SHS 5890:Water Resources: Quantitative Aspects


1st VIRTUAL WATER PROBLEM
Version 7.2016

3rd Generation Water Balance: "AquaMemo for Migrant People under a Changing Anthropocene Century"

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1. Background

A Virtual Water Problem (VWP) is a virtual narrative example of using hydraulic and hydrologic tools, only for e-learning purposes. A VWP lets students, scientists and stakeholders to play water scenarios by created storylines, through a river basin approach, but without endorsements nor commitments to people/institutions mentioned in the storylines. The following VWP is the first of a series of VWPs being shared for e-learning. Its narratives encompass: 1) global water policies, 2) a case-study with a river basin-driven problem, 3) international task force, 4) driving forces, 5) water scenarios, 6) executive summaries, 7) adaptive intervention protocols and 8) equations, tables, etc. References are presented, with appendices of simulation code (Appendix 1) and conceptual paper on scenarios from Millennium Ecosystem Assessment (Appendix 2).

2. Virtual Water Problem Narratives and Rationale

In the following sections, the storylines of the VWP-1 are presented through narratives and rationale.

2.1 Global water policies towards 3rd Generation of Water Balance

Since early XXIst Century, the United Nations (UN) is establishing a new discussion policy with countries in order to evaluate how to manage the humanitarian migrant crisis. Also the UN incorporates the feasibility of new global scenarios, thereby linking three global frameworks since early XXIst Century: the Sustainable Development Goals (SDGs), the Disaster Risk Reduction Post-Sendai 2015-2030 Framwork (DRR-GAR) and the United Nations Summit for Climate Change, in Paris 2015 (COP21). Those global frames were also related to former Scenario Working Group of the Millennium Ecosystem Assessment (www.MAweb.org). Global scenarios are named: “*Global orchestration(GO)*”, “*Order from Strength(OS)*”, “*Adaptive Mosaic(AM)*” and “*Technogarden(TG)*”, with own storylines until year 2100. Further details of MA scenarios are enclosed in a document called “Four Scenarios” with this VWP.

According to “Vision 2050”: “the transformation ahead represents vast opportunities in a broad range of business segments as the global challenges of growth, urbanization, scarcity and environmental change become the key strategic drivers for business in the coming decade. In natural resources, health and education alone, the broad order of magnitude of some of these could be around US$ 0.5-1.5 trillion per annum in 2020, rising to between US$ 3-10 trillion per annum in 2050 at today’s prices, which is around 1.5-4.5% of world GDP in 2050”.

Different vectors of “Vision 2050” are related to urbanization, global economic power shifting, greenhouse emissions, environmental degradation, “peak oil” and ecological and hydrological footprinting. Prospective business towards 2050 would be focused on sustainability, innovation and entrepreneurship. The “Conscious Brand” story, very famous in the decade 2000-2010, will shape forthcoming generations of managers and leaders into new alliance for water stewardship. GDP per capita, economic well-being and happiness criteria would be composite addressed into foreseeable strategies with a special kernel: a new generation of water balance formulation. According to Figure 1, water demand and water withdrawals must be incorporated into widespread balance equation. Both local and side effects also be fitted to plain interests and sectors. Moreover, the water consumption is both real and virtual, thereby regarding to the water footprint assessment (Figure 2).

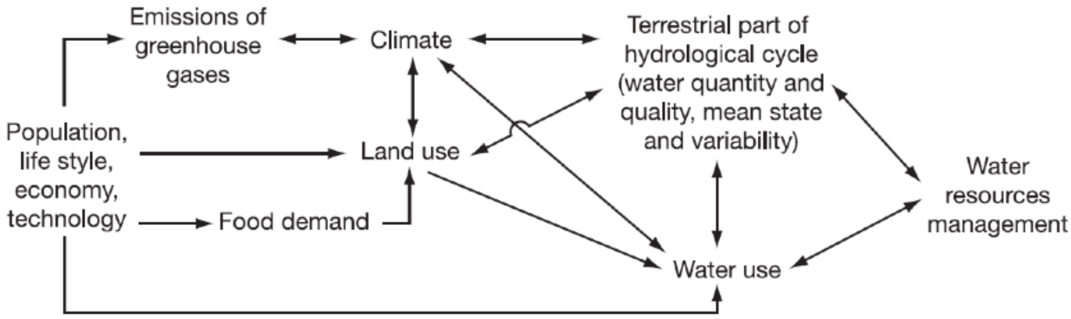

Fig. 1: Impact of human activities on freshwater resources and their management, with climate change being only one of the multiple pressures (from Kundzewicz et al., 2007; modified after Oki, 2005)

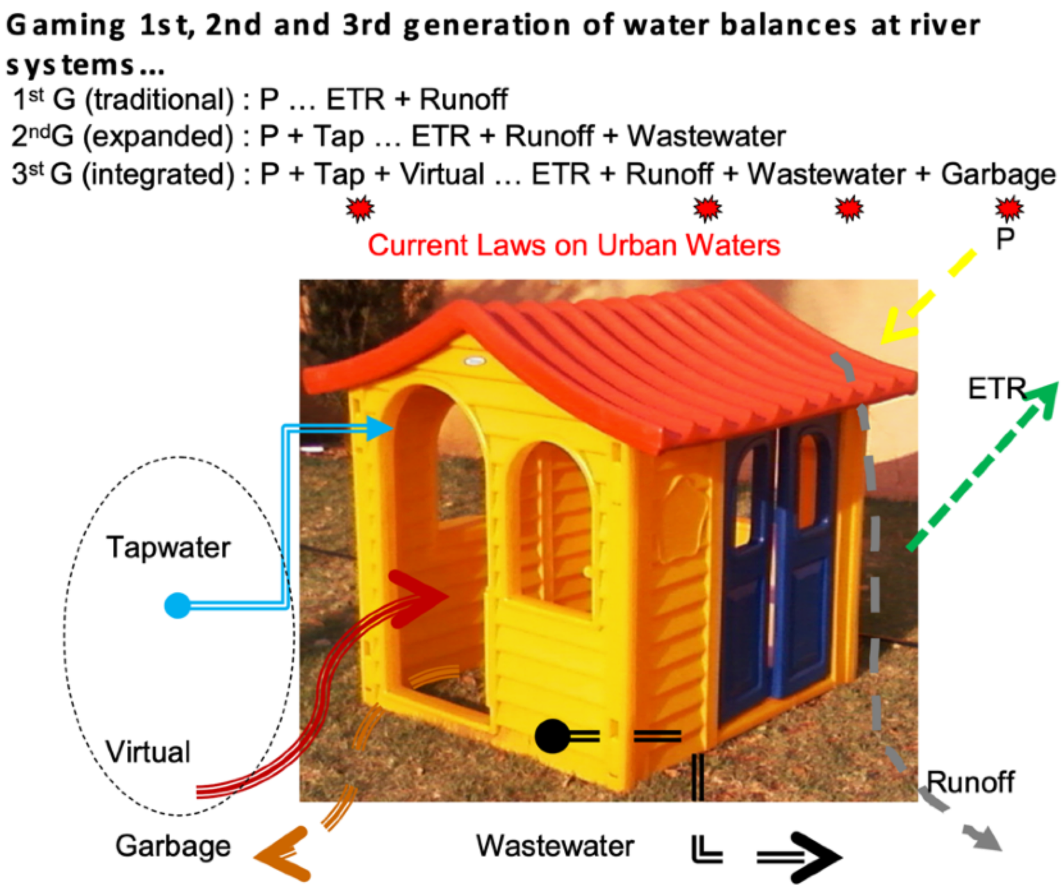

Figure 2: The emergence of 3rd Generation of Water Balance Equation through Water Footprint.

