SWIM and Horizon 2020 Support Mechanism

Working for a Sustainable Mediterranean, Caring for our Future

SWIM-H2020 SM EFS-EG-1 & 2

Methods and tools for assessing water budgets at the river basin scale

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Training Workshop with the competent authorities on the process of designing measures and policy targets at the local/ decentralized level

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Presentation Outline

- Why do we need water balance information?
- Basic definitions
- Hydrological water balance
- Water budgets: incorporating anthropogenic influence
- Models, Tools
- Policy relevance

Why do we need to know water balances?

You can't manage what you don't measure !!

- Quantifying the components of water balance is the **foundation of effective water management** and environmental planning and of any Water Resources Management Plan
- Indispensable input for the drafting of the **River Basin Management Plans**
- Water balance evaluations are important in assessing the **effects of climate variability,** the level of **pressure that human activity exerts** on the natural water resources of a particular territory, **water stress conditions, and the sustainability** of the various economic activities
- Supports **proper water allocation**, the design of adequate **Programmes of Measures**, and helps prioritize water **demand management** efforts
- Contributes to **better governance** at the decentralized level, initiating a **better coordination** between stakeholders at the local level when it comes to the monitoring of water balance components, the definition of **water management targets, and the design of mitigation measures**

Basic Definitions

It is often observed that stakeholders do not necessarily have a common understanding of the basic definitions and use the different terms interchangeably.

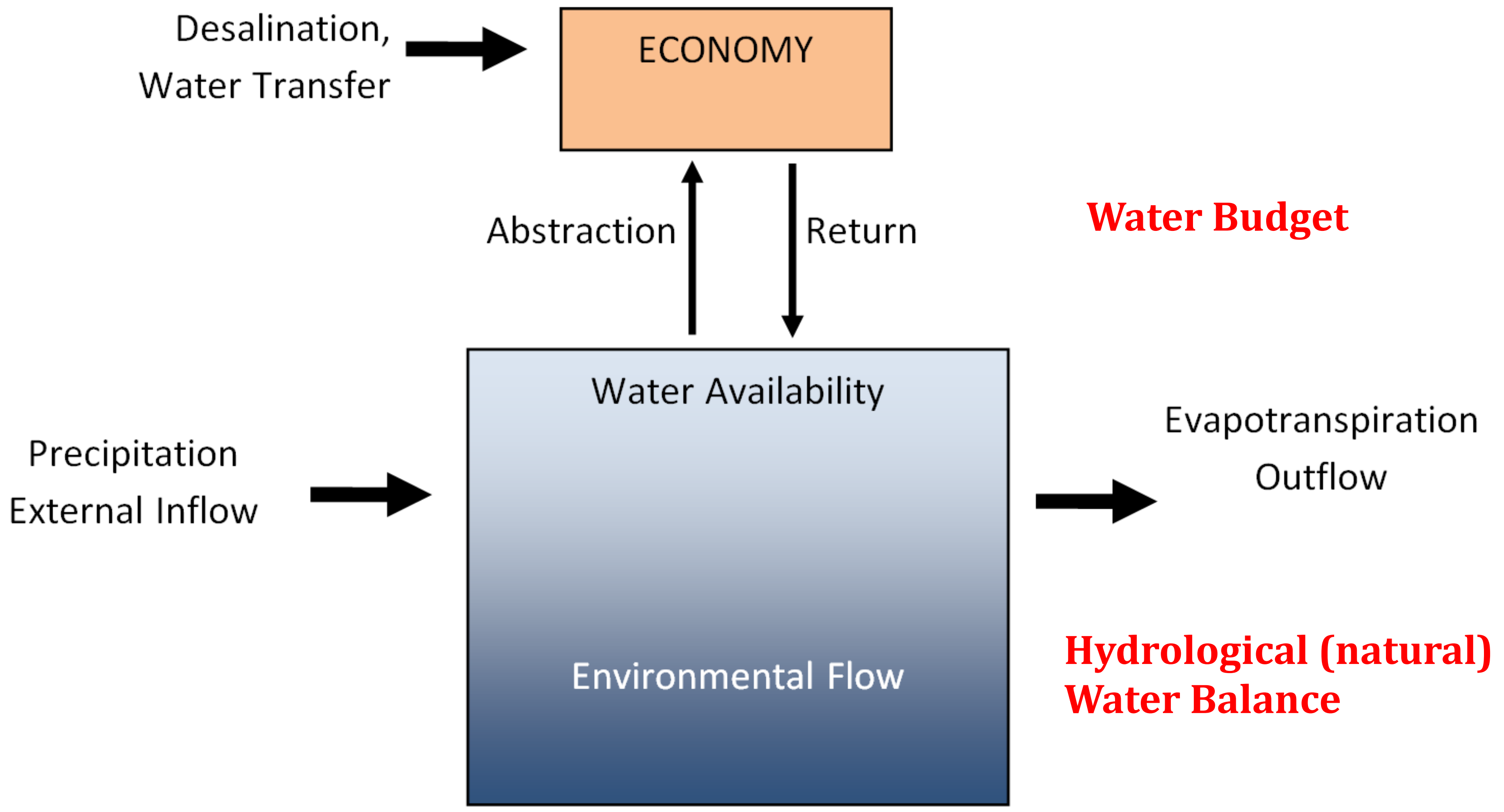
- **Hydrological (natural) Water Balance:** the analysis and quantification of the components of the water cycle, accounting for flow and storage changes in natural systems that contain water. Systems of interest can be features such as rivers, lakes, river basins, the land surface, or aquifers.
- **Freshwater Availability:** the sum of available and exploitable natural freshwater resources, originating from all potential sources (surface water, groundwater, precipitation, snow).
- **Freshwater Abstraction (or withdrawal):** the process of taking water from a natural hydrological regime (ground or surface water body), either temporarily or permanently, and conveyed to a place of use.
- **Water Budget:** the analysis and quantification of the components of the hydrological (natural) water balance **together with** the human-induced changes (abstractions, returns, etc.)

