Improvement of waterflows in the National Water Balance; Water Stocks; feasibility of Water Balances per River Basin

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The views expressed in this paper are those of the author(s) and do not necessarily reflect the policies of Statistics Netherlands

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Explanation of symbols

.	data not available
*****	provisional figure
******	revised provisional figure (but not definite)
x	publication prohibited (confidential figure)
–	nil
–	(between two figures) inclusive
0 (0.0)	less than half of unit concerned
empty cell	not applicable
2011–2012	2011 to 2012 inclusive
2011/2012	average for 2011 up to and including 2012
2011/'12	crop year, financial year, school year etc. beginning in 2011 and ending in 2012
2009/'10–2011/'12	crop year, financial year, etc. 2009/'10 to 2011/'12 inclusive

Due to rounding, some totals may not correspond with the sum of the separate figures.

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Content

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Summary

In this project we have tried to compile a full water balance sheet for the year 2009 for the Netherlands. Required methods and data collections have been developed to compile the water balance at the national scale. We have also assessed whether compilation of a regionalized water balance at the levels of the (sub-)River Basin was feasible and whether the required quantifications could be made.

The study predominantly focuses on the improvement of the four main items of the water balance i) precipitation, ii) actual evapotranspiration, iii) actual external inflow and iv) external outflow. With respect to the temporal resolution of the data we were able to distinguish between data on the summer half year (April-September) and winter half year (January-March and October-December).

Data on precipitation and evapotranspiration were calculated by a third party, WaterWatch. This company uses Remote Sensing data and techniques in an attempt to derive all kinds of information in a spatial explicit manner, as for water. Precipitation data were compiled by WaterWatch using radar images calibrated by the dense network of precipitation gauging stations of the Royal Dutch Meteorological Institute (KNMI). The actual evaporation for the Netherlands is calculated by application of energy balance models. The procedure they apply allows for calculation of both evaporation and transpiration by crops and other vegetation separately.

For actual external inflow and total outflow of surface water to sea, all significant water courses that enter or leave the Netherlands territory, were identified. From the responsible water authorities daily flow data were inventoried, that allow to compile monthly or seasonal inflow and outflow. The data available from individual monitoring stations facilitated to compile inflow and outflow figures by River Basin. The aggregated total actual external inflow of surface water in 2009 amounted up to nearly 70 billion m^3, where total actual outflow was calculated to be 76 billion m^3.

From the four main items of the water balance, it was possible to calculate additional parameters for the Joint Questionnaire Inland waters, like the ‘total freshwater resources’, the so-called ‘internal flow’ and the ‘recharge into the aquifer’.

While for surface water flow data were easy to access and available, it turned out to be hardly possible to quantify the flows of groundwater to and from the territory. We discovered that modellers particularly neglect this flow in their quantification efforts or at least were hardly able to make reliable estimates. We aim to stay in touch and intensify the connection with hydrologists and water modellers in future and discover whether it will be possible to come up with reliable estimates.

In the project also some additional parameters that could influence the water balance and the availability of water resources in the country were quantified. Information on the import and export of tap water was provided by the association of public water supply companies, the VEWIN. Moreover, by using trade statistics and well

established assumptions on moisture content, data on the import and export of water embedded in products is compiled. Data on abstraction of surface water and ground water as well as data on discharges of waste water by industries, power plants and waste water treatment plant were compiled via the existing inventories and registers. For discharges these data could be aggregated easily per River Basin. The data on abstraction were distributed to the River Basins along the existing methodology.

Aggregated and regionalized results of the water balance are presented in chapter 7. A summary of the data for the whole territory is given in table 0.1.

Table 0.1 Water balance for The Netherlands, total and per season, 2009.

	Year	Summer	Winter
	million m^3		
1. Precipitation	28 294	12 193	16 101
2. Actual evapotranspiration	17 022	14 240	2 782
3. Internal Flow = 1 - 2	**11 273**	**-2 047**	**13 319**
4. Actual external inflow from foreign territory	67 962	31 231	36 731
5. Total actual outflow to sea	75 839	32 311	43 530
6. Total freshwater resources = 3 + 4	**79 235**	**29 184**	**50 050**
7. Recharge into the Aquifer = 6 - 5	3 396	-3 127	6 521
8. Groundwater available for annual abstraction = 7 (max)	3 396		
Abstraction of ground water	1 011		
Abstraction of fresh surface water	10 654		
Discharges to fresh water	11 478		
Discharges to sea	175		
Balance abstraction - discharges	13		
Imports of tapwater and water in product	54		
Exports of tapwater and water in products	33		

Compared to the methodology applied previously, the water balance that result from this study has improved on three main aspects:

1. The total precipitation and its spatial distribution is calculated more accurately by making use of radar images calibrated by data of numerous precipitation gauging stations.
2. The quantification of actual evapotranspiration, instead of potential evapotranspiration, results in a more realistic value for Internal Flow and Total fresh water resources.
3. The quantification of actual external inflow is more accurate because of the use of additional flow data from numerous small rivers.

In the project methodologies have been studied, dedicated method has been developed and data sources inventoried for the assessment of the stocks of fresh water within the country and some additional items. Reasonable estimates were made for stocks of fresh groundwater and surface water and to less extend for soil water. Also water stored in (growing) biomass and in sewers is estimated. Although the stock doesn't tell the full story regarding available fresh water resources persé, there are several reasons why the stocks cannot be used for 100 percent or not used at all. However the figures made provide additional insight in the order of magnitude of the stocks, the size of potential uses of the stocks, how they compare to each other. Moreover it enables the connection and confrontation of flows with stocks of fresh water. Further improvement of the data sources is aimed for, for example via better connection to hydrological and water management community.

1. Introduction

In hydrological terminology, a water balance describes the water flows in and out a system, like in a national system, at a river basin scale or even a more localised area. Main items of a nations water balance are the exchanges with the atmosphere, namely precipitation and evapotranspiration. In addition, the inland fresh water resource system exchanges water with other territories via import and export of water and through inflow from upstream territories and outflow to downstream territories or the sea. Moreover, flows occur between the inland water system and the economy, namely extractions of surface and groundwater, the uptake of water by agriculture and reuse and discharge of waste water. Another part of a country's inland fresh water resource system are the existing stocks of fresh water, namely fresh water apparent in groundwater, surface water and in soil water. The understanding and monitoring of the water balance, including flows within the environment and flows between the economy and the environment as well as the existing stocks, is elementary for all kind of water related policies.

Currently, Statistics Netherlands produces national figures on a number of fresh water flows like water abstraction of groundwater and surface water, on water use by households and by the different industries of the economy[1]. Last year also on a regional scale[2] figures have been produced for a single year on abstraction and use[3]. However, data on the water balance within the national territory, including opening and closing stocks and annual flows and changes in between, is by no means complete and can be improved in several respects. In this project, a major step will be taken to achieve this.

The UN, Eurostat, the European commission and the European Environmental Agency (EEA) by means of required inventories for the OECD/Eurostat Joint Questionnaire (JQ) or the State of the Environment reports, want to gather more data both at national level as well as at the level of river basins. To ensure the development, collection of data, and elaboration of methods for such surveys, Eurostat in its Water Grants program 2010 listed the regionalization of water statistics as first priority, parallel to the further improvement of national data.

This project assigned to Statistics Netherlands as part of the Water Grants program 2010 has been executed by the Environment Statistics department and by the

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[1] CBS publication 'Dutch Environmental Accounts 2009',(2010) and http://statline.cbs.nl/statweb/ (search for: 'watergebruik', table is only available in Dutch).

[2] The Netherlands is divided into 4 river basins: Ems, Meuse, Scheldt and Rhine. The Rhine basin is divided into 4 sub-basins: Rhine West, Rhine North, Rhine Centre and Rhine-East.

[3] Kees Baas and Cor Graveland. 2011. EU Water Statistics Grant: Water Abstraction and -use at River Basin Level. Final Report for Eurostat.

Environmental Accounts group within the National Accounts department. The project started in January 2011 and was finalized in March 2012.

This report presents the results on the different activities as formulated in the project proposal. Chapter 2 describes the objectives of the project. In chapter 3 the project activities are listed. The methods and results of the calculation of the four main items of the water balance are presented in chapter 4, followed by a short description of the additional items of the Joint Questionnaire on Inland Waters in chapter 5.

In chapter 6 the methods and results of the compilation of data on abstractions, discharges and import and export of water are given. Chapter 7 provides a full overview of the water balance, including water balance tables for the four River Basins and a comparison of the data with the previously applied method. Finally chapter 8 treats the assessment of the existing stocks of groundwater, soil water and surface water as well as the stocks of wastewater and the water in growing or standing biomass. We elaborate the compilation methodology and parameterisations and first results are presented. Chapter 9 finishes with conclusions and some recommendations.

2. Objectives of the project

The primary objective of the project is, starting from existing data, to compile a national water balance for the Dutch national territory 2009. For that purpose, missing parts should be filled in conjunction with the improvement of the quality of the data underlying the different parts of the balance. A prerequisite is that data should be available over the full coverage of the balance.

Second objective of the project is to collect data at disaggregated level and attempt to compile water balance data for the countries' four River Basins districts or – if feasible – the seven (sub) River Basins. In particular for the four (sub-)River Basins of the Rhine, characterized by a complex hydrological structure, this meant to be a feasibility study. For a selection of items, compilation could be achieved though.

The last objective, when data would proof to be sufficient, was to develop a method for and make assessment of, stocks or resources of freshwater in the country (eventually supplemented with brackish water) for groundwater, surface water or soil water within the system. Compilation of stocks will be tested. Water stored in the sewage system and biomass could be inventoried.

The methods will be applied to the data for 2009.

The project will cover the following products:

- An English report on the methodologies applied;
- A national dataset on water flows and stocks for 2009;
- Optional: A regionalized dataset at River basin level of water flows and stocks for 2009.

The dataset will then be used for at least the following reports:

- OECD / Eurostat Joint Questionnaire on 'Inland Waters';
- Statistics Netherlands Environmental Accounts: Annual publication;
- EEA State of the Environment datasheet on water availability (in collaboration with The Directorate-General for Public Works and Water Management ('Rijkswaterstaat' / 'Water Service')[4];
- The Regional Environment Questionnaire of Eurostat.

[4] Is an executive department of the ministry of Transport, Public Works and Water management.

3. The project activities

In the project the following activities were foreseen:

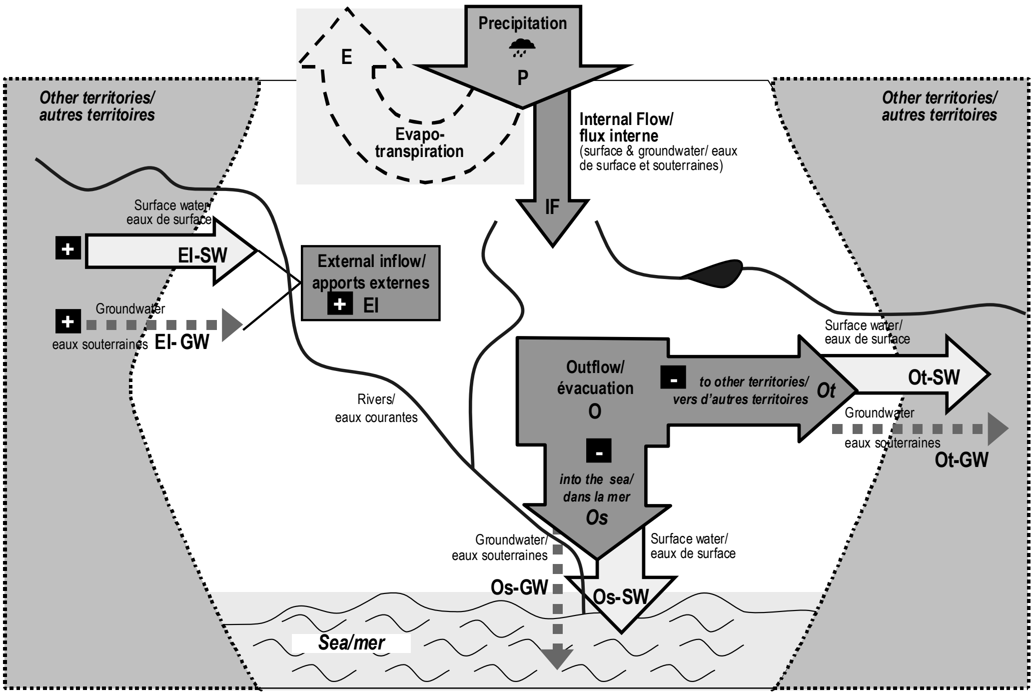
1. **Improvement** of the 4 main elements of the water balance:
   a. **Precipitation data** will be recalculated using micro-data per measuring station, enabling the breakdown into (sub) river basins;
   b. Data on **actual evapotranspiration** will be included, instead of the current use of data on the so-called 'reference crop evapotranspiration'. This is the most important improvement of the national water balance. This includes assessment of the actual evapotranspiration from the National territory relying on remote sensing data to be obtained externally from third party, namely 'Waterwatch';
   c. Improvement of the existing data on **actual external inflow** from upstream territories via rivers and **other flows** and **actual outflows**;
   d. **Regionalized external inflow** to (sub-) River Basins (where possible);
   e. Quantification of **groundwater flows** in the water balance (an important extension to current balance).
2. Aim for estimation of three major items in the ES-JQ (table 1) as is based upon results of activity 1. and other relevant input:
   a. The '**internal flow**';
   b. The '**recharge into aquifer**' and;
   c. The '**groundwater available** for abstraction'.
3. Quantification of some **balance items** as (minor but also relevant):
   a. The import and export of water (not being surface water or groundwater: see activity 1a);
   b. Extend data on **water abstraction** to 2009 and incorporate it in the balance.
   c. Production and discharge of **waste water** and the **reuse of water**;
4. Completion of the information on certain water categories as:
   a. Completion of **flows between types of water** and;
   b. Completion of **flows to and from territories**, with information on opening and closing **stocks** for each year (these stocks distinguishes groundwater, soil water and fresh surface water in rivers, lakes and polders behind the dikes and for example of the water stored in the IJsselmeer).
   c. Compilation of **opening stocks** (1^{st} of January) and;

d. Compilation of **closing stocks** (31st of December).

5. Optional: Water **used and supplied by economic units** will be i**ntegrated** in the water balance. This means that both water flows within the national economy as well as between the national economy and the environment will be showed.

Figure 3.1 shows the different items to be reviewed and improved as described above, in connection with the Joint Questionnaire (JQ). Results of the different actions are reported in next chapters of this report, beginning of 2012.

Figure 3.1 Simplified hydrological cycle



Source: Eurostat/OECD – Joint Questionnaire on Inland waters (2010).

4. Improvement of the main elements of the water balance

In the Netherlands data for main parts of the water balance stem from the Ministry of Infrastructure and Environment[5] and the Dutch water boards. In context of this study for Eurostat, WaterWatch as a third party calculated precipitation as well as actual evapotranspiration for the Netherlands with the requested level of detail using remote sensing technology.

4.1 Precipitation

In the Netherlands annual precipitation amount at average an approximated 800 millimeters. The prime focus lies on the inland including the fresh water system. The North Sea with salt water is excluded here. The largest part of the precipitation for the inland goes to land. The exact distribution between those depends on the surface of both land and (fresh) surface water.

4.1.1 Compilation

For this study for Eurostat, WaterWatch calculated both precipitation and actual evapotranspiration for the Netherlands. The calculations are done for the calendar year 2009. Here the annual data is distributed over a summer period (April-September) and a separated winter period (January - March and October - December). The applied methodology will briefly be explained in the relevant sections. The first priority of WaterWatch was to calculate both Actual Transpiration and Evaporation and as a result Evapotranspiration (next paragraph). For actual evapotranspiration calculations, remote sensing data is used. Details on the origin of these data and the results for evapotranspiration are described in paragraph 4.2. WaterWatch thus also aimed to assess and quantify precipitation, as worked out well.

For precipitation (rainfall), the applied method calculates the amount of water upon the precipitation being measured every 5 minutes by the KNMI precipitation radar network. The raw images are calibrated using number of dozens of precipitation gauges in the country. The resolution of the precipitation radar is 1 * 1 kilometer. That means that for every square kilometer the precipitation is determined (Waterwatch, 2011). Precipitation is calculated for the annual total and both the summer and winter period. By using a GIS overlay, the precipitation was also broken down to (sub-)River Basins.

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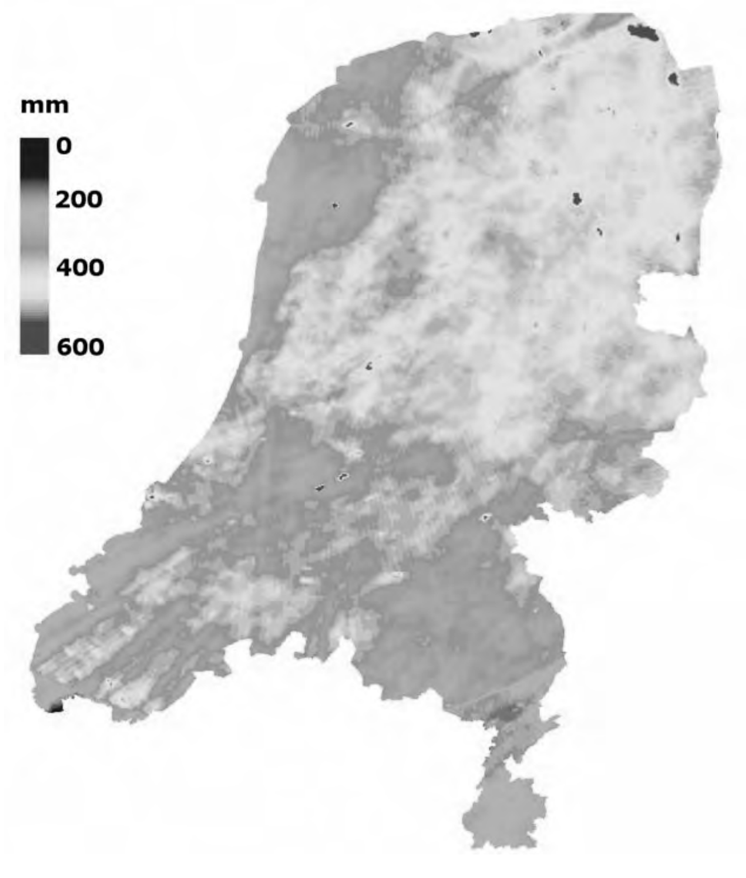
[5] Merger in 2010 of the Netherlands ministry of transport public works and water management with the Netherlands ministry of the environment actually mentioned the Dutch Ministry of Housing, Spatial Planning, and the Environment.

