REPUBLIKA SLOVENIJA
MINISTRSTVO ZA OKOLJE IN PROSTOR
AGENCIJA REPUBLIKE SLOVENIJE ZA OKOLJE

HIDROLOŠKI LETOPIS SLOVENIJE 2005

THE 2005 HYDROLOGICAL YEARBOOK OF SLOVENIA

AGENCIJA REPUBLIKE SLOVENIJE ZA OKOLJE

Naslovnica / Cover page:
Poplava reke Radulje v Škocjanu na območju vodomerne postaje ARSO, 22. 08. 2005 (foto: Marko Burger).
Flood of the Radulja River in Škocjan on the location of gauging station EARS, 22. 08. 2005 (Photo: Marko Burger).

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LETNIK 16
YEAR 16

LJUBLJANA, 2009

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THE 2005 HYDROLOGICAL YEARBOOK OF SLOVENIA

IZDALA IN ZALOŽILA / PUBLISHED BY
Agencija Republike Slovenije za okolje – Environmental Agency of the Republic of Slovenia
Vojkova 1b, Ljubljana
e-mail: arso@gov.si
internet: http://www.arso.gov.si

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LEKTORIRANJE SLOVENSKEGA BESEDILA / PROOFREADING OF SLOVENIAN TEXT
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PREVOD IN LEKTORIRANJE ANGLEŠKEGA BESEDILA / TRANSLATION AND PROOFREADING OF ENGLISH TEXT
Prevajalska agencija ALKEMIST

TISK – PRINTED BY
SYNCOMP d. o. o.

NAKLADA / EDITION
330 izvodov / 330 copies

ISSN 1854-2662

Hidrološki letopis Slovenije 2005
Agencija RS za okolje, 2009

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Predgovor

Ob svetovnem dnevu voda leta 2005 so Združeni narodi obdobje 2005–2015 razglasili za desetletje varovanja voda z naslovom »Voda za življenje«. Voda namreč postaja najbolj cenjena surovina in naloga vseh nas je, da jo znamo ohranjati, tako kakovostno kot količinsko, in z njo celostno upravljati. Posebna tema dneva voda 2005 je bila »Obvladovanje pomanjkanja vode« z namenom, da se izpostavi naraščajočo problematiko svetovnega pomanjkanja vode ter trajnostnega in učinkovitejšega ravnanja z vodnimi viri.

V letu 2005 so v nekaterih predelih sveta trpeli zaradi suše, v nekaterih pa zaradi preobilnih padavin. Te so povzročile poplave in veliko škodo tudi v osrednji in vzhodni Evropi. Najhujše poplave v zadnjih 200 letih so doživeli v južni Kitajski. Globalne padavine so bile blizu povprečja obdobja od 1961–1990. Globalna temperatura se v letu 2005 ni statistično značilno razlikovala od dosedanje rekordne vrednosti iz leta 1998.

V Sloveniji je bilo leto 2005 v pretežnem delu države toplejše od dolgoletnega povprečja. Temperatura, z izjemo Ljubljane, ni odstopala več kot pol °C, navzgor ali navzdol, od dolgoletnega povprečja, kar je v mejah običajne spremenljivosti povprečne letne temperature zraka. Le v Ljubljani je bilo 0,6 °C topleje kot običajno. Tudi rekordno visoke ali nizke temperature zraka niso bile zabeležene. Padavin je v nekaterih delih Slovenije padlo več, v nekaterih pa manj kot znaša dolgoletno povprečje. V primerjavi z dolgoletnim povprečjem je padavin najbolj primanjkovalo v Posočju, zabeležene pa so bile nadpovprečne na Dolenjskem ter v Celjski in Ljubljanski kotlini. Avgust je bil povsod nadpovprečno moker, oktobra pa je padavin izrazito primanjkovalo v Prekmurju.

Vodnatost rek v letu 2005 je bila v povprečju za okrog deset odstotkov manjša od dolgoletnega povprečja v obdobju 1971–2000. Zlasti časovna razporeditev pretokov se je razlikovala od običajne. Ti so bili manjši od običajnih vrednosti v prvi polovici leta in večji v drugi polovici leta. V avgustu so veliki pretoki Mure in manjših hudourniških rek v Posavju, ki so presegli tudi 50 letne povratne dobe, povzročili veliko škode. Na Muri v Gornji Radgoni je bil izmerjen večji pretok kot je bil zabeležen kadarkoli do tedaj, 1350 m^3/s. Ker je bila v običajno poletno sušnem obdobju vodnatost rek povečana, izrazitega sušnega obdobja in pomanjkanja vode ni bilo.

Zaloge podzemnih vod so bile v pretežnih delih aluvialnih vodonosnikov v letu 2005 glede na dolgoletno povprečje v večini normalne in bolj ugodne kot v letih pred tem. Vodonosniki severovzhodne Slovenije so si v tem letu povečini opomogli od hidrološke suše iz let 2002 in 2003. Zelo nizke vodne zaloge so prevladovale le v osrednjem delu Prekmurskega polja. Z letopisom 2005 za opis stanja zalog podzemne vode

Foreword

On the occasion of the World Water Day 2005, the United Nations proclaimed the 2005–2015 period as the decade of water conservation under the title »Water for Life«. Water is becoming the most valued resource and it is the task of us all to know how to conserve it, both in terms of quality and quantity, and to manage it sustainably. A special topic of the 2005 World Water Day was »Coping with Water Scarcity« and it was aimed at highlighting the increasing issue of global water scarcity and the sustainable and efficient management of water sources.

In 2005, some parts of the world suffered from drought while others endured too abundant precipitation. This also caused flooding and extensive damage in Central and Eastern Europe. Southern China experienced the worst flooding in last 200 years. Global precipitation levels were close to the 1961–1990 period norms. Statistically, the global temperature in 2005 did not statistically significantly differ from the current recorded value from 1998.

In 2005 in Slovenia, the major part of the country experienced warmer temperatures than the normals. With the exception of Ljubljana, the temperature did not deviate by more than half a degree Celsius in either direction from the normals, which is within the limits of the normal variation of the average annual air temperature. Only Ljubljana experienced temperatures that were 0.6 °C warmer than normal. There were also no record high or low air temperatures recorded There was more precipitation than normal in some parts of Slovenia and less in other parts. In comparison with the norms, Posočje saw the greatest shortage of precipitation, while above-average precipitation was recorded in the Dolenjska region and the Celje and Ljubljana basins. August was an above-averagely wet month, while Prekmurje experienced a distinct shortage of precipitation in October.

The river water discharges in 2005 were lower by around 10 percent on average compared to the multi-annual 1971–2000 reference period mean. It was the temporal distribution of discharges in particular that differed from the normal distribution. The discharges were lower than normal in the first half of the year and higher in the second half of the year. In August, the high discharges of the Mura River and the smaller torrential rivers in the Posavje river basin, which even exceeded the 50-year return periods, caused a lot of damage. On the Mura River in Gornja Radgona, a higher discharge was measured than has ever been recorded before, namely 1350 m^3/s. Because the river water discharges were increased in the usually dry summer period, there was neither a distinctive drought period nor a shortage of water to be felt.

For the most part, the groundwater reserves in the major part of the alluvial aquifers in 2005 were normal uvajamo enotno primerjalno obdobje dvanajstih let 1990–2001, ki je bilo uporabljeno tudi za opis količinskega stanja podzemnih vod, k čemur je Slovenija kot članica Evropske skupnosti zavezana z okvirno vodno direktivo (Directive 2000/60/EC2000).

Morje je bilo v letu 2005 zelo visoko. Srednja letna višina morja je v Kopru dosegla drugo najvišjo vrednost v obdobju spremljanja gladin od leta 1958 naprej. Le leta 2004 je bila srednja letna višina morja višja.

Na vodomerni postaji v Hrastniku na Savi je bila v letu 2005 izmerjena največja vsebnost suspendiranega materiala doslej, povečane vsebnosti pa v Muri in Savinji v času avgustovskih visokih voda. Skupna vsota transportiranega materiala v Muri, Savi in Savinji je bila v primerjavi s preteklimi leti precej večja.

Za potrebe merjenja hitrosti v manjših in plitvejših rečnih strugah je v letu 2005 prišlo do uvedbe ultrazvočnega krila, s komercialnim imenom FlowTracker. Metoda meritev je po sami izvedbi analogna metodi meritev s hidrometričnim krilom, le da se hitrost v posamezni točki določa na podlagi Dopplerjevega pojava. Podatki o hitrostih vode ter o končnem pretoku prereza so znani sočasno z zaključkom meritve. Poleg uvajanja novih merilnih metod za merjenje hitrosti in pretoka vode je postopoma potekala nadgradnja vodomernih postaj v postaje z avtomatskim prenosom podatkov v realnem času, z moderno merilno opremo za merjenje vodostajev, kot so radarski merilniki vodostaja. Nadgradnja hidrološke merilne mreže prispeva k boljšemu in učinkovitejšemu spremljanju vse pogostejših hidroloških ekstremov.

