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

HIDROLOŠKI LETOPIS SLOVENIJE 2003

THE 2003 HYDROLOGICAL YEARBOOK OF SLOVENIA

AGENCIJA REPUBLIKE SLOVENIJE ZA OKOLJE

NASLOVNICA - COVER PAGE

Suha struga Dragonje (foto: Jože Uhan, 18. avgust 2003).
Dried-up riverbed of the Dragonja River (photo: Jože Uhan, 18 August 2003).

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VSEBINA

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PREDGOVOR

Leto 2003 je Generalna skupščina Združenih narodov razglasila za mednarodno leto celinskih voda. Posvečeno je bilo ozaveščanju prebivalstva o trajnostni rabi vodnih virov z bolj odgovornim ravnanjem in učinkovitejšo zaščito vode. Pomen omenjenih dejavnosti je v letu 2003 poudarilo vremensko dogajanje, ko se je v Evropi ob vročinskih valovih močno povečala umrljivost. Meteorološke in hidrološke razmere so povzročile veliko gospodarsko in ekološko škodo.

Značilnosti globalnih podnebnih razmer ponazarja temperaturni odklon + 0,6 °C . Leto 2003 je bilo enako toplo kot leto pred tem in le malo hladneje od leta 1998, najtoplejšega leta v času instrumentalnih meritev. Globalna količina padavin je bila pod dolgoletnim povprečjem. V mnogih predelih sveta so leto 2003 zaznamovale preobilne ali preskope padavine.

Tudi v Sloveniji je bilo leto 2003 toplejše od dolgoletnega povprečja, s temperaturnim odklonom v pretežnem delu države med 1 in 2 °C. Po številu vročih dni z najvišjo dnevno temperaturo vsaj 30 °C, je bilo leto rekordno. V letu 2003 je v primerjavi z običajnimi razmerami skoraj povsod po državi primanjkovalo padavin, najbolj na severovzhodu države, na Krasu in Goriškem. Suša se je začela spomladi in je trajala do konca poletja; v precejšnjem delu države je bila to najhujša suša v zadnjih petdesetih letih.

Leta 2003 je bilo po podatkih vodne bilance v Sloveniji v primerjavi z referenčnim obdobjem za tretjino manj padavin, nekoliko nižja je bila evapotranspiracija, odtok pa je bil kar za polovico manjši. V avgustu so se pretoki rek na najbolj prizadetih območjih zmanjšali pod najmanjše izmerjene vrednosti do sedaj. Zaradi podpovprečnih pretokov in nadpovprečne temperature vode je bilo življenje v potokih in rekah zelo ogroženo. Visokih voda je bilo manj kot prejšnja leta, izrazitejše so bile le avgustovske hudourniške poplave v Zgornjesavski dolini. Transport suspendiranega materiala v rekah je bil manjši od večletnega povprečja.

Tudi zaloge podzemnih voda so bile večji del leta nizke. Leto je bilo izjemno sušno in na nekaterih postajah merilne mreže podzemnih voda so bile zabeležene najnižje gladine. Že četrto leto zapovrstjo so bile sušne razmere bolj izrazite kot navadno, kar kaže na izrazit odklon od dolgoletnega režima podzemnih voda. Po podatkih Uprave RS za zaščito in reševanje je bilo v letu 2003 zaradi sušnih razmer prepeljane dvakrat več pitne vode kot leto poprej. Od tovrstne pomoči je bilo odvisnih več kot 47.000 ljudi.

FOREWORD

The United Nations General Assembly declared the year 2003 as the international year of inland waters with attention dedicated to informing the general public on the sustainable use of water resources aimed at more responsible management and effective protection of water. The significance of the aforementioned activities in 2003 was emphasized by the weather situation in 2003 when the death rate considerably rose in connection with the heat waves prevailing throughout Europe. The meteorological and hydrological conditions caused enormous economic and ecological damage.

The characteristics of the global climatic conditions are indicated by a temperature deviation of + 0.6 °C. The year 2003 was as warm as the year before it and only slightly cooler than 1998, which was acknowledged as the warmest year since measurements with the use of instrumentation were introduced. The global quantity of precipitation was below normals. In many areas of the world, 2003 was characterized by either excessive or deficient precipitation.

In Slovenia, 2003 was also warmer when compared to normals, with temperatures in the majority of the country being between 1 and 2 °C higher than average. According to the number of hot days with the highest daytime temperature of at least 30 °C, the year was considered a record one. In 2003, when compared to the normal conditions, a precipitation deficit was felt almost everywhere throughout the country, particularly in the north-eastern part, in Kras and Goriško. The drought started in spring and lasted until the end of summer; this was the worst drought in the past fifty years for a predominant part of the country.

According to the data on the water balance of Slovenia, 2003 in comparison with the reference period showed that there was less precipitation by a third and that evapotranspiration was slightly lower. The runoff, however, was by half as great as the normal runoff. In August, the river discharge in the most affected territories dropped below the lowest measured values to date. Due to below-average discharges and above-average water temperatures, life in streams and rivers was extremely endangered. High waters were less frequent than in previous years with the August torrential flooding in the headwaters of the Sava River being much more pronounced. The transport of suspended material in rivers was lower than the multi-annual mean.

The groundwater reserves were also low for the most part of the year. The year was an extremely

V hidrološkem letopisu, ki je pred nami, izpostavljamo uvajanje novih merilnih metod in tehnik, ki naj bi v naslednjih letih prispevale h kakovosti podatkov ter racionalnosti in varnosti pri terenskem delu. Z novimi tehnikami meritev se bo v državnem hidrološkem monitoringu bolje spremljalo vse pogostejše hidrološke ekstreme po Sloveniji.

mag. Jože Uhan,
vodja sektorja za hidrologijo

dry one and at several groundwater stations in the groundwater station network, the lowest groundwater levels were recorded. For the fourth consecutive year, drought conditions were more pronounced than usual which shows a prominent variation from the multi-annual groundwaters regime. According to data from the Administration for Civil Protection and Disaster Relief of the Republic of Slovenia, twice as much drinking water was needed to be delivered in 2003 than in the year before due to drought conditions. Over 47,000 people had to rely on this type of aid.

In the Hydrological Yearbook before you, we wish to highlight the introduction of new measuring methods and techniques, which should contribute to the quality of data and rationality and safety in field work in the upcoming years. The new measuring techniques will allow for improved national hydrological measurement of the ever more frequent hydrological extremes witnessed throughout Slovenia.