In order to calculate the total volume of precipitation (in m^3), the average precipitation in millimeters for each area (country or River Basin) can be combined with the area considered.

4.1.2 Results

Figure 4.1 shows the map of the Netherlands with spatial distribution of precipitation during the 6-month summer period for 2009 based on the KNMI precipitation radar network with calibration procedure. For the winter period, the 3 months at the beginning and 3 months at the end of the year, a similar figure is generated. It must be mentioned that in the calculation of total precipitate water (m^3) the surface of marine and brackish waters (like the Westerschelde and Waddensea) were left out. The resulting quantities thus only refer to precipitate water on land surface and on fresh surface waters.

Figure 4.1 Distribution of precipitation in the Netherlands, summer 2009.

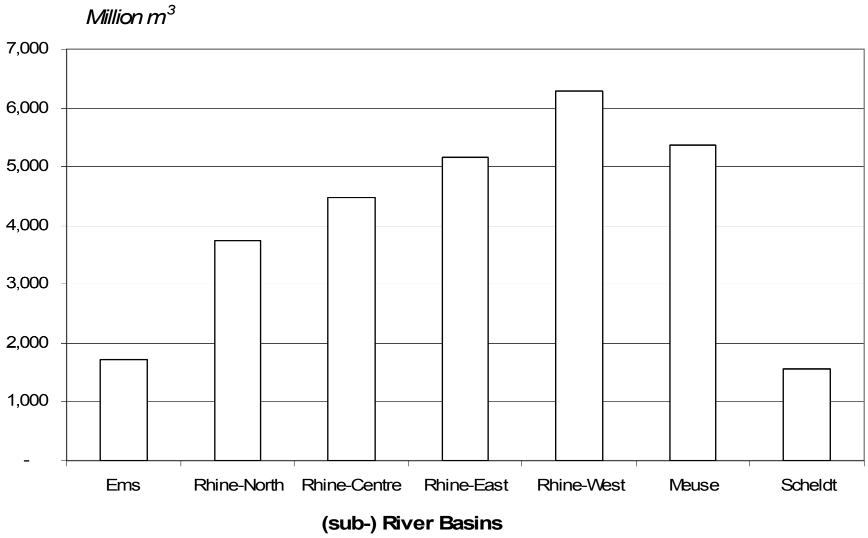


Source: WaterWatch (2011).

The annual average precipitation of 761 mm, is composed by 328 mm in summer and 433 mm in winter period, a 43 – 57 percent distribution. Such precipitation levels at an area of 3.72 million hectare, give an incoming annual (internal) flow of 28.3 billion m^3 water, distributed over the summer and over the winter period in

2009 for the country as a whole. This flow that enters the country can be distributed to the seven (sub-) River Basins (figure 4.2) via spatial allocation of the precipitation.

Figure 4.2 Precipitation in summer & winter distributed over the River Basins, 2009



Source: WaterWatch (2011).

4.2 Actual evapotranspiration

Existing data on Evapotranspiration, either evaporation & transpiration for the country as a whole so far is limited and particularly based on the so-called 'reference crop evapotranspiration', which shows the evapotranspiration under conditions with sufficient water supply / availability for the crops. For this subject we aimed to make an important improvement of the national water balance. We therefore used an assessment of the 'actual evapotranspiration' instead of evapotranspiration partially based on 'reference crop evapotranspiration'.

4.2.1 Compilation

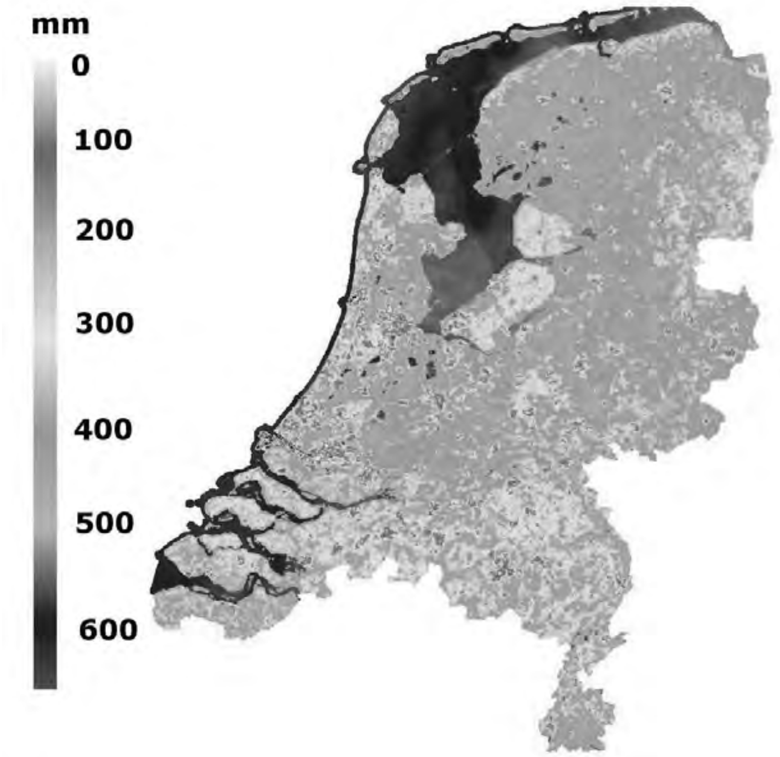
The assessment of 'actual evapotranspiration' was done for the National territory and for the regional subdivisions as is the (Sub-)River basins. This assessment is based upon spatial and temporal explicit data that has been obtained from WaterWatch. WaterWatch as a company uses Remote Sensing data and techniques in order to derive all kinds of information in a spatial explicit manner, as for water. For our purpose the actual evapotranspiration next to precipitation is assessed in detail.

The actual evapotranspiration for the Netherlands is calculated by WaterWatch by application of energy balance models. While standard evaporation models are based on a water balance, WaterWatch exclusively uses energy balance models. The model 'ET-Look' as used determines the energy available per pixel each day and calculates how this energy is distributed over the physical processes[6]. This procedure allows for the calculation of both evaporation (soil evaporation) and transpiration (crop transpiration) separately (WaterWatch, 2011). The input parameters of the 'ET-Look' model, includes the meteorological conditions observable such as cloud cover, air temperature, wind speed and relative humidity. These Meteorological conditions are measured at a number of specified points in the concerned area. With the 'MeteoLook algorithm' these meteorological point measurements can be converted to a coverage area map with high level of detail as each individual pixel has a unique value[7].

4.2.2 Results

Figure 4.3 shows a map again, now with the spatial distribution of evapotranspiration over the country, during the 6-month summer period (April – September) for 2009 based on the Remote sensing methodology applied by WaterWatch. For the winter period, which is an aggregation of the 3 months at the beginning and 3 months at the end of the year a similar figure, although with much smaller quantities, can be generated.

Figure 4.3 Actual evapotranspiration in summer season 2009 (mm / half year).



Source: WaterWatch (2011).

6 For more information on ET-Look (Pelgum et al. (2010).

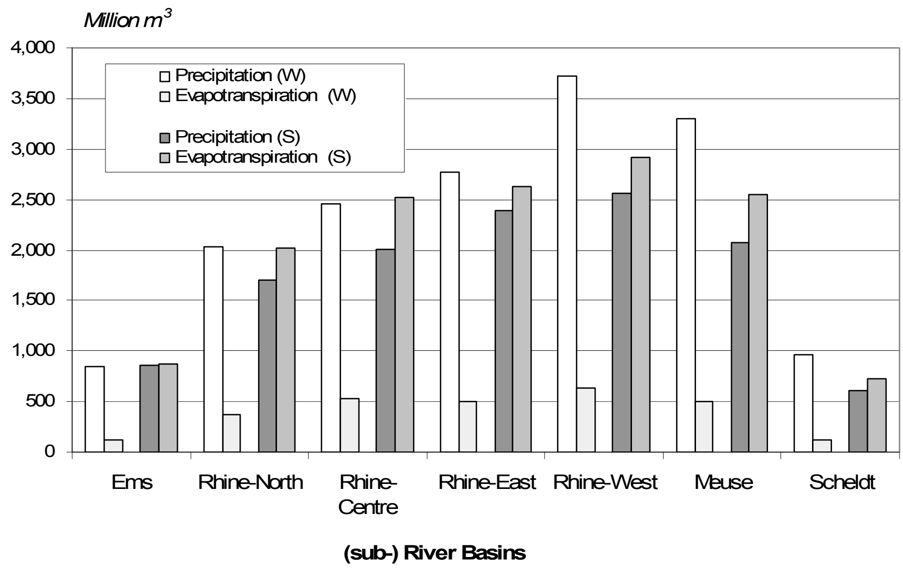
7 For more information about the 'MeteoLook algorithm, see Voogt (2006).

The average annual evaporation that covers the summer and winter period, amounted to 142 mm. As transpiration ran up to 316 mm, together for the country as a whole an average evapotranspiration of 458 mm for 2009 was calculated. As one may well expect, with a summer – winter distribution of 383 mm to 75 mm, by far the largest share (84 percent) of the evapotranspiration in 2009 was observed in the 6-month summer period.

The evapotranspiration of 458 mm at an area of 3.72 million hectare gives 17.0 billion m^3 of evapotranspiration in 2009. This compares to 60 percent of the total amount precipitated in 2009. The remaining 40 percent principally is available for groundwater replenishment. Although in summer period, the countries' evapotranspiration exceeds the precipitation with around 17 percent.

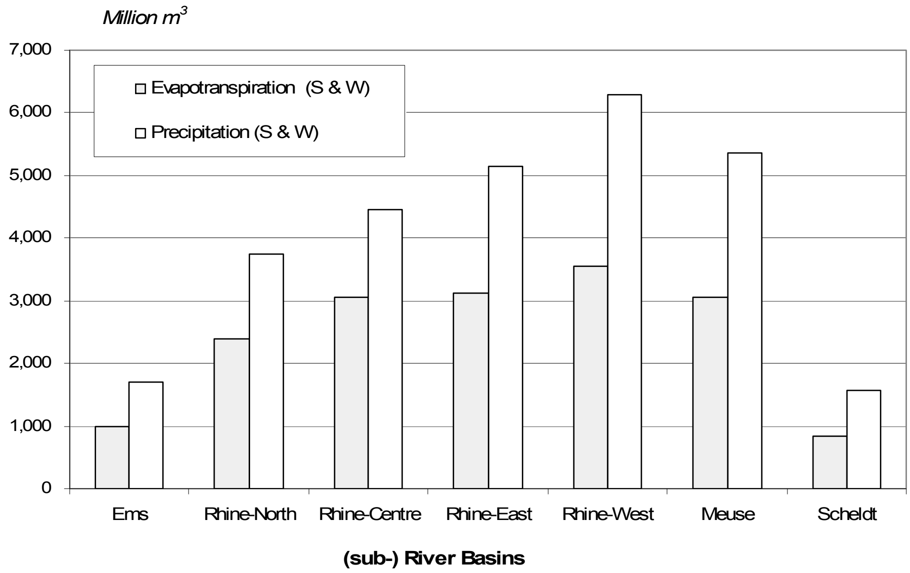
The evapotranspired fresh water quantity, in principle the fresh water diverted from the countries' inland water system, is also distributed to the seven (sub-) River Basins (figure 4.4 and 4.5). In chapter 7, a synthesis is made of the different improved elements of the Water balance, including precipitation and evapotranspiration.

Figure 4.4 Precipitation & Evapotranspiration in winter en summer, 2009



Source: WaterWatch (2011).

Figure 4.5 Precipitation & Evapotranspiration distributed over the River Basins, 2009



Source: WaterWatch (2011).

4.3 Actual external inflow of surface water from foreign territory

External inflow consists of two flows, external inflow of surface water and external inflow of groundwater. In this paragraph we will present the method and results of the quantification of external inflow of fresh surface water.

4.3.1 Introduction

The Netherlands is situated downstream of the river Rhine, Meuse and Scheldt. In practice that means that nearly all cross-border fresh surface waters bodies, flow into the country. Figure 4.6 shows a map of the Netherlands with the major surface waters. The by far largest inflow (over 85 percent) of fresh surface water stems from the river Rhine, entering the country in the East at the location Lobith. Also some small rivers, like the Overijsselse Vecht, enter the country along the Eastern border, adding up to the total inflow in the Rhine River Basin District.

In the south, the river Meuse enters from Belgium. Also a number of small rivers and brooks from Germany and Belgium add to the water inflow in the Meuse River Basin District.

In the South-western part of the Netherlands, the river Scheldt flows into the Scheldt estuary. Given the marine conditions in the mouth of the river Scheldt, this inflow is not regarded as fresh water and is not taken into account in the water balance. Only the external inflow from Belgium via the Canal Gent-Terneuzen will be taken into account.

Figure 4.6 Major surface waters in the Netherlands

Source: Rijkswaterstaat (2011a).

4.3.2 Methods

Current data on **external inflow of surface water** is solely based upon the yearly flows (m^3/year) of the river Rhine (gauging station Lobith) and river Meuse (gauging station Eysden). For extension and further enhancement of data on external inflow of surface waters, two actions were formulated:

Action i): Identification of all the smaller rivers contributing to external inflow of surface water and allocation to (sub) river basins. This is done via a desk study of reports and websites of the responsible water boards.

Action ii): Collection of all available data of river flows (m^3/sec, m^3/day) measured at gauging stations situated at or near the border location. This meant an inventory among the responsible water authorities. Data obtained covers the full length of the year as from 1-1-2009 to 31-12-2009.

4.3.3 Results

Table 4.1 gives the result of action i). The table lists the major and minor rivers entering the Dutch territory from the neighboring countries Germany and Belgium. The table also specifies the responsible water authority, the border location and the allocation to sub-River Basin.

Table 4.1 Surface waters entering the Dutch territory

Name River	Water Control Authority [1)]	Gauging station / Border	From	To NL-RBD
Rijn[2)]	National Water Authority	Lobith	Germany	Rhine-West
Maas[2])	National Water Authority	Eijsden	Belgium	Meuse
Kanaal Gent Terneuzen	National Water Authority	Sas van Gent	Belgium	Scheldt
Schelde[3)]	National Water Authority	Schaar van ouden d(	Belgium	Sea
Aa of Weerijs	WB Brabantse Delta	Wielhoef	Belgium	Meuse
Bovenmark	WB Brabantse Delta	Blauwe Kamer	Belgium	Meuse
Molenbeek	WB Brabantse Delta	Nispen	Belgium	Meuse
Boven-Dommel	WB De Dommel	Borkel en Schaft	Belgium	Meuse
Tongelreep	WB De Dommel	Achelse Kluis	Belgium	Meuse
Nieuwe Leij	WB De Dommel	Goirle	Belgium	Meuse
Zuid-Willemsvaart	National Water Authority	Lozen	Belgium	Meuse
Jeker	WB Roer en Overmaas	Nekum	Belgium	Meuse
Voer	WB Roer en Overmaas	Mesch	Belgium	Meuse
Geul	WB Roer en Overmaas	Cotessen	Belgium	Meuse
Roer	WB Roer en Overmaas	Stah	Germany	Meuse
Swalm	WB Peel en Maasvallei	near Swalmen	Germany	Meuse
Niers	WB Peel en Maasvallei	near Gennep	Germany	Meuse
Eckeltsebeek	WB Peel en Maasvallei	Beekheuvel	Germany	Meuse
Gelderns-Nierskanaal	WB Peel en Maasvallei	near Arcen	Germany	Meuse
Wellse Molenbeek	WB Peel en Maasvallei	Well	Germany	Meuse
Lingsforterbeek	WB Peel en Maasvallei	Arcen	Germany	Meuse
Oude IJssel	WB Rijn en Ijssel	Gendringen	Germany	Rhine-East
Aa-strang	WB Rijn en Ijssel	near Dinxperloo	Germany	Rhine-East
Bovenslinge	WB Rijn en Ijssel	Kotten	Germany	Rhine-East
Berkel	WB Rijn en Ijssel	near Rekken	Germany	Rhine-East
Buurserbeek	WB Rijn en Ijssel	Reinkstuw	Germany	Rhine-East
Hegebeek	WB Regge en Dinkel	Hegeveld	Germany	Rhine-East
Geestmerstroomkanaal	WB Regge en Dinkel	Langeveen	Germany	Rhine-East
Dinkel [4)]	WB Regge en Dinkel	near Losser	Germany	Rhine-East
Overijsselse Vecht	WB Velt en Vecht	De Haandrik	Germany	Rhine-East

Source: Water boards (2011), Rijkswaterstaat (2011b).

1) WB = Water board.
2) Main River.
3) Not taken into account; import into marine waters.
4) Not taken into account, flows back to Germany after a few kilometres.

For nearly all surface waters listed in table 4.1, data files containing daily average flow rates (m^3/sec) were provided by the responsible water authorities. For some less relevant small rivers we received yearly values which were broken down to daily values along the temporal trend in flow-rates as observed in rivers flowing nearby.

The daily average values of flow rate (m^3/sec) facilitate aggregation of data to whatever temporal scale. For both the Meuse and Rhine River Basin the results are presented in three graphs, representing (i) average daily flow rate of the main river and the sum of daily flows of the small rivers in m^3/sec, (ii) the total monthly flow in m^3 and (iii) a separate graph of total monthly flow of the small rivers (m^3). For the

Meuse River Basin the latter graph distinguishes between inflow from Germany and inflow from Belgium.

Figure 4.7 and 4.8 show these three graphs for the Meuse River Basin and Rhine River basin respectively. The graphs illustrate that in the period from August to November the flow drops sharply due to less rainfall and to reduced contribution from melting water, particularly from the Alps. Especially the flow rate of the river Meuse strongly depends on rainfall upstream, while the smaller rivers in the Meuse RBD are less sensitive. Probably partly because of continuous discharges of Urban Waste Water Treatment Plants (UWWTP's) effluents upstream, the flows in the small rivers maintain a certain minimum level. In the months of August and September the total inflow via the smaller rivers in the Meuse RBD even exceeds the inflow from the river Meuse.