Jože Knez,
direktor Urada za hidrologijo
in stanje okolja

with respect to the multi-annual mean and were more favourable than in previous years. For the most part, the aquifers of north-eastern Slovenia have recovered from the hydrological drought in 2002 and 2003. Very low water reserves only prevailed in the central part of the Prekmursko field. With the 2005 Hydrological Yearbook, we are introducing a uniform comparative period spanning twelve years from 1990 to 2001 to describe the state of the groundwater reserves. The same period was also used for the description of the quantitative state of the groundwater, which Slovenia is obliged to report as a member of the European Community in accordance with the EU Water Framework Directive (Directive 2000/60/EC).

The sea was very high in 2005. The mean annual sea level in Koper achieved the second highest value in the period of sea level monitoring since 1958. The mean annual sea level was only higher in 2004.

At the Hrastnik water gauging station on the Sava River, the highest concentration of suspended material to date was measured in 2005, while increased concentrations during the August high waters were measured in the Mura and Savinja rivers. The total sum of the transported material in the Mura, Sava and Savinja rivers was significantly higher in comparison with previous years.

For the purpose of measuring the velocities in the smaller and shallower river channels in 2005, an ultrasonic acoustic Doppler velocimeter with the commercial name of FlowTracker was introduced. In terms of execution, this measurement method is analogous to the method of measurement with the current meter, the difference being that the velocity at a certain point is determined based on the Doppler effect. The data on water velocities and on the final discharge of the cross-section are known when the measurement is completed. In addition to the introduction of new measuring methods for measuring the velocity and discharge of water, the upgrading of water gauging stations to automatic data transfer in real time took place. This upgrade involved modern measuring equipment for the measurement of water stages such as radar water stage meters. The upgrade of the hydrological gauging network contributes to the improved and more effective monitoring of increasingly more frequent hydrological extremes.

Jože Knez,
Director of the Hydrology and
State of the Environment Office

Spremembe v mreži hidroloških merilnih mest

mag. Marjan Bat

Uvod

Zaradi vsebinskih posebnosti delimo državno mrežo hidroloških opazovanj na mrežo za opazovanje podzemnih voda, mrežo za opazovanje izvirov, mrežo za opazovanje površinskih voda in mrežo za opazovanje morja. Mreža za opazovanje podzemnih voda obsega merilna mesta na vodonosnikih z medzrnsko poroznostjo, ki zavzemajo okoli 20 % ozemlja R Slovenije. Zaradi izdatnih zalog podzemne vode postopno vzpostavljamo merilna mesta tudi na vodonosnikih z razpoklinsko in kraško razpoklinsko poroznostjo, ki skupaj obsegajo nadaljnjih 50 % ozemlja. Osnovna veličina, ki jo spremljamo na merilnih mestih, je globina gladine podzemne vode; ponekod merimo tudi temperature in specifično električno prevodnost vode. Merilna mesta za opazovanje izvirov so namenjena spremljanju njihove izdatnosti, ki veliko pove tudi o količinskem stanju podzemnih voda v njihovem zaledju. Praviloma so na kraških izvirih, ki se odlikujejo prav po velikih vodnih količinah. Nekateri od njih so precej odmaknjeni od naselij in tudi zaradi tega bolj zahtevni za opazovanje. Osnovna veličina, ki jo opazujemo na merilnih mestih, je višina gladine vode. Kjer nam lokacije to dopuščajo, opravljamo na izvirih hidrometrične meritve, tako da lahko določamo njihov pretok. Praviloma merimo na izvirih tudi temperaturo in ponekod specifično električno prevodnost vode. Mreža za opazovanje površinskih voda ima najdaljšo tradicijo in je zaradi tega najbolj ustaljena. Vključuje tudi vodomerni postaji na Blejskem in Bohinjskem jezeru. Na vseh merilnih mestih beležimo vodostaje, na večini pa opravljamo tudi hidrometrične meritve, ki omogočajo izdelavo pretočnih krivulj za določanje pretoka vode skozi presek vodomerne postaje. Zaradi povednosti in medsebojne primerljivosti podatkov je pretok na vodomernih postajah za površinske vode bistvena veličina. Na izbranih merilnih mestih beležimo tudi temperaturo vode in zajemamo vzorce za določanje koncentracij suspendiranega materiala. Spreminjanje višine morske gladine beležimo na mareografski postaji Luška Kapitanija v Kopru. Meritve so se pričele že leta 1958. Neprekinjeno časovno vrsto podatkov je pomagala zagotoviti dodatna mareografska postaja, ki deluje v Luki Koper, v skrajni sili pa so bili v pomoč podatki postaje v Trstu. Na postaji merimo tudi temperaturo vode. Na morju, pred Punto v Piranu, meri oceanografska boja, ki je rezultat sodelovanja z Morsko biološko postajo, med drugim tudi smeri in hitrosti tokov, slanost, električno prevodnost in temperaturo morske vode.

Changes to the network of hydrological monitoring gauging stations

Marjan Bat, MSc

Introduction

Because of substantive differences, we divide the national hydrological monitoring network into the groundwater observation monitoring network, the spring monitoring network, the surface water monitoring network and the sea monitoring network. The network for monitoring groundwaters comprises observation stations on the aquifers with intergranular porosity that cover around 20% of the territory of the Republic of Slovenia. Because of the abundant groundwater reserves, we are gradually setting up observation stations on the aquifers with fissure and karstic fissure porosity as well, which together encompass a further 50% of the territory. The basic quantity that we monitor at the observation stations is the groundwater table level, though in certain places we also measure the temperature and specific electrical conductivity of the water. Spring observation stations are intended for monitoring the water abundance in the springs, which also tells us a lot about the quantitative state of the groundwaters in their catchment areas. As a rule, they are located on karstic springs characterised by considerable water quantities. Some of them are significantly far removed from settlements and are therefore more difficult to monitor. The basic quantity measured at observation stations is the water level. If the location permits it, we also carry out hydrometric measurements on the springs to determine their discharge rates. As a rule, we also measure the temperatures of the springs and in some places the specific electrical conductivity of the water as well. The network for monitoring surface waters has the longest tradition and is therefore the most stable. It also includes the hydrometric stations on lakes Bled and Bohinj. We are recording water stages at all the gauging sites, while we perform hydrometric measurements at the majority of gauging sites. These measurements enable the production of rating curves for determining the water discharge through the cross-section of the hydrometric station. Because of the informative character and mutual comparability of the data, the discharge at surface water hydrometric stations is a significant quantity. At selected gauging sites, we also record water temperatures and take samples for determining suspended material concentrations. The changing of sea levels is recorded by the Luška kapitanija tide gauge station at Koper, where measurements began in 1958. The additional tide gauge station in Luka Koper helped us obtain an uninterrupted time series and we used data from the tide gauge station in Trieste in cases

Leto 2005

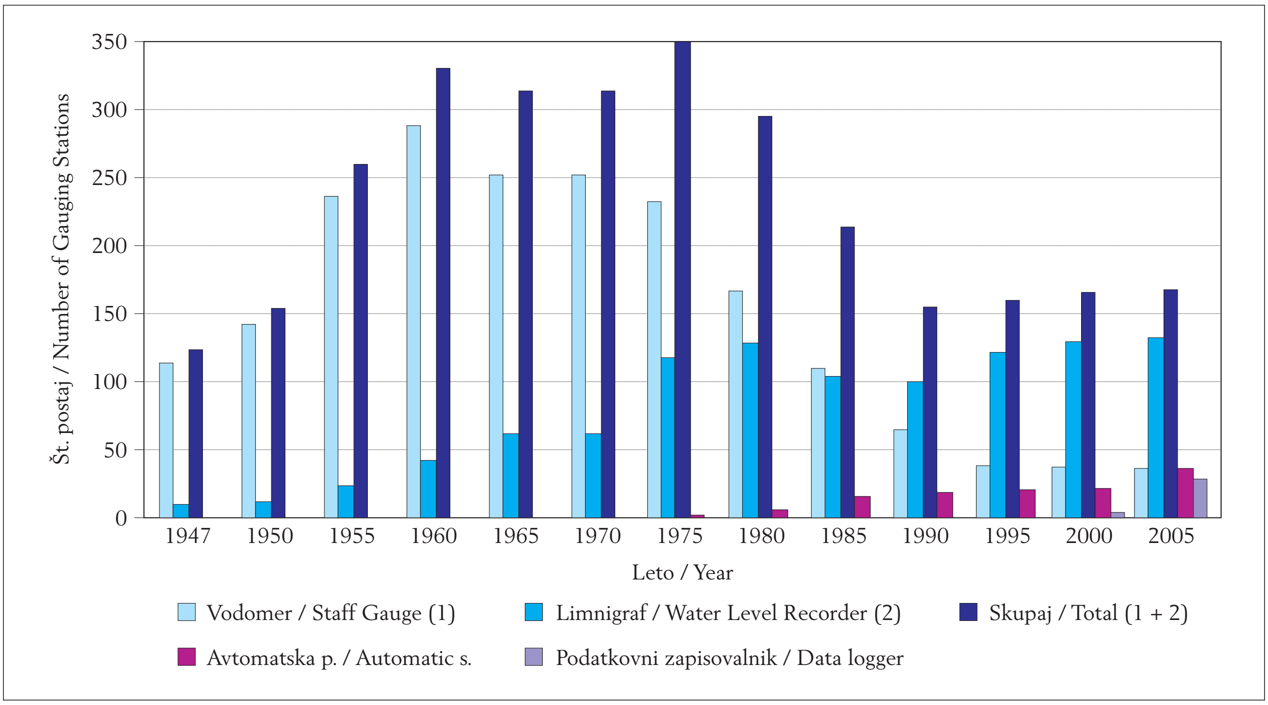
V mreži državnega spremljanja površinskih voda je leta 2005 delovalo 168 vodomernih postaj (slika 1). V letopisu objavljamo vodostaje za 159 postaj, podatki preostalih desetih merilnih mest pa se podvajajo ali pa iz različnih vzrokov niso primerni za objavo. Glede na leto 2004 so dodane vodomerne postaje: Cankova (šifra 1100) na Kučnici, kjer so bila opazovanja prekinjena 3 leta; Ovsiše I (4025) na Lipnici, kjer deluje limnigrafska postaja na novi lokaciji, na stari pa so bila opazovanja ukinjena; Sodna vas (4770) na Mestinjščici, kjer so bila opazovanja za 9 mesecev prekinjena zaradi regulacije; Branik (8640) na Branici, za katero smo zadnjič objavili podatke leta 2000. Ukinjena je bila vodomerna postaja Dvor (7040) na Krki, ki jo je v drugi polovici leta nadomestila vodomerna postaja Soteska (7060). V Tolminu (8330) na Tolminki se je profil med letom tako spreminjal, da je bil merilnik limnigrafa večkrat na suhem in so opazovanja pomanjkljiva. Tako pogostim spremembam hidravličnih lastnosti merilnega mesta ni bilo mogoče slediti z zanesljivimi pretočnimi krivuljami. Zato podatkov nismo objavili. Moteno je bilo tudi delovanje vodomerne postaje Log

