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**Water in artificial reservoir –
A produced asset?**

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² The views expressed in this paper are the views of the authors and do not represent the views of UNSD or Austrian Umweltbundesamt GmbH (Austrian Environment Agency)

Treatment of water in artificial reservoirs

Issue 16

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Introduction

1. Issue number 16 of the list of issues for the revision of the SEEA covers water in artificial reservoirs. There are arguments in favor of changing the current treatment of artificial reservoirs as non-produced assets to produced asset. Considerable money is spent to build dams to retain the water from flowing downstream to the sea. Also, continuous control and management of the water resources is exercised both in the case in which the water is used for abstraction, purification and distribution, or for other uses such as hydroelectric power generation. It is argued that in line with the definition of cultivated assets in the SEEA and in the SNA, water in the reservoirs should be considered a produced asset. This would imply that, in parallel with the treatment of natural growth of cultivated forest and fish as produced asset, net recharge of water in the reservoir would constitute production and would be recorded as capital formation³.

2. The issue of water in artificial reservoir as a produced asset was discussed in several occasions, namely during the drafting of the System of Environmental-Economic Accounting for Water (SEEAW) and the update of the System of National Accounts (SNA). Both the SEEAW and the SNA continue to treat water in artificial reservoir as a non-produced asset. The SEEAW clearly states that the discussion on whether to consider water in a reservoir as a produced asset has not yet concluded. For this reason, the SEEAW has retained the classification of the SEEA-2003 (SEEAW paragraph 6.23). More recently, the Expert Group Meeting (EGM) on the International Recommendations on Water Statistics (IRWS) held in New York, USA, 5-7 November 2008 identified the issue of the artificial reservoirs being considered part of the environment, and not the economy, as an issue that needed clarification in the SEEA revision process and recommended that the matter should be brought to the attention of the London Group⁴.

3. This paper discusses the reasoning of treating water in artificial reservoirs as a produced asset and it shows the consequences of this change in the asset classification, supply and use tables and asset accounts.

Water in artificial reservoirs: part of the economy or the environment?

4. In the SEEA-2003, in the SEEAW and in the 2008 SNA the stock of water held in reservoirs is considered in as a non-produced asset and is included in the asset accounts as a subcategory of “surface water”. Water enters the economy only when it is abstracted from the environment.

5. As such the changes to the natural hydrological regime due to artificial reservoirs such as net recharge are not currently recorded in the physical supply-use tables, but considered as a part of “natural” interactions between inland water resources and the atmosphere. This may lead to a

³ (<http://unstats.un.org/unsd/envaccounting/seearev/restricted/issue.asp?iID=23&vID=1>).

⁴ Summary of Recommendations and Conclusions of the Expert Group Meeting on IRWS (UNSD 2008): <http://unstats.un.org/unsd/envaccounting/irws/egm2008/ac170-8.pdf>

significant distortion of the real world situation in the water accounts and may have implications for decisions on the building or reservoirs, the allocation of water and the calculation of water consumption and productivity for the units operating artificial reservoirs. Several studies show that the increased surface area of reservoirs often leads to high volumes lost by evaporation⁵.

6. The SNA 2008 defines produced assets as non-financial assets that have come into existence as outputs from production processes that fall within the production boundary of the SNA. (2008 SNA paragraph 10.9a.)

7. In the 2008 SNA the growth and regeneration of crops, trees, livestock or fish which are controlled by, managed by and under the responsibility of institutional units constitute a process of production in an economic sense. Growth is not to be construed as a purely natural process that lies outside the production boundary (2008 SNA paragraph 6.136).

8. The above arguments used to draw the line between cultivated and non-cultivated crops and trees can be used also in the case of water. The recharge of water in artificial reservoirs constitutes a process of production. The water recharge should not be considered as a purely natural process as the natural course of water is changed. Not only do dams have to be built but also activities of operation and management of the dam that regulate the stock level of the water have to be exercised on a continuous and regular basis (SEEAW paragraph 6.23).

