

DOLOČITEV EKOHIROGRAFSKIH OBMOČIJ V REPUBLIKI SLOVENIJI DETERMINATION OF ECOHYDROGRAPHICAL REGIONS IN SLOVENIA

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Direktiva Evropske unije o politiki do voda (WFD) daje podlago za zaščito in izboljšanje vodnega okolja. Vodna telesa površinskih voda je treba določiti po kategorijah in jih ločiti po tipih. V članku je prikazan osnutek razvrstitve vodotokov in jezer v Sloveniji na tipe ekohidrografskih območij. WFD predvideva dva načina določanja tipov vodotokov: sistem A po Illiesu, na podlagi ekoregij, prikazanih v Prilogi I WFD, in sistem B. Sistem B omogoča upoštevanje posebnosti posamezne države s pomočjo obveznih in neobveznih dejavnikov. Pri upoštevanju sistema B moramo doseči enako ločljivost tipov, kot bi jo dosegli s sistemom A. Meje ekoregij na karti sistema A v WFD niso dovolj razločne in se ne pokrivajo z mejami porečij. Slovenija je razdeljena na dve ali štiri ekoregije. Sistem B je upoštevan z ekohidrografskimi območji, od katerih smo tri območja določili na podlagi homogeniziranih obveznih dejavnikov. Obvezni dejavniki določajo glavne vodotoke s prispevno površino večjo od 1000 km² in jezera. Tipe manjših vodotokov določamo na podlagi ekohidrografskih regij. Tipe vodotokov (za oboje glavne in manjše) nato opredelimo na osnovi neobveznih dejavnikov – transport plavin in sestava substrata. Slovenijo smo razdelili na sedem ekoregij: tri v porečju Jadranskega morja in štiri v porečju reke Donave. Meje ekoregij so opredeljene na podlagi meja prispevnih površin vodotokov. Glavna dejavnika za določanje ekohidrografskih območij sta: nadmorska višina na goratih območjih in geološke formacije na območjih z izrazitimi kraškimi pojavi.

Ključne besede: direktiva o politiki do voda, tipi površinskih vodotokov, ekoregije

The European Union Water Framework Directive (WFD) provides the framework for protection and improvement of the aquatic environment. Surface water bodies should be classified into categories and differentiated according to type. A method for the differentiation of rivers and lakes in Slovenia into different types of ecohydrographical regions is presented in the paper. The WFD provides a two-fold characterisation of surface body types: System A according to Illies with ecoregions presented in Annex XI of WFD, and System B, which gives the grounds for consideration of specific country conditions according to obligatory and optional factors. The same degree of differentiation should be achieved by System B as by System A. The contours on the map, provided by WFD for System A, are rather vague and do not coincide with the contours of watersheds. They divide the territory of Slovenia into two and four ecoregions, respectively. System B implements ecohydrographical regions, which are regions with homogenized obligatory factors. Obligatory descriptors define large rivers with watersheds larger than 1000 km², and lakes. Small-sized rivers are differentiated according to ecohydrographical regions. Types of rivers (both large and small) are then determined by the optional descriptors: transport of sediment and substratum composition. The country is subdivided into seven ecohydrographical regions: three in the Adriatic Sea basin and four in the Danube River basin. Watershed borders determine the boundaries of ecohydrographical regions. The main factors for determination of ecohydrographical regions are altitude for alpine regions and geology for regions with predominantly karst phenomena.

Key words: Water Framework Directive, surface water body types, ecoregions

1. UVOD

Direktiva o politiki do voda je začela veljati leta 2000. Eden od glavnih ciljev je doseganje dobrega stanja površinskih voda do leta 2015 za različne kategorije površinskih vodnih teles: vodotokov, jezer, tranzicijskih in obalnih voda. Kategorije vodnih teles so razvrščene na tipe, njihov dober ekološki status pa je opredeljen glede na tip vodnega telesa. V tem prispevku razpravljamo samo o razvrstitvi vodotokov. V Sloveniji imamo samo dve naravni jezera in več umetnih zadrževalnikov s površino, večjo od 0,5 km. Obalne in tranzicijske vode se nahajajo v eni regiji.

Temeljni problem je določanje dobrega, nespremenjenega, naravnega ekološkega stanja vodotokov glede na različne pogoje v okolju. Pri tem se srečamo s pomanjkljivimi biološkimi podatki in raziskavami podlag za potrebe WFD. Naš sistem smo razvili na podlagi obstoječih abiotskih in terestričnih biotskih regionalizacij, vključno z nekaterimi vodnimi biotopi (Brilly *et al.*, 2001).

Vodotoke smo razvrstili glede na velikost njihove prispevne površine z uporabo državnega šifrantna vodotokov (slika 1; Brilly, 2000; Šraj, 2001). Velikost je avtomatično določena z GIS-i in pridruženo bazo podatkov (preglednica 1).

Večina vodnih teles vodotokov je v kategoriji srednjih in malih vodotokov, ki so zunaj uradnega državnega sistema monitoringa. Ta vodna telesa so tesno povezana tudi z okoliškimi terestričnimi ekološkimi sistemi in so tudi odvisna od teh sistemov.

Posamezna država lahko izbere med dvema sistemoma za razvrščanje vodnih teles na tipe: sistem A z ekoregijami, prikazanimi na karti v prilogi WFD, ali sistem B z enako stopnjo razvrščanja in z uporabo abiotičnih obveznih in neobveznih dejavnikov. Za vsak tip vodnega telesa je treba določiti posebne biološke referenčne pogoje.

