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PREDLOG CELOVITE UREDITVE OBVODNEGA PROSTORA HE BREŽICE
A PROPOSAL FOR INTEGRATED DEVELOPMENT OF THE WATER AREA OF THE BREŽICE HPP

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V prispevku predstavljamo možnost celovite ureditve območja ob bodoči akumulaciji HE Brežice. Primarni namen je z izgradnjo gramoznice zagotoviti pokrivanje potreb po materialu za gradnjo spodnjesavske verige HE, saj se na predlaganem območju nahaja dober material tako za vgradnjo v betone kot za gradnjo nasipov. Gramozno jamo se nato z ureditvijo in zapolnitvijo z vodo uporabi kot dodaten zadrževalnik ob akumulaciji HE Brežice in s tem bistveno izboljša umestitev le-te v prostor, ki ga je možno na ta način uporabiti tudi za turistično-rekreacijske namene. Ti vključujejo tako gradnjo kajakaške proge kot tudi ureditev gozdnih polotokov, sprehajalnih poti, mokrišča in drugih turistično-rekreacijskih področij. Študija zajema poleg predloga ureditve tudi ocene prostornin materialov iz gramoznice, vodni režim v zadrževalniku v primerih ekstremnih vremenskih sprememb, in različne hidravlične rešitve regulacij pretokov z izračuni. Ob gradnji spodnjesavske verige se pojavlja problem migracije vodnih organizmov, ki jim je z izgradnjo pregrad onemogočena. Rešitev bi bile ribje steze, ki pa v Sloveniji žal še ne funkcionirajo kot bi morale, in pomenijo tudi izgubo energije za HE. V prispevku predstavljamo alternativno rešitev ribje steze v sklopu celovitega urejanja obvodnega prostora akumulacije HE Brežice z zasnovo, ki prinaša prihranek energije.
Ključne besede: *urejanje vodotokov, vodne elektrarne, gramoznice, ribje steze, kajakaška proga, rekreacija*

The paper discusses an integrated development scheme of the future HPP Brežice reservoir area. The primary goal of the development is to establish a gravel pit, which would furnish material for the construction of the Lower Sava HPP chain, as the gravel found in the area is well suited for concrete manufacture and embankment construction. Later, the gravel pit could be redeveloped and filled with water to be used as an additional reservoir to the HPP Brežice reservoir, which would significantly improve the siting of the plant by using the area for tourist and recreational purposes. These include the creation of a kayaking trail and the development of forested peninsulas, walking trails, wetlands and other tourist and recreational sites. Besides the development scheme proposal, the study includes estimates on the volume of material extracted from the gravel pit, flow regime in the reservoir during extreme weather changes, and different hydraulic solutions of flow control, along with the calculations. During the construction of the Lower Sava HPP chain, the problem of migration of aquatic organisms impeded by the dams became evident. Fishways are a feasible solution; however, in Slovenia they are still not properly implemented, and they also mean power loss for the HPPs. The paper represents an alternative solution of the fish passage as part of the integrated development of the HPP Brežice area, along with the benefit of energy saving.
Key words: *river engineering, hydro power plants, gravel pits, fishways, kayaking trail, recreation*

1. OPIS PROBLEMATIKE

Na odseku Save med Radečami in Mokricami je v teku projekt energetske izrabe vodnega potenciala, ki obsega gradnjo sklenjene verige šestih hidroelektrarn (Vrhovo, Boštanj, Blanca, Krško, Brežice in Mokrice) (IBE, 1979; MOPE, 2003; 2004). Prva stopnja v verigi, HE Vrhovo, obratuje že od leta 1993; gradnja energetske verige pa se je z manjšim premorom nadaljevala leta 2001 in bo predvidoma sklenjena leta 2015. Ko bo energetska veriga na spodnji Savi dokončno zgrajena, bo skupna instalirana moč znašala okoli 210 MW, s proizvodnjo okoli 900 TWh na leto, kar predstavlja okoli 7 % potreb po električni energiji v Sloveniji (SEL, 1995). Zagotavljanje sistemskih storitev (proizvodnja rezervne moči, sodelovanje v regulaciji, črni start,…) v okviru slovenskega energetskega sistema znatno povečujejo energetsko vrednost in pomembnost hidroelektrarn na spodnji Savi, ki bi jo imela zgolj s proizvodnjo električne energije.

Pogoji umeščanja objektov v okolje in prostor so predpisani s koncesijsko pogodbo, v kateri koncedent (Republika Slovenija) nalaga koncesionarju (Holding slovenske elektrarne) posebne pogoje, ki jih mora izpolniti za rabo vodne dobrine (Vlada RS, 1994). Pri podpisu koncesijske pogodbe je bila, prvič v Sloveniji, uporabljena praksa, da je koncesionar pri načrtovanju energetske verige tudi v imenu koncedenta obvezan zagotavljati celovitost reševanja prostorske problematike, kot so: urejanje vodnega režima, vzpostavljanje prometnih tokov, urejanje komunalne infrastrukture, ipd., s ciljem v čim večji meri izkoristiti sinergične investicijske učinke pri umeščanju energetskih in ostalih infrastrukturnih objektov v okolje in prostor.

V prispevku bomo predstavili eno od možnih prostorskih ureditev na območju bodoče HE Brežice, ki sama po sebi ni izrecen pogoj za izvedbo energetskega dela, obravnavamo pa jo kot omilitveni ukrep v okolju in prostoru zaradi načrtovanih posegov, ki hkrati omogoča optimizacijo tehnično-

1. DESCRIPTION OF TOPIC

In the section of the Sava River between Radeče and Mokrice (length approx. 45 km) the project of energy utilisation of water potential is underway, which includes the construction of a continuous chain of six hydropower plants (Vrhovo, Boštanj, Blanca, Krško, Brežice and Mokrice) (IBE, 1979; MOPE, 2003; 2004). The first stage in the chain, Vrhovo HPP, has been in operation since 1993; the construction of the energy chain resumed, after a short pause, in 2001 and it will presumably be completed by 2015. When the energy chain on the Lower Sava is completed, the total installed power will be approx. 210 MW, with a generation of around 900 TWh per year, representing approx. 7 % of electricity consumption in Slovenia (SEL, 1995). The provision of ancillary services (generation of reserve power, services in control area, activation of black start...) within the Slovenian energy system increases the energy value and significance of hydropower plants on the Lower Sava to more than mere generation of electricity.

The rules governing the siting of facilities and plants are laid down in the concession contract, where the Concession Grantor (the Republic of Slovenia) imposes on the Concessionaire (HSE Group) special conditions to be fulfilled for the utilisation of the commodity of water (Vlada RS, 1994). For the first time in Slovenia, the concession contract included the provision that in the planning of the energy chain the Concessionaire was obliged, on behalf of the Concession Grantor, to ensure integrated solutions for spatial problems: river regime control, organisation of traffic flows, construction of municipal infrastructure etc., to exploit the synergistic effects of investments related to siting of energy facilities and other infrastructure facilities into the environment.