9. The SNA 2008 defines inventories as stocks of outputs that are still held by the units that produced them prior to their being further processed, sold, delivered to other units or used in other ways and stocks of products acquired from other units that are intended to be used for intermediate consumption or for resale without further processing (2008 SNA 10.12). Water in artificial reservoirs has therefore the characteristic of being an inventory: it came into existence in the current period or in an earlier period and is held for sale, used in production or other use at a later date.

10. Apart from the losses of water in reservoirs due to evaporation and seepage to groundwater there are a number of other ecological effects (e.g. sediment trapping, changes of water quality, changing pattern of stream-flow, stopping of the migration of aquatic organisms etc.⁶) which could also be of interest to water managers and policy analysts. As such this paper outlines the current treatment of the water in artificial reservoirs (i.e. as being part of the environment) and examines the impacts of changing this treatment in SEEAW.

Recording of water in artificial reservoirs in the SEEA-2003 and in the SEEAW

11. The SEEA-2003 and the SEEAW consider all water resources as a non-produced asset. The SEEAW asset classification of water resources includes the following categories:

- EA.13 Water Resources (measured in cubic metres)
 - EA.131 Surface water
 - EA.1311 Artificial Reservoirs
 - EA.1312 Lakes
 - EA.1313 Rivers and streams
 - EA.1314 Glaciers, Snow and Ice
 - EA.132 Groundwater

⁵ The World Commission on Dams estimated that evaporation from reservoirs is of the order of 188 km³ y⁻¹, which equates to more than 8% of the total human consumption of freshwater (WCD 2000).
<http://www.dams.org/docs/kbase/thematic/tr21main.pdf>

⁶ See e.g. 2nd World Water Report (WWC 2006): <http://www.unesco.org/water/wwap/wwdr/wwdr2>

EA.133 Soil Water

Water in artificial reservoirs is therefore a sub-item of surface water and it is part of the water resources.

12. The SEEAW includes in its asset boundary all water resources that provide use and non use benefits. The asset boundary of the SEEAW further expands that of the SNA which only covers those resources that have a market value. In the SEEAW and the SNA all water resources are, as indicated earlier considered as non-produced assets and not a result of production process.

13. To illustrate the recording of water in artificial reservoirs and the abstraction of water from them in the SEEAW standard tables, we make use of an example. We assume a simplified hydrological system and a simple closed economy (no import and exports). The water resources system consists of water in artificial reservoirs and water in other resources (we do not disaggregate other resources to keep the example simple). The economy consists of 3 groups of industries and households: Divisions 1-3 of ISIC Rev. 4 *Agriculture, forestry and fishing* Divisions 10-33 *Manufacturing industry* and Division 36 of ISIC Rev.4 *Water collection treatment and supply industry*.

14. The water resources, including artificial reservoirs, are within the environment. The water collection, treatment and supply industry owns and manages the reservoir. This industry collects water from the artificial reservoirs (100), treats it and supplies it to users, namely other industries – agriculture, forestry and fishing (60), manufacturing (15) and households (5). Some of the water used is returned back to the water resources as a return flows (70). Industries and households also abstract water directly from the water resources (not from the reservoirs in this example) (50). Within the environment there are exchanges between the various water resources (150 from other water resources to the artificial reservoir and 10 from the artificial reservoir to other water resources), precipitation directly on the artificial reservoir (10) and evaporation from it (2).

15. Figure 1 shows the simplified example in a diagram. Tables 1 and 2 show these stocks and flows of water are recorded in the SEEAW standard physical asset accounts and supply and use tables. The SEEAW recording is consistent with that of the SEEA-2003.

16. Table 2 presents the asset account for water resources. It shows how the stocks of water resources change during a period of time. It includes: (a) opening and closing stocks which are the stocks level at the beginning and end of the period of time; (b) increases in stocks which include those due to human activities (i.e. abstraction) and natural causes (e.g. inflows, precipitation), and (c) decreases in stocks which includes those due to human activities (i.e. returns) and natural causes (e.g. evaporation, outflows etc.). They link water use by the economy (represented by abstraction and returns) to the stocks of water in a country as well as natural flows of water (SEEAW paragraph 6.23).

