View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Elsevier - Publisher Connector

Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 70 (2014) 563 – 572

Procedia Engineering

www.elsevier.com/locate/procedia

12th International Conference on Computing and Control for the Water Industry, CCWI2013

Complementary use of the WEAP model to underpin the development of SEEAW physical water use and supply tables

G. Dimova[a*], E. Tzanov[a], P. Ninov[b], I. Ribarova[a], M. Kossida[c]

[a] *University of Architecture, Civil Engineering and Geodezy, Sofia, Bulgaria,*

[b] *Bulgarian Academy Sciences- National Institute of Meteorology and Hydrology, Sofia, Bulgaria*

[c] *National Technical University of Athens, Department of Water Resources and Environmental Engineering, Athens, Greece*

Abstract

Two modern tools, the System of Economic and Environmental Accounts for Water (SEEAW) and the Water Evaluation and Planning System (WEAP), have been applied in combination to assess in a holistic way the available water resources and the socio-economic water needs within a selected river catchment. The approach is based on integration of hydrological information and economic data for water use in a coherent manner. The use of the WEAP model underpins the development of asset water accounts within the SEEAW platform, thus mitigating some difficulties in evaluating parameters that cannot be directly monitored. The studied catchment is the Vit River in Bulgaria, which is a tributary of the Danube River. An average year in terms of water resources availability was used for the case study. In addition to the demonstration of the applicability and the benefits of the suggested approach, important site specific outcomes were achieved, mainly getting a complete overview on the complex water resource and water use relations, as well as outlining measures for efficient water resource utilization at a river basin scale.

© 2013 The Authors. Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
Selection and peer-review under responsibility of the CCWI2013 Committee

Keywords: Water resources management, water balance; watter accounts, Water Evaluation and Planning System (WEAP); System of Economic and Environmental Accounts for Water (SEEAW)

* Corresponding author. Tel.:+359-2- 9635245
E-mail address: dimova_fhe@uacg.bg

1877-7058 © 2013 The Authors. Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
Selection and peer-review under responsibility of the CCWI2013 Committee
doi:10.1016/j.proeng.2014.02.062

1. Introduction

Water is not like any other commercial product; instead it is a heritage which must be protected, defended and treated with respect, OJ (2000). In 2000, the EU Water Framework Directive (WFD) has established the framework for sustainable protection of waters based on several innovative principles like sustainable water management at river basin scale, public participation in planning and integration of economic approaches. In 2007 Communication on water scarcity & droughts in the EU laid down a water hierarchy under which water demand management should come first, COM (2007). Seven main policy options were identified there among which: allocating water and water-related funding more efficiently; improving drought risk management and improving knowledge and data collection. At present limited progress has been achieved in implementing these policy instruments, in particular cost recovery policies are not completely applied, mostly due to lack of metering or narrow interpretation of the concept of water services by some Member States, COM (2012a). As a result, in all water-using sectors there is a high untapped potential for efficient water use.

In the most recent EU policy water related document, the Blueprint to Safeguard Europe's Water Resources, the Commission has identified several additional actions that could greatly improve the water management and water efficiency. The first proposed action is to developed water accounts at river basin and sub-catchment level aiming at, COM (2012b):

- providing detailed review on the physical water supply and use within a river basin;
- allowing the managers to do sustainable planning on water resources at river basin scale respecting the complex environment and economic interactions.
- helping to identify the ecological flow ensuring that the needs of nature are respected and that water balances within a river basin stay within sustainable limits.

In order to provide a uniform platform of water accounting throughout the EU Countries the System of Economic and Environmental Accounts for Water (SEEAW) was proposed. Although it is relatively new system, over fifty countries around the world are compiling or planning to compile water accounts, UN (2011). A key element in the SEEAW concept is setting of tables for physical water supply and use coupling hydrological and economic information. The experience showed that SEEAW tables require a more extensive data set that is usually available. This provoked searching of a complementary means for completing the necessary data set. The paper discusses an approach, developed within the EU Project "Assessment of water balances and optimization based target setting across EU river basins" (ABOT). Water Evaluation and Planning System (WEAP) modeling platform was selected as an additional tool. The approach was applied and tested in Vit River Basin in Bulgaria.