- **Water scarcity or stress:** occurs when availability at a certain time step is not enough to meet the demand. If this is a short term condition, then we refer to water stress, but if the problem further develops in time (longer term condition) or if re-occurs often for a certain time period we then refer to water scarcity.

Basic Definitions (cont.)

- **Returned water**: the part of the water which has been abstracted from a fresh water source and discharged/ returned into its source or into another fresh water body (surface or groundwater) **either before use (leakage losses) or after use (as treated effluent or as non-treated)**. Discharges to the sea are not included.
- **Reused water:** water that **has undergone wastewater treatment and is delivered to a user as reclaimed wastewater**. Wastewater discharged into a watercourse and used again downstream is excluded (i.e. this is considered returned water).
- **Recycled water**: is **used multiple times by the same user** (either treated or non-treated) after withdrawal and before it returns to the natural hydrologic system.
- **Recycled drainage water**: multiple reuse of drainage water in the Nile Delta has been adopted as an official policy since the‘70s. The policy calls for recycling agriculture drainage water by pumping it from main and branch drains and mixing it with fresh water in main and branch canals (CEDARE, 2014). The reused quantity amounts to more than 13.5 billion m3/yr in 2017

Basic Definitions

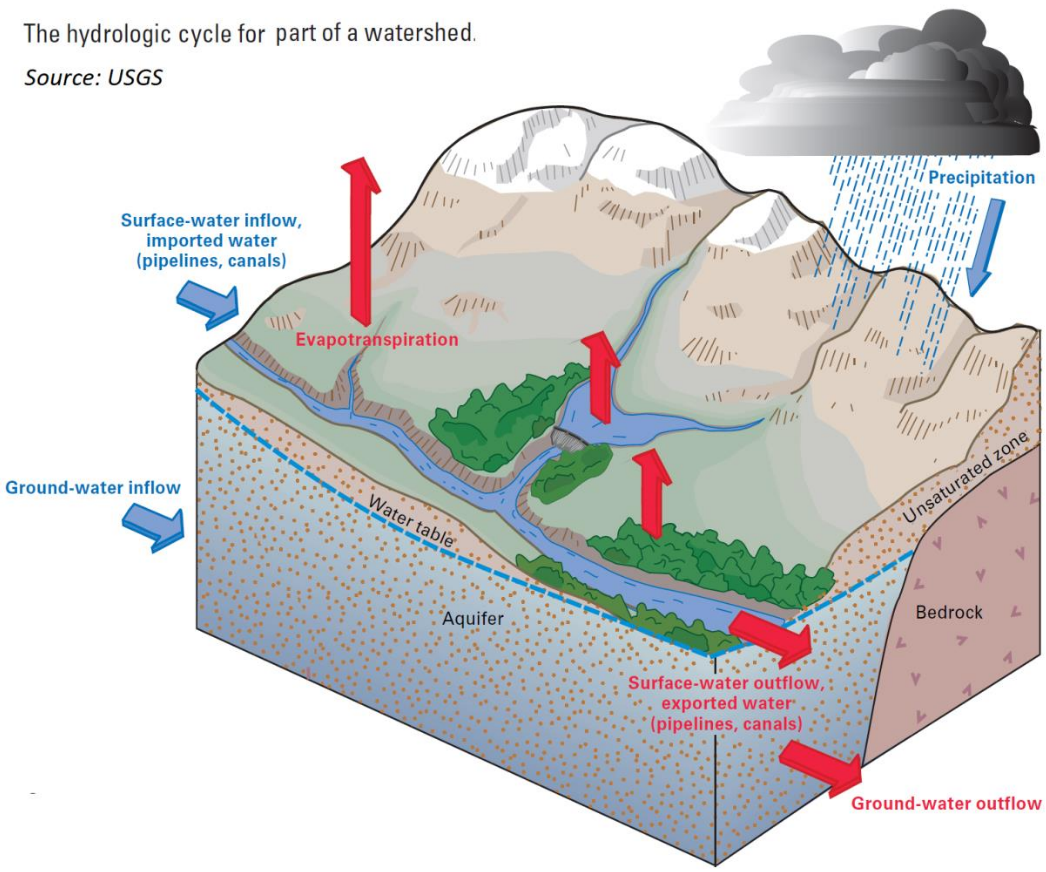


Hydrological Water Balance

Flow In – Flow Out = Change In Storage

The hydrologic cycle for part of a watershed.