Jože Uhan, MSc.
Head of the Hydrology Section

SPREMEMBE V MREŽI MERILNIH MEST HIDROLOŠKEGA MONITORINGA

Marjan Bat

Večjih sprememb glede števila in opremljenosti merilnih mest, kakršne so se dogajale pred letom 1990, v državnem hidrološkem monitoringu leta 2003 ni bilo (graf 1 in 2). Število postaj se zadnjih nekaj let spreminja zaradi zagotavljanja kakovosti podatkov in zunanjih vzrokov (npr. regulacije vodotokov, zasipanje vodnjakov, vzporedne meritve ob prestavitvi postaje na novo lokacijo itd.). Prizadevamo si, da bi merilna mesta imela čim daljše, homogene podatkovne nize. Tudi zamenjava merilne opreme in uvajanje novih merilnikov potekata postopno. Na večini merilnih mest želimo zagotoviti neprekinjene meritve izbranih veličin z grafičnimi (limnigraf) ali digitalnimi zapisovalniki (podatkovni zapisovalnik ali avtomatska merilna postaja) in jih tako posodobiti. Pri monitoringu podzemnih voda je praviloma na merilnem mestu le en podatkovni vir (opazovalec ali zapisovalnik), na nekaterih merilnih mestih za opazovanje površinskih voda pa je iz različnih vzrokov lahko podatkovnih virov več. Poleg opazovalca lahko beleži vodostaje še limnigraf in z njim povezana ali neodvisna avtomatska merilna postaja (AMP), ki sproti posreduje podatke prognostični službi Agencije Republike Slovenije za okolje (ARSO). Po letu 2000 uvajamo v merilno mrežo podatkovne zapisovalnike. Nekateri, podobno kot limnigraf, samo beležijo vrednosti izbranih veličin, nekateri pa zabeležene vrednosti kot AMP posredujejo prognostični službi. Pri monitoringu izvirov, ki so na odmaknjenih krajih, uporabljamo predvsem podatkovne zapisovalnike.

V Hidrološkem letopisu Slovenije za leto 2003 objavljamo podatke 156 vodomernih postaj za meritve površinskih vodotokov in jezer. Mreža vodomernih postaj je prikazana na karti A v III. delu publikacije. Po enoletni prekinitvi so spet objavljeni podatki vodomerne postaje Rožni Vrh na Temenici (šifra 7310), prekinjena so bila opazovanja na Sevnični v Orešju (šifra 4705), na novo pa je začela delovati vodomerna postaja Medlog na Savinji (šifra 6120). Vodomerna postaja v Medlogu beleži vodostaj Savinje neprekinjeno in podatke pošilja na ARSO. Informativne vrednosti sproti objavljamo na teletekstu in medmrežju:

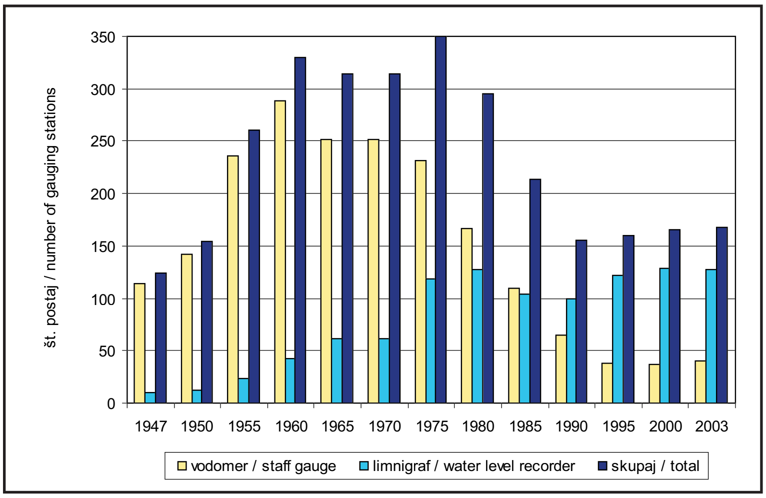
http://www.arso.gov.si/ podro~cja/vode/napovedi_in_podatki

CHANGES IN THE NETWORK OF THE HYDROLOGICAL MONITORING GAUGING STATIONS

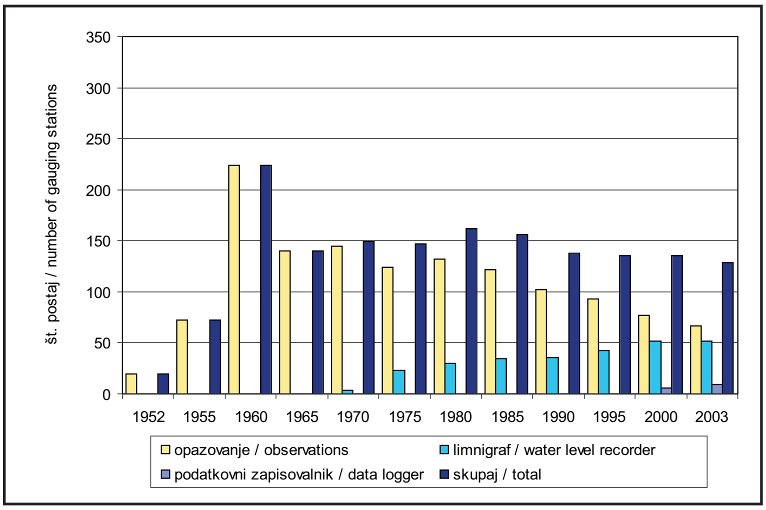
Marjan Bat

In the national hydrological monitoring in 2003, there were not as many changes carried out with regard to the number and instrumentation of hydrological stations that were being implemented prior to 1990 (see Graphs 1 and 2). The number of stations in the last several years has been changing so as to ensure quality of data due to external causes (e.g. regulation of watercourses, backfilling of wells, simultaneous measurements upon the relocation of stations, etc.).We endeavour to ensure that gauging stations have the longest possible homogenous time series at their disposal. The substitution of measuring equipment and the introduction of new gauges are also being carried out gradually. We strive to ensure the uninterrupted measurement of selected quantities at the majority of measuring locations using water level recorders or digital loggers (data loggers or automatic gauging stations) and thus update them. As a rule, in the monitoring of groundwaters, one data source is used per gauging station (an observer or measuring device) whereas at some gauging stations for the observation of surface waters, there can be several data sources due to various reasons. In addition to an observer, water level recorders and automatic gauging stations (AGS), which are either connected to the water level recorders or not and which transmit data in near real time to the hydrological prognostic office of the Environmental Agency of the Republic of Slovenia can measure water levels. After 2000, we have been introducing data loggers into the hydrological network. Some of these only record the values of selected quantities in a similar way to water level recorders while others, such as automatic hydrological stations, transmit the recorded data to the hydrological prognostic office. Primarily data loggers are used when monitoring springs in remote areas.

The data of 156 water gauging stations on surface watercourses and lakes are presented in the 2003 Hydrological Yearbook of Slovenia. The network of gauging stations is shown on map A in Part III. Following a one-year interruption, the data from the water gauging station Rožni Vrh on the Temenica River (code 7310) are once again published. The observations on the Sevnična River in Orešje (code 4705) have been terminated and the gauging station Medlog on the Savinja River (code 6120) has once again begun operations. The water gauging station in



Graf 1: Število vodomernih postaj na površinskih vodah v obdobju od leta 1947 do 2003.
Graph 1: Number of water gauging stations on surface waters in the period from 1947 to 2003.