Figure 1: Current treatment: water in artificial reservoir as part of the environment

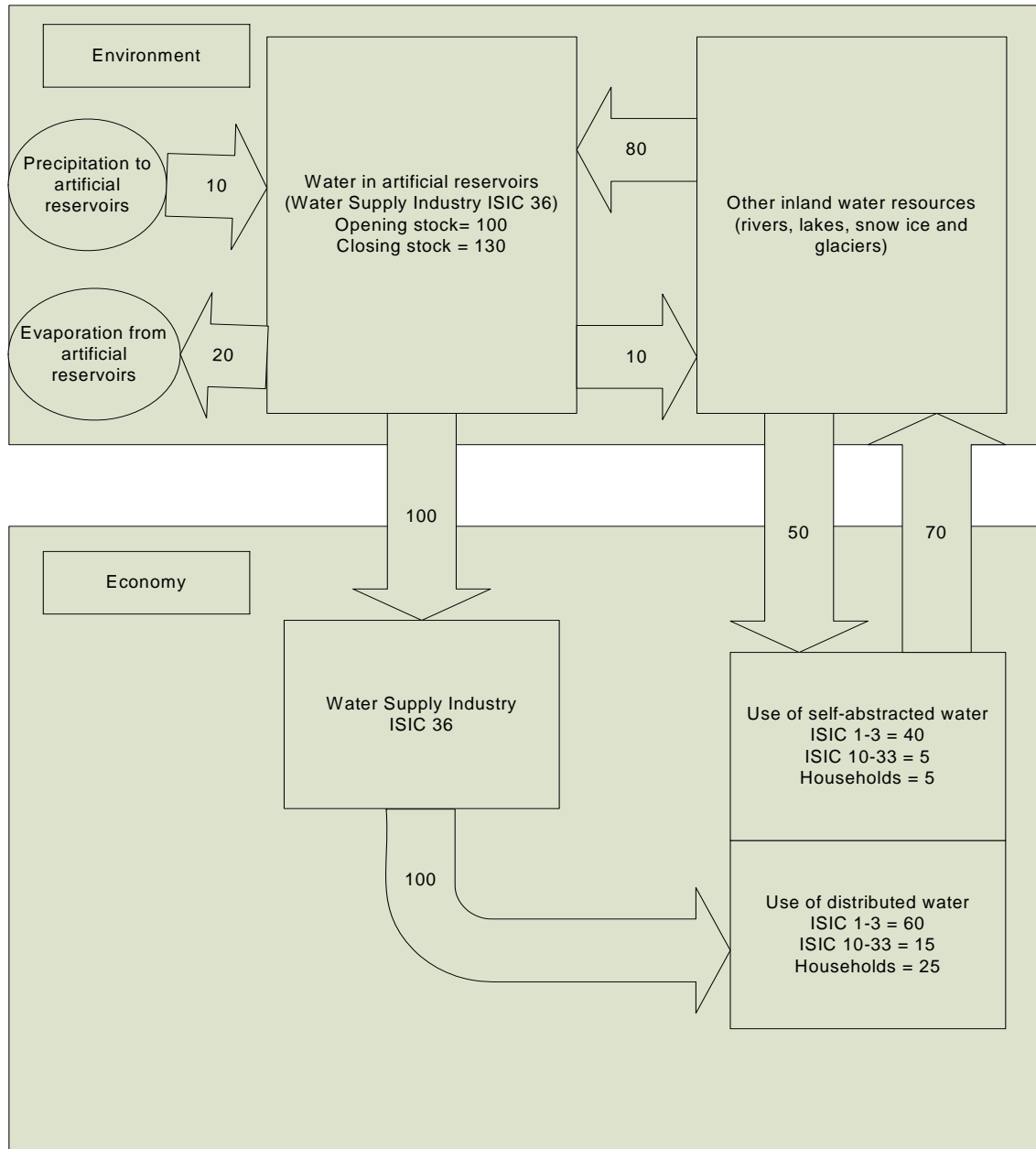


Table 1: Water asset account in the SEEAW

	Physical units		
	EA.1311 Reservoirs	Other inland water resources	Total
1. Opening Stocks	100		
Increases in stocks			
2. Returns (from the economy)		70	70
3. Precipitation	10		10
4. Inflows			
4.b. from other resources in the territory	150	10	160
Decreases in stocks			
5. Abstraction	100	50	150
6. Evaporation/Actual evapotranspiration	20		20
7. Outflows			
7.c. to other resources in the territory	10	80	90
9. Closing Stocks	130		