To cope with global water scarcity scenarios between year 1950 and 2050, the United Nations (UN) encourages, through a "***Call for HydroProjects***", for a new generation of projects on sustainable water use at small *eco-villages*. The World Bank will pay, thereby granting Non Governamental Organizations (NGOs), to develop selected projects with descentralized approach on "*agropoles*", which are microscale projects at country areas, expected to provoke a wise migration of people, from megacities to rural areas.

To accomplish new water balance formulation, diluted loads are to be reassessed in order to compute analogous quantities of water at the water balance formulation. Table 1.2, extracted from Tucci (2010; Parkinson et al, 2010), outlines BOD concentration of stormwaters for different urban settlements.

Authorities of several countries submitted projects to UN and World Bank for the occupation of human settlements and migrant crisis through the agropole approach. All these projects should be standardized in terms of regional (spatial) impact, inter-generational (time) sustainability and located in different latitudes (international relevance). Agropoles should hold proactive policies with early-warning systems and focused in local equity.

Table 1.2 Comparison of mean values of water quality parameters from stormwater in several United States cities and Porto Alegre (Brazil) (mg/l)

Parameter	Durham (1)	Cincinnati (2)	Tulsa (3)	P. Alegre (4)	APWA (5) Interval	
					Lower	Upper
BOD		19	11.8	31.8	1	700
Total solids	1440		545	1523	450	14,600
Ph		7.5	7.4	7.2		
Coliforms (NMP/100 ml)	23,000		18,000	1.5×10^7	55	11.2×10^7
Iron	12			30.3		
Lead	0.46			0.19		
Ammonia		0.4		1.0		

(1) Colson (1974); (2) Weibel et al. (1964); (3) AVCO (1970); (4) Ide (1984); (5) APWA (1969)

2.2 A case-study: a river basin problem

Under sponsoring of International Decade 2003-2012 of 'PUB' Program—*Prediction in Ungauged Basins* www.iahs.info, both UN and World Bank decided to grant those agropoles that will be fully set **until the year 2050,** that will affect, under sustainable terms, a river basin up to a **20-km²** area and with no previous urbanization.

In order to help UN agropole approach, the PUB Program recommended the VWP for a representative basin under a subtropical biome in Brazil (Figure 3). Previously, this basin had been affected by agricultural land-use conversion during the period 1950-2005. Non conservative land-use practices, i.e. "slash-and-burn" activities applied in this period, inducted to high erosion rates in this basin and soil water content decrease. Future conservative practices in this river basin will attempt to either mitigate the high rates of rill- and gully-erosion formed at the hillslopes or determine impacted eco-hydrologic cycles of the river basin. One problem pointed by PUB program is the high uncertainty related to the total previous soil water storage capacity *Smax* of the river basin. Probably, *Smax* had been decreased since year 1950 to 2000 due to non conservative soil practices and maybe it will newly change until year 2050. In short, river basin storage is expected to change in the period 1950-2050.

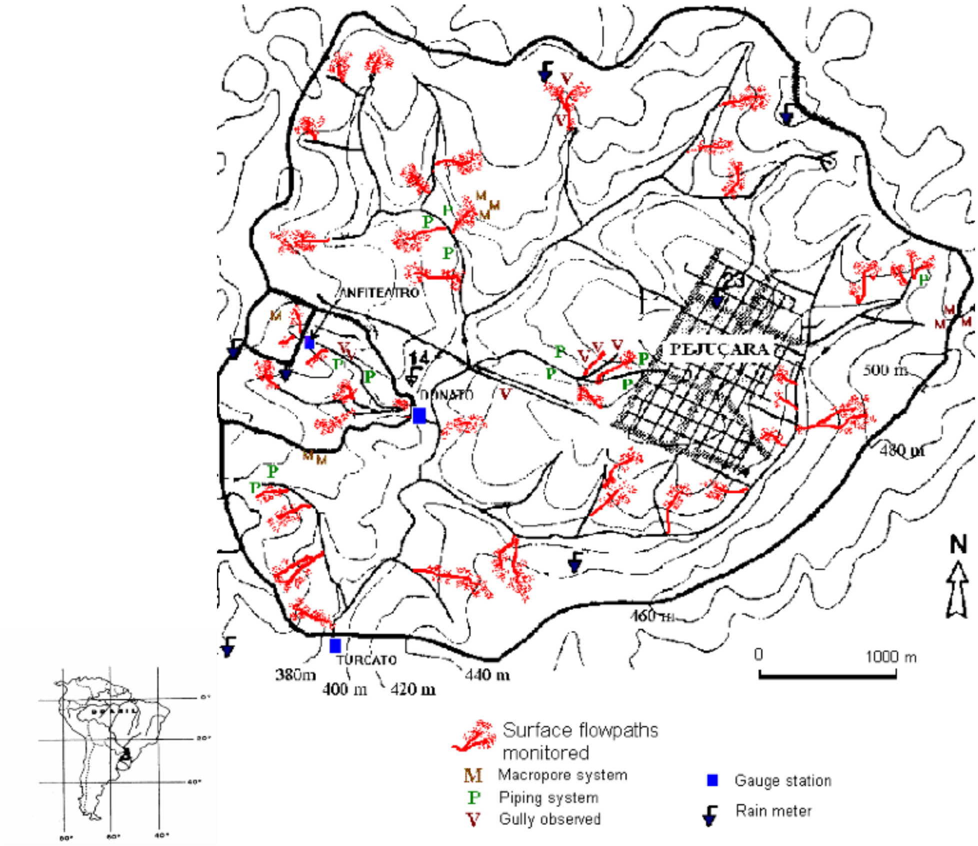

Figure 3. An example of Virtual Water Problem layout: the proposed agropole on 20 km² a river basin. The same agropole should be replicated in other Brazilian river basins of Canca(SP), Moinho(SP), Guariroba(MS), Pipiripau (DF/GO), Peruaçu(MG), Lençóis (SP), Igarapé Santa Rosa (AC), and Longá(PI)

2.3 An International Task-Force

Selected river basin scenarios were ranked according to: 1) varying total capacity storage, (*Smax*) 2) distinct climate change scenarios until year 2050 and 3) several water demand possibilities. All these combinations are presented in Table 1, with the corresponding chairperson from an international task force of whom UN will receive guidelines. These chairpersons are junior researchers from postgraduate program of Escola de Engenharia de São Carlos, Universidade de São Paulo, Brazil, with training in hydrology and hydraulics.

