Regional Water Accounts and the Transformation of Spatial Data

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United Nations

March 2007

1 Abstract

There is an increasing interest in regional water accounts and they have already been produced by a number of countries. To date, the compilation of these accounts has relied mostly on information collected for a variety of purposes and by multiple agencies. The spatial boundaries (or reference areas) associated with existing information are not usually consistent and may not coincide with the boundaries desired for regional water accounts. Two classes of boundaries were identified: (1) physical boundaries based on hydrological characteristics and often called river basins and; (2) administrative boundaries used by different levels and parts of governments or by water suppliers. The administrative boundaries vary widely in terms of their purpose and names. They include local government areas, postcodes (zipcodes) and areas defined by population censuses.

Several countries have developed methods to transform information from one spatial boundary to another and this has also given rise to the concept of the accounting catchment. Accounting catchments are hybrid areas derived from physical and administrative boundaries and represents the best possible matching of data using different boundaries.

Temporal boundaries also exist. Physical water data is often reported for the 'water year', while monetary data is available for the 'financial year'. These do not always coincide. In comparison to spatial boundary issues, temporal boundaries have been given little consideration in water accounting and no countries have developed methods to transform information.

This paper identifies, describes and analyzes the different approaches used to transform data from one boundary to another. It concludes that transforming data can introduce large errors and recommends that the accuracy of the data is described so that data users can make decisions about the fitness of the data for their purpose(s). It also recommends that in the design or review of data collections to support water accounting, the spatial boundaries of the accounts are taken into consideration.

2 Introduction

The Handbook on Environmental and Economic Accounting for Water Resources (UN, 2007a) has recently been released and accepted as an interim international standard. To date, 27 countries are either producing water accounts, or are initiating water accounting programs (Table 1).

The focus of the handbook is the preparation of water accounts at a national level and for an annual time step. However, there is an increasing interest in regional water accounts which allow a greater understanding of spatial variation. The stocks and flows of water in the environment and economy vary across a country due to both climatic and topological characteristics. Spatial variation in the abstraction of water is due to variations in population, economic activity and land use. There will also be variation in the associated monetary data due to the influence of local factors and regional economics and policies. Regional water accounts present these regional variations and allow for more effective policy development. There is an increasing emphasis being placed on integrated water resource management that encourages water resources to be managed for physical boundaries, rather than administrative boundaries. The European Water Framework Directive requires countries to define major river districts (based on topography) and to report economic and water data using these boundaries (European Parliament and Council, 2000). Demand for regional water accounts has also been reported by countries outside of the European Union (e.g. ABS, 2006 and Statistics South Africa, 2006).

The compilation of water accounts has to date relied on data collected for other purposes and by multiple agencies. As such, data is not always available for the spatial boundaries or time steps desired. Typically monetary data is collected for financial years and administrative regions, while physical water data is for physical regions and water or calendar years. Countries often have to take data from one boundary and apply it to another.

To date, 27 countries are either producing water accounts, or are initiating water accounting programs (Table 1). At least ten of the countries who have compiled water accounts have done so at a regional level. Approximately half of these based their regional accounts on administrative boundaries, and the other half on physical boundaries. A variety of countries have transformed primary data to a new boundary. These include Australia, Sweden, The Netherlands and Denmark.

The aim of this paper is to identify and analyze the different approaches used in transforming data from one space or time boundary to another. It draws on published country experience with water accounts as well as other relevant environmental accounts and statistics[1].

The paper begins with a very brief introduction to the concepts of spatial and temporal boundaries (Section 3). Section 4 discusses the source of data used in the water accounts and their associated spatial and temporal boundaries. Methods to transform data between boundaries and common issues or themes identified in country reports are described in Section 5. Section 6 summaries the issues and suggests area for future work. To gain an understanding of the concepts of water accounting refer to the UN SEEAW (2007a)[2].

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[1] It should be noted that this paper has relied upon reports prepared in English and available to the authors and which described the methods used to transform information.

[2] A database of water accounts is also available and it shows how the water accounting concepts have been applied (http://unstats.un.org/unsd/envaccounting/ceea/archive/Introduction.asp).

Table 1 Countries with Water Accounts

Country	Spatial Boundary used in Accounts			Reference
	National	Regional		
		Administrative boundaries	Physical boundaries	
Australia	Yes	Yes	Yes[1]	ABS (2006a). ABS (2006b) ABS (2006c)
Belgium[5]	Yes	No	No	Federal Planning Bureau (2002)
Bhutan	NA	NA	NA	NA
Botswana[5]	Yes	Yes	No	CSO and NCSA (2001)
Bulgaria	NA	NA	NA	NA
Canada	Yes	No	No	Statistics Canada (2006)
China[2]	Yes	Yes	Yes	Ministry of Water Resources: People's Republic of China (2005)
Colombia[3]	NA	NA	NA	NA
Denmark	Yes	Yes	No	Statistics Denmark (2005)
Dominican Republic[3]	NA	NA	NA	NA
Germany	Yes	No	No	Federal Statistical Office of Germany (2002)
India	NA	NA	NA	NA
Israel	NA	NA	NA	NA
Mexico[3]	NA	NA	NA	NA
Mongolia	NA	NA	NA	NA
Nauru	NA	NA	NA	NA
Namibia[5]	Yes	No	No	Lange (1997)
Netherlands	Yes	No	Yes	Brouwer, R., S.Schenau and R.van der Veeren (2005) Van der Veeren, R., R.Brouwer, S.Schenau and R. van der Stegen (2004)
New Zealand	Yes	No	Yes[1]	Statistics New Zealand (2004)
Norway[5]	Yes	No[4]	No[4]	Statistics Norway (2001) Statistics Norway (2005)
Papua New Guinea	NA	NA	NA	NA
Philippines	Yes	No	No	National Statistical Coordination Board (1998)
South Africa	Yes	No	Yes[1]	Statistics South Africa (2006)
Spain	Yes	Yes	No	Luengo, F.A and F.E. Morales (2001)
Sweden	Yes	No	Yes	Statistics Sweden (2003)
United Kingdom	Yes	No	No	National Statistics (2006)
United Republic of Tanzania	NA	NA	NA	NA

Source: The table is based on the results of the Global Water Assessment survey and a review of reports available on the 'Searchable Archive of Publications on Environmental-Economic Accounting' (UN, 2007b).

Notes:

NA – water accounting reports were not available to the authors

1 – only some components of the physical water accounts available. No disaggregation of monetary or data.

2 – not in the SEEA water accounting format

3 – reports not available in English

4 – plans to collect and report information for a range of spatial boundaries, including the river basin

5 – these countries did not respond to the UN Global Water Assessment survey indicating they undertake water accounting, but water accounting reports were available for them on the 'Searchable Archive of Publications on Environmental-Economic Accounting' (UN, 2007b), indicating that they have produced water accounts.

3 Concepts

The purpose of this section is to explain the concepts associated with the spatial and temporal boundaries associated with data inputs to the water accounts. Firstly, the different physical and administrative boundaries associated with the data used in water accounts are discussed in Section 3.1. This section also discusses spatial boundary used to report regional water accounts, the accounting catchment. Secondly, in Section 3.2 the concepts of a water year and a financial year are discussed.

3.1 Spatial Boundaries

There can be disparity in the spatial boundaries used to collect different data. Physical water data tends to be collected and reported based on physical spatial boundaries, such as a river catchment. Monetary data tends to be collected from business entities and reported for administrative regions, such as province or state. Similarly, population data is collected from household surveys and also reported for administrative regions. Accounting catchments are hybrid areas derived from physical and administrative boundaries and represent the best possible matching of data using different boundaries. The nature of physical and administrative boundaries are described below, followed by a description of the accounting catchment.

Physical Spatial Boundaries

The largest physical spatial boundary is that between land and sea. A *continent* is 'a connected or continuous tract of land' (Oxford University Press, 1989). However, our common understanding of continents is based largely on convention and is not entirely physically based. For example, Europe and Asia are considered to be separate continents although they are part of a connected land mass.

River basins are physical spatial boundaries existing within continents. A river basin is "the area of land from which all surface run-off flows through a sequence of streams, rivers and, possibly, lakes into the sea at a single river mouth, estuary or delta" (European Parliament and Council, 2000).

A *catchment* is an "area having a common outlet for its surface runoff" (UN, 2007a). Unlike a river basin, the outlet of the surface runoff does not need to be the sea, it can be at any point along the watercourse. A river basin, therefore, can be made up of several smaller catchments. The downstream point of a catchment may be based on the confluence of larger rivers or to coincide with an administrative boundary or the location of a streamflow gauge. Therefore the spatial boundary of a catchment may not be entirely defined based on physical characteristics. In the SEEAW glossary (UN, 2007a) a catchment is synonymous with river basin.

An *aquifer* is the physical spatial unit of groundwater and is a "geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs" (UN, 2007a). The physical spatial boundaries that define surface water and groundwater do not necessarily coincide. For example, in Australia the largest aquifer (Great Artesian Basin) and river basin (Murray-Darling Basin) do not follow the same boundary. Furthermore, some countries do not contain any river basins. Small atoll islands, such as Kiribati, do not have any rivers and rely completely on groundwater.