Figure 4.7 Temporal variation in external inflow from foreign territory, Meuse 2009

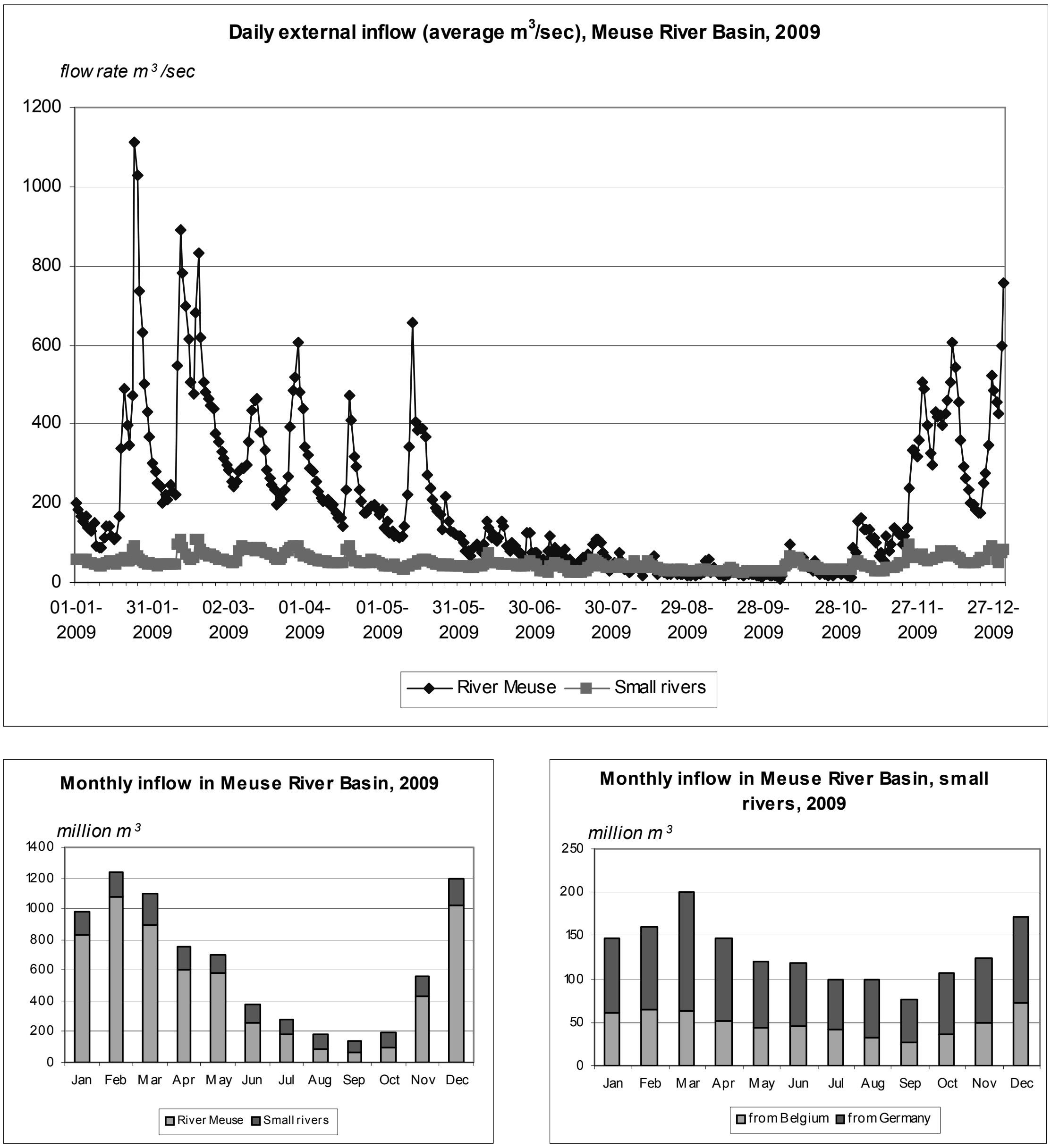
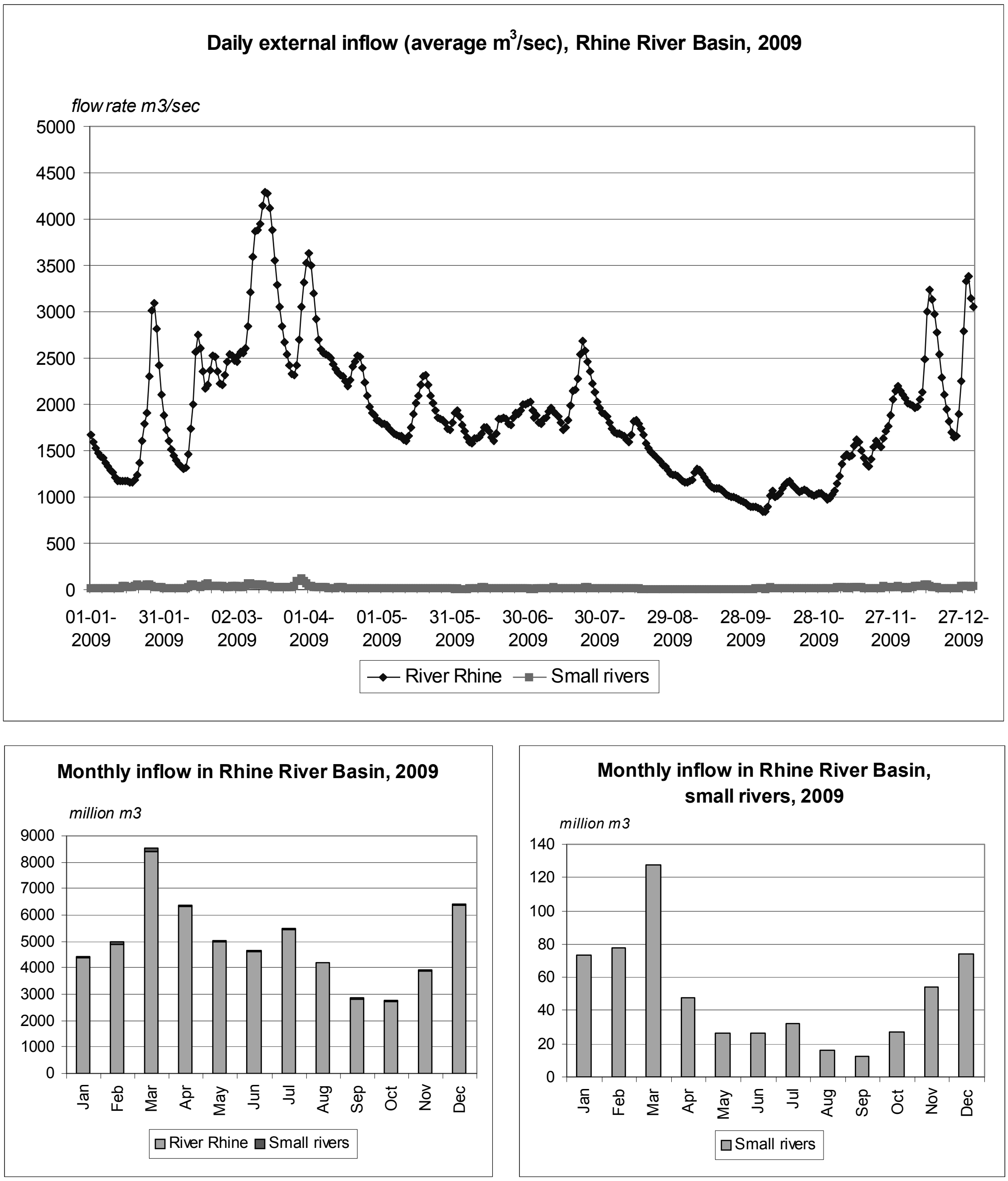


Figure 4.8 Temporal variation in external inflow from foreign territory, Rhine RBD, 2009



From the data it can be calculated that in 2009, 20% of total annual inflow in the Meuse River basin can be attributed to inflow of small rivers. In the summer season (April-September) the share of small rivers is nearly 30%. In the Rhine River basin with 1%, the contribution of small rivers is limited. For the Meuse River Basin in particular, the more complete inventory of cross-border flows proves to be of large influence for the water balance of the concerned region.

Table 4.2 summarizes the results for total actual external inflow of fresh surface water from foreign territory. In there distinction is made between the winter period and the summer period, with a breakdown to sub-river basin as well. In this table also the data for the Scheldt River Basin are included. The latter figure reflects only the inflow from Belgium via the Canal Gent-Terneuzen. As mentioned earlier, inflow of the River Scheldt into the Scheldt Estuary will not be included in the national fresh water balance, because this water has become already brackish/marine once it enters the Dutch territory.

Table 4.2 Total external inflow, 2009, per (sub-)River Basin

(sub-) River Basin	total	winter	summer
	million m^3		
Rhine	59 652	31 083	28 569
of which:			
Rhine-West	59 056	30 649	28 407
Rhine-East	596	434	162
Meuse	7 709	5 268	2 441
Scheldt	601	380	221
Total inflow	**67 962**	**36 731**	**31 231**

4.4 Actual outflow of surface water

4.4.1 Introduction

Outflow of surface water includes outflow to the sea (North Sea, Wadden Sea, Ems-Dollard and Scheldt estuary) only. As the Netherlands is situated downstream in all the relevant River Basins, the outflow particularly reflects the large quantities of inflow of fresh surface water from the rivers. Outflow of surface water to neighbouring countries does not occur, except for one small river (Dinkel) that crosses the Dutch-German border twice. For surface water, the current figures of outflow to the sea are produced on an annual basis and taken from the OSPAR RID report on riverine inputs to the North Sea catchment area (OSPAR Commission, 2011). Table 4.3 provides an overview of all rivers contributing to the total outflow from the Dutch territory and their coincidence with gauging stations situated close to the outflow points from these rivers (Rijkswaterstaat, 2011b; OSPAR, 2011). The table also provides the name of the responsible water authority, the allocation to River Basin and name of the receiving marine water. Besides the large outflow points of the Rhine and Meuse delta, also pumping stations that evacuate excess water from polders and waterways directly into the sea, contribute to the total external outflow of fresh surface water from the territory .

4.4.2 Methods

For further enhancement of data on external outflow of surface waters, one additional action is formulated:

Action i): Collection of all available data of flows (m^3/sec, m^3/day) measured at gauging stations situated at or near outflow points at rivers, canals, dams or pumping stations. This involved a short inventory among the responsible water authorities. Data is obtained for the period 1-1-2009 to 31-12-2009.

Table 4.3 Outflow gauging stations

Name River [1)]	Water Control Authority [2)]	Gauging station	From NL-RBD	To sea / estuary
Nieuwe Waterweg[3)]	National Water Authority	Maassluis	Rhine-West	Northsea
Haringvliet[3)]	National Water Authority	Sluis, binnen	Meuse	Northsea
Noordzeekanaal[3)]	National Water Authority	Ijmuiden	Rhine-West	Northsea
Ijsselmeer[3)]	National Water Authority	Den Oever	Rhine-Central	Waddensea
Ijsselmeer[3)]	National Water Authority	Kornwerderzand	Rhine-Central	Waddensea
Kanaal Gent - Terneuzen	National Water Authority	Terneuzen	Scheldt	Westerschelde
Polder Effluents Westersche	WB Scheldestromen	several	Scheldt	Westerschelde
Grevelingenmeer	National Water Authority	Brouwersdam	Scheldt	Northsea
Polder Effluents Oostersche	WB Scheldestromen	several	Scheldt	Oosterschelde
Spuikanaal Bath	National Water Authority	Bath	Scheldt/Meuse	Westerschelde
Zuiderdiep	WB Hollandse Delta	Stellendam	Meuse	Northsea
Oosterschelde (Krammerslu	National Water Authority	Bruinisse	Meuse	Oosterschelde
PS Vlotwatering	WB Delfland	Ter Heyde	Rhine-West	Northsea
PS Scheveningen	WB Delfland	Scheveningen	Rhine-West	Northsea
PS Katwijk	WB Rijnland	Katwijk	Rhine-West	Northsea
PS de Helsdeur	WB Hollands Noorderkwartier	Den Helder	Rhine-West	Waddensea
Spuisluis Oostoever	WB Hollands Noorderkwartier	Den Helder	Rhine-West	Waddensea
Wieringermeer	WB Hollands Noorderkwartier	Den Oever	Rhine-West	Waddensea
Texel	WB Hollands Noorderkwartier	Texel	Rhine-West	Waddensea
Lauwersmeer	WB Fryslan	Lauwersmeer	Rhine-North	Waddensea
Harlingen/Van Harinxmakan	WB Fryslan	Harlingen	Rhine-North	Waddensea
PS Zwarte Haan	WB Fryslan	Zwarte Haan	Rhine-North	Waddensea
PS Roptazijl	WB Fryslan	Roptazijl	Rhine-North	Waddensea
PS Duurswold	WB Hunze en Aas	Delfzijl	Ems	Ems/Dollard
Eemskanaal	WB Hunze en Aas	Delfzijl	Ems	Ems/Dollard
Nieuwe Statenzijl	WB Hunze en Aas	Drieborg	Ems	Ems/Dollard
PS Damsterdiep	WB Noorderzijlvest	near Delfzijl	Ems	Ems/Dollard
PS Termunterzijl	WB Hunze en Aas	Termunterzijl	Ems	Ems/Dollard

Source: OSPAR (2011).

[1)] PS = Pumping Station (polder effluents); [2)] WB = Water board; [3)] Major riverine outflow.

4.4.3 Results

Figure 4.9 presents the aggregated monthly outflow with a breakdown into (sub-) River Basin. Table 4.4 summarizes the data, per season and per (sub-)River basin. It can be concluded that the Rhine(-West) delta has by far the largest outflow volume compared to the other River Basins. In fact, the Dutch delta area is formed by the tail of both the large river Rhine and Meuse, but specific outlets to the sea can be designated to either one of the sub-River Basins.

The “key” waterworks in the water discharge from the territory are the Haringvliet drain-sluices. When opened, all the Meuse water leaves the country via the Haringvliet, together with a part of the river Rhine flow. When closed, the Meuse river flow is redirected to the Nieuwe Waterweg, which is say the natural riverine outflow of the Rhine. Under specific conditions, Meuse and even Rhine water can also be redirected to the Scheldt sub-River Basin, via the Volkerak-drain sluices and the Bathse Spui Canal. This facility is particularly designed to protect the south-western part of the Netherlands against salination. This is relevant as salt intrusion more and more becomes a concern, particularly in the south-west part of the country.

The two regulated drains of the lake IJsselmeer (Rhine-Central), form together the second largest outflow point of fresh surface water. The main part of this fresh water outflow originates from the river Rhine, more specific comes from the river (Gelderse) IJssel, which branches off from the river Rhine near Arnhem and flows to the North into the lake IJsselmeer.

The outflow from the other sub river basins is limited and consists mainly of small draining sluices or pumping stations which function to evacuate excess water from the polders and the waterways situated on the landside of the dikes.

Figure 4.9 Total monthly outflow to sea per (sub-) river basin, 2009

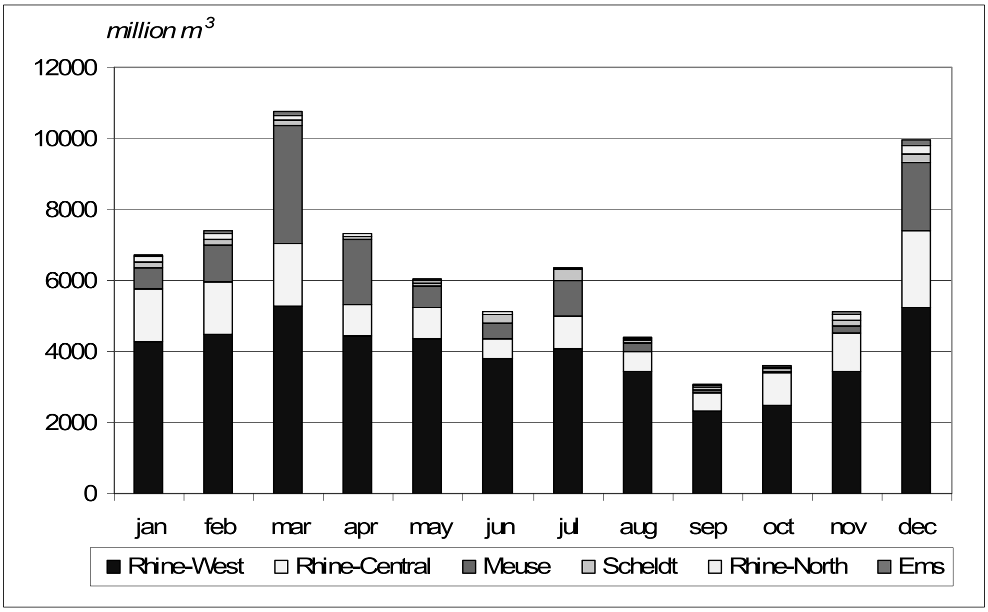
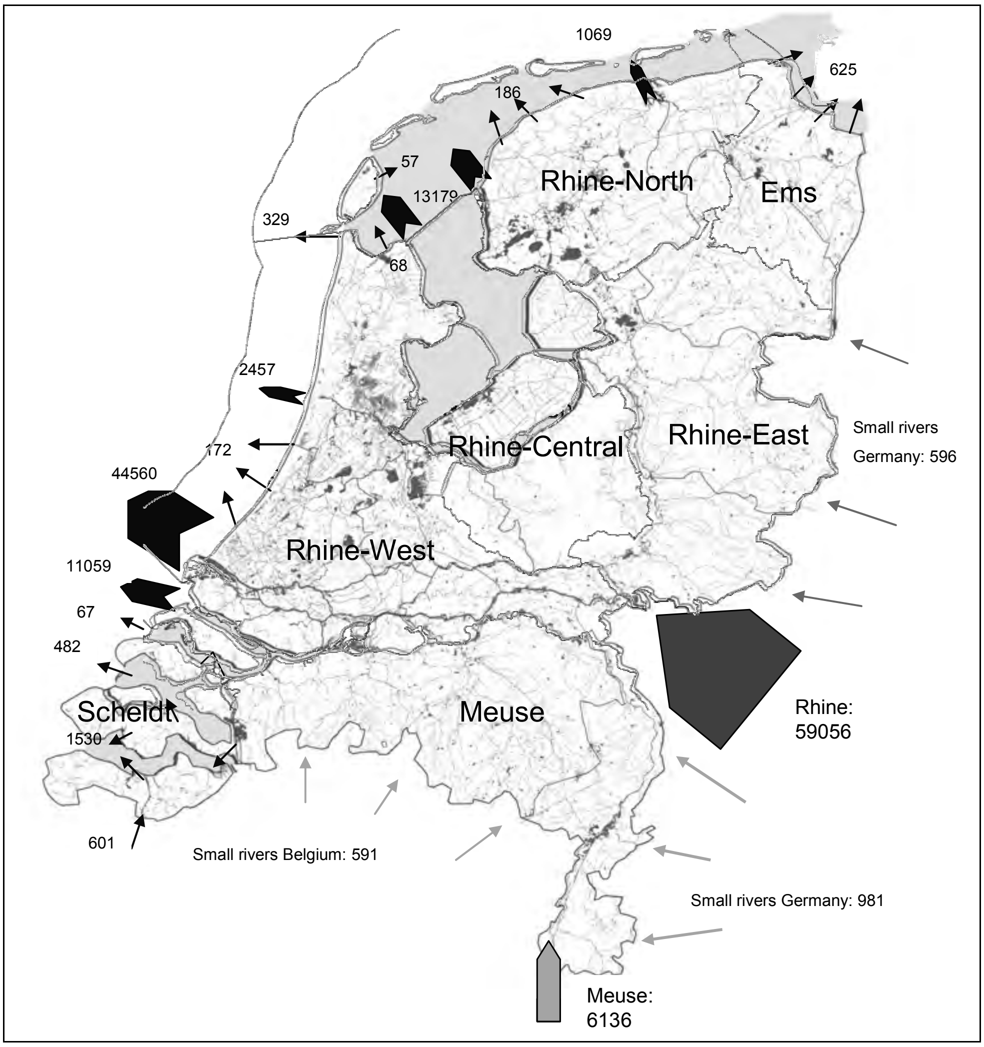