2.4 Driving forces at agropole river basin

Main driving forces are the land-use change due to human settlement on agropole river basin (see Table 1). For the period 2000-2050, two climate change scenarios are being studied: +1,5^{o}C and +2,5^{o}C. Until year 2050, local NGOs are looking for a settlement of pilgrims to live in the projected agropole. The number of pilgrims and water demand depend on which global scenario is being evaluated. New water-demand sectors will appear until 2050: household (d), microscale commercial trade & tourism (c&t), irrigation (ir), local-industry (i) and livestock (l), wastewater dilution (dil), recreation (re) and hydropower (hy). Because of global change, extra monthly water demand could occur during the 7 hottest months of the year. For example, the "occurrence seed" "3482755" means that there will be extra monthly water demand of +3mm,+4mm, +8mm, and so on, in correspondence with the occurrence of the 1st-, the 2nd-, the 3rd- hottest month of the year. The same agropole approach should be replicated in other Brazilian river basins of Canca(SP), Moinho(SP), Guariroba(MS), Pipiripau (DF/GO), Peruaçu(MG), Lençóis (SP), Igarapé Santa Rosa (AC), and Longá(PI), following Table 1.

Table 1. Scenarios with temperature change of + 1 °C between year 1950 and year 2000. "I"=industry, "l"=livestock, "ir"=irrigation, "c&t"=commerce & tourism; usp=9-9-2-3-6-5-7 (first scenario) and 9-8-7-1-1-7-6 (second scenario)

Scenario group (Name of international expert)	Estimated river basin reserve (*Smax1950*) in year 1950 [m³]	Pilgrims in 2050 [No.]	Monthly water demand in year 2050 [litres/ (inhab.day)]	Distribution of water demand (%) of monthly water demand in 2050							
				Consumptive					Non-consumptive		
				D	i	l	ir	C&T	hy	dil	Re
1 - Camila I	2.000.000	40000	150	9	**9**	**9**	**2**	**3**	**6**	**5**	**7**
2 – Rafaela	2.000.000	30000	400	20	9	8	7	1	1	7	6
3 -Camilla II	1.500.000	40000	150	9	8	1	5	0	0	1	6
4	1.000.000	40000	150								
5	1.000.000	30000	200								
6	750.000	20000	250								
7	750.000	30000	400								
8	500.000	40000	150								
9	500.000	30000	300								
10	400.000	30000	400								
11	350.000	40000	150								
12	300.000	40000	150								

Observation: "d": domestic water use (household), "i": industry, "l": livestock, "ir": irrigation, "c&t": commerce trade & tourism, "hy": hydropower energy, "dil": dissolved of pollution loads flowing to rivers and to maintain in-stream needs, "re": recreation, leisure, navigation, etc.

2.5 Water scarcity scenarios

Future scenarios foresight higher water scarcity in this tropical biome and will limit the potential water use for inhabitants and water-demand sectors of the agropole. The occupation of the agropole, if authorized by water agencies and boards, will moderately occur between 2000 and 2050. A regional River Basin Committee (RBC) has an internal report prepared by a scenario-working group of Millennium Ecosystem Assessment which prepared an Executive Summary of scenarios until 2050 for this region.

2.6 Executive summary of future scenarios for year 2050:

2.6.1. Land use change and soil water capacity decreasing in time. Proposed urbanization and land-use of the agropole until 2050 pointed that $Smax_{2050}$ will decrease in ca. **XX**% with respect to $Smax_{2000}$. However, in year 1950, prior the slash-and-burn activities, $Smax_{1950}$ was of ca. **YY**% higher than $Smax_{2000}$. One problem is that $Smax_{1950}$ is uncertain. Different scenarios of Table 1 depict the $Smax_{1950}$. For practical purposes, *Smax* [mm]= maximum soil water storage volume divided by the area of the basin.

2.6.2. Global warming between 1950 and 2050. Global climate change scenarios foresight an increase in temperature in the region until 2050 with two scenarios: +1,5 ^{o}C and +2,5 ^{o}C. (Table 1). Accordingly, those temperature increases will produce the increments in monthly temperatures of the year 2050 in comparison with the monthly temperatures of the year 2000. This climate change will produce a change in the regime of evapotranspiration and precipitation in the year; consequently, the regime of water deficits and water excesses will differ between scenarios. Also, monthly temperatures in year 1950 were about -1,0 ^{o}C in comparison to monthly values in 2000. Note: temperature changes, in absolute values, are expected to be the same for all months in the year.

2.6.3. Atmospheric water content remains constant. Prospective studies pointed that the water vapor pressure (*ea*) in year 2050 will approximately remain constant as compared with the monthly *ea*'s values in year 2000 (Table 2).

2.6.4. Water vapor threshold is time dependent. However, temperature differences in the period 1950-2000 and 2000-2050, respectively, affected and will affect the physical threshold of condensation of water vapor in the local atmosphere of the basin. It is so because the saturated water vapor pressure (*eas*), the maximum value of water pressure at a given temperature, is a function of ambient temperature. In short, monthly dew-point temperatures will be different in 2050 with respect to years 1950 and 2000, according to the scenarios pointed in Table 1.

2.6.5. Relative humidity is time varying. Due to climate (temperature) change, the relative humidity *RH* ($\% = ea / eas \cdot 100$) differ for all months of the years 1950, 2000 and 2050.

2.6.6. Precipitation changes with time. According to increments of *T*, *eas* and *RH*, precipitation patterns changed from 1950 to 2000 and will change from 2000 to 2050 for all months. Those changes could be assessed from values of *RH* (%) that have physical relationships with the monthly precipitation *P* (mm) showed in Figure 2. This physical relationship RH vs. P, computed in 2000, is characteristic curve assumed valid also for year 1950 and year 2050. Exact computations of RH vs. P relationship are outlined at the section "**Equations**".

2.6.7. Evapotranspiration is not time-constant. Monthly potential evapotranspirations (*ETp*) for years 1950, 2000 and 2050 will not be the same, because *ETp* depends on the temperature. ETp's are estimated by common procedures suggested by FAO, using the Thornthwaite formula (see "**Equations**") which is function of latitude, temperature and local coefficients.

2.6.8. Water demand uncertainty in 2050. Until year 2050, monthly water withdrawals (*Dem*) from all water-consume sectors will appear and will affect the hydrologic balance in the river basin. Preliminary estimates bound this total demand are affected by global scenario perspectives: "*Global orchestration*", "*Order from Strength*", "*Adaptive Mosaic*" and

"*Technogarden*", with different expected consumption showed in Table 1, ranging from 150 to 400 litres / (capita.day). The high uncertainty of this estimate is due that water conflicts among water-use sectors are expected to occur in the agropole under global scenarios. This water withdrawal will be constant for all months in 2050, and it is inexistent in year 1950 and 2000.