Although some countries have developed comprehensive systems for delineating and numbering physical water boundaries (e.g. USA - Seaber et al, 2005), there is no international standard classification system in existence.

Administrative Spatial Boundaries

An *administrative region* is a "geographic area designated by the provincial government for administrative purposes" (UN, 2007a). Throughout this paper, other spatial boundaries, such as political boundaries, statistical boundaries and water supply areas are also considered to be administrative regions.

The largest administrative boundary is a country and most water accounts have been presented using this spatial boundary. Most countries are divided into smaller administrative units, such as states or counties. There are also smaller administrative boundaries, such as municipalities, cities, towns or villages.

In order to present spatially disaggregated information, many statistical agencies have adopted statistical boundaries. For example, the Netherlands was divided in 1971 into 40 so-called COROP areas. Each COROP area is an aggregation of several municipalities. The COROP boundaries are based on a nodal principle, meaning that each COROP area has a central kernel (for instance a city) and a peripheral area (for instance with commuters). This principle is not always followed as COROP areas also follow provincial boundaries. Two of the 12 Dutch provinces coincide with precisely 1 COROP area.

Australia has a standard Geographical Classification system (ASGC) for reporting spatial information (ABS, 2005). It includes multiple classification structures that are interrelated. The smallest unit is the census collection district. This traditionally referred to the area over which one person could collect census information within ten days. All other spatial units are an aggregation of the census collection district.

Eurostat devised the Nomenclature of Territorial Units for Statistics (NUTS). These spatial boundaries are used to present regional statistics (European Commission, 2005). NUTS is a hierarchical classification system. The boundaries are based on a number of criteria, including institutional divisions, geographical features and socio-economic homogeneity. There are guidelines for the maximum and minimum size of each level of the NUTS system.

Another administrative boundary issue related to water accounting is that of the water supply area. A water supplier will supply water to customers in a specific spatial region. This region may not coincide with a river basin or with the other administrative boundaries discussed above. For example, in Victoria, Australia, the service areas for urban water authorities do not coincide with river catchments (Figure 1). The administrative boundaries associated with catchment management authorities may follow physical boundaries more closely.

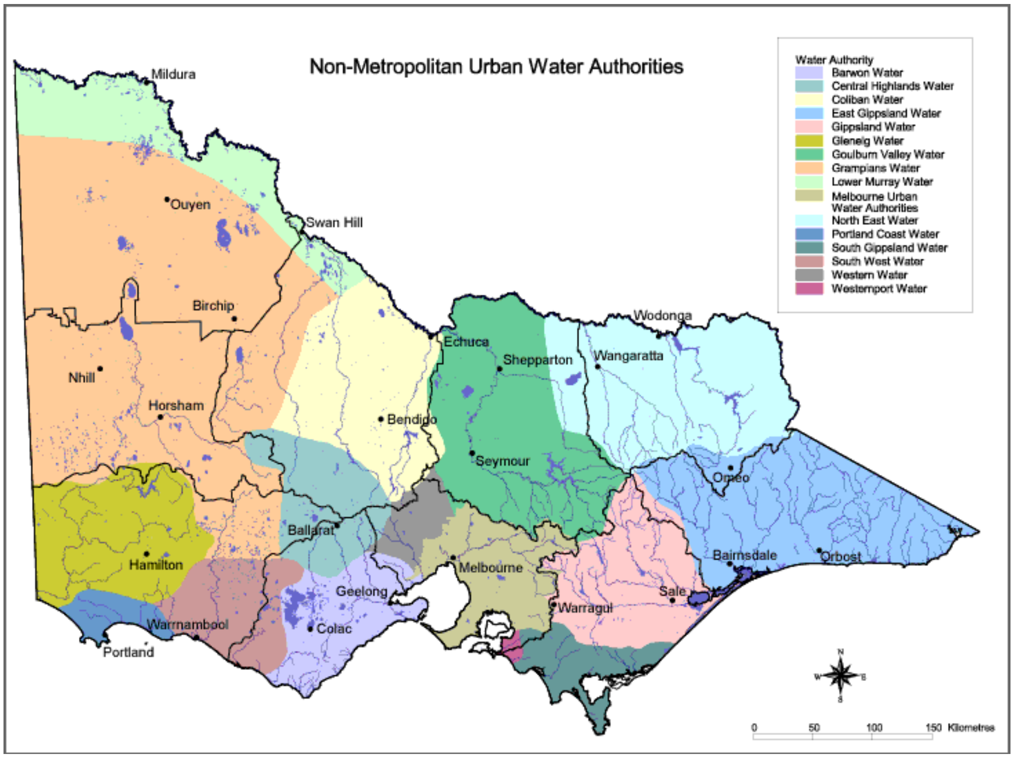


Figure 1 Spatial Boundaries for Urban Water Authorities in Victoria, Australia (Source: DNRE, 1998).

Accounting Catchment

The compilation of regional water accounts requires the definition of clear spatial boundaries. The physical and administrative spatial boundaries, for which existing information is available, do not often coincide. *Accounting catchments* are:

> "regions for the compilation of water accounts for which both economic and physical data are more easily available" (UN, 2007a).

Accounting catchments provide a practical spatial boundary for water accounting. Accounting catchments are already established for several countries. In some countries the boundaries are predominately based on physical boundaries, while in others, they are based on administrative boundaries.

The European Water Framework Directive uses the term river basin district and defines it as "…the area of land and sea, made up of one or more neighboring river basins together with their associated groundwaters and coastal waters…" (European Parliament and Council, 2000). It allows smaller river basins to be amalgamated to a reasonable size for reporting and management purposes. Where a river basin crosses country boarders, it is divided into a number of smaller river basin districts that are contained within country boarders.

Some countries prepared regional water accounts for river basins, but further divided the river basins to show variability within large or heavily populated river basins. There are four river basins in the Netherlands: Meuse, Scheldt, Ems and the Rhine. Because the Rhine covers 70%, it was further divided into North, West, East and Centre, creating seven river basin districts (Brouwer et al, 2005). South Africa also bases its 19 Water Management Areas on river basins, but river basins are divided into river reaches (eg Upper and Lower Vaal) (Statistics South Africa, 2006).

Other countries have produced water accounts for some level of administrative regions. Statistics Denmark (2005) produced accounts at an administrative level to coincide with available economic information (Statistics Denmark, 2005). Australia produces water accounts for each of its states and territories (ABS, 2006c).

In China water resource information is reported for both water resource regions (which are aligned with river basin boundaries) and Provincial Administrative Regions (Ministry of Water Resources, 2005).

Statistics Norway wants to be able to produce information at a range of spatial levels (national, country, municipal and watershed). To enable this, they are collecting information at the municipal level and will be able to aggregate the information to all other levels (Statistics Norway, 2005).

3.2 Temporal Boundaries

The initial focus of water accounting was to prepare reports on an annual basis (UN, 2007a). When information for the water accounts is available at an annual time step, it may not be for the same annual period. Water data is often available for the 'water year' while economic information is available for the 'financial year'. The nature of the water year and financial year are described below.

Water Year

The 'water year' is used in hydrology and water resource management. It is defined as a "continuous 12-month period selected in such a way that overall changes in storage are minimal so that carryover is reduced to a minimum" (UNESCO and WMO, 1992). The water year generally begins and ends during winter or at the end of the wet season. As the definition of the water year is driven by climate and geography, it varies greatly between countries, and even between regions within the same country. The following examples illustrate the variability:

- In Namibia, the water year starts 1 April to correspond with the end of the rainy season (Lange, 1997).
- In South Africa the water year starts 1 October (Statistics South Africa, 2006).
- In New Zealand the water year starts 1 July. This period was selected because it includes the whole of the irrigation season and whole of the low flow period (Statistics New Zealand, 2004).
- In Australia, the water year used varies between regions (Sinclair Knight Merz, 2006).

Financial Year

The financial (or fiscal) year is 'the annual period for which accounts are made up' (Oxford University Press, 1989). It also varies between countries. The following are a few examples of government fiscal years:

- In the USA the financial year is 1 October to 30 September.
- In the UK the financial year is 6 April to 5 April.
- In Australia the financial year is 1 July to 30 June.

4 Sources of Data

The compilation of water accounts has mostly relied on data collected for other purposes and by multiple agencies. The purpose of this section is to discuss the common spatial and temporal characteristics of different sources of data.

4.1 Scientific Measurement

Many physical water components of the water accounts can be quantified using scientific measurement. Flows within the environment are scientifically monitored using, for example, rain gauges, streamflow gauges and groundwater bores. Abstractions by water supply companies are monitored, and it is common for water supply companies to meter water use by their customers to enable billing. Emissions to the environment may also be monitored, particularly if they are associated with wastewater treatment or required by environmental protection authorities.

As scientific measurements are undertaken by a piece of equipment, precise spatial references are often available. For example, all emission data collected in the Netherlands has associated co-ordinates so that they can be directly allocated to a river basin (van der Veeren et al, 2004). Even if co-ordinates are not available, an address may be available for the measuring device.