where there was no other data available. We also measure the water temperature at the said stations. At sea, there is an oceanographic buoy just before Punta in Piran, which is the result o cooperation with the Piran Marine Biology Station. This measures the direction and velocity of currents, the salinity, the electrical conductivity and the temperature of the sea water among other things.

The Year 2005

168 hydrometric stations (Figure 1) operated within the national monitoring network of surface streams in 2005. We are publishing data for 159 stations in the Yearbook. The data from the remaining ten gauging sites are duplicated or are not suitable for publication for various reasons. With respect to 2004, the following hydrometric stations have been added: Cankova (code 1100) on the Kučnica River, where observations were suspended for 3 years; Ovsiše I (4025) on the Lipnica River, where a water level recording station operates at a new location while observations were discontinued at the old site; Sodna vas (4770) on the Mestinjščica

Vodomerna postaja Tolmin na Tolminki (foto: Mira Kobold, 13. 4. 2005).
Tolmin hydrimetric station on the Tolminka River (photo: Mira Kobold, 13. 4. 2005).



Slika 1: Število vodomernih postaj na površinskih vodah v obdobju od leta 1947 do leta 2005.
Figure 1: *The number of hydrometric stations on surface waters in the period from 1947 to 2005.*

pod Mangartom (8245) na kanalu Roje. Na Mutski Bistrici sta v letu 2005 vzporedno delovali dve vodomerni postaji. Vodostaje in pretoke prvič objavljamo za novo merilno mesto.

Na 106 postajah so bili vodostaji odčitani z limnigrafskih trakov, na 36 pa so jih zabeležili opazovalci z vodomerov. Na 17 merilnih mestih je bil osnovni vir podatkov o vodostaju digitalni zapis avtomatske merilne postaje ali podatkovnega zapisovalnika. Leto poprej je bil digitalni zapis uporabljen le na štirih merilnih mestih.

V letu 2005 je bilo na vodomernih postajah opravljenih 1137 hidrometričnih meritev. Od teh je bilo 660 meritev s hidrometričnim krilom (aritmetična sredina izmerjenih pretokov je bila 2,5 m^3/s), 403 z akustičnim dopplerjevim merilnikom pretokov (ADMP – srednji pretok meritev 68,4 m^3/s) in 74 meritev z akustičnim hidrometričnim krilom (FlowTracker – srednji pretok meritev je bil 2,8 m^3/s). Akustično hidrometrično krilo so terenske skupine ARSO začele uporabljati v drugi polovici leta. Nadomešča mehansko krilo in je posebej primerno za meritve malih pretokov pri nizkih hitrostih toka. Za merilca je postopek izvajanja meritve z obema merilnikoma enak. Rezultati meritve (npr. pretok) se sproti izpisujejo, kar predstavlja dodatno prednost merilnika. Na Dravi, Muri in Savi so bili v letu 2005 po dvakrat merjeni pretoki nad 1000 m^3/s. Poleg rednih je bilo v letu 2005 še 37 izrednih meritev.

Pretoki so objavljeni za 153 vodomernih postaj. Brez njih sta seveda vodomerni postaji na Blejskem in Bohinjskem jezeru, ne določamo pa jih tudi na merilnih mestih Komin na Ljubljanici, Gorenje in Dolenje Jezero na Strženu ter v Postojnski jami na Pivki.

River, where observations were suspended for 9 months due to regulation; Branik (8640) on the Branica River, for which the last data to be published was from 2000. The Dvor (7040) hydrometric station on the Krka River hydrometric station was abolished and replaced by the Soteska (7060) hydrometric station for the second half of the year. At Tolmin (8330) on the Tolminka River, the cross-section changed so much during the year that the meter of the water level recorder was dry on several occasions, rendering the observations deficient. Such frequent changes in the hydraulic properties of a gauging site could not be monitored with reliable rating curves and, therefore, we did not publish the data. The operation of the Log pod Mangartom (8245) hydrometric station on the canal of the Roja River was also interrupted. On the Mutska Bistrica River, two hydrometric stations operated simultaneously in 2005. The water stages and discharges for the new gauging site are published for the first time.

At 106 stations, the water levels were read from water level recorder strips while the stages were recorded by observers from gauges at 36 stations. At 17 gauging sites, the basic source of the data on the water stages was the digital record made by an automatic gauging station or data logger. In the previous year, digital recording was only used at four gauging sites.

In 2005, 1137 hydrometric measurements were performed at hydrometric stations. Of these, 660 were carried out using current meters (the arithmetic mean of the measured discharges was 2.5 m^3/s), 403 with the acoustic Doppler current profilers (ADCP – the mean discharge of the measurements was 68.4 m^3/s) and

Meritev z akustičnim hidrometričnim krilom na v. p. Središče – Ivanjševski potok (foto: Barbara Cankar, maj 2006).

Measurements with the acoustic Doppler velocimeter on the Središče hydrometric station on the stream Ivanjševski potok (photo: Barbara Cankar, Maj 2006).

Temperature objavljamo za 52 vodomernih postaj. Na 33 merilnih mestih so jih merili opazovalci z živosrebrnim termometrom, na 19 pa merilniki v sklopu avtomatske merilne postaje. Zaradi primerljivosti so podatki avtomatskih postaj o temperaturah vode izvedeni iz odčitkov med 7 in 8 uro, ker jih tedaj opazuje tudi večina opazovalcev. Podrobnejše podatke hranimo v podatkovni zbirki.

Na 4 merilnih postajah je potekal redni zajem vzorcev za določanje koncentracij in izračun transporta suspendiranega materiala. V Radovljici na Savi in v Suhi na Sori sta vzorce zajemala avtomatska vzorčevalnika, ki sta bila zaradi nizkih temperatur pozimi izklopljena. Nepopolnih podatkov v letopisu nismo objavili. Prav tako v letopisu niso objavljeni vsi rezultati odvzemov vzorcev ob izrednih hidroloških razmerah, ki so potekali na dopolnilni mreži monitoringa suspendiranega materiala.

V mreži za spremljanje podzemnih voda je leta 2005 delovalo 135 postaj. V letopisu objavljamo podatke 132. Glede na leto 2004 sta novi merilni mesti B-1 Brnik na Kranjskem polju in H-1 Ljubljana – Hajdrihova na Ljubljanskem barju. Ukinjena je bila postaja v 0851 v Mednem. Na novih merilnih mestih se spremlja nihanje gladine podzemne vode neprekinjeno z limnigrafom ali avtomatskim merilnikom. V letu 2005 je bilo tako opremljenih že 70 merilnih mest. Podatke z merilnih mest v Hrastju in Levcu sta postaji avtomatsko

74 with the ultrasonic acoustic Doppler velocimeters (the FlowTracker – the mean discharge of the measurements was 2.8 m^3/s). The field teams of the Environmental Agency of the Republic of Slovenia began using the ultrasonic acoustic Doppler velocimeter in the second half of the year. The device replaces the mechanical current meter and is especially suitable for measuring low discharges at low current velocities. The people taking the measurements have the same job irrespective of the type of device. The results of the measurements (e. g. the discharge) are displayed concurrently, which is an additional advantage of the new device. On the Drava, Mura and Sava rivers, discharges in excess of 1000 m^3/s were measured twice in 2005 and there were 37 extraordinary measurements performed in addition to the regular ones.