Table 4.4 Total outflow to sea, 2009

(Sub-)River Basin	Total	Winter	Summer
	million m³		
Rhine	62 077	34 971	27 105
of which			
Rhine-North	1 255	906	349
Rhine-Central	13 179	8 834	4 345
Rhine-West	47 643	25 231	22 412
Ems	625	516	111
Meuse	11 351	7 146	4 205
Scheldt	1 787	897	890
Total Outflow	**75 842**	**43 530**	**32 311**

Figure 4.10 shows a map of the Netherlands with a synthesis of actual inflow and outflow to and from the Netherlands territory.

Figure 4.10 Actual external inflow of surface water and outflow to sea, 2009



4.5 Regionalized inflows and outflows of surface water

4.5.1 Introduction

Paragraph 4.3 and 4.4 already described activities to determine the inflow from neighbouring countries and outflow to the sea. Data collection on the level of individual gauging stations here makes it possible to distinguish between (sub-)river basins. However, as part of the compilation of regional data on inflow and outflow, the domestic transfers of surface water between at least the 4 River Basins but favourably also between the 7 sub-River Basins must be determined. Data of so-called intermediate gauging stations, that consider as much as possible the relevant flows, must be collected.

Because of the rather complex hydrological situation, an exhaustive analysis of the transfers of surface water between the 7 sub-River Basins cannot be established within the scope and timing of this project. Among the 4 sub-River Basins of the river Rhine, numerous transfers are observed, either ones that take place via pumping stations, canals, drains etc. Therefore it is decided to determine just the transfer of surface water between the 4 main River Basins.

The transfer of surface water among the four main River Basins in fact only includes the distribution of water in the Rhine-Meuse-Scheldt delta area:

- The mixture and exchange of river flows of river Rhine and Meuse, in the south western delta;
- The transfer of fresh surface water from the Meuse area to the Scheldt Area, via the Volkerak sluices and the drain sluices near Bath.

See paragraph 4.4.3 for a description of the functioning of the Haringvliet sluices as the main water work in the area.

4.5.2 Method and results

For the situations with transfers the following action is formulated:

Collection is required of all available flow data on surface water (m^3/sec, m^3/day) measured at gauging stations situated at or near rivers, canals, dams or pumping stations, that transfer water from one River Basin to another. This requires a short inventory among the responsible water authorities. Data is obtained for the period 1-1-2009 to 31-12-2009.

By combining the daily average flow rates of several stations, the main flows of water between the River Basins could be constructed. Figure 4.11 visualizes the monthly transfers between the river basins Rhine and Meuse and between Meuse and Scheldt. The net yearly and seasonal flows are given in table 4.5.

Figure 4.11 Monthly regional flows of fresh surface water, per RBD, 2009

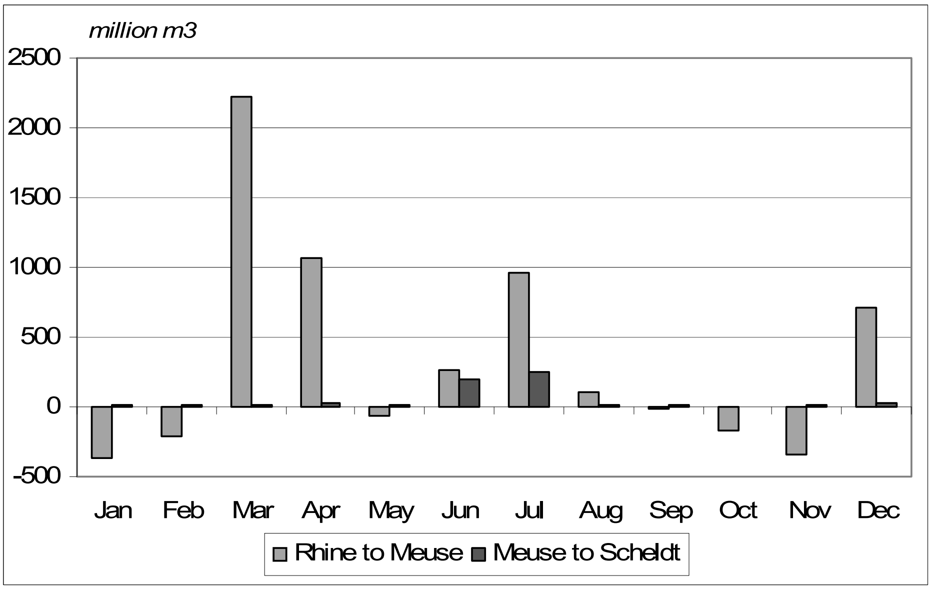


Table 4.5 Regional in- and outflow of fresh surface water, 2009

	Regional Inflow		
	Total	Summer	Winter
	million m³		
From Rhine to Meuse	4 167	2 318	1 848
From Meuse to Scheldt	597	521	76

Figure 4.11 shows that the transfers between Rhine and Meuse differ from month to month. In some months, when the Haringvliet sluices are mainly closed, water is diverted from Meuse to Rhine (the negative values). In months with high river flows, the Haringvliet sluices are opened, allowing more water to flow from Rhine to Meuse. The yearly result is a net flow from Rhine to Meuse (see table 4.5).

In the summer, more water is diverted from the Meuse region to the Scheldt region in order to combat the salt intrusion into the fresh water system of the Scheldt region.

4.6 Flows of groundwater to and from the Dutch territory

The groundwater stock in the Dutch underground, next to other flows, is also partly influenced by groundwater flows that run in underground layers / aquifers. There exists exchange of groundwater with neighboring countries Belgium and Germany. As the Netherlands is situated downstream in all three relevant River Basins, external inflow of groundwater from these countries is expected to exceed the outflow of groundwater to these countries. As a result of altitude and pressure, differences occur in the groundwater flows. To quantify the resulting flows isn't an easy task after all. For quantification of the cross-border groundwater flows, either net or gross, no clear data in the existing literature or either databases was found.

Currently no sufficient sources exist for compilation of external inflow of groundwater for the country as a whole. For one province (Noord-Brabant) an attempt was made resulting in a rough estimate for the (net) inflow of groundwater of 0.1 billion m^3 for 2007 while the stock was estimated at around 500 billion m^3 (Telos, 2010), supposing only a tiny amount of the stock. Uncertainties surrounding existing data on groundwater flows, cross-border or else, in any case are high.

In the project it was foreseen to collect data or figures that are used by groundwater modelers. Within the scope of the project we were not able to obtain such data with reliable quality. We discovered that modelers particularly neglect this flow in their quantification efforts or at least were hardly able to make reliable estimates. We aim to stay in touch and intensify the connection with hydrologists and water modelers in future and see whether it will be possible to come up with reliable estimates.

Quantification of the domestic flows between national sub-River Basins could not be achieved due to lacking data.

5. Estimation of three major items in the ES-JQ

Three major items in the Eurostat joint questionnaire (ES-JQ, questionnaire table 1), will be estimated based on the four main items of the water balance, as presented in chapter 4. Below follows a short description of the calculation methods applied. The resulting figures are incorporated in the water balance tables as presented in chapter 7.

5.1 Estimation of 'Internal flow'

The internal flow represents the total volume of river runoff and groundwater generated, in natural conditions, exclusively by precipitation into a territory. To be more precise, the internal flow is equal to the amount from precipitation less actual evapotranspiration and can either be calculated or measured. If the river runoff and groundwater generation are measured separately, transfers between surface and groundwater have to be netted out to avoid double counting in the calculation[8].

This internal flow, is water 'generated inland' that makes it different from the so-called 'Actual external inflow' because that represent the total volume of actual flow of rivers and groundwater, coming from neighbouring territories. Source: Eurostat – OECD Joint Questionnaire, definitions (Eurostat, 2010).

In this project the figure of 'Internal Flow', will be calculated as the volume of water (nationally) that stem from precipitation, less the actual evapotranspiration (see paragraph 4.1 and 4.2).

5.2 Estimate 'Recharge into aquifer'

The 'Recharge into aquifer' represents the total volume of water added from 'outside' to the zone of saturation of an aquifer within the soil. This volume neglects the amount charged artificially or 'injected' into aquifers. This is because the latter is considered already in the category of 'Water abstractions from groundwater resources' from which these volumes are originally withdrawn[9]. Source (Eurostat – OECD Joint Questionnaire). This can be the case for using the subsoil for heat and cold storage purposes.

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[8] The United Nations Statistics Division (UNSD) & United Nations Environment Programme (UNEP) in their questionnaires on environmental statistics call this 'Total volume of river run-off and groundwater generated over the period of a year, in natural conditions, exclusively by precipitation into a territory. The internal flow is equal to precipitation less actual evapotranspiration and can be calculated or measured. If the river run-off and groundwater generation are measured separately, transfers between surface and groundwater should be netted out to avoid double counting'.

[9] Water abstractions from groundwater resources, is defined as: the difference between the total amount of water withdrawn from aquifers and the total amount recharged artificially or injected into aquifers.

The maximum value of the recharge is represented by the sum of a. Internal flow plus b. actual external inflow, together the ‘Total fresh water resources’, less the total actual outflow. The water that remains is available for recharge of the saturated zone of the aquifer or for additions to stocks of surface water and/or soil water. Thus the sum of the changes of the three stocks mentioned, should match the ‘for recharge available water’.

As in some (eastern part, higher grounds) parts of the country, groundwater tables are monitored in detail via an extensive network of groundwater stations, the change of groundwater (‘recharge’) for a specified reporting period (year, season or else) can be estimated for each aquifer as a weighted mean of the differences in groundwater table.

5.3 Estimate ‘groundwater available for annual abstraction’

The ‘groundwater available for annual abstraction’ is represented by the ‘recharge of the aquifer’, as calculated above, less the long term annual average rate of flow required to achieve ecological quality objectives for associated surface water. It takes account of the ecological restrictions imposed to groundwater exploitability, nevertheless other restrictions based on economic and technical criteria could also be taken into account in terms of accessibility, productivity and maximum production cost deemed acceptable by developers. The theoretical maximum of ‘groundwater available’ is the ‘recharge of the aquifer’ as calculated in the previous sections.

Another reason the mentioned ‘theoretical maximum of groundwater available’ isn’t achieved is that in a particular year there will be additions to stocks of surface water and/or soil water or the other way around.

6. Quantification of some remaining balance items

In this section a few so-called balance items not covered yet will be dealt with, namely a. The import and export of water; b. Existing data on water abstraction and c. The Production and discharge of waste water and reuse of water.

6.1 Compilation of import and export of water directly or captured in products that passes the national borders

In this paragraph the import of water either as product for sale by water companies, bottled, or as water contained by a wide range of products imported and exported as part of the fresh weight, will be discussed.

Im- and export of drinking (Tap water) and 'other water'

With regard to import from water supply companies abroad and export by Dutch water supply companies of water as a product as such, several figures can be compiled. For drinking water the import is 9.24 million m^3 in 2009 (VEWIN, 2010a). For the category of 'other water', possibly semi-processed water, no import was identified, presumably because it didn't exist. Also import of raw water and semi-processed water hasn't been observed.

For drinking water the export in 2009 was 3.44 million m^3 (VEWIN, 2010a). For the category of 'other water'[10], like semi-processed water (by the water companies), no export has been observed (2007).

With regard to the allocation of im- and exports of water to (sub-)River Basins, no sufficient information could be collected, even not by the Association of Dutch Water Companies, VEWIN (Geudens, 2011), on the locations and thus (sub-) River Basins where import and/or export of tap water occurs.

Im- and export of cross-border abstracted groundwater and surface water

Given the permit systems that regulates the abstraction of ground water and surface water, it is not likely that companies situated at the Dutch side of the borderland, abstract water from the foreign side and vice versa. VEWIN (the Association of Dutch Water Companies) also couldn't confirm any cross-border abstraction took place in 2009. Import and export of ground- and surface water via cross-border abstractions therefore is assumed to be zero. Although abstractions do influence

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[10] 'Other water' is water of different, superior or inferior quality compared to tap water. One can think of unfiltered and filtered water, or distilled and demineralised water. This water is produced by water companies or other industries and delivered to other companies, particularly in the chemical industry. This category of 'other water' on average compares to 6–7% of the total use of tap water (VEWIN, 2010b). The delivery of 'other water' by the water companies is excluded from 'tap water'.

these flows in an indirect manner, we assume no substantial import or export via abstractions itself in the borderland.

Water contained by im- and export products

In Economy wide Material flow accounting (EW-MFA), so called 'bulk water' is not taken into account[11]. For the product categories distinguished within EW-MFA, actually total (fresh) weight is considered (Delahaye, 2008). Dry weight is not considered separately. Elsewhere, in other studies, one tried to estimate the dry content (percentages) and resulting dry weight (REF). With a combination of both, total weight and dry weight, water content can be derived relatively easily. This can be done for both extractions of (fresh) materials and products from inland, and for import and export flows. With these sources figures for water import and water export within products can get generated.

Information on import and export of bottled water is available from the International Trade Statistics (CBS Statline, 2011). Also the import and export of products that contain little to large amount of water can be found from the trade statistics. We have calculated the water that is contained by all kinds of products being imported and exported in taking a share of water from the total fresh weight.

In the Netherlands in 2009 total fresh weight of imported products added up to 301 million ton (and thus m^3), while total weight of exported products added up to 206 million ton (m^3). This total has detailed break down to products following international trade statistics. The result is a detailed vector with products or product groups for both import and export.

The moisture content of the aforementioned products in principle varies from 0 to 100 percent; many products contain close to zero percent. Next to bottled water and beverage, particularly products from agriculture, from the food & beverages manufacturing, in waste and manure processing, forestry, wood industry and chemicals & pharmaceuticals do contain water. Although the exact moisture content of all of these products is not known, products can be grouped according moisture content resulting in a vector with moisture content. Both vectors, of total product weight and of moisture content, combined give a vector result with moisture contained by products, grouped by product category. The three vectors for both import and export can also be totalled resulting in total weight of water contained by products either being imported or exported. The result is an estimated 45 million m^3 imported water and 30 million m^3 of exported water contained by products.

6.2 Existing data on water abstraction

6.2.1 Introduction

In 2009 and 2010 a pilot study has been done for and granted by Eurostat, by which the national figures on abstraction of surface water and groundwater (next to tap

[11] Bulk water is water not considered an embedded component in materials.

water use) are broken down to one of the seven (sub-)River basins. Detailed figures on abstractions now are available for 2003 (2001) onwards till 2008. The methodology applied for the several breakdowns has been described in the Pilot study for Eurostat (Baas and Graveland, 2011), while parts of the compiling process of the water accounts is described in the report Dutch water flow accounts (Graveland, 2006).

The data on water abstraction till 2009 can partly be found in StatLine (http://statline.cbs.nl/), the electronic database of Statistics Netherlands. These data are regionalized among the seven (sub-)River Basins according to the methods described in Baas and Graveland 2011. The compilation of the different abstractions is briefly described here.

6.2.2 Abstraction by agriculture

National data on water abstraction in the Agricultural Sector are calculated each year by the Agricultural Economic Research Institute, LEI. LEI makes use of the Farm Accountancy Data Network (FADN) being a limited sample of the farms that are included in the so-called Farm Structure Survey (FSS). In last years' pilot study for Eurostat (Baas and Graveland, 2011) we have particularly asked LEI to distribute their (annually) existing national data to Sub River Basin Level. The national abstraction (next to other) data is requested by Statistics Netherlands from LEI at an annual basis, also making use of their FADN data. For the regionalisation procedure, the farms in the sample and their reported water abstraction figures were allocated to the different River Basins. Available sample figures are weighted and raised to totals per River Basin by making use of the so-called 'Statistical matching methodology' (Veen, van der, et al., 2010). Distinction is made between a number of sub sectors within agriculture as well as between abstraction from surface water or groundwater, next to use of tap water, the purpose of the use / abstraction (irrigation or drinking).