The paper aims to present one of the possible spatial development solutions in the area of the future Brežice HPP, which by itself is not an express condition in performing the energy works. It is, however, a measure mitigating the environmental impacts of the planned activities, while at the same time

tehnoloških rešitev pri gradnji energetskih objektov. Območje poplavne ravnice na levem bregu Save na območju Vrbine, pod NEK, je zaradi črpanja proda v preteklosti in prepustitvi degradacijskim procesom večje površine opuščenih gramoznic v veliki meri degradirano. V omejenem obsegu se črpanje proda izvaja v gramoznici Stari grad. Z izgradnjo HE Brežice se je povečal tudi interes lokalne skupnosti, da se celotno vplivno območje akumulacije HE Brežice revitalizira in izkoristi v turistično-rekreacijske namene. Pretežni del teh aktivnosti je predviden vzdolž levega brega akumulacije, medtem ko se na desnem bregu ohranja poplavna ravnica kot retenzijski prostor v času nastopa poplavnih voda. Zasnova revitalizacije prostora na območju Vrbine temelji na aktivaciji gramoznice ob akumulacijskem jezeru, s katero bodo v celoti pokrite potrebe po materialu za čas gradnje HE Brežice. Po zaključku izkoriščanja gramozne jame se območje preuredi v zadrževalnik z namenom zmanjševanja poplavnih konic Save. Na območju ureditev je predvideno, da se uredi prehod za vodne organizme, s katerim bo omogočen njihov prehod po Savi navzgor, ki je prekinjen s pregrado Brežice. Funkcija zadrževalnika je bogatenje prehoda za vodne organizme z dodatnimi količinami vode, ki omogočajo stalno prehodnost, ne glede na hidrološke razmere. Celotno območje zadrževalnika in akumulacije Brežice celostno dopolnjujejo krajinske ureditve, kot sanacijski ukrepi na degradiranih območjih (ureditev mokrišč v opuščeni gramoznici) in infrastrukturni objekti (pristanišče, kajakaška steza), s katerimi bo povečana atraktivnost širšega območja akumulacije HE Brežice za razvoj turistično-rekreacijskih dejavnosti.

2. UREDITEV GRAMOZNICE V VRBINI

Zagotavljanje ustreznih količin in kvalitete kamenega agregata za konstrukcijske betone in gradbenega materiala za nasipe je eden od poglavitnih tehnoloških problemov pri gradnji hidroelektrarn na spodnji Savi. V bližini lokacij bodočih elektrarn so možnosti črpanja

enabling the optimisation of technical and technological solutions in the construction of energy facilities. The floodplain on the left bank of the Sava in the Vrbina area, below the Krško Nuclear Power Plant, has been considerably degraded due to past gravel extraction, while much of the abandoned gravel excavation site was left to degradation. In a limited scope, the gravel extraction is conducted in the gravel pit Stari grad. The construction of the Brežice HPP boosted the interest of the local community to revitalise the entire influence area of the Brežice HPP storage reservoir and exploit the area for tourism and recreation. A major part of the activities is planned along the left bank of the Brežice reservoir, while on the right bank there is a floodplain for retention during floods. The revitalisation design of the Vrbina area is based on the opening of the gravel pit at the Brežice reservoir, which will fully meet the needs for gravel during the construction of the Brežice HPP. After the completion of gravel extraction, the area will be redeveloped into a retention reservoir for control of the Sava flood peaks. In order not to impede the passage of aquatic species by the Brežice dam, there is a plan to install a fishway for upstream migration. The function of the retention reservoir is to supply the fishway with additional water, enabling continuous passage, regardless of the hydrological conditions. The entire area of the reservoir and the HPP Brežice storage reservoir is complemented by landscape development as remediation measures on degraded areas (development of wetlands in the abandoned gravel pit) and infrastructure facilities (port, kayaking trail), which will boost the amenity value of the wider area of the Brežice HPP storage reservoir for tourism and recreation.

2. ESTABLISHMENT OF THE GRAVEL PIT IN VRBINA

The provision of proper quantity and quality of the rock aggregate for construction concrete and building material for embankments is one of the main technological problems in the construction of the Lower Sava HPPs. In the vicinity of the future HPP

rečnega proda za potrebe gradnje, bodisi zaradi goste poseljenosti, bodisi iz naravovarstvenih razlogov, bolj ali manj omejene. Na ožjem območju ureditev HE Brežice so v preteklosti za lokalne potrebe že obstajale gramoznice. Zato se je s prostorskega in okoljevarstvenega vidika izkazala kot najmanj sporna ideja o oživitvi njihove eksploatacije na območju, kjer so nekoč že delovale. Kot najustreznejša izbira se je pokazala možnost črpanja proda na lokaciji opuščene gramoznice na območju Vrbine, ki se nahaja neposredno ob bodoči akumulaciji HE Brežice.

Na širšem območju Vrbine so bile v preteklosti že izvedene analize možnih nahajališč materiala za gradbene namene. Material iz tega območja je primeren tako za vgradnjo v betone, kot za nasipe. Širše območje akumulacije predstavljajo različno debeli prodni in peščeno meljni skladi (GZL, 1984). Vse ugotovljene zemljine so uporabne za vgrajevanje v nasipe, z razliko stopnje težavnosti pri vgrajevanju, ki je odvisna od tipa zemljine. V analizah je za težavnejše zemljine priporočeno, da se pred vgrajevanjem v nasipe dodatno homogenizirajo. Za pripravo betonov so praviloma primerni vsi prodni materiali. Smiselno pa je, da se za posamezne sloje – predvsem za globlje ležeče sklade – izvedejo predhodne raziskave ustreznosti in uporabnosti materialov ter preveritve dostopnosti količin posameznega materiala. Glede na razpoložljive količine materiala je kot najprimernejša predlagana lokacija na širšem območju pod NEK, kjer se že nahaja obstoječa gramoznica Stari grad (GZL, 1984). Lokacija je primerna iz več vidikov (slika 1):

- Gramoznica se nahaja v neposrednem vplivnem območju HE Brežice, kar je z vidika organizacije gradnje pri premikih zemeljskih mas ugodno in s tem posledično zmanjšujemo tudi škodljive vplive med gradnjo na širšo okolico.
- Črpanje proda je mogoče organizirati na način, da se smiselno vključi celotno območje, ki je zaradi črpanja proda v preteklosti že degradirano in da se po končanih gradbenih delih na vseh degradiranih površinah izdela celovit program renaturacijskih ukrepov, ki

sites the possibilities of river gravel extraction for construction purposes are limited, either due to population density or due to environmental reasons. In the vicinity of the HPP Brežice, gravel pits for local needs existed in the past. Spatially and environmentally, the idea of their further exploitation in the areas where they existed in the past seemed the most sensible. Gravel extraction at the site of the abandoned gravel pit in the Vrbina area, in close proximity of the future HPP Brežice reservoir, was found to be the best choice.

