the agricultural production in the catchment and implementation of both wetlands and buffer zones influence the retention in the catchment. Furthermore, Hasler et al. (2012) have measured the costs of reducing nutrient loads from waste water treatment plants. Cost-effectiveness analyses of the management of other pollutants are more scarce.

The above mentioned analyses do not cover the value of all the regulating services related to the water resources, but they are relevant for some of the most important services. Therefore, they represent a good starting point for further work on quantification and valuation of water resources related to regulating services.

6.9 Cultural services

Cultural services include recreational and intellectual use of the water resources. The different uses are very difficult to quantify and separate. Therefore, presumably in most cases these services might best be valued by estimating the total use values directly instead of by quantifying use and estimating separate prices for each use. Exceptions from this procedure may be hunting and angling activities where market prices exist.

The economic value of cultural services is determined by the users' willingness to pay for the services. As described in Chapter 4 several valuation methods can be used and most of them are resource demanding. Therefore, it is not realistic to base valuation of cultural services on individual studies for each water resource. The benefit transfer technique can be applied to reduce costs.

In Denmark one detailed study of the cultural services related to surface water quality has been made for the Odense Fjord catchment in 2009/2010, cf. Hasler et al. (2011), Kataria et al. (2012), Jørgensen et al. (2013) and Jensen et al. (2013). A study using exactly the same survey design was performed for Roskilde Fjord in 2009/2010, cf. Källstrøm et al. (2010) and in the Næstved area (Susåen/Karrebæk fjord) in 2010, cf. Hasler et al. (2011). The results from these studies can be used as basis for benefit transfer to other similar water catchment area as demonstrated in Jensen et al. (2013) and tested by Bateman et al. (2011b) and Källstrøm et al. (2010).

In the following the above mentioned studies in Odense and Roskilde will be described briefly, and it will be discussed if – and how – the results can be used in a national water resource account context. Admittedly, these waters are not part of the freshwater resources that are included in the water accounts of this report. However, the ecosystem services provided by fjords are very similar to the services supplied by lakes and streams. Therefore, the results of the valuation studies from Odense and Roskilde Fjords are relevant in the water accounting context of this report. Still, a number of problems prevail as the studies are based on stated preference methods, and therefore hypothetical. The values are also associated with particular scenarios which are not necessarily relevant in a national accounting context.

6.9.1 Valuation study Odense Fjord and Roskilde Fjord 2008-2011

As mentioned quite extensive stated preference studies were conducted in the Odense Fjord Catchment and the Roskilde Fjord Catchment in the period 2008-2011. The studies conducted in the two case study areas were based on a common design developed in an international study (Aquamoney) focusing on peoples Willingness-to-pay (WTP) for implementation of the Water Framework Directive (WFD). The surveys are not developed from an ecosystem service accounting perspective. Therefore, they are not designed to value the range of services from water resources but only changes in water quality.

The studies employed both the choice experiment (CE) method and the contingent valuation method (CVM) to assess respondents mean WTP for obtaining improvements in the water quality and water resource status in specified water bodies. Water quality and water resource status was divided into four distinct classes defined according to the water quality and status classes used in the WFD. The water quality classes were described in terms of 1) suitability for recreational activities in the form of boating, angling and swimming, and 2) the living conditions for plants, fish and birds. In the studies respondents were asked to state their WTP for different levels of improvements compared to the baseline situation - i.e. the current water quality or status.

In the Odense study four different studies were conducted:

- One focusing on water quality improvements in lakes
- One focusing on water quality improvements in Odense River
- One focusing on Odense Fjord
- One encompassing the entire Odense catchment, i.e. including river, lakes and fjord.

In the Roskilde case WTP was only assessed for water quality improvements in the fjord. For more detailed information on survey design and results see Aquamoney case study report for the Odense case, cf. Hasler et al. (2011). The Roskilde study is described in Källstrøm et al. (2010).

In relation to if and how the results of the Odense and Roskilde studies can be used in a water resource accounting context several issues are relevant to consider.

- What has actually been valued
- Flow value or stock value
- Marginal value or total value
- Site specific valuation or generalized values
- The overall validity of the estimates
- The temporal validity of the value estimates
- The partial nature of studies

Below these potential problematic issues related to the use of the valuation results in a national accounting context will be discussed more thoroughly.