Source: USGS



<u>Flow In</u>
P: precipitation,
Qin: water flow into the basin

<u>Flow Out</u>
ET: evapotranspiration (the sum of evaporation from soils, surface-water bodies, and plants),
Qout: water flow out of the basin

<u>Change in Storage</u>
ΔS: is change in water storage (in all compartments – surface, groundwater, snowpck, etc.)

(P + Qin) - (ET + Qout) = ΔS

Hydrological Water Balance

$$(P + Q_{in}) - (ET + Q_{out}) = \Delta S \qquad \text{[Equation 1]}$$

- **Units**: volumes (for a fixed time interval), fluxes (volume per time, e.g. m3/day, m3/month), flux densities (volume per unit area of land surface per time, e.g. millimeters per day)

- Equation 1 can be **refined and customized** depending on the goals and scales of a particular study.

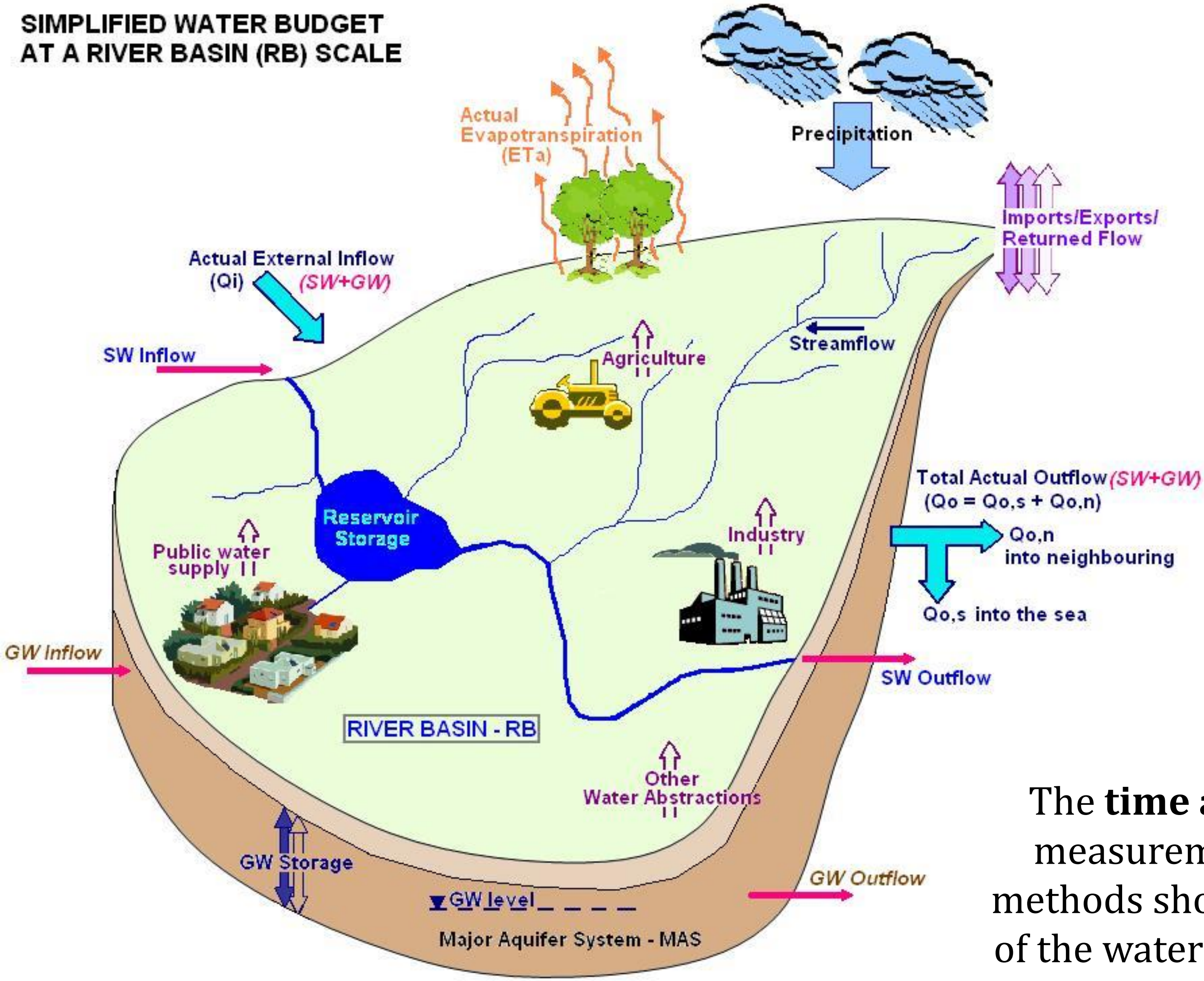
$$P + Q_{sw,in} + Q_{gw,in} = ET_{sw} + ET_{gw} + ET_{uz} + \Delta S_{sw} + \Delta S_{snow} + \Delta S_{uz} + \Delta S_{gw} + Q_{gw,out} + RO + Q_{bf} \qquad \text{[Equation 2]}$$