2.7. Adaptive intervention protocols

Adaptive intervention protocols are special policy mechanisms provided in the VWP in order to approach alternative scenarios of intervention, as a way of recording water availability and vulnerability (says "AquaMemo", as well), according to baseline scenarios of Table 1. They are proactive policy protocols composed by different principles: "hydrosolidarity", "water detention, retention and reuse", "water penalty pricing" and "climate certification".

2.7.1 Hydrosolidarity: **Water detention, retention and reuse**. Under these scenarios, the River Basin Agency promotes a Hydrosolidarity Program, called *HydroSOS,* in order to perform a wise attitude of profiting to water-access, thereby prevailing with an upstream-downstream planning in the basin. The *HydroSOS* program requested that the agropole demand in 2050 be properly satisfied from using rainwater water at roofs, pavements and cisterns adapted in houses and buildings, as well reusing *greywater* through small-decentralized-biodigestors located in urban lots. After being satisfied this water withdrawal with rainwater and greywater reuse, water sectors will be allowed to withdraw water from surface water and groundwater that will deplete the water storage (S) of the river basin. See the HYDROSOS Protocol (Box 1).

2.7.2 Water penalty pricing. Induced by crossed subsidy studies and compensatory environmental trade-offs, the *HydroSOS Program* foresight **penalties** for water use sectors in 2050, according to:

(a) expected annual water deficits in the river basin, which will decrease the storage of the water balance in the basin, will pay US$ **106.900** per millimeter of deficit, and

(b) expected annual water excess or surplus, which increase the risk of flooding to communities located downstream the agropole-basin, will be paid through a tax of $ **117.995** per millimeter of water excess. Those expected penalties ***should*** be augmented (++) or diminished (--) if the efficiency of evaporation mechanism is either dropped or elevated. See EFFICIENCY Plea (Box 2).

2.7.3 Certified Climate-Protected Agropole: National Ministeries were officially requested in 2000 by a Manifesto of the Association of Environmental Refugees' Families and Migrants of the Future (**ECOREF**), a NGO interested in living at this Agropole-Basin, only **if** it will be converted into a Certified Climate-Protection Agropole. The ECOREF states that the water penalties estimated by the River Basin Agency for year 2050 should be negotiated as a compensation of environmental trade-offs of previous impacts occurred between year 1950 and year 2000. The main argument of these families is showed in Box 3.

Box 1. ***"The HYDROSOS Protocol for AQUAMEMO"***
"If future technologies in water detention (temporally-stored), water retention (long-term infiltrated) and reuse (new uses after prior ones) are to be fully developed, it is expected that total water storage at the basin scale will increase up to 2.5% of maximum future basin storage, according to what global scenario is

envisaged by the chairperson (expert): 0% increment for reactive scenarios and from 1% to 2.5% for proactive scenarios. As a global stakeholder, each Chairperson could choose what global scenario is better for her/his Scenario Run in order to the time-water penalty difference ($2050-$2000) should be not more than 7% Those figures should be updated in the future water balance and in relation with the ´ECOREF Manifesto´ (Box 3).”

Box 2. ***"The EFFICIENCY Plea for Refugees and Migrants"***

"A wise comparison of scenarios could be made if hydrological process at the basin scale are studied as a whole, for instance when compared two ratios: "precipitation divided by potential evaporation" and "actual evaporation divided potential evaporation". According to imminent hydrologist J C Dooge, this relationship is expected to maintain time-invariant under a specified climate. The performance of HYDROSOS Protocol could be better outlined when this relationship is analyzed for different time-scenarios whether change exists or not. It is worth noting that this relationship is on a relative basis depending on scenario. Anomalous behavior of this relationship could detect some trends in terms of efficiency of how people are using water and/or how biological transpiration is working. For instance, carbon sequestration is proportional to the rate of actual water transpiration from plants and forests. The Plea points this relationship, if evaluated for the periods 1950, 2000 and 2050, could show underpinnings of this efficiency. And the pricing of deficits and excesses of the basin should be over-weighted by this (or lack of) efficiency."

Box 3. ***"The ECOREF Manifesto"***

"Total penalties to be paid by future generations of people living at the agropole-basin scale in 2050, when new expected water deficits and excesses will appear, could be near the same value of the environmental costs due to water excesses and deficits from non conservative practices during the period 1950-2000. The explicit justification of that statement is twofold: first, that until year 1950 this river basin was neither affected by climate change nor agriculture, as occurred during the period 1950-2000 when both moderate climate change and unwise uses of river basin produced forest devastation, high land-use conversion and huge gully erosions, also decreasing surface waters and groundwaters; second, in the period 2000-2050, a stronger global climate change will occur that would intensify water deficits and water excesses in regional scale. It is mandatory that compensatory environmental trade-offs be assessed with basis on a comparison of water balances for periods 1950, 2000 and 2050 and their respective water penalty pricing."

Box 4. ***"The Water Footprint"***

" Because of water and trade, the virtual water and growing awareness of water footprints must be coped with in the future, especially when comparing retrospective-, present and prospective scenarios. Thus the water penalty pricing should be related to the water footprint and virtual water. The parties of*

this conflict, where refugees and migrants take part, thereby combine to identify the water footprint of each scenario and to evaluate the virtual water in general terms and addressing the new ISO Norm on Water Footprint (Appendix 3).”

2.8 Assessment of the international task force

Compute water balances in river basin, according to the next requirements (with scores):

#1 (Score= **3,0**) show details of the corresponding annual water balances, month per month, for the years 1950, 2000 and 2050, for the two projected global warming scenarios (+1°C and +3°C),

#2 (Score= **2,0**) appraise the total costs of water deficits & excesses ($) for 1950, 2000 and 2050 for two projected global warming scenarios (+1°C and +2.5°C), and

#3 (Score= **5,0**) construct contingency matrices of *temperature change*(ΔT)*, Smax*, *Dem* and *Water Penalty* for 1950, 2000 and 2050, answering for what combination of *Smax* vs. *Dem* vs. ΔT , the ECOREF Manifesto is valid, the HYDROSOS Protocol is possible and EFFICIENCY Plea are valid.