Discharges have been published for 153 hydrometric stations. There is no discharge data for lakes Bled and Bohinj and we also do not determine them for the gauging sites at Komin on the Ljubljanica River, Gorenje and Dolenje Jezero on the Stržen River and in the Postojna cave on the Pivka River.

We are publishing temperatures from 52 hydrometric stations. At 33 gauging sites, temperatures were measured by observers using mercury thermometers and at 19 by gauges within the scope of the automatic gauging station. For the purpose of comparability, data on water temperatures at the automatic stations was derived from readings made between 7 and 8 a. m., because this is when the temperatures are measured by the majority of observers. Detailed data is kept in the database.

At 4 gauging stations, regular sampling took place for the determination of concentrations of suspended material and the calculation of its transportation. In Radovljica on the Sava River and in Suha on the Sora River, samples were taken by automatic samplers that were deactivated in the winter because of low temperatures. We have not published incomplete data in the Yearbook. We also have not published all the results of sampling during extreme hydrological conditions that took place at the supplementary network for suspended material monitoring.

135 stations operated in the groundwater monitoring network in 2005 and we are publishing data for 132 in the Yearbook. Compared to 2004, the new gauging sites are B-1 Brnik on Kranjsko field, ŠM-1/2 Hrastje on the Ljubljana field, G-12 Črna vas and H-1 Ljubljana-Hajdrihova on the Ljubljana Moor and LE-1/01 Levec in the Lower Savinja Valley. Gauging site 0851 in Medno was abolished. At the new gauging sites, the fluctuation of the groundwater level is monitored continuously by a water level recorder or automatic gauge. In 2005, 70 gauging sites were equipped with this kind of equipment. Data from the gauging sites in Hrastje and Levec was communicated automatically by the stations to the Environmental Agency of the Republic of Slovenia so that we could follow the fluctuation of

posredovali na ARSO, tako da smo nihanje gladine podzemne vode že lahko spremljali sproti (v realnem času), v letopisu pa še niso objavljeni. Na 65 merilnih mestih so gladine beležili opazovalci. V Preserju (0430) se je pogostost opazovanj zmanjšala, drugje pa bistvenih sprememb glede na leto 2004 ni bilo.

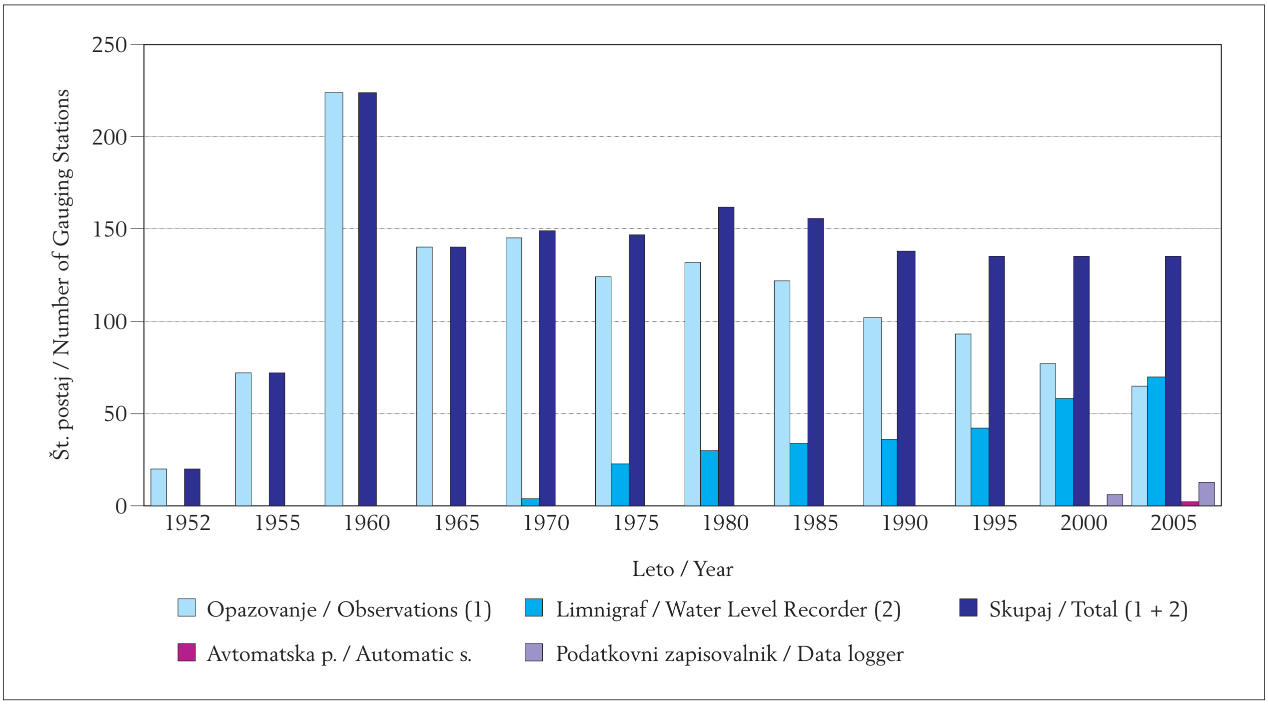
Opazovanje izvirov poteka na 13 postajah. Novi sta merilni mesti Letožnik (šifra 6253) na kraškem izviru Letošča pod Menino in Bilpa (4965). Skozi Bilpo se v Kolpo izliva del voda, ki poniknejo na Kočevskem polju. Obe merilni mesti imata podatkovni zapisovalnik. V letopisu objavljamo podatke šestih merilnih mest. Mednje smo uvrstili vodomerni postaji Dolence I (4985) na Krupi in Stopiče (7350) na Težki vodi, ne objavljamo pa podatkov za postajo Divje Jezero (8452) na Jezernici, ki predstavlja visokovodni preliv sistema kraških izvirov pri Podroteji.

Pri opazovanju morja je bila leta 2005 v okviru projekta ESEAS-RI zaključena prenova mareografske postaje Luška Kapitanija v Kopru (šifra 9350; podrobneje glej: **http://www.arso.gov.si/vode/morje/projekti/ESEASnet3.pdf**). V času gradbenih posegov so bili na merilnem mestu postavljeni nadomestni merilniki. Delovali sta tudi postaja v Luki Koper (9352) in oceanografska boja Piran (9400).

groundwater levels in real time but they are not published in the Yearbook. At 65 gauging sites, water levels were recorded by observers. The frequency of observations was reduced at Preserje (0430) though there were no significant changes elsewhere with respect to 2004.

Spring observations take place at 13 stations. The new observation sites are Letožnik (code 6253) on the Letošč karstic spring below Mount Menina and Bilpa (4965). A portion of the streams that infiltrate the Kočevsko field drain into the Kolpa River through Bilpa. Both gauging sites have data loggers. We are publishing data for six gauging sites in the Yearbook and have included data from the observation stations of Dolence I (4985) on the Krupa River and Stopiče (7350) on the Težka voda River, though we are not publishing data from the Divje Jezero (8452) observation station on the Jezernica River, which represents the weir of the system of karstic springs at Podroteja.

The renovation of the Luška kapitanija tide gauge station at Koper was completed in 2005 within the scope of the ESEAS-RI project (code 9350; for details see: **http://www.arso.gov.si/vode/morje/projekti/ESEASnet3.pdf**). During construction, replacement gauges were set up at the gauging site. The station at Luka Koper (9352) and the oceanographic buoy in Piran (9400) were also operational.



Slika 2: Število vodomernih postaj na podzemih vodah v obdobju od leta 1952 do leta 2005.

Figure 2: *The number of groundwater observations stations in the period from 1952 to 2005.*

Seznam opazovalcev v mreži merilnih mest hidrološkega monitoringa
The list of observers in the network of the hydrological monitoring gauging stations