Graf 2: Število vodomerni postaj na podzemnih vodah v obdobju od leta 1952 do 2003.
Graph 2: Number of groundwater stations in the period from 1952 to 2003.

Vodostaji so objavljeni za vseh 156 vodomernih postaj površinskih voda, pretoki za 149 vodomernih postaj, temperature za 45, podatki o vsebnosti in prenosu suspendiranega materiala pa za 4 vodomerne postaje. V letu 2003 je bilo na presekih vodomernih postaj s hidrometričnim krilom opravljenih 990 meritev. Zaradi hidrološko izrazito suhega leta, je bilo več meritev kot običajno opravljenih pri malih pretokih. Od sprememb, ki so se tega leta zgodile v merilni mreži hidrološkega monitoringa, je treba vsekakor omeniti prve hidrometrične meritve z uporabo akustičnega dopplerjevega merilnika pretoka (ADMP). Izvedenih je bilo 58 meritev. Namenjene so bile uvajanju nove merilne opreme. Enaindvajset meritev je bilo opravljenih sočasno s hidrometričnim krilom, 37 meritev pa je bilo samostojnih. Sočasne meritve so pokazale, da so rezultati obeh metod primerljivi. Določeni so bili pogoji in

Medlog continuously records the water levels of the Savinja River sending the data to the Environmental Agency of the Republic of Slovenia. Informative values are published concurrently on the Internet at the Web site: *http://www.arso.gov.si/ podro~cja/ vode/napovedi_in_podatki/* and on the teletext.

Water levels are published for all 156 water gauging stations for surface waters while data on discharges are published for 149 stations, data on temperatures for 45 gauging stations and data on the concentrations and transport of suspended materials for 4 water gauging stations. At cross-sections of river gauging stations, 990 current meter measurements were carried out in 2003. Due to the hydrologically pronounced dry year more measurements of small discharges than normally were carried out. Of the changes occurring in that year in hydrologiizbrane vodomerne postaje, na katerih je priporočena uporaba ADMP. Med drugim bo merilnik omogočal meritve velikih pretokov, ki jih zaradi tveganja in drugih vzrokov do sedaj na večini merilnih mest ni bilo mogoče opraviti. Ekipe, ki delajo z novim merilnikom, so učinkovitejše, rezultati meritve, npr. pretok, pa so znani takoj po opravljeni meritvi. Skupaj je bilo torej v letu 2003 narejenih 1027 kompletov hidrometričnih meritev, v povprečju okoli 6 na vodomerno postajo.

Globine gladin podzemnih voda so objavljene za 128 merilnih mest, eno manj kot leto poprej. Mreža postaj je prikazana na karti B v III. delu publikacije. Na merilnem mestu 0360 Brnik na Kranjskem polju, ki se nahaja na območju letališča, so bile zaradi gradnje meritve prekinjene. Na merilnih mestih 3552 Murski Petrovci na Prekmurskem polju, 1270 Črna vas na Ljubljanskem barju in 0111 Cerklje na Krškem polju smo meritve posodobili in opazovanja nadomestili z neprekinjenimi meritvami gladin. Zaradi hidrološke suše so vodnjaki na 14 merilnih mestih vsaj za nekaj časa presahnili, kar 5 na Dravskem polju, kjer je bil vodnjak v Brunšviku suh celo leto.

V merilni mreži monitoringa izvirov so se v aprilu začela opazovanja na merilnem mestu Metliški Obrh v Metliki (šifra 4995). Podatkov zaradi nepopolnega niza v Letopisu nismo objavili. Meritve so bile že v oktobru leta 2002 prekinjene na izviru Podroteja in jih v letu 2003 nismo ponovno vzpostavili. Na merilnem mestu Divje jezero so meritve potekale celo leto nemoteno, na Kamniški Bistrici in Globočcu pa so bile meritve za krajši čas zaradi tehničnih težav motene ali prekinjene.

Vodomer
(foto: Marko Burger)
Staff gauge
(photo: Marko Burger)

cal monitoring, the introduction of the first hydrometric measurements with the aid of an Accoustic Doppler Current Profiler (ADCP) must certainly be mentioned. Fifty-eight measurements were carried out aimed at the introduction of the new measuring equipment. Twenty-one ADCP measurements were performed simultaneously with the current meter while 37 were performed independently with only the ADCP. The simultaneous measurements showed the results of both methods to be comparable. The conditions were determined and the water gauging stations selected, for which the use of the ADCP was recommended. Among other things, the gauge will enable the measurement of high water discharges, which due to the risk and other factors has not been possible until now in the majority of the gauging stations. Teams working with the new gauges are now more effective in delivering measurement results such as discharges being immediately computed following the performed measurements. Altogether, 1027 sets of hydrometric measurements were carried out in 2003 with an average of 6 measurements at each water gauging station.

The depth of groundwater levels are published for 128 groundwater stations representing one less than the year before. Groundwater network is shown on map B in Part III. At the groundwater station 0360 Brnik on Kranjsko polje, which is located in the area of an airport, measurements were terminated due to construction works. At the groundwater station 3552 Murski Petrovci on Prekmursko polje, 1270 Črna vas in the Ljubljana marshes and 0111 Cerklje on Krško polje, measurements were modernized with observations being replaced by continuous water level gauging. Due to the hydrological drought, wells at 14 groundwater stations have dried up at least for a while, of which as many as 5 were in Dravsko polje where the well in Brunšvik remained dry throughout the year.

In the spring monitoring network, observations commenced in April at the spring observation station Metliški Obrh in Metlika (code 4995). Data were not published in the Yearbook due to incomplete time series. At the spring in Podroteja, measurements have already been terminated in October 2002 and were not reinstated in 2003. At the spring observation station of the lake of Divje jezero, measurements were carried out continuously throughout the entire year while measurements on the Kamniška Bistrica River and Globočec were disrupted or suspended for a short while due to technical problems.

Obnova in posodobitev vodomerne postaje Šentjakob na Savi.
(foto: Marko Burger, 17. september 2003)
Reconstruction of gauging station at Šentjakob on the Sava River.
(photo: Marko Burger, 17 September 2003)

UVEDBA AKUSTIČNEGA DOPPLERJEVEGA MERILNIKA PRETOKA V PROCES HIDROLOŠKEGA MONITORINGA

Roman Trček

Na Agenciji RS za okolje (ARSO) imamo z letom 2003 za meritev pretoka rek, poleg ostale (klasične) opreme, na razpolago tudi akustični Dopplerjev merilnik pretoka (v nadaljevanju ADMP). Merilnik ADMP RioGrande ZedHed 1200 kHz je bil razvit v podjetju Teledyne RD Instruments iz San Diega, v Kaliforniji, ZDA. Omogoča meritve pretokov v strugah, globljih od 0,4 m. Zaradi specifičnega, t.i. širokopasovnega postopka merjenja lahko merimo z istim merilnikom hitrostni profil do globine 15 metrov ter hitrosti toka do 10 m/s. ADMP hitrost toka po predpostavki enači s hitrostjo v vodi raztopljenih oz. suspendiranih delcev. Za njeno določitev izkorišča merilnik princip Dopplerjevega pojava. Meritev hitrosti in globine se izvaja sočasno, z enim samim prečkanjem struge. Z uporabo programske opreme WinRiver in radijske zveze med merilnikom ter prenosnim računalnikom, prenesene podatke o izmerjenih vrednostih preverjamo v realnem času. Končni rezultati meritev (pretok, površina prereza, srednja hitrost ipd.) so tako znani takoj po končanem prečkanju.