Scientific measurements are often made on a small temporal scale. For example, it is common for rainfall data to be recorded on a daily basis. Water use meters often continuously monitor water use and the volume is recorded and collected at a time step appropriate to the billing period. It is, therefore, not difficult to aggregate the data collected to the temporal time step of interest.

4.2 Surveys

Data collected via survey will represent a specific spatial area. The size of the area the data is collected for will depend on the purpose of the study, the resources available and the expected spatial heterogeneity of the data. Some surveys will only provide information at the national level while others will provide information for smaller areas (such as a census collection district).

Surveys not designed to provide regional information are used in the production of regional water accounts. Additional information included in the survey may enable each individual response to be located spatially. For example, the address of each respondent may be provided. However, this may not always correspond to the location of water use. In the compilation of their regional water accounts, Statistics Denmark (2005) found that postal addresses corresponded to the location of the company headquarters, and not necessarily the site where the water supply or use occurred.

Survey results will also represent a particular point in time or a specific time period. For example, Australia's household survey reflected the situation for at a specific point in time (i.e. March 2006) while the agricultural survey related to the period from 1 July to 30 June.

4.3 Administrative Data

Administrative data is a valuable source of information for regional water accounts. For example, the water license registers and the taxation office may have information that is spatially located. In Sweden, the location of water extracted for own use by households could be located using spatial data on houses available from the real estate industry. The spatial and temporal boundaries associated with administrative data will vary.

5 Methods

When the boundaries associated with available information do not coincide with those used in the regional water accounts, methods are required to transform the information to the accounting catchment. The purpose of this section is to summarize existing methods (Section 5.1) and discuss common issues associated with the preparation of regional water accounts (Section 5.2).

The water year and financial year do not necessarily overlap and some countries may find that available physical water data and monetary data are not compatible. However, no countries so far have reported this as being a problem. As such, existing methods to transform information between temporal boundaries do not exist, and are not discussed in this section.

This section provides a summary of the methods used by the countries in Table 1 who prepared regional water accounts and for whom detailed reports on the methods they used were available to the authors. The European Water Framework Directive (European Parliament and Council, 2000) requires each country to manage water resources for river basin districts. Article 5 of the WFD requires each country to undertake an economic analysis of water use for their river basin districts. This task also requires information collected for different boundaries (such as administrative regions) to be combined. Useful reallocation methods resulting from the WFD process are also included in this summary. More details on individual country methods are provided in Appendix A.

5.1 Reallocation Methods

Methods to reallocate water information between different spatial boundaries have been developed by a number of countries. In the majority of cases, methods were developed to translate information collected for administrative regions to river basins (e.g. Australia, Ireland, Latvia, Lithuania, Netherlands and Sweden). Methods were also developed for different types of water information. Water use information was reallocated for Australia, Denmark, Netherlands and Sweden. Monetary data was reallocated for Australia, Ireland, Latvia, Lithuania, Netherlands and Sweden. Ireland also reallocated information on the value of wetlands and special riparian areas to River Basin Districts.

Reallocation methods can be based on a correlation with area, population or other variables as described below and illustrated in Figure 3. The accuracy of reallocating information to accounting catchments can be improved by using additional information (Figure 4). These are discussed below.

Based on a correlation with area, population or other variable

Information used for the compilation of regional water accounts will be available for primary spatial areas. These primary spatial areas may be based on either physical or administrative boundaries. If the primary spatial areas are smaller than the accounting catchments, some of the primary spatial areas can be directly allocated to accounting catchments. However, it is likely that some of the primary spatial areas will cover multiple accounting catchments (Figure 2). For the area of overlap the information will need to be reallocated between the accounting catchments. If the primary spatial areas are larger than the accounting catchments, information will also need to be reallocated.

The information can be reallocated to the accounting catchments based on area. In this case it is assumed that the variable of interest is correlated with area, that is, as the size of the accounting catchment increases, so does the quantity of the variable of interest. Consider the example provided in Figure 2. The total water use for administrative region A is known and needs to be reallocated to River Basin 1 and River Basin 2. It is known that 36% of the area of administrative region A falls within River Basin 1 and 64% falls within River Basin 2. Water use is assumed to be correlated with area, hence the total water use in River Basin 1 is assumed to be 36% and 64% in River Basin 2. For example, this approach was used to reallocate agricultural water use in Australia (ABS, 2006a). Irrigation areas within the primary spatial area (i.e. administrative region) were located. If they fell entirely within one accounting catchment, all of the irrigation water use was allocated to that accounting catchment. Otherwise it was reallocated based on the percentage of irrigation area that fell within each accounting catchment. The Netherlands and Latvia also based reallocation of information on area.

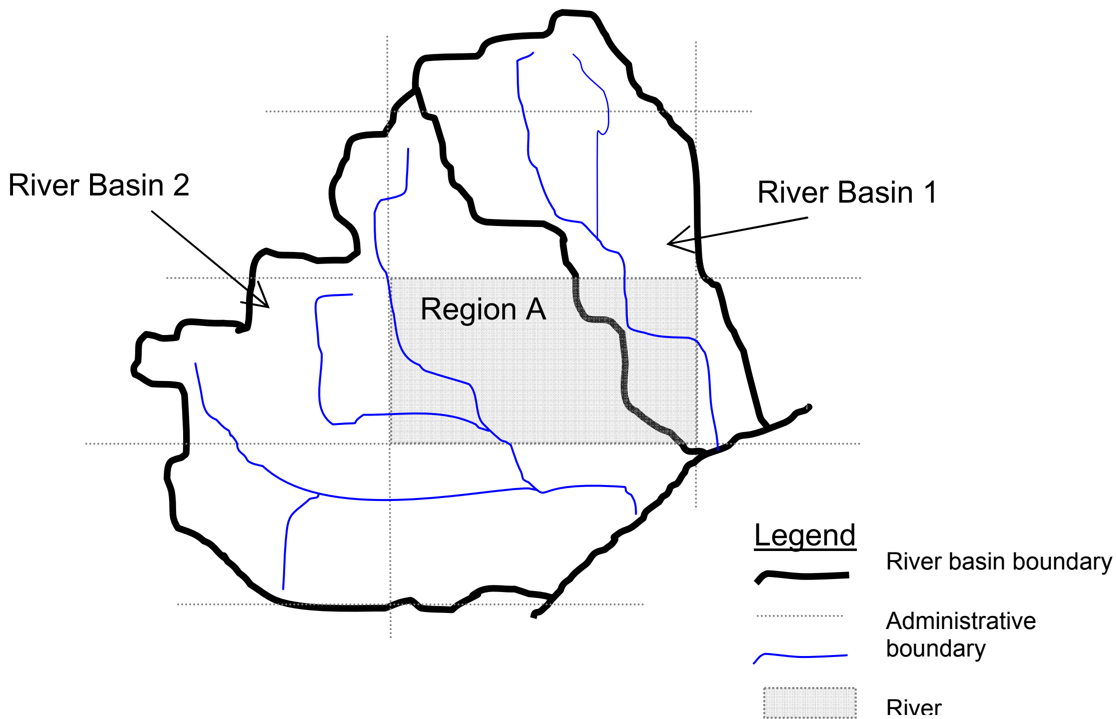
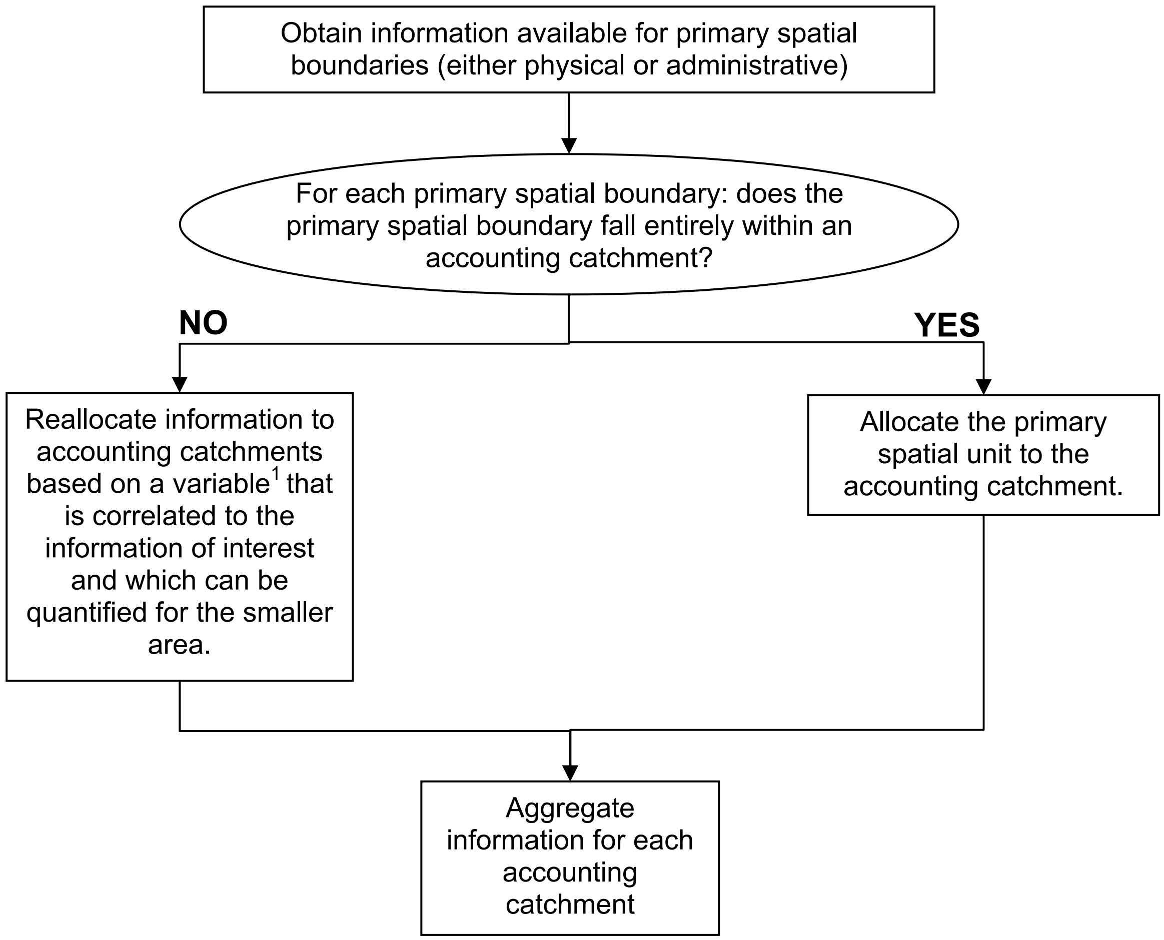


