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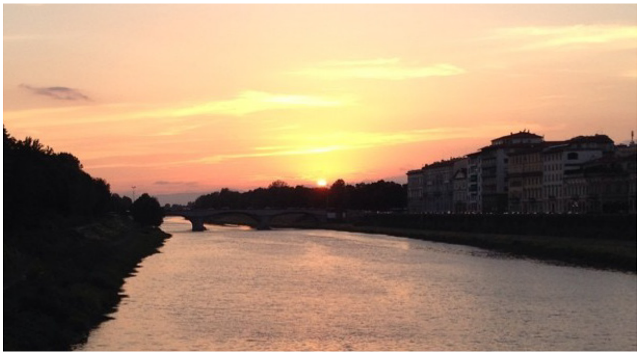
Pilot Arno Water Accounts



Deliverable: D6.2 Compendium of lessons learnt

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1 Introduction

The PAWA project is composed of four successive technical activities and two horizontal activities, as presented in **Figure 1**.

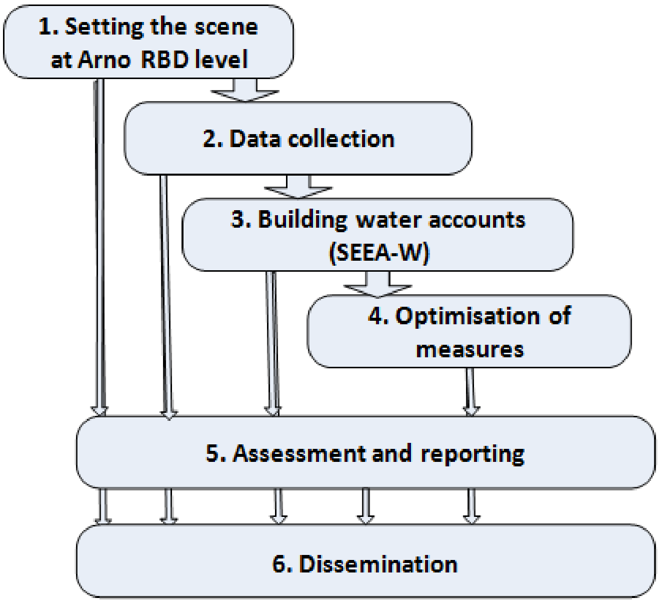

Figure 1 – PAWA project activity chart.

During the Activity 1, three sub-basins were identified over the Arno River Basin as priority areas to prepare water accounts on a monthly basis (see [D1.2 Prioritisation list of sub-basins]). These sub-basins, reported in **Figure 2**, are:

- Chiana valley (1.373 sq. km);
- Bisenzio valley (320 sq. km);
- Pisa aquifer (407 sq. km).

The three sub-basins were identified using the following criteria: *i*) vulnerability to drought and water scarcity; *ii*) data availability; and *iii*) operational governance structure.

A participatory approach was applied to each activity through the organisation of stakeholder workshops (see the meeting webpage on the PAWA website) and regular exchanges with local stakeholders and data providers, in particular concerning data collection, estimations, validations, and measures assessment.

The current deliverable presents the main recommendations, resulting from the PAWA implementation, for future use of the SEEA-Water for water efficiency management purpose at river basin level.

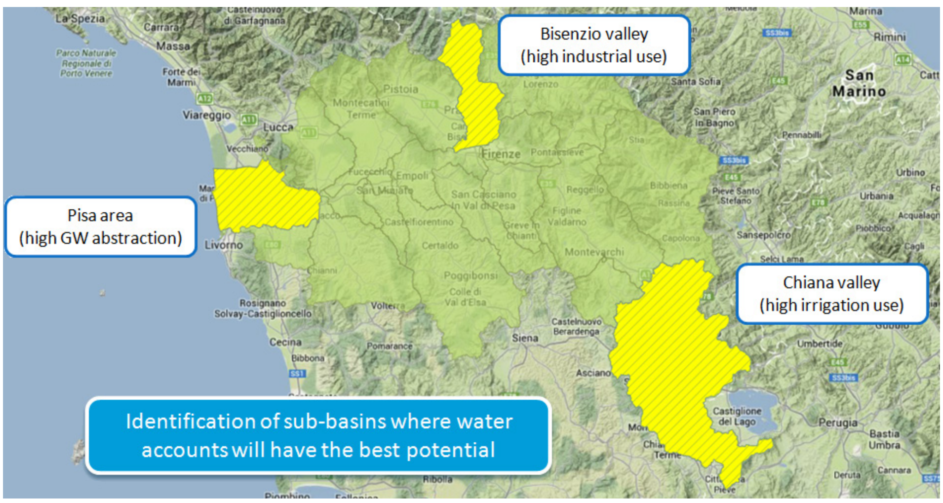

Figure 2 – Identification of the priority sub-basins (yellow shaded) comprised in the Arno River Basin (green shaded), with indication of the main use affecting the three areas.

2 Data collection

2.1 Inventory of data available

The inventory and sharing of available data has been facilitated thanks to a metadata catalogue (see **Figure 2**), compliant with the [INSPIRE Directive 2007/2/EC](). More than 100 sources of data were harvested in the Arno River Basin Authority (ARBA) metadata catalogue, which is available at http://dati.adbarno.it/geonetwork.