Akustični merilniki pretokov uporabljajo princip Dopplerjevega pojava, torej merijo spremembo med oddano in sprejeto frekvenco. Za določanje pretoka rek se uporablja frekvenčno območje od 500 do 2000 kHz. Hitrost vode se meri posredno, preko v vodi raztopljenih delcev, zračnih mehurčkov ipd. Globina se meri kot čas potovanja signala do dna struge in nazaj. Novejša, širokopasovna metoda meritev upošteva poleg sprememb frekvence tudi fazni zamik odboja, kar poveča natančnost meritev ter merilno območje hitrosti.

Meritev izvajamo s prečkanjem struge, med katerim mora merilnik v vsakem trenutku poznati svoj položaj. Le-tega določi glede na položaj na začetku gibanja, lastno hitrost in smer gibanja ter čas, ki je pretekel med posameznima vertikalnima meritvama (profiliranjema). Vertikalna meritev je sestavljena iz vsaj dveh odbojev – od raztopljenih delcev in od dna, zato jo imenujemo skupek oz. garnitura. Glede na dinamičnost sprememb hitrosti in/ali globine lahko povečamo število posameznih odbojev v skupku, s čimer se razumljivo poveča tudi časovni interval med skupkoma. Rezultat meritve enega skupka predstavljajo torej povprečne, relativne

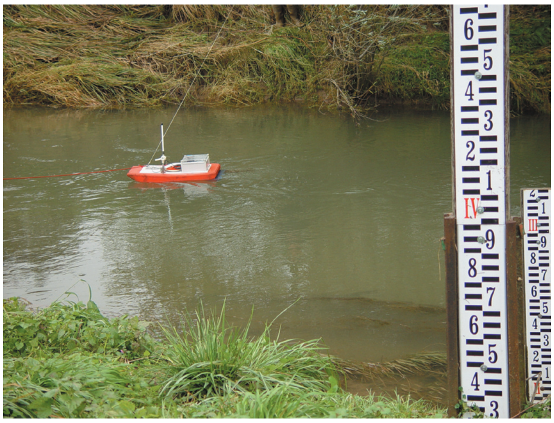
INTRODUCTION OF THE ACOUSTIC DOPPLER CURRENT PROFILER INTO THE HYDROLOGICAL MONITORING PROCESS

Roman Trček

At the Environmental Agency of the Republic of Slovenia (ARSO), we have had at our disposal an Acoustic Doppler Current Profiler (hereinafter ADCP) for the measurement of the river discharge since 2003 in addition to the other (classic) equipment. The RioGrande ZedHed 1200 kHz ADCP gauge was developed by the Teledyne RD Instruments, a San Diego based company from California, USA. It enables the measurement of discharges in riverbeds that are deeper than 0.4 m. Due to the specific or so-called broadband measurement procedure we can measure the velocity cross-section up to the depth of 15 m and the velocity of the currents of up to 10 m/s with the same gauge. The ADCP equates the velocity of the current with the velocity of the suspended load dissolved in water. To determine this velocity, the gauge uses the Doppler effect principle. The measurement of velocity and depth is carried out simultaneously with a single pass over the river. With the use of the WinRiver software and a radio link between the gauge and a laptop computer, the transferred data on the measured values is verified in real time. The final results of measurements (discharge, cross-section surface area, average velocity etc.) are thus known immediately after the finished passage over the river.

The acoustic current profiler uses the principle of the Doppler effect, therefore, it measures the change between the emitted and received frequencies. For the determination of the river discharges, a frequency band between 500 and 2000 kHz is used. Water velocity is measured indirectly via the particles dissolved in water, air bubbles, etc. Depth is measured as the signal travel time to the bottom of the riverbed and back. The latest broadband measurement method takes into account the phase shift of the reflection in addition to frequency changes, which increases the accuracy of measurements and the velocity measurement range.

Measurements are carried out by passing the riverbed during which time the gauge must have the data on its position at all times. The position is determined with respect to the position at the start of the movement, the velocity and direction of the movement of the gauge itself and the time that has passed between individual vertical measurements



Primer ultrazvočnega merilnika tipa WorkHorse Rio Grande 1200 kHz podjetja Teledyne RD Instrument, pritrjenega na čolniček, t.i. surfboard. Merilnik uporablja štiri žarke in princip primerjanja dveh parov podatkov. Na ta način je vzpostavljena visoka kontrola izmerjenih vrednosti.
(foto: Marko Burger)
An example of the WorkHorse Rio Grande 1200 kHz type ultrasound gauge of the Teledyne RD Instrument company fixed to a boat, the so-called surfboard. The gauge uses four rays and the principle of comparison of two pairs of data. In this way, a comprehensive control of the measured values is enabled.
(photo: Marko Burger)

(glede na merilnik) vrednosti vektorjev hitrosti vode v vodnem stolpcu ter oddaljenosti in hitrosti dna. Slednjo enači merilnik s svojo hitrostjo. Izmerjenemu vektorju zamenja le smisel oz. orientacijo.

Za natančnost meritve je pomembno, da je gibanje merilnika preko struge enakomerno v razponu od 0,2 m/s do 1 m/s. Istočasno naj bi bil, zaradi večjega števila vertikal, čas med posameznima skupkoma čim krajši. Običajno znaša med 0,5 s ter 1,5 s. Ker merilnik nenehno nadzira svoj položaj, za določitev pretoka ni potrebno, da se giblje pravokotno preko struge, niti po ravni črti. Merilnik namreč pretok skozi posamezen skupek sproti integrira ter kumulativno prišteva oz. odšteva. Pomembna nastavitev meritve je debelina plasti v vodnem stolpcu. Dejansko predstavlja debelina plasti časovni interval, na katerega se razdelijo odbiti signali. Med meritvami debeline plasti ne moremo spreminjati, zato je pomembno, da s pravilno izbiro pokrijemo tako plitke kot globoke dele. Podrobni razdelitvi vodnega stolpca se izogibamo zaradi večjega števila prenesenih podatkov in posledično daljšega časa med skupki, večje porabe energije in možnosti izgube podatkov pri prenosu ter, kot posledica manjšega merskega volumna in pulzacij hitrosti, tudi večjega standardnega odklona izmerjenih hitrosti.