Which services are actually being valued?

The Odense and Roskilde studies focus on valuation of cultural services – i.e. the services listed under cultural services in the flow and stock tables 3.8 and 3.9 in Chapter 3 - however, with no focus on educational and scientific use values. What is important to note here is that the valuation encompass use as well as non-use values. Jørgensen et al. (2013) investigates if there are difference between users and non-users WTP for water quality improvements in Odense River when the availability of substitutes and distance decay is included in the estimations. The results of the study indicate that there are preference differences between users and non-users but it is difficult – if not impossible – to separate the non-use and use components of the total value. That is, based on the survey design it is not possible to assess how much of the value that can be attributed to e.g. walking, boating and existence. If the total value is of interest this is not a problem, but when disaggregation is necessary this is a problem.

It is difficult to value the flow of cultural services separately, because the estimated WTP often also includes non-use values which are only relevant as a part of the asset value of the water resource, cf. Section 4.4. For this reason the estimated WTP may overestimate the value of the annual flow of cultural services. It may also be a problem if you are in a situation with stakeholders with conflicting interests and different schemes are considered. In this case it may be problematic not to know the relative contribution of the different services to the overall value of the good.

The use of the study results for benefit transfer is also restricted to transfer of the total value. However, in this context it may also be relevant to distinguish between use and non-use related values. Hence for use values it could be desirable to know how much of the value that is attributable to e.g. boating and walking, since this could create the base for adjusting the estimates to reflect potential differences in the characteristics between areas, e.g. in terms of availability of substitutes and accessibility.

Finally, being able to distinguish between the relative contributions of different services may be important in relation to identifying the relevant population (or geographical area) for aggregation of WTP estimates. In this connection Jørgensen et al. (2013) concluded that different spatial boundaries are likely to apply for users and non-users when aggregating WTP results for use in Cost-Benefit analyses. In this connection it may be important to note, that the distinction between users and non-users in the Jørgensen et al. (2013) study does not correspond to a distinction between use and non-use value. Hence, while non-users can be expected only (or primarily) to hold non-use values, users must be expected to hold both use and non-use related values.

Stock versus flow

As discussed in chapter 3, ecosystem services represent both stock (asset) value and flow value, and it is important that the two types of values are assessed consistently. In the Odense and Roskilde studies WTP is assessed as annual household WTP and as explained above the stated WTP reflects the total use and non-use value that respondents expect to get from the water resource in the future. Therefore, the annual WTP can be used as the base for calculating the asset/stock value which is given by the present value of the expected future flow of use value (value of cultural ecosystem services) and non-use value that respondents get from the resource.

If this approach to calculating asset value is adopted it is, however, important to consider carefully if the use giving rise to the values and the overall management of the resource is sustainable. Hence, a prerequisite for the method being valid is that the water resource neither deteriorates nor improves. If it deteriorates, the asset value will need to be depreciated to reflect the decrease in the future flow of ecosystem services decreases, and if it improves the asset value has to be appreciated to reflect the expected increase in the future flow of ecosystem services.

Marginal versus total value

As discussed in Section 4.5.1 it is the marginal value of ecosystem services that are relevant in a national accounting context, and this is mentioned to be a problem in relation to many valuation studies. However, in relation to the Odense and Roskilde studies the willingness to pay for improvements from one water quality class to a better is valued and the results must be interpreted as respondents marginal WTP for improvements in water quality.

Site specific valuation versus generalized values

The results of the Odense and Roskilde studies are specific for the two case study areas, and – provided that the value estimates are considered valid –

they can be used in a national accounting context to describe the value of cultural ecosystem services in these specific localities. Since it is very resource demanding to conduct stated preference surveys a commonly used / suggested approach in many different connections is to transfer benefit estimates from a case study to other areas. There are broadly speaking two different approaches to benefit transfer – simple transfer of mean values or transfer of benefit function. Which of the methods to prefer, seems to vary from case to case.