2.9 Equations to be considered (please, assume months of 30 days):

Monthly temperature: T (given in Table 2, in 2000, changing in 1950 and 2050, Tables 3 and 4);

Saturated water vapor pressure: *eas* [Pa]=611.e$^{[(17{,}27\,T)/(237{,}3+T)]}$, T [°C] (*eas* changes accordingly with changes in temperature for 1950 and 2050, with respect to 2000, in Tables 3 and 4);

Water air-vapor pressure: *ea* (data given; it remains the same of 2000 for 1950 and 2050);

Relative humidity: *HR*[%] = (*ea* / *eas*) .100 (it varies for 1950 and 2050, Tables 3 and 4);

Monthly precipitation: *P* [mm] (varies for 1950 and 2050, Tables 3 and 4)

For 0 % <= RH < 20 % : $P = 0$
For 20 % <= RH <= 100 % : $P = 0{,}004.RH^3 - 0{,}4965\ RH^2 + 21{,}398\ RH - 249{,}41$ ($R^2 = 0{,}97$); thus this relationship (RH versus Monthly Precipitation assumed constant in all scenarios, see Figure 4)

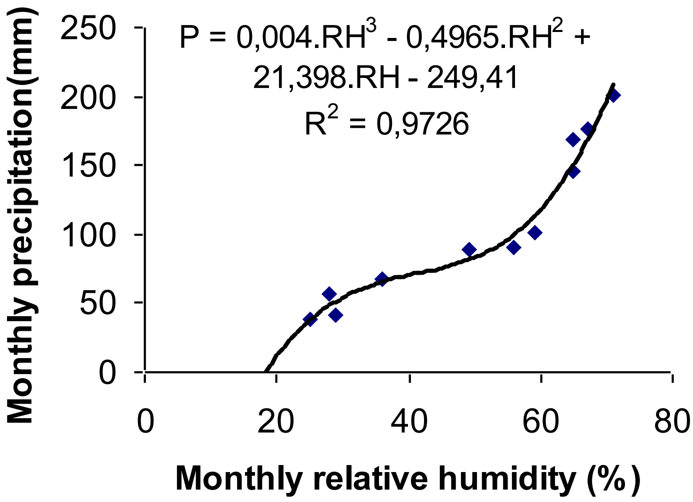

Figure 4. Physical relationship between monthly relative humidity and precipitation at the river basin. This physical relation is applied for conditions in 1950, 2000 and 2050, respectively.

Monthly evapotranspiration: *ETp* [mm]= $d \cdot 16 \cdot (10 \cdot T / \boldsymbol{I})^a$; T [ºC] (to be obtained for 1950, 2000 and 2050). Coefficient "*d*" varies according to month (Table 2) and remains constant for 1950, 2000 and 2050.

Coefficient "*a*" = $67{,}5.10^{-8} I^3 - 7{,}71.10^{-5} I^2 + 0{,}01791.I + 0{,}492$

Coefficient $I = \sum_{i=1}^{12} (\frac{T}{5})^{1{,}514}$

Water withdrawal: *Dem* [mm] (only in 2050, Table 4); to convert [litres/(hab.day)] to a monthly depth [mm/month].

Simulation procedure: For any arrow of Table 2, 3 and 4, and after computing: P and ETp*, and given S(initial)=S(t-1), do perform S* = (P-ETP)+S(initial). Three situations could occur, as follows:

if Smin ≤ S* ≤ Smax	S* < Smin	S* > Smax
ETR = ETP; S(end) = P-ETP +S(initial); Excess = 0; ΔS = S(end) – S(initial)	ETR = P + S(initial); Deficit = ETP – ETR; Excess = 0; ΔS = S(end) – S(initial)	ETR = ETP; S(end) = Smax; Excess = S* - Smax; ΔS = S(end) – S(initial)

The full simulation code is annexed in Appendix 1 of this VWP.

Table 2. Water balance and costs in 2000 (present). Consider initial storage (t-1)= 0.6 · *Smáx*$_{2000}$ [mm] ; *Smín*$_{2000}$= 3.7 mm.

#	*T* (°C)	*(T/5)*^{1,514}	*RH* (%)	*eas* (Pa)	*ea* (Pa)	*d* (adim.)	*ETP* (mm)	*P* (mm)	*P-ETP* (mm)	*S* (mm)	*ΔS* (mm)	*ETR* (mm)	*Excess* (mm)	*Deficit* (mm)
1	25,3			2861,8	2031,8	1,17		213						
2	24,4			2710,0	1815,7	1,01		179						
3	23,5			2726,5	1772,2	1,05		164						
4	21,8			2612,7	1541,5	0,96		101						
5	19,8			2310,2	1132,0	0,94		87						
6	18,9			2184,4	786,4	0,88		67						
7	18,4			2117,2	592,8	0,98		56						
8	19,8			2310,2	577,6	0,98		39						
9	21,6			2581,0	748,5	1,00		41						
10	23,4			2710,0	975,6	1,10		67						
11	24,1			2827,4	1583,3	1,11		91						
12	26,1			3002,9	1951,9	1,18		142						
	I=					Σ =	( )	( )			Σ =	( )	( )	( )
	a=											R$=	( )	( )

Notations:

#: month of the year; T: monthly temperature; *RH:* relative humidity*; ea:* water vapor pressure, that remains approximately constant for situations in 1950, 2000 and 2050*; eas:* saturated water vapor pressure, it varies from 1950, 2000 and 2050, according to temperature changes*; d, a* and *I:* non-dimensional coefficients of evapotranspiration equation; *d* remains equal to every month when compared 1950, 2000 and 2050 situations, *a* and *I* vary according to given formula*; ETp:* monthly potential evapotranspiration due to meteorological conditions*; P:* monthly precipitation*; dem* (only for 2050)*:* water withdrawal due to water-demand sectors*; S:* water storage in the basin, ranging from *Smin*= 0 to *Smax ; ETR:* monthly real evapotranspiration, assessed as the real evapotranspiration, that occurs due according to the state of water storage *S* and the difference *P-ETp* or *P-ETp-Dem; Exc:* monthly excess, when net water depths are higher than *Smax; Def:*monthly water deficit, when net water depth are lower than *Smin*=0.

Table 3. Water balance and costs in 1950 (past). Consider initial storage (t-1)= 0,6 · *Smáx*1950 [mm], according to Table 1; *Smín*1950= 3.7 mm

#	*T* (oC)	*(T/5)*^{1,514}	*UR* (%)	*eas* (Pa)	*ea* (Pa)	*P* (mm)	*P-ETP* (mm)	*S* (mm)	*ΔS* (mm)	*ETR* (mm)	*Excess* (mm)	*Deficit* (mm)
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2												
3												
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6												
7												
8												
9												
10												
11												
12												
	I=					( )			Σ =	( )	( )	( )
	a=									R$=	( )	( )

Notations:

#: month of the year; T: monthly temperature; *RH:* relative humidity*; ea:* water vapor pressure, that remains approximately constant for situations in 1950, 2000 and 2050*; eas:* saturated water vapor pressure, it varies from 1950, 2000 and 2050, according to temperature changes*; d, a* and *I:* non-dimensional coefficients of evapotranspiration equation; *d* remains equal to every month when compared 1950, 2000 and 2050 situations, *a* and *I* vary according to given formula*; ETp:* monthly potential evapotranspiration due to meteorological conditions*; P:* monthly precipitation*; dem* (only for 2050)*:* water withdrawal due to water-demand sectors*; S:* water storage in the basin, ranging from *Smin*= 0 to *Smax ; ETR:* monthly real evapotranspiration, assessed as the real evapotranspiration, that occurs due according to the state of water storage *S* and the difference *P-ETp* or *P-ETp-Dem; Exc:* monthly excess, when net water depths are higher than *Smax; Def:*monthly water deficit, when net water depth are lower than *Smin*=0.