Opazovalec *Observer*	Vodomerna postaja *Gauging station*	Reka, jezero *River, lake*
Avsec Igor	Gor. Jezero	Stržen
Avšič Boštjan	Čatež	Sava
Balog Milena	Hotešk	Idrijca
Banič Jože	Podbočje	Krka
Baša Slavko	Šalara	Badaševica
Baša Slavko	Podkaštel	Dragonja
Baša Slavko	Koper	Jadransko morje
Baša Slavko	Koper luka	Jadransko morje
Baša Slavko	Pišine	Drnica
Bevc Franc	Šoštanj	Velunja
Bevk Marija	Trzin	Pšata
Bizjak Marija	Rečica	Paka
Bizjak Nada	Okroglo	Sava
Blažič Filipina	Prestranek	Pivka
Bucaj Lidija	Kubed	Rižana
Buh Ljudmila	Komin	Ljubljanica
Cankar Darinka	Medno	Sava
Čas Pavla	Solčava	Savinja
Čelesnik Alenka	Škocjan	Radulja
Černigoj Jože	Ajdovščina	Hubelj
Dremelj Marija	Veliko Širje	Savinja
Feher Irinka (Irena)	Kobilje	Kobiljski potok
Ferfolja Alojz	Miren I	Vipava
Fideršek Jože	Tržec	Polskava
Filipič Marija	Pristava	Ščavnica
Fortuna Jožefa	Bistra	Bistra
Furlan Emil	Vipava	Vipava
Gaber Marija	Draža vas	Oplotnica
Gabrijelčič Zlatko	Nova Gorica	Koren
Gabrijelčič Zlatko	Solkan	Soča
Globevnik Melita	Gorenja Gomila	Krka
Glojek Marta	Kraše	Dreta
Gogala Dušan	Cerknica	Cerkniščica
Gregorič Radoš	Volčja Draga	Lijak
Heberle Olga	Mlino	Blejsko jezero
Heberle Olga	Mlino	Jezernica
Herzog Jerneja	Cankova	Kučnica
Horvat Ladislav	Središče	Ivanjševski potok
Hren Antonija	Borovnica	Borovniščica
Ilijev Zlata	Jesenice	Sava Dolinka
Ive Anton	Preska	Tržiška Bistrica
Janič Karel	Nuskova	Ledava
Jereb Matevž	Žiri	Poljanska Sora
Jurglič Jasna	Rožni Vrh	Temenica
Kac Jože	Stari trg	Suhodolnica
Kalič Matjaž	Otiški Vrh	Meža
Kalič Matjaž	Otiški Vrh	Mislinja
Kapš Stanko	Prečna	Prečna
Karničnik Elizabeta	Ruta	Radoljna
Kelenc Branko	Ranca	Pesnica
Kelenc Karolina	Gočova	Pesnica
Kelenc Katja	Borl	Drava
Kerčmar Geza	Hodoš	Velika Krka
Kern Janez	Pšata	Pšata
Klemen Slanc Marija	Razori	Šujica
Knafelj Jožica	Podhom	Radovna
Knap Vesna	Muta	Bistrica
Knap Vesna	Muta I	Bistrica
Koblar Alojzija	Železniki	Selška Sora
Kočevar Franc	Gradac	Lahinja
Komac Zdravko	Kršovec	Soča
Korošec Matilda	Makole	Dravinja

Opazovalec *Observer*	Vodomerna postaja *Gauging station*	Reka, jezero *River, lake*
Košir Luka	Sodražica	Bistrica
Kovač Anica	Log pod Mangartom	Koritnica
Kovačec Ivana	Zamušani	Pesnica
Krajnik Rudolf	Suha	Sora
Kramar Milena	Iška	Iška
Kranjc Tadej	Dolenje	Vipava
Kuhar Karel	Škofja vas	Hudinja
Leban Ivan	Tolmin	Tolminka
Lesjak Matilda	Levec	Ložnica
Leskovec Alojz	Podroteja	Idrijca
Lešnik Antonija	Medlog	Savinja
Levičnik Niko	Šentjakob	Sava
Lindič Martin	Radenci	Kolpa
Malis Viljem	Hrastnik	Sava
Martinčič Andrej	Dolenje Jezero	Stržen
Matjaž Božidar	Jelovec	Mirna
Mejač Antonija	Nevlje	Nevljica
Mesarič Gizela	Polana	Ledava
Milavec Andrej	Malni	Malenščica
Milavec Ivanka	Hasberg	Unica
Mlinarič Franc	Gornja Radgona	Mura
Moličnik Vinko	Luče	Lučnica
Mrvar Albin	Dvor	Krka
Mudrinič Aleksander	Bodešče	Sava Bohinjka
Mudrinič Aleksander	Radovljica	Sava
Mustar Marija	Rašica	Rašica
Nemet Ladislav	Zagaj	Bistrica
Novak Jože	Postojnska jama	Pivka
Oberstar Vida	Prigorica	Ribnica
Obštetar Borut	Dolenja Trebuša	Trebuša
Omerzel Jože	Metlika	Kolpa
Ovčjak Matej	Šoštanj	Paka
Pavša Silva	Golo Brdo	Idrija
Pec Franc	Loče	Dravinja
Peršolja Silvo	Neblo	Reka
Peršolja Silvo	Neblo	Kožbanjšček
Plešnik Francka	Gaberke	Velunja
Podbevšek Peter	Laško	Savinja
Podlipnik Janez	Kranjska Gora	Sava Dolinka
Potočnik Jože	Podnanos	Močilnik
Potočnik Nataša	Črna	Meža
Potokar Janez	Litija	Sava
Potrebuješ Ivan	Petrina	Kolpa
Pušavec Luka	Ovsiše	Lipnica
Rovšček Edvin	Bača pri Modreju	Bača
Roženbergar Vojko	Kranj	Kokra
Sadar Fanči	Kamnik	Kamniška Bistrica
Samec Oton	Polže	Hudinja
Sekljič Edvard	Pesje	Lepena
Simončič Franc	Celje	Savinja
Skubic Anica	Meniška vas	Radešca
Slavinec Angela	Škale	Sopota
Sotošek Avgust	Sodna vas II	Mestinjščica
Stegel Vida	Mali Otok	Nanoščica
Strniša Jure	Žebnik	Sopota
Šafarič Viktor	Petanjci	Mura
Šavli Marija	Cerkno	Cerknica
Šepec Terezija	Rakovec	Sotla
Šestan Boris	Cerkvenikov mlin	Reka
Šestan Boris	Ilirska Bistrica	Bistrica
Šestan Boris	Trpčane	Reka
Šestan Boris	Trnovo	Reka

Opazovalec *Observer*	Vodomerna postaja *Gauging station*	Reka, jezero *River, lake*
Šetina Marija	Sveti Duh	Bohinjsko jezero
Šetina Marija	Stara Fužina	Mostnica
Šetina Marija	Sveti Janez	Sava Bohinjka
Škoflek Biserka	Velenje	Paka
Škrbec Simon	Branik	Branica
Šorn Stanislav	Vir	Rača
Šorn Stanislav	Podrečje	Rača
Štancer Drago	Črnolica	Voglajna
Štibelj Tončka	Vešter	Selška Sora
Šturm Albin	Kobarid	Soča
Šturm Albin	Robič	Nadiža
Švarc Janko	Dvor	Gradaščica
Tivold Marija	Martjanci	Martjanski potok
Tominec Franc	Medvode	Sora
Trauner Julijus	Celje	Voglajna
Triller Marjeta	Zminec	Poljanska Sora
Trojok Evgen	Čentiba	Ledava
Tršinar Milka	Martinja vas	Mirna
Trunkelj Frančiška	Trebnja Gorica	Višnjica

Opazovalec *Observer*	Vodomerna postaja *Gauging station*	Reka, jezero *River, lake*
Verčnik Jožef	Zreče	Dravinja
Vidic Ana	Blejski most	Sava Dolinka
Vodišek Ivanka	Vodiško	Gračnica
Vodopivec Jože	Dornberk	Vipava
Vodovnik Vlado	Letuš	Savinja
Vošnjak Martin	Dolenja vas	Bolska
Vugrinec Štefanija	Videm	Dravinja
Zagorc Cveto	Nazarje	Savinja
Zajc Anton	Podbukovje	Krka
Zalokar Marjan	Domžale	Mlinščica Kanal
Zalokar Marjan	Vir	Kamniška Bistrica
Založnik Zvonko	Kokra	Kokra
Zapušek Marija	Škale	Lepena
Zavržen Viola	Mlačevo	Grosupeljščica
Žagar Bojan	Log Čezsoški	Soča
Žagar Bojan	Žaga	Učja
Žakelj Janez	Vrhnika	Ljubljanica
Žakelj Janez	Verd	Ljubija
Žvab Pavla	Bohinjska Bistrica	Bistrica

Opazovalec *Observer*	Postaja za podzemne vode *Groundwater observation station*
Artač Jože	Brezovica I.
Artenjak Stanko	Spodnja Hajdina
Beranič Ivan	Jablane
Beranič Slava	Brunšvik
Bizjak Ivan	Gotovlje
Bone Branko	Vipavski Križ
Cvetko Božidar Sandi	Trgovišče
Cvikl Anton	Zgornje Grušovlje
Čih Elizabeta	Gornji Lakoš
Drobnič Frančiška	Malence
Erjavec Franc	Lipovci
Filipič Igor	Ključarovci
Fišer Ana	Zgornja Gorica
Galun Janez	Kungota
Jarkovič Frančiška	Drama
Jenko Marta	Meja
Jerebic Franc	Brezovica
Kač Irena	Arja vas
Kaučič Anton	Plitvica
Kmeclj Leopold	Škofja vas
Kološa Elizabeta	Radmožanci
Kovač Marija	Sinja Gorica
Kregar Marija	Dolenja vas
Krpan Adrijan	Ajdovščina
Krušec Ivana	Segovci
Lepej Darinka	Starše
Mali Viljem	Šempeter
Medle Martina	Šmalčja vas
Medvešek Jožica	Hrvaški Brod