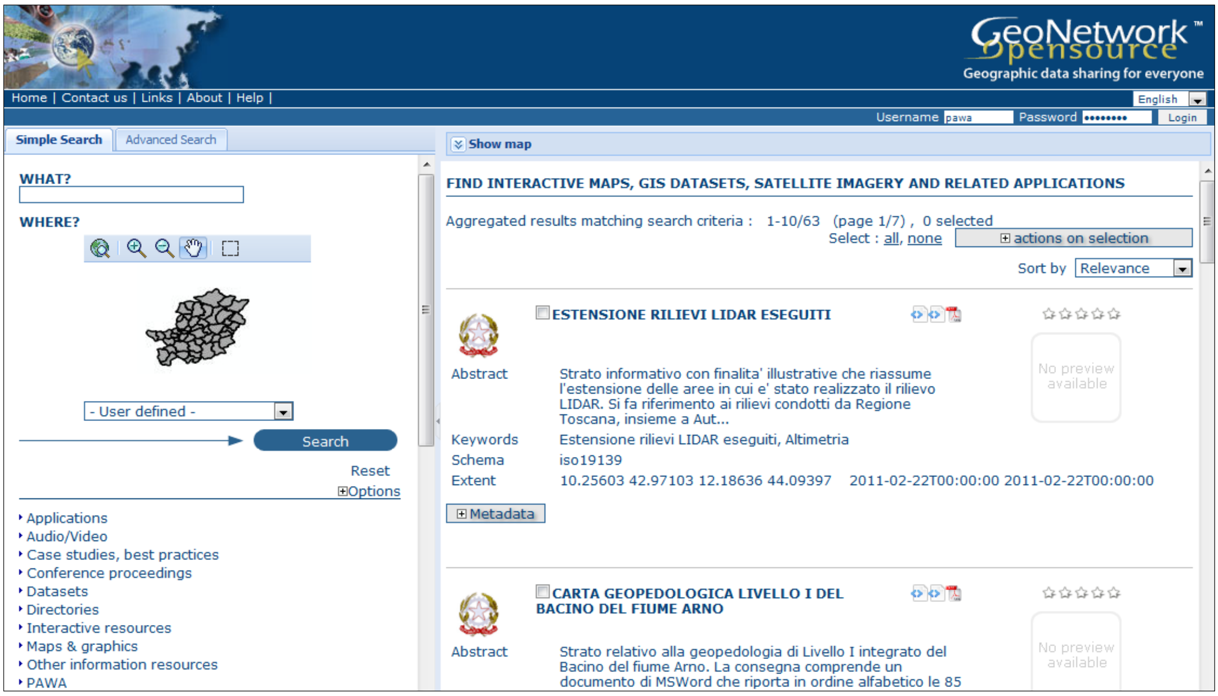

Figure 3 – Public interface of the ARBA metadata catalogue.

2.2 Water flows diagrams

Creating water flow diagrams (**Figure 2**) implies agreeing with stakeholders on the main sets of data that need to be gathered and the volumes that can be neglected. Such a graphical tool was very useful to this process.

2.3 Spatial and temporal resolution

During the design of the project, it was decided to work on a 20-year time series, due to the availability of some hydrometeorological monitoring data from 1993. Such a long time series are useful to define long term averages for climatic parameters (e.g., rainfall), but compiling the Water Account (WA) tables provided by SEEA-Water requires much more data related to water; these data (even the estimated ones), with an acceptable level of uncertainty, are available from 2006. Hence, realistic datasets cover the period 2006–2013.

Monthly resolution is a must when identifying and analysing water stress situations, since water scarcity and drought events usually appear for one or a few months during the year. When