Nomenclature

EEA	European Environment Agency
EU	European Union
HPP	Hydro Power Plant
ISIC	International Standard Industrial Classification
SEEAW	System of Economic and Environmental Accounts for Water
UNSD	United Nations Statistics Division
WEAP	Water Evaluation and Planning System

2. Methodological Approach

The SEEAW was developed by the UNSD in collaboration with the London Group on Environmental Accounting, UN (2012). The idea of water accounts is not new – making water balance of a certain system (e.g. reservoir or industrial unit) is a common approach that helps the managers to outline certain trends, to react adequately on forthcoming changes and finally to undertake measures for efficient water use. The innovation within the SEEAW is to put together physical data for natural phenomena (e.g. rainfall, hydrological data) with economic data for water use from different sectors (agriculture, industry) and thus to generate a comprehensive picture of the natural hydrological cycle and its links to the economy. The SEEAW scale of application, as originally designed, is at country level and annual resolution. In the present study we have applied the SEEAW framework at a much finer spatial scale, i.e. the river basin. This system is an attempt to provide the 'missing link' in many river basins for water management. It is intended to specify how much water flows in and out of a river basin and how much water can realistically be expected to be available before allocation takes place.

The general philosophy of the SEEAW is that the economy and the inland water resource system of a given territory are in continuous interactions. The inland water resource system of a territory is composed of surface water, groundwater and soil water and the natural connections between them. The economy of a territory consists of different types of water users who abstract water for production and consumption purposes and put in place the infrastructure to store, treat, distribute and discharge water back to the natural resources, UN (2012).

The classification of economic users in the SEEAW is presented according to the ISIC (http://unstats.un.org). Based on the type of production several main groups of industries are featured:

- ISIC 1-3 - agriculture, forestry and fishing;
- ISIC 5-33, 41-43 - mining and quarrying, manufacturing and construction;
- ISIC 35 - electricity, gas, steam and air conditioning supply;
- ISIC 36 - water collection, treatment and supply;
- ISIC 37 - sewerage
- ISIC 38,39,45-99 corresponds to the service industries;

The SEEAW physical water supply and use tables make possible to analyze the origin of the water abstracted by different economic sectors, the transfers within the economy, and finally the returns to the water resources. Three main types of flows are discussed for each group of economic activities: *(1) from the environment to the economy; (2) within the economy; (3) from the economy to the environment.* The water use table is obtained by merging information on water use: the total water intake of an economic unit is the result of direct water abstraction (flows from the environment to the economy) and water received from other economic units (flows within the economy). Similarly, the water supply table is obtained by merging information on the two types of water flows leaving an economic unit: one destined to other economic units (flow within the economy) and the other returned to the environment (flow from the economy to the environment). Physical supply and use tables can be compiled at various levels of detail, depending on the policy concern of a country and data availability.

Although the SEEAW concept is relatively simple, its implementation requires collecting a variety of data from numerous actors and stakeholders. Populating the physical supply and use tables requires adoption of additional tools since the existing information is often:

- Not complete or not detailed enough – usually the flow monitoring is scarce, as either the flow is measured at the abstraction point or at the discharging point thus making hard to evaluate the consumption within the economic unit, the losses through physical leakages or evaporation
- The available data sets can't be used directly, since the system boundary which they represent does not match the boundaries of the river basin - usually data are available at the level of administrative units (settlements, districts) or business units (water supply operators or manufacturers).
- Some important water related parameters cannot be measured directly, like evaporation, evapotranspiration, water exchange between surface and ground waters;

Furthermore often the existing data at national level are neither fully coherent nor fully consistent with the SEEAW concept and its terminology. Compiling them must therefore be done with caution while harmonization, normalization and modeling steps are often needed, EEA (2012). For this reason the WEAP model was selected in the case study of Vit Basin to underpin the development of SEEAW tables.