Opazovalec *Observer*	Postaja za podzemne vode *Groundwater observation station*
Merljak Luka	Renče
Mesarič Feliks	Bakovci
Mulec Eda	Žepovci
Ouček Franc	Rankovci
Pečnik Franc	Spodnji Stari Grad
Pinter Ervin	Nemčavci
Pleško Jože	Kozarje
Plošinjak Franc	Stojnci
Rat Alojz	Letuš
Repnik Anica	Zg. Jarše in Mengeš ter Preserje
Repnik Anton	Parižlje
Rodošek Dušan	Veliki Podlog
Rojc Cvetka	Volčja Draga
Simončič Ivan	Gorica
Simonič Rajko	Dornava
Slapnik Milena	Podgorje
Stamničar Dejan	Veščica
Stropnik Marko	Medlog-V1941
Šavrič Daniela	Bukošek
Škraban Avguštin	Krog
Tement Lidija	Sobetinci
Tonja Helena	Sveti Duh
Toplak Jože	Renkovci
Vilčnik Avgust	Ptuj
Vintar Nada	Kalce-Naklo
Weingerl Jože	Mali Segovci
Zadobovšek Rudolf	Trnava
Zevnik Marija	Celje
Žibrek Jelena	Zgornje Krapje

Primerjalne meritve pretokov z merilnikom FlowTtracker in hidrometričnim krilom

mag. Roman Trček, Barbara Cankar

Vrsto let se je na ARSO za potrebe izvajanja meritev pretokov uporabljala le metoda merjenja s hidrometričnim krilom. V uporabi je krilo z oznako C31, podjetja Ott Hydrometrie iz Kemptna, Nemčija. Premer elise (vetrnice) krila znaša 8 cm, s čimer lahko pokrijemo meritve hitrosti na območju 0,05 m/s do 3,5 m/s ali 5,0 m/s. Zgornja meja je odvisna od zahtev pri umerjanju, ki poteka kontinuirno, vsaj na 3 leta.

Zaradi togega prilagajanja ekstremnim razmeram (meritvam visokih in nizkih voda) ter dolgotrajnim meritvam višjih pretokov je bilo potrebno poiskati alternativne metode. Problemi so se pojavili tudi z vzdrževanjem merilne opreme ter zagotavljanjem rezervnih delov spremljajočih inštrumentov (npr. števna naprava),

Slika 3: Ultrazvočni merilnik FT v uporabi Agencije RS za okolje. Senzor (v spodnjem levem kotu) je sestavljen iz oddajnika na sredini in sprejemnikov na obeh koncih konzol. Vnos nastavitev in pregled rezultatov omogoča enota z zaslonom in tipkami, ki je povezana s senzorjem preko 2 m kabla.

***Figure 3:** The FT ultrasonic velocimeter used by the Environmental Agency of the Republic of Slovenia. The sensor (in the bottom left corner) consists of a transmitter in the centre and receivers on both sides of the consoles. The entry of settings and the review of the results are enabled by a screen and keyboard that is connected to the sensor by a 2-metre cable.*

Comparative measurements with the FlowTracker velocimeter and the current meter

Roman Trček, MSc, Barbara Cankar

For a number of years, only the current meter method was used by the Environmental Agency of the Republic of Slovenia for measuring discharges. The agency uses the C31 current meter manufactured by Ott Hydrometrie from Kemptn, Germany. The diameter of the propeller is 8 cm and it can cover velocity measurements in the range from 0.05 m/s to 3.5 m/s or 5.0 m/s. The upper limit depends on the requirements during calibration that proceeds continuously, at least every three years.

Because of its poor flexibility when adjusting to extreme conditions (measuring high and low waters) and long lasting measurements of higher discharges, we needed to find alternative methods. Problems also arose in the maintenance of the measuring equipment and with the provision of spare parts for the accompanying instruments (e. g. the counting device), which are slowly disappearing from the market. This is why the method of measuring discharges with the ADCP (acoustic Doppler current profiler) was introduced in 2003, as described in the 2003 Hydrological Yearbook of Slovenia.

The quality of discharge measurements on larger rivers and during high water was thus assured. But an alternative solution still needed to be found for the measurement of velocity in the smaller and shallower river channels. For these conditions, the most suitable device is the FlowTracker (FT) acoustic velocimeter or current meter. The FT is manufactured by the SonTek/YSI company from San Diego, California, USA (Figure 3).

This method of measuring discharges began to be introduced by the Environmental Agency of the Republic of Slovenia in mid-2005. By the end of the year, 81 measurements had been performed at 66 different hydrometric stations. At 23 gauging sites, measurements using current meters were performed simultaneously. The locations of these measurements and the dates of implementation are given in the tablet below (Table 1).

Description of the Method of Measuring Discharges with the FT Velocimeter

The method of measurement using the FT velocimeter is analogous to the current meter method in terms of execution, but the principle of determining the velocity at individual points is different. The velocity is determined based on the Doppler effect (changes between the emitted and received frequency or wavelength phase shifts), while the current meter measures the

Preglednica 1: Vzorec primerjalnih meritev.
***Table 1:** A sample of comparative measurements.*

	Šifra *Code*	Vodomerna postaja *Gauging station*	Vodotok *Stream*	Datum *Date*
1	3015	Kranjska Gora	Sava Dolinka	16. 11.
2	3060	Jesenice	Sava Dolinka	16. 11.
3	3250	Bodešče	Sava Bohinjka	15. 11.
4	3260	Ukanc	Savica	15. 11.
5	3320	Bohinjska Bistrica	Bistrica	15. 11.
6	3370	Natega	Mlino	15. 11.
7	4206	Medvode I	Sora	11. 11.
8	4215	Žiri II	Poljanska Sora	10. 11.
9	4230	Zminec	Poljanska Sora	10. 11.
10	4270	Železniki	Selška Sora	10. 11.
11	4298	Vešter	Selška Sora	10. 11.
12	4660	Martinja vas I	Mirna	26. 10.
13	4695	Jelovec	Mirna	26. 10.
14	4705	Orešje	Sevnična	26. 10.
15	6020	Solčava I	Savinja	02. 11.
16	6280	Velenje	Paka	02. 11.
17	6300	Šoštanj	Paka	02. 11.
18	6340	Rečica	Paka	02. 11.
19	6350	Škale	Lepena	02. 11.
20	6385	Pesje IV	Lepena	02. 11.
21	6400	Škale	Sopota	02. 11.
22	6415	Gaberke	Velunja	02. 11.
23	7310	Rožni Vrh	Temenica	26. 10.

ki počasi izginjajo s tržišča. Tako se je leta 2003 vpeljala metoda merjenja pretokov z ultrazvočnim merilnikom ADMP (akustični Dopplerjev merilnik pretoka), opisana v Hidrološkem letopisu Slovenije 2003.

Kvalitetne meritve pretokov na večjih rekah in ob visokih vodah so bile s tem zagotovljene. Potrebno pa je bilo poiskati alternativno rešitev merjenja hitrosti v manjših in plitvejših rečnih strugah. Za te razmere je najprimernejši točkovni merilnik hitrosti, t. i. ultrazvočno krilo, s komercialnim imenom FlowTracker (FT). FT proizvaja podjetje SonTek/YSI iz San Diega, Kalifornija, ZDA (slika 3).

Metoda merjenja pretokov s FT se je začela uvajati na ARSO sredi leta 2005. Do konca leta je bilo narejenih 81 meritev na 66 različnih vodomernih postajah. Na 23 merilnih mestih so se sočasno izvedle tudi meritve s hidrometričnimi krili. Lokacije teh meritev ter datumi izvedbe so podani v spodnji preglednici (preglednica 1).

Opis metode merjenja pretokov s FT

Metoda meritev s FT je po sami izvedbi analogna metodi meritev s hidrometričnim krilom, le da je princip določanja hitrosti v posamezni točki drugačen. Določa se na podlagi Dopplerjevega pojava (spremembe med oddano in sprejeto frekvenco oz. spremembe v faznem zamiku valovanja), medtem ko se pri krilu določa na podlagi števila vrtljajev elise. FT sestavljajo senzor, pritrjen na spodnji del jeklenega droga, in vhodno-izhodna enota (mini prenosni računalnik), ki je prav tako

number of revolutions of the propeller. The FT is made up of a sensor attached to the end of a steel pole and an input-output unit (a mini portable computer), which is also attached to the pole. The program allows us to manage and monitor the measurements and enter data on depths and the crosswise location within the channel (the distance of verticals from the bank). Simultaneously with the completion of measurements, we receive data on the velocities and the total discharge of the section, which is a significant advantage in comparison with the current meter, where the values are written in a booklet. It is necessary to rewrite the algorithm prior to evaluating the measurements performed with the current meter, which is done subsequently at the office. So several days or even weeks can elapse before we obtain the data.

The first and most important condition for a quality measurement is the selection of an appropriate gauging site. Such a site must be located in a flat, stable section of the channel. The river bed should be as regular and even as possible and without vegetation or larger rocks. A tape measure is run across the channel to serve for positioning the verticals. The verticals, where the velocities of the current are to be measured, are determined so that the individual discharge in each vertical does not exceed 10% of the total discharge. Thus we get at least 12 verticals in each section (two for the determination of the left and right banks and 10 verticals for the determination of the velocity). The depth of the cross-section and the velocity at the selected points are determined simultaneously in each vertical.

pritrjen na drog. Preko programa vodimo in spremljamo meritev ter vnašamo podatke o globinah in stacionaži (oddaljenosti vertikal od brega). Sočasno z zaključkom meritve dobimo podatke o hitrostih ter o končnem pretoku prereza, kar je velika prednost v primerjavi s hidrometričnim krilom, pri katerem se vrednosti izpisujejo v knjižico. Pred izvrednotenjem meritve s krilom je potreben prepis v algoritem, ki se izvede kasneje, v pisarni. Do pridobitve podatka o pretoku tako navadno preteče več dni, lahko tudi tednov.