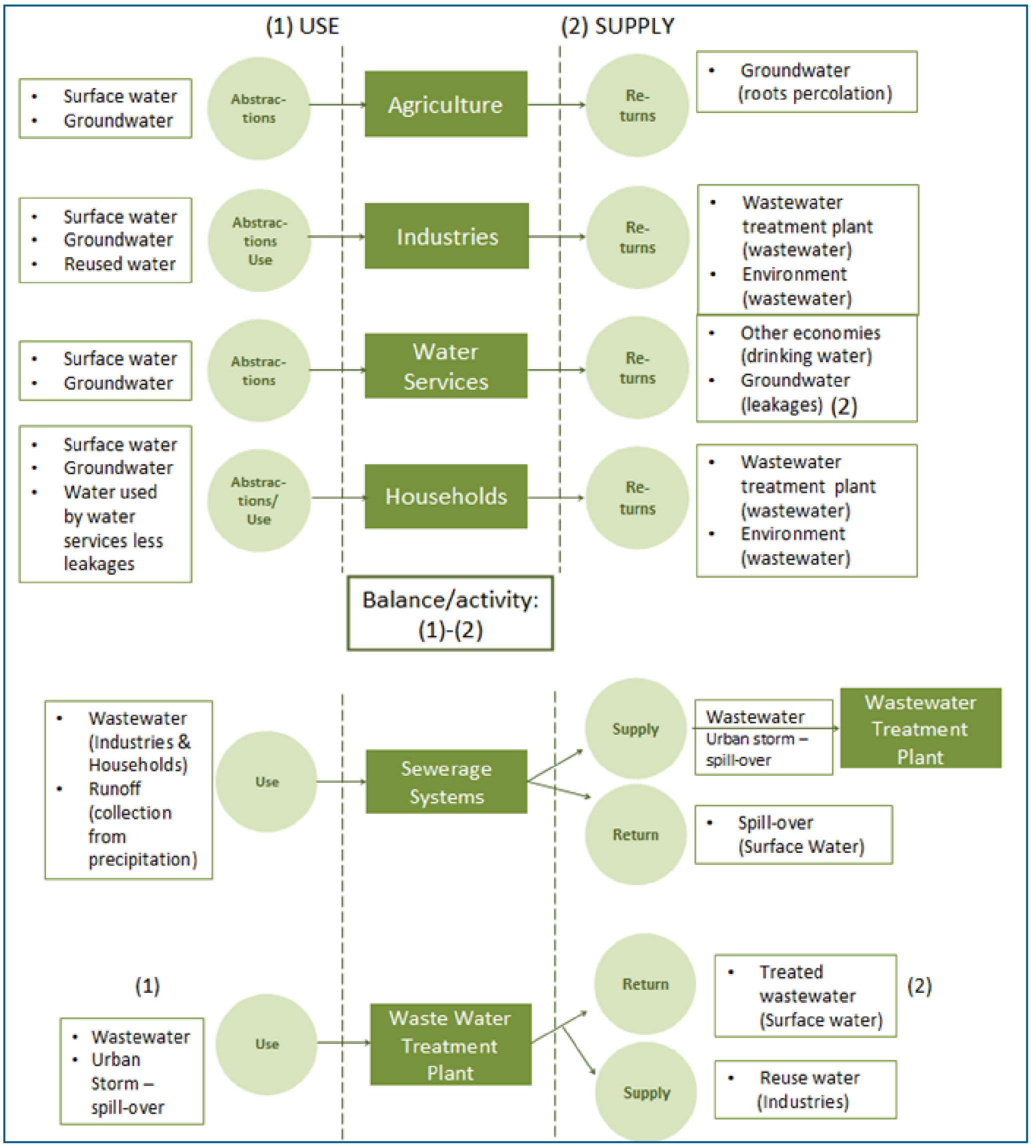

Figure 4 – Diagram representing the "Water Supply and Use Accounts" in the Arno River Basin.

datasets are only available on a yearly basis, monthly values are reconstructed using formulas or models. In compiling the WA tables, it has been kept the possibility to generate them for a specific month or a full calendar year.

On the one hand, the focus on three sub-basins allowed highlighting their main characteristics, thus adapting the choice of measures to the local context:

- Chiana valley: high agriculture water use;
- Bisenzio valley: high industrial water use;
- Pisa aquifer: high ground water use.

On the other hand, the investigation by sub-basins added complexity since it is more complicated to gather water flow data in terms of inflows or outflows by sub-units, for instance, shared aquifer and wastewater transfer in the Bisenzio valley. In addition, the datasets resulting from the hydro-modelling tool used (MOBIDIC) have taken the whole Arno River Basin as reference area.

2.4 Data compilation and assessment

The **interpretation of data is very important** when preparing the WA tables. Extensive exchanges with data producers are necessary. During the PAWA project, these exchanges have been supported by:

- Workshops with local stakeholders and data providers;
- The PAWA FTP repository to share modelled/calculated datasets that have been revised during the discussions (e.g., modelled monthly value for agriculture abstraction);
- Data analysis forms based on the parameters necessary for the WA tables.

The datasets used can be categorised as follow:

- Direct measurements; for instance, river discharge from gauge stations;
- Data from models (e.g., MOBIDIC for water balance and modflow for groundwater);
- Data from water rights and waste water discharge permits;
- Estimates based on expert judgement;
- Statistical surveys, mainly provided by the Italian National Institute for Statistics (ISTAT);
- Reference datasets; mainly geographical information (i.e., GIS layers) such as hydrographic networks, catchment areas, land cover and land use, groundwater bodies.

The main data sources used are reported in **Table 1**.

Table 1 – Main data sources used for filling in the SEEA-Water tables.

Provider	Main activity	Type of data sets
Nuove Acque S.p.A. Publiacqua S.p.A. Acque S.p.A. Gida SpA, etc.	Water Supply systems and wastewater management	Water abstraction Water supply Wastewater discharge Treated Wastewater supplied for reused
Provincia di Firenze, Arezzo, Prato, Pistoia, Pisa, Siena, Livorno, Lucca	Local government	Water abstraction Water levels (surface and groundwater)
Autorità Idrica Toscana	Water supply government	Water demand data
ARBA	River basin organisation	River discharge Surface and ground water balance Results from models
Regione Toscana	Local government	Climatic data
ISTAT	National Institute of Statistics	Water supply networks leakages Population / GDP (not yet exploited)

Some limitations and potential improvements have been identified:

1) Most of the water return data are based on expert estimations; therefore, a percentage of inaccuracy and uncertainty remains. A survey or a monitoring campaign could help in terms of data reliability.