1. INTRODUCTION

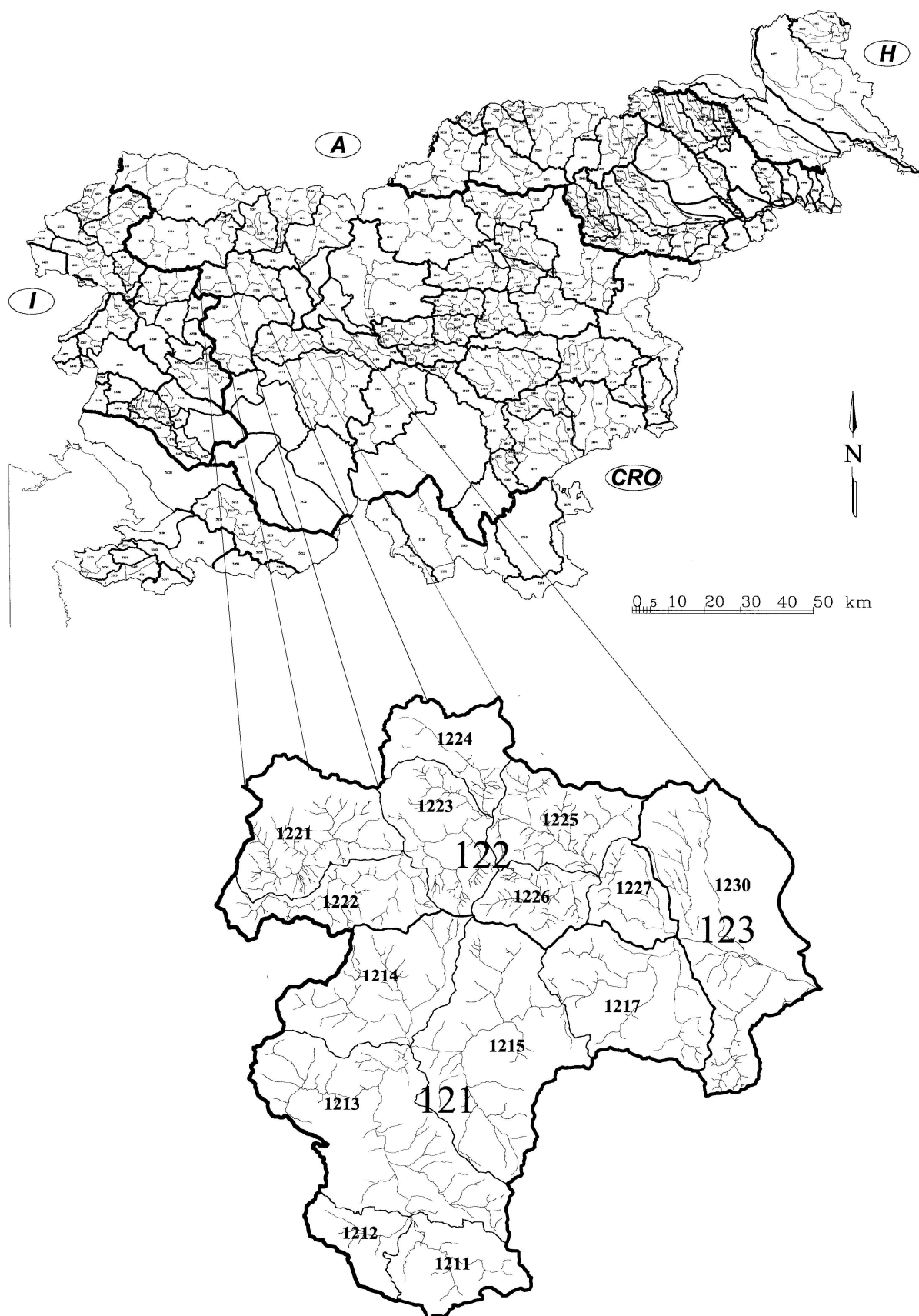
The Water Framework Directive has entered into force in 2000. Until 2015, one of the major tasks will be to achieve a good surface water status for the different categories of water bodies: rivers, lakes, transitional, and coastal waters. The categories of the surface water bodies are differentiated into types and their ecological status is described according to type. In this paper, only the differentiation of rivers is discussed. In Slovenia, there are only two natural lakes and several artificial storages with a surface larger than 0.5 square kilometre. The coastal and transitional waters are present in one region.

The main question is the definition of a good, undisturbed ecological status of the rivers according to different environmental conditions. What is lacking is the collection of biological data and thorough background research done within the framework of WFD. The developed system is based on the existing abiotic and terrestrial biotic regionalizations, including some aquatic biota (Brilly *et al.*, 2001).

In Figure 1, the rivers are separated according to the catchment size, by using the country coding system (Brilly, 2000; Šraj, 2001). The sizing was done automatically by GIS and an associated database (Table 1).

The majority of river water bodies are in the categories of medium and small-sized rivers that are outside the official national monitoring system. Moreover, the water bodies are in close relationships with the surrounding terrestrial ecosystems, and are dependent upon them.

A country may choose among two systems for the differentiation of water bodies by type: System A with ecoregions in accordance with the map enclosed in the annex of WFD, or System B with the same degree of differentiation and incorporating abiotic obligatory and optional descriptors. Specific biological reference conditions should be developed for each water body type.



Slika 1. Šifrant prispevnih območij v Republiki Sloveniji (Šraj, 2001).
Figure 1. The River watershed coding system in the Republic of Slovenia (Šraj, 2001).

Preglednica 1. Reke.

Table 1. Rivers.

reke – razvrščene po velikosti prispevne površine <i>River size typology based on the area of watershed</i>	dolžina [km] <i>Length [km]</i>
zelo velike – <i>very large</i> : > 10 000 km ²	244
velike – <i>large</i> : 1000–10 000 km ²	391
srednje – <i>medium</i> : 100–1000 km ²	1485
majhne – <i>small</i> : 10–100 km ²	2086
SKUPNO – <i>TOTAL SUM</i>	4206

Preglednica 2. Sistem A v skladu s prilogo XII WFD.

Table 2. System A according to Annex II, WFD.

<i>določena tipologija – Fixed typology</i>	<i>opisi – Descriptors</i>
ekoregija – <i>Ecoregion</i>	ekoregije so prikazane na karti A v prilogi XI <i>Ecoregions shown on Map A in Annex XI</i>
tip – <i>Type</i>	nadmorske višine – <i>Altitude typology</i> : visoko – <i>high</i> : > 800 m; srednje nadmorske višine – <i>mid-altitude</i> : 200–800 m; nižine – <i>lowlands</i> : < 200 m obseg, določen na osnovi povprečne površine – <i>Size typology based on watershed area</i> : majhen – <i>small</i> : 0,5–1 km ² ; srednji – <i>medium</i> : 1–10 km ² ; velik – <i>large</i> : 10–100 km ² ; zelo velik – <i>very large</i> > 100 km ² Geologija – <i>Geology</i> : apnenčasta – <i>calcareous</i> ; silikatna – <i>siliceous</i> ; organska – <i>organic</i> .

Preglednica 3. Rezultati razvrščanja vodotokov po tipih.

Table 3. System A: Results of the river body differentiation on types.