2.1. The Water Evaluation and Planning System (WEAP)

The WEAP system (http://www.weap21.org/), developed by the Stockholm Environment Institute's U.S. Centre, was selected in the current application because of its strengths: i) it is a generic, integrated water resource planning software tool that provides a comprehensive, flexible and user-friendly framework for development of water balances, scenario generation, planning and policy analyses; ii) it can be applied to municipal and agricultural systems, a single watershed or complex trans-boundary river basin systems; iii) It can simulate a broad range of natural and engineered components of these systems, including rainfall runoff, baseflow and groundwater recharge from precipitation; sectorial demand analyses; water conservation; water allocation priorities, reservoir operations; hydropower generation; pollution tracking and water quality; vulnerability assessments; and ecosystem requirements and iv) it has also an internal financial analysis module that allows the user to investigate cost-benefit implications for various management alternatives under different future scenarios. SEI (2011). Since the model is analytical and physical based, it makes possible to better represent some salient features of the hydrological cycle, i.e. surface-groundwater interaction, returned water, transfers etc.

The development of water balance through WEAP requires a certain set of climate and hydrological data, as well as data on water supply and water demand in order to map the existing water resources and users within the basin and to allocate the abstraction and discharge of water. The model of the water balance of the Vit RB using the WEAP several key steps have been performed:

1) Mapping of water resources and users and the connections among them (abstractions, discharge, water transfer);
2) Defining of priorities in water abstraction from different water supply sources to different users;
3) Hydrological modeling – a module in WEAP is created to simulate the rainfall - runoff processes in the watershed, rendering an account of existing processes of evapotranspiration, infiltration losses and transformation of excess precipitation into surface runoff. Within the hydrological modeling the following have also been undertaken:
    a. Modeling of water use by different economic units (industrial units, settlements) including monthly water demand, water losses and consumption;
    b. Defining the potential evapotranspiration for different crop and the efficiency coefficient of the irrigation system;
4) Input of water losses along the distribution networks and evaluation of the resulting flow to the groundwater and/or evaporation.
5) Running of the model and calibration;

3. Case Study Vit, Results and discussion

3.1. Description of the catchment area

The Vit River basin is situated in the central northern Bulgaria with watershed area covering 3220 km^2 (Fig.1). The river starts from the Stara Planina mountain at an altitude of 2030 m, flows through the central part of Danube Valley and discharges into the Danube river. Within the catchment two administrative districts are situated - Pleven and Lovech, including in total 11 Municipalities, 7 towns and 74 villages. The biggest town is Pleven - a district center with population over 100 000 residents; the population of the rest of the towns vary between 2 800 and 10 600 residents; the population of the villages varies between 50 and 3800 residents. The water supply system is operated by two companies and it is characterized with a quite high share of non-revenue water (50%), mostly due to significant physical leakages resulting from the outdated pipe network. There is a number of industrial water consumers concentrated mainly in two towns: Pleven and Dolna Mitropolia. At present, the irrigated agricultural land covers 0.60% of the territory; in the past however the share of the irrigated agricultural land was much higher (22%).

Within the catchment there are four big reservoirs of economic significance – Sopot , Telish , Gorni Dabnik and Dolni Dabnik and several smaller reservoirs that are used randomly, mainly for flood protection of the towns. The latest are not actively involved in the water cycle of the river basin, since during the last years they have been empty. On the territory there are also 3 HPPs in operation. In addition, there are numerous small water consumers irregularly spread over the territory.