Table 4. Water balance and costs in 2050 (future). Consider initial storage (t-1)= 0,6 · *Smáx2050* [mm]; *Smín*2050= 3.7 mm

#	*T* (o C)	*(T/ 5)1,514*	*UR* (%)	*eas* (Pa)	*ea* (Pa)	*d* (adim.)	*ETP+ Dem* (mm)	*P* (mm)	*P-ETP-Dem* (mm)	*S* (mm)	*ΔS* (mm)	*ETR* (mm)	*Excess* (mm)	*Deficit* (mm)
1														
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ANNEX WATER FOOTPRINT Chapagain e Hoekstra (2004)

Water footprint – The water footprint is an indicator of water use that looks at both direct and indirect water use of a consumer or producer. The water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business. Water use is measured in terms of water volumes consumed (evaporated) and/or polluted per unit of time. A water footprint can be calculated for any well-defined group of consumers (e.g. an individual, family, village, city, province, state or nation) or producers (e.g. a public organization, private enterprise or economic sector). The water footprint is a geographically explicit indicator, not only showing volumes of water use and pollution, but also the locations.

Water footprint of an individual – Is defined as the total water used for the production of the goods and services consumed by the individual. It can be estimated by multiplying all goods and services consumed by their respective virtual-water content.

Water footprint of a nation – Is defined as the total amount of water that is used to produce the goods and services consumed by the inhabitants of the nation. The national water footprint can be assessed in two ways. The bottom-up approach is to consider the sum of all goods and services consumed multiplied with their respective virtual-water content. In the top-down approach, the water footprint of a nation is calculated as the total use of domestic water resources plus the gross virtual-water import minus the gross virtual-water export.

Internal and external water footprint – The total water footprint of a country includes two components: the part of the footprint that falls inside the country (internal water footprint) and the part of the footprint that presses on other countries in the world (external water footprint). The distinction refers to the appropriation of domestic water resources versus the appropriation of foreign water resources.

Water footprint of a product – The water footprint of a product (a commodity, good or service) is the volume of freshwater used to produce the product, measured at the place where the product was actually produced. It refers to the sum of the water use in the various steps of the production chain. The 'water footprint' of a product is the same as its 'virtual water content'.

Water footprint of a business - Is defined as the total volume of freshwater that is used directly and indirectly to run and support a business. The water footprint of a business consists of two components: the direct water use by the producer (for producing/manufucturing or for supporting activities) and the indirect water use (the water use in the producer's supply chain). The 'water footprint of a business' is the same as the total 'water footprint of the business output products'.

Blue, green and gray components of the total water footprint – The total water footprint of an individual or community breaks down into three components: the blue, green and gray water footprint. The blue water footprint is the volume of freshwater that evaporated from the global blue water resources (surface water and ground water) to produce the goods and services consumed by the individual or community. The green water footprint is the volume of water evaporated from the global green water resources (rainwater stored in the soil as soil moisture). The gray water footprint is the volume of polluted water that associates with the production of all goods and services for the individual or community. The latter has been calculated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water remains below agreed water quality standards.

Water self-sufficiency vs. water dependency - The 'water self-sufficiency' of a nation is defined as the ratio of the internal water footprint to the total water footprint of a country or region. It denotes the national capability of supplying the water needed for the production of the domestic demand for goods and services. Self-sufficiency is 100% if all the water needed is available and indeed taken from within the own territory. Water self-sufficiency approaches zero if the demand for goods and services in a country is largely met with virtual-water imports. Countries with import of virtual water depend, de facto, on the water resources available in other parts of the world. The 'virtual-water import dependency' of a country or region is defined as the ratio of the external water footprint of the country or region to its total water footprint

ANNEX: VIRTUAL WATER Chapagain e Hoekstra (2004)

Virtual water content – The virtual-water content of a product (a commodity, good or service) is the volume of freshwater used to produce the product, measured at the place where the product was actually produced (production-site definition). It refers to the sum of the water use in the various steps of the production chain.

The virtual-water content of a product can also be defined as the volume of water that would have been required to produce the product at the place where the product is consumed (consumption-site definition). We recommend to use the production-site definition and to mention it explicitly when the consumption-site definition is used. The adjective 'virtual' refers to the fact that most of the water used to produce a product is not contained in the product. The real-water content of products is generally negligible if compared to the virtual-water content.

The three colors of a product's virtual water content – The virtual-water content of a product consists of three components, namely a green, blue and gray component.

- The 'green' virtual-water content of a product is the volume of rainwater that evaporated during the production process. This is mainly relevant for agricultural products, where it refers to the total rainwater evaporation from the field during the growing period of the crop (including both transpiration by the plants and other forms of evaporation).

- The 'blue' virtual-water content of a product is the volume of surface water or groundwater that evaporated as a result of the production of the product. In the case of crop production, the blue water content of a crop is defined as the sum of the evaporation of irrigation water from the field and the evaporation of water from irrigation canals and artificial storage reservoirs. In the cases of industrial production and domestic water supply, the blue water content of the product or service is equal to the part of the water withdrawn from ground or surface water that evaporates and thus does not return to the system where it came from.

- The 'gray' virtual-water content of a product is the volume of water that becomes polluted during its production. This can be quantified by calculating the volume of water required to dilute pollutants emitted to the natural water system during its production process to such an extent that the quality of the ambient water remains beyond agreed water quality standards.

It is relevant to know the ratio of green to blue water use, because the impacts on the hydrological cycle are different. Both the green and blue components in the total virtual-water content of a product refer to evaporation. The gray component in the total virtual-water content of a product refers to the volume of polluted water. Evaporated water and polluted water have in common that they are both 'lost', i.e. in first instance unavailable for other uses. We say 'in first instance' because evaporated water may come back as rainfall above land somewhere else and polluted water may become clean in the longer term, but these are considered here as secondary effects that will never take away the primary effects.

Virtual water flow – The virtual-water flow between two nations or regions is the volume of virtual water that is being transferred from one place to another as a result of product trade.

Virtual water export – The virtual-water export of a country or region is the volume of virtual water associated with the export of goods or services from the country or region. It is the total volume of water required to produce the products for export.

Virtual water import – The virtual-water import of a country or region is the volume of virtual water associated with the import of goods or services into the country or region. It is the total volume of water used (in the export countries) to produce the products. Viewed from the perspective of the importing country, this water can be seen as an additional source of water that comes on top of the domestically available water resources.

Virtual water balance – The virtual-water balance of a country over a certain time period is defined as the net import of virtual water over this period, which is equal to the gross import of virtual water minus the gross export. A positive virtual-water balance implies net inflow of virtual water to the country from other countries. A negative balance means net outflow of virtual water.

