2 Vodna bilanca
Water Balance

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Vodnobilančni račun temelji na kroženju vode. Kaj je vodni krog?

Voda na Zemlji je v stalnem gibanju, hkrati pa spreminja fizikalna stanja – od tekočega in plinastega do trdnega ter obratno. Neprestano premikanje vode z vsemi stanji opisuje vodni krog, ki deluje na Zemlji že milijarde let. Vse življenje temelji na njem.

Pri vodnem kroženju na Zemlji ločimo mali in veliki vodni krog. Kroženje vode med oceani in atmosfero predstavlja glede na količine glavnino vodnega kroga. Imenujemo ga tudi mali vodni krog. Veliki vodni krog poteka tudi na kopnem in je bolj razvejan in raznovrsten. Seveda se oba krogotoka prepletata.

Vodna bilanca ocenjuje količine vode na določenem območju v določenem časovnem obdobju. Upoštevati mora vse dotoke in odtoke ter spremembe zalog. Za preprost sistem, kakršen je npr. posoda ali vodni zbiralnik z merljivim dotokom in odtokom, je bilanca preprosta in lahko razumljiva. Shematično je preprosta tudi bilanca malega vodnega kroga, pri katerem so glavni »dotok« padavine, glavni »odtok« pa je izhlapevanje (Ritter, 2006). Veliko bolj zapletena je vodna bilanca izbranega območja, kot je npr. država, pokrajina itd. Tovrstna bilanca je vedno poenostavljen prikaz dejanskih razmer, smiselna pa, če zajame vse bistvene bilančne elemente in pravilno poda razmerja med njimi.

Osnovna enačba vodne bilance temelji na kroženju vode med ozračjem in površjem Zemlje (Van Abs et al., 2000; Kolbezen et al., 1998):

> Padavine (P) = Odtok (Q) + Izhlapevanje (I) +
> + Sprememba zalog (dS)

Padavine so po definiciji atmosferska voda, ki po kondenzaciji in sublimaciji izhaja iz zraka in zaradi težnosti pada proti tlem oz. pade na tla (DIN 1996 po Schöniger et al., 2003). S pojmom

The water balance calculation is based on the circulation of water. What is the water cycle?

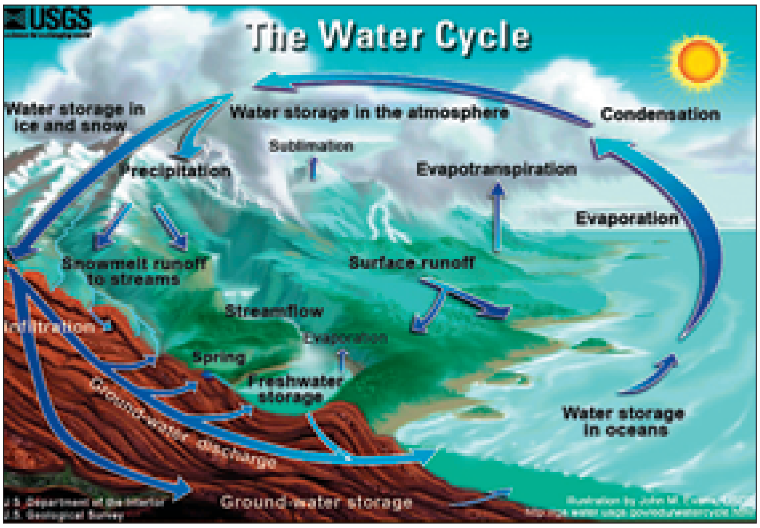
Water on Earth is in constant motion and, at the same time, it changes its physical states – from liquid and gaseous to solid and vice versa. The constant movement of water in all its physical states is the water cycle that has been going on on Earth for billions of years. All life is based on it.

We distinguish between the small water cycle and the large water cycle in the circulation of water on Earth. The circulation of water between the oceans and the atmosphere represents the major part of the water cycle because of the quantities involved. We also call it the small water cycle. The large water cycle takes place on land and is more diversified and differentiated. Both cycles, of course, intertwine with one another.