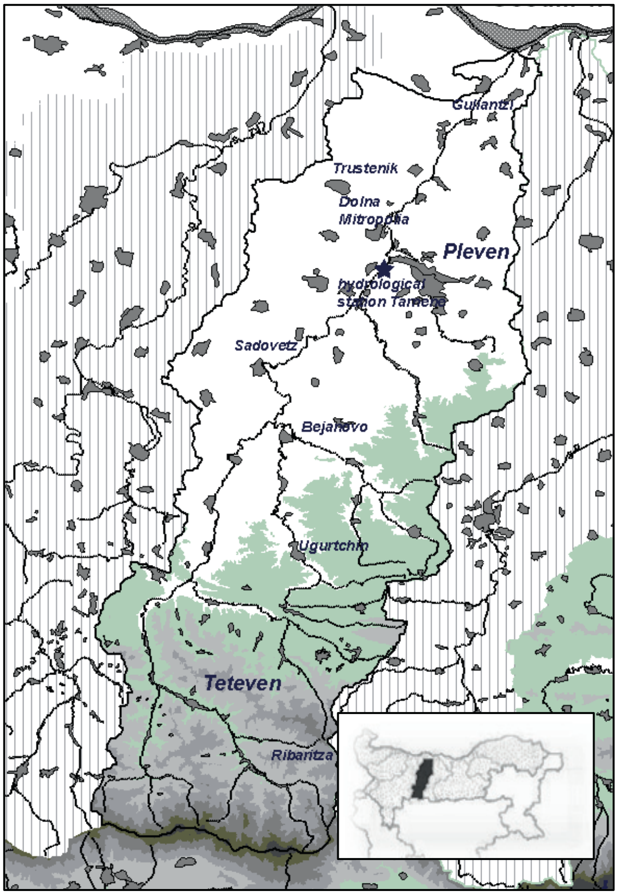

Figure 1. Vit river basin (the small map presents location of Vit basin in Bulgaria)

The main water sources within the catchment are: Vit river and its tributaries, groundwater, rainfall and snow events and the artificial reservoirs for seasonal/annual water storage; while the main water users are: agriculture, hydropower plants (HPP), the settlements (incl. both water for potable purposes and for industrial needs) and other industrial users not mentioned above (including water supply and sewerage operators)

The relation between the different water sources and water users within Vit Basin is very complex. There are plenty of existing technical connections (channels, pipes, boreholes) among the major water sources and the different water users (Fig. 2). Due to the seasonal fluctuations of the river flow, water abstractions directly from the river are mainly used for feeding the reservoirs and for hydropower generation. The reservoirs are built in cascade as the upper reservoirs feed the lower ones and thus one and the same amount of water is used several times. Industrial water supply and water for irrigation are mostly provided by the reservoirs. Groundwater is used for industrial and potable water needs. Since groundwater abstraction requires pumping, therefore costs for energy have turned to be a costly option for water yield. That's why imported water from the neighboring basin, transferred by gravity, is also used for drinking water supply, accounting for about 80% during the last years.

Along with the composite engineered process of water transportation between the water sources and water users, there are complex natural processes like evaporation and evapotranspiration, groundwater exchange and run-off precipitation that cannot be directly measured. A simplified model of interconnections among the sources and the water users is presented on Fig. 3. The dotted lines show flows that cannot be directly measured, but rather evaluated through development of water balance using the WEAP model.