Water saving through trade – A nation can preserve its domestic water resources by importing a water-intensive product instead of producing it domestically. International trade can save water globally if a water-intensive commodity is traded from an area where it is produced with high water productivity (resulting in products with low virtual-water content) to an area with lower water productivity.

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Links:

Decade 2003-2012 of PUB – Prediction in Ungauged Basins, IAHS www.iahs.info

Example of an international scenario program, www.usf.uni-kassel.de/waves/english/index.htm

International Glossary of Hydrology, UNESCO www.cig.ensmp.fr/~hubert/glu/aglo.htm

Millennium Ecosystem Assessment, UNESCO www.MAweb.org/scenarios

World Bank Group, www.worldbank.org/

World Wildlife Fund, www.worldwildlife.org/

WWC - World Water Council – http://www.worldwatercouncil.org/index.php?id=866

Appendix 1:

Simulation procedure for each water balance of 1st Virtual Water Problem

Given values of:

T(t); *ea* (t); *Sinitial*YEAR = *Smax*YEAR, *Smin*YEAR = 0; *P*2000(t)

sum= 0;
FOR *t*=1 to 12
sum = *sum* + (*T*(t)/5)^1,514;
END FOR

I = sum;
a = 67,5.10^{-8}. I^{3}- 7,71. 10^{-5} . I^{-2} + 0,01791. *I* + 0,49;
Sinitial = *Smax*(YEAR)
S(t-1) = *Sinitial*(YEAR);

FOR *t*= 1 TO 12
eas (t) = 611.e$^{[(17{,}27\,T)/(237{,}3+T)]}$;
RH(t) = *ea* (t) / *eas* (t);

IF YEAR ≠ 2000
P(t) = 0,004.*RH*(t)^{3} - 0,4965 *RH*(t)^{2} + 21,398 *RH*(t) - 249,41;
END IF

ETp(t) = *d*(t) 16 . (10. *T*(t) / *I*)^{a} ;
*S** (t)= *P*(t)-*ETP*(t)+*S*(t-1);
"according to *S**, three situations could occur"

IF *Smin* ≤ *S**(t)≤ *Smax*;
ETR(t) = *ETP*(t);
S(t) = *P*(t)-*ETP*(t) +*S*(t-1);
ΔS (t) = *S*(t) – *S*(t-1);
Excess(t) = 0;
Deficit(t) = 0;
END IF;

IF *S**(t) < *Smin*
ETR (t)= *P*(t) + *S*(t-1);
S(t) = *Smin;*
ΔS(t) = *S*(t) – *S*(t-1);
Deficit (t)= *ETP* (t) – *ETR* (t);
Excess(t) = 0;
END IF;

IF *S**(t) > *Smax*
ETR(t) = *ETP*(t);
S(t) = *Smax*;
ΔS(t) = *S*(t) – *S*(t-1);
Deficit(t) = 0;
Excess(t) = *S**(t) - *Smax*;
END IF;

END FOR

Note that both *Smin* and *Smax* differ for years 1950, 2000 and 2050, but both remain constant during intra-annual (inter-monthly) simulation of every table. "*T*" means "temperature" and "*t*" refers to time-step (i.e. month).

Appendix 2:

A Short View of Scenarios from the Millennium Ecosystem Assessment to Help on 1st Virtual Water Problem

Source:

Author (org.)	**ECOSYSTEMS AND HUMAN WELL-BEING: SCENARIOS** **Findings of the Scenarios Working Group**
Series:	Millennium Ecosystem Assessment Series
Subject:	Ecosystem Studies , Ecosystem Science and Management
ISBN:	1-55963-391-3
Pub. Date:	12/14/2005
Publisher:	Island Press
Web:	http://www.maweb.org/en/Scenarios.aspx
Chapter:	8

APPENDIX 3 –

WATER FOOTPRINT - PRINCIPLES, REQUIREMENTS AND GUIDANCE

<table>
<tr><th colspan="2">NEW WORK ITEM PROPOSAL</th></tr>
<tr><td>Date of presentation
2009-03-09</td><td rowspan="2">Reference number (to be given by the Secretariat)

ISO/TC 207 / SC 5 N 333</td></tr>
<tr><td>Proposer
SNV</td></tr>
<tr><td colspan="2">Secretariat
AFNOR</td></tr>
</table>

A proposal for a new work item within the scope of an existing committee shall be submitted to the secretariat of that committee with a copy to the Central Secretariat and, in the case of a subcommittee, a copy to the secretariat of the parent technical committee. Proposals not within the scope of an existing committee shall be submitted to the secretariat of the ISO Technical Management Board.

The proposer of a new work item may be a member body of ISO, the secretariat itself, another technical committee or subcommittee, or organization in liaison, the Technical Management Board or one of the advisory groups, or the Secretary-General.

The proposal will be circulated to the P-members of the technical committee or subcommittee for voting, and to the O-members for information.

See overleaf for guidance on when to use this form.

IMPORTANT NOTE: Proposals without adequate justification risk rejection or referral to originator. Guidelines for proposing and justifying a new work item are given overleaf.

Proposal (to be completed by the proposer)

Title of proposal (in the case of an amendment, revision or a new part of an existing document, show the reference number and current title)

English title Water footprint - principles, requirements and guidance

French title (if available)

Scope of proposed project

The proposed International Standard will deliver principles, requirements and guidelines for a water footprint metric of products, processes and organizations, based on the guidance of impact assessment as given in ISO 14044. It will define how the different types of water sources (for example ground, surface, lake, river, green, blue, gray, etc.) should be considered, how the different types of water releases should be considered, and how the local environmental conditions (dry areas, wet areas) should be treated. For products, it will apply the life cycle approach and will be based on the same product system as specified in ISO 14040 and ISO 14044. At the organization level, it will consider the guidance given by ISO 14064 for greenhouse gases. The standard will also address the communication issues linked to the water footprint, in accordance with the related published standards (ISO 14020, 14025) and standards under preparation (ISO 14067-2).

Concerns known patented items (see ISO/IEC Directives Part 1 for important guidance)

Yes No If "Yes", provide full information as annex

Envisaged publication type (indicate one of the following, if possible)

International Standard Technical Specification Publicly Available Specification Technical Report

FORM 4 (ISO) v.2007.1 Page 1 of 4 New work item proposal FORM 4 (ISO) v.2007.1 Page 2 of 4