<i>ekoregija – Ecoregion</i>	različica I <i>variant I</i>	različica II <i>variant II</i>
Italija (3) – <i>Italy (3)</i>	4	
Alpe (4) – <i>Alps (4)</i>	7	7
Dinarski zahodni Balkan (6) – <i>Dinaric western Balkan (6)</i>	7	10
madžarsko nižavje (11) – <i>Hungarian lowlands (11)</i>	8	
vsota – <i>Sum total</i>	26	17

2. SISTEM A – EKOREGIJE POVRŠINSKIH VODA

Razdelitev Slovenije na podlagi sistema A mora biti izdelan skladno z raziskavami, ki jih je izvedel Illies (1978), in so prikazane na karti v dodatku XIA WFD (EU, 2000). Na karti je prikazana celotna Evropa, zato meje ekoregij niso natančno določene. Karto smo prikazali v manjšem merilu z dvema ekoregijama: z Alpami in dinarskim zahodnim Balkanom (slika 2).

Na sliki 2 so prikazane tudi glavne geografske enote Slovenije: Alpe, Sredozemlje, Dinaridi in Panonija. Obe regionalizaciji nista v soglasju z mejami med porečji. Vprašanje je tudi, ali bi bilo treba upoštevati tudi bližnje ekoregije: madžarsko nižavje in Italijo. Sistem A tudi vključuje obvezne lastnosti (preglednica 2).

Izdelali smo dve različici delitve za tipe vodotokov po sistemu A:

1. Prvo različico I, s štirimi ekoregijami (slika 3): Italija, Alpe, dinarski zahodni Balkan in madžarsko nižavje; in
2. Drugo različico II z dvema ekoregijama (slika 4): Alpe in dinarski zahodni Balkan.

Tipi vodotokov so ločeni glede na velikost prispevne površine in nadmorsko višino. Geološke formacije so več ali manj apnenčaste, z izjemo dela na severovzhodu države. Rezultati razvrščanja so prikazani v preglednici 3.

Razvrščanje vodotokov v skladu z različico I vsebuje 26 tipov vodotokov ter je bolj prilagodljivo in v skladu z geografsko regionalizacijo, medtem ko ima različica II samo 17 tipov. Slovenski vodotoki pripadajo porečjema Donave in Jadranskega morja, toda sistem A ne vključuje te meje na karti ekoregij.

2. SYSTEM A – ECOREGIONS FOR SURFACE WATERS

The division of Slovenia according to System A should be carried out in accordance with the research carried out by Illies (1978), as presented on the map in Annex XIA of WFD (EU, 2000). The entire Europe is presented on the map and, thus it cannot be presented in detail. We transposed the map into a smaller scale map with two ecoregions: the Alps and the Dinaric western Balkan (Figure 2).

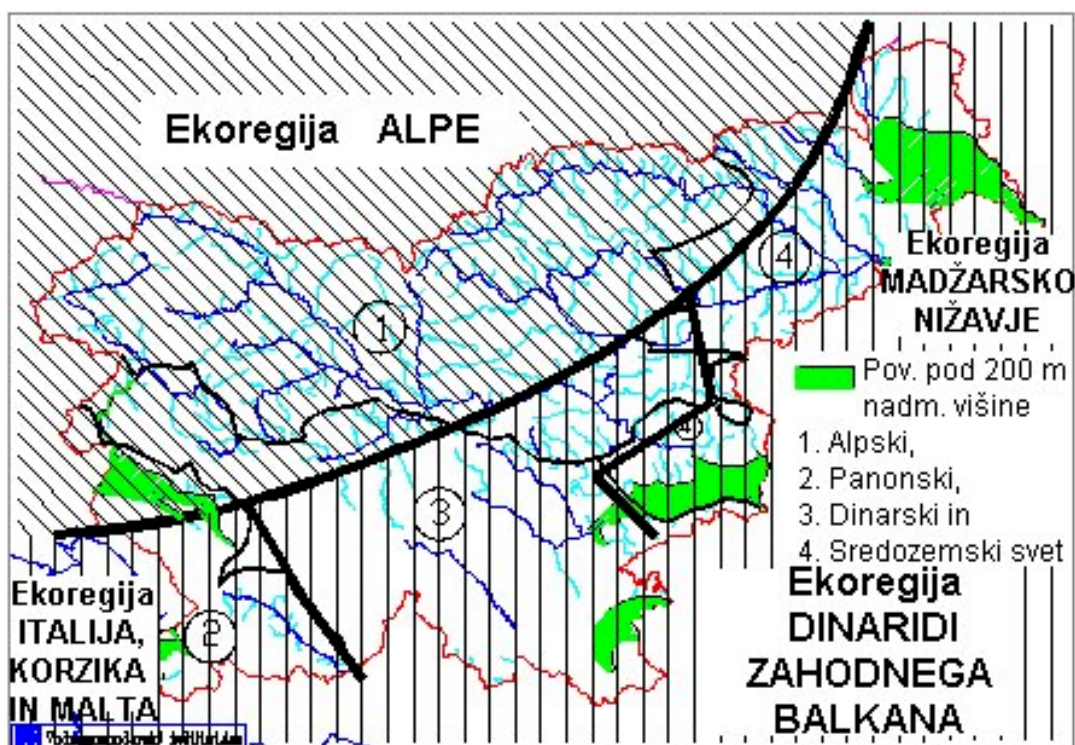
In Figure 2, major geographical units of Slovenia are presented: the Alps, the Mediterranean, the Dinaric Alps and the Pannonian plain. Both regionalizations are in discrepancy with the existing watershed borders. On the other side, the question is, whether the surrounding ecoregions should also be considered: the Hungarian lowlands and Italy. System A also includes some obligatory descriptors (Table 2).

Two variants of watercourse types in accordance with System A were derived:

1. A first one I, with four ecoregions (Figure 3): Italy, the Alps, the Dinaric western Balkan and Hungarian lowlands, and
2. A second one II with two ecoregions (Figure 4): the Alps and the Dinaric western Balkan.

The river body types are differentiated according to the watershed area and altitude. The geology is predominantly calcareous, except on the north-eastern part of the country. Results of the differentiation are presented on Table 3.

Differentiation of water bodies according to variant I includes 26 watercourse types. It is more flexible and in accordance with the geographical regionalization. On the other hand, variant II includes only 17 types. Slovenian rivers belong to the basins of the Danube River and the Adriatic Sea, however, within System A the border is not included on the map of ecoregions.



Slika 2. Ekoregije v Sloveniji.