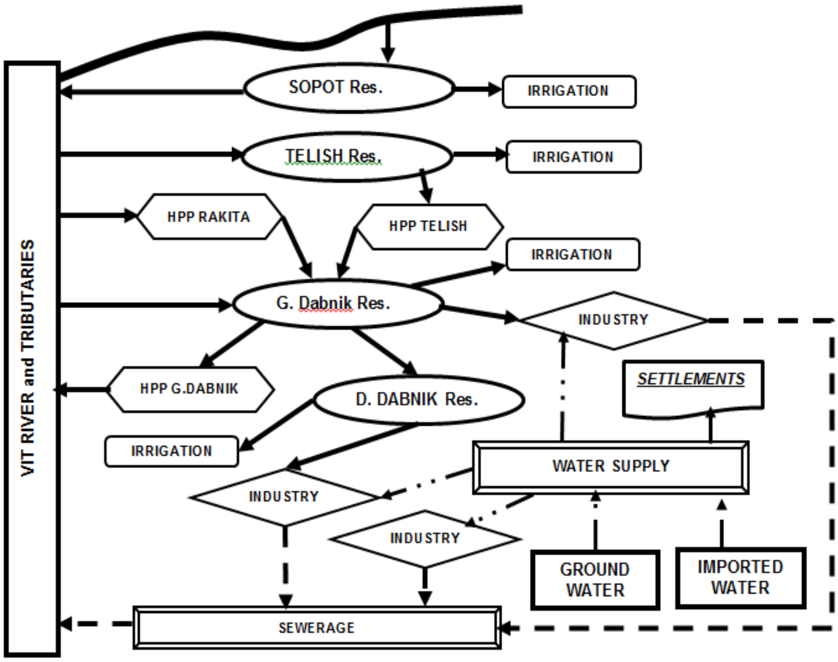

Figure 2 Simplified diagram of the main existing technical connections among the water sources and water users within the Vit River Basin

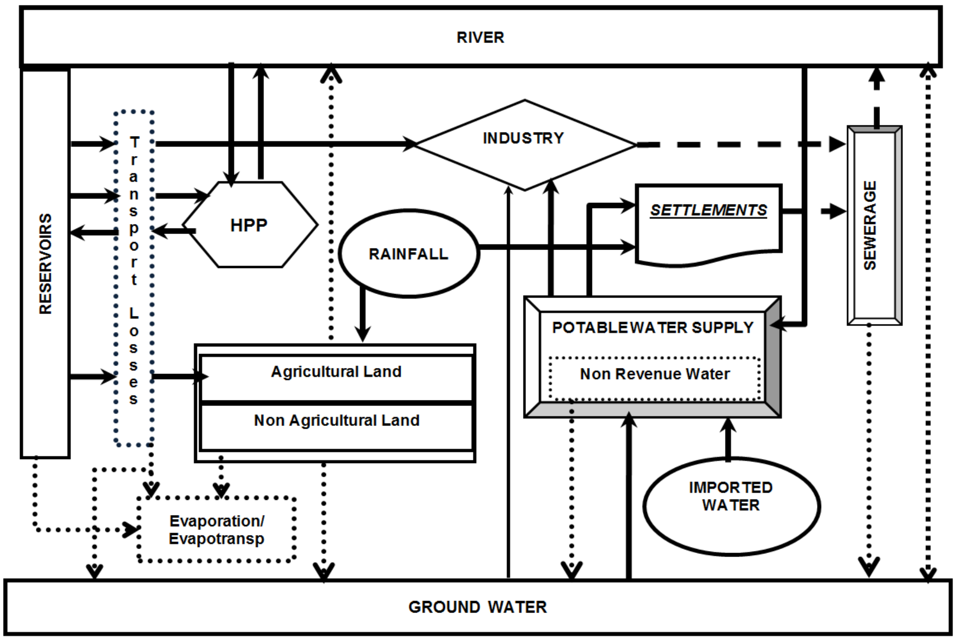

Figure 3. Simplified diagram of water flows within the Vit River Basin

3.2. Modeling of the VIT River Basin using the WEAP software

For the purpose of developing the water balance in the Vit basin using the WEAP, the following hydrological and socio-economic datasets have been collected for the period 2000-2009:

- Monthly stream flow data at the hydrological gauge of Tarnene for the period 2000-2009;
- Annual (2000 -2009) and monthly (2009) data for supplied and accounted potable water to different users within the settlements;
- Monthly data on reservoir inflow, outflow, volume and abstraction (irrigation, industrial needs) for the significant reservoirs and for the year 2009
- Monthly and annual data on surface and groundwater abstraction for industrial needs or hydropower production according to the permissions issued by River Basin Directorate;
- Annual data for 2009 regarding the irrigated agricultural land (areas, crops and the type of irrigation);

The existing water resources and water uses were mapped using design nodes in the WEAP model; additional design nodes were added simulating pumping stations, controllers of inflows and outflows of the reservoirs and connections among water resources and users.

Crop requirements have been calculated assuming a demand site with simplified hydrological and agro-hydrological processes such as precipitation, evapotranspiration, and crop growth, separating irrigated and rainfed agriculture. The potential evapotranspiration for the irrigated crops has been determined according to literature references. Precipitation is divided into effective precipitation which is used for evapotranspiration, and direct run-off to the surface water. The effective precipitation which is not utilized for evapotranspiration is simulated again as runoff that can be proportioned as flow to the river and flow to the groundwater. If the effective precipitation is less than the potential evapotranspiration for the irrigated land, then additional water should be supplied through abstraction from the available water resources.