Note: Grey cells indicate non relevant or zero entries by definition

17. Table 2 shows the supply and use of water. The use table records: (a) the flows from the environment to the economy in the form of water abstraction separately identified according to whether it is for own use or for distribution and by source (artificial reservoirs or other sources) and the flows; and (b) the flows within the economy that are the water used and reused by industries and households. These flows correspond to the SNA transactions in monetary terms.

18. The supply table records: (a) flows within the economy that is the supply of water by economic activities – these flows correspond to the SNA transactions in monetary terms; and (b) the flows to the environment which include the water returned back to the environment after use.

19. Treating water in artificial reservoir as a non-produced asset, implies that the abstraction from the environment is recorded when the water is abstracted from the reservoir. As a result net recharges of artificial reservoirs are not shown in the physical supply-use tables (Table 2). They are recorded in the asset accounts ($30=10+150-(100+20+10)$) (Table 1) as they are flows within the environment.

20. The concept of water consumption which appears at the bottom of the supply table in Table 2 is consistent with the hydrological concept. It differs, however, from the concept of consumption used in the national accounts which instead refers to water use. Water consumption gives an indication of the amount of water that is not returned by the economy to water resources or to the sea. It is the difference between the water that entered the economy and the water that has not returned to the inland water resources (surface water, groundwater or soil water) or the sea. This happens because during use part of the water is incorporated into products, evaporated, transpired by plants or simply consumed by households or livestock. The difference between the water use (row 3) and the water supply (row 6) is referred to as water consumption. It can be computed for each economic unit and for the whole economy (SEEAW, paragraph 3.44).

Table 2: Physical supply and use tables in SEEAW

		Industries (by ISIC categories)				Physical units	
						Households	Total
		01-03	10-33	36	Total		
From the environment	1 - Total abstraction (=1.a+1.b = 1.i+1.ii)	40	5	100	145	5	150
	1.a Abstraction for own use	40	5		45	5	50
	1.b Abstraction for distribution			100	100		100
	From water resources:						
	1.i Artificial reservoirs			100	100		100
	1.ii Other inland water resources	40	5		45		45
Within the economy	2. Use of water received from other economic units	60	15		75	25	100
3. Total use of water (=1+2)		100	20	100	220	30	250

Supply table

		Industries (by ISIC categories)				Physical units	
						Households	Total
		01-03	10-33	36	Total		
Within the economy	4. Supply <i>of which:</i> Water for delivery			100	100		100
				100	100		100
To the environment	5. Total returns (= 5.a+5.b) 5a. To artificial reservoirs 5b. To other sources	58	2		60	10	70
		58	2		60	10	70
6. Total supply of water (= 4+5)		58	2	100	160	10	170
7. Consumption (=3-6)		42	18	0	60	20	80

Note: grey cells indicate zero entries by definition.

Proposal to record water in artificial reservoirs as a produced – accounting consequences

21. Classifying water in artificial reservoirs as produced asset will have consequences on the asset classifications, the asset accounts and the physical supply and use tables and the hybrid accounts, which are not discussed further here.

22. The asset classification will change in the sense that water in artificial reservoirs will no longer be a category of non-produced non-financial asset but of the produced assets.

23. The stock of water in reservoirs will be treated as an inventory. As indicated earlier, water in artificial reservoirs can be considered the result of a production process – infrastructure has to be put in place to ensure that water is held and regular and continuous management, including monitoring of the stock and sometime quality, has to be exercised. Artificial reservoirs alter the natural water balance, water quality and ecosystem habitats. Therefore from an environmental perspective they are not considered as part of the environment.