Figure 2 Aggregation of Administrative Regions to River Basin

Population was also used to reallocate information (Australia, Ireland, Latvia and Lithuania). For example, it may be assumed that the population is correlated with domestic water use. If the total domestic water use is known for the primary spatial unit, it can be reallocated to accounting catchments based on the population falling within each accounting catchment.

Countries used a wide range of variables to reallocate information between spatial boundaries. The variables used were correlated with the information of interest and were quantifiable for all spatial boundaries. Some examples include using the number of employees to reallocate industry information (Netherlands), using the license register to reallocate water use (Australia), using the number of farms to reallocate agricultural information (Ireland), using the volume of wastewater discharged to reallocate industrial wastewater expenses (Sweden) and using the distribution of water use surveyed for a smaller area in a previous year (Australia).

Figure 3 summarizes the method of reallocation based on a correlation with area, population or another variable.



Notes:
1 – The location could be an exact co-ordinate or address
2 – The variable of interest may be area, population, etc

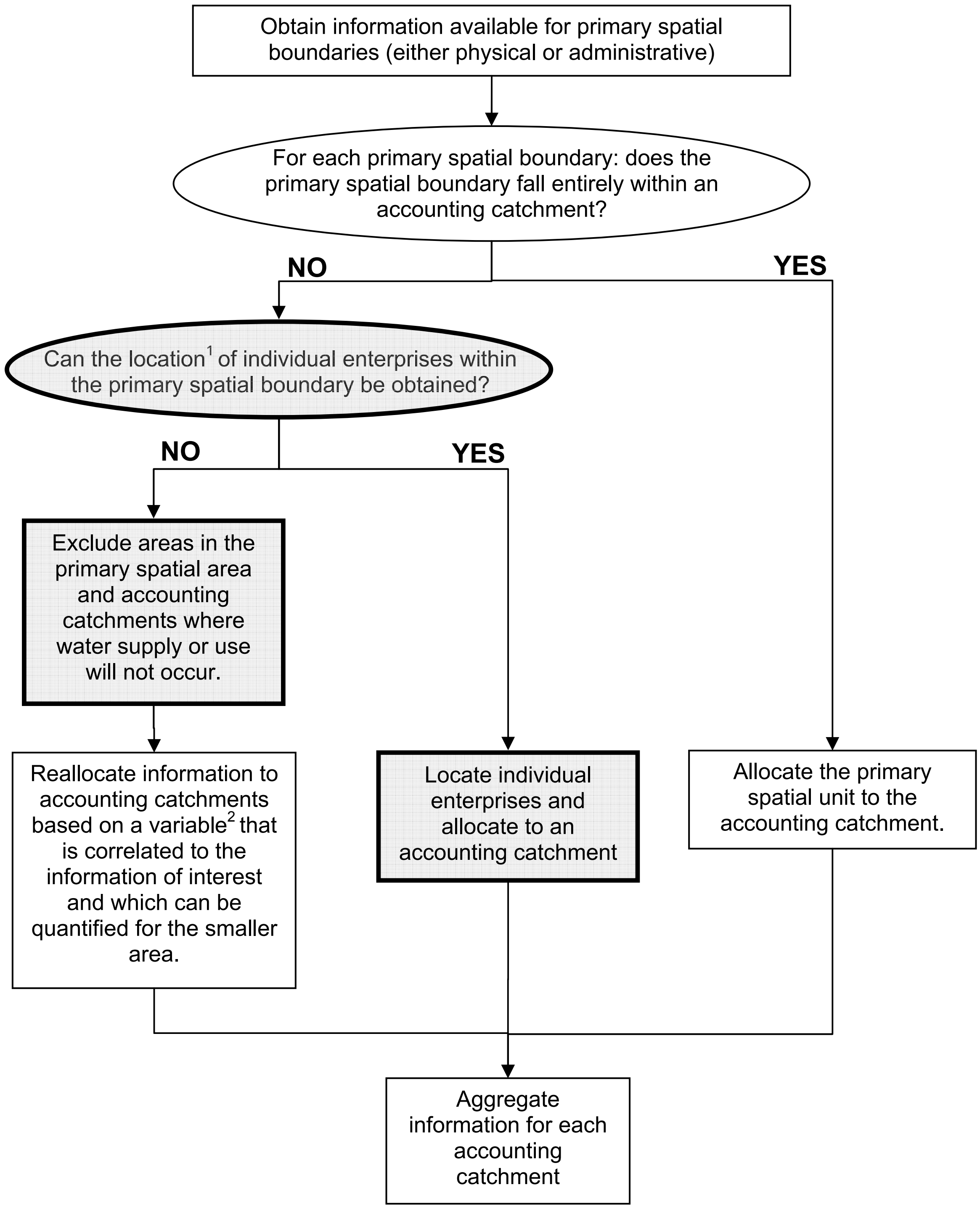
Figure 3 Method of reallocation using a simple assumption

Based on Correlations and Additional Data

Additional data can be used to reallocate information between spatial boundaries (Figure 4). There are two broad types of additional information. Firstly, a more precise location of water suppliers and water users may be obtained and used to allocate individual enterprises into an accounting catchment. In the second approach additional information on the accounting catchments are used to exclude areas in which it can be assumed that water supply or water use do not occur.

Australia and Denmark provide examples of obtaining a more precise location of water users. Australia used the address and metered water use of industrial water uses to reallocate water use between river basins. Australia used more detailed information for the large water users. In Denmark, 98 of 130 industries receive a tax rebate based on the volume of water they use. The magnitude of the tax rebate was used to estimate the volume of water use and the company address used to allocate the water use to the administrative region.

Australia improved their estimates of agricultural water use in accounting catchments by considering the characteristics of the accounting catchments. Urban areas and parkland were identified and removed to enable the area to be used for reallocating agricultural water use.



Notes:
1 – The location could be an exact co-ordinate or address
2 – The variable of interest may be area, population, etc

Figure 4 Method of reallocation based on assumptions and additional data. Steps additional to the simple assumption methods are highlighted.

5.2 Common Issues

Some common issues were identified in the preparation of regional water accounts and include the accuracy of the estimates and cross-border issues and confidentiality. These are discussed below.

Data Availability

Countries which produced regional water accounts (see Table 1) did not necessarily include all components in these accounts. In the Netherlands, monetary data is not currently collected for river basins. As such, only a subset of economic information was able to be reallocated to the river basins (van der Veeren et al, 2004). In South Africa and New Zealand the monetary data sets were simply not constructed for water management areas due to the lack of information (Statistics South Africa, 2006 and Statistics New Zealand, 2004). The collection of data for a smaller spatial boundary to assist the preparation of regional accounts would result in higher costs (DEFRA, 2004).

Accuracy

The reallocation process introduces errors in the regional water accounts. The accuracy of the estimates of reallocated variables is often not reported. When it is, the errors are large. Australia (ABS, 2006b) and the United Kingdom (DEFRA, 2004) state that there is less confidence in the results presented at lower spatial levels. The most comprehensive investigation, known to the authors, of the accuracy has been undertaken by the Australian Bureau of Statistics (2006a). The discussion below is largely based on this reference.

There are a number of factors that influence the accuracy of the water accounting variables that are estimated using reallocation methods. These include any measurement error, sampling error, non-sampling error and model specification error.