Prvi in najpomembnejši pogoj za kvalitetno meritev je ustrezna izbira merilnega mesta. To mora biti na ravnem, stabilnem odseku struge. Dno struge naj bo čim bolj nespremenljivo ter brez zarasti ali večjih skal. Preko struge se napelje tračno merilo, ki služi za določanje položaja vertikal. Vertikale na katerih se merijo hitrosti toka se določijo tako, da posamezen pretok pripadajoči vertikali ne presega 10 % celotnega pretoka. Tako imamo v vsakem prerezu vsaj 12 vertikal (dve za določitev levega in desnega brega ter 10 vertikal za določitev hitrosti). Na vsaki vertikali se sočasno določi globina prečnega prereza ter hitrost v izbranih točkah.

Za določanje števila točk na posamezni vertikali obstaja več priporočil in metod. Odločili smo se za uporabo eno oz. dvo-točkovne metode, ki sledi tudi standardu ISO 748: 1997. V globinah manjših od 0,8 m se meri hitrost toka v eni točki na globini 0,6 h (merjeno od gladine navzdol). V primeru večjih globin uporabljamo dvotočkovno metodo na globinah 0,2 h ter 0,8 h. Izredna enotočkovna metoda, z meritvijo hitrosti na 0,5 h, se uporabi vedno, ne glede na globino vode, v primeru, ko merimo hitrosti pod ledom oziroma kadar menimo (glede na izkušnje), da vertikalna porazdelitev hitrosti ni teoretična (logaritmična), npr. potopljena matica toka. Dobljeno hitrost pri globini 0,5 h pomnožimo s korekcijskim faktorjem 0,89, da dobimo srednjo hitrost v vertikali.

V vseh primerih je časovni interval meritve dolg 60 s. Zmanjšamo ga le v primeru hitro spreminjajočih se pogojev, npr. hitrega padanja oz. dviganja gladine vode. Vsaki vertikali se določi pripadajoča površina prečnega prereza ter srednja hitrost toka. Z metodo površina-hitrost najprej določimo posamezne pretoke po lamelah, preko katerih dobimo celoten pretok reke.

FT meri hitrosti z dovolj veliko natančnostjo le, če je v vodi dovolj veliko število delcev, ki povzročijo močan odboj signala. Moč in kvaliteto odboja merimo s parametrom SNR (signal-to-noise ratio). SNR mora biti ob vsaki meritvi nad 10 dB. Meritve s parametrom SNR okrog 4 dB niso več povsem optimalne, vendar jih še vedno lahko uporabljamo kot okvirne vrednosti za nadaljnjo obdelavo, meritve s SNR pod 4 dB pa so nezanesljive.

Težave povzročajo tudi predvsem robna območja, če se tam nahajajo večji balvani ali skale oziroma, če je brežina zaraščena. FT meri hitrosti toka v volumnu vode na razdalji 10 cm od oddajnika zvočnega signala. To razdaljo moramo upoštevati pri določanju lege merjenega vzorca glede na celotno strugo ter pri meri-

There are several recommendations and methods for determining the number of points in an individual vertical. We decided on using the one- or two-point method, which is in line with the ISO 748: 1997 standard. At depths less than 0.8 m, the velocity of the current is measured at one point at the depth of 0.6 h (measured from the surface of water downwards). In the case of greater depths, we use the two-point method with depths of 0.2 h and 0.8 h. The non-standard one--point method measuring velocity at 0.5 h is used, irrespective of the depth, whenever we measure velocity beneath ice or when we believe (from experience) that the vertical distribution of velocity is not theoretical (logarithmic), e. g. a submerged current field. The velocity obtained at the depth of 0.5 h is multiplied by the correction factor of 0.89 in order to obtain the mean velocity in the vertical.

In all cases, the duration of the measurement is 60 seconds. We shorten the interval only in cases of rapidly changing conditions, e. g. a rapid decrease or increase of the water level. An associated surface of the transverse cross-section is determined for every vertical as well as the mean velocity of the current. Using the surface velocity method, we first determine the individual discharges by lamella, through which we obtain the total discharge of the river.

The FT velocimeter only measures velocity with high enough accuracy if there is a sufficient number of particles in the water to cause a strong signal reflection. The strength and quality of the reflection is measured with the SNR parameter (signal-to-noise ratio). The SNR must be higher than 10 dB on each measurement. Measurements taken with the SNR parameter at around 4 dB are not entirely optimal, but can still be used as indicative values for further treatment, though measurements with SNR of below 4 dB are unreliable.

It is primarily the verges that cause problems if there are larger boulders or rocks there or if the bank is overgrown. The FT velocimeter measures current velocities in a volume of water at a distance of 10 cm from the sound signal transmitter. This distance must be taken into account when determining the position of the measured sample with respect to the entire river channel and in the measurements at the last vertical so that we do not hit the bank. The setup of the pole on which the gauge is attached also affects the quality of the measurements. During the measurement, we must stand completely vertical and perpendicular to the (measurement) transverse cross-section. Any deviation from the vertical directly affects the accuracy of the results.

The method of measuring velocity with the FT velocimeter is useful in a range of from 0.001 m/s to 5 m/s and from a depth of 2 cm and up. The upper depth limit is determined by the length of the cable with the attached probe (2 m in our case) and the length of the staff onto which the gauge is attached. The gauge can store up to 64 measurements, though it is recomtvah na zadnji vertikali, da s signalom ne zadenemo ob brežino. Na kvaliteto meritve vpliva tudi postavitev droga, na katerega je merilnik pritrjen. Ob meritvi mora stati povsem vertikalno ter pravokotno na (merski) prečni prerez. Odmik od vertikale neposredno vpliva na natančnost rezultatov.

Metoda merjenja hitrosti s FT je uporabna v območju od 0,001 m/s do 5 m/s ter od globine 2 cm naprej. Zgornja omejitev globine nam predstavlja dolžina kabla s sondo (v našem primeru 2 m) ter dolžina palice, na katero je merilnik pritrjen. Merilnik lahko shrani do 64 meritev, kljub temu je priporočljivo, da se meritve redno (vsaj enkrat tedensko) prenašajo z merilnika v bazo meritev.

Najpomembnejše prednosti meritev s FT v primerjavi s konvencionalno metodo s hidrometričnim krilom so:

- rezultati meritev so pridobljeni hitreje,
- povečana kvaliteta meritev zaradi lažje kontrole izmerjenih vrednosti in zmanjšanja verjetnosti človeške napake,
- cenejše, enostavnejše in zanesljivejše vzdrževanje (ni kalibracij in težav z zagotavljanjem rezervnih delov, programska oprema za enostavno kontrolo delovanja).

Frekvenca izmerjenih hitrosti s FT je 1 Hz. Za izbran časovni interval merjenja to pomeni 60 meritev v eni točki, s čimer se doseže večja natančnost meritev. Metoda je uporabna pri širšem spektru meritvenih pogojev (že v globini od 2 cm dalje, medtem ko so po standardu veljavne meritve s hidrometričnim krilom šele od globine večje od 3 × premera elise, kar znaša več kot 20 cm). Zaradi občutljivih delov (keramičnih open, krmilna enota z displejem) je potrebno nekoliko previdnejše rokovanje z inštrumentom, sama metoda pa zahteva strokovno bolj usposobljeno ekipo.

Analiza rezultatov primerjalnih meritev

Na triindvajsetih različnih merilnih mestih so se sočasno oz. pri istem vodostaju izvedle meritve pretokov. Najprej si bomo ogledali rezultate primerjalnih meritev celotnega vzorca (slika 4, preglednica 2).

Pri sedemdesetih odstotkih primerjalnih meritev je bilo odstopanje parametrov meritev manjše od 10 %, pri osmih meritvah manjše od 5 %. Običajno se s povečanjem razlik pri izmerjeni površini ter srednji hitrosti poveča tudi odstopanje pretoka. Pri nekaterih meritvah se je pokazal trend razlik srednjih hitrosti npr. v pozitivno smer ter razlik površine prereza v negativno smer (ali obratno). Tako je lahko kljub precejšnjemu neujemanju parametrov površine in hitrosti ujemanje končne vrednosti pretoka precejšnje.

Pri 90 % primerjalnih meritev se vrednosti pretokov razlikujejo za manj kot 10 %, pri 57 % je odstopanje manjše od 5 %. Že samo ta podatek je indikator smiselnosti uporabe ultrazvočnega merilnika in nadomestitve hidrometričnega krila.

mended that the measurements are regularly (at least once a week) transferred from the gauge to the measurement database.

The most important advantages of measurements using the FT velocimeter in comparison with the conventional method using the current meter are:

- measurement results are obtained more quickly,
- increased quality of the measurements because it is easier to control the values measured and there is lower probability of human error,
- cheaper, simpler and more reliable maintenance (no calibration and problems with assuring spare parts, software for easy control of the operation).