- It is unlikely that all elements in equation 2 will be of importance at any one site; some will be of negligible magnitude and can be ignored. **Simplifications**, often Qin negligible, Qout = runoff

- When selecting an **accounting unit for developing a water balance**, careful selection of boundaries can greatly facilitate the accounting process

- Accurate **measurements** are important, often difficult (e.g. groundwater recharge)

Water Budget



- Abstractions
- Returned flows
- Water Transfers (imports/ exports)
- Additional water resources (desalination, TWW, artificial recharge)

The **time and space scales** of measurement and estimation methods should **match the needs** of the water-budget study at hand

Water budget parameters

WATER AVAILABILITY

WATER BALANCE (WB)

A. Hydrometeorological Parameters

- Areal Precipitation (P)
- Potential Evapotranspiration (PET)
- Actual Evapotranspiration (ETa)
- Internal Flow (D = P - ETa)
- Total actual external inflow (Q_i)
- Total actual outflow (Qo = Qo,s + Qo,n)
- Water Requirements (WR)
- Aquifer Recharge (Re)

B. Water Storage

- Snowpack
- Changes in reservoir storage
- Changes in groundwater storage

C. Additional Water Resources

- Return flow (before/after use)
- Reused water (and leakages)
- Desalinated water
- Water imports
- Water exports
- Artificial groundwater recharge

POINT DATA

- Streamflow (Q) at selected gauges located within the WB reporting unit
- Reservoir (R) inflow/outflow at selected reservoirs located within in the WB reporting unit
- Groundwater level (H) at selected wells located within in the WB reporting unit
- Precipitation from Rain gauge stations located within the WB reporting unit

WATER ABSTRACTION

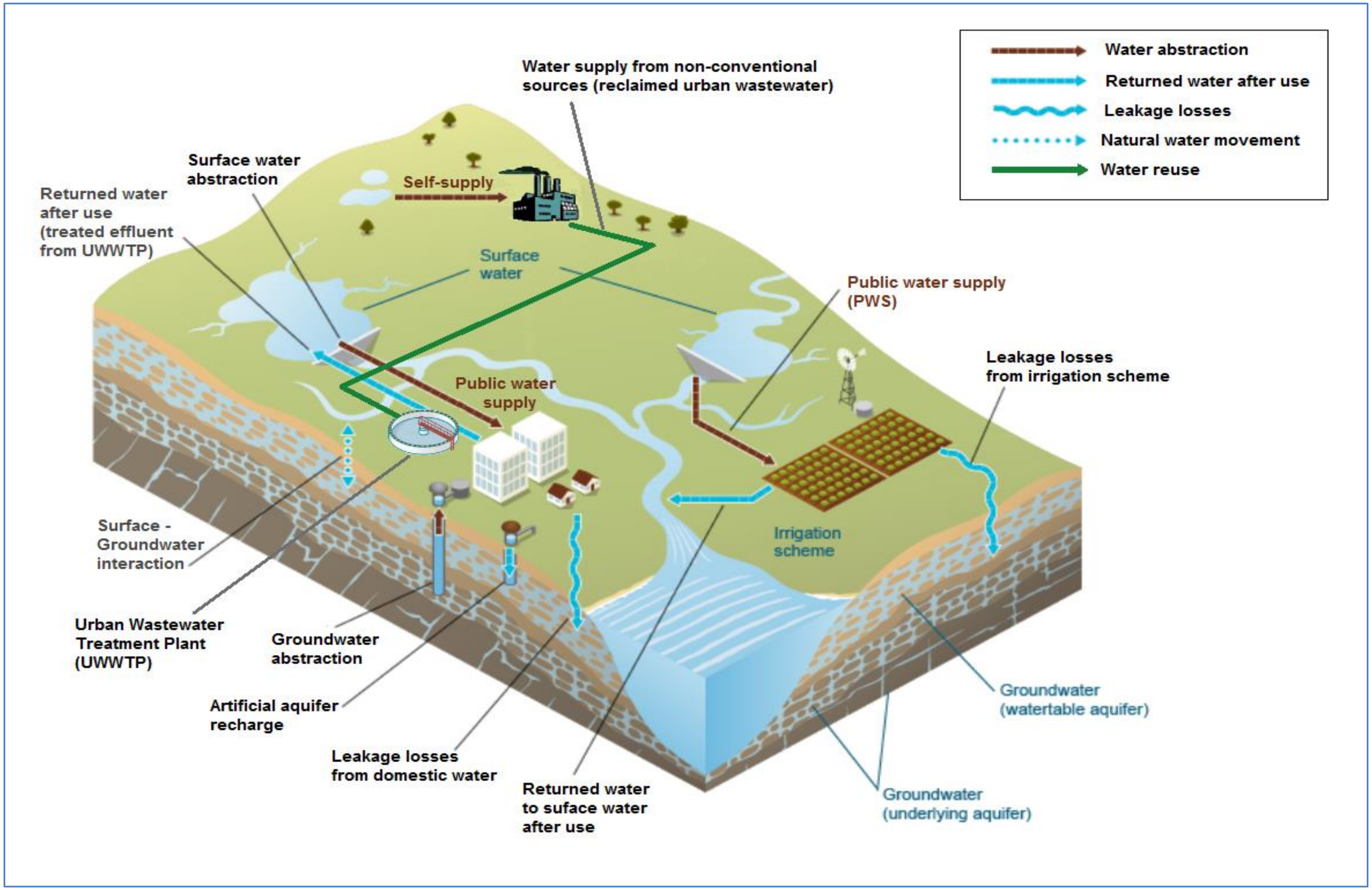
- Total Volume of freshwater abstraction (from both SW + GW)
- Groundwater available for annual abstraction
- Losses (during transport and use)
- Non freshwater sources (marine and brackish water) and breakdown per sector (according to NACE classes)