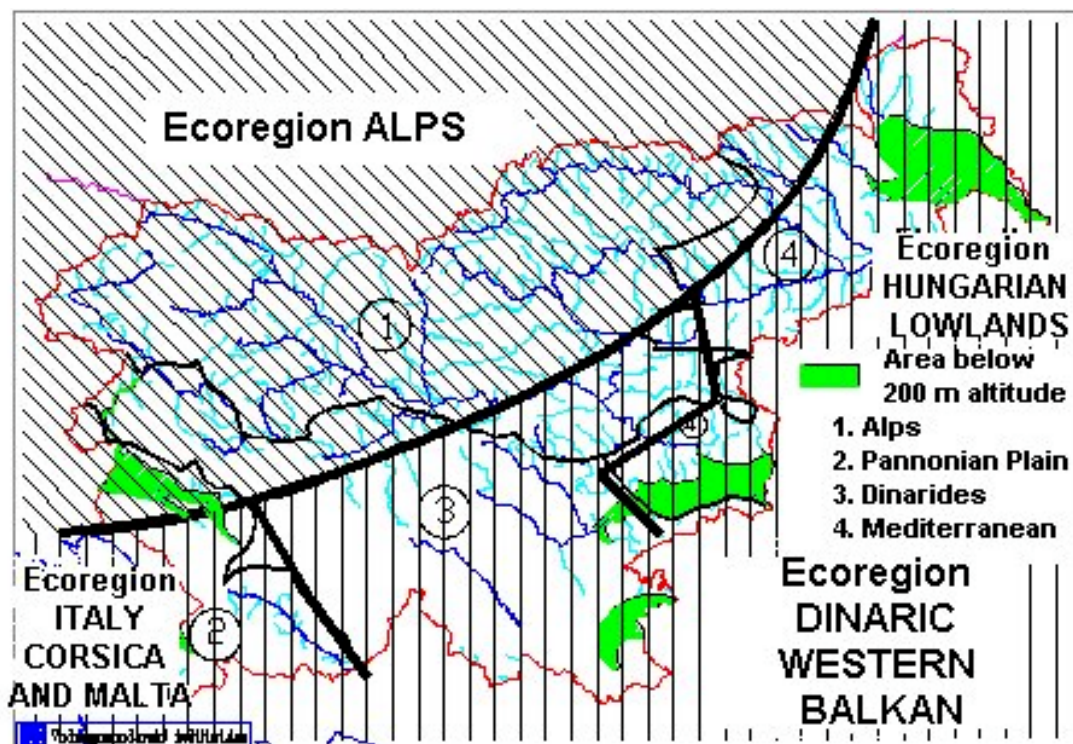
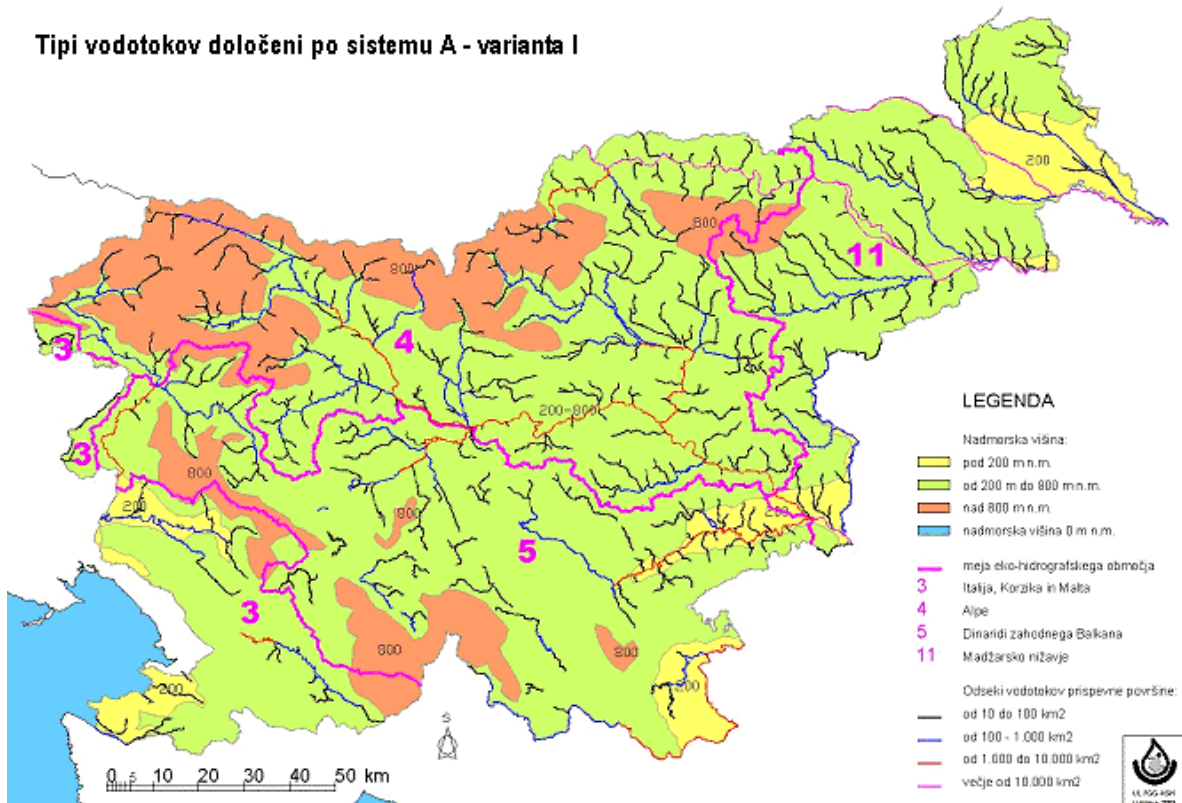


Figure 2. Ecoregions in Slovenia.

Tipi vodotokov določeni po sistemu A - varianta I



Slika 3. Ekoregije v Sloveniji: sistem A, varianta I.