The frequency of the velocities measured with the FT is 1 Hz. For the selected time interval of measurement, this means 60 measurements per point, meaning greater accuracy is achieved. The method is useful for a wider spectrum of measurement conditions (from a depth of 2 cm, while the measurements taken with the current meter in line with the standard can only be made from a depth of 3-times the propeller diameter onwards, meaning a depth of more than 20 cm). Because of the sensitive components (ceramic bricks and a control unit with a display), it is necessary to handle the instrument with greater care, while the method itself demands an expertly qualified team.

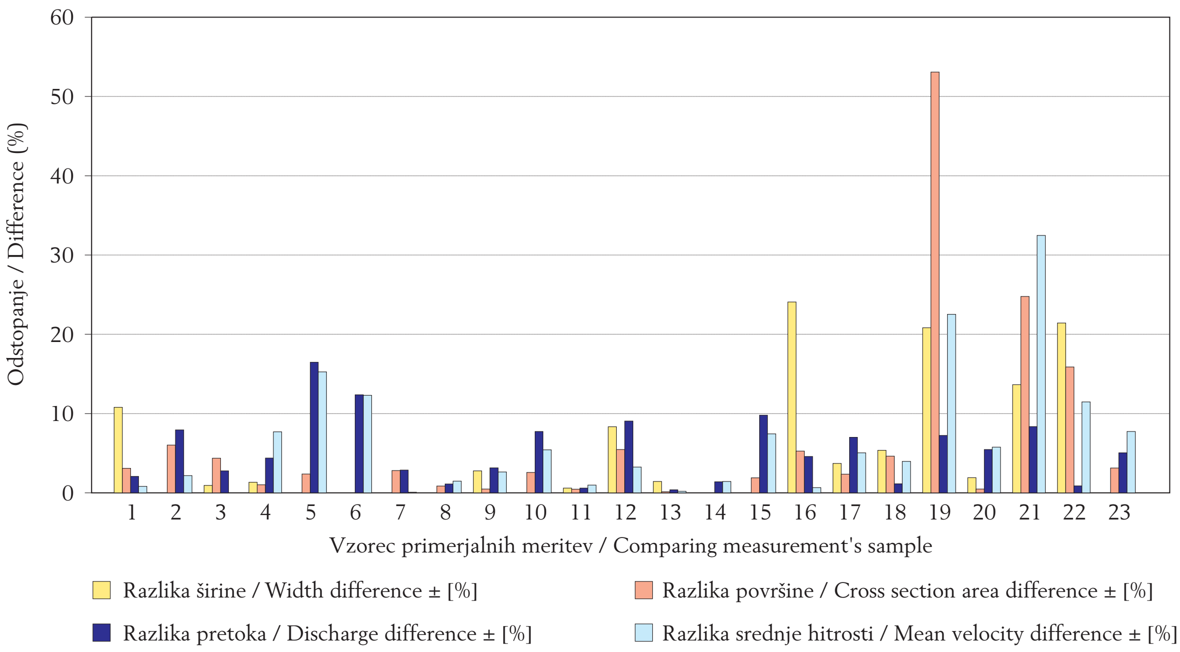
Analysis of the Results of the Comparative Measurements

At 23 different gauging sites, discharge measurements were performed simultaneously or at the same water level. We will, first take a look at the results of the comparative measurements of the complete sample (Figure 4, Table 2).

In 70% of the comparative measurements, the deviation of measurement parameters was less than 10%, while in 8% of the measurements it was less than 5%. Usually, the increase in differences of the measured surface and the mean velocity also increases the deviation of the discharge. In certain measurements, a trend of differences in the mean velocities could be observed, e. g. in the positive direction, while the differences in the cross-section surface were negative (or vice versa). Thus, despite the significant disagreement of the parameters of the surface area and velocity, the agreement of the final discharge value can be significant.

In 90% of the comparative measurements, the discharge values differ by less than 10%, while in 57% the deviation is lower than 5%. This data alone is an indicator that using the ultrasonic gauge (FT) and consequently replacing the current meter is a reasonable choice.

Considering the assurances of the manufacturer (namely that every gauge is inspected prior to use) and additional tests by independent organisations (Morlock et al, 2002 and Corbett, 2005), we can justifiably conclude that the majority of discrepancies are the result



Slika 4: Absolutno odstopanje rezultatov meritev narejenih s FT, v primerjavi z rezultati meritev narejenih s hidrometričnim krilom za določene parametre meritve pretoka po merilnih mestih. Opis lokacije merilnega mesta z zaporedno št. je podan v spodnji preglednici 2.

Figure 4: *The absolute deviation of measurement results obtained with the FT velocimeter in comparison with the results of measurements taken with the current meter for certain parameters of discharge measurements by gauging site. A description of the gauging site location with the serial number is given in the table below (Table 2).*

Preglednica 2: Razlika izmerjenih pretokov obeh merilnikov po merilnih mestih.

Table 2: *The difference of discharges measured with both gauges by gauging site.*

	Vodomerna postaja *Gauging station*	Vodotok *River*	Krilo *Current meter*	FlowTracker *FlowTracker*	Razlika pretoka ± (%) *Discharge difference ± (%)*
			Pretok (m^3/s) *Discharge (m^3/s)*		
1	Kranjska Gora	Sava Dolinka	0,794	0,827	2,1
2	Jesenice	Sava Dolinka	7,87	6,62	7,9
3	Bodešče	Sava Bohinjka	6,89	6,51	2,8
4	Ukanc	Savica	0,53	0,577	4,4
5	Bohinjska Bistrica	Bistrica	0,25	0,168	16
6	Natega	Mlino	0,24	0,181	12
7	Medvode I	Sora	12,6	11,9	2,8
8	Žiri II	Poljanska Sora	0,66	0,645	1,1
9	Zminec	Poljanska Sora	4,58	4,87	3,2
10	Železniki	Selška Sora	1,75	1,48	7,7
11	Vešter	Selška Sora	3,34	3,38	0,59
12	Martinja vas I	Mirna	1,6	1,89	9,1
13	Jelovec	Mirna	2,58	2,56	0,39
14	Orešje	Sevnična	0,258	0,251	1,4
15	Solčava I	Savinja	0,97	1,16	9,8
16	Velenje	Paka	0,655	0,715	4,6
17	Šoštanj	Paka	1,5	1,29	7,0
18	Rečica	Paka	1,76	1,72	1,1
19	Škale	Lepena	0,038	0,0435	7,2
20	Pesje IV	Lepena	0,127	0,113	5,5
21	Škale	Sopota	0,061	0,0508	8,4
22	Gaberke	Velunja	0,25	0,254	0,88
23	Rožni Vrh	Temenica	0,659	0,592	5,1

Glede na zagotovila proizvajalca, da je vsak merilnik pred uporabo preverjen, in dodatne teste neodvisnih organizacij (Morlock et al, 2002 in Corbett, 2005) lahko upravičeno sklepamo, da je večina neskladij posledica napak človeškega izvora. Glede na izvajanje meritev majhnih pretokov moramo biti za zagotovitev natančnosti v okviru ± 4 % izredno vestni in natančni zlasti pri izbiri profila in izvedbi meritve.

Končna ocena primerjave

Zaradi primerjave inštrumentov smo uporabili isti princip merjenja: časovni interval 30 s in isto število vertikal. Ujemanje rezultatov je bilo pričakovano dobro. Za dvig kvalitete meritev v prihodnosti smo povečali čas merjenja hitrosti na 60 s in število vertikal na (vsaj) 10, z možnostjo razumnega zmanjšanja v zelo ozkih umetnih koritih. Ujemanje rezultatov pri večjih prerezih je bilo zelo dobro. Manjše razlike nastopijo pri obliki prečnih prerezov, ki nastanejo zaradi večjega števila vertikal pri meritvi s hidrometričnim krilom. Tudi ta napaka bi bila s povečanjem števila vertikal odpravljena. Pri manjših in plitvejših prečnih prerezih nastopijo večja odstopanja. Zaradi majhnih merjenih vrednosti parametrov se vsaka netočnost v ponovitvi meritve pokaže kot veliko odstopanje rezultatov. Pazljivost pri izvedbi meritve v takšnih profilih mora biti še toliko večja.

of human error. When doing measurements at low discharges, we must be highly conscientious and precise in order to ensure accuracy within the range of ± 4%, especially when selecting the hydrometric profile and when doing the measurement.

Final Evaluation of the Comparison

In order to compare the instruments, we employed the same principle of measurement: a time interval of 30s and the same number of verticals. As expected, the agreement of the results was good. In order to enhance the quality of the measurements in the future, we increased the time of the velocity measurements to 60s and the number of verticals to (at least) 10, but have allowed for a reasonable decrease in very narrow artificial channels. The agreement of the results in larger cross-sections was very good. Smaller differences arise from the shape of the transverse cross-sections because of the greater number of verticals when taking measurements with the current meter. This error could also be done away with by increasing the number of verticals. Greater deviations occur in smaller and shallower transverse cross-sections. Because of the low values of the measured parameters, any inaccuracy in the repetition of the measurement manifests itself as a major deviation of the results. Care when taking measurements in such hydrometric profiles must be that much greater.

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