In relation to whether or not benefit transfer of the results from the Odense and Roskilde studies can be used in a national accounting context to derive aggregate estimates of the total value of the stocks and flows of cultural ecosystem services from water it is relevant to look at Källstrøm et al. (2010). In this paper the merits of the benefit transfer approach is investigated for the contingent valuation (CV) method by transferring estimates between the Odense and Roskilde case studies. 4 different benefit transfer approaches are investigated – transfer of mean values and 3 different function transfers – and the transfer errors are found to be 11 % for the mean value approach and 18-19% for the function transfers. These transfer errors are of an acceptable magnitude, which suggests that the results of the two valuation studies can be used for benefit transfer at least as long as it is to fairly similar areas. A similar benefit transfer is conducted between European countries in Bateman et al. (2012), leading to similar conclusions as in Källstrøm et al. (2010).

Jensen et al. (2013) present a Cost Benefit Analysis based screening procedure for identifying river basins where the costs of fulfilling the Water Framework Directive requirements are likely to be disproportionate. In their analysis they base their benefit estimates on the benefit estimates from the Odense choice experiment (CE) study, i.e. they rely on the benefit transfer approach. More specifically, they rely on the mean value transfer approach, where values are transferred separately for fjords, lakes and streams according to the current and target status of the given water body. Also, as the mean values are WTP per household per year, the transferred benefits are multiplied by the number of households in the different catchments. In the study it is concluded that the proposed approach is useful for the purpose of screening, i.e. to identify where more comprehensive analyses are needed to examine if benefits exceeds costs.

Overall validity of value estimates

An important issue in relation to whether or not it is appropriate to use the results from the Odense and Roskilde studies – or perhaps stated preference studies in general – as input to national water accounts concerns the validity of the value estimates. Many papers deals with different factors affecting the validity of stated preference studies, and we will not here provide any comprehensive account of the many different opinions and findings. Nevertheless, we find it relevant to highlight the fact that the validity of value estimates are likely to be affected by at least two factors:

- The unfamiliar and hypothetical situation by which the value estimates are elicited
- The way that the valuation scenario is described.

In terms of the former, it may be difficult to assess in practice, if validity is affected negatively by the fact that value estimates are derived from information which respondents' provide in an unfamiliar setting. Intuitively, however, it seems likely to be the case that (at least some) respondents have not made quite as rational and fully-informed choices as it is implicitly assumed in the analysis of data. Moreover, it cannot be dismissed that some people due to the hypothetical (i.e. non-binding) nature of the choices have resorted to simplistic decision strategies, which they would not have adopted in reality where real money would be involved.

In terms of the latter, i.e. the scenario description underlying the valuation exercise, it may be easier to assess potential problems. This is in fact done in Kataria et al. (2012) where it is investigated if respondents' perception of the scenario in terms of it being realistic or not, has an effect on the resulting welfare estimates. The results of the study show that respondents' perception of scenario realism does indeed affect welfare estimates. This suggests that the validity of stated preference studies very much depend on survey design, and prior to using the estimates e.g. in a national accounting context one should certain of not only that the constructed scenario is valid for the context but also that it is described realistically.

The Odense and Roskilde studies are made according to internationally acknowledged valuation standards used in the Aquamoney project, and they are published in international journals with peer review. Therefore, the results may be considered valid according to international standards, but as discussed above and as apparent from the papers, there are a number of methodological issues that should be carefully considered when using the results.

Temporal validity

Another important aspect which relates to use of the valuation results is the temporal validity of the derived value estimates. The estimates derived in the studies are context specific in the sense that the choices people made in the experiment were contingent upon the situation prevailing at the time of the survey. The surveys were conducted in the period 2009-2010, and the results could be different now due to the financial crisis. Hence, both respondents' preferences might have changed, as well as their overall economic situation. Seen from this perspective it seems relevant to consider the temporal validity of the value estimates, even if the studies are not old.