The water balance assesses the quantities of water in a certain area and over a certain time period. It must consider all the inflows and outflows as well as changes in storage. For simple systems, such as a container or water reservoir with measurable inflow and outflow, the balance is straightforward and easily understood. The small water cycle schematic, where the main »inflow« is precipitation and the main »outflow« is evaporation, is also straightforward (Ritter, 2006). The water balance of a selected area, such as a country, region, etc., is much more complicated. Such a balance is invariably a simplified depiction of the actual conditions and is only practical if it covers all the essential water balance elements and accurately portrays the relations between them.

The basic water balance equation is based on the circulation of water between the atmosphere and the surface of the Earth (Van Abs et al., 2000, Kolbezen et al., 1998):

> Precipitation (P) = Runoff (Q) + Evaporation (I) +
> + Changes in the storage (dS)



http://ga.water.usgs.gov/edu/watercyclehi.html

Slika 3: *Kroženje vode na Zemlji*

Figure 3: *The circulation of water on Earth*

izhlapevanje označimo prehajanje vode v paro z odprtih vodnih površin, kar pojmujemo kot evaporacijo, in preko rastlinstva, kjer prehajanje poteka s transpiracijo. Izraz izhlapevanje zajema obe obliki, ki ju združeno imenujemo tudi evapotranspiracija. Z odtokom zaobjamemo različne oblike pretakanja vode od ploskovnega površinskega odtoka, premikanja (infiltracije in pronicanja) vode v preperelini (prst, tla) in tokov podzemne vode, do pretoka rek. V naših razmerah zaradi dolgega obdobja analize lahko zanemarimo sneg in led. V vodni bilanci se omejimo na analizo območij – hidrometričnih zaledij, katerih odtok lahko izmerimo kot pretok vode (Q) skozi merski profil vodomerne postaje.

Pri obravnavi vodne bilance izbranega območja je potrebno poleg padavin upoštevati še ostale dotoke vode (Q_v). Tako enačbo lahko zapišemo:

P (padavine) + Q_v (dotok) = Q_o (odtok) +
+ I (izhlapevanje) + dS (sprememba zalog)

Po priporočilih Svetovne meteorološke organizacije je povprečne podnebne in hidrološke

According to the definition, precipitation is atmospheric water that exits from the air either by condensation or sublimation and falls to or towards the ground because of gravity (DIN 1996 according to Schöniger et al., 2003). The term evaporation signifies the transfer of water into vapour from areas of open water, while transpiration means the transfer through vegetation. The term evaporation in this book encompasses both forms, which are together called evapotranspiration. The term runoff covers various forms of water transfer ranging from arial surface runoff, the movement (infiltration and percolation) of water into the eluvium (soil, ground) and the flow of groundwater, to the discharge of rivers. Snow and ice may be disregarded in our analysis due to longterm period concerned. When analysing the water balance, we limit ourselves to the analysis of the areas – to hydrometric catchment areas – whose runoff can be measured as the water flow rate (Q) through the water-gauging cross-section of the water gauging station.

In addition to precipitation, it is necessary to consider other inflows of water (Q_v) when dealing with the water balance of a selected area. The equation is thus as follows:

P (precipitation) + Q_v (inflow) = Q_o (runoff) +
+ I (evaporation) + dS (changes in the storage)

According to the recommendations of the World Meteorological Organization, it is reasonable to treat the average climatic and hydrological conditions in a certain area covering a longer (30-year) period. To calculate the water balance, we covered precipitation, evaporation and runoffs in the 1971–2000 period. We have not considered changes in water storage (dS) in the balance for the 1971–2000 period, as we assume that these can be neglected over a long-time period (Frantar et al., 2005).

In a spatial sense, the main building block of the water balance is the hydrometric catchment area. This area (polygon) is delimited by the water divide of balance cross-sections that are predominantly the water divides of the water gauging stations used. Aside from precipitation, the headwater hydrometric catchment areas do not have other inflows. The precipitation surplus that does not evaporate and simply flows out of them and is measured as a discharge (Q) on the water balance cross-section at the appropriate water gauging station. Intermediate hydrometric catchment areas receive water from both precipitation and inflow from the upstream hydrometric catchment area. The inflow (Q_v) and runoff (Q_i) are measured as the discharges razmere na nekem območju smiselno obravnavati v daljšem (30-letnem) obdobju. Za izdelavo vodne bilance smo obravnavali padavine, izhlapevanje in odtoke v obdobju 1971–2000. V bilanci obdobja 1971–2000 sprememb vodnih zalog (dS) nismo upoštevali, saj predpostavljamo, da so zaradi povprečevanja zanemarljive (Frantar et al., 2005).