The WEAP model was calibrated for 2009, which represents an average year in terms of water resources availability. Four parameters were used for the calibration (water volumes of Sopot, Gorni Dabnik and Telish reservoirs and stream flow at the Tarnene station). The difference between the calibrated and simulated water volumes for three of the reservoirs vary between 0.45 and 6%. The observed and simulated monthly flows at the hydrometric station of Tarnene have an average annual difference of less than 3%. This goodness of fit metrics give confidence that all the natural hydrological and anthropogenic factors were adequately modeled.

3.3. Filling in SEEAW Tables

Using the WEAP model outputs the SEEAW physical water supply and use tables have been completed as presented in the section below.

Table 1. Physical use table for the Vit River Basin, for the average year 2009, (units in million m^3)

	Industries (by ISIC categories)							**House holds**	**Rest of the world**
	1-3	5-33, 41-43	35	36	37	38,39, 45-99	Total		
1. Total abstraction	**14,9**	**3,78**	**84,0**	**7,13**	**0,18**	**0,87**	**110,8**	**0,0**	
1.a. Abstraction for own use	14,9	3,78	84,0	0,0		0,87	103,5	0,0	
1.b. Abstraction for distribution	0,0	0,0	0,0	7,13	0,0	0,0	7,13	0,0	
1.i. From water resources:	14,9	3,78	84,0	7,13	0,0	0,87	110,6	0,0	
1.i.1 Surface water	2,95	0,42	80,4	2,15	0,0	0,0	86,0	0,0	
1.i.2 Groundwater	0,0	3,36	3,5	4,99	0,0	0,87	12,7	0,0	
1.i.3 Soil water	11,9	0,0	0,0	0,0	0,0	0,0	11,9	0,0	
1.ii. From other sources:	**0,0**	**0,0**	**0,0**	**0,0**	**0,18**	**0,0**	**0,18**		
1.ii.1 Collection of precip.	0,0	0,0	0,0	0,0	0,18	0,0	0,2	0,0	
1.ii.2 Abstraction from the sea	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	
2. Use of water received from other economic units	**6,52**	**1,19**			**13,36**	**2,16**	**23,2**	**7,00**	**12,3**
3. Total use of water (=1+2)	**21,4**	**4.97**	**84,0**	**7,13**	**13,54**	**3,03**	**134,1**	**7,00**	

Table 2. Physical supply table for the Vit River Basin, for the average year 2009(units in million m3)

	Industries (by ISIC categories)							House holds	Rest of the world
	1-3	5-33, 41-43	35	36	37	38,39, 45-99	Total		
4. Supply of water to other economic units	**0,0**	**3,69**	**8,55**	**9,40**	**0,0**	**2,43**	**24,1**	**3,86**	
of which:							0,0		
4.a. Reused water	0,0	0,0	7,48	0,0	0,0	0,0	7,5		
4.b. Wastewater to sewerage	0,0	3,69	1,07	9,40	0,0	2,43	16,6	3,86	
5. Total returns (=5.a+5.b)	**9,10**	**0,60**	**73,8**	**9,06**	**13,5**	**0,29**	**106**	**2,44**	
5.a. To water resources	9,10	0,60	73,8	9,06	13,5	0,29	106	2,44	
5.a.i. Surface water	5,14	0,60	73,8	0,0	10,9	0,29	90,7	0,0	
5.a.ii. Groundwater	3,96	0,0	0,0	9,06	2,6	0,0	15,6	2,44	
5.a.iii. Soil water	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	
5.a. To other sources (e.g. sea)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	
6. Total supply of water (=4+5)	**9,10**	**4,29**	**82,3**	**18,5**	**13,5**	**2,73**	**130**	**6,30**	
7. Consumption (=3-6) of which	**12,3**	**0,68**	**1,62**	**-11,3**	**0,0**	**0,30**	**3,6**	**0,70**	
losses through evaporation	2,86								
trade losses				1,0					