24. The implications for the physical accounts are the following: (a) the opening and closing stocks of water will become opening and closing inventories, in line with the changes in the classification of assets; and (b) the changes in stock will no longer be classified in other changes in volume accounts but they will be moved to the capital account as changes in inventories.

25. In the physical supply and use tables, the output of the industry owning and managing the artificial reservoirs will no longer be the quantity of water abstracted but the net recharge. The water used by the economy will be recorded as withdrawal from inventories. This is the result of the change in the boundary between the economy and the environment. The inflows from other resources and precipitation that will enter the reservoir will be recorded as flows from the environment to the economy and the water that exits the reservoir through evaporation and outflows to other resources will be recorded as flows from the economy to the environment.

26. To illustrate the changes in the recording in the supply and use tables when water in artificial reservoirs is considered as a produced asset, we use the same example as presented in diagram form in Figure 1. Figure 2 below shows the case in which water in artificial reservoirs is a produced asset and it is therefore within the economy.

27. Table 3 shows the physical supply and use tables. An additional column, changes in inventory has been added to the table to record the water that is stored in the reservoir that is the amount of water above the recharge that is not used during the accounting period. A new line has been added to the consumption to separately identify the changes in inventories, which represent the amount of water which is stored in the economy. This concept is not too aloof to the concept of water consumption that represent the water that does not return to the hydrological system because of evaporation or because it is incorporated into products.

28. The flows in all parts of the tables have been modified. The implications of these changes are particularly noteworthy in the case of the flows within the economy as these flows no longer correspond to the SNA monetary transactions. These changes would then imply that the monetary tables will have to be changed accordingly to ensure consistency between monetary and physical flows.

Figure 2: Water in artificial reservoirs as produced asset (increase in stocks)