The partial nature of studies

It has already been discussed how the unfamiliar and hypothetical nature of the valuation exercise may affect the validity of the results. The scenario approach used in stated preference surveys may however also affect validity in a broader sense. Hence, the values derived through stated preference surveys relate to an *all-else-equal* situation - i.e. the only thing that changes is the level of goods/services provided by the good subjected to valuation. As long as the obtained values only are used to value the change in focus, and provided that the change is not part of a bigger scheme and that it is going to happen within the foreseeable future, then this may not be a problem. However, it may be problematic in relation to using the estimates in non-similar situations where the *all-else-equal* situation is different from the one prevailing when the study was conducted. As an example, if we have 10 lakes with bad water quality, WTP for improving the water quality in the first lake is likely to be significantly higher than WTP for improving water quality in the tenth lake once water quality has been improved in the first nine lakes. Hasler et al. (2008) tested this, but did not find such scale effects, however.

Summing-up on the usability of results from the Odense and Roskilde studies in a national water accounting context

As it should be evident from the above there are many problematic issues that suggests that the scope for using the value estimates from the Odense and Roskilde studies in a national water account context is limited. Still, despite all the potential problems and shortcomings it may be important to bear in mind that as of now, there is no better alternative. Seen from this point of view, it could be argued that some approximated value – e.g. based on the valuation studies – is better than no value. However, if this approach is chosen it is important to bear the limitations in mind. Hence, the primary value of the results does not lie in the exact value estimates but rather in the information that they convey regarding peoples preferences for the cultural ecosystem services that the water resource provides. Accordingly, based on the magnitude of the estimates there seem to be no doubt that the services are considered valuable.

6.9.2 Asset value of the water resources

The asset value of the Danish water resources are determined by the present and expected future use of their ecosystem services, their possible option value and existence value, cf. Section 4.4.

The asset value of present and expected future use of the water resources related ecosystem services is calculated as the present value of the actual and expected future value of these services. This calculation can be based on the use values of present services determined as explained in Section 4.4. So, in principle no more prices or values need to be estimated. However, valuation of expected future ecosystem services represents a huge problem. The empirical basis for this is very weak. Thus, future values to a high degree depend on how present use of the ecosystem services affects future supply - in many cases after long time lags - and these relations are not very well described.

This also means that depreciation of the value of the water resources as a result of e.g. pollution is very difficult to estimate. This is important because in many cases it is only through depreciations in the asset accounts that changes in the present loads of the aquatic environment will be stated.

The asset value of water resources also depends on their possible option and existence values. In most valuation studies these are not estimated separately, but are more or less included in the total values estimated. Therefore, the empirical basis for stating separate option or existence values for water resources normally do not exist. One exception is a Danish groundwater protection study, cf. Hasler et al. (2005). The study clarifies peoples' willingness to pay for having access to a groundwater resource with pure drinking water and the results can be interpreted as an expression of the option value and perhaps also existence value of the groundwater resource.

6.9.3 Groundwater protection study from 2005 - stated preference valuation of groundwater protection and treatment of drinking water

In 2004 a stated preference study focusing on assessment of peoples WTP for groundwater protection compared to their WTP for treatment of drinking water was conducted, see Hasler et al. (2005) for a detailed description of survey design, analyses and results. As was the case with the Odense and Roskilde studies both the CE and the CVM methods were employed. In the following the study and its results will be discussed in the context of their usability as input to a national water resource account.

What has actually been valued in the study

The baseline scenario for both the CE and the CVM study are described as follows: No further protection of the groundwater resource takes place and consequently future drinking water quality is uncertain and surface water quality is less good. The baseline scenario as well as the scenarios were discussed and explained in accordance with expert knowledge.

In the CE study there were three attributes describing both the status quo and the alternatives in the valuation:

- A monetary attribute (annual increase in water bill).
- Drinking water quality (uncertain, treated, and naturally clean).
- Surface water quality (poor, less good and very good).

In the CVM study there were two different scenarios:

- A protection scenario (natural clean drinking water and very good surface water quality).
- A treatment scenario (treated drinking water and less good surface water quality).

What is valued in the CVM is peoples WTP for the change associated with going from the baseline to 1) the treatment scenario (only difference is drinking water quality) or 2) the protection scenario (different both with respect to drinking water quality and surface water quality); i.e. obtaining clean drinking water from either protection of the groundwater or purification. In the CE study separate WTP estimates are elicited for changes in drinking water and surface water quality of going from the status quo/baseline level to the other levels specified by the attributes.