V prostorskem smislu je osnovni gradnik vodne bilance hidrometrično zaledje. To je območje (poligon) omejeno z razvodnicami bilančnih profilov, ki so v večini kar razvodnice uporabljenih vodomernih postaj. Povirna hidrometrična zaledja razen padavin nimajo dotokov, presežek padavin, ki ne izhlapi, pa iz njih odteče in ga kot pretok (Q) izmerimo na bilančnem profilu na ustrezni vodomerni postaji. Pretočna hidrometrična zaledja prejemajo vodo s padavinami in dotokom iz gorvodnega hidrometričnega zaledja. Dotok (Q_v) in odtok (Q_i) merimo kot pretok na gorvodnih in dolvodnih vodomernih postajah. Razlika med njima je neto odtok hidrometričnega zaledja ($Q_i – Q_v = Q_n$). Pri povirnih hidrometričnih zaledjih je pretok, ki ga izmerimo ne merskem profilu že neto odtok ($Q = Q_n$). Pravilna prostorska razmejitev hidrometričnega zaledja je torej zelo pomembna.

Za bilančne analize so bile izbrane postaje, ki imajo popolne podatkovne nize pretokov ali pa jih je bilo s pomočjo statističnih metod mogoče dopolniti. Nepopolne nize vodomernih postaj smo dopolnili s pomočjo Pearsonovega koeficienta linearne korelacije na podlagi srednjih mesečnih pretokov obdobja 1961–2001. Postaj, ki imajo ustrezne podatkovne nize, nimajo pa zanesljivo omejenih hidrometričnih zaledij, v bilanci nismo upoštevali (npr. vodomerna postaja Hasberg na Unici ima kraško vodozbirno zaledje, katerega obseg se spreminja v odvisnosti od hidroloških razmer).

Za izbrana območja smo analizirali in usklajevali člene vodne bilance – padavine, izhlapevanje in odtok. Odtoke, ki so izvedeni iz pretokov vodomernih postaj (Q), smo primerjali z odtoki, ki jih izračunamo z bilančno enačbo ($Q_b = Q = P – I$).

Pravilnost razmerij med elementi vodne bilance smo pregledali s pomočjo analize bilančne napake. Bilančna napaka je oblika kontrole osnovnih elementov vodnega kroga in medsebojnega vpliva. Vzroki za odstopanja med njimi so lahko različni, od napake meritev pa do nezanesljivih razvodij na vodonosnikih z veliko vodoprepustnostjo (kraški razpoklinski ali vodonosniki z medzrnsko poroznostjo).

V vodni bilanci pretoke (Q) praviloma podajamo v m^3/s, padavine (P) in izhlapevanje (I) pa v mm. Zaradi medsebojne primerjave pa smo lahko tudi padavine in izhlapevanje izrazili

at the upstream and downstream water gauging stations. The difference between them is the net runoff of the hydrometric catchment area ($Q_i – Q_v = Q_n$). The discharge measured at the water-gauging cross-section in the headwater hydrometric catchment area is the net runoff ($Q = Q_n$). The correct spatial delimitation of the hydrometric catchment area is therefore very important.

The water balance analysis required the selection of water gauging stations with complete data sets for discharges or with data sets that could be supplemented with the aid of statistical methods. Incomplete data sets were supplemented with the aid of the Pearson linear correlation coefficient based on the mean monthly discharges in the 1961–2001 period. Stations with suitable data sets but without reliably delimited hydrometric catchment areas were also not taken into account in the water balance (e. g. the Hasberg water gauging station on the Unica River has a karstic water basin catchment area whose size changes depending on the hydrological conditions).