Zaradi potopljenosti oz. ugreza merilnika ter dejstva, da je vsak od štirih oddajnikov hkrati tudi sprejemnik, dobimo na površini plast, ki je merilnik ne more izmeriti. Njena debelina znaša od 20 cm do 30 cm. Podobno neizmerjeno območje, kot posledica motnje uklona zvočnega žarka, nastane tudi ob dnu struge. Debelina območja v tem primeru znaša 6 odstotkov globine vode. Neizmerjen del pa predstavljata tudi oba robova struge, zato moramo na začetku in na koncu meritve oceniti oddaljenost merilnika od bregov. Pretok skozi neizmerjene dele prištejemo k izmerjenemu pretoku z uporabo inter- oz. ekstrapolacijskih metod. Velikost posameznih pretokov lahko s pomočjo programske opreme kontroliramo že med samo meritvijo (desno zgoraj; slika

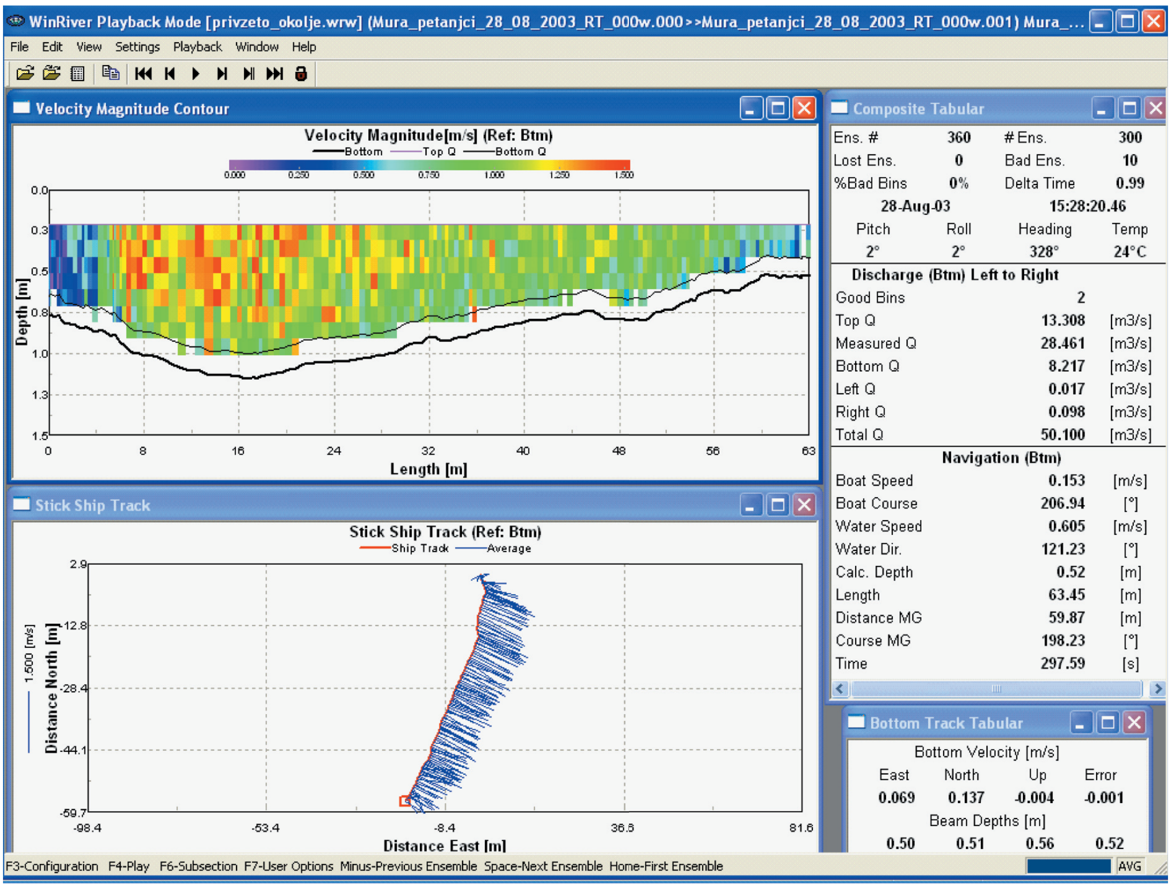
(profiling). Vertical measurement comprises at least two reflections – from the dissolved particles and from the bottom, which is why it is called a set. With respect to the dynamics of velocity changes and/or the depths, we can increase the number of individual reflections in a set whereby it is understandable that the time interval between two sets is increased. Results of the measurement of a single set, therefore, represent the mean relative (with respect to the gauge) values of water velocity vectors in a water column and the distance and velocity of the bottom. The latter is equated by the gauge with its own velocity. It only changes the measured vector's orientation.

For the purpose of measurement accuracy, it is important that the movement of the gauge over the riverbed is uniform within the range of 0.2 m/s to 1 m/s. At the same time, the time between individual sets should be as short as possible because of the greater number of verticals. It is usually between 0.5 and 1.5 s. Because the gauge monitors its position constantly, it is unnecessary for it to move perpendicularly to the watercourse or in a straight line for the determination of the discharge. The gauge namely simultaneously integrates the discharge through an individual set and adds or detracts it cumulatively. An important setup for the measurement is the thickness of the layer in the water column. Layer thickness actually represents the time interval, into which the reflected signals are divided. During measurement, layer thickness cannot be changed, which is why it is important that we cover the shallow as well as the deep parts with an appropriate choice. We avoid making a detailed division of the water column because of the greater amount of transferred data and consequently longer time between the sets, greater consumption of energy and the possibility of loosing data during transfer and, as the result of a smaller measurement volume and velocity pulsations, also the greater standard deviation of the measured velocity.

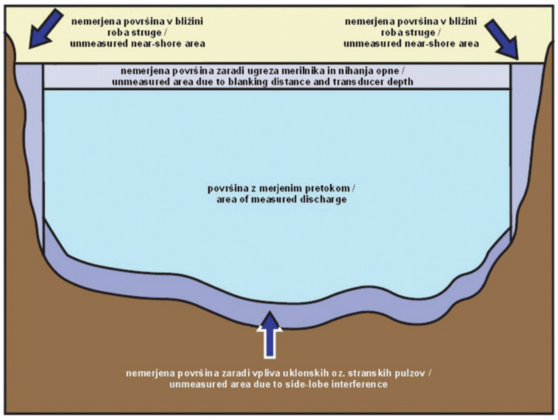
grafičnega prikaza). Manjši, ko je delež izmerjenega pretoka (Measured Q – na sliki) glede na skupni pretok (Total Q – na sliki), bolj moramo biti pazljivi pri izbiri metod za določitev pretoka skozi neizmerjene dele.

Leto 2003 je bilo z vidika hidrometrije leto primerjave nove metode z ADMP s konvencionalno metodo, ki predvideva uporabo hidrometričnih (HM) kril. Poleg primerjave obeh metod smo preverjali tudi uporabnost merilnika ADMP glede posebnosti slovenskih rek oz. obstoječih vodomernih profilov. Sočasno z izvajanjem meritev smo določili tudi postopek vnosa merjenih podatkov v bazo. Sama struktura izhodnih podatkov (rezultatov) je pri obeh metodah precej različna, zato je bilo potrebno skrbno določiti kateri podatki se bodo vpisovali v bazo in kateri bodo dostopni le zahtevnejšim uporabnikom.