6.2.3 Abstraction by industries

For the main (abstraction) sectors within the manufacturing industry, data on water abstraction (and tap water use) are derived from the Annual Environment Reports (AER) and raised to totals per NACE category. Allocation to River Basin of the individual registered companies is done via x-y coordinates of the manufacturing locations. The share of the number of employees of the individually registered AER companies in the number of employees per River Basin per NACE category are used as a key to raise / extrapolate the abstraction data that were distributed to the River Basins. Sectors of the manufacturing industry not covered by the AER national totals for water abstraction and use of tap water are currently estimated based upon extrapolations of historical data. These data too were distributed to the River Basins along the number of employees per River Basin per NACE category (Baas and Graveland, 2011).

6.2.4 Abstraction by Public Water Supply companies

Data on water abstraction by PWS companies is available from the Association of Dutch Water Companies (VEWIN) at national level as well as for the water supply areas of these companies. For the breakdown to River Basins, data available for each individual abstraction location of the PWS companies is used. GIS-coordinates of the geographical locations and spatial allocation to the River Basins were used to sum the quantities for each (sub-) River Basin, for both ground and surface water. The GIS action was carried out by the Association of Dutch Water Companies (VEWIN) for a single year (2008). For the 2009 River basin breakdown of abstractions by the PWS companies, the available data were obtained from the individual PWS companies that cover the abstractions they've done in order to supply their customers with (tap) water in their respective water supply areas. In order to derive the abstraction data at the River Basins level, the 2008 abstraction distribution to the River Basin distribution was used.

6.2.5 Results

The results of the three categories described will be included in the quantifications of the overall water balance. Table 6.1 and 6.2 give the results for abstraction of groundwater and fresh surface water respectively, divided by (sub-)River Basin.

Table 6.1 Abstraction of groundwater per sector and RBD, 2009

(sub-) River Basin	Total	Agriculture	Industry; power plants	PWS companies
	million m^3			
Rhine	611	34	123	454
of which				
Rhine-North	73	4	9	60
Rhine Central	121	9	18	94
Rhine-East	189	19	36	133
Rhine-West	228	1	59	168
Ems	42	1	4	37
Meuse	334	39	53	242
Scheldt	24	1	4	19
Total	**1 011**	**74**	185	752

Table 6.2 Abstraction of fresh surface water, per sector and RBD, 2009

(sub-) River Basin	Freshwater	abstracted by			Marine Water
	Total	Agriculture	Industry; power plants	PWS companies	
	million m³				
Rhine	6 252	14	5 963	274	*1 117*
of which					
Rhine-North	489	3	485	-	-
Rhine Central	100	2	99	-	-
Rhine-East	277	2	276	-	-
Rhine-West	5 385	8	5 103	274	*1 117*
Ems	49	1	41	7	*1 772*
Meuse	3 901	4	3 695	202	
Scheldt	453	0	452	-	*767*
Total freshwater	**10 654**	**19**	**10 152**	**483**	

For information, in table 6.2 also the abstracted amounts of seawater are given. These amounts reflect intake of marine cooling water by electricity power plants and some industries situated at the seashore. These data are thus not included in the freshwater balance.

6.3 Production and discharge of wastewater, cooling water and reuse of water

6.3.1 Introduction and data sources

Households and companies produce significant amounts of waste water. In the Netherlands, 99% of the collected waste water is discharged via sewer systems to the Urban Waste Water Treatment Plants (UWWTPs) (Rioned, 2010). Data on the volumes of effluents, discharged per (sub-)River basin is readily available from the standard yearly survey among all UWWTPs in the Netherlands (CBS Statline, 2012).

Also, significant amounts of water from precipitation enter the sewer system. The main part of this precipitated water ends up in the UWWTP's. But in case of combined sewer systems, during extreme weather conditions with large amounts precipitated, a part of the mix of waste water and rainwater is discharged to surface water via 'emergency' sewer outlets, the combined sewer overflows called storm water overflows. In case of separated sewer systems, the run-off rainwater is collected separately and discharged to surface water via separate rainwater sewers. In the project estimation is made of the volumes discharged from the sewer outlets, based upon information from Rioned as well as on the PRTR linked model on sewer emissions and discharged volumes.

In addition, big manufacturers and electricity power plants, discharge large amounts of process waste water and/or cooling water directly to surface water. Data on all significant direct discharges from industries is available at the individual company level, via the Annual Environmental Reports, AERs (including e-PRTR reports)[12]. From the PRTR database, a data file containing the geographical location of the individual discharge points in the receiving waters has been made available to Statistics Netherlands. This facilitates aggregation of the discharge data to sub-river basin. Resulting data on discharged amounts per sub river basin will be incorporated in the water balance.

6.3.2 Methods and results

For UWWTP's individual data on the effluents is known including the (sub-)River Basin in which the receiving water is lying and the type of water. In 2009, total effluents of UWWTPs amounted up to 1,818 million m^3 (Statline, 2011) of which 141 million m^3 is discharged into marine waters.

The total volume of water that is discharged via combined sewer overflows (CSO's) and separate rainwater sewers, is estimated on basis of the following underlying data:

1. Total influent volume of all UWWTP's (CBS Statline, 2012) for 2009, this volumes is 1,818 million m^3.
2. The breakdown of the shares of waste water connected to the main types of sewer systems (source: Rioned, 2009), namely:
    a. Combined sewer systems 4%
    b. Improved combined sewer systems: 59%
    c. Separated sewer systems: 22%
    d. Improved separated sewer systems: 9%
    e. Other sewer systems / private treatment: 6%
3. Per type of sewer system: the division of total waste water and incoming rainwater over a. influent UWWTP, b. combined sewer overflows and c. separate rainwater sewers. This information is taken from the so-called EMOS model (that is used in the Dutch Emission Inventory database)[13].

By combining this data, the share of the collected volumes of wastewater and run-off rainwater to sewer outlets is estimated, resulting in a total volume of 441 million m^3 for the whole year. From this volume, 389 million m^3 is discharged by the separated rainwater sewers and 52 million m^3 is discharged by the combined sewer overflows. Since the basic data to calculate the sewer outlets is not available at the level of River Basins, the total volume is distributed over the (sub-) River Basins in proportion to the total influent volumes per (sub-) River Basin (Source: CBS Statline, 2012).

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[12] PRTR: Pollutant Release and Transfer Register.

[13] EMOS (EmissieMOdel voor Systeemkeuze), is calculation model that assesses the influence of specifications of the UWWTP system, see STOWA (2009).

Table 6.3 shows the data on effluent discharges of UWWTP's as well as sewer outlets to either fresh surface water or seawater, with a breakdown into (sub-)River Basin.

Table 6.3 Discharge of UWWTP's and sewer outlets, per RB and by destination, 2009

(sub-)River basin	Total discharge UWWTP's	of which		Sewer outlets 1) to freshwater
		To freshwater	To sea	
	million m³			
Rhine	1 240	1 151	90	301
of which:				
Rhine-North	97	94	3	23
Rhine-Central	113	113	-	27
Rhine-East	246	246	-	60
Rhine-West	785	698	87	190
Ems	74	74	-	18
Meuse	414	414	-	100
Scheldt	90	39	51	22
Total	**1 818**	**1 677**	**141**	**441**

Source: Statistics Netherlands, this study.

1) Combined Sewer Overflows and Rainwater Sewers.

For industrial discharges and cooling water discharges, the available data do not facilitate a seasonal breakdown of the discharged volumes. Within certain industry branches the volumes of wastewater discharged strongly depends on the time of the year, for example the discharge of sugar-beet processing factories. But the majority of the industries and power plants produce continuously throughout the year. For this study it is assumed that the industrial discharge of waste water is equally divided over the winter and summer season.

In table 6.4 the results on direct industrial wastewater discharges and cooling water are listed, with a breakdown into (sub-)River Basin. Also the source and destination of the discharges is given. The discharges of freshwater into fresh surface water are the most common. Some industries situated at coastal waters discharge 'fresh' water into seawater, which in fact contributes to the actual outflow from the territory. This will be specified in the balance tables. In order to complete the picture of discharges also the discharges of seawater into seawater are listed. These amounts reflect cooling water discharges by electricity power plants situated at the seashore and will not be taken into account in the freshwater balance.

Table 6.4 Direct discharges of wastewater and cooling water, 2009

(sub-)River basin	Total discharge freshwater	by source and destination		salt to sea
		fresh to fresh	fresh to sea	
	*million m^3^*			
Rhine	5 488	5 464	25	*1 169*
of which:				
Rhine-North	11	11	-	*27*
Rhine-Central	470	470	-	-
Rhine-East	195	195	-	-
Rhine-West	4 813	4 789	25	*1 142*
Ems	16	15	1	*1 764*
Meuse	3 428	3 428	-	-
Scheldt	462	454	8	*442*
Total	**9 394**	**9 360**	**34**	

Source: Annual Environmental Reports (2009).

Reuse of water

According to the definition of the Joint Questionnaire (Eurostat, 2010) 'reused water' is 'water that has undergone wastewater treatment and is delivered to a user as reclaimed wastewater. This means the direct supply of treated effluent to the user. Excluded is waste water discharged into a watercourse and used again downstream. Recycling within industrial sites is also excluded'. In the Netherlands, reuse of water is not a common process because in general water availability over the whole territory is not a problem. Although, recycling of water within industrial sites, often including treatment is frequently applied. It only will affect the water balance indirectly. Nevertheless, some cases of 'reuse of water' are known. For example, two UWWTPs deliver effluent water to water companies for preparation of 'other water' used in industry, which has different quality than the standard specifications of tap water. Given the relatively limited volumes involved, quantification of this item is not given priority in the project.

7. Synthesis: national and regional water balances for 2009

In paragraph 4.1 to 4.5 main items of the water balance which determine 'internal flow' and 'external inflow' and explain the different flows of fresh surface water are addressed and calculated. By use of the forthcoming data per river basin and per winter/summer season, a water balance in accordance with Table 1 of the OECD/Eurostat Joint Questionnaire on Inland Waters can be compiled[14]. Table 7.1 provides this national balance for 2009 in terms of annual totals as well as for the summer and winter season separately. The balance in table 7.1 includes the four main flows (precipitation, evapotranspiration, actual inflow and actual outflow). Moreover table 7.1 presents calculated values for several other parameters, namely:

a) The 'Internal flow', defined as the total volume of river runoff and groundwater generated, in natural conditions, exclusively by precipitation into a territory. The internal flow is equal to precipitation less actual evapotranspiration (see paragraph 5.1)

b) The total freshwater resources. According to the definition of the Joint Questionnaire Inland Waters, this is calculated as the Internal flow plus the Actual external inflow into the territory.

c) The recharge into the aquifer (see paragraph 5.2), calculated as the total freshwater resources minus the actual outflow to sea.

d) The groundwater available for annual abstraction (see paragraph 5.3). Here the theoretical maximum is given, which is the total recharge (item c)).

In addition to the main items of the water balance, table 7.1 provides additional information on total abstractions and discharges as well as imports and exports of tap water and water contained in products as calculated in chapter 6. The purpose of presenting these items is to facilitate comparison with the main items of the water balance as to indicate the relative importance of abstractions, discharges and imports and exports.

Table 7.1 shows that in the summer season the actual evapotranspiration exceeds the precipitation with as a result a negative value for internal flow. This is caused by i) excess evaporation from large surface waters, like the Lake IJsselmeer and ii) uptake and transpiration of soil water by vegetation. A negative value for internal flow means thus that either the existing stocks of surface and ground water at the territory are being used or the stocks will have to be maintained or replenished by external inflow.

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[14] Table 1 of the Joint Questionnaire captures the items: 1 .Precipitation, 2. Actual evapotranspiration, 3. Internal Flow, 4. Actual external inflow and 5. Total actual outflow (to the sea or to neighbouring territories. Furthermore it enables calculation of fresh water resources, recharge into Aquifer and groundwater available for annual abstraction.

During the winter season, the internal flow is positive due to higher precipitation volumes and a low level of evapotranspiration. This allows for replenishing of stocks.

Table 7.1 Water balance for the Netherlands, 2009

	Year	Summer	Winter
	million m³		
1. Precipitation	28 294	12 193	16 101
2. Actual evapotranspiration	17 022	14 240	2 782
3. Internal Flow = 1 - 2	**11 273**	**-2 047**	**13 319**
4. Actual external inflow from foreign territory	67 962	31 231	36 731
5. Total actual outflow to sea	75 839	32 311	43 530
6. Total freshwater resources = 3 + 4	**79 235**	**29 184**	**50 050**
7. Recharge into the Aquifer = 6 - 5	3 396	-3 127	6 521
8. Groundwater available for annual abstraction = 7 (max)	3 396		
Abstraction of ground water	1 011		
Abstraction of fresh surface water	10 654		
Discharges to fresh water	11 478		
Discharges to sea	175		
Balance abstraction - discharges	13		
Imports of tapwater and water in product	54		
Exports of tapwater and water in products	33		

The outcomes of this balance perfectly illustrate the need to compile not only annual data but at least data per season. Annual totals do not explicitly show the precipitation deficit in the summer months and the resulting negative internal flow. Of course, monthly data are even more accurate for identifying water stress situations, but within the scope of the project it was not possible to have monthly data on evapotranspiration.

For the country as a whole it can be concluded that in 2009 the annual ground water abstraction is approximately one third of the maximum recharge. This means that in 2009 the use of ground water resources was not higher than the maximum replenishment.

Furthermore it can be concluded that total abstractions are somewhat higher then total discharges which is according to expectations. A portion of the abstracted water is consumed or used, for instance in products.

Table 7.2 provides a comparison of the data resulting from this study with data compiled two years ago for the (Eurostat/OECD, 2010) Joint Questionnaire on inland waters.

Table 7.2 Comparison of results from newly developed method with former methods

	This study	Reported in JQ 2010
	million m³	
1. Precipitation	28 294	27 568
2. Actual evapotranspiration	17 022	23 270
3. Internal Flow = 1 - 2	**11 273**	**4 293**
4. Actual external inflow from foreign territory	67 962	65 192
5. Total actual outflow to sea	75 839	75 839
6. Total freshwater resources = 3 + 4	**79 235**	**69 485**
7. Recharge into the Aquifer = 6 - 5	3 396	not reported
8. Groundwater available for annual abstraction = 7 (max)	3 396	not reported

The main differences as is the higher precipitation, lower evapotranspiration and higher external inflow, stem mainly from:

1. The total precipitation is calculated more accurately by making use of radar images calibrated by data of numerous precipitation gauging stations. In the old method for the whole country the average precipitation was used, as published by the KNMI (Royal Dutch Meteorological Institute).
2. In this study a reliable estimate is made of the **actual** evapotranspiration, while in the previous data compilations, data on the 'reference crop evapotranspiration' (source: KNMI) were used. The latter value was significantly higher, because the reference crop evapotranspiration is a maximum value for evapotranspiration under circumstances for which the available water does not hamper the evaporation. It more or less reflected the **potential** evapotranspiration.
3. For actual external inflow, the quantification of the small contributing rivers is more accurate, with the result a higher value for the actual external inflow for the country as a whole.

Tables 7.3 to 7.6 provide the water balance data for the four River Basins. The gross exchange of surface water between the national River Basins is included in these tables.

Table 7.3 Water balance for the Rhine river Basin, 2009

	Year	Summer	Winter
	million m³		
1. Precipitation	19 646	8 661	10 984
2. Actual evapotranspiration	12 124	10 094	2 031
3. Internal Flow = 1 - 2	**7 521**	**-1 432**	**8 953**
4. Total actual external inflow	60 814	28 652	32 161
4.1 from foreign territory	59 652	28 569	31 083
4.2 from other national river basin (gross)	1 161	83	1 078
5. Total actual outflow	67 405	29 507	37 897
5.1 to foreign territory	62 077	27 105	34 971
5.2 to other national river basin (gross)	5 328	2 402	2 926
6. Total freshwater resources = 3 + 4	**68 335**	**27 220**	**41 115**
7. Recharge into the Aquifer = 6 - 5	930	-2 286	3 217
8. Groundwater available for annual abstraction = 7 (max)	930		
Abstraction of ground water	611		
Abstraction of fresh surface water	6 252		
Discharges to fresh water	6 915		
Discharges to sea	114		
Balance abstraction - discharges	- 166		

Table 7.4 Water balance for the Ems River Basin, 2009

	Year	Summer	Winter
	million m³		
1. Precipitation	1 711	861	850
2. Actual evapotranspiration	997	873	124
3. Internal Flow = 1 - 2	**714**	**- 13**	**726**
4. Total actual external inflow	0	0	0
4.1 from foreign territory	0	0	0
4.2 from other national river basin (gross)	0	0	0
5. Total actual outflow	625	111	516
5.1 to foreign territory	625	111	516
5.2 to other national river basin (gross)	0	0	0
6. Total freshwater resources = 3 + 4	**714**	**- 13**	**726**
7. Recharge into the Aquifer = 6 - 5	89	- 124	211
8. Groundwater available for annual abstraction = 7 (max)	89		
Abstraction of ground water	42		
Abstraction of fresh surface water	49		
Discharges to fresh water	106		
Discharges to sea	1		
Balance abstraction - discharges	- 16		

Table 7.5 Water balance for the Meuse river basin, 2009

	Year	Summer	Winter
	million m^3		
1. Precipitation	5 370	2 070	3 300
2. Actual evapotranspiration	3 057	2 550	507
3. Internal Flow = 1 - 2	**2 314**	**- 480**	**2 793**
4. Total actual external inflow	13 037	4 843	8 194
4.1 from foreign territory	7 709	2 441	5 268
4.2 from other national river basin (gross)	5 328	2 402	2 926
5. Total actual outflow	13 109	4 809	8 300
5.1 to foreign territory	11 351	4 205	7 146
5.2 to other national river basin (gross)	1 758	604	1 154
6. Total freshwater resources = 3 + 4	**15 351**	**4 363**	**10 988**
7. Recharge into the Aquifer = 6 - 5	2 241	- 446	2 688
8. Groundwater available for annual abstraction = 7 (max)	2 241		
Abstraction of ground water	334		
Abstraction of fresh surface water	3 901		
Discharges to fresh water	3 942		
Discharges to sea	0		
Balance abstraction - discharges	293		

Table 7.6 Water balance for the Scheldt river basin, 2009

	Year	Summer	Winter
	million m^3		
1. Precipitation	1 568	601	967
2. Actual evapotranspiration	844	723	120
3. Internal Flow = 1 - 2	**724**	**- 122**	**846**
4. Total actual external inflow	1 198	742	456
4.1 from foreign territory	601	221	380
4.2 from other national river basin (gross)	597	521	76
5. Total actual outflow	1 787	890	897
5.1 to foreign territory	1 787	890	897
5.2 to other national river basin (gross)	0	0	0
6. Total freshwater resources = 3 + 4	**1 922**	**620**	**1 302**
7. Recharge into the Aquifer = 6 - 5	135	- 270	405
8. Groundwater available for annual abstraction = 7 (max)	135		
Abstraction of ground water	24		
Abstraction of fresh surface water	453		
Discharges to fresh water	515		
Discharges to sea	60		
Balance abstraction - discharges	- 98		

From the tables 7.3 to 7.6 a few conclusions can be drawn:

- In the summer half year, the precipitation deficit varies between the regions: In the Ems regions the deficit is just small (1%), while in the Meuse region the deficit is almost 19%.
- There is a remarkable difference between the data of the two largest river basins. In the Rhine river basin the calculated remaining quantity for annual

recharge of aquifers that is generated ‘internally’ is limited: 0.9 billion m^3 compared to an annual Internal Flow of 7.5 billion m^3. In the Meuse river basin the annual recharge is 2.2 billion m^3 compared to an annual internal flow of 2.3 billion m^3. As the recharge into the aquifer is calculated as the total freshwater resources minus the actual outflow, the reason for the difference is the height of the actual outflow. Actual outflow is relatively large in the Rhine River basin, which means that a larger share of the total freshwater resources is evacuated via outflow of surface water, leaving less water for replenishment of ground water resources.