For the wider area of Vrbina, analyses of possible localities of material extraction for construction have been made in the past. The material found in the area is appropriate for concrete manufacture as well as for embankments. In the wider area of the storage reservoir differently thick gravel and sandy silty strata are found (GZL, 1984). All the soils can be used as a structural fill for embankments, with different difficulty levels of filling, depending on the type of the soil. In the case of difficult soil conditions, it is recommended that prior to the filling into the embankments the soils are additionally homogenized. In general, all types of gravel are suitable for preparation of concrete. It is, however, sensible to conduct preliminary research into the suitability and applicability of the materials – especially for deeper lying strata – and check the accessible volumes of the material. Based on the available volume of material the location deemed as the most suitable is in the wider area, below Krško NPP, with an existing gravel pit Stari grad (GZL, 1984). The location is suitable from several standpoints (Figure 1):

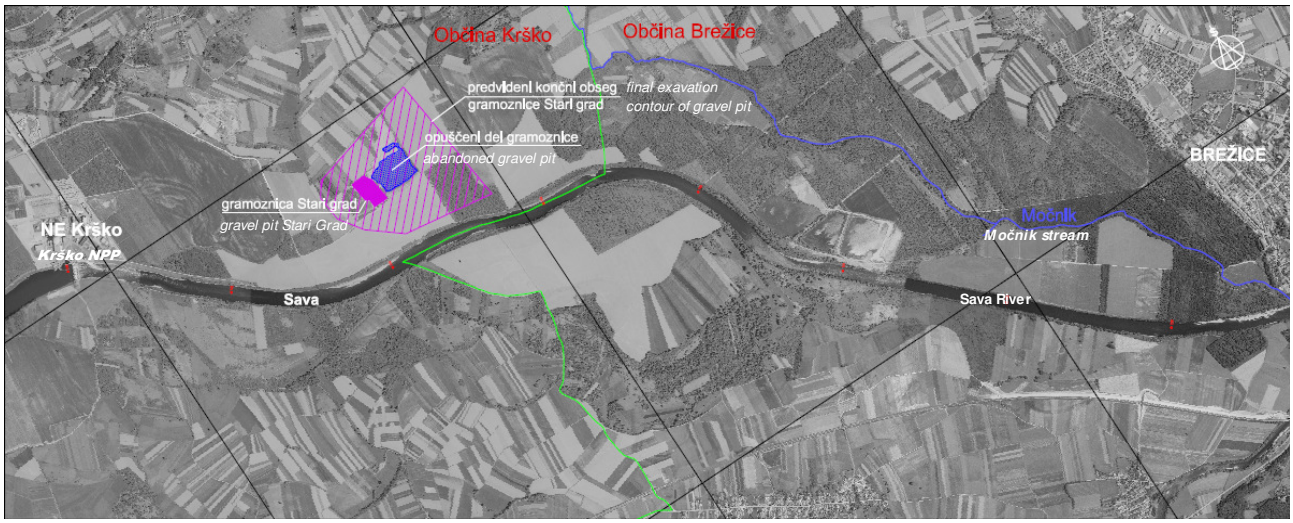
- The gravel pit is located in the immediate area of influence of the Brežice HPP, which is favourable from the viewpoint of construction organisation during earth mass movements, thereby reducing the adverse effects on the wider environment during the construction.
- Gravel extraction can be organized in a way to reasonably include the entire area degraded in the past due to gravel excavation, while after the completion of construction a comprehensive remediation

predstavljajo novo vrednost v okolju in prostoru.

- Novo pridobljen prostor omogoča nove retenzijske površine, ki jih je možno izkoristiti v času evakuacije poplavnih voda.

scheme will be put in place in all the degraded areas, which will represent a new value in the environment.

- The reclaimed space provides new retention areas to be utilised during flood evacuation.



Slika 1. Obstoječe stanje.
Figure 1. Existing situation.

Predvideno območje izkopa materiala se nahaja zahodno od obstoječe gramoznice Stari grad do struge reke Save. Mejni rob izkopa gramoznice je prilagojen lokalnim geografskim značilnostim širšega zaledja bodoče akumulacije (ježe, mrtvice, poljske poti, brežine,…) z namenom, da se bo po renaturaciji območje izkopov prostorsko in vizuelno čim bolj vklopilo v okolico. Ob tem pa določena kontura izkopa omejuje dovolj veliko površino, da bodo pričakovane količine materiala zadoščale potrebam pri gradnji HE Brežice ter z upoštevanjem omejitve globine izkopa zaradi gladine podtalnice, ki je ocenjena na 147,8 m.n.m. Najnižja kota dna izkopa ne presega 145 m.n.m., kar je pogojeno s tehnološkimi možnostmi izkopa z običajno gradbeno mehanizacijo.

Material iz krovnega sloja (pretežno humus in zaglinjen melj), skupne količine 0,16 hm^3, je možno uporabiti za fino površinsko urejanje in zatravitev brežin nasipov ter za renaturacijo širšega območja izkopa. Material iz spodnjih plasti izkopa (okoli 1,26 hm^3) pa je možno vgraditi v energetske in visokovodne nasipe in

The site planned for gravel excavation is located west of the existing gravel pit Stari grad to the Sava riverbed. The edges of the gravel pit follow the geographical features of the wider area of the future reservoir (slopes, oxbows, field paths, banks...) so that the excavation area will later be reconnected with the environment, both spatially and visually. At the same time, the specified excavation contour provides an area large enough to supply the expected volume of material for the needs of Brežice HPP construction, while taking into account the depth of the excavation with respect to the water table (estimated at 147.8 m. a.s.l.). The lowest level of excavation does not exceed 145 m a.s.l., which is determined by the technological possibilities of excavation with standard construction machinery.

The material from the surface layer (mostly top soil and clayey silt), with a total volume of 0.16 hm^3, can be used for fine surface works and grassing of embankment slopes, and also for remediation of the wider excavation area. The material from the lower layer of excavation (around 1.26 hm^3) can be built into

uporabiti za proizvodnjo konstrukcijskih betonov. Evidentirane količine materiala zadoščajo potrebam gradnje objektov HE Brežice in vseh drugih spremljajočih ureditev. Po oceni zadoščajo skupno izkopane količine štiriletnim potrebam po gradbenem materialu v regiji. Lokacija gramoznice je v samem središču izvajanja ureditvenih del v bazenu HE Brežice. Transportne poti za dobavo gradbenega materiala so organizirane znotraj gradbiščnih meja, kar pomeni, da zaradi transportov materiala za čas gradnje objektov ne bo nikakršnih negativnih vplivov na javno prometno infrastrukturo ali območja poselitev.