Types of river water bodies system A, variant I

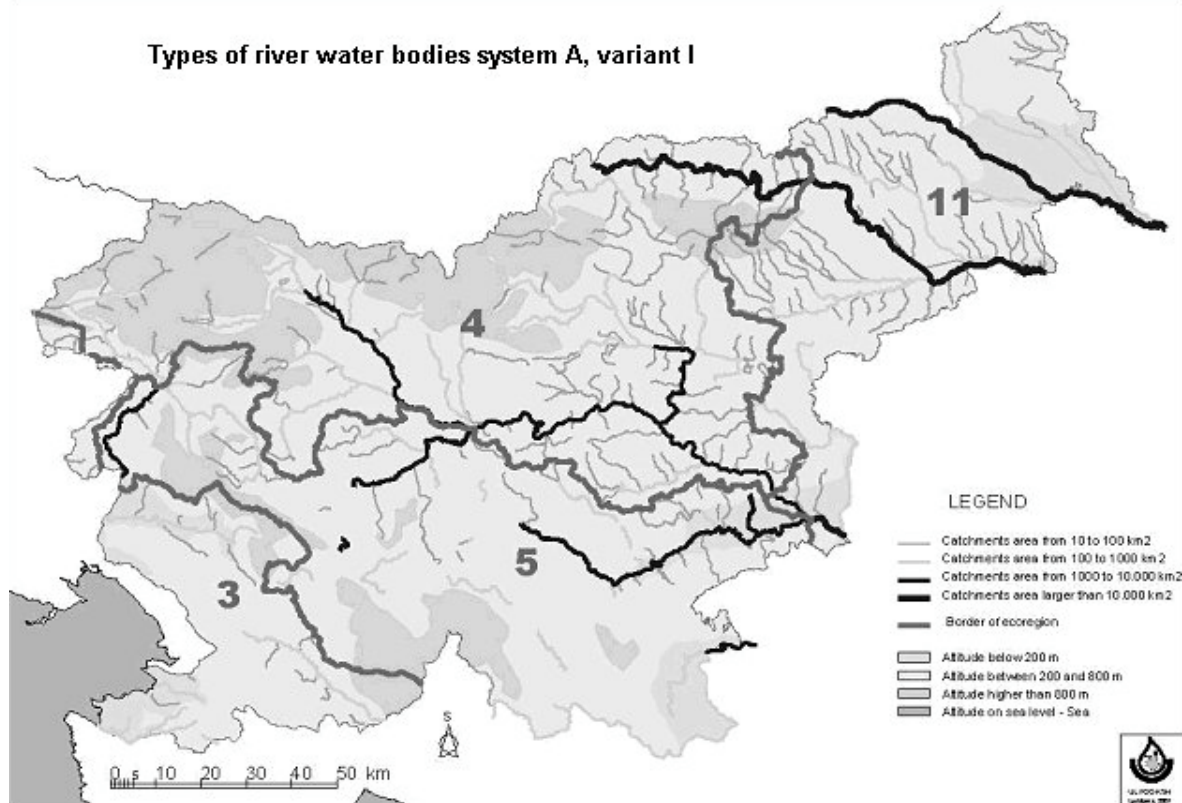
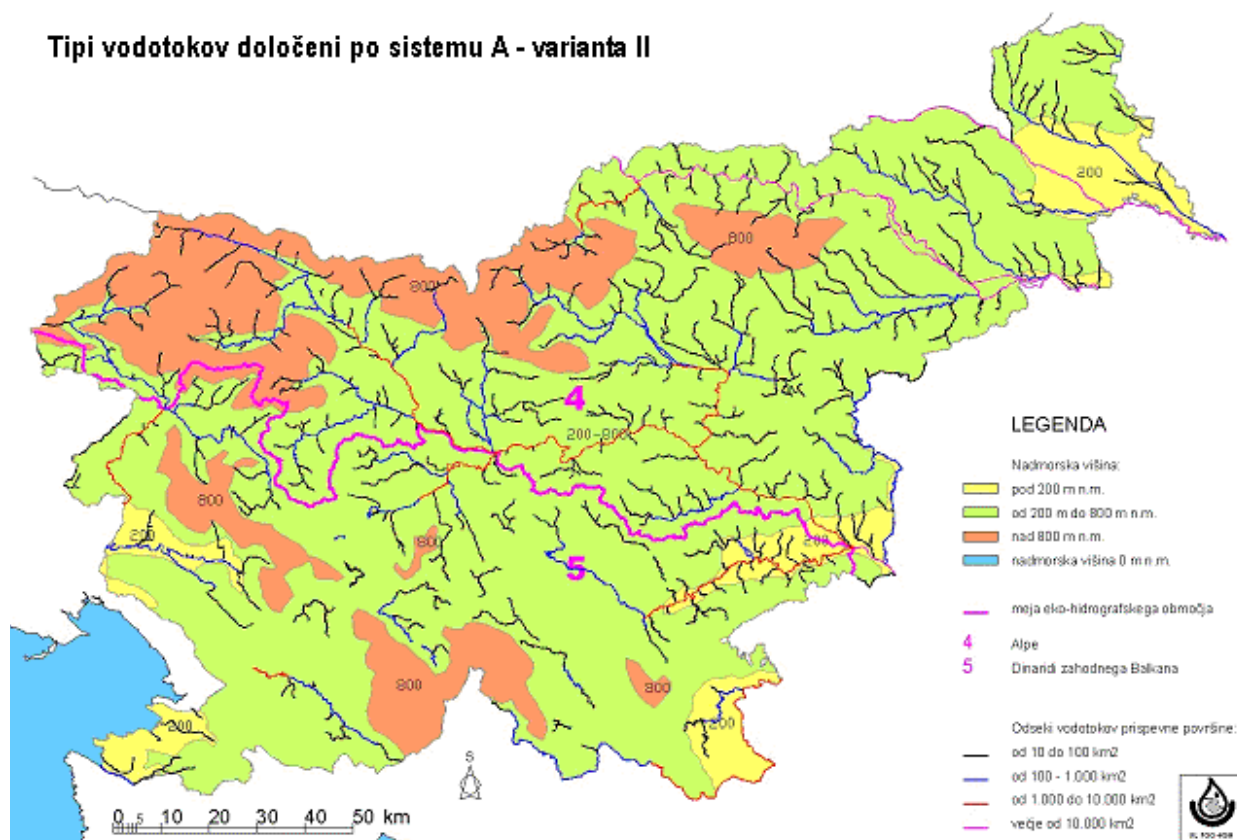


Figure 3. Ecoregions in Slovenia: System A, variant I.



Slika 4. Ekoregije v Sloveniji: sistem A, varianta II.