2) When irrigation abstraction volumes are reduced, the total amount of irrigation groundwater losses and evapotranspiration gets affected because its value depends on the irrigation use. The irrigation technique is not taken into account because figures about its impact on the ratio of evaporation and irrigation losses are not available at the moment. Such information could help in terms of applying a more realistic (and lower) value of WEI+:
    a. Irrigation methods and efficiency data from Confagricoltori, the organisation representing the Italian farmers;
    b. Types of crops cultivated for each area in order to estimate abstraction from soil water for rain-fed agriculture and to improve evapotranspiration estimation;
    c. Satellite data on evapotranspiration for validating/improving modelled data.
3) All analyses are based on monthly variations over a year, this is sufficient to work on the most water-stressed months (i.e., summer). However, multi-year trends have not been investigated because they are deemed to be irrelevant due to the fact that water abstraction data are almost the same every year; water abstraction data result from fixed maximum values defined in water permits and not from monitoring data.
4) Water supply to industry and households is not differentiated:
    a. Water utilities could provide a breakdown by extrapolating data from their billing system.
5) Abstraction from surface water and groundwater for distribution (drinking water supply) is not differentiated:
    a. Water utilities could provide monthly breakdown for recent years.
6) The only variation on water abstraction has been introduced for prospective scenarios with a fixed increase of water demands by year due to population and activity growths. An improvement could be obtained by changing the growth ratio every year.
7) Soil water has not been taken into account:
    a. Satellite data on soil moisture can provide relevant estimations.
8) Hybrid economical accounts not yet explored:
    a. Investments and service costs could be provided by water utilities.

3 Building SEEA-Water tables

A Visual Basic Application (VBA) tool for MS-Excel has been produced by the PAWA partners to automatically compile the SEEA-Water "Physical Use & Supply" tables (PSUAT) and the "Asset Account" tables. Thus, it is possible to perform the compilation of tables and the production of thematic graphs, in a quick and reliable way, directly using the data stored in the PAWA Geo-Database that has been developed and populated for the project activities.

As shown in **Figure 5**, this tool, named "PAWA Scenario Tool V.1", allows using the historical data sets over the period 2006–2013 (exported from the PAWA Geo-Database) as well as modelled data generated from climate change scenarios or datasets simulating the impact of measures (e.g., water efficiency).

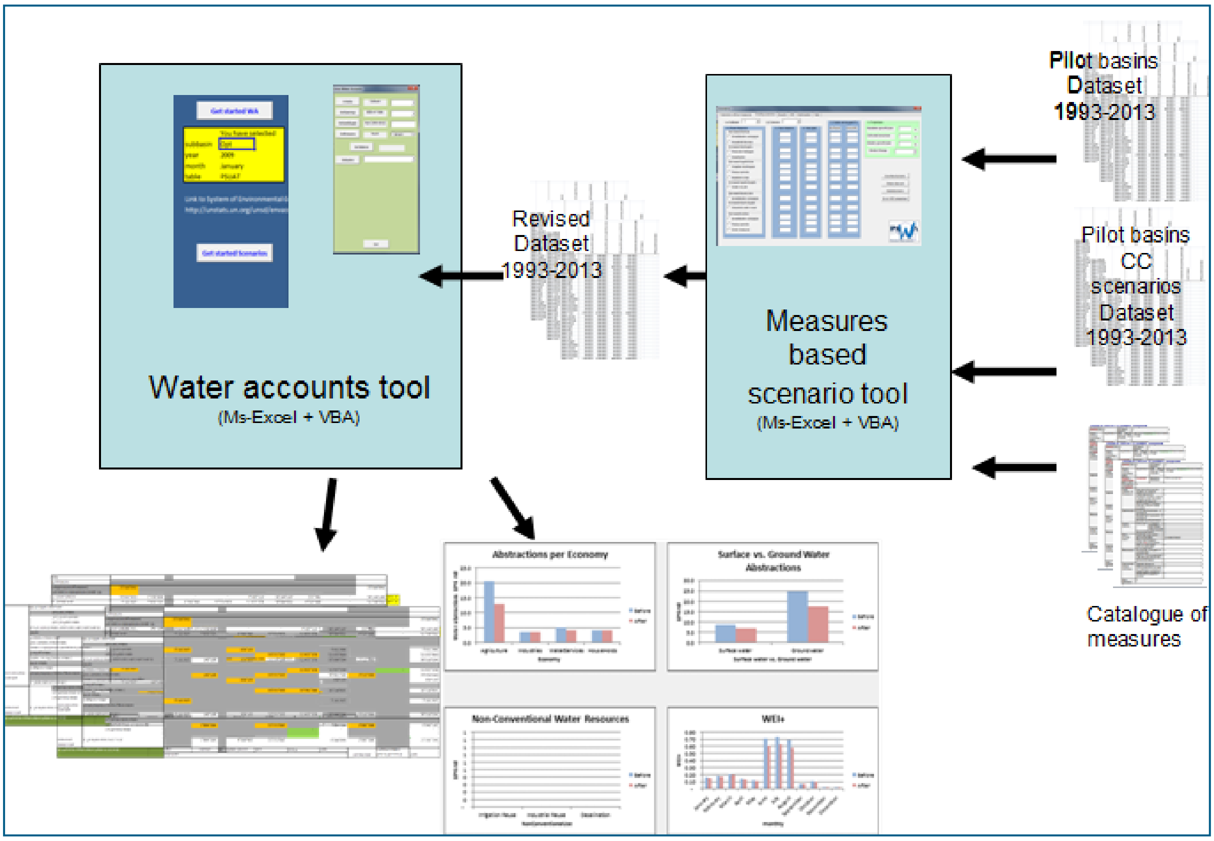

Figure 5 – Process followed to assess the impact of measures.