Model specification error is the error associated with all of the assumptions made in the reallocation process. The main assumption made in the reallocation process is that the variable chosen to disaggregate represents the variability in the variable of interest. If, for example, area is used to disaggregate the volume of irrigation water use, the assumption is that the data is evenly spread. In reality the irrigation areas may be clustered together and predominantly in one of the accounting catchments. Even if the distribution of irrigation areas is known, the application rate of irrigation water may vary across the region. The application rate may vary due to differences in climate, soil type, and sophistication of irrigation equipment. The ABS (2006a) compared the area of irrigated land falling within a river basin estimated using an area-weighted disaggregation method with the direct estimation. The results in Figure 5 show considerable differences.

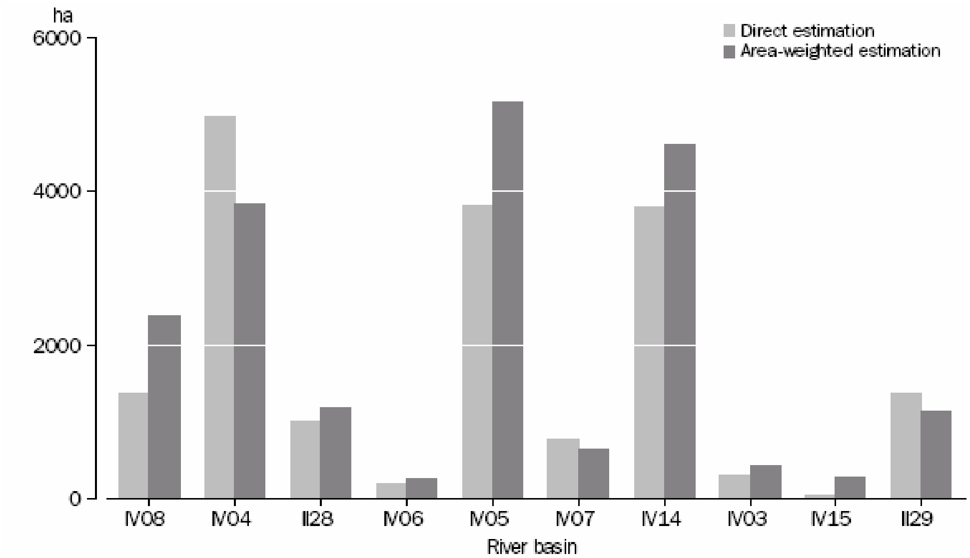


Figure 5 Comparison of irrigation areas within River Basins estimated directly[3] and estimated using an area-weighted disaggregation method[4] (Source: Figure 4.5 in ABS, 2006a).

The accuracy of the final estimate for an accounting catchment will depend on the amount of reallocation required to obtain the estimate. The smaller the spatial size used for the initial data collection, the more accurate the results will be. The Australian Bureau of Statistics (ABS, 2006a) also investigated the impact of spatial size on the overall accuracy. They compared the volume of irrigation water use for a river basin by aggregating data collected for both statistical local areas (smaller size) and statistical divisions (larger size). Figure 6 shows large differences between the estimates made with the two spatial sizes. The spatial size over which the data was initially collected will have a large impact on the final accuracy of the estimates.

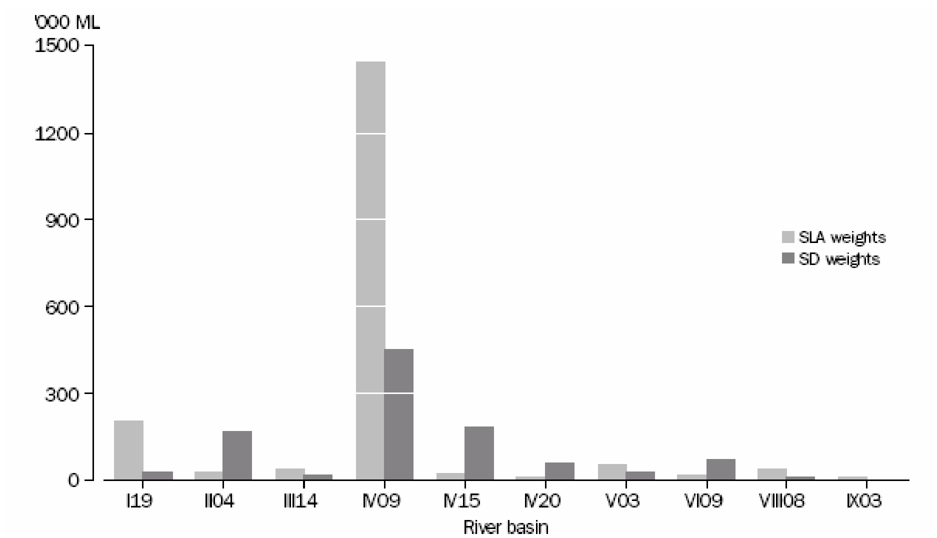


Figure 6 Comparison of estimating irrigation water usage within River Basins from small statistical units (SLA) and large statistical units (SDs) (Source: Figure 4.4 in ABS, 2006a).

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[3] The irrigation area within each collection district (the smallest unit in Australia's ASGC) was available from a geocoding test exercise (ABS, 2006a).

[4] Irrigation areas were available for Statistical Local Areas (larger areas than the collection district). These were disaggregated to River Basin based on area.

Cross-boundary Activities

One of the main features of the water accounts is the combination of physical water data and monetary data. In preparing regional water accounts the economic and physical impacts of water use by households and companies should be presented within the same accounting catchment. In some instances the location of the company or household may be located in a different accounting catchment than the water extractions and discharges take place.

All emission data collected in the Netherlands has associated co-ordinates so that they can be directly allocated to a river basin. However, the associated economic activity may not be located in the same river basin and this results in discrepancies between the economic and emissions data (van der Veeren et al, 2004).

Although this issue was explicitly identified in the Netherlands, it will be an issue in many regions. Ballarat, a town located in Australia, is one other example. The town is located in the Loddon River basin. However it abstracts most of its water from the Moorabool River basin and discharges its wastewater into the Barwon River Catchment.

Another similar issue will arise where a water supply company abstracts water from multiple river basins and supplies to a town. It is not possible to identify which river basin supplied water to which households and industries.

In regional water accounts in the above situations the water flowing across the accounting catchment boundaries will be identified as such, just as in national accounts water can flow to or from 'rest of world'. Largely, this situation will not cause any problems. However, this issue will need to be addressed if water accounts are used to inform decisions regarding the allocation of water in a river between instream benefits (such as environmental requirements) and other users.

Confidentiality

Issues of confidentiality were raised by Australia, England and the Netherlands. In the presentation of their regional water accounts, the Netherlands only included information on a sector if there are three or more companies within the sector and if no company had either more than 75% of the employees or used more than 70% of the water (van der Veeren et al, 2004). Most statistical offices have confidentiality rules to address this issue.

6 Conclusions and Recommendations

There is a demand for regional water accounts and countries are responding. At least ten of the countries who have compiled water accounts have done so at a regional level. The compilation of regional water accounts has relied heavily on existing data sources that are collected based on a variety of spatial boundaries. Physical water data is more commonly collected and reported for physical spatial boundaries such as river basins while monetary data is more commonly collected for administrative regions. Generally, these spatial boundaries do not directly coincide.

Accounting catchments are hybrid areas derived from physical and administrative boundaries and represent the best possible matching of data using different boundaries. There are no international guidelines for the delineation of accounting catchments for use in regional water accounts. The specification of accounting catchments within a country will be based on, firstly, the need for information presented at this spatial size and secondly, the availability of data. This will vary between countries. For example, regional water accounts based on river basins may be of little use to a country in which groundwater is the main source of water abstraction.

Countries have developed methods to reallocate information to the accounting catchments. In the most simple case, it is assumed that the information for the accounts is correlated to a variable that can be quantified for all spatial boundaries. Area and population were commonly used, however, a variety of variables have been employed. The accuracy of the reallocation method can be improved by considering additional information, such as the address of individual enterprises and spatial characteristics of the accounting catchment. However, a suitable variable for reallocation or additional information are not always available.

Temporal boundary issues have been given little consideration in water accounting. Where data is available on an annual time step, it is possible that the temporal boundaries used to collected water data and monetary data will not coincide. However, this has not been identified as an issue by any country. It may require further attention in the future.

The accuracy of results has received little attention by the countries that have prepared regional water accounts. When it is, the errors are large. It would be useful to know the magnitude of the errors and the impact this has on the usefulness of the regional water accounts. The issue of accuracy needs to be adequately addressed before existing methods are widely adopted and implemented. Further research into more robust methods to reallocate data between regions is recommended.

It is recommended that, where possible, surveys be designed to allow the construction of regional water accounts. This will allow the reallocation of information between spatial and temporal boundaries to be avoided.