3.4. Discussion on the applicability of the approach

The simulated monthly values by the WEAP model enable the detail assessment of the water resources in the studied watershed. The water balance modelling allowed determining some parameters that are required in the SEEAW tables and which cannot be products of monitoring and reporting alone, such as:

- the potential evapotranspiration for the non-irrigated land,
- the effective precipitation and the percentage distribution between the surface and groundwater bodies of the non-effective precipitation run-off,
- the losses along the water distribution networks and the resulting flows to the groundwater and for evaporation;
- the water received from other economic units (ISIC 1-3 and ISIC 5-33, 41-43);
- the returns to groundwater and surface water;
- the amount of soil water.

For complex systems like the presented case study, characterized with multiple reservoirs connected in cascade, the filling of SEEAW water supply and use tables is quite challenging, since the reservoirs are not identified as “economic” unit most probably because they store water and this is not considered as “production unit”. Within the SEEAW platform they belong to the general category “surface water”. The construction and operation of such reservoirs however demands huge investments and significant expenses for operation and maintenance. Therefore their consideration as “economic unit” should not be neglected.

3.5. Discussion on the site specific results

The results have been analysed from three different perspectives:

(1) Identifying the most significant water users within the system;
(2) Analysing the water consumption (e.g. the water that is not returned to the water sources) and
(3) Analysing the level of water reuse within the system.

Figures 4 and 5 present the main results from the physical water supply and water use tables. The total water use within the Vit River Basin in 2009 amounts to 134 million m^3. The electricity and steam producing industries (ISIC 35) have the biggest share (63%), followed by the agriculture (16%) and sewerage (10%). It should be noted however that the HPPs that belong to this group are situated in cascade (Fig. 2) thus one and the same amount of water is registered several times. Also a part of the water used by the industries with code ISIC 35 is reused afterwards from other economic units like agriculture and industries.

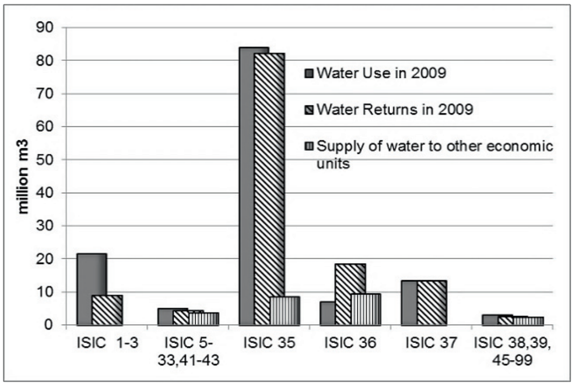

Figure 4. Water use and water returns of the different economic units within the Vit Basin for the year 2009

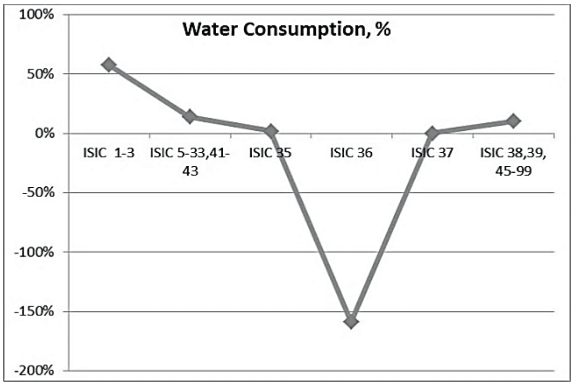

Figure 5. Percent of water consumption over total use of water for the economic units within the Vit Basin for the 2009

Concerning the water returns, amounting in total at 127 million m^3, the largest share belongs again to the industries with code ISIC 35 (63%), followed by the drinking water industry (ISIC 36) which holds 14% and by the wastewater collection and treatment (ISIC 37), whose share is 11%. In the specific case for Vit Basin, as mentioned above, significant amounts of drinking water are imported from the neighboring basin and that is why the return is bigger than the water used for potable purposes within the river basin. The imported water is registered in the SEEAW physical use table in column "rest of the world". This is also the reason for the negative figure for consumption for the industry with code ISIC 36 in the physical supply table, as well as the negative percentage reaching -160% (Fig. 5). It should also be noted that the physical leakages of the drinking water supply network that result in direct groundwater recharge are extremely high – 9,1 million m^3, i.e. almost 50% of the abstracted water (Table 1: 5a.ii; ISIC 36).