The results of the CVM study include

- WTP for natural clean drinking water and good surface water quality compared to uncertain future drinking water quality and poor surface water quality in many water recipients.
- WTP for treated drinking water, where no change occurs for surface water, i.e. surface water bodies will be in poor water quality. This option is compared to the same status quo as above; uncertain future drinking water quality and poor surface water quality in many water recipients.

These WTP include both use value and non-use value. The use value is related to the use of surface water for recreational purposes - good surface water quality means more possibilities for recreational activities than poor surface water quality. On the other hand the non-use value (existence value) is mainly related to natural clean drinking water. Both protection and purification of the water secures clean drinking water in terms of chemical content, smell etc. and therefore, the use value of natural clean water and treated water is the same. So, the difference between the two WTP results can be attributed to the use value of good surface water quality compared to poor quality and existence value of natural clean drinking water. It is not possible on the basis of the CVM study to determine the existence value of natural clean ground water.

In the CE study each attribute - including treated and natural clean drinking water - is valued separately. Therefore, it is possible directly to deduce the existence and option value of natural clean water from the difference between the WTP for the two attributes treated and natural pure drinking water. Of course, this difference may reflect other values than just existence and option value - e.g. an irrational feeling that it is unnatural or unappetizing to drink treated water even if it is as clean as natural pure groundwater - but as a rough estimate of existence and option value it may be useful.

Flow value or stock value

The studies elicit annual household WTP and as such they can be interpreted as estimate of the annual flow value of the ecosystem services that respondents expect to get from the specified scenarios. As discussed before, the use value, the asset existence and option values subsequently can be calculated as the present value of the expected future annual values. These may increase or decrease depending on how the stock of natural clean groundwater develops. Thus, activities today that are expected to reduce the number of aquifers with natural clean groundwater should be stated in the asset account as a depreciation of existence and option value.

Marginal value or total value

Both in the CE and in the CVM, focus is on estimating respondents WTP for marginal changes - i.e. they are not asked to state their WTP for drinking water and surface water as such, but to state their WTP for specified changes regarding the future quality of drinking water and surface water. Nor are they asked to state their WTP for plant and animal life in lakes and streams. They are asked to state their WTP for changes in the conditions facing plants and animals. Hence, the usability of the estimates cannot be dismissed on account of being non-marginal.

Site specific valuation versus generalized values

Seen from a national accounting context an advantage of the groundwater/water treatment study is that it is conducted at a very general level - i.e. the national level. This basically implies that the values already are in a form suitable as input to national water accounts. This stands in stark contrast to most valuation studies which are very geographically specific - i.e. case studies of single projects/initiatives - and where many adjustments founded on more or less well-founded assumptions has to be made before the value estimates can be used in more general contexts. If the water accounts are to be made at a more disaggregated level determined e.g. by watershed boundaries then the value estimates from Hasler et al. (2005) can still be used – the total value for a given area can be obtained by multiplication of WTP estimates with the number of households in the relevant area.

Overall validity of the estimates

The primary reason for conducting stated preference valuation studies is that there are basically no other way of obtaining an estimate of the value of the good / service in focus. Existence and option values cannot be estimated with other valuation methods that stated preference methods. The lack of information regarding the actual value of the goods / services also implies that it is difficult to say anything definite about the validity of the obtained value estimates. As discussed previously, the unfamiliar and hypothetical nature of the valuation exercise may serve to hamper the validity of the results. However, for this particular study it may be an ameliorating fact that the primary good subjected to valuation is drinking water which everybody is familiar with. Hence the validity problems posed by unfamiliarity are probably not as pronounced in the present context as they may be in relation to many other stated preference studies.