3. ZADRŽEVALNIK

Izbor lokacije ob akumulacijskem bazenu ima še druge prednosti: s črpanjem proda bo ustvarjena sorazmerno velika gramozna jama, ki bo po zaključku gradnje preurejena v retenzijski prostor z namenom zadrževanja manjšega dela poplavnih voda s ciljem zmanjšanja konic poplavnih valov pod pregrado Brežice. Z okoljskega vidika je ugodno, če je površina retenzijskega prostora ojezerjena, ker so s tem omogočeni življenjski pogoji za vodne in obvodne organizme. Stalna vodna površina omogoča tudi razvoj rekreacijskih dejavnosti. Zaradi neposredne bližina akumulacije je izvedba dotoka sveže vode v retenzijski prostor tehnično izvedljiva. Stabilnost ekoloških razmer v zadrževalniku pa je mogoče zagotavljati s stalno izmenjavo vode v zadrževalniku z ureditvijo izpusta v spodnjo strugo Save pod HE Brežice.

Retenzijski prostor in akumulacijski bazen razmejuje energetski nasip, ki se nivojsko nadaljuje v nasip, ki poteka po celotni konturi izkopa zadrževalnika. Energetski nasip je vzdolž celotne akumulacije, kakor tudi na odseku zadrževalnika, tesnjen s sredinsko postavljeno tesnilno diafragmo, ki preprečuje dvig podtalnice v zaledju akumulacije. V zadrževalniku je zaradi okoljevarstvenih razlogov ohranjena minimalna stalna ojezeritev (slika 2). Dotok vode v zadrževalnik je v času normalnih obratovalnih razmer, ko

dikes and flood embankments and used for manufacture of construction concretes. The volume of available material can satisfy the needs of construction of Brežice HPP facilities and ancillary developments. The total excavated material is estimated to supply the construction material in the region for 4 years. The location of the gravel pit is in the very centre of development works in the Brežice HPP reservoir area. The transport ways for supplying the construction material are organized within the building site area. There will therefore be no negative impacts upon public traffic infrastructure and/or urban areas due to transport.

3. RESERVOIR

The location next to the storage reservoir has other advantages as well: with gravel excavation a relatively large gravel pit will be created, which will upon completion of construction be redeveloped into a retention area for storage of a small portion of high flows in order to reduce floodwave peaks before the Brežice HPP dam. Environmentally, it is favourable if the surface of the retention area is covered by a lake, which provides living conditions for aquatic and riparian organisms. The permanent water surface also enables the development of recreation. Due to the immediate proximity of the reservoir, it is technically feasible to bring fresh water into the retention area. The stability of ecological conditions in the reservoir can be ensured by a constant exchange of water in the reservoir by installing an outlet into the tailwater of the Sava below the Brežice HPP.

The retention area and the storage reservoir are divided by a dike which continues in different levels into the embankment located along the entire contour of the reservoir excavation. Along the entire plant area, as well as on the section of the reservoir, the dike is sealed with a centrally positioned sealing diaphragm by a jet-grouting curtain, which prevents the elevation of groundwater in the hinterland of the reservoir. A minimum constant level is maintained in the reservoir for environmental reasons (Figure 2). The inflow into the reservoir during normal operating

višina pretoka reke Save ne preseže instaliranega pretoka elektrarne (do 500 m^3/s), urejen preko posebno oblikovanega vtočnega objekta, meniha z zapornico, ki zagotavlja stalen pretok do 1 m^3/s, kar zadošča za ohranjanje minimalnih ekoloških razmer v zadrževalniku. Zadrževalnik za visoke vode se aktivira, ko pretok Save preseže instaliran pretok elektrarne. Dotok v zadrževalnik je preusmerjen s prelivnim pragom z zaklopko s pretočno zmogljivostjo do 10 m^3/s. V času izjemnih sušnih razmer, ko pretok Save pade pod 100 m^3/s, je dotok v zadrževalnik prekinjen.

Izpust vode iz zadrževalnika je urejen s povezavo s spodnjo strugo Save pod HE Brežice. Pri ureditvi iztoka smo v največji možni meri izkoristili struge obstoječih pritokov reke Save na območju akumulacije Brežice. Kot najprimernejši se je izkazal potok Močnik s pritokom Pšeničnika, ki je glavni odvodnik za zaledne vode in retenzijskih površin na levem bregu Save in se izliva v Savo pod lokacijo bodoče HE Brežice. Za izpust vode iz zadrževalnika je bilo analiziranih več variant izvedbe iztoka:

a. z navezavo preko opuščene gramoznice Stari grad na potok Močnik;
b. z navezano na potok Pšeničnik in potok Močnik;
c. z navezavo direktno na potok Močnik.

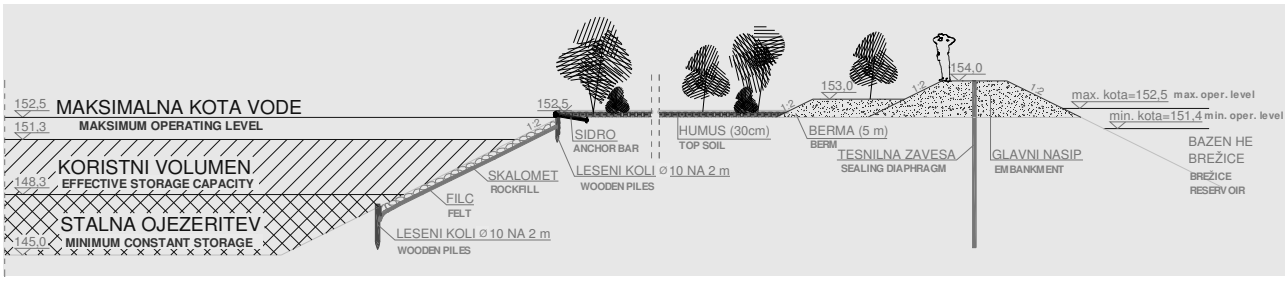
Vodni režim v zadrževalniku je neposredno odvisen od izvedbe iztoka in temu ustrezno koristne prostornine v zadrževalniku. V izračunih smo upoštevali, da znaša zgornja obratovalna gladina HE Brežice 152,5 m.n.m. in je pogojena z obratovanjem NEK. Pri normalnem obratovanju je pričakovano dnevno nihanje 1,1 m, spodnja obratovalna kota je tako 151,4 m.n.m. Minimalna gladina na iztoku iz zadrževalnika je pogojena z zagotavljanjem ustreznih hidravličnih pogojev in odtočnega režima na odvodniku: pri variantah a in b znaša minimalna iztočna gladina 149,0 m.n.m., pri varianti c pa 148,3 m.n.m. Temu ustrezno znaša koristni volumen zadrževalnika pri variantah a in b okoli 0,92 hm^3 oziroma 1,09 hm^3 pri varianti c (slika 3).

conditions, when the Sava river flow does not exceed the design flow of the power station (up to 500 m^3/s) comes through custom made intake works with a gate, which is enough for preserving the minimum ecological conditions in the reservoir. The flood control reservoir is activated when the Sava flow exceeds the design flow of the power plant. The inflow into the reservoir is diverted by a sill with a flap with a flow capacity of 10 m^3/s. During extremely dry spells when the Sava River flow falls below 100 m^3/s, the inflow into the reservoir is cut off.