Because of the immersion or draught of the gauge and the fact that each of the four transmitters is at the same time a receiver, we get a layer on the surface that the gauge cannot measure. Its thickness is between 20 and 30 cm. A similar area that cannot be measured as a result of the disruption of the diffraction of the sound ray also occurs at the bottom of the riverbed. The thickness of the area in this case amounts to 6 percent of the depth of the water. The unmeasured part also comprises both edges of the riverbed, which is why we have to assess the distance of the gauge from the banks in the beginning and at the end of the measurement. The discharge through the unmeasured parts is added to the measured discharge with the use of inter- or extrapolation methods. The size of individual discharges can be controlled with the aid of software already during the measurement (on the right above, on figure of graphic representation). The smaller the ratio of the measured discharge is (measured Q – on the figure)



Programska oprema WinRiver omogoča sprotno kontrolo izmerjenih vrednosti. Levo zgoraj in spodaj sta grafična prikaza, desna stran pa vsebuje najpomembnejše številske vrednosti (rezultate). Okno levo zgoraj predstavlja prečni prerez, velikost vektorjev hitrosti je prikazana z barvno lestvico. Okno desno spodaj prikazuje tloris prečenja struge. Z rdečo črto je označena pot merilnika glede na smer sever-jug, z modro pa so prikazani povprečni vektorji hitrosti (smer in velikost) po posameznih vertikalah.
WinRiver software enables real time control of measured values. On the left side – above and below – there are graphic representations while the right side comprises the most important numerical values (results). The window on the left side above represents the cross-section while the velocity vector size is represented with a colour scale. The window on the right below represents the ground plan of the passing over the riverbed. The path of the gauge with respect to the north-south direction is marked with a red line while the blue line represents the mean velocity vectors (direction and size) according to individual verticals.



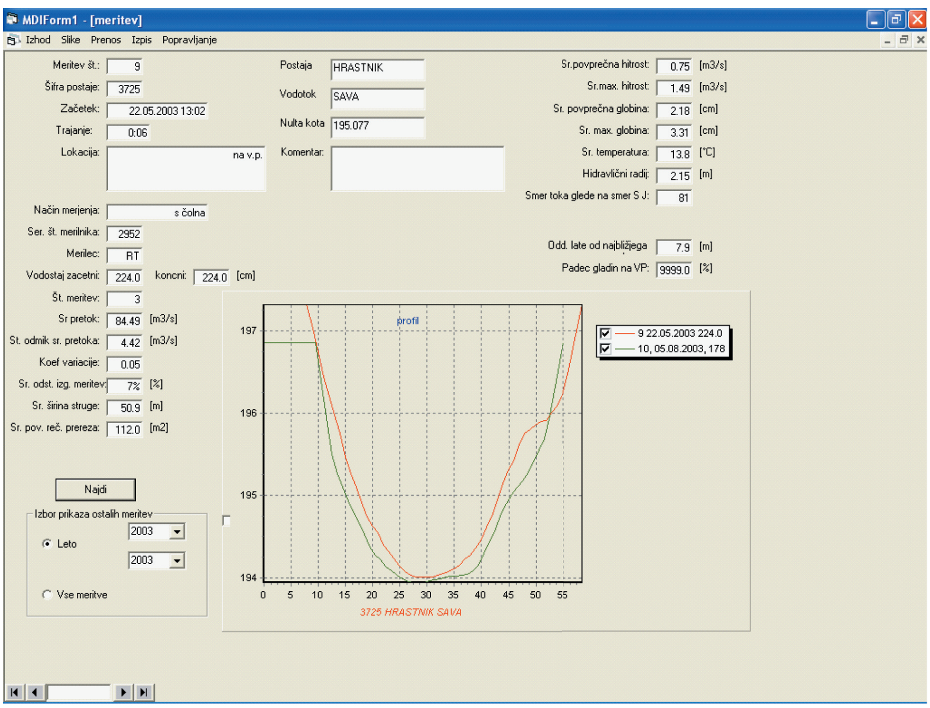
Prikaz nemerjenih površin prečnega prereza pri meritvi pretoka z ADMP.
Presentation of the unmeasured cross-section surface areas in the discharge measurement with the ADCP.

Pri interpretaciji meritev ADMP v smislu metode površina-hitrost, ki je podlaga izračunu pretoka za meritve s HM krilom, nam je bilo v veliko pomoč programsko orodje Agila. Razvili so ga kolegi iz Nemškega zveznega zavoda za vodne znanosti - BfG (nem. Bundesanstalt für Gewasserkunde) iz Koblenza, prav za namen primerjave obeh metod.

with respect to the total discharge (total Q – on the figure), the more careful we must be in the choice of the method for the determination of the discharge through the unmeasured parts.

From the hydrometrological point of view, 2003 was a year of comparison of the new method with the ADCP with the conventional method, which uses current meters (HM). In addition to the comparison of both methods, we verified the usefulness of the ADCP gauge with respect to the peculiarities of Slovenian rivers or the existing water gauging cross-sections. Simultaneously with carrying out measurements, we determined the procedure of entering data into the database. The structure of the output data itself (results) is quite different in the two methods, which is why it was necessary to carefully determine which data would be entered into our database and which would be available to the more demanding users only.

In the interpretation of ADCP measurements in the sense of the surface area-velocity method, which is the basis for the calculation of the discharge with measurements using the current meter, the Agila software proved of great use. It was developed by our colleagues from the German federal water science institute – BfG (Bundesanstalt für Gewasserkunde) from Koblenz for the purpose of comparing the two methods.



Struktura baze podatkov meritev z ADMP. Podani so najosnovnejši podatki ter grafični prikaz prečnega profila. Ena najpomembnejših prednosti glede na prejšnje rezultate meritev je ocena zanesljivosti izmerjenega pretoka v obliki koeficienta variacije.
Structure of the database for the measurement data obtained with the use of ADCP. The most basic data and a graphic representation of the cross-section are given. The most important advantage with respect to the previous results of measurements is the assessment of reliability of the measured discharge in the form of a coefficient of variation.