Comparison of the value estimates obtained by the two different methods used in the study may give an indication of how well defined respondents preferences are in relation to the good and this in turn may give an indication of the level of validity and reliability of the results. For the groundwater protection scenario annual WTP per household is estimated to 3,104 DKK and 711 DKK for the CE and CVM respectively. For the water treatment scenario the corresponding WTP estimates are 912 DKK and 529 DKK. The differences between the methods are larger for the groundwater protection part of the study which can be explained from the fact that the benefits for surface water quality are explicit in the CE and not in the CVM. Hence, the quite large differences between the estimates resulting from applying the two different methods are explainable. It is furthermore common to see even quite significant differences between WTP estimates for the same good obtained by the two different valuation methods. Hence, the difference in itself does not give reason to conclude that the results are not valid, but it serves to complicate things in the sense that one has to decide how to use the estimates - i.e. if the CVM or the CE estimates are the most correct or if some average of the two is more appropriate. Moreover, the observed difference serves as a reminder of the uncertainties inherent in the valuation of non-marketed goods and services, implying that care should be taken not to accept the value estimates at their face value as exact representations of ecosystem values but rather to interpret them as indicators of the likely magnitude of the values. In relation to which estimates should be used in future analyses Hasler et al. (2005) recommends that the CE results are used. The arguments underlying this recommendation relates to incentive structures handling of substitution possibilities and options for expressing indifference. As explained above it is also the results from the CE study alone that can be used to estimate existence and option values of natural clean drinking water.

Temporal validity

As discussed in relation to the Odense and Roskilde studies, the value estimates derived in stated preference studies are specific to the situation prevailing at the time of the study. Considering that the groundwater and water treatment study was conducted in 2005 - i.e. almost 10 years ago - it cannot be dismissed that either changes in preferences, increased knowledge or changes in the overall economic situation may challenge the temporal validity of the results. Hence, prior to actually using the estimates it may be important to explicitly consider the limitations imposed by using numbers referring to 2004 as the base for predicting values in 2014 and onwards.

The partial nature of studies

As discussed in relation to the Odense and Roskilde studies, stated preference studies are based on an *all-else-equal* assumption and in many contexts this may be a bit problematic since the *all-else-equal* assumption very seldom holds. In the present context, however, it is not considered to be a big problem. Hence, the good being value - i.e. natural pure drinking water - is both a basic and unique good and the study appears to consider the relevant substitute-ways of obtaining the good. Accordingly, it seems quite fair to assume that *all-else is equal.*

Summing up on the usability of the results from the groundwater protection and water treatment study

The primary problem in relation to assessing the existence and option value of water resources is that these values have to be estimated through stated preference surveys. Such surveys are not only expensive to conduct but also quite challenging due to the fact that existence and option value represent quite intangible non-use values which are difficult to describe in a way that is both meaningful and easy to understand. Moreover, it may be remembered that such surveys are not even ideal seen from a water resource accounting context where cost-based methods are preferable as they will ensure the greatest degree of correspondence with the generally applied valuation approach used in national accounting.

6.10 Conclusions on data availability and sufficiency for Danish water resources accounts

The presentation and discussion in the sections above can be concluded in this way.

Data are available and sufficient for drawing up physical flow and stock accounts for the Danish freshwater resources - except stock accounts for surface water. Flow accounts have been published on a national scale by Statistics Denmark until 2010. It is also possible to draw up accounts on a regional scale

Data are available and presumably in many cases sufficient for drawing up emission accounts for emissions to Danish water resources. However, further analyses are necessary to decide the exact geographical scale, which emissions can / should be covered and at which aggregation level and finally which industrial sector division should be chosen in accordance with the sector division in economic national accounts.

Data are available and presumably in many cases sufficient for drawing water quality accounts for the Danish water resources. Further analyses are needed to decide which water quality indicators should be used. Should a few aggregated indicators and correspondingly a limited number of accounts be preferred or will the accounts be more informative and useful - but less easy to grasp - if a larger number of indicators and accounts are chosen. With regard to geographical scale it is important that the same scale is used both for emission accounts and water quality accounts.

Data are available and sufficient for calculation of the value of provisioning ecosystem services related to the water resources. It may be possible to calculate detailed cost based estimates of the value of regulating ecosystem services - especially for nutrient retention, based on retention mapping and modelling (cf. coming results from the Nature Protection Agency from an ongoing catchment modelling programme).

The possibilities for calculating the value of cultural ecosystem services are available using the Danish study valuing the WFD improvements in the Odense Fjord catchment area and the Roskilde Fjord. The results might be added up to a total national value based on the small transfer error found in the study. The data is sparse however, as there only exist one valuation study. The potentials and problems are further discussed in Termansen et al (2014).