- Within the Scheldt region (table 7.6), the internal flow, thus at the territory plays an important role in the water balance during the summer season, it shows that precipitation in that period isn’t sufficient to keep fresh water stocks intact. Water managers in such cases will act via operation of sluices and drains in a way that water is transported from the Meuse River basin to the Scheldt River basin and stocks can be replenished still.

- In the Netherlands and even more so in the Western part, in water management ‘polders’ play a major role. In principal these low lying polders are marked or surrounded by long polder dike or dikes. The water system in these polders is managed by the Water boards. These polders in summer time principally rely on the available water (internal flow) generated within the polder via precipitation. However once evapotranspiration exceeds the water collected from precipitation, there will be a deficit once it isn’t replenished from either available stock of for example groundwater and soil water or via external inflow. All four river basins though show such shortage for the whole summer period. For shorter periods the deficit may even be more severe. Replenishment from external inflowing sources is not always preferred due to lacking quality, cannot be organised or else.

- During the final stage of this project, we received information on the situation with respect to abstraction of fresh surface water by industries in the Scheldt River Basin. It became clear that a portion of the water is initially abstracted in the Meuse River basin and transported by pipelines to collection basins in the Scheldt River basin. This could amount up to 45 million m^3 per year (Mecksenaar et al, 2012). In future data compilation of water abstraction per River Basin, this transport will have to be taken into account.

- In the Meuse river basin the seasonal differences in actual external inflow are larger then in the Rhine river basin. This can partly be explained by the fact that the Meuse river is more rain-fed, while the river Rhine also depends on melting snow and glaciers in the Alps, processes that results in a more continuous water flow, even during summer and autumn.

8. Compilation of stocks of fresh water resources

Besides a description of the flows, the respective stocks of water are relevant as part of the fresh water balance. For this purpose the boundaries of the relevant area need to be defined. In this balance approach, all domestic fresh water resources are included, while including water at the Frisian Islands (Islands of the Wadden Sea).

Excluded from the balance sheet are the salty waters, like the Wadden Sea, the Scheldt delta waters, Grevelingen Lake and the North Sea.

The original aim was to estimate stocks for both the beginning and the end of the year. This chapter will show whether this was achieved or not. In the paragraphs below a short overview will be given of the methods applied, choices made and data sources used for the estimation of stocks of respectively groundwater (par. 8.1), soil water (par. 8.2), surface water (par. 8.3), waste water (par. 8.4), assessment of water contained in growing / standing biomass (par. 8.5).

8.1 Groundwater, opening and closing stocks

According to the Joint Questionnaire definition, ‘fresh groundwater’ is ‘water being held in, and can usually be recovered from, or via, an underground formation’. It includes all permanent and temporary deposits of water, both artificially charged and naturally, in the subsoil, of sufficient quality for at least seasonal use. This category includes phreatic water-bearing strata, as well as deep strata under pressure or not, contained in porous or fracture soils. For purposes of the questionnaire, ground water includes springs, both concentrated and diffused, which may be sub aqueous (Eurostat/OECD, 2010). The groundwater is situated in porous layers of underground formations known as aquifers. Depending on the rate of recharge of the aquifer, groundwater can be fossil (or non-renewable) in the sense that water is not replenished by nature within a human life span (SEEAW, 2008).

Here groundwater and soil water are treated separately. The total stock of groundwater consists of the water under the groundwater table, in the water saturated soil zone.

8.1.1 Compilation

For this study not just the assessment of total stock of groundwater either fresh, brackish, or salt is relevant, but particularly the stock of fresh groundwater is considered as the most relevant[15]. Fresh ground water is groundwater with less than

[15] The threshold between fresh and brackish groundwater can either be set at <150 mg Cl^-/l or at <300 mg Cl^-/l (personal message Deltares 5-12-2011). In this report we choose to set the threshold of fresh groundwater at < 300 mg Cl^-/l). It is estimated that only 2.5 percent of all water sources on earth is fresh water. This represents an amount of fresh water of approximately 35 million km^3. Approximately 70 of this fresh water is ice and 30 percent

300 milligrams of chloride per litre (< 300 mg Cl^-/l). The existing estimates of the fresh groundwater stock within the country show significant bandwidth, up to a factor 2 due to variation in parameters underlying the calculation. Variation stem from variation in the chosen salinity as the ultimate for classification of 'fresh water', ranging from 150 mg/l Cl^-- till 450 mg/l Cl^-. Other explanation for variation is the uncertainty of the fresh/brackish with salt threshold layer or interface in the subsoil. Moreover, physical boundaries of the relevant soil volume and soil porosity contribute to varying assessments.

The geological history of the Netherlands makes there is a significant difference between generally the Eastern part and Western part of the country. The (North) western part of the country has low lying land mainly around 20 centimetres above surface water levels, with maximum of up to 2 metres above surface water level. As a result, groundwater tables are always relatively close to the surface. This part is dominated by peat and clay soils. This part of the country obviously carries much risk of getting flooded from the seaside due to its altitude.

In contrast, in the (South) Eastern part of the country the land is situated much higher compared to the national altitude standard NAP (Normaal Amsterdam Peil). This higher altitude makes the rivers continue to flow to the Wadden Sea and the North Sea. In these areas the risk of floods comes not from the seaside but from the large rivers that enter the country from the east and south. The land or grounds in (South)Eastern Netherlands often are sandy soils, with orientations of the surface up to several tens of meters above surface water level. As one may well expect, groundwater tables there do exist up to several tens of meters below the surface. As a result the (excess) water in the system in the Eastern part receives less control. The change of the groundwater table across the country from South-East to North-West is shown in the figure in Annex I, which shows the Groundwater table relative to NAP.

The East-West difference also shows why there is more seepage in the east and drainage in the west. West Netherlands also has numerous polders, areas protected from outer water by a dike and with a controlled water level on the inside of the diked area. Any water that enters the polders via precipitation, from seepage or else that is not used or stored has to be pumped out.

Figure 8.1 shows that the management of surface water and related groundwater in North-West is different from and do face much more control compared to the South-East part of the country.

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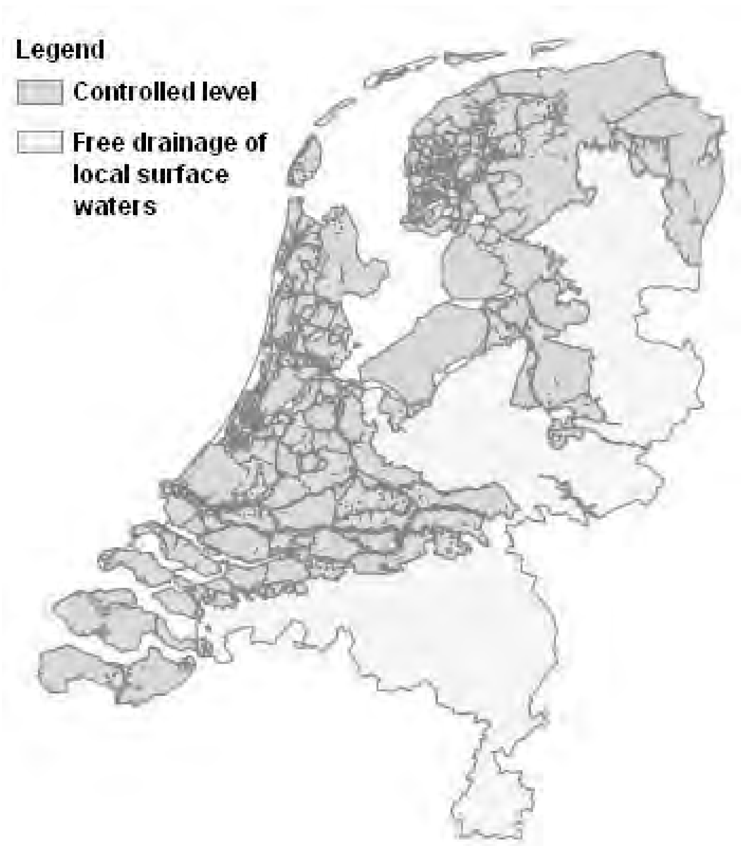
occurs as groundwater and soil moisture. Surface water represents less than 1 percent of the global stock of fresh water. Source: Water for the Recovery of the Climate - A new water paradigm, Kravcik, M. et al Slovakia, 2008.

Figure 8.1 Drainage classification for the Netherlands

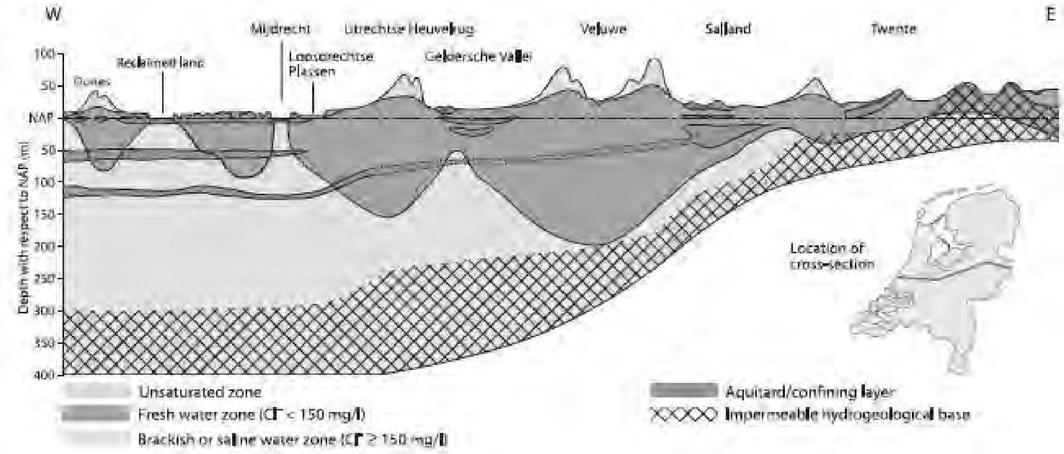


* Controlled level versus free drainage of local surface waters. …
Source: NHI: Delsman and Prinsen (2008).

The different components of the water system with high and low grounds, polders, rivers are all interconnected. There is constant interchange, as can be seen from the water level in rivers or lakes which influences the seepage water and thus influence groundwater flows and stocks. Water may also evaporate from the soil surface, leaving it dry and water from lower layers in the soil can be drawn to the surface or to plant roots by capillary action and enhance evaporation. In short, everything in the water systems is interconnected. Severe water-related interventions has also resulted in continual subsidence of low-lying areas of the Netherlands particularly this is found for the peaty soils, with at the same time a continued rise of the mean sea level.

The assessment of the groundwater stocks at a particular moment do require quantification of the following elements in detail, which is, defining the relevant area, define and calculate the subsoil volume underneath that carry the groundwater. Furthermore, account for the porosity of the subsoil, as well as the groundwater table in order to define topside of the fresh groundwater column and account for the interface between fresh and brackish/salt groundwater in the subsoil in order to define the bottom of the fresh groundwater column. Figure 8.1 show a cross section of Dutch subsoil with the fresh and brackish/salt groundwater interface the top surface and the lower bound being the impermeable layer.

Figure 8.2 Distribution of fresh groundwater stocks in Dutch subsoil *)



Source: KNAW: Geology of the Netherlands. Groundwater in the NL (KNAW), by De Vries. Royal Netherlands Academy of Arts and Sciences (KNAW), 2007: 295–315.

*) Shows Cross section off Dutch subsoil, with schematic the topographic-hydrogeologic East-West section that show the depth of the fresh-brackish water interface (> 150 mg CL-/l). Length of the section is approximately 200 km.

The depth, to which the groundwater will have to be quantified, up to 300 – 400 metres below the surface, should be determined. This depth can be determined by either the maximum depth of the existing groundwater abstraction facilities, presumably with a significant plus, to cover the feature that groundwater flows aren't necessarily horizontal. Groundwater extractions by the water supply companies are to a depth of 250 metres below ground level at the maximum (Geudens, 2011 personal communication). It can, and preferably it is, determined by the permeability of the subsurface that carries the water (includes water in aquifers). As this is a more objective measure and no subject to eventual variation over time. At a certain depth below the surface, permeability of the hydro geological base, the subsoil, becomes close to zero. It becomes hard as rock with hardly to carry any water that may seep down.

For the assessment and calculations of the different freshwater stocks within the country, a systematic framework is set up that structures the compilation procedures and covers the subsequent set of formulas that has been developed. The relevant formulas (and parameterisations) of the fresh water stocks are presented in this chapter. First the model abstraction and parameterisation for calculation of the groundwater stock is given.

Stock of fresh groundwater: 1,115 billion m^3 (maximum volume of total water 1,859 billion m^3)[16]:

[16] This parameter represents solely the fresh water with chloride concentration up to 300 mg Cl^-/l. It thus only covers the fully saturated soil zone between the groundwater table (upper bound) and the threshold with the brackish/salt groundwater (lower bound). It thus excludes the 'groundwater' that is brackish or salt, with over 300 mg Cl^-/l. The lower bound can also

– Soil volume that carries the fresh groundwater: 5,575. billion m^3;[17] (1)

– Soil volume that carries fresh, brackish or salt groundwater: 9,293. billion m^3; (2)

– Area of land concerned: 37.173 billion m^2;[18] (3)

– Thickness at maximum of soil column saturated with water: 250m (range: 0 – 350m)[19]; (4)

– Relevant soil column (height): 200m (range: 0 – 300m) defined by: (5)

- Upper bound (top side) of the groundwater column, groundwater level (m under NAP or m above NAP): -/- 5m – + 40m with respect to NAP[20]; (5b)

- Lower bound of groundwater column, the interface fresh / brackish groundwater (<300 mg Cl^-/l), average depth (m minus NAP): 150m[21]; (5c)

– The average porosity (here=water content), of the soil volume which solely is saturated with fresh groundwater[22]: ranges from 0 to 45 percent at average 20 percent[23]; (6)

– Optional: porosity (=water content) of the subsurface being permeable and which carries groundwater whatever salinity, fresh, brackish or salt: 20 percent. (6a)

Parameterisation of the groundwater compilation model

For the parameterisation a variety of sources have already been used or preferably are to be used in future improvement, and are required in order to get sufficient data

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be determined by the texture of the underground in cases where it becomes hardly impermeable.

[17] This soil volume overall, also partly, carries brackish and salt water.

[18] According to the land use statistics, total area for the Netherlands is 41.54 billion m^2, for the area 'Open water' (expectedly mainly brackish/salt marine water) 3.63 billion m^2, leaving a total calculated 'inland area' of 37.35 billion m^2 including 'inland waters'.

[19] Defined by the threshold where the hydro-geological base becomes (close to) impermeable. This depth spatially varies over the country.

[20] It includes fresh water alone (<300 mg Cl^-/l). This however excludes soil water and excludes surface water in surface water bodies as well. It thus only covers the fully saturated soil zone with groundwater underneath the unsaturated soil zone with soil water and the zone under surface water bodies. Small part of the country in the Province of Limburg has groundwater level up to 120 metres above NAP.

[21] Wolters Noordhoff, 2009. Figure 'Verzilting' with threshold fresh / brackish groundwater (although different concentration namely 1000 mg Cl^-/l.).

[22] The porosity or 'pore volume' of the soil, as in the soil layer with groundwater, determines the water content since all the pores are expected to be saturated with (ground)water.

[23] Porosity (water content) distribution is far from homogeneous in the Dutch subsurface. It varies strongly vertically, thus between the different layers as it depends on the occurrence of aquifers in the subsoil. It also changes in horizontally.

as well as data that are well embedded in the hydrological and hydro geological communities, their models and data:

1. The area of land, including inland waters, is taken from the statistics on land use (http://statline.cbs.nl/StatWeb/, search for 'land use', in Dutch: 'Bodemgebruik; naar gebruiksvorm en gemeente'). Little adjustment is made in order to align with the figure used in the study done by WaterWatch. The difference is less than half percent.

2. For the thickness of the permeable layer over the country, but also for parameterisation of the other relevant parameters, national exercises in context of the National hydrological Instrument (NHI), may well function as an interesting source. The Netherlands Hydrological Instrument (NHI) is a nationwide integrated groundwater and surface model of the Netherlands[24]. The basis of the NHI is a state-of-the-art coupling of the saturated zone of groundwater (MODFLOW), the unsaturated zone (metaSWAP) and two surface water models (MOZART and DM), one for regional and one for national waters. The resolution of the groundwater model is 250 by 250 meters and the groundwater flow for example is computed on daily basis.

Although NHI is a modelling attempt and not statistics per se, the different parameters used in the different models are well developed and based upon a list of observations and measurements, as well as on calibration. Thus these potentially would function as a well developed data source.

The only issue in context of the project is that the required data could not be obtained, as there is some capacity required to customise the data to the needs within this exercise. We hope and intend in future to continue cooperation and get the data with the wanted level of detail.