Water Budget

$(P + Q_{in}) - (ET + Q_{out}) = \Delta S$ [Equation 1]

	Flow In	Flow Out	Change in Storage
NATURAL SYSTEM	Precipitation External Inflow into the basin (surface) External Inflow into the basin (groundwater)	Evapotranspiration Baseflow Runoff/ river discharge Goundwater flow out of the basin	Change in natural reservoir/ lake storage Change in groundwater storage (caution if artificial recharge) Change in soil moisture storage Change in snowpack
MAN-MADE	Returned flows (TWW, non-treated) Water imports Desalination Artificial recharge (not double-count with returned flow or imports)	Abstractions Water exports (not double-count with abstraction)	Change in artificial reservoir/ dam Water Requirements (e.g. environmental flows, treaties, conventions, etc.)

Schematic chart of the water flows and transfers in a river basin



Adopted from: Australian Government, Bureau of Meteorology, Supporting information for water accounting statements, Perth Region

Water Budget calculations - tips

- When selecting an **accounting unit for developing a water budget**, careful selection of boundaries can greatly facilitate the accounting process
- Often **mismatch of scales**, **hydrological vs. administrative boundaries**
- **Water quality** poses additional constraints to water availability since its limits some uses, needs to be considered
- Accurate **measurements** and/or estimates are important, often difficult (e.g. illegal abstractions)
- All water-budget calculations contain some uncertainty. There are **two general sources of this uncertainty**: **natural variability of the hydrologic cycle** and **errors associated with measurement techniques**

Models, Tools for calculating water budgets

Watershed models are perhaps the most complete form of a water-budget model.

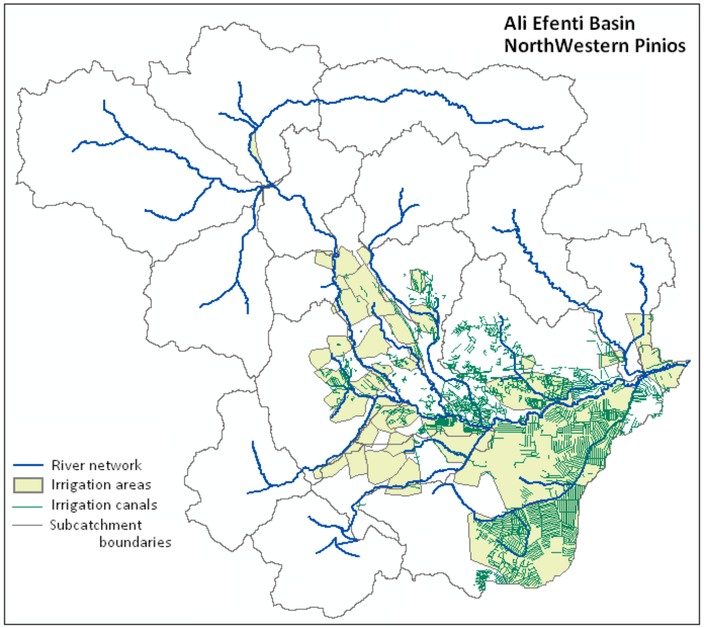
They predict stream discharge within a basin in response to precipitation and snowmelt, usually accounting for processes such as evapotranspiration, ground-water/surface-water exchange, and surface-water routing .

Watershed models are widely used for watershed management and planning, e.g. they can be used to predict the effects of land-use changes (such as urban development) on streamflow.

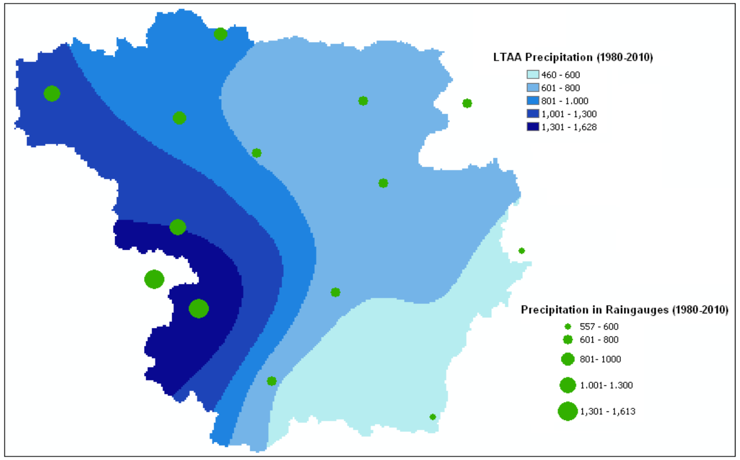
Some examples:

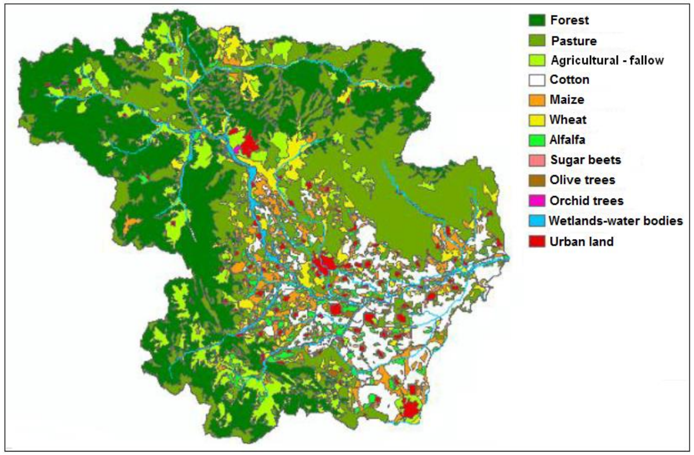
- Water Evaluation and Planning System (**WEAP21**) https://www.weap21.org/
- Hydrologic Modeling System (**HEC-HMS**) www.hec.usace.army.mil/software/hec-hms/
- Soil and Water Assessment Tool (**SWAT**) https://swat.tamu.edu/
- Better Assessment Science Integrating Point and Non-point Sources (**BASINS**)
- https://www.epa.gov/ceam/better-assessment-science-integrating-point-and-non-point-sources-basins

Case Study: Ali-Efenti River Basin, Greece



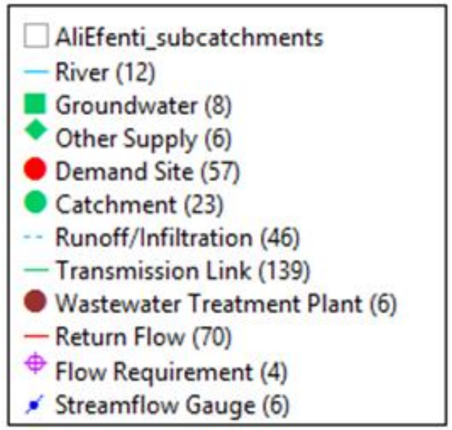
- Drainage area: 2,920 km2 (1/3 of Pinios)
- Population: 190,276 inhabitants
- Mean Annual Precipitation: 460-1,630 mm
- Land Use: 33% Forest, 33% Agriculture, 31% Pasture, 2% Urban
- Main crops: cotton, maize, alfalafa, sugarbeet, (wheat)
- Extensive irrigation, low efficiency
- Water stress, unmet demand is highly pronounced during the summer
- Over-abstraction → degradation of groundwater resources, declining groundwater levels
- Week institutional and policy setting