3.1 Water supply, use and asset tables

For the PAWA project, the following variations on PSUAT have been considered in comparison with standard SEEA-Water tables:

- All industries have been grouped together (as no breakdown between categories is available), while usually in SEEA-Water at least two separate groups are considered:
  - mining quarrying, manufacturing and construction industries (**ISIC** 5–33/ 41–48);
  - other industries, such as waste collection, treatment and disposal activities, materials recovery (38), remediation activities and other waste management services (39), and service industries (45–99).
- The sewerage activity (37) has been disaggregated into sewerage network and waste water treatment plant (WWTP), as it is more user-friendly and eases understanding of water flows and taking management decisions.

"Supply and Use" tables (**Figures 6** and **7**) are also useful (e.g., realistic values for water consumption) to assess the quality of the estimations done and data collected, in particular when monitoring data are available only for restricted periods (e.g., outflows from WWTP). Using colours to differentiate the monitoring data from modelled/estimated data is also very convenient in this process.

A. Physical water use table (Table III.3) [m3]		Activities							Households	Rest of the world	Total
		Agriculture	Industry	35	Water Services	Sewerage	WWTP	Total		(exports water)	
From the environment	1.a Abstraction for own use	18 539 762	3 728 788			25 278 831		47 547 381	4 229 734		51 777 114
	(Type of use) Hydroelectric power generation										
	Irrigation water	18 539 762						18 539 762			18 539 762
	Mine water										
	Urban run-off (urban storm water)					25 278 831	*15 167 299*	25 278 831			25 278 831
	Cooling water										
	Other										
	1.b Abstraction for distribution				5 165 185			5 165 185			5 165 185
	1.i From inland water resources	18 539 762	3 728 788		5 165 185			27 433 735	4 229 734		31 663 468
	Surface water	4 869 762	1 728 788		1 895 185			8 493 735	309 734		8 803 468
	Groundwater	13 670 000	2 000 000		3 270 000			18 940 000	3 920 000		22 860 000
	Soil water										
	1.ii Collection of precipitation					25 278 831	*15 167 299*	25 278 831			25 278 831
	1.iii Abstraction from the sea										
	1. Total abstraction (1.a+1.b(=1.i+1.ii+1.iii))	18 539 762	3 728 788		5 165 185	25 278 831		52 712 566	4 229 734		56 942 299
Within the economy	2. From other economic units	-	-		-	6 310 475	6 310 475	12 620 949	4 235 452		16 856 401
	Water services		-						4 235 452		4 235 452
	Recycle/Reused water		-					-			-
	Wastewater to sewerage / sewerage to WWTP					6 310 475	6 310 475	6 310 475			6 310 475
	Desalinated water							-			-
	3. TotalA (1+2)	18 539 762	3 728 788		5 165 185	31 589 305	6 310 475	65 333 515	8 465 185		73 798 700

Figure 6 – Example of "Physical Use" table.

B. Physical supply table (Table III.3) [m3]		Activities							Households	Rest of the world	Total
		Agriculture	Industry	35	Water Services	Sewerage	WWTP	Total		(Imports water)	
Within the economy	4. To other economic units		6 424 996		16 005 038	25 756 797	1 030 146	23 460 180	16 295 385		39 755 565
	4.a Reused water						1 030 146	1 030 146			1 030 146
	4.b Wasterwater to sewerage		6 424 996			25 756 797		6 424 996	16 295 385		22 720 381
	4.c Desalinated water										
Into the environment	5. Total returns (=5a+5b)	66 039	1 070 833		9 440 173	27 327 742	4 860 322	15 437 367	1 088 801		16 526 168
	Hydroloelectric power generation										
	Irrigation water	66 039						66 039			66 039
	Mine water										
	Urban run-off (storm water)					27 327 742	3 036 416	30 364 158			30 364 158
	Cooling water										
	Loses in distribution because of leakages				9 440 173			9 440 173			9 440 173
	Non treated wastewater		1 070 833			27 327 742		28 398 575	1 088 801		29 487 376
	Treated wastewater						4 880 155	4 880 155		19 833	4 880 155
	Other										
	5.a To inland water resources (=5a.1+5a.2+5a.3)	66 039	1 070 833		9 440 173	27 327 742	4 860 322	42 765 109	1 088 801		43 853 910
	5a.1 Surface water					27 327 742	4 860 322	32 188 065			32 188 065
	5a.2 Groundwater	66 039			9 440 173			9 506 212			9 506 212
	5a.3 Soil water										
	5b To other resources										
	6. TotalB (4+5)	66 039	7 495 829		25 445 211	53 084 539	4 860 322	37 867 401	17 384 186	19 833	55 251 587
	7. Consumption	264 155	3 212 498		-	-	20 896 475	24 373 127	72 587	- 19 833	8 440 676
	7a Loses in distribution (evap. Or malfunctioning meters)	198 116									198 116

Figure 7 – Example of "Physical Supply" table.

In the "Water Asset Accounts" (**Figure 8**), the relevant information is the balance and not the opening stock (and therefore closing stocks) that cannot be assess with sufficient accuracy. In addition, it must be noticed that for Pisa area (the only costal area studied) the groundwater flow to sea could not be estimated in a realistic way.