The thickness of the permeable layer over the country thus ranges between 0 to 350 meters below the surface. Spatially this has to be translated to a standard measure to compare with, for example the standardised NAP water level. More important the spatial distribution of the thickness of the permeable layer requires sound assessment of both measurements and translation to national aggregates. Both issues have to be solved, as we hope, with the data in the NHI instrumentation. For the moment a straightforward calculation is that an average value is chosen in between the range 0 – 350, being 175 metres below surface. Combined with the area of land the soil volume is 6,505 billion m^3.

3. For determining the upper bound of the groundwater stock, namely the groundwater tables hopefully use can be made (in future) of the national

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[24] The NHI is supposed to be used by policy makers and others stakeholders in national water policy issues, such as drought management, manure policy and climate change. In NHI, the nations' large hydrological institutes, including Deltares, Alterra, the national Environmental Assessment Agency (PBL) and the Ministry of Infrastructure and the Environment (I&M) have joined forces to build a new national hydrological modelling instrument.

groundwater register ('Landelijk Grondwater Register', LGR). As this is still under development, it couldn't be used for the purpose of the project and by other parties than the ones directly involved in the development as were provinces and the water boards. As this is facilitated by the governmental bodies being the 12 provinces and the Water Boards in the country we expect that for statistical purposes, the data within the LGR-Register can be used by our NSI (Statistics Netherlands). We like to stress that variation over the years in groundwater tables isn't very serious at the end (31 December) / beginning of the year (1 January). Particularly this holds for the North-Western part of the country with all the polders with high degree of controlled water levels (if not all) of the local surface waters. Eventually there may be some difference in the South-Eastern part of the country over a single year. Of course when temporal resolution is extended, such figure may well change over time particularly in periods (growing season) with warm dry weather.

Apart from the LGR-Register, a general picture and development can still be derived for the country as several provinces publish groundwater tables of registration stations, thus in a kind of spatial explicit manner. These sources, frequently made available online, can be quite helpful to derive a general picture. The dry spring of 2011 was well reflected by the results of the different measurement stations.

Alternatively, use can be made of the so-called Groundwater level classes (In Dutch: 'Grondwatertrappen'). These classes are spatially distributed and registered for the country, as shown in Annex II. This implies that for the country in detail (spatial resolution is 10 hectares or less) the average annual highest and the average annual lowest groundwater level have been registered. From this bandwidth eventually a sufficient level at the end of a year can be derived (close to the highest groundwater level class) resulting in a reasonable parameter that describes the upper bound of the groundwater stocks.

Another alternative may be the information on ground water tables from the DINO set of data for the Dutch underground. DINO is the nationwide database run by TNO that consists of a large number of ground and surface water levels. We discovered some problems to obtain data, because of the restricted availability and the accessibility of the data. Hopefully in the future this may serve as a sufficient data source as well.

4. The Parameterisation of the lower bound of groundwater column, the interface fresh / brackish groundwater isn't an easy task. For that purpose one has to rely on the data in the Netherlands Hydrological Instrument (NHI) again. For the moment we have looked at reports in which the NHI data is used and described.

5. Finally determination of the porosity isn't easy as well. The best option will be to rely on the data in NHI as well. Here too we have for now just looked at reports in which the NHI data is used and described.

8.1.2 Results

The estimated stock of fresh groundwater for the Dutch territory with less than 300 mg Cl^-/l concentration range from approximately 800 billion m^3 (Noordhoff, 2009) to around 1,100 billion m^3 and is particularly situated in the eastern and southern provinces, excluding the province of Zeeland (Stuurman, et al., 2008)[25]. This is roughly 1000 times the amount of groundwater abstracted annually and 200 times the volume of surface water stored in the IJsselmeer. The amount of groundwater up to 1000 mg Cl^-/l is estimated at about 1,475 billion m^3 (Stuurman, et al., 2008). The fresh groundwater stock with chloride content up to 300 mg Cl^-/l for the Netherlands, amount to around 1,100 billion m^3.

Despite the relatively large stock of fresh groundwater, groundwater in specific locations and periods / seasons can be a scarce resource in the Netherlands, which should be managed with care, both in quantity and in quality terms. This becomes apparent when spatial and temporal scales would be more detailed. In the Dutch groundwater act, the efficient and effective use of groundwater ánd the protection of the scarce groundwater resource is envisaged. Scarce groundwater primarily will have to be used for purposes for which the use of water is essential, such as for drinking water and specific industrial applications.

To conclude on groundwater, the method / approach to be applied is clear. The parameterisation and required data is reasonable, but can be improved, particularly on the porosity and upper and lower bounds of the groundwater column. Data was scattered and can and presumably may be improved via a closer connection to the hydrological and hydro geological community in the country, their models and data.

Due to significant bandwidth and uncertainty for different sources, annual monitoring of opening stocks (at 1st of January) and closing stocks, hardly make sense. Once every 5 year probably is also sufficient and than only certain parameters can / has to be updated. For the right and well embedded parameterisation the connection with (ground) water modellers and hydrological community is believed to be essential to make a step forward.

The fresh water stocks quantified as such obviously doesn't mean these stocks are readily available for abstraction or use. For groundwater, only a limited share on an annual basis can be abstracted and used for economic and non-economic activities. Over-abstraction would cause the stock to decrease and particularly the fresh to brackish/salt interface may be affected in the sense this threshold may rise with several negative effects. One effect that occurred some decades ago was that at certain abstraction points the resource became brackish or even salt, with the effect that abstraction of fresh water was no longer possible. The abstractions from the

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[25] There is debate or at least a range of the 'salinity' of water what is supposed to be fresh water or at least what is water with quality that can be used for a wide variety of uses. For example in the Netherlands in certain regions intake of water with above 300 mg Cl^-/l concentration has shown growth in recent years. This water has still fresh character and is used for similar purposes for which before indeed water with < 300 mg Cl^-/l was used.

stock have to be in balance with the replenishment of the stock. The rate of replenishment is also restricted to a maximum.

8.2 Stocks of soil water

Soil water can be defined as water suspended in the uppermost belt of soil, or in the zone of aeration near the ground surface, that can be discharged in to the atmosphere by evapotranspiration (SEEAW, 2006). This water represents a stock or an asset, as it can be used by the vegetation for transpiration as well. The stock of soil water, in contrast to groundwater, represents the water in the unsaturated zone of the soil, situated above the (ground)water table. Principally the soil water represents the volume of water between the soil particles, next to the volume of air within the unsaturated soil zone. The pore volume is shared between air and (soil)water. Plants for a part can benefit from soil water, while soil water can also be replenished by water from groundwater via capillary action.

8.2.1 Compilation

Assessment of the fresh soil water stock has some similarities but also differences compared to compilation procedure of fresh groundwater stocks. Determining the stocks of fresh soil water in a specified area at a certain point, requires quantification of the following elements in detail, which is, defining the area of concern, the relevant soil column (depth), porosity and water (un)saturation or simply water content of the soil.

Soil water is just relevant for land that at least at some point in a year is not saturated with water, because then it isn't covered by water, for example in (part of) the riverbeds or floodplains. First the size of the relevant area of land has to be determined. Preferably this is done for each soil type separately, because the soil type or class clearly influences the (maximum) amount of water the soil can hold. Secondly the thickness of the soil layer that 'carries' the soil water needs to be determined. The layer thickness is determined by the distance between surface level and the groundwater table ('groundwater depth'). The latter in fact represents the threshold from which the saturated zone with groundwater begins. The threshold between saturated and non-saturated zone thus is also the threshold between groundwater and soil water. However, determining the layer thickness is not straightforward as, for example, the layer thickness is not at all constant over time as it moves due to changing 'balances' between precipitation and evapotranspiration for example.

From the area, ideally per soil type, and the average layer thickness as is the calculated slice or soil column, the soil volume that does contain soil water can be derived. The resulting soil volume, consists of a combination of soil particles, air and (soil) water. Per soil type the average share in volume of soil particles is well known, while the remainder consists of a combination of air and water. The ratio between these two however can vary severely throughout the year. The maximum content of soil water is well known per soil type. The actual content of soil water for each particular area of a certain soil type should preferably be assessed in a custom manner. This thus is affected by the (recent) weather circumstances.

As for groundwater, here a similar procedure has been set up for the assessment of the national soil water stock and for quantification of the required elements that underlie the calculation of the stock. The relevant formulas (and parameterisations) are presented here:

Stock or volume of fresh soil water: 11 – 44 billion m^3 [26];

- Soil volume that carries the volume of fresh soil water: 137.5 billion m^3 [27]; (1)
  - Area of land concerned, land with an unsaturated soil zone with soil water above the groundwater table. Thus land not covered with surface water: 37.2 billion m^2; (2)
  - Maximum soil column unsaturated with water (height): 0.50 m (range 0.0 – 20.0m); (3)
  - Relevant soil column (height): 0.50m (range 0.0 – 2.0m); (4)
    - Top side of the soil water column, at surface level (at or m under NAP or m above NAP): -/- 5.0m – + 40.0m with respect to NAP [28]; (4b)
    - Bottom side of the soil water column, the threshold with the groundwater table that contains fresh soil water (<300 mg Cl^-/l), average depth (m minus ground level or eventual compared to NAP): 0.50m [29]; (4b)
- The porosity (= pore volume) of the soil volume at average that is unsaturated while it combines air next to fresh soil water (m3 of pores / m3 of soil; or % of volume)[30]. Ranges from 20.0 to 60.0 percent at average 40 percent[31]; (5)

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[26] This is for fresh water alone (<300 mg Cl-/l) too. It excludes the 'groundwater' as this parameter presents solely the water in the unsaturated zone. It thus only covers the fully unsaturated soil zone between the ground level and the groundwater table.

[27] Preferably a distinction is made to volumes (and area of land and height) of the main soil types, as significant differences in soil water capacities exists between the different soil types.

[28] This ground level practically is constant over time. The higher East-Southern part of the country has, due to the low groundwater levels compared to the ground level, a significant (partly permanent) unsaturated zone of water. The water stored in this unsaturated zone cannot fully be covered or used for example in agriculture as only in the upper part of such soil zone the plant roots will grow and are able to capture the water. For this reason eventually a correction can be made, dependent on the purpose. In the Western part of the country with controlled water levels the unsaturated zone is 2 meters at the maximum and for large area with peat grassland even less then 1 metre. In the Eastern part this unsaturated soil zone is much thicker.

[29] This groundwater table is changing constantly over the season / during the year, due to constant change in (weather) conditions and changing land cover.

[30] The porosity or 'pore volume' of the soil, as in the soil layer with groundwater, determines the water content since all the pores are expected to be saturated with (ground)water.

– Saturation level with fresh water of the unsaturated soil zone at average (m3 of water / m3 of pores; or % of the pore volume) 20.0 – 80.0 percent [32]; (6)

Parameterisation of the soil water compilation model

For the parameterisation a variety of sources already has been used or preferably will be used as these are required for a sound parameterisation. Several data sources used for the parameterisation of the soil water calculations are similar to those for the groundwater parameterisation and thus already described above in section 8.1. Therefore these will not be repeated here. Additional sources primarily will be dealt with here:

1. Correction has to be made for the land under surface water as this has no unsaturated zone. The simple procedure is to correct the total area of land for the land covered with surface water. This can be done with the same land use statistics.

2. Calculate the difference between a. the groundwater tables and b. the ground / surface level (in Dutch: 'drooglegging'). This can be done via connection of both parameters to the standardised mean surface water level in the Netherlands, the NAP level.

3. For porosity different values are required as this soil zone that carries the soil water is different from the soil zone with groundwater, We intend them to base on the same data stemming from the NHI set of hydrological instruments.

4. For estimation of the saturation levels with fresh soil water of the pores in the unsaturated soil zone, a brief literature / internet search has been done. In future for saturation levels, we intend to rely on site measurements, expert knowledge with the Water boards and most probably on the parameterisations in the NHI set of instruments and modelling exercises.

8.2.2 Results

The estimated stock of water in the unsaturated soil zone ranges from 11.0 to around 44.0 billion m^3. This is roughly 1 – 4 percent of the fresh groundwater stock calculated in section 8.1 and about 10 times the volume of surface water stored in the IJsselmeer.

It should be emphasised, this result is a first preliminary estimate with significant bandwidth due to data sources that could not fully be used or obtained. We also

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[31] Porosity (pore volume) distribution is far from homogeneous in the Dutch subsurface. It varies vertically and horizontally. At surface level 40 percent is reasonable; it will be less the deeper the subsoil.

[32] The soil water content can alternatively be calculated by using the total calculated soil volume (m^3) -/- volume of soil particles (m^3) -/- air volume of the soil (m^3).

expect that some range in the result exists because of lacking accuracy or quality of the extensive set of data that would be required for a solid result. We aim for improvement of the data in the future though.

Due to significant bandwidth and uncertainty for different parameters, annual monitoring of opening stocks (at 1st of January) and closing stocks, will be difficult and will always be surrounded by uncertainties. Update of soil water figure probably is sufficient once every 5 or even 10 years. Also for soil water, the right and well embedded parameterisation via connection with the hydrological community in the country is believed to be valuable and needed to make as step forward.

From this exercise we learned there is significant seasonal variation in the required parameters and thus in the result. Annual monitoring of the national soil water stock principally requires real time monitoring of the different parameters for the calculation model. For which the average groundwater level and the average saturation of the pores with fresh water are the crucial parameters. The other parameters stay more or less constant or only change slightly over time.

Eventual regionalization to the 7 (sub-) River Basins in future do require accurate datasets at the level of the 7 (sub-) River Basins. Future will learn whether this can be achieved.

As for groundwater, for the stock of fresh soil water as quantified here, only a share can be used for economic activities as for the intake for plant/crop growth (transpiration) or either for evaporation from the soil.

8.3 Stocks of surface water

This paragraph deals with the assessment of the national stock of surface water. 'Fresh surface water' is supposed to flow over, or rest on the surface of a land mass, natural watercourses such as rivers, streams, brooks, lakes, etc., as well as artificial watercourses such as irrigation, industrial and navigation canals, drainage systems and artificial reservoirs (Eurostat, 2010). For the questionnaire, bank filtration (by pumping from wells sunk into the gravel strata) with the intention of improving the water quality, is included under 'fresh surface water'. Sea-water, and transitional waters, such as brackish swamps, lagoons and estuarine areas are not considered fresh surface water and so are included under Non-fresh water sources (Eurostat, 2010).

8.3.1 Compilation

For assessment of the groundwater stocks within the Netherlands it probably is relevant to stress that the Netherlands, although a small country, is situated in a large delta region and part of four international river basins with Rhine, Meuse, Scheldt and Ems. All water that flows down these rivers passes through the country on its way to the Wadden Sea and the North Sea as is described in sections 4.3 to 4.5. These inflows and outflows of fresh surface water largely explain the actual external inflow respectively actual outflow by means it renews or refreshes part of the existing stocks. This particularly holds for the large rivers and canals and directly connected water bodies.

The stock of fresh surface water for the specified area principally can be calculated from two main elements. That is first the size of the area covered by the surface water bodies and second the average water depth (or water height) of this 'water cover'. As for ground- and soil water, not the overall stock of surface water is relevant but particularly the stock of fresh surface water. Thus the volume of fresh surface water that contain up to 300 milligrams of chloride per litre (< 300 mg Cl^-/l).

The surface water stock types or resource categories consist of: 1. ditches, 2. canals, 3. rivers, 4. lakes (including the IJsselmeer), 5. open water (connected to the North Sea till the barriers), and 6. other.

Here the model for calculation of the surface water stock at the national level is presented.

Stock or volume of fresh surface water bodies: 11.3 billion m^3;

– Area of water (bodies) within the country, eventually per category of water body: 3.3 billion m^2 [33] (1)

– Average depth of the fresh water bodies within the country, depth specified per distinct water body category: 0.0m – 25.0m) [34]; (2)

Parameterisation of the surface water compilation model

For the parameterisation of the calculation model on surface water stocks, a number of sources will be dealt with, few only briefly as they may have been discussed already earlier in sections 8.1 and/or 8.2. The following sources are relevant for the assessment of the surface water stocks:

1. Here for quantification of the surface area the figure is taken from data for the WFD. The respective areas of the existing water bodies in the country are summed. Out of this data a selection is made for the fresh water bodies alone. The nations' water bodies are described in the Water Framework Directive (WFD). It covers primarily the larger water bodies in the country. With the implementation of WFD a typology has become available that can be applied to all surface waters in the Netherlands. This typology is used in the map of 'water bodies', an administrative

[33] The land use statistics, for the area 'inland waters' (expectedly mainly brackish/salt marine water) provide 3.63 billion m^2. As some small parts of the 'inland waters' are excluded, it well aligns with the figure used here, as derived from the sum of the fresh water bodies that solely represent the fresh waters and exclude some brackish/salt inland waters.

[34] The depth is defined as the surface water level and the average level of the bottom of the water body, the threshold with the soil underneath each water body. These two levels regularly are defined in contrast to the NAP that represents 'Normaal Amsterdams Peil' (the national reference for surface water levels to compare with, being the standardised 'Normal Amsterdam Level').

classification adopted for the Dutch surface waters. The water bodies, along with the locations of the River Basin Districts (RBDs), are the spatial orientation of the WFD. However, only part of the Dutch water is determined as a WFD water body. Many small streams and ditches are too small to get included in the WFD assessments. For nature conservation purposes, a broader selection of surface water is needed (Puijenbroek and Clement, 2010).

2. Here alternatively the area of water bodies can also be derived from the land use statistics which captures ‘inland waters’ with a break down in the area for nine subcategories as for lakes, although here no classification is made for fresh or brackish/salt water. However with these subcategories a reasonable estimate can be made for fresh inland waters. Also areas for four open water categories (and total area) are quantified. The results from the statistics generally compare reasonably well with the WFD data on water bodies.

For the surface area the ‘land use statistics’ can be used, with classification that distinguishes ‘inland waters’ (> 6 wide, including IJsselmeer, rivers, canals, lakes e.d. i.e. polder water) next to agricultural land, built up land, etc. This in total gives 363.5 km^2. This figure excludes the ‘Open water’, which is (saline) water that is in open communication with the saline environment of the North Sea (Wadden Sea, Eastern and Western). The New Waterway is made distinct by an imaginary line between the breakwaters.