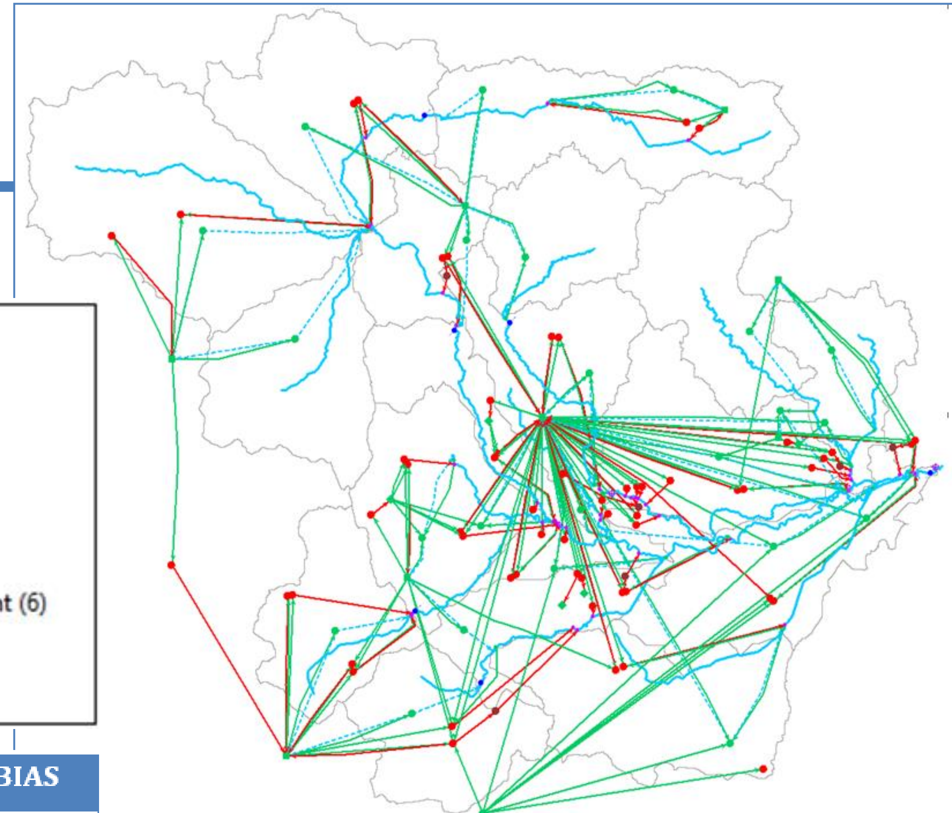




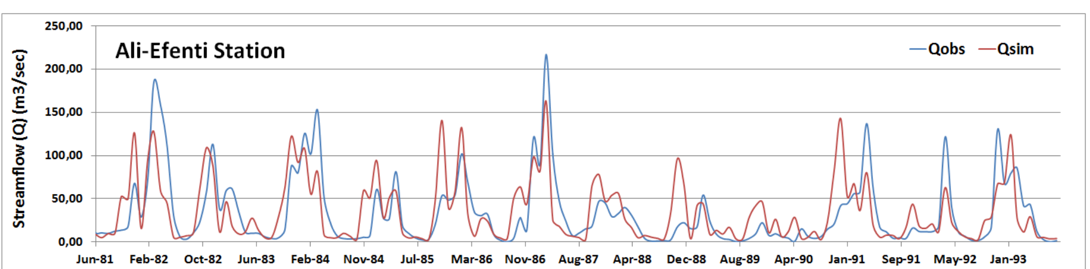
Ali-Efenti: WRMM setup

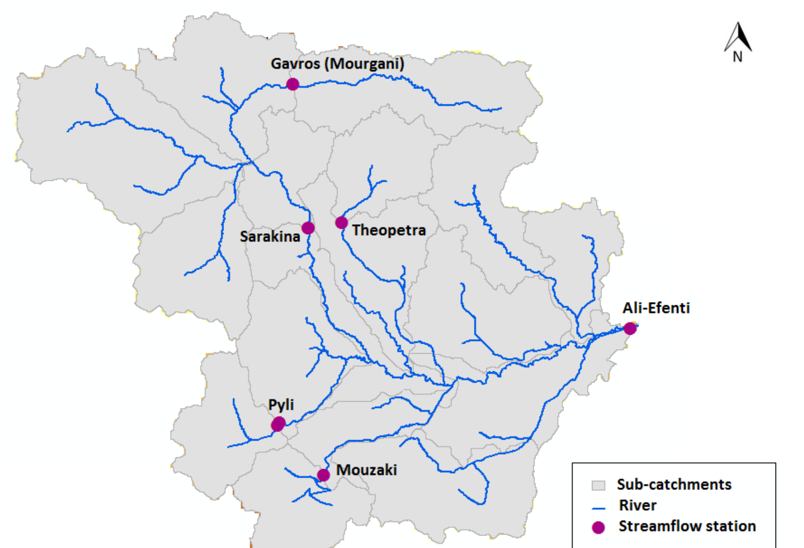
- **WEAP21 software**
- node-based
- monthly resolution
- Calibrated and validated for 1980-1994
- Baseline (reference) period 1995-2010



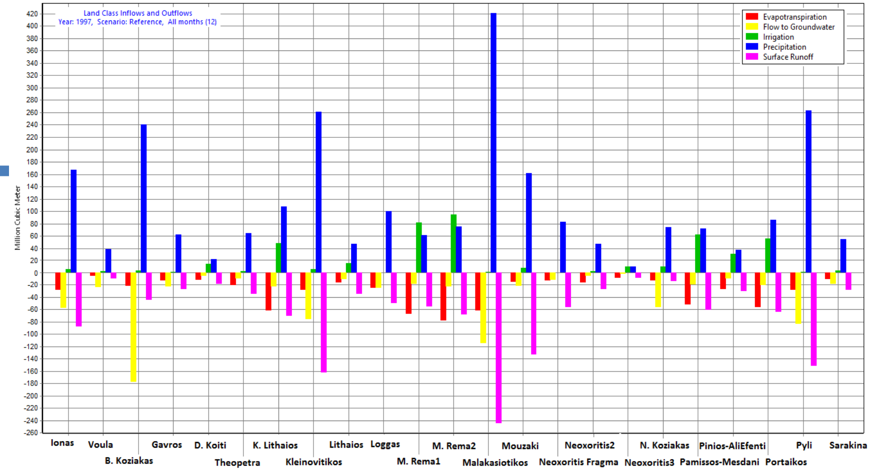


Gauge station	Validation period	E	r	BIAS
Pyli	10/1990 - 9/1993	0.639	0.811	-0.133
Mouzaki	10/1992 - 9/1994	0.565	0.802	-0.309
Gavros (Mourgani)	10/1988 - 9/1993	0.650	0.820	0.197
Sarakina	10/1988 - 9/1993	0.680	0.875	-0.201
Theopetra	10/1988-9/1993	-0.088	0.161	-0.683
Ali Efenti	10/1984 - 9/1993	0.595	0.790	0.078