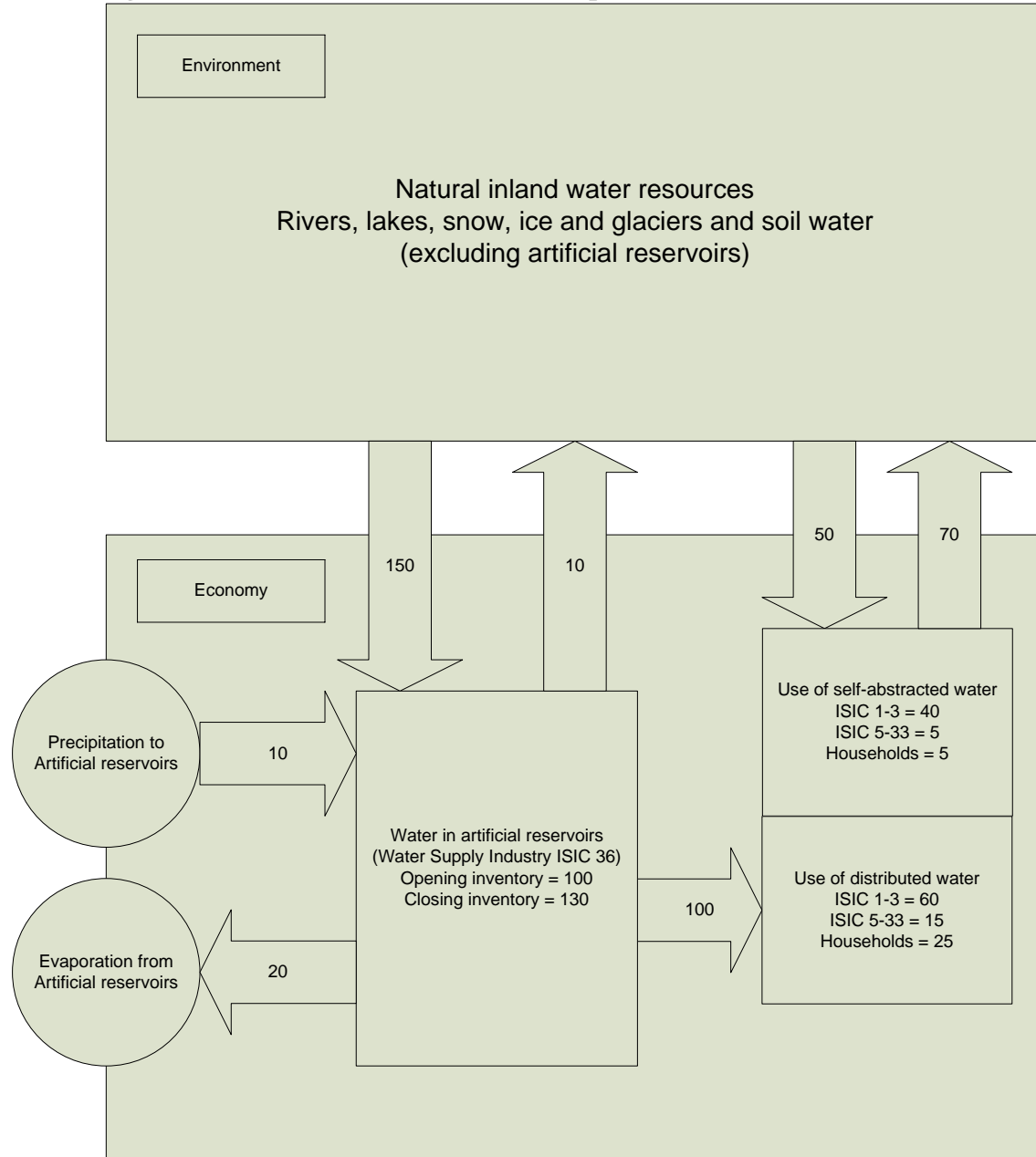


Table 3: PSUT- Water in artificial reservoirs is a produced asset (increase in stocks)**Use table**

		Industries (by ISIC categories)				Households	Changes in inventories (ISIC 36)	Total
		01-03	10-33	36	Total			
From the environment	1 - Total abstraction (=1.a+1.b = 1.i+1.ii)	40	5	160	205	5		210
	1.a Abstraction for own use	40	5		45	5		50
	1.b Abstraction for distribution and storage			160	160			160
	1.i From water resources: Other inland water resources	40	5	150	195	5		200
	1.ii From other sources Collection of precipitation			10	10			10
Within the economy	2. Use of water received from other economic units	60	15		75	25	30	130
3. Total use of water (=1+2)		100	20	160	280	30	30	340

Supply table

		Industries (by ISIC categories)				Households	Changes in inventories (ISIC 36)	Total
		01-03	10-33	36	Total			
Within the economy	4. Supply <i>of which:</i>	130						130
	Water for delivery			100	100			100
	Water for storage			30	30			30
To the environment	5. Total returns to other sources	58	2	10	70	10		80
6. Total supply of water (= 4+5)		58	2	140	200	10		210
7. Consumption (=3-6) <i>Of which: Changes in inventories</i>		42	18	20	80	20	30	130
							30	30

Note: grey cells indicate zero entries by definition.

29. Figures 2 and Tables 3 above show the case in which there is a net addition to the water stored in artificial reservoirs. However, in many cases there will be a net decrease in water stored. This is common for artificial reservoirs, which are often constructed on purpose to deal with the fluctuations in the hydrological cycle to meet water demands also in draught situations. This case is presented in Figure 3 and Table 4. In this case, the inflows to artificial reservoirs are reduced by half to represent a drought. The demand for water (100) is higher than the natural recharge (50) so the difference (50) is withdrawn from the inventories.