3. In context of the Water Framework Directive (WFD) the different waters are classified, and their respective surfaces. When only the objects containing fresh surface water are totalled an estimated area of 727,455 hectare results (van Puijenbroek and Clement, 2010). The advantage of this source is that per category a reasonable estimate for the average depth can be made. The combination of the two generates a reasonable estimate for the volume of surface water in place at a certain moment.

4. Eventually one could opt for determining the area for each single Water board. However the required data can only partially be obtained from some of the water boards, as they deal with the relevant data of their water bodies. The data appeared to be limited. The surface of land covered by water, like in ditches, rivers, lakes, as in the ‘IJsselmeer’, etc. is well known for the country at the national level and at the level of the individual water boards.

One difficulty is to get a good estimate for the (average) water level. This is not at all straightforward. However, for some large water reservoirs data is well known though. A good example is the IJsselmeer as well as the Markermeer. For these reservoirs both the area is known, as well as the average depth. This can provide an accurate gauge for determination of the water stock in the lake on the 1st of January / 31st of December (of previous year). For some other large reservoirs within the country, the average (water) depth is known as well. The different categories of reservoirs or water bodies that contain surface water must first be inventoried. And than for each type of water reservoir or category of water body both, the area and the average depth, will have to be quantified. Eventually a selection of reservoirs / bodies can be used.

5. Finally, for surface water too, the National hydrological instrumentation (NHI), may well function as a useful and practical tool and source of information of the necessary parameters of the aforementioned calculation. The Netherlands Hydrological Instrument (NHI) also accommodates two surface water models (MOZART and DM), one for the regional and one for national waters. The description of the different surface waters is well developed and very recently in process of updating. There is serious attention paid to it.

8.3.2 Results

The method or approach for assessment of the surface water stocks within the country is clear and sort of straightforward.

On the parameterisation, for the area sound data sources exist, while for the assessment of the depth of the surface waters / surface water bodies figures are so far poor. We hope to improve the depth assessment via connection with the hydrological community.

First assessment of the countries' surface water bodies that hold fresh surface water, result in about 3.3 billion m^2 by use of area quantification in context of the Water Framework Directive (WFD). According to the land use statistics, with only slightly different numbers, these 'inland surface waters' represent close to 10 percent of the total surface area of land inclusive the 'inland waters' with particularly fresh water characteristics. The estimated stock of fresh surface water, as a result of the area of surface waters and a preliminary estimate of the average depth for each water body category, for the Dutch territory results in about 11.3 billion m^3. This is only 1 percent compared to the groundwater stock and is comparable to the annual abstraction of fresh surface water (10.6 billion m^3). The annual external inflow of fresh surface water is 6 times as big as this stock. The IJsselmeer inclusive the Markermeer represents almost half of the national fresh water stock. Therefore the IJsselmeer plays a major role in all kinds of exercise for future fresh water management activities in the country.

Regionalization to the 7 (sub-) River Basins (RBs) would require more detailed data for both area of surface water per River Basin and also for the related depths. Such figures couldn't be obtained in the project. Hopefully it can in future via the different hydrological modelling platforms which obviously also include significant parameterisation efforts. Due to significant variation in determining variables, in particular for the detailed per water body average water depths, annual monitoring is hardly feasible. As phrased before we aim to extend and improve connecting with geological/geo-hydrological/ hydrological and water modelling communities within the country and for the River Basins, as well as with the monitoring efforts, models and relevant data in context of the WFD.

8.4 Stocks of wastewater

In this paragraph the assessment of the national stock of wastewater will briefly be treated. The amount of waste water deals with the (waste-)water present in waste water treatment plants, and in the sewer system. Compared to the quantities treated in the previous sections, the wastewater stocks represent only small amounts of water. By making use of existing data and some assumptions, a rough estimate can be made.

The amount of waste water contained in **Urban Waste Water Treatment Plants** (UWWTP) is easily to determine by making use of the database of Statistics Netherlands with all major design features of the plants. For each major treatment step the volume of the basins/tanks/reactors is known well. In 2009, the total volume of the treatment basins amounted up to 7.3 million m^3. Given the fact that the treatment plants are (nearly) always fully loaded with waste water, the volumes of the different treatment steps in cubic meters thus is a good indication for the quantity of waste water present in the treatment plants.

For **industrial waste water treatment plants** (IWWTP) similar information on the volumes of the treatment basins is not known. The only available information is the design capacity, expressed in population equivalents, and the treatment type. By comparison with similar values of UWWTPs, a rough estimate of the volumes stored in the treatment basins is made. Table 8.1 gives per treatment step the total volume of all UWWTP's, as well as the estimated volumes of the Industrial WWTP's. The stock of waste water present at a certain moment in all waste water treatment plants is estimated to be 11.5 million m^3.

Table 8.1 Volumes of wastewater contained in waste water treatment steps, 2009

	Capacity	Volume of treatment steps
	1 000 p.e. [1)]	*1 000 m^3*
Urban WWTP's	**24 200**	**7 338**
of which		
Mixing and pumping basins		3
Pre-settling tanks		455
Pre-treatment tanks		414
Aeration tanks		4 127
Intermediate and post-settling		2 339
Industrial WWTP's	**13 800**	**4 185** [2)]
Total of WWTP's	**24 200**	**11 523**

1) p.e. = population equivalent.
2) Estimation.

Another significant amount of waste water is captured by the **sewer system** (sewage pipes), the infrastructure that transport the wastewater from its origin to the destined plants. This amount at a specific point in time can be estimated roughly by making use of the sewer statistics compiled by Rioned (Rioned, 2010). These statistics give a distribution of total length of sewer system by range of internal diameter and by type of sewer. In general two types of sewers exist. The first type is the high-pressure tube which can be considered as permanently fully loaded with waste water. As a consequence the stock can be determined by multiplication of the (average) diameter by length of the sewer.

In the second sewer type the waste water is transported by making use of gravity enabling waste to flow under free fall conditions. These generally have larger diameters and normally aren't fully loaded. For assessing the amount of wastewater captured, an assumption should be made, such as a load of 25 percent of maximum capacity. The result of the assessment for the stock than is: (average) diameter times length of the sewer times 25% loading.

Table 8.2 provides the underlying data on sewer systems from Rioned (2010) and the calculated stocks of waste water, assuming a 25% loading of gravity sewers. The results show that the total stock of waste water present in the sewer system at a certain moment is estimated to be nearly 5.1 million m^3.

Table 8.2 Calculation of stock of waste water in sewer systems, 2009

Type of sewer	average diameter	lenght	average loading	wastewater stock[1)]
	m	*km*	*%*	*1 000 m^3*
Gravity sewer	0.25	19 500	0.25	239
	0.3	28 000	0.25	495
	0.4	13 500	0.25	424
	0.5	8 000	0.25	393
	0.6	4 000	0.25	283
	0.7	1 700	0.25	164
	0.8	2 000	0.25	251
	0.9	900	0.25	143
	1.0	1 200	0.25	236
	1.1	1 300	0.25	309
total gravity sewers				**2 936**
Pressure sewers	0.08	19 000	1	96
Long range transport sewers	0.5	8 600	1	2 042
Total, all sewers				**5 073**

1) Stock = $(\text{diameter}/2)^2$ * pi * length * average loading

Concluding: The total stock of waste water present in sewer systems as well as in the treatment basins of all waste water treatment plants is estimated to be approximately 16.5 million m^3. These results confirm that this stock can be neglected compared to the enormous stocks of surface water, soil water and ground water.

8.5 Estimate of water contained in growing / standing biomass

Finally, in this paragraph, some general remarks will be made about water that is contained by standing and growing biomass, such as in trees, plants, or crops.

In Dutch arable farming predominantly annual crops in stead of perennial crops are grown. Only few crops have standing and living biomass that has dry matter and contain at least some water in the winter, at the end of the year or beginning of a new year. Thus some water volume can be considered. This is the case for winter cereals like winter wheat, winter barley and winter rye. But large part of the arable land is empty at the end of the year as is the large area used for (green) maize, other summer cereals, potatoes, sugar beets, carrots, and most of the horticultural cultivated crops and plants. Only in horticulture (inc. green houses), fruit growing (apples / pears), and tree nursery significant area of perennial plants/crops are grown or at least are there at the end of the year. For grassland that covers 1.00 million hectares, out of a total of 1.85 million hectares of agricultural land in the country, the aboveground biomass containing dry matter and water still in place at the end of the year is limited.

Suppose there is 10 ton of biomass per hectare of grassland or winter cereals still in place at 31st of December and it contains 85 percent water, it means 8.5 m^3 of water per hectare. When spread it would cover a hectare with only 1 millimetre of water. The water contained by the grassland and eventual (winter)crops with limited biomass in place can be neglected when compared to the amount of soil water and certainly to the amount of groundwater. Concluding, in general stocks of water in living biomass in agriculture at the mentioned dates can be neglected.

For the forests in the country this may be a bit different. First the area covered by forest is well known; in 2010 the area covered with forest was about 365 thousand hectares. Second the volume of the trees within this forested area is known. This area has a (living) growing stock volume of 70 million cubic meters over bark in 2010 (Dirkse et. al., 2006; Ministry of Agriculture, Nature and Food Quality, 2010). Using an average specific mass (Specific gravity) of wood including the moisture content of 700 kg/m^3, this results in an approximated national stock of 50 million ton of wood. Freshly cut wood from forest contains approximately 50 percent water. This implies an approximated 25 million m^3 (or ton) of water contained by the Dutch forests aboveground. This represents a layer of only 7 millimetres of water for the area covered by forest which is only a tiny fraction of the other stocks of surface, ground- and soil water. Moreover with less than 1 percent compared to annual rain in this area, it underpins that the water contained by standing forests represents just a tiny share of the quantity of the fresh water stocks overall in the countries' inland water systems.

9. Conclusions / recommendations

We can draw some conclusions with regard to applied methodology, sources and compilation activities.

1. The study has resulted in sound methods for the compilation of the four main items of the water balance. The methods used facilitate temporal disaggregation (summer versus winter season) as well as spatial disaggregation into the four domestic River Basins.
2. The quantification of precipitation and actual evapotranspiration was performed by a third party, WaterWatch. The use of advanced methods based on Remote Sensing and radar images, calibrated by gauging stations, has delivered more realistic values compared to the previous method. In particular, the quantification of actual evapotranspiration as is defined proved to be crucial for the whole water balance, as it influences the quantification of the internal flow, the total freshwater resources as well as the potential recharge into the aquifers.
3. Data on total external inflow via the river Rhine and River Meuse were completed with inflow data of numerous small rivers and flows. In particular for the Meuse River basin this is a significant improvement, because the added data raise the annual external inflow in this region with 20%. In contrast, for the Rhine River basin the increase due to inclusion of the data on small rivers is only 1%.
4. The quantification of domestic flows of surface water between River Basins was achieved via the use of data of flow gauging stations at the transfer points. Exchange of fresh surface water between the River Basins predominantly occurs in the Rhine/Meuse/Scheldt delta area, situated in the South-western part of the Netherlands. In particular for the Scheldt River Basin the domestic inflow is essential for the water balance in the summer season.
5. It turned out to be hardly possible to quantify the flows of groundwater to and from the territory. We discovered that groundwater modelers particularly neglect this flow in their quantification efforts or at least were hardly able to make reliable estimates. We aim to stay in touch and intensify the connection with hydrologists and water modelers in future and see whether it will be possible to come up with reliable estimates.
6. Estimation of the fresh groundwater stock shows a significant bandwidth, varying from 800 till 1,450 billion m^3. The differences stem from variation in parameters underlying the calculation. Variation for example is explained by difference in the chosen salinity as threshold of being fresh water, ranging from 150 mg/l Cl^- till 450 mg/l Cl^-. Other explanation is the uncertainty of the depth and shape of the fresh / brackish & salt threshold layer and even from, although to less extent, inaccuracy in averages derived from measured groundwater

tables. Also the physical boundaries of the relevant soil volume and soil porosity contribute to varying estimate.

7. In general the question can be raised what would be the proper salinity threshold to get classified as fresh water? For example these days also brackish water is used for certain (economic) purposes, which is different from the practices a few decades ago. From literature different salinity levels were chosen as thresholds for 'fresh water', ranging from 150 mg/l Cl^- till 450 mg/l Cl^-. We hope this issue can be clarified and agreed upon in the Water Statistics and Water Accounts communities among European countries and Eurostat in near future.
8. The estimated fresh surface water stock in the country with an estimated 11 billion m^3 is much smaller (1 percent) than the groundwater stock of around 1,100 billion m^3. The estimated volume of the soil water ranges from 11 – 44 billion m^3 for which the lower bound is more or less similar to the surface water stock size.
9. The use of hydrological and hydro geological models would well support the parameterisation of some calculations, in particular the ones for groundwater, surface water and eventually soil water. The question may be whether or for which parameters this is supportive to compile water statistics? Probably clear distinction may be required for which parameters to rely on model parameterisations and for which not.
10. In the quantifications of some of the parameters for the stock assessments, serious bandwidth has been discovered. This makes it reasonable also to present a range for the calculated stocks.
11. Annual monitoring of stocks seems not to make much sense as there do exist to large variations in a selection of the required parameters, or either lacking behind in updates of some of the parameters like for groundwater tables, fresh to brackish/salt interface for groundwater, saturation levels for soil water and surface water depths as the most important ones.
12. In the project, rough estimates were made of stocks of waste water, present in sewer systems and waste water treatment plants at a certain moment. Also a rough estimate was made on the volumes of water present in standing biomass. These volumes proved to be insignificant, when compared to the huge stocks of ground water, soil water and surface water and the uncertainty in it. Also as a resource the latter quantifications were not very relevant.

For future work on the water balance data compilation, the following recommendations can be made:

1. Find agreement on what would be the proper threshold for salinity classification of the fresh water stocks (and flows).

2. The estimated fresh surface water stock is much smaller than the variation in the assessment of the Groundwater stock. This may influence where the priorities for improvement of certain data may be put.
3. For parameterisations of certain parameters of fresh water stock assessments, in future we aim to connect to hydrologists and water modelers communities and discover how we can use the connection and let different parties benefit from the connection.
4. In the quantifications of precipitation and actual evapotranspiration easily better and realistic values can be obtained by use of advanced methods based on Remote Sensing and via radar images, sufficiently calibrated by gauging stations. In particular this is relevant for quantification of actual evapotranspiration.
5. Stocks at beginning / end of each year can be relevant but isn't a priori the key indicator. For getting a feel for the availability of (scarce) water resource for agriculture for example, it is not only relevant to know the size of the resource at the 1st of January, but it is at least relevant to know the stock at the beginning or during the growing season. While the incoming flows of fresh water that can be relied upon for all kind of uses in the course of a year, may at least be equally important for assessment of scarcity of the fresh water resources within a specified territory as the stocks themselves.

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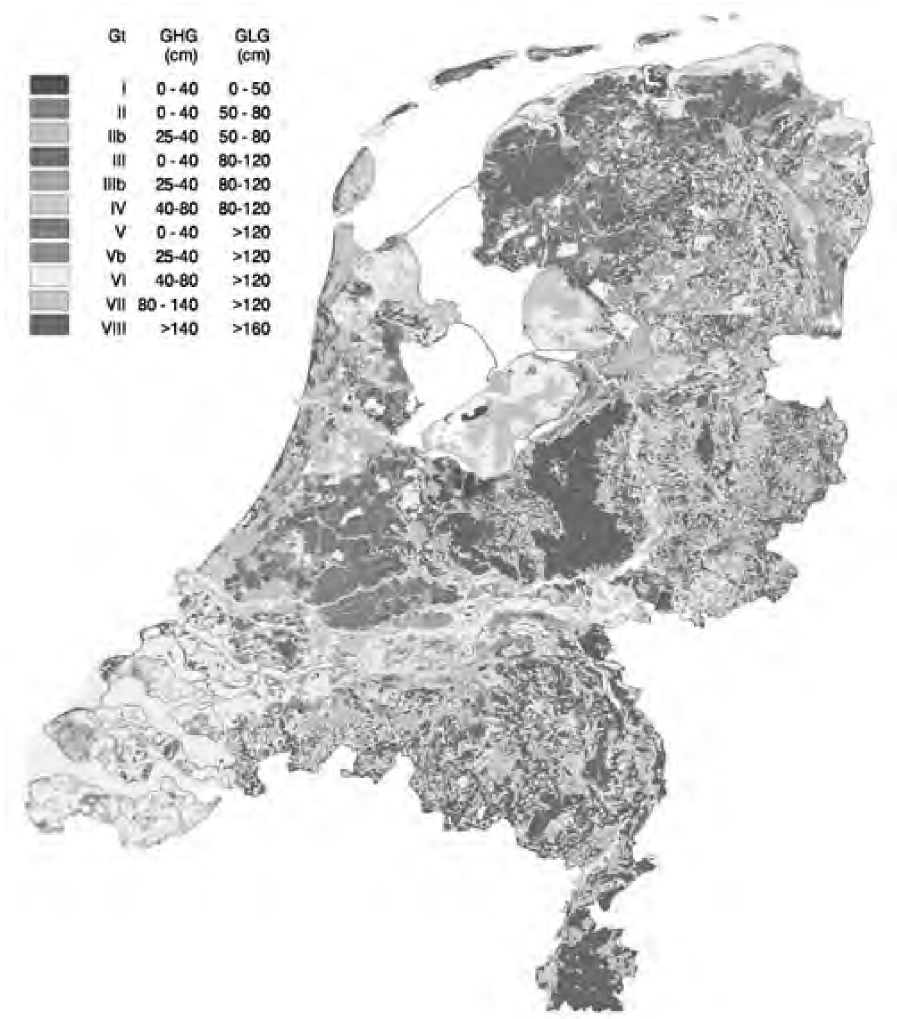
Annex I Groundwater table relative to NAP [1)]

Source: De Vries; 2007. Groundwater in the Netherlands. By KNAW (Geology of the Netherlands).

[1)] NAP: represents ‘Normaal Amsterdams Peil’ (Normal Amsterdam Level).

Annex II Groundwater levels (stages)



Source: Alterra, 2011.

1) Figure presents Groundwater levels or stages ('Grondwatertrappen') with average highest & average lowest groundwater tables (GHG & GLG). These are managed by the respective Water boards and relevant for water management in the summer and in the winter.