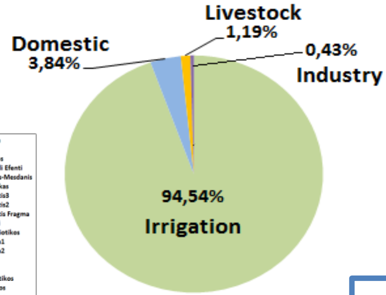


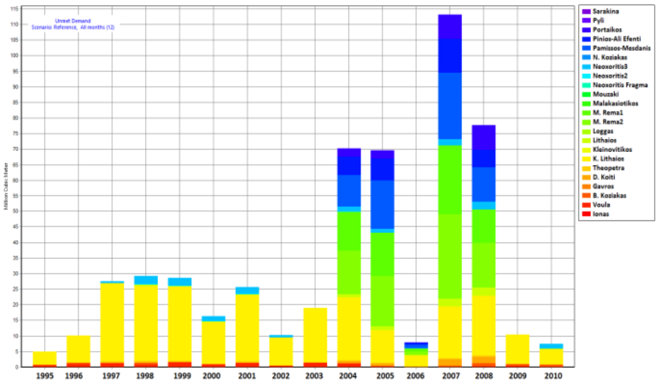


WRMM results



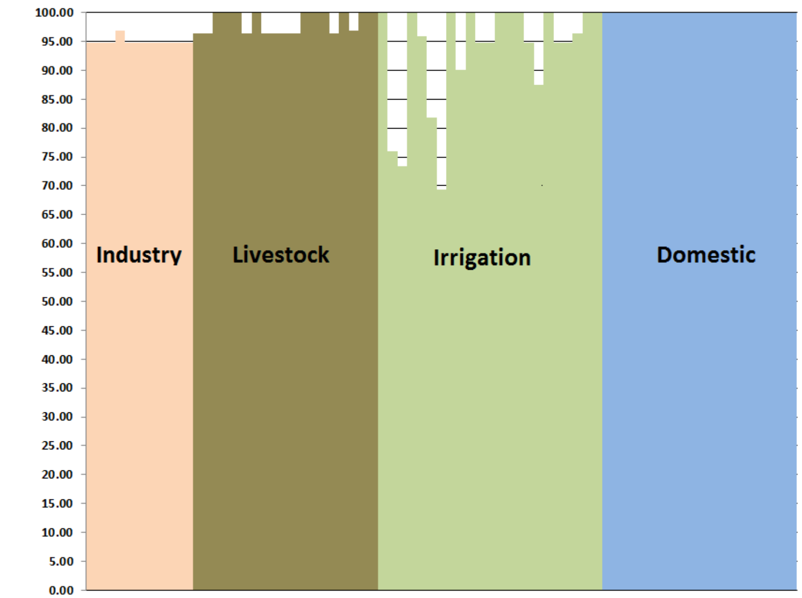
Share(%) of water abstraction per sector





Year	Total Supply Delivered (mio m³)	Total Demand (mio m³)	Total Unmet Demand (mio m³)	Unmet Demand as % of Total demand
1995	476.65	481.57	4.92	1,02%
1996	489.16	499.33	10.18	2,04%
1997	483.39	510.87	27.47	5,38%
1998	494.44	523,.72	29.30	5,59%
1999	490.44	518.97	28.52	5,50%
2000	519.46	535.78	16.31	3,04%
2001	508.02	533.63	25.62	4,80%
2002	483.82	494.07	10.25	2,07%
2003	479.53	498.49	18.97	3,81%
2004	446.36	517.16	70.79	13,69%
2005	442.35	512.34	70.02	13,67%
2006	500.47	508.65	8.21	1,61%
2007	402.39	516.27	113.96	**22,07%**
2008	436.75	515.06	78.34	15,21%
2009	504.13	514.60	10.47	2,03%
2010	495.64	503.03	7.38	1,47%
SUM	**7,653.00**	**8,183.54**	**530.71**	**6,49%**
Average	**478.30**	**511.50**	**33.17**	**6,49%**

% Reliability



Reliability	Domestic users	Livestock users	Industrial users	Irrigation users
Very High (>97%)	100%	53%		43.5%
High (90-97%)		47%	100%	34.8%
Medium (75-90%)				13.0%
Low (<75%)				8.7%

Policy relevant questions ....

- How much water do humans use?
- How much water do ecosystems need to flourish?
- How much water is available for humans and ecosystems? Are our practices "tapping" into the renewable resources and thus our sustainability (water stress, over-abstraction, etc.)?
- Where is this water?
- How does the hydrologic cycle naturally change over time?
- In what ways do human activities affect the hydrologic cycle?
- How will changes in the hydrologic cycle affect water availability and use, and in-turn socio-economic development?
- What effects do uncertainties in estimates of the water budget parameters have on our understanding of water budgets in general and of the availability and sustainability of water resources in particular? How can we minimize these uncertainties?

Points for open discussion

- Do you perform water budget calculations?
- At which temporal and spatial scales?
- What is the importance of the water budget estimates in the River Basin Water Management Plans?
- Are the primary data available and easily accessible? What are the identified data gaps?
- What are the main constraints and challenges in periodically calculating water balances and water budgets?
- What would be the necessary actions forward?

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Thank you!

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