If we compare the data availability to the data used for e.g. the NAMWA, cf. Section 2.3 - the conclusion is that the available data are sufficient to carry out national water resources accounts –but that the data might be sparse for the assessment of the cultural ecosystem services. Most of the data are not only available at national scale, but also at regional water district level. The data are available from databases, but as noted in the presentation of the groundwater monitoring data of stocks and flows the data is of different quality.

7 Conclusions

On the basis of the discussions in Chapter 3 - 6 it can be concluded that the possibilities of making water resources accounts for Denmark are fairly good while further work is needed to make real accounts for the value of ecosystem services related to the Danish water resources. This means that a Danish water accounting system can be built up following the steps below:

The publishing of flow accounts showing water flows between the aquatic environment and the economy can be revived and can be supplemented with stock accounts for groundwater. Making stock accounts for surface water don't seem to be realistic at the moment, but the possibilities of making such accounts should be further analysed. The possibilities for making emission accounts on a regional and national scale are good. This applies first of all to emissions from point sources, but emission data from the NOVANA monitoring programme seems to be of a quality and at a geographical scale that make them usable in an accounting context. Therefore, work on emission accounts should be started.

The possibilities of making national and regional accounts for water resources quality and status also seem to be good. This applies to accounts for groundwater quality as well as accounts for surface water quality and status. However, some further methodological work has to be done before these accounts can be published. It has to be decided which water quality and status indicators are most usable in an accounting context. Also the geographical scale has to be decided. On the one hand it need to be in accordance with the geographical scale of the emission accounts and on the other hand it should be environmentally relevant - not least in relation to valuation of water resources related ecosystem services which among other things depends on water quality and status.

The work on national and regional ecosystems services accounts is in its preliminary phase. Therefore, further methodological and empirical work should be done. A more comprehensive discussion and modelling of the aquatic ecosystem services are presented in Termansen et al. (2014).

The possibilities of calculating the annual value of provisioning services are good. Data and models about the costs of regulating the amounts of emissions to the aquatic environment exist, especially for nutrients, cf. Jacobsen (2013), Hasler et al.(2012) and Konrad et al. (in press), which may be relevant for valuation of regulating services. Further analyses are needed to assess whether and how these data can be used in an accounting context. The largest methodological and empirical problems are related to quantification and valuation of non-market cultural ecosystem services. These are valued by use of indirect and direct valuation methods which makes it problematic to use the results in an accounting context. Thus, only few valuation studies estimate marginal WTP which are needed in an accounting context and as the studies are partial analyses it may be difficult to aggregate the results to a national level. Finally, there is the problem with regard to the possibilities of transferring results from one research area to another area. Even though the Odense/Roskilde study concluded that the benefit transfer error was very low, further analysis should concentrate on these problems and the existing

Danish valuation studies from Odense Fjord and Roskilde Fjord might be a good basis for these analyses.

The possibilities of making an asset account of the total value of Danish water resources are very much related to the possibilities of making the ecosystem service account. The problems in relation to that account have to be solved before work on the asset account can start. This work will give rise to further problems related to estimation of the expected future value of ecosystem services as well as estimation of existence and option value related to the water resources.

If necessary resources are available, flow and stock accounts could be published within 1 - 3 years. Including emission accounts as well as water quality and status accounts, which are difficult to determine, might take a little more time. With regard to ecosystem services the possibilities for mapping and assessments are outlined in a study described in Termansen et al. (2014).

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WATER RESOURCE ACCOUNTS AND ACCOUNTS FOR THE QUANTITY AND VALUE OF ECOSYSTEM SERVICES CONNECTED WITH THE DANISH WATER RESOURCES

Methods and Requirements

The report explains how a water resource accounting system can be structured and the possibilities of making Danish water resource accounts are discussed. The accounting system includes five accounts of quantities of water flows, quantities of water stocks, emissions of pollutants, water quality and the value of water resource related ecosystem services, respectively. For each account it is discussed if necessary data are available for making Danish water resource accounts. It is also discussed if and how different water resource related ecosystem services can be valued. Finally, different possible uses of the water accounting system are discussed. It is concluded that if necessary resources are available flow and stock accounts could be published within 1-3 years, while the possibilities of including emission accounts and water quality and status accounts are difficult to determine.

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