7 Glossary

Term	Definition	Source
Abstraction	The amount of water that is removed from any source, either permanently or temporarily, in a given period of time for final consumption and production activities.	UN (2007a)
Accounting catchment	Regions for the compilation of water accounts for which both economic and physical data are more easily available.	UN (2007a)
Administrative region	A geographic area designated by the provincial government for administrative purposes.	UN (2007a)
Aquifer	A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.	UN (2007a)
Catchment	Area having a common outlet for its surface run-off.	UN (2007a)
Financial year	The annual period for which accounts are made up.	Oxford University Press (1989)
Groundwater	Water which collects in porous layers of underground formations known as aquifers.	UN (2007a)
River basin	The area of land from which all surface run-off flows through a sequence of streams, rivers and, possibly, lakes into the sea at a single river mouth, estuary or delta.	European Parliament and Council (2000)
River basin district	The area of land and sea, made up of one or more neighboring river basins together with their associated groundwaters and coastal waters.	European Parliament and Council (2000)
Water use	Water intake of economic unit. Water Use is the sum of water use within the economy and water use from the environment.	UN (2007a)
Water year	Continuous 12-month period selected in such a way that overall changes in storage are minimal so that carryover is reduced to a minimum.	UNESCO and WMO (1992).

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Appendix A – Country Examples of Dissagregation Techniques for Spatial Boundaries

Australia

The water accounts produced by Australia provide information for each state and territory, that is, for administrative boundaries. There has been increasing interest in presenting regional water accounts based on river basins. However, surveys undertaken by the Australian Bureau of Statistics (ABS) were not conducted for river basins due to time and resource constraints.

In Australia, surveys undertaken by the ABS are based on statistical areas. The statistical boundaries, increasing in size, are: census collection district, statistical local area (SLA), statistical sub-division, statistical division (SD) and state or territory. A comparison of water management areas (WMA), which are hydrologically based, and statistical divisions in Figure 8 shows that there is little overlap between these regions.

The ABS (2006b) developed a methodology to apportion survey results for water use to water management areas (WMA). The following summarizes their approach.

In some states, the smaller local governments report the volume of domestic water used within local government areas. For these states it was possible to aggregate local government areas to WMAs. In other states the volume of domestic water use was reallocated from the state level to WMAs based on population. The methodology is shown in Figure 7.

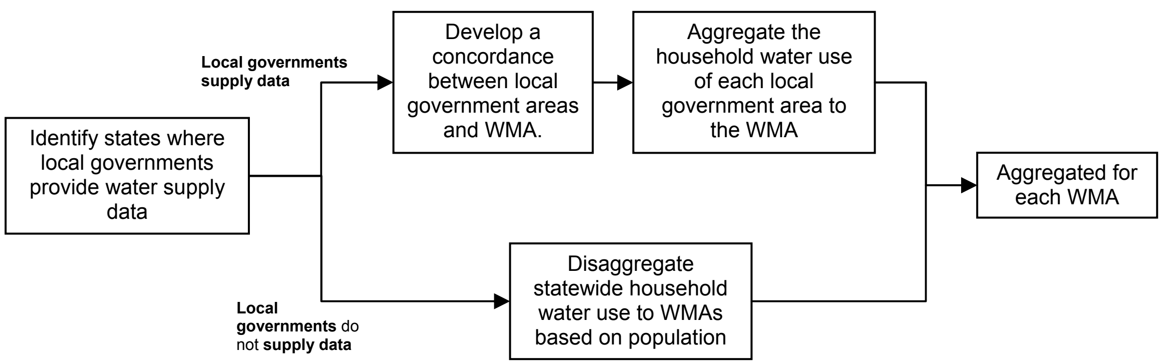

Figure 7 Steps for reallocating domestic water use in Australia to water management areas (WMA)

The process used to reallocate industrial water use is shown in Figure 9. Each industry water user was categorized as either a large or small water user to enable the effort expended on reallocation to be rationalized. The actual water use by all large water users was based on metered water use. The water use by small water users was estimated based on the average water use per employee.

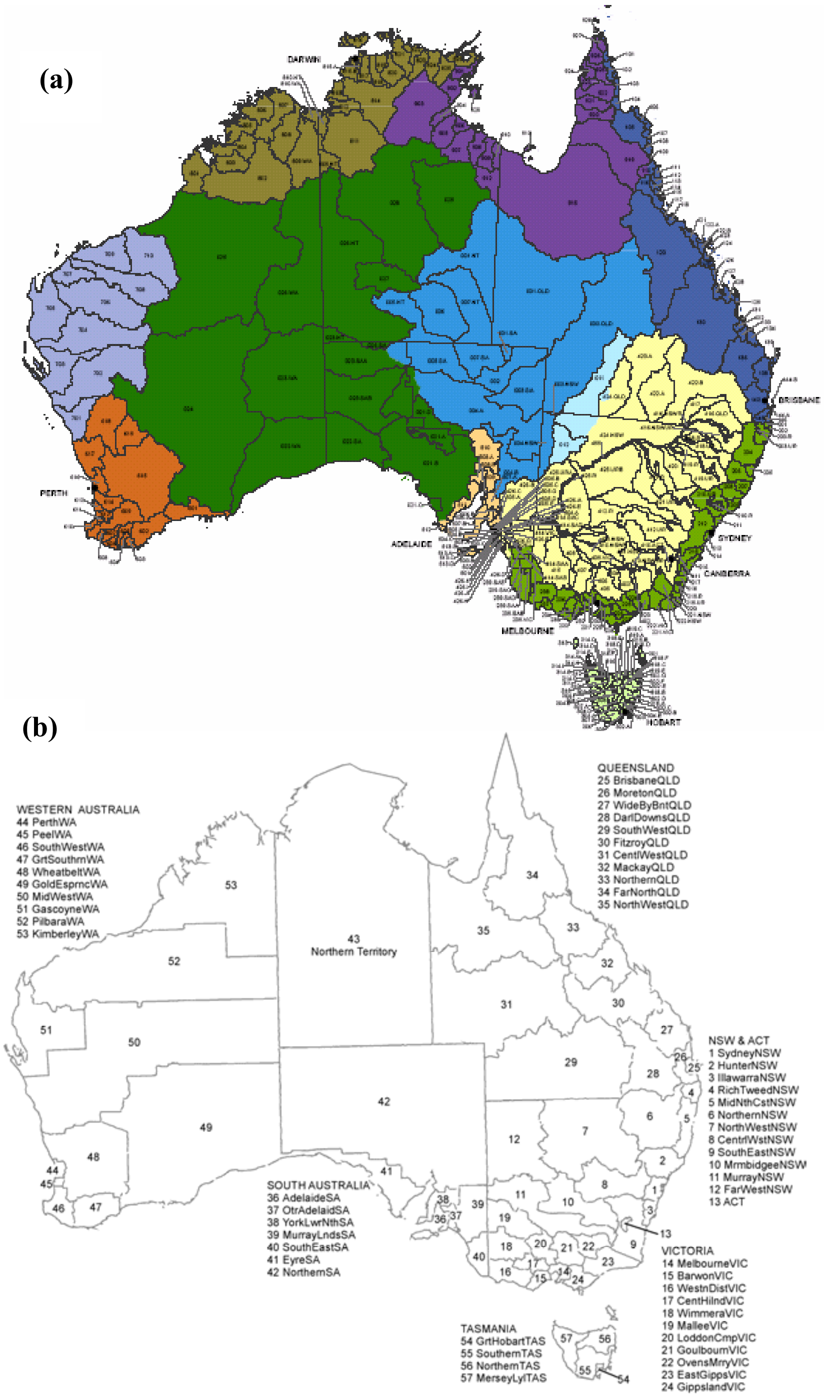

Figure 8 Comparison of (a) Australian Surface Water Management Areas (Source: www.water.gov.au) and (b) Australian Statistical Divisions (Source: www.abs.gov.au).

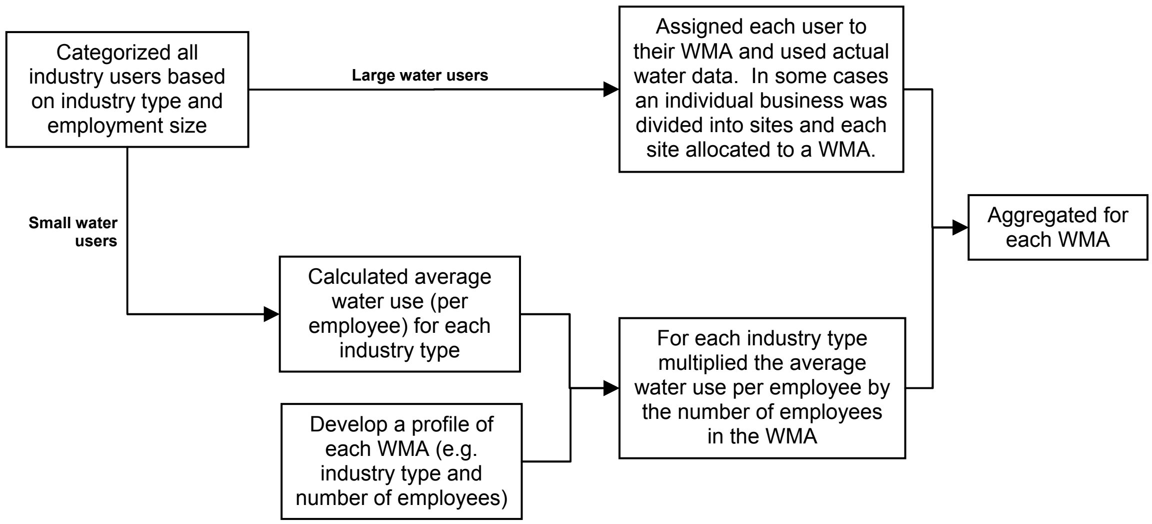

Figure 9 Steps for reallocating industrial water use in Australia to water management areas (WMA)