Figure 3. Water in artificial reservoirs as produced asset (decrease in stocks)

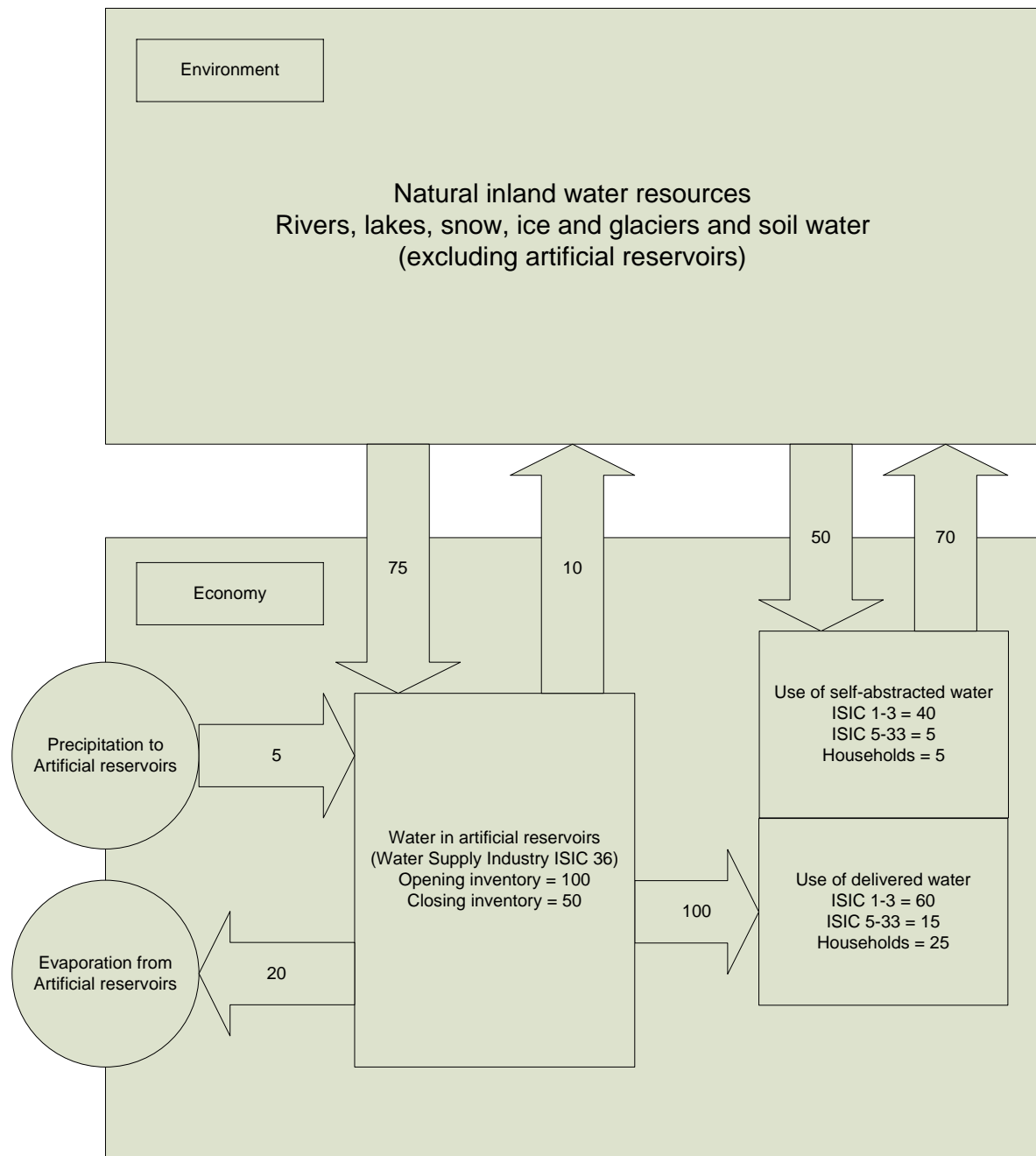


Table 4. PSUT- water in artificial reservoirs produced asset (decrease in stocks)
Use table

		Industries (by ISIC categories)				Households	Changes in inventories (ISIC 36)	Total
		01-03	10-33	36	Total			
		Physical units						
From the environment	1 - Total abstraction (=1.a+1.b = 1.i+1.ii)	40	5	80	125	5		130
	1.a Abstraction for own use	40	5		45	5		50
	1.b Abstraction for distribution/sorage			75	75			80
	1.i From water resources:							
	Other inland water resources	40	5	75	120	5		125
	1.ii From other sources							
	Collection of precipitation			5	5			5
Within the economy	2. Use of water received from other economic units	60	15		75	25	-50	50
3. Total use of water (=1+2)		100	20	80	200	30	-50	180