The outlet from the reservoir is connected with the tailwater of the Sava below the Brežice HPP. When designing the outflow the existing channels of the tributaries to the Sava in the area of the Brežice HPP were used as much as possible. It was found that the Močnik stream with the tributary Pšeničnik was the most appropriate, making up most of the drainage for hinterland waters and retention areas on the left bank of the Sava, and flowing into the Sava under the site of the future Brežice HPP. For outlet works from the reservoir several variant solutions were analysed:

a. connection through the abandoned gravel pit Stari grad to the Močnik stream;
b. Connection to the Pšeničnik and Močnik streams;
c. Connection directly to the Močnik stream.

The water regime in the reservoir depends directly on the execution of the outflow and the corresponding effective storage capacity in the reservoir. The calculations took into account the maximum operating level of the Brežice HPP at 152.5 m a.s.l., which depends on the NPP operation. During normal operation the expected daily fluctuation is 1.1 m, and thus the minimum operating level is 151.4 m a.s.l. The minimum level at the outflow from the reservoir is ensured by proper hydraulic conditions and flow regime on the tailrace: in variants a and b the minimum outflow level is 149.0 m a.s.l., and in variant c it is 148.3 m a.s.l. Accordingly, the effective storage capacity of the reservoir in variants a and b is around 0.92 hm^3 and in variant c, 1.09 hm^3 (Figure 3).



Slika 2. Prečni prerez zadrževalnika.
Figure 2. Cross-section of the reservoir.

Slika 3. Prikaz možnih variant ureditev.
Figure 3. Illustration of solution variants.

4. PREHOD ZA VODNE ORGANIZME

V skladu s koncesijskimi pogoji je treba na profilih bodočih pregrad zagotoviti take razmere, da bo omogočena prosta migracija vodnih organizmov po toku navzgor in navzdol. V ta namen je treba oblikovati posebne prehode, ribje steze, ki omogočajo vodnim organizmom premagovanje višinske razlike na pregradah (Beach, 1984). Za dosego funkcionalnosti prehodov je treba zagotoviti ustrezne ekološke pogoje (Cowx & Welcomme, 1998), in to predvsem: zadostni in stalni pretok vode na prehodu; uravnavanje hitrosti, ki mora biti prilagojena plavalnim sposobnostim vodnih organizmov; ustrezne strukture, ki zagotavljajo ekološko funkcionalnost prehoda; ter ekonomičnost tehničnih rešitev.

Zasnova prehoda za vodne organizme je eden ključnih elementov ureditev obvodnega

4. PASSAGE FOR AQUATIC ORGANISMS

In accordance with the concession conditions on the sites of future dams, such conditions need to be ensured that free migration of aquatic species, both upstream and downstream is enabled. To this effect special passages have to be designed, i.e. fishways, which enable the fish to overcome the height difference on the dams (Beach, 1984). To achieve functionality of the passages, proper ecological conditions must first be ensured (Cowx & Welcomme, 1998), especially the following: sufficient and constant flow in the passage; velocity control adapted to the swimming abilities of aquatic organisms; proper installations ensuring ecological functionality of the passage; and economic efficiency of technical solutions.

The design of the fishway is one of the key elements in the development of the riparian

prostora pri HE Brežice. Pri zasnovi tehnične rešitve smo morali upoštevati, da je treba na prehodu za vodne organizme zagotoviti stalen pretok, neodvisno od režima obratovanja hidroelektrarne, tudi v primeru izjemnih razmer. Karakteristike steze je treba prilagoditi višinski razliki med normalnima obratovalnima kotama HE Brežice (152,5 m) in HE Mokrice (141,5 m), vključno z upoštevanjem denivelacije gladin pri rednem obratovanju. Prehod za vodne organizme smo v naši zasnovi predvideli na lokaciji visokovodnega zadrževalnika v Vrbini. Lokacija je utemeljena s tem, da je prehod za vodne organizme z minimalnimi ureditvenimi ukrepi možno izvesti po dovodno-odvodnem sistemu zadrževalnika, ki hkrati zagotavlja stalnost pretokov na prehodu za vodne organizme.

Kot prvo smo analizirali možnost, da prehod za vodne organizme poteka preko zadrževalnika, kar je s stališča funkcionalnosti delovanja izjemno ugodno. Ta rešitev pa s stališča migracije vodnih organizmov ni najustreznejša, ker obstaja velika verjetnost, da se migracijske poti do gornje akumulacije ne bi niti vzpostavile in bi prišlo zgolj do koncentracije ribjega življa v zadrževalniku. Zato je utemeljeno, da prehod za vodne organizme poteka ločeno od zadrževalnika, iztok iz zadrževalnika pa uporabimo za bogatenje pretoka vode na prehodu. Varianti a in b izvedbe iztoka iz zadrževalnika s sočasno izvedbo prehoda za vodne organizme tako ne prideta v poštev. Najustreznejša rešitev je varianta c s preusmeritvijo prehoda za vodne organizme čez potok Močnik: vtok v prehod je oblikovan na sotočju s Savo, pod pregrado Brežice, od tod poteka slabih 5 km po naravni strugi Močnika in nato še po 1,4 km dolgi umetni strugi do iztoka v akumulacijo, na območju bodočega športnega centra (slika 4).

Iztok iz zadrževalnika je zasnovan tako, da omogoča bogatenje pretoka po prehodu za vodne organizme predvsem v času sušnih pretokov v Savi, ko je prekinjen dotok v zadrževalnik. Zato je smiselno, da se v primeru napovedi daljših sušnih obdobij predhodno v celoti izkoristi kapacitete zadrževalnika in s tem zagotovi dodatne vodne

area at the Brežice HPP. The design of technical solutions has to provide permanent flow in the passage, independent of the operating regime of the HPP, also under extreme conditions. The characteristics of the fishway have to be adapted to the height difference between the normal operating levels of the Brežice HPP (152.5 m a.s.l.) and Mokrice HPP (141.5 m a.s.l.), while taking into account the lowering of levels during normal operation. In our design, the fishway was planned in the area of the flood control reservoir in Vrbina. The locality was based on the assumption that the fishway could be installed with minimum regulatory actions using the inflow–outflow system of the reservoir, which would also ensure permanent flow in the fishway.