The methodology used to apportion agricultural water use to WMAs was developed in ABS (2006a) and further refined in ABS (2006b). In 2004/05, the year for which the regional water accounts were being developed, the water use survey was conducted for statistical divisions. However, in 2001 a more detailed survey was undertaken and results for available for statistical local areas (SLAs), a smaller statistical unit. The 2004/05 agricultural water use was reallocated to SLAs based on the proportions in the 2001 survey. The SLAs were then allocated to WMAs. In some instances the SLA covered more than one WMA. Irrigation areas within these SLAs were identified. If the irrigation area fell completely within one WMA all of the irrigation water use was allocated to that WMA. Otherwise the water use was allocated based on the percentage of the irrigation area falling within each WMA. A similar approach was used to reallocate stock water use. Areas in which stock water use could occur were identified by removing urban areas and parklands. If all of the potential stocking area fell within one WMA, all stock water use was allocated to that WMA. Otherwise the stock water use was reallocated based on the percentage of stocking area falling within each WMA. The methodology used is illustrated in Figure 10.

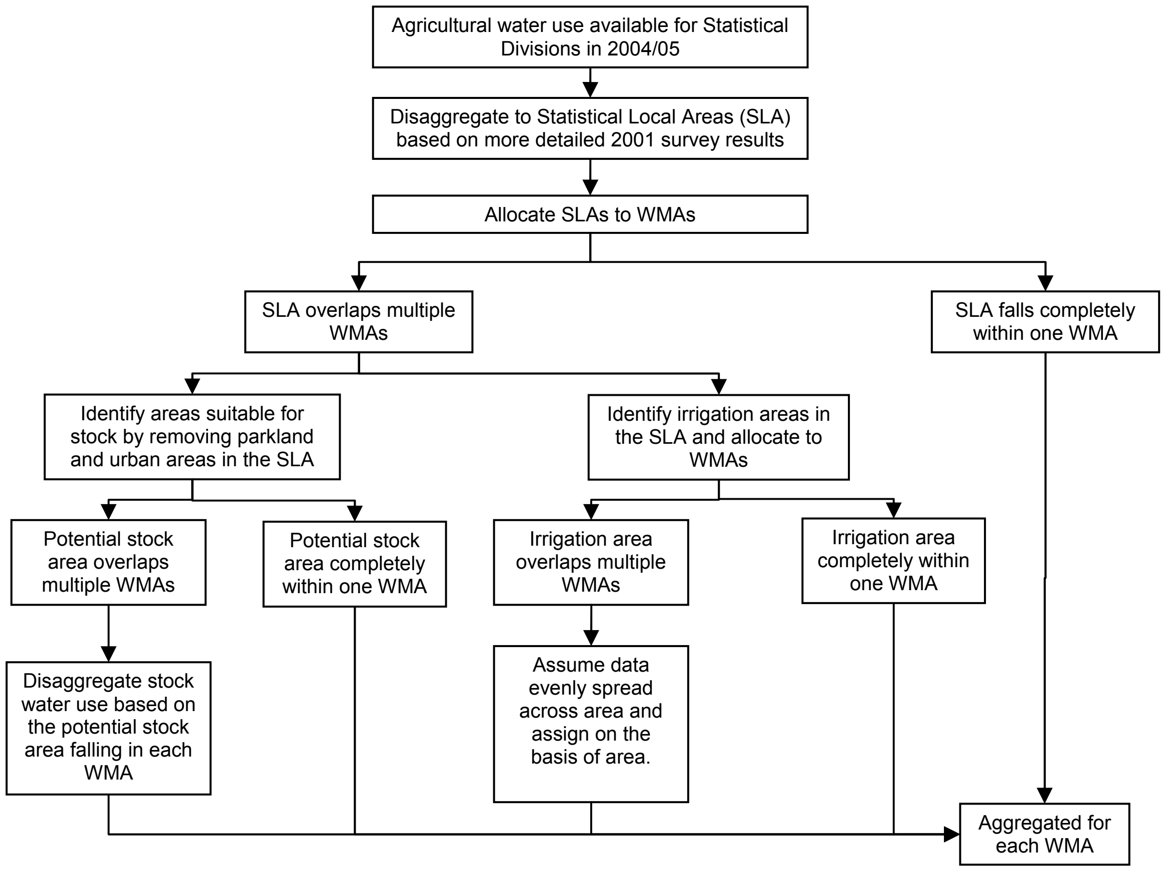

Figure 10 Steps for disaggregating agricultural water use in Australia to water management areas (WMA)

Issues of data disaggregation are also being faced by practitioners in the field of economic modeling. TERM (The Enormous Regional Model) facilitates regional economic modeling. It treats "each of Australia's 57 statistical divisions as a distinct economy with its own input-output and trade relationships" (Wittwer, 2003). TERM-water is a version of TERM that has been adjusted to allow for modeling of water related issues. The spatial boundaries used in TERM-water have varied slightly between studies. For example, Young et al (2006) used 18 regions that allowed focus on major population centers and Appels et al (2004) looked at irrigation districts.

Not all economic data inputs to the model are available for the required spatial boundary (e.g. statistical division). Regional input-output tables are not published in Australia and therefore needed to be disaggregated to represent the regions. These tables were estimated for regional areas using other data collected by the Australian Bureau of Statistics for statistical divisions. Data used to disaggregate included agricultural quantities, employment data, manufacturing census date or state information on government spending.

Water data in TERM-water is obtained from the Australian water accounts. Again, information is only available at the national or state level. However, unpublished information was available from the ABS to disaggregate to the regional level. For example, the irrigation area for each statistical division was available and could be multiplied by the water use rate by area for each sector. However, this caused anomalies with the water accounts that also gave the total water use for sector within each state. The water used by industry was disaggregated based on the proportion of industry output in each region (Young et al, 2006).

Initially TERM-water did not have variations in the availability of water between years (Wittwer, 2003). Research is underway to include more detailed hydrological information in the models, beyond the information contained in the water accounts. According to Dixon et al (2004), the selection of spatial boundaries in the model (hydrological areas or statistical boundaries) will be one of the early decisions made in the research.

Denmark

In response to a need for regional water accounts, Statistics Denmark (2005) investigated their ability to produce such accounts. The accounts were produced for administrative regions, i.e. counties, to coincide with the availability of economic information. The largest county, Bornholm, was divided into two regions for the purpose of water accounting. The regional water accounts presented water supply and use tables for each county. Monetary data was available for the boundaries of interest (i.e. counties), but the physical flows of water needed to be allocated to the administrative regions.

The following information on physical flows was readily available for use in the regional accounts:

- The volume of water supplied and used by households within each county
- The volume of water supplied and used by the water supply industry within each county
- The overall volume of water supplied and used for each county
- The total volume of water used by each industry at the national level

The volume of water supplied and used by each industry (including agriculture) within each county was not readily available. This information needed to be disaggregated from the national level to the county level. In Denmark, 98 of the 130 industries are eligible for a tax rebate that is proportional to the amount of water they use. Information available from the tax office was used to estimate the volume of water used for each industry within a basin. For the 32 industries that were not eligible for a tax rebate, water use was estimated using average water use figures. The steps followed are given in Figure 11.

The total water use for a county estimated using the approach outlined in Figure 11 did not match the overall volume of water supplied and used for each country. Companies who were reimbursed for water use only received one reimbursement for their total water use. If a company had several sites it was assumed that the water use occurred at the company headquarters. This is suspected to be the cause of the imbalance.

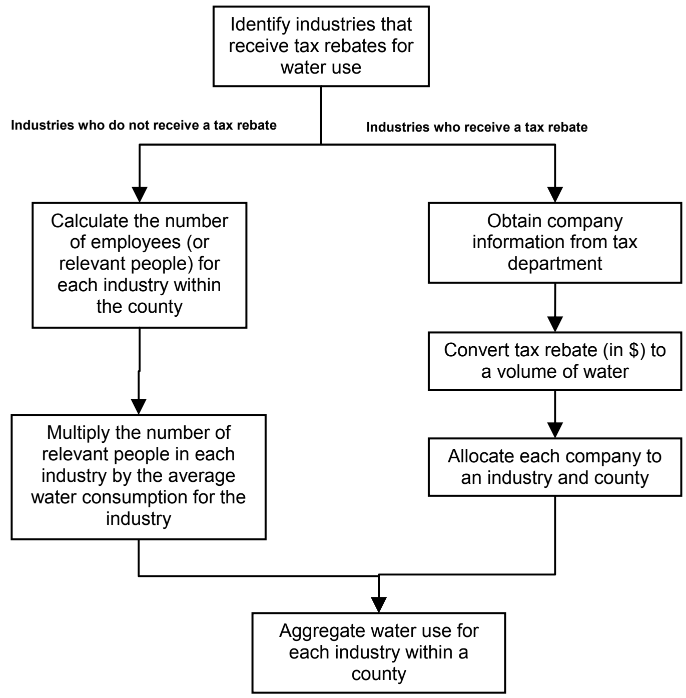

Figure 11 Steps for disaggregating industrial water use in Denmark to counties

Ireland

Ireland undertook an economic analysis of water as required by the European WFD. In Ireland economic information is largely available only at the national level. CDM (2004) describes the disaggregation of economic information to River Basin Districts (RBD).