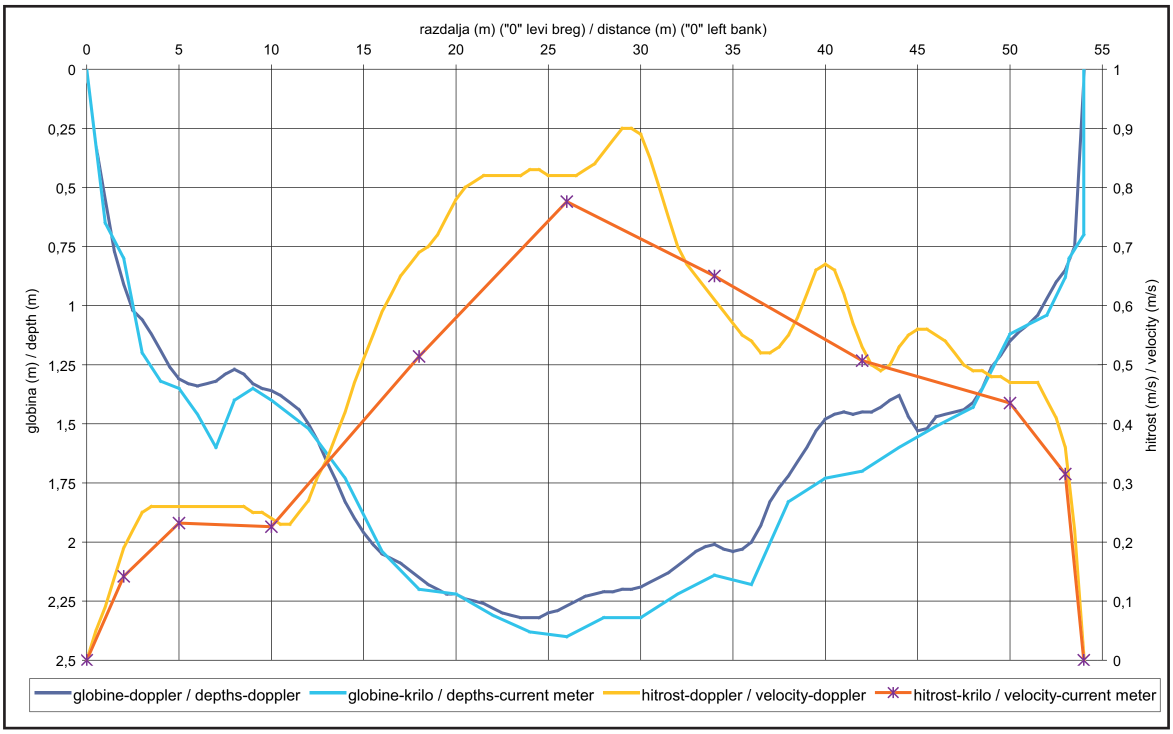
Skupno je bilo v letu 2003 izvedenih 58 meritev pretoka z ADMP. Zaradi želje po neprekinjenem izvajanju t.i. rednih meritev s HM krili je bila slaba polovica meritev (21) izvedenih simultano. To pomeni, da sta meritvi pretoka s hidrometričnim krilom in merilnikom ADMP sledili ena drugi.

Kontrolo merilnika ADMP smo izvedli tudi samostojno, brez primerjave s HM krilom, s ponavljanjem meritev ali seštevanjem rezultatov meritev. Eden takih primerov je bila meritev pretoka Save v Čatežu. Ta je bila najprej izvedena v profilu vodomerne postaje (v.p.) ter tik za tem ponovljena 450 m gorvodno z mostu. Druga kontrola merilnika je potekala tako, da je bil naprej določen pretok na v.p. Blejski most na Savi Dolinki, sledila je meritev na v.p. Bodešče na Savi Bohinjki, kot zadnji pa je bil izmerjen še pretok na v.p. Radovljica I. Slednji naj bi bil seštevek obeh predhodno izmerjenih pretokov. Primerjalna meritev je bila izvedena tudi skupaj z avstrijsko hidrološko službo v profilu v.p. Cmurek na Muri.

Za natančnejšo analizo meritev z ADMP in s HM krilom je bilo izbranih 14 primerjalnih meritev. Kriterij izbora so predstavljali stabilnost vodnih razmer in lokacija izvedbe meritve. Rezultati so podrobneje dokumentirani v internem poročilu »Poročilo o primerjalnih meritvah z merilnikom ADMP in

In total, 58 discharge measurements were performed in 2003 with the use of ADCP. Due to our policy of continuity of the so-called regular measurements with the current meters, slightly less than half of the measurements (21) were carried out simultaneously. This means that discharge measurements with the current meter and the ADCP gauge followed one another.

We also carried out the control of the ADCP gauge independently without a comparison with the current meter by repeating measurements or adding up measurement results. The first type was the measurement of the discharge of the Sava River in Čatež. It was first carried out in the cross-section of the water gauging station and after that repeated 450 m upstream from the bridge. The second type of control of the gauge was performed by first determining the discharge at the water gauging station Blejski most on the Sava Dolinka River followed by a measurement at the water gauging station Bodešče on the Sava Bohinjka River and concluded by the measured discharge at the water gauging station Radovljica I. The last was supposed to be the sum total of the two previously measured discharges. The comparative measurement was also carried out jointly with the Austrian hydrological service in the cross-section of the water gauging station Cmurek on the Mura River.



Graf 3: Prečni prerez ter hitrostni profil primerjalne meritve na v.p.Radovljica na Savi. Na sliki vidimo pomanjkljivost metode meritve pretoka v posameznih točkah, med katerimi je predpostavljen linearni potek hitrosti.

Graph 3: Transverse cross-section and the velocity profile of the comparative measurement at the water gauging station Radovljica on the Sava River. Deficiencies of the discharge measurement method in certain points, between which a linear velocity course is presumed, are evident from the figure.

hidrometričnim krilom ter program meritev za leto 2004«. Na tem mestu podajamo le posamezen primer ter poglavitne ugotovitve primerjave (graf 3).