First, we analysed the possibility of installing the fishway at the reservoir, which would be highly favourable in terms of functionality of operation. From the point of view of fish migration however, this solution is not the most appropriate: most probably the migration ways to the upper storage reservoir would not be established, while at the same time concentration of fish in the reservoir would occur. Therefore it was decided that the fishway should be provided separately from the reservoir, while the outflow from the reservoir is used for boosting the flow at the fish passage. Variants a and b of executing outflow from the reservoir with a simultaneous installation of the fish passage were therefore taken out of consideration. The most suitable solution was variant c with diversion of the fish passage through the Močnik stream: the inflow into the passage is designed at the confluence with the Sava, under the Brežice dam, along a 5-km stretch of the natural riverbed of the Močnik stream and a 1.4 km stretch of the artificial riverbed to the outflow into the reservoir, in the area of the future sports centre (Figure 4).

The design of the outflow from the reservoir enables flow recharge along the fishway, especially during low flows of the Sava, when the flow into the reservoir dries up. Therefore, in case of dry spell forecasts, it would be sensible to first fully exploit the storage capacity and enable additional volume

količine za bogatenje pretokov na prehodu za vodne organizme v obdobju sušnih pretokov Save. Pretok vode na prehodu za vodne organizme ne sme pasti pod 0,2 m^3/s (Jens *et al*., 1997), saj pri manjšem pretoku ni več možno zagotavljati ekoloških pogojev prehoda za vse vrste vodnih organizmov. Pri določitvi minimalni pretokov smo upoštevali tudi dejstvo, da del pretoka po naravni strugi Močnika ponikne. Po hidroloških študijah znaša minimalni sušni pretok potoka Močnik okoli 20 l/s (IzVRS, 2004). Po razgovoru z lokalnimi prebivalci pa smo pridobili tudi informacijo, da v izjemnih primerih pretok vode v Močniku popolnoma presahne. Posebne meritve izdatnosti vodnega vira po nam dostopnih podatkih niso bile izvedene. Glede na navedeno ugotavljamo, da bodo s preusmeritvijo dodatne količine 1 m^3/s, ki jo zagotavljamo iz visokovodnega zadrževalnika oz. akumulacije Brežice, ter upoštevanju naravnega pretoka Močnika, ustvarjeni zadostni pogoji za dosego tehnične funkcionalnosti delovanja prehoda za vodne organizme. Za dosego polne ekološke funkcionalnosti delovanja prehoda za vodne organizme pa je treba pri načrtovanju upoštevati še posebne konstrukcijske detajle:

- na trasi umetnega dela struge je treba upoštevati sonaravna načela pri oblikovanju (tolmuni, kaskade, ovire,…);
- na sotočju prehoda za vodne organizme in iztokom iz zadrževalnika je treba postaviti mehanske ali elektronske zapore, ki preprečujejo prehod vodnih organizmov v zadrževalnik;
- na vtočnem delu v akumulaciji je treba oblikovati natočni del tako, da se prilagaja dnevnemu nihanju gladin v akumulaciji.

5. PROSTORSKE IN OKOLJSKE UREDITVE OBMOČJA

Namen prostorskih ureditev obvodnega prostora ob akumulaciji Brežice je vzpodbuditi razvoj rekreacijsko-turističnih dejavnosti na novo vzpostavljenih vodnih površinah s povezavo na urbano področje mesta Brežice, in sicer:

for recharging the flows in the fishways during low flows of the Sava. The flow in the fishway must not drop below 0.2 m^3/s (Jens *et al.*, 1997), since with lower discharge the ecological conditions for passage cannot be ensured for all aquatic species. In determining minimum flows we also considered the fact that part of the flow in the natural Močnik riverbed is intermittent. Hydrological studies report a minimum low flow of the Močnik stream at around 20 l/s (IzVRS, 2004). After interviews with local inhabitants it became evident that under extreme conditions, the flow of the Močnik stream disappears completely. According to available information, there are no records of yield measurements. We find that by diverting the additional volume of 1 m^3/s from the flood control reservoir or the Brežice storage reservoir, taking into consideration the natural flow of the Močnik stream, sufficient conditions for achieving technical functionality of the fishway would be met. In order to achieve full ecological functionality of the fishway, the following construction elements have to be considered in the planning:

- on the course of the artificial stretch of the channel, sustainable principles have to be adhered to in the design (pools, cascades, barriers ...);
- on the confluence of the fishway and the outflow from the reservoir, mechanical and electronic gates have to be provided, preventing the passage of species into the reservoir;
- the design of the inflow part of the reservoir should allow adapting to daily fluctuations in storage reservoir levels.

5. SPATIAL AND ENVIRONMENTAL DEVELOPMENT OF THE AREA

The aim of spatial development of the riparian area at the Brežice reservoir is to encourage the development of recreation and tourism on the new aquatic and riparian surfaces with a connection to the urban area of

Pristopne poti: Na območju zadrževalnika je po nasipu speljana krožna kolesarska steza in pešpot, ki se priključuje na dostopne poti. Do zadrževalnika je mogoč dostop po javnih dostopnih poteh, ki so izvedene z razširitvijo obstoječih poljskih poti in lokalnih cestnih povezav do gramoznice Stari grad. Na območju načrtovanega športnega centra so urejene parkirne površine z ustreznimi dostopi do vode. Glede na potrebe so dostopi do vode namenjeni tudi za reševanje iz vode in rekreacijo.

Access ways: In the area of the reservoir there is a cycling circle route and footpath, which connect to access ways. The reservoir can be accessed by public roads, which were built by expanding the existing field paths and local road connections to the Stari grad gravel pit. In the area of the planned sports centre, parking areas with suitable access to the water area are provided. The access to water is also intended for water rescue and recreation.

Slika 4. Situacijski prikaz predlaganih ureditev.
Figure 4. Representation of the proposed development.