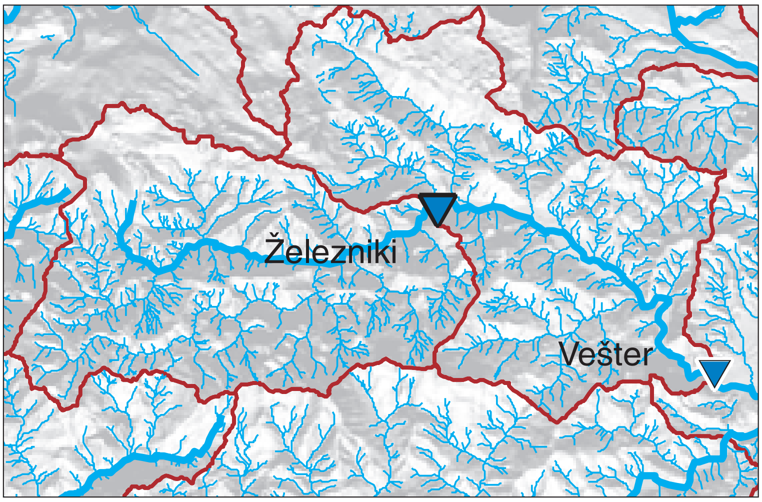
We analysed and reconciled the water balance elements of precipitation, evaporation and runoff for the selected areas. The runoffs derived from the discharges at water gauging stations (Q) were compared with the runoffs calculated using the water balance equation ($Q_b = Q = P – I$).

The correctness of the relationships between the elements of the water balance was reviewed with the help of balance error analysis. The balance error is a form of control over the basic elements of the water cycle and their interaction. The causes of deviations between them are diverse, ranging from an error in the measurement to unreliable water divides in aquifers with high permeability (karstic fissured aquifers or aquifers with intergranular porosity).

Slika 4: *Deroča voda Učje*

Figure 4: *Storm water in the Učja River*

ARSO



Slika 5: *Primer povirnega hidrometričnega zaledja je vodozbirno zaledje Selške Sore gorvodno od vodomerne postaje Železniki, primer pretočnega pa vodozbirno zaledje Selške Sore med vodomernima postajam Železniki in Vešter. Hidrometrična zaledja so omejena z razvodnico.*

Figure 5: *An example of a headwater hydrometric catchment area is the watershed area of the Selška Sora River upstream from the Železniki water gauging station, while an example of an intermediate hydrometric catchment area is the area of the Selška Sora River between the water gauging stations of Železniki and Vešter. The hydrometric catchment areas are delimited by a drainage divide.*

v m^3/s in pretok v mm. Za pretvorbo je potreben podatek o površini območja. Specifični odtoki podajajo povprečno količino odtekle vode z določenega območja in so izraženi v $l/s/km^2$ ali v mm. Izvedeni so iz obdobnih srednjih letnih pretokov (Qs) – **Hq** ali pa so izračunani na osnovi bilančnega računa z razliko padavin in izhlapevanja – **Kq**.