Pisa	EA.131.Surface water						
Asset accounts (Table VI.1) [m3]	EA.1311 Artificial reservoir	EA.1312 Lakes	EA.1313 Rivers	EA.131 SurfaceWater	EA.132 Groundwater	EA.133 Soil water	Total
1. Opening stocks	-	-	-	-	250,082,454,227.9	-	250,082,454,227.9
Increases in stocks			104,264,761.6	752,961.3	5,341,199.9	7,773,003.0	118,131,925.7
2. Returns				752,961.3	245,892.4		998,853.6
3. Precipitation						7,773,003.0	7,773,003.0
4. Inflows			104,264,761.6	-	5,095,307.5		109,360,069.1
4.a From upstream territories			104,264,761.6		1,069,416.7		105,334,178.2
4.b From other resources in the territory					4,025,890.8		4,025,890.8
Decreases in stocks		-	154,975,728.0	-	1,454,674.3	4,792,381.2	161,222,783.5
5. Abstraction					1,454,674.3		1,454,674.3
6.Evaporation/actual evapotranspiration						766,490.4	766,490.4
7. Outflows			154,975,728.0		-	4,025,890.8	159,001,618.8
7.a To downstream territories							-
7.b To the sea			154,975,728.0				154,975,728.0
7.c To other resources in the territory						4,025,890.8	4,025,890.8
8. Other changes in volume							119,634.6
9. Closing stocks		-			250,086,340,753.5		249,996,392,146.9
10.Balance	-	-	- 50,710,966.4	752,961.3	3,886,525.6	2,980,621.8	- 86,062,080.9

Figure 8 – Example of "Water Asset Accounts" table.

3.3 Comparison with EU water balance for Arno river basin

The European Commission DG Environment and the European Environment Agency produced in 2012 standard SEEA-Water accounting matrixes for "Uses and Supply" (based on SEEA-Water 2007) per basin and sub-basin at a monthly scale over an eight-year period (2001–2008). The calculation was built on the "European Catchments and Rivers Network System" (ECRINS) using accessible and homogeneous datasets and modelled data. It was aimed at making an assessment rather than taking management decisions, so a larger degree of uncertainty was acceptable.

The results for PSUAT and the related approach are documented in a report[1] dated June 2012. In that report, the Arno River Basin corresponds to the "Middle Apennines" and the PSUAT are provided for year 2002 (see **Figure 9**). Of course, the values reported in the EU water balance for the "Middle Apennines" cannot be compared against those of PAWA because the geographical scales are different and extrapolation is not possible. However, the analysis of the differences highlights interesting issues for future developments.

Appendix 1: SEEAW 2007 standard Table 3.1 of yearly water use & supply account matrix per Basin

Basin	WFD0000083	Physical use table		All volumes are in millions cubic meter (Mm3)			
Basin : WFD0000083 : Middle Appenines Year : 2002							
Somme de Vol	Étiquettes de Industries						Households
Étiquettes de lignes	01-03	05-33/41-43	35	36	37	38/39/45-99	00
2- Within the Economy; Use of water received from other economic units					**663**	**245**	**483**
Households					444		
Service industries					219		
Water collection, treatment and supply						245	483
1- From the Environment; Total abstraction	**173**	**114**	**628**	**1 241**		**1**	**13**
1311: Reservoirs	2			22			
1312: Lakes	0			1			
1313: Rivers	14	48	40	522		1	
132: Groundwater	156			696			13
21: Sea Water		66	589				
Total général	**173**	**114**	**628**	**1 241**	**663**	**246**	**496**

Basin	WFD0000083 :	Physical supply table		All volumes are in millions cubic meter (Mm3)			
Basin : WFD0000083 : Middle Appenines Year : 2002							
Somme de Vol	Étiquettes de Industries						Households
Étiquettes de lignes	01-03	05-33/41-43	35	36	37	38/39/45-99	00
4- To the Environment; Total returns	**581**	**682**	**3 603**	**3 080**	**5 295**	**210**	**314**
1313: Rivers		153	71	110	4 571	4	
133: Soil Water	581			2 970		206	314
21: Sea Water		529	3 532		724		
3- Within the Economy; Supply of water to other economic units		**20**		**4 365**		**1 753**	**2 661**
Sewerage		20				1 753	2 661
Service industries				1 469			
Households				2 896			
Total général	**581**	**702**	**3 603**	**7 445**	**5 295**	**1 963**	**2 975**

Figure 9 – "Supply and Use" table for Middle Apennines in 2002 produced at EU level with SEEA-Water 2007.

An obvious difference is the use of SEEA-Water 2007 tables for the EU water balance, while for the PAWA project the latest version of 2012 has been used. The presentation of the tables is a bit different. In the 2012 format, the items (rows) of the "Supply and Use" tables are more explicit, but require more data (see **Table 2**).

[1] Preparatory Action – Development of Prevention Activities to halt desertification in Europe – Service Contract to contribute to the building of Water and Ecosystem accounts at EU level – Final Report 2 – Uses & Supply – June 2012 POYRY / VITo.

Table 2 – Main differences in PSUAT between SEEA-Water 2007 and SEEA-Water 2012.