Economic data, such as gross output value, gross value added, employment and wages was reallcoated to RBD based on the percentage of a relevant parameter that fell within each RBD. For example, the Shannon RBD contained 28% of all farms in Ireland. Therefore the agricultural gross output value associated with the Shannon RBD was estimated to be 28% of the national agricultural gross output value. The sectors analyzed and the parameters used to distribute the data to RBDs are presented in Table 2. Economic data for the industrial sector was available for smaller administrative regions. These were aggregated to RBDs. Where an administrative region overlapped two RBDs the data was apportioned to each RBD based on population.

Table 2 Parameters Used to Reallocate Economic Data to River Basin Districts in Ireland

Sector	**Disaggregation parameter**
Agriculture	Number of farms
Agricultural (Cattle and Sheep)	Number of cattle and sheep
Agricultural (potatoes)	Hectares of potato crop
Hydroelectric and Thermoelectric Power Generation	Giga-watt hour production (found by mapping each utility)
Inland commercial fishing	Total collective number of salmon caught in the national tagging scheme
Seaweed Harvesting	Number of seaweed enterprises
Aquaculture	Number of sites licensed for aquaculture
Water-based leisure	Population

Amongst other valuations, CDM (2004) estimated the value of wetlands and special riparian areas (SRA). A valuation coefficient of valuation was estimated in €/year/person/ha. The total value of wetlands and SRAs was estimated for each District Electoral Division by multiplying the coefficient by the number of hectares of wetland and SRAs by the population. The values obtained for each District Electoral Division were aggregated to RBD.

Latvia

Latvia undertook an economic analysis of water use for four river basins to fulfill the requirements of the European WFD (Ministry of the Environment of the Republic of Latvia, 2005). The analysis relied on existing data, most of which had been collected for administrative units by the Central Statistical Bureau. Therefore the information needed to be recalculated to represent river basin districts.

The method used to reallocate information from administrative regions to river basin districts followed the method outlined in Figure 3. Socio economic data were available for administrative units. These were allocated to river basin districts. The information for administrative units that overlapped multiple river basin districts was reallocated using either area or population. Area was used to reallocate Gross Added Value for agriculture and agricultural production and population was used to reallocate all other information.

Lithuania

The economic analysis undertaken by Lithuania was in response to Article 5 of the European WFD (Environmental Protection Agency, Lithuania, 2005). Socio-economic data was not available for the River Basin District, only for administrative districts. In order to present information for River Basin Districts:

- Small administrative districts were assigned to River Basin Districts and the data amalgamated.
- Data collected for large administrative districts (including national data) was reallocated to the River Basin District based on population.

Netherlands

The water accounts in the Netherlands were disaggregated to river basins. These accounts are called NAMWARB. There are four river basins in the Netherlands, and the largest river basin, the Rhine, covers 70% of the total area. To provide greater spatial disaggregation, the Rhine river basins was further divided into four catchments (Brouwer et al, 2005).

Statistics Netherlands collects economic information for 40 regional economic units called CORP areas. These areas do not coincide with the river basins and hence a method was required to reallocate the information to river basins. However, only a subset of economic information was dissagregated to the river basins (van der Veeren et al, 2004).

The method for disaggretating water use information to the river basin is illustrated in Figure 12. Of the 40 COROP areas only 23 of 40 fell within a river basin (Brouwer et al, 2005). For the remaining 17 COROP areas the monetary data was diaggregated based on the number of employees in each basin. First they worked out the industries located in each of the 17 COROPs. Then the total number of employees associated with each industry were identified. These were then allocated to municipalities which were allocated to river basins. If the municipality didn't sit entirely within a river basin, then they went down to the level of postcode. If a postcode sat in more than one river basin, it was allocated based on the % of the area falling within each river basin (Brouwer et al, 2005).

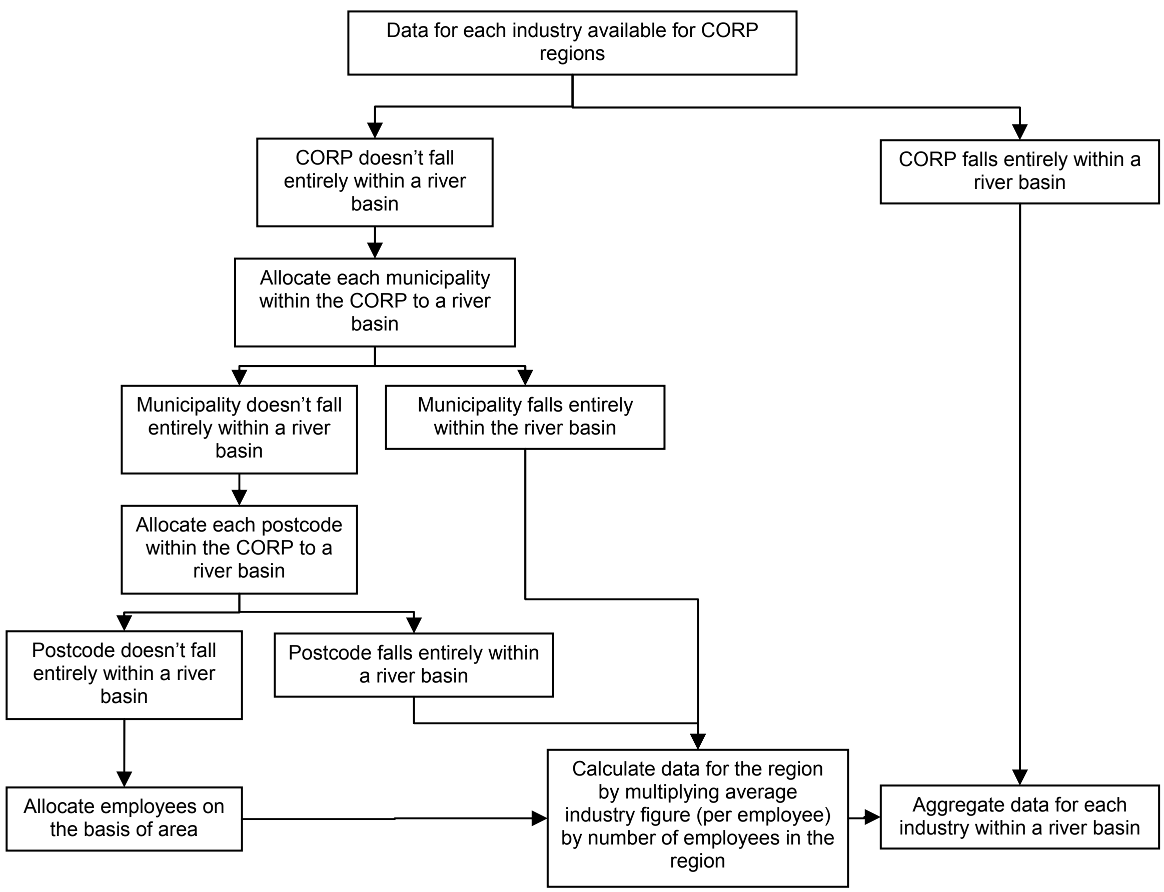

Figure 12 Steps for disaggregating industrial water use in the Netherlands to river basins

Sweden

Sweden produced water accounts at the river basin level in response to the requirements of the European Water Framework Directive (WFD). Statistics Sweden (2003) describes the methodology developed for distributing physical and monetary data to river basin districts.

For the purposes of the WFD, Sweden was divided into five water districts. However, the EPA in Sweden had regularly reported environmental information for eight, smaller, water districts. As such, the eight smaller districts were adopted for the water accounts.

Statistics Sweden (2003) describes four methods to allocate physical and monetary flows to sea basins.

1. Some data was readily available for each municipality. As such, municipalities were allocated to river basin districts. Where a municipality intersected two river basin districts the data was reallocated based on the percentage of urban population living in each river basin district. This method was used for both the physical and monetary related to the supply and use of distributed water.

2. Some environmental statistics had already been collected for 114 main drainage areas. This included information on the abstraction of water by the manufacturing industry and wastewater releases. These drainage areas were easily aggregated to water districts.

3. The exact location of houses extracting water for own use was available from a Real Estate register. Therefore they could be easily allocated to River Basin Districts.

4. Some expense data for the manufacturing industry was only available at a national level. This data was reallocated to River Basin Districts using a ‘distribution key’. That is, monetary flows were allocated to River Basin Districts based on the volume of wastewater discharged in the basin.