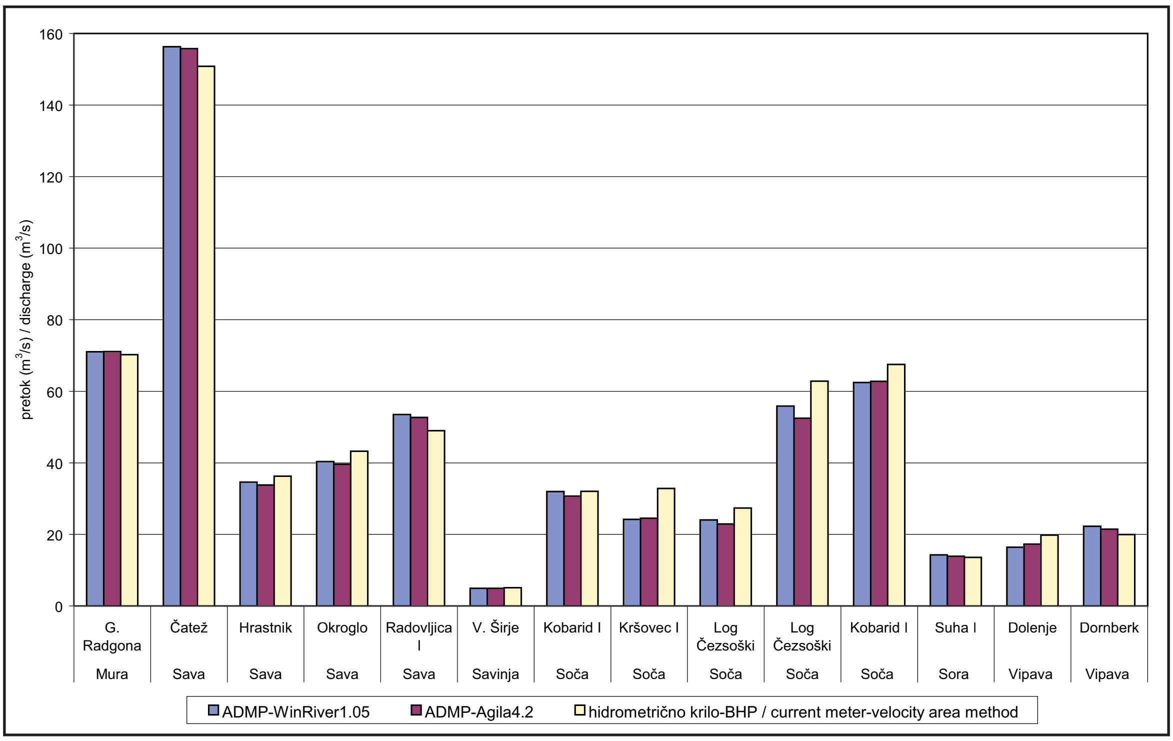
Analiza primerjalnih meritev na večini slovenskih rek je pokazala, da se v prečnih presekih hidrometrične meritve ujemajo z enakomerno oblikovanim dnom in brez izrazite turbulence toka. Kontinuiteta meritev pretoka je na ta način z uvedbo merilnika ADMP zagotovljena. Še več. Kot bomo videli v nadaljevanju, prinaša uvedba nove merilne metode kar nekaj izrazitih izboljšav v proces hidrološkega monitoringa.

Na turbulenco v največji meri vplivata hitrost vode ter stopnja hrapavosti ostenja, ki v tem smislu (eno dimenzijski tok) vključuje vpliv dna ter ostalih ovir v toku (mostni oporniki, potek struge ipd.). V nekaterih primerih prihaja do izrazite turbulence že pri hitrostih okrog 1 m/s. Taki profili so za izvajanje meritev pretokov neugodni in zahtevajo dobro teoretično in praktično usposobljeno ekipo (npr. Dolenje na Vipavi, večina profilov v zgornjem toku Soče). Pred izvajanjem meritev na takih mestih moramo zelo dobro preučiti vsa možna merska mesta in izbrati najbolj ugodnega. Neracionalno bi namreč bilo, da bi za sleherno določitev pretoka potrebovali meritve v več različnih merskih profilih. Pri tem so neprecenljive pretekle izkušnje pri izvajanju meritev na določeni lokaciji. Natančnost izmerjenih

For a more precise analysis of the measurements with the ADCP and the current meter, 14 comparative measurements were selected. The selection criteria were stability of water conditions and the location of measurement. Results were recorded in more detail in an internal report »Report on Comparative Measurements with the ADCP Gauge and the Current Meter and the Measurement Programme for 2004«. Here, only an individual case and the main findings of the comparison are given (Graph 3).

The analysis of comparative measurements on the majority of Slovenian rivers has shown that in cross-sections with the uniformly shaped bottom and without a pronounced turbulence of the water current both methods conform to one another. The continuity of the discharge measurements is thus ensured with the introduction of the ADCP gauge. Even more so, as we will see in the continuation, the introduction of the new measurement method brings with it a few significant improvements in the process of hydrological monitoring.

Turbulence is most affected by water velocity and the level of unevenness of the riverbed, which in this sense (one-dimensional water current) includes the effect of the bottom and other obstacles in the current (bridge piles, the course of the riverbed, etc.). In some cases, pronounced turbulence appears already at speeds around 1 m/s. Such



Graf 4: Grafični prikaz pretokov primerjalnih meritev, določenih po različnih metodah: meritev z ADMP (algoritma WinRiver in Agila) ter meritev s HM krilom (algoritem BHP – banka hidroloških podatkov).
Graph 4: Graphic presentation of discharges of comparative measurements determined according to different methods: measurements with the ADCP (WinRiver and Agila algorithms) and the measurement with the current meter (BHD algorithm – bank of hydrological data).

vrednosti na takih mestih je pri izbiri metode ADMP bolj obvladljiva v primerjavi z meritvijo s HM krili, saj s povečevanjem števila prečenj obvladamo (vsaj) statistično napako. Sistemske napake, kot posledice neugodnih razmer v prerezu, z meritvijo zgolj v enem prerezu namreč ne moremo oceniti ne po eni, ne po drugi metodi. Ker se tehnika merilnikov ADMP še vedno izpopolnjuje, lahko pričakujemo, da bodo meritve tudi v turbulentnih razmerah vedno bolj natančne.

Nasprotno lahko ocenimo, da so določeni profili (npr. na Muri, spodnji Savi, Sori ipd.) dokaj enakomerni in z vidika izvajanja meritev enostavni. Izvajanje meritev pretoka je (bila) na takih mestih mogoča tudi pri ekstremnih vrednostih. Prav slednje predstavlja bistveno prednost meritev z ADMP, v primerjavi z metodo s HM krilom, kjer se je v ekstremnih razmerah v najboljšem primeru izmerila le površinska hitrost. Razlika v kvaliteti podatkov je torej očitna. Dodatna, mogoče celo najpomembnejša, prednosti ultrazvočne metodologije pred metodo s HM krili, pa je varnost merilcev tako pri visokih, kakor tudi pri srednjih vodnih stanjih.

cross-sections are unfavourable for the performance of discharge measurements and require a crew that is well-trained in theory and practice (for example Dolenje on the Vipava River, the majority of cross-sections in the upstream part of the Soča River). Prior to the performance of measurements in such places, we must study all the possible water gauging stations well and select the most favourable one. It would be irrational if we needed measurements in several different measuring cross-sections for every determination of the discharge. This is why previous experience is invaluable in the performance of measurements at a certain location. The accuracy of measured values in such places is much more easily handled in the choice of the ADCP method in comparison with the measurement with current meters as with the increase in the number of passes we can at least control the statistical error. System errors as a result of unfavourable conditions in the cross-section with the measurement only in a single cross-section cannot be determined by either of the methods. Because the technology of the ADCP gauges is still being improved, we can expect that measurements will be increasingly more precise, even in turbulent conditions.

Quite oppositely, we can assess that certain cross-sections (for example on the rivers Mura, lower Sava and Sora, etc.) are rather uniform and from the point of view of the performance of measurements simple. The performance of discharge measurements is (was) possible in such places even at extremely high values. It is the latter that represents the essential advantage of measurements using the ADCP in comparison with the method using the current meter where only surface velocity was measured in the best cases when conditions were extreme. The difference in the quality of data is, therefore, obvious. Additional, maybe even the most important, advantage of ultrasound methodology over the current meter method is the safety of the crew at high as well as medium water conditions.