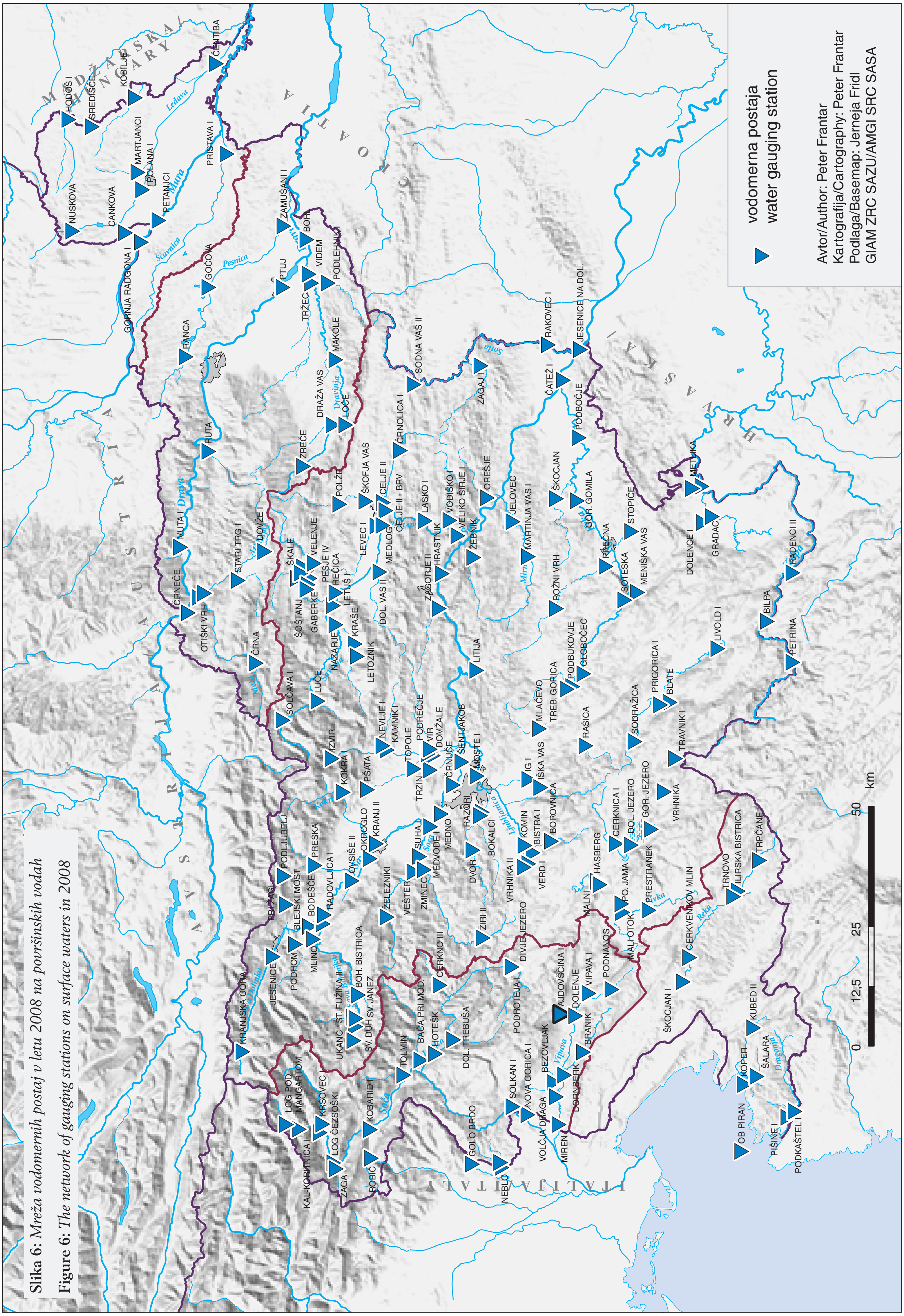
Odtočni količniki podajajo delež padavin, ki odtečejo z določenega območja, in so pridobljeni na osnovi izmerjenih hidroloških pretokov in padavin (KH – hidrološki odtočni količnik) ali na osnovi izračunanih odtokov (KK – klimatološki odtočni količnik).

Razen v poglavju o trendih podatki vedno pomenijo srednje letne vrednosti obdobja 1971–2000, če ni drugače navedeno.

The discharges (Q) in the water balance are, as a rule, expressed in m^3/s, while precipitation (P) and evaporation (I) are expressed in mm. For the purpose of comparison, we also expressed precipitation and evaporation in m^3/s and the discharge in mm. The surface area of a sector is required for the conversion. Specific runoffs give the average quantities of water that ran out of a certain sector and these are expressed in $l/s/km^2$ or in mm. They are derived from the reference period mean discharges (Qs) – **Hq** or are calculated based on the balance equation with the difference between the precipitation and evaporation – **Kq**.

The runoff coefficients give the share of precipitation that runs out of a certain area and are obtained based on the measured hydrological discharges and precipitation (KH – hydrological runoff coefficient) or on the basis of the calculated runoffs (KK – climatic runoff coefficient).

Except in the Trends chapter, the data always refers to the mean annual values for the 1971–2000 period if not stated otherwise.



Slika 6: *Mreža vodomernih postaj v letu 2008 na površinskih vodah*

Figure 6: *The network of gauging stations on surface waters in 2008*

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Slika 7: *Predaselj* / **Figure 7:** *The Predaselj gorge*