PSUAT items	SEEA-Water 2007 (EU)	SEEA-Water 2012 (PAWA)
Use within the Economy	Households → 37 Service Industries → 37	Waste water to sewerage
	Water collection, treatment and supply → 28/39/45-99 + Households	Water services → Industry + households Reused water → Industry
Use from the Environment	Reservoirs, Lakes, Rivers	Surface water
	Ground water	Ground water Soil Water
	Sea water	Sea water
Supply to the Environment (returns)	Item not considered in SEEA-W 2007	Return of non treated waste water
Supply to other economic activities	Water services → industry + households	Breakdown not considered

Taking into account the differences in structure, the content analysis is showing some different interpretations of the SEEA-Water items in particular in terms of water flows. It would be useful to share and compare the different approaches and to produce some EU recommendations to harmonise the production of the water accounts. The main differences identified are summarised in **Table 3**.

Table 3 – Different interpretation of SEEA-Water data items at EU and PAWA levels.

Table	EU water account (SEEA-Water 2007)	PAWA (SEEA-Water 2012)	Comments
Use table	No reused water [i.e., water collection, treatment and supply → Agriculture (01–03) + Industries (05–33/41–43)]	This water flow exists in one of the studied sub-basin	
	Sea water for industries (05–33/41–43) + Energy (35)	Not identified on the studied coastal sub-basin (Pisa)	Might exist in other sub-basins
	No use of ground water of industry	This water flow exist in the studied sub-basins	Information obtained by PAWA from water permits
	Hydropower or cooling for energy report	No energy production in the studied sub-basins	
Supply table	Water returned from agriculture (01–03) flows to soil water	Considered to be returned to ground water	Actually, part of the surplus of irrigation water flows into the soil and another part percolates to groundwater; the model used by PAWA provides the groundwater flow and the water used by the crop (including the soil water used later on by the crop)
	Water services return water to rivers and groundwater	Only groundwater was considered	For the purposes of the PAWA project, all returns from water services are considered as due to leakages percolating groundwater
	Sewerage (37) → rivers and sea	Sewerage (urban stormwater collected) →rivers	In PAWA, this breakdown has not be considered, since it is relevant only for one sub-basin (Pisa)

Given that, the EU water balance system uses ECRINS as reference structure, an analysis on the whole Arno River Basin has been carried out during the project.

ECRINS is a fully connected system of watersheds, rivers, lakes, monitoring stations, dams made from version 2.1 of the Joint Research database "Centre Catchment Characterisation and Modelling" (**CCM2.1**) and many other sources. The number of elementary catchments in ECRINS (with an average size of 92 km^2) is smaller than those in CCM2.1 (138,000 *vs.* more than 2,000,000). Only the main drainage system, comprising ~1.4 million km of rivers, has been kept. ECRINS is organized in four folders: *i*) "hydrography" that provides the current and archived layers of ECRINS; *ii*) "documentation" that contains the construction, coding and data models; *iii*) "Ancillary data" that provides computed data , such as the **Corine Land Cover**; and *iv*) "**WISE** data" that contains the publicly available datasets reported under the **Water Framework Directive 2000/60/EC**.

According to the latest official available dataset (see **WISE Main Rivers v1, draft April 2012**), 14 water bodies are listed in the Arno River Basin, as detailed in **Table 4**. The hydrographic network is composed of 112 different polylines, with a length varying between 100 m and 29 km (downstream element of the Arno main channel).

Table 4 – WISE water bodies in the Arno River Basin.

Code WISE	Name	Area (sq. km)
IT09CI_N002AR058ca	CANALE MAESTRO DELLA CHIANA	1083.9
IT09CI_N002AR082fi	FIUME ARNO CASENTINESE	721.8
IT09CI_N002AR081fi1	FIUME ARNO ARETINO	817.5
IT09CI_N002AR082fi2	FIUME ARNO VALDARNO SUPERIORE	2877.1
IT09CI_N002AR082fi3	FIUME ARNO FIORENTINO	5072.8
IT09CI_N002AR082fi4	FIUME ARNO VALDARNO INFERIORE	6633.9
IT09CI_N002AR082fi5	FIUME ARNO PISANO	7272.4
WISE IT09CI_N002AR093fi	FIUME ELSA MONTE	18.5
IT09CI_N002AR094fi	FIUME ELSA MEDIO SUP	119.9
IT09CI_N002AR095fi1	FIUME ELSA VALLE SUP	524.2
IT09CI_N002AR095fi2	FIUME ELSA VALLE INF	829.5
IT09CI_N002AR096fi	FIUME ERA MONTE	48.9
IT09CI_N002AR097fi	FIUME ERA MEDIO	215.9
IT09CI_N002AR098fi	FIUME ERA VALLE	586.0

For the Chiana valley (1st sub-basin studied in PAWA), the main basin channel (Canal Maestro della Chiana) is included in the hydrographic network (see **Figure 10**). The overlapping of information between the River Basin Management Plan water bodies and ECRINS network allows a direct information transfer between the two systems.