Plovnost Save: Z načrtovanjem hidroelektrarn na reki Savi je ponovno oživljena stara ideja o možnosti izrabe akumulacij za organiziranje plovnih poti vzdolž Save. V razvojnih planih je omenjena realna možnost za vzpostavitev plovnih poti za manjša rečna plovila na območjih akumulacij HE Mokrice in HE Brežice. Zato smo v sklopu prostorskih ureditev na območju zadrževalnika predvideli manjše pristanišče za rečna plovila, ki so pretežno namenjena turistično-rekreativni rabi za lokalne potrebe. Pristanišče je del bodočega športnega centra, ki se nahaja v umetno izvedenem rečnem zatoku, 300 m dolvodno od konca zadrževalnika. Priveze za plovila smo uredili na dolvodni strani zatoka, s čimer je pristan zavarovan pred neposrednimi vplivi obratovalnih manevrov v akumulaciji. Dostop do pristanišča je urejen z ureditvijo dostopnih poti v sklopu širših ureditev na območju zadrževalnika.

Kajakaška steza: je zasnovana kot del turistično-rekreacijske ponudbe v sklopu

Navigation on the Sava: The planning of the HPPs on the Sava revived the idea of the exploitation of the reservoirs for provision of navigable waterways along the Sava. In development plans there is a real possibility of establishing navigable waterways for small river boats in the area of reservoirs of the Mokrice and Brežice HPPs. Therefore the spatial development in the area of the reservoir anticipated a small port for river boats, primarily for tourism and recreation for local needs. The port is part of the future sports centre located in the artificially built river bay, 300 m downstream from the end of the reservoir. Mooring was provided on the downstream side of the bay, which ensures protection from direct impacts of operating manoeuvres in the reservoir. The access to the port is by access roads provided within the wider development of the reservoir area.

Kayaking trail: The trail is designed as part of the tourist and recreation offer within

izvedbe športnega centra, ki vključuje tudi bližnje pristanišče. Steza je zasnovana tako, da izkorišča višinsko razliko med gladino vode v akumulaciji Brežice in v visokovodnem zadrževalniku. V projektnih zasnovah po Bondu in Snelu (1999) smo razmišljali tudi o možnosti združitve kajakaške steze s prehodi za vodne organizme, ki pa je bila kasneje iz funkcionalnih razlogov zavržena. Postavljena je vzdolžno z energetskim nasipom in oblikovana tako, da je vtočni del postavljen na zahodnem robu pristanišča, iztočni del pa se nahaja v bližini izpusta iz zadrževalnika. Padec kajakaške steze je odvisen od nivoja gladin v obeh bazenih z maksimalnim padcem do 4,2 m. Za normalno obratovanje kajakaške steze je pri postavljenih elementih steze (širine 10 m in dolžine 300 m) potrebno zagotoviti 15 m^3/s pretoka, ki ga reguliramo z gumenim, gibljivim jezom na vtoku v kajakaško stezo (Sava, 1994). Glede na parametre in regulacijo pretoka je predvideno, da je obratovanje kajakaške steze usklajeno z obratovanjem HE Brežice pod pogoji, ki so predpisani z energetsko proizvodnjo in z upoštevanjem okoljevarstvenih pogojev. V skrajnih razmerah je mogoče preko kajakaške steze zagotoviti večji pretok sveže vode v zadrževalnik in dodatne vodne količine za bogatenje prehoda za vodne organizme.

Ureditev kopnih površin: Na območju zadrževalnika so z namenom izboljšanja integriranosti posega v prostor predvidene določene krajinske ureditve v obsegu oblikovanja brežine z ureditvijo kopnih površin, ki segajo v vodno telo zadrževalnika. Pri načrtovanju kopnih površin smo upoštevali morfološke značilnosti prostora, načrtovane rabe vodnih površin za turistično-rekreativne namene in ureditev dostopov do vode. V območju zadrževalnika smo predvideli dve ureditvi: na gorvodni strani je predvidna manjša kopna površina, polotok, ki sega v območje zadrževalnika in je višinsko nad gladino v akumulaciji (na koti 152,8 m), na dolvodni strani pa je kopna površina oblikovana na višjem delu območja zadrževalnika z nadvišanjem terena za 0,8 m na končno koto 152,3 m. Pri normalnem režimu obratovanja zadrževalnika (151,3 m) sta obe površini kopni, v izjemnih razmerah pa

the sports centre, which includes the nearby port. The trail is designed to make use of the height difference between the water levels in the Brežice reservoir and the flood control reservoir. In design drafts after Bond and Snel (1999), the possibility of connecting the kayaking trail with the fishway was taken into consideration and, for functional reasons, the idea was later rejected. The trail is located along the dike and designed so that the start is at the west edge of the port, while the end of the trail is near the outflow from the reservoir. The gradient of the kayaking trail depends on the levels in both reservoirs with a maximum head up to 4.2 m. For normal operation of the kayaking trail (width of 10 m and length of 300 m), 15 m^3/s flow must be ensured, controlled by a rubber movable dike at the start of the kayaking trail (Sava, 1994). Regarding the parameters and flow control the kayaking trail operation is harmonized with the Brežice HPP operation, under the conditions prescribed by energy production and in line with the principles of environment protection. Under extreme conditions, larger fresh water flow into the reservoir can be ensured through the kayaking trail, as well as additional water for boosting the flow in the fishway.

Development of land areas: A landscape development scheme in the reservoir area is planned in order to improve the integration of spatial interventions, which includes the development of the banks by providing land areas jutting into the water body of the reservoir. In the planning of land areas the morphological characteristics, planned use of water areas for tourism, and recreation and access to water were considered. In the area of the reservoir two development schemes were planned: on the upstream side a small land area is planned – a peninsula jutting out into the reservoir, positioned above the level of the reservoir (at 152.8 m a.s.l.), and on the downstream side, the land area is planned on the higher part of the reservoir area by elevating the terrain level by 0.8 to the final level of 152.3 m a.s.l.. During normal operating regime of the reservoir (151.3 m a.s.l.) both surfaces are above water, while

je za kratek čas preplavljen spodnji polotok. Na obeh kopnih površinah je predvidena ozelenitev, pri čemer so na gorvodnem delu, glede na nivo podtalnice, ugodnejše razmere za nasaditev nižinskega hrasta, na spodnjem delu pa zaradi višje podtalnice bolj primerne razmere za nasaditev hidrofilnega tipa rastja (jelša, jesen, vrba). Zavarovanje brežin kopnih površin bomo zagotovili z zagatno steno iz nosilnih lesenih oblic in lesenih plohov, ki jo po potrebi lahko sidramo v zaledje. Podobna rešitev je bila uspešno uporabljena pri sanaciji akumulacije Završnica pri podobnih obratovalnih razmerah in se vizuelno in funkcionalno zelo skladno vključuje v prostor (slika 5).

under extreme conditions the lower peninsula is temporarily flooded. Both land areas will be planted; on the upstream part the conditions – with regard to the water table – are favourable for planting English oak, while on the lower part due to the higher water table, the conditions are more suitable for hydrophilic plants (alder, ash, willow). The protection of banks of land areas will be secured by a sheet pile wall made of load-bearing half-cut logs and wooden boards, which can be anchored on land. A similar solution was successfully used in remediation of the Završnica reservoir with similar operating conditions, and both visually and functionally it fits well into the environment (Figure 5).