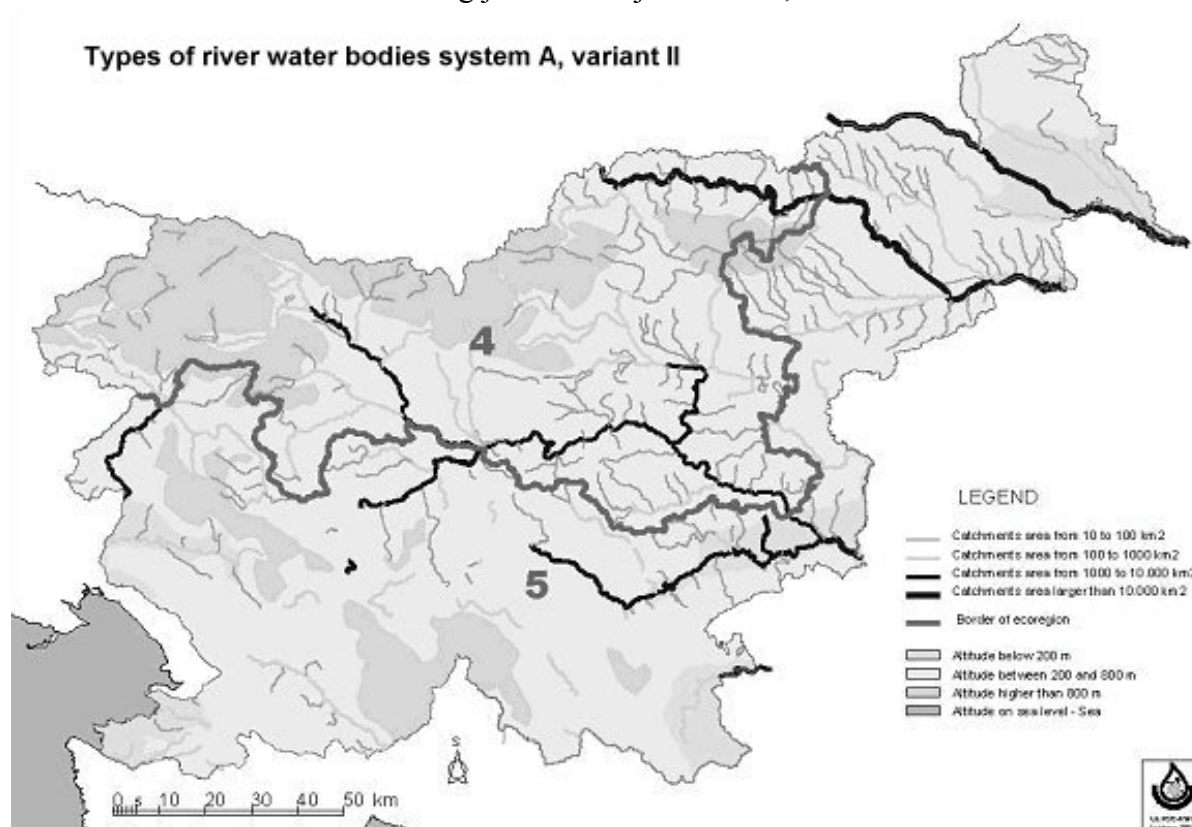


Figure 4. Ecoregions in Slovenia: System A, variant II.

3. SISTEM B – EKOHIĐROGRAFSKE REGIJE

Sistem B je v primerjavi s sistemom A bolj prilagodljiv in upošteva naravne pogoje. Porazdelitev mora upoštevati obvezne dejavnike po WFD in takšne neobvezne dejavnike, da lahko razločimo značilne abiotične vplive. Dosežena ločljivost mora biti enaka, kot bi jo dosegli s sistemom A.

Pri uporabi sistema B smo upoštevali:

- Študijo o sestavi in ogroženosti ribje populacije v Sloveniji (Bertok *et al.*, 2000), ki državo zelo jasno deli na del, ki pripada porečju Jadranskega morja, in del, ki pripada porečju Črnega morja.
- Da ima Slovenija znano, prostrano, posebno območje krása, ki zahteva posebno pozornost.
- Uradni državni monitoring vsebuje tudi biološke podatke o velikih rekah.

Omenjena izhodišča in rezultati analiz razvrščanja po sistemu A so bili dobra podlaga za uporabo sistema B. Država je bila razdeljena na regije, imenovane ekohidrografske regije za razvrščanje tipov majhnih in srednjih vodotokov. Velike vodotoke smo opredelili ločeno ob upoštevanju vodnega režima in podatkov monitoringa. Ekohidrografske regije, določene glede na omenjena izhodišča in obvezne dejavnike (preglednica 4 in slika 5), so:

1. alpska ekohidrografska regija porečja Jadranskega morja;
2. alpska ekohidrografska regija porečja reke Donave;
3. kraška ekohidrografska regija porečja Jadranskega morja;
4. kraška ekohidrografska regija porečja reke Donave;
5. predalpska ekohidrografska regija;
6. panonska ekohidrografska regija in
7. primorska ekohidrografska regija.

3. SYSTEM B – ECOHYDROGRAPHICAL REGIONS

In comparison to System A, System B is more flexible and considers specific natural conditions. The differentiation should consider obligatory descriptors according to WFD and such optional descriptors that would enable the identification of specific abiotic influence. The degree of differentiation should be the same as that found in the differentiation, which uses System A.

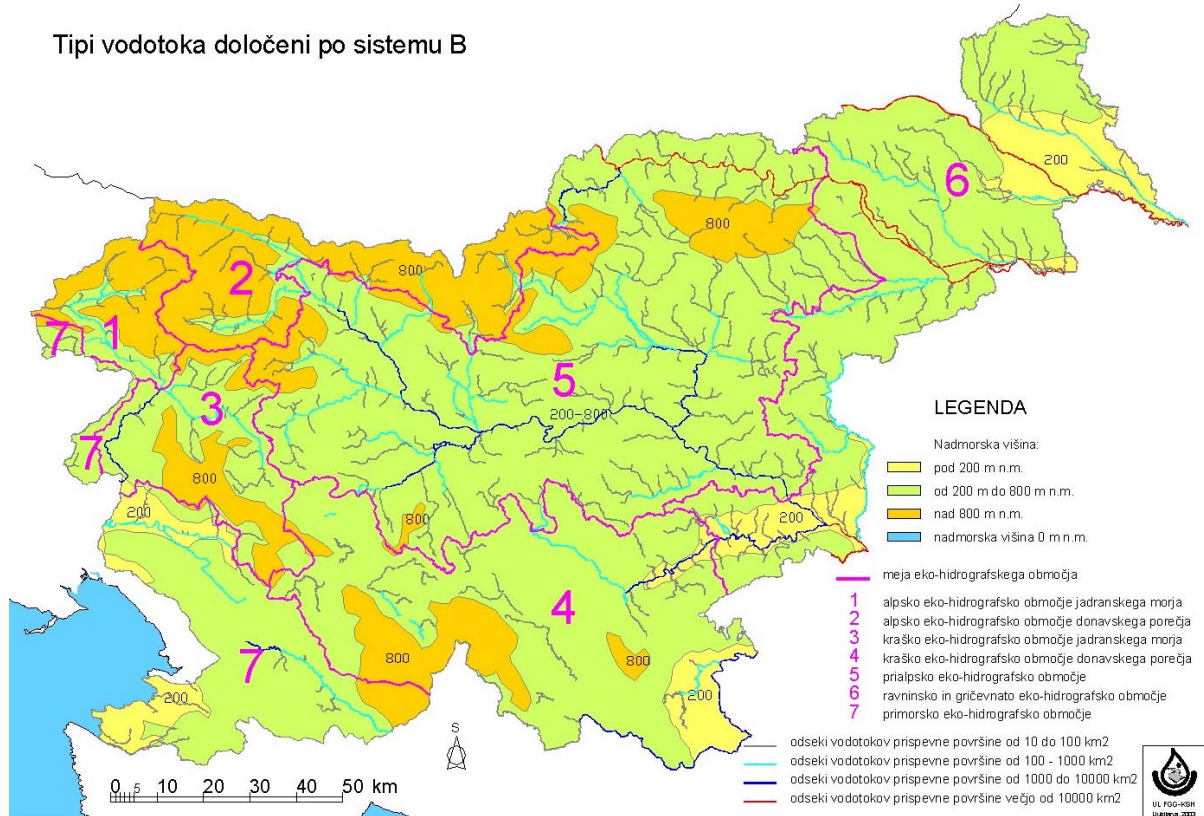
While implementing System B, the following has been taken into account:

- Studies on composition and abundance of fish fauna in Slovenia (Bertok *et al.*, 2000), which clearly divides the country into the part belonging to the Adriatic Sea River Basin and the part belonging to the Danube River Basin.
- Slovenia has a renowned, wide karst region, which needs special treatment.
- The official country monitoring system provides data about biota for large rivers.

These points of departure and the results from the analyses of differentiation according to System A were a starting points to develop a System B classification. The country is subdivided into regions, i.e. into ecohydrographical regions for differentiation of small and medium-sized rivers. Large rivers are differentiated separately according to water regime and monitoring data. The ecohydrographical regions defined in accordance with the points of departure given above and the obligatory factors (Table 4 and Figure 5) are:

1. Alpine ecohydrographical region of the Adriatic Sea River Basin;
2. Alpine ecohydrographical region of the Danube River Basin;
3. Karst ecohydrographical region of the Adriatic Sea River Basin;
4. Karst ecohydrographical region of the Danube River Basin;
5. Perialpine ecohydrographical region;
6. Hilly and plain ecohydrographical region and
7. Mediterranean ecohydrographical region.

Tipi vodotoka določeni po sistemu B



Slika 5. Ekoregije v Sloveniji – sistem B.

Types of river water bodies - system B

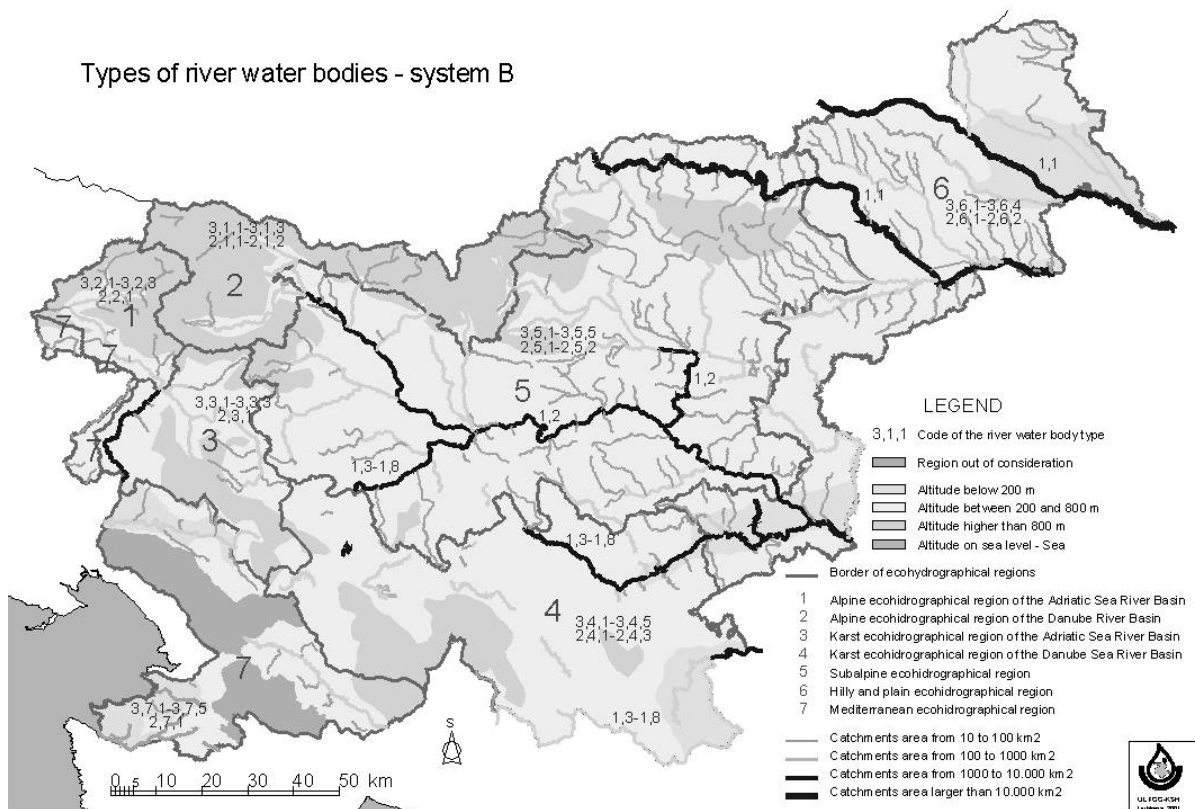


Figure 5. Ecoregions in Slovenia: System B.