Purpose and justification (attach a separate page as annex, if necessary) The scope of ISO/TC 207 is "standardization in the field of environmental management systems and tools in support of sustainable development". Freshwater is a very important natural resource, which everyday becomes more scarce and therefore urgently requires appropriate management tools to be used in an internationally consistent fashion by different stakeholders. This proposed ISO standard would provide such an essential tool. Freshwater use is not sufficiently considered as an impact category in present LCA studies and in other ISO norms. A methodological basis how to elaborate such an impact category is given in ISO 14044, but a specific environmental mechanism for “fresh water use” is not described in ISO 14044, nor are examples of such an impact category mentioned in ISO 14047. Therefore, the water consumption is typically treated in LCAs as an input parameter to be used for the LCI, without further consideration if the water is used from limited resources in dry areas or from abundant and renewable resources in wet areas, and the resulting data cannot be used for decision making. In their environmental reports, organisations often specify different types of water use, e.g., ground water use and surface water use, and they specially address the use of cooling water which is taken from a nearby river and released to this river without major losses or pollution. However, as international standards are missing, each organisation follows different definitions and criteria. Water footprint is a growing issue, as shown by the many conferences organised in recent months on this topic. Different organisations are working on this topic, such as the UNEP/SETAC Life Cycle Initiative and the Water Footprint Network. The fact that ISO/TC 207 is starting standardisation activities in the field of desertification is reflecting this trend, as well. The finding of consensus on how to quantify and report the use of fresh water resources, i.e., the water footprint, will be more difficult to reach than for greenhouse gases (GHG), as the local environment and the type of use play a crucial role. However the use of ISO 14044 as basis will facilitate the consensus finding on the international level. There is a strong need for an ISO standard to ensure the coherence with the other standards of the ISO 14000 series. Many national organisations and companies are developing GHG footprint and labelling initiatives, and ISO has reacted to this by working out ISO 14067. Water is a very important resource to manage for the coming years, especially for agricultural products, and therefore a standard that can explain and describe what a water footprint is will be crucial to ensure the coherence with other environmental metrics (especially carbon footprint and other life-cycle based indicators).
Target date for availability (date by which publication is considered to be necessary) 2011-12-31
Proposed development track 1 (24 months) 2 (36 months - default) 3 (48 months)
Relevant documents to be considered ISO 14040. International Organization for Standardization, Geneva, Switzerland. ISO 14044. International Organization for Standardization, Geneva, Switzerland. Verones F, Margni M, Loerincik Y, Humbert S (2009). Assessment of water use in LCA: State-of-the-art and case study, internal paper, submited to SETAC Europe conference, Goteborg, Sweden, June 2009. Koehler A, Bayart J-B, Bulle C, Margni M, Pfister S, Vince F (2008). A framework for assessing freshwater use within LCA: First results from the related project under the UNEP/SETAC Life Cycle Initiative. LCAVIII, Seattle WA, USA, October 2008. Koehler A (2008). Water use in LCA: managing the planet’s freshwater resources. Int J LCA 13(6): 451–455. Hoekstra AY, Chapagain AK (2007). Water footprints of nations: Water use by people as a function of their consumption pattern. Water Resource Management (21): 35-48. Hoekstra AY, Chapagain AK (2008). Globalisation of water, Blackwell publishing, Malden, USA.
Relationship of project to activities of other international bodies Water footprint network, UNEP/SETAC life cycle initiative, WRI/WBCSD standards

Liaison organizations	Need for coordination with: IEC CEN Other (please specify)

New work item proposal FORM 4 (ISO) v.2007.1 Page 3 of 4

Preparatory work (at a minimum an outline should be included with the proposal) A draft is attached An outline is attached. It is possible to supply a draft by March 2010 The proposer or the proposer's organization is prepared to undertake the preparatory work required Yes No	
Proposed Project Leader (name and address) Sébastien Humbert Ecointesys - Life Cycle Systems c/o Ecointesys - Life Cycle Systems PSE - A, EPFL CH - 1015 Lausanne Switzerland	Name and signature of the Proposer (include contact information) SNV Swiss Association for Standardization Urs Fischer Bürglistr. 29 CH - 8400 Winterthur Switzerland
Comments of the TC or SC Secretariat Supplementary information relating to the proposal This proposal relates to a new ISO document; This proposal relates to the amendment/revision of an existing ISO document; This proposal relates to the adoption as an active project of an item currently registered as a Preliminary Work Item; This proposal relates to the re-establishment of a cancelled project as an active project. Other: Voting information The ballot associated with this proposal comprises a vote on: Adoption of the proposal as a new project Adoption of the associated draft as a committee draft (CD) Adoption of the associated draft for submission for the enquiry vote (DIS or equivalent) Other:	

Annex(es) are included with this proposal (give details)

Date of circulation	Closing date for voting	Signature of the TC or SC Secretary
2009-03-09	2009-06-09	Mélanie RAIMBAULT - AFNOR

Use this form to propose:
a) a new ISO document (including a new part to an existing document), or the amendment/revision of an existing ISO document;
b) the establishment as an active project of a preliminary work item, or the re-establishment of a cancelled project;
c) the change in the type of an existing document, e.g. conversion of a Technical Specification into an International Standard.
This form is not intended for use to propose an action following a systematic review - use ISO Form 21 for that purpose.
Proposals for correction (i.e. proposals for a Technical Corrigendum) should be submitted in writing directly to the secretariat concerned.

Guidelines on the completion of a proposal for a new work item (see also the ISO/IEC Directives Part 1)
a) Title: Indicate the subject of the proposed new work item.
b) Scope: Give a clear indication of the coverage of the proposed new work item. Indicate, for example, if this is a proposal for a new document, or a proposed change (amendment/revision). It is often helpful to indicate what is not covered (exclusions).
c) Envisaged publication type: Details of the types of ISO deliverable available are given in the ISO/IEC Directives, Part 1 and/or the associated ISO Supplement.

d) Purpose and justification: Give details based on a critical study of the following elements wherever practicable. Wherever possible reference should be made to information contained in the related TC Business Plan.
1) The specific aims and reason for the standardization activity, with particular emphasis on the aspects of standardization to be covered, the problems it is expected to solve or the difficulties it is intended to overcome.
2) The main interests that might benefit from or be affected by the activity, such as industry, consumers, trade, governments, distributors.
3) Feasibility of the activity: Are there factors that could hinder the successful establishment or global application of the standard?
4) Timeliness of the standard to be produced: Is the technology reasonably stabilized? If not, how much time is likely to be available before advances in technology may render the proposed standard outdated? Is the proposed standard required as a basis for the future development of the technology in question?
5) Urgency of the activity, considering the needs of other fields or organizations. Indicate target date and, when a series of standards is proposed, suggest priorities.

New work item proposal FORM 4 (ISO) v.2007.1 Page 4 of 4
6) The benefits to be gained by the implementation of the proposed standard; alternatively, the loss or disadvantage(s) if no standard is established within a reasonable time. Data such as product volume or value of trade should be included and quantified.
7) If the standardization activity is, or is likely to be, the subject of regulations or to require the harmonization of existing regulations, this should be indicated.
If a series of new work items is proposed having a common purpose and justification, a common proposal may be drafted including all elements to be clarified and enumerating the titles and scopes of each individual item.
e) Relevant documents and their effects on global relevancy: List any known relevant documents (such as standards and regulations), regardless of their source. When the proposer considers that an existing well-established document may be acceptable as a standard (with or without amendment), indicate this with appropriate justification and attach a copy to the proposal.
f) Cooperation and liaison: List relevant organizations or bodies with which cooperation and liaison should exist.