Supply table

		Industries (by ISIC categories)				Households	Changes in inventories (ISIC 36)	Total
		01-03	10-33	36	Total			
		Physical units						
Within the economy	4. Supply			50	50			50
	<i>of which:</i>							
	Water for delivery			100	100			100
	Water for storage			-50	-50			-50
To the environment	5. Total returns (= 5.a+5.b)	58	2	10	70	10		80
	5a. To artificial reservoirs							
	5b. To other sources	58	2	10	70	10		80
6. Total supply of water (= 4+5)		58	2	60	120	10		130
7. Consumption (=3-6)		42	18	20	80	20	-50	50
<i>Of which:</i> Changes in inventories							-50	-50

Note: grey cells indicate zero entries by definition.

Other issues

30. A number of additional issues related to water accounting were raised in the preparation of this paper. Some of these were related to the recording water in artificial reservoir as a produced asset but are not addressed in detail this paper. They are listed in brief below:

- The implications of treating water in artificial reservoir as a produced asset in the monetary supply and use tables and in the asset accounts and the links with the SNA transactions need to be further explored.

- The treatment of losses due to theft, evaporation (to atmosphere) and seepage (to groundwater), and over spill ways (i.e. water flowing over when the reservoir is full) from water stored in artificial reservoirs (see paper on issue 17)
- There is an issue of the recording of the flows of water to and from chains of artificial reservoirs in rivers (usually for hydropower production like e.g. the Nile or Danube). At present each reservoir would record an abstraction from the environment to the economy and then a return from the economy to the environment. If there was a chain of three reservoirs, then and the abstraction (and use) and return was 50 in each case then both the total abstraction and the total returns would be 150 (i.e. $150 = 3 \times 50$) and the consumption would be zero (0). If they were considered as one unit then total abstraction and use would be 50, and consumption would remain zero (0).
- Artificial reservoirs are one sub-category of anthropogenic water bodies. Other examples, are artificial canals, artificial ponds and artificial lakes, which are not mentioned in the SEEAW. In addition the Member States of the European Union use the concept of “altered water bodies” for the implementation of the EU Water Framework Directive. The classification of these anthropogenic and heavily modified water bodies, how to record the stocks and flows of water from them as well as account for the physical infrastructure that is used to manage the water are issues not explicitly covered in the SEEAW. This is an area which deserves some attention.

31. The SEEAW recording of water in artificial reservoir is not consistent with the treatment proposed. If this proposal were to be accepted in the revised SEEA then the SEEAW will need to be re-evaluated. This would be in accordance with the request by the Statistical Commission.⁷

Conclusion and recommendation and future work

32. Treating water in artificial reservoirs as produced assets is analytically meaningful. The boundary between what should be considered a produced asset and a non-produced asset has to be further analyzed, in particular considering the various types artificial water bodies. Furthermore, we should look at the International Accounting Standards and the International Public Sector Accounting Standards to better understand the current recording of water in business accounting, especially within the water supply and hydro-electricity industries. This would allow an informed decision of whether we should differ from the 2008 SNA and treat water in artificial reservoir as a produced asset or whether we should limit the recording only to the physical accounts (in supplementary tables) while maintaining full consistency with the SNA monetary flows.

Questions for the London Group

(1) Do you agree that water in artificial reservoir is conceptually a produced asset? If yes,

⁷ Report of the 38th Session of the UN statistical Commission (UNSD 2007): <http://unstats.un.org/unsd/statcom/doc07/Report-English.pdf>

- (a) Do you agree with changing the classification of assets for water resources and treat water in artificial reservoirs as a produced asset?
- (b) Do you agree with recording the net recharge of water in artificial reservoirs in the capital account rather than in the other changes in volume of asset account?
- (c) Do you agree that the output of the industry owning the artificial reservoir is the net recharge and not the water abstracted for sale?

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