Normally the agriculture has the biggest percentage of consumed water, almost reaching 60%. The water supply table shows however that the transport losses are significant, reaching almost 24% of the consumed water for irrigation (Table 2: 7; ISIC 1-3)

Concerning the supply of water to other economic units it amounts at 24,1 million m^3, which represents around 18 % of total water abstraction, as the shares of potable water industry (ISIC 36) and electricity steam production units (ISIC 35) are the largest (Fig. 4). The amount of reused water however is relatively small – 7,5 million m^3 provided by the industries with code ISIC 35 for further use by agriculture and/or other industries.

4. Conclusions

By studying the SEEAW tables and the proposed methodology, the authors have identified that some elements/parameters of the tables are very difficult to fill based on observed and measured data (e.g. soil water, flows between the water resources from one water body to another). That is why analytical water balance modelling in WEAP was implemented to provided (as output of the modelling) some of these very challenging parameters to feed the SEEAW tables.

As a global conclusion the WEAP software is a reliable tool that can easily support the production of water accounts under the SEEAW methodology, where many of the requested parameters in the SEEAW table cannot simply be obtained as products of reporting but require the set-up and output of a detailed water management model.

Concerning the water use and supply tables under the SEEAW platform their future development could focus on precising the water use in complex systems, where there are multiple reservoirs, cascade transfers of water and imported water outside the river basin.

The application of the developed approach for the specific case of Vit Basin revealed that significant efforts should be undertaken for decreasing the water leakages within the water supply network and during the transportation of the irrigation water. Thus the water demand in these sectors would significantly decrease, resulting in a decrease of water abstraction. Measures for increasing water resuse should also be considered in the future.

Acknowledgements

This work was supported financially by the European Commission – DG Environment, ABOT project, Grant Agreement no. 07.032900/2011/612888/SUB/D1. The authors thank ViK Pleven AD, Irrigation Systems Pleven and the Danube Basin Directorate for the fruitful discussions and for providing the necessary data.

References

Communication from the Commission to the European Parliament and the Council, 2007 (414 final). Addressing the challenge of water scarcity and droughts in the European Union, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0414:FIN:EN:PDF

Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the committee of the regions, 2012a (672 final). Report on the Review of the European Water Scarcity and Droughts Policy, http://ec.europa.eu/environment/water/quantity/pdf/COM-2012-672final-EN.pdf

Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the committee of the regions, 2012b (673 final). A Blueprint to Safeguard Europe's Water Resources, European Environment Agency, 2012. Towards efficient use of water resources in Europe, EEA Report No 1/2012, ISSN 1725-9177,

Official Journal of the European Communities, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, L 327/1

Stockholm Environment Institute, 2011. WEAP Water Evaluation And Planning System User Guide. Stockholm Environment Institute, U.S. Center Somerville, MA 02144 USA, http://www.weap21.org/index.asp?action=208

United Nations (2012). System of Environmental-Economic Accounting for Water. United Nations, Department of Economic and Social Affairs, Statistics Division, New York, 2012. ST/ESA/STAT/SER.F/100 United Nations publication. http://unstats.un.org/unsd/publication/seriesf/Seriesf_100e.pdf

United Nations World Water Assessment Programme (WWAP) and United Nations Statistics Division (UNSD), 2011. Monitoring framework for water. The System of Environmental-Economic Accounts for Water (SEEA-Water) and the International Recommendations for Water Statistics (IRWS), http://unstats.un.org/unsd/envaccounting/WWAP_UNSD_WaterMF.pdf