Preglednica 4. Sistem B v skladu s prilogo II.
 Table 4. System B according to Annex II.

nadomestna opredelitev – <i>alternative characterisation</i>	Fizikalni in kemijski dejavniki, ki določajo značilnosti reke ali dela reke in s tem strukturo in sestavo populacij – <i>Physical and chemical factors that determine the characteristics of the river or part of the river and hence the biological population structure and composition</i>
obvezni dejavniki – <i>obligatory factors</i>	nadmorska višina – <i>altitude</i> zemljepisna širina – <i>latitude</i> zemljepisna dolžina – <i>longitude</i> geološka podlaga – <i>geology</i> velikost – <i>size</i>
izbirni dejavniki – <i>optional factors</i>	oddaljenost od rečnega izvira – <i>distance from river source</i> energija toka (funkcija pretoka in strmca) – <i>energy of flow (function of flow and slope)</i> povprečna širina vode v strugi – <i>mean water width</i> povprečna globina vode v strugi – <i>mean water depth</i> povprečni strmec – <i>mean water slope</i> oblika in konfiguracija glavne rečne struge – <i>form and shape of main river bed</i> kategorija pretoka (toka) reke – <i>river discharge (flow) category</i> oblika doline – <i>valley shape</i> transport plavin – <i>transport of solids</i> sposobnost nevtralizacije kislin – <i>acid neutralizing capacity</i> povprečna sestava substrata – <i>mean substratum composition</i> kloridi – <i>chloride</i> razpon temperature zraka – <i>air temperature range</i> povprečna temperatura zraka – <i>mean air temperature</i> padavine – <i>precipitation</i>

Končna razdelitev vodnih teles vodotokov upošteva dodatne neobvezne dejavnike, kot sta transport plavin in povprečna sestava substrata. Povprečna sestava substrata bolj ali manj vključuje integrirane vplive drugih neobveznih dejavnikov, kot so: razdalja od izvira, energija toka (funkcija pretoka in nagiba), povprečna širina vodne gladine, povprečna globina vode, povprečni nagib gladine vode, oblika in razsežnost glavne struge, pretok vode, kategorija oblike doline in transport trdih delcev materiala. Kriterij za razvrščanje na tipe, na podlagi povprečne sestave substrata, je matriks, ki vključuje kompaktne kamenine, gramoz, pesek ali mulj.

Drugi neobvezni dejavnik, tj. transport plavin, na podoben način kot povprečna

The final differentiation of river water bodies has taken into account additional optional factors, such as the transport of solids and mean substratum composition. The mean substratum composition includes the integrated influence of other optional factors, such as: distance from river source, energy of flow (function of flow and slope), mean water surface width, mean water depth, mean water slope, form and shape of main river bed, river discharge, category of valley shape, and transport of solids. The criterion used for differentiation among types by means of substratum composition is a matrix that includes compact rocks, gravel, sand and silt.

The second optional factor, i.e. the transport of solids, similarly integrates the influence of

sestava substrata tudi integrira vplive več drugih dejavnikov. Kriterij za razvrščanje je pojav letnega transporta plavin.

Velike vodotoke ločimo na:

(1.1) – Reki Drava in Mura s prevladujočimi silikatnimi geološkimi formacijami na porečju, gramoznim substratom, pojavom prodonosnosti in prevladujočim odtokom zaradi tajanja snega.

(1.2) – Reki Sava in Savinja z apnenci v geološki sestavi porečja, gramoznim substratom in transportom plavin.

(1.3–1.8) – Reke Ljubljana, Unec, Kolpa in Krka s kraško geologijo in z različno oblikovanim substratom in delno brez transporta plavin.

(1.9) – Reka Soča pripada porečju Jadranskega morja z gramoznim substratom in pojavom transporta plavin.

Končna razporeditev malih in srednjih vodotokov je zaradi pomanjkljivih podatkov zgolj ocenjena. Izračunali smo teoretično razporeditev (na največje možno število tipov), pričakovano število tipov na podlagi izkušenj, ki mora biti potrjeno s terenskimi ogledi, in minimalno pričakovano število tipov (preglednica 5).

other factors, such as the mean composition of substratum. The criterion for differentiation is the yearly transport of solids.

Large rivers in Slovenia are differentiated into:

(1.1) – The Drava and the Mura Rivers with predominant silicate geology on the watershed, gravel composition of substratum, existing solid transport and predominant snowmelt runoff.

(1.2) – The Sava River and the Savinja River with calcareous geology, gravel composition of substratum and existing solid transport.

(1.3–1.8) – The Ljubljana, Unec, Kolpa and Krka rivers within the karst region and with a different composition of substratum; the sediment load is partially disconnected.

(1.9) – The Soča River belongs to the Adriatic Sea River Basin with gravel substratum and solid transport.

Given the current lack of data, only an estimation of the final differentiation of small and medium-sized rivers can be made. We have calculated the theoretical differentiation (the maximum possible number of types), the expected number of types based on experience (that should be further confirmed by site visits), and the minimum expected number of types (Table 5).

Preglednica 5. Pregled tipov srednjih in manjših vodotokov po ekohidrografskih območjih.
 Table 5. Differentiation of small and medium-sized rivers by ecohydrographical regions.

število tipov – <i>Number of types</i>	oznaka območja – <i>Region No.</i>							skupaj – <i>Sum total</i>
	1	2	3	4	5	6	7	
po velikosti – <i>by size</i>	2	2	2	2	2	2	2	–
po sestavi dna – <i>by substratum composition</i>	2	2	4	4	4	3	4	–
po premeščanju plavin – <i>by transport of solids</i>	2	2	2	2	2	2	2	–
teoretično – <i>theoretical</i>	8	8	16	16	16	12	8	84
pričakovano – <i>expected</i>	5	4	4	8	7	6	6	40
glavni tipi – <i>basic types</i>	4	–	–	5	3	4	3	19

4. RAZPRAVA IN ZAKLJUČKI

1. Sistem A, namenjen razločevanju vodnih teles vodotokov na tipe, loči 11 tipov vodnih telesov vodotokov ob upoštevanju

4. DISCUSSION AND CONCLUSIONS

1. System A, used for the differentiation of river water bodies by type, differentiates river water bodies into 11 types

- dveh ekoregij in 26 tipov ob upoštevanju štirih ekoregij. Sistem A ne upošteva meje med jadranskim in donavskim porečjem kot tudi ne posebnega in obsežnega kraškega območja.
2. Sistem B se bolje prilagaja naravnim razmeram kot sistem A. O tem po obsežni razpravi soglašajo tudi strokovnjaki. Največje število tipov, opredeljenih po sistemu B, je 84, in najmanjše število glavnih tipov znaša 19. Pričakovano število tipov vodnih teles vodotokov pa znaša 40.
 3. V kratkem času bo treba opraviti še veliko raziskav za določanje bioloških referenčnih pogojev za vsak tip. Obstaja tudi veliko pomanjkanje podatkov za majhne in srednje vodotoke za ločevanje in opredelitev dobrega statusa.
2. System B is more flexible and is able to relate to natural conditions more closely than System A. Several expert discussions have supported this conclusion. The maximum number of types, differentiated by System B, is 84, and the minimum number of basic types of water bodies is 19. The expected number is 40.
 3. An extensive investigation of describing the biological reference conditions for each type should be undertaken in a short time period. Furthermore, for small and medium-sized rivers there is a lack of data, which restrains the ability to correctly categorize and define an ecologically good status.

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