In the PAWA Geo-Database all hydrological, water supply, and use datasets are always referred to the WISE codification. Therefore, the correlation at water body scale is guaranteed. The water body is segmented in 17 polylines: if necessary, it is possible to re-arrange all available datasets

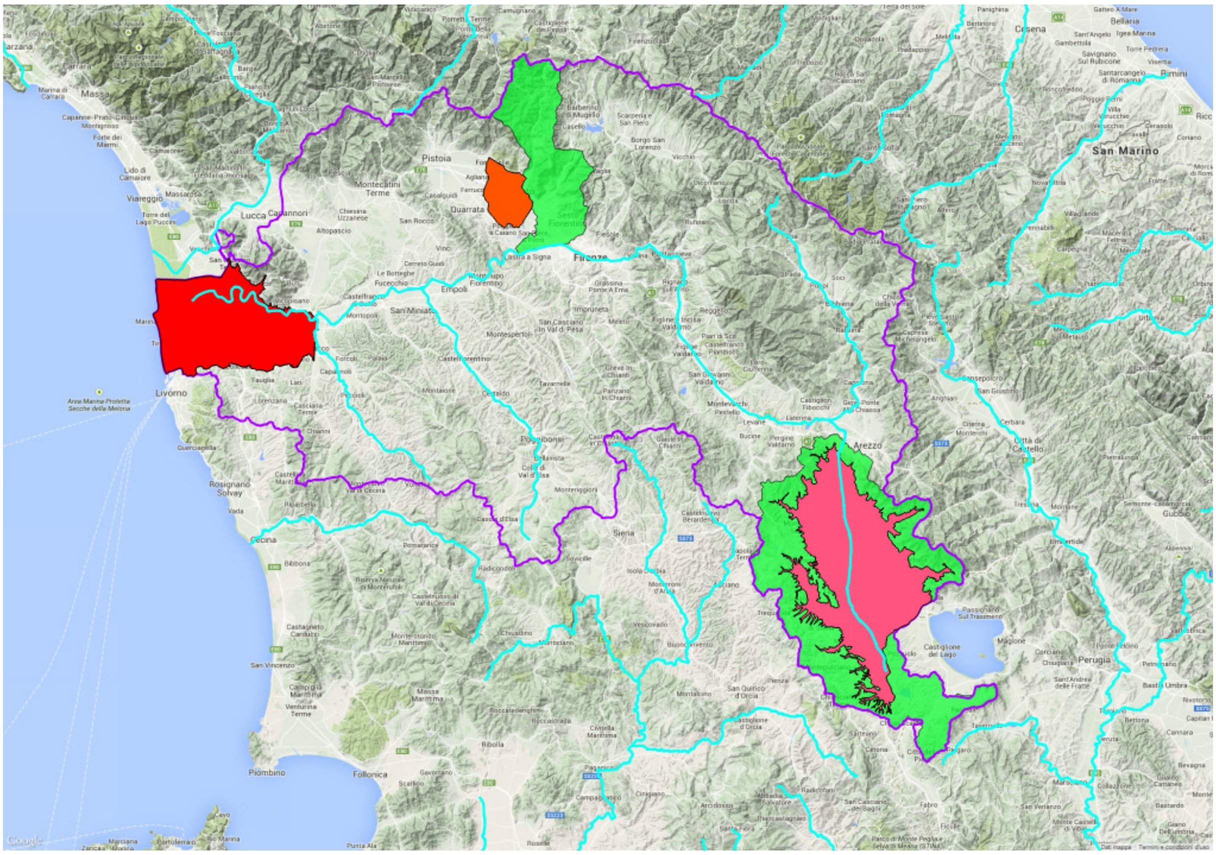

Figure 10 – Map of the ECRINS network (in cyan) overlapped to the three sub-basins identified for the PAWA activities.

(hydrological data extracted from model; water use volumes aggregated from point data) to the basin extension of each river reach.
Due to the basin dimension, Bisenzio valley and Prato aquifer (2nd sub-basin studied in PAWA) are neglected in the analyzed version of ECRINS network (see **Figure 10**), but data adaptation principles for information transfer are potentially the same.

The comparison for Pisa area (3rd area studied in PAWA) is impossible, since ECRINS is only covering surface bodies (see **Figure 10**) while territory studied is an related to an underground water body category (an aquifer).

Therefore, **comparison between PAWA results and EU water balance could only be done for Chiana sub-basin, if the dataset or water accounts tables would be provided by the European Commission**.

4 Optimisation of measures

The WA approach together with prospective scenarios based on the application of a set of measures and various climate change hypotheses allowed the assessment of their potential impact compared to a reference situation (i.e., without applying any measure). Thus, the **WA tables appear to be a good decision support tool** to define the most suitable water efficiency measures for a selected area.

A simulation tool is necessary to facilitate the process of calculating the WA tables, related indicators and graphs under various scenarios. As mentioned in **Chapter 3**, in the framework of the PAWA project, a prototype VBA tool based on MS-Excel has been set-up. This tool allows a lot of time saving when comparing different scenarios and it supports decision making to find the best combination of measures to be implemented in the different territories, in order to reach specific water saving targets. In the future, **economical assessment of measures implementation should be added** as it is an important criterion for planning. It could be done either by compiling SEEA-Water "Hybrid Economic Account" table or by adding some economical criteria related when simulating the implementation of measures with the tool.

As the **SEEA-Water tables do not take into account e-flows**, such requirement can be considered during the optimisation of measures process by defining **a specific target for the WEI+** indicator (set below 40% in the case of the simulation done for PAWA).

The main visualization outputs used have been values of indicators and graphs, if the approach was to be applied to all the sub-basins, the production of thematic maps would be useful for communication and decision making purposes.