Slika 5. Primer obvodnih ureditev na akumulaciji Završnica.
Figure 5. Example of riparian development on the Završnica reservoir.

Sanacija gramoznice: Severovzhodno od območja predvidenega zadrževalnika se nahaja že obstoječa gramoznica Stari grad, ki obratuje že več kot dve desetletji. V tem obdobju so bile izčrpane razpoložljive količine materiala na večji površini od sedanje. Na zahodni strani obstoječe gramoznice je bila gramozna jama zasuta z elektrofiltrskim pepelom iz papirnice v Krškem, na vzhodni strani pa je obsežna površina opuščenega izkopa ojezerjena. Gladina vode je na nivoju podtalnice. Glede na projektne pogoje, da se nivo podtalnice v zaledju akumulacije Brežice ne sme

Gravel pit remediation: To the northeast of the area of the planned reservoir is the location of the existing gravel pit Stari grad, which has been in operation for more than two decades. During that time gravel has been excavated on a larger surface area than the present one. On the west side of the existing gravel pit, the pit was filled with fly ash from the Krško paper mill, while on the eastern side a vast area of the abandoned excavation site is covered by a lake. The water level is at the groundwater level. The contract conditions stipulate that the water table in the hinterland of the Brežice reservoir should remain the same, preventing

spreminjati, bodo okoljske razmere tudi po izgradnji HE Brežice enake sedanjim. Na območju ojezerjenega dela opuščene gramoznice predlagamo ureditev mokrišča, kot dodatni ukrep urejanja prostora. Za ohranitev stabilnih razmer za razvoj mokriščnega ekosistema smo predvideli, da se vse drenažne vode iz območja zadrževalnika stekajo v območje mokrišča. Neposredno vplivno območje mokrišča prepuščamo naravni sukcesiji, brez posebnih interventnih ukrepov. Na širšem vplivnem območju pa je predvideno, da se uredijo pristopne peš in kolesarske poti ter celovita sanacija prostora zahodno od mokrišča po končani eksploataciji proda v gramoznici Stari grad.

6. ZAKLJUČEK

Pri načrtovanju verige hidroelektrarn na spodnji Savi je investitor pogodbeno obvezan zagotavljati celovitost projektnih rešitev, ki niso omejene zgolj na energetski del, temveč sočasno celotno rešujejo tudi ostalo prostorsko problematiko, kot so: urejanje vodnega režima, vzpostavljanje prometnih tokov, urejanje komunalne infrastrukture, ipd. (Kryžanowski, 2000). Cilj takega pristopa pri načrtovanju energetskih objektov na spodnji Savi je ohranjati oz. izboljšati stanje v prostoru, da ljudje, ki so neposredno prizadeti ob posegu, novonastale razmere sprejemajo kot kvalitativno izboljšanje glede na prvotno stanje.

V prispevku smo predstavili možnost celovitega urejanja dela obvodnega prostora v vplivnem območju bodoče akumulacije HE Brežice, s katerimi skušamo degradacijske učinke, povzročene z načrtovanimi posegi gradnje, umiliti s predlogom celovitih okoljskih ureditev stičnega območja med akumulacijo Brežice in novo nastalimi vodnimi površinami zaradi potreb po črpanju gradbenega materiala. Predlog omilitvenih okoljskih ukrepov predvideva izvedbo prehoda za vodne organizme, rehabilitacijo območja opuščene gramoznice in vzpostavitev nadomestnih habitatov. Program ukrepov celovito povezuje novonastale naravne

the change of environmental conditions after the completion of the Brežice HPP. In the area of the abandoned gravel pit covered by the lake we propose the development of a wetland, as an additional measure of spatial development. To preserve stable conditions for development of the wetland ecosystem, all drainage from the reservoir area should flow into the wetland area. The immediate area of influence of the wetland should be left to natural succession, without any special interventions. On the wider area of influence, however, access footpaths and bicycle trails should be provided, as well as integrated remediation of the areas west of the wetland, following the completion of gravel exploitation in the gravel pit Stari grad.

6. CONCLUSION

When planning the HPP chain on the Lower Sava, the investor is contractually obligated to ensure integrated design solutions, which are not limited to the supply of electrical power, but include addressing other spatial problems such as: flow regime control, development of traffic flows, provision of municipal infrastructure etc. (Kryžanowski, 2000). The goal of such an approach in designing power plants on the Lower Sava is to preserve or improve the situation in the environment, so that the inhabitants who are directly affected by such activities perceive the new conditions as an improvement compared to the situation before.

The paper presents the possibility of integrated development of the riparian area in the area of influence of the future Brežice HPP, while trying to mitigate the degradation caused by the proposed activities by suggesting comprehensive environmental development of the contact area between the Brežice reservoir and the new aquatic areas formed as a result of extraction of construction material. The proposal of mitigating environmental measures includes the installation of a fishway, rehabilitation of the abandoned gravel pit area and introduction of supplementary habitats. The proposed scheme provides a comprehensive link between the

vrednote s programom izvajanja prostočasnih dejavnosti (vodni športi, plovba), s katerimi želimo aktivirati interes prebivalstva po rabi novo pridobljenih površin na širšem območju akumulacije Brežice.

new natural amenities and the program of leisure activities (water sports, navigation), which will help activate the interest of inhabitants to use the reclaimed surfaces in the wider area of the Brežice reservoir.

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VIRI – REFERENCES

Beach, M. H. (1984). Fisheries research technical report No. 78, Fish pass design-criteria for the design and approval of fish passes and other structures to facilitate the passage of migratory fish in rivers. Lowestoft, Ministry of agriculture, fisheries and food directorate of fisheries research: 46 p.

Bond, K., Snel, R. (1999). Functional design proposal for the Grave White Water Park. Concept version 10^{th} .

Cowx, I. G., Welcomme, R. (1998). Rehabilitation of rivers for fish. A study undertaken by the European Inland Fisheries Advisory Commission of FAO, Published by arrangement with the Food and Agriculture Organization of the United Nations (FAO) by Fishing News Books, 260 p.

GZL (1984). HE Brežice na Savi, Geološko-geotehnični elaborat. Ljubljana, Geološki zavod Ljubljana, Ljubljana.

IBE (1979). Energetska izraba Save od Medvod do Mokric. Inženirski biro Elektroprojekt, podjetje za projektiranje in inženiring, Ljubljana.

IzVRS (2004). Hidrološka študija pritokov Save. Inštitut za vode RS, Ljubljana.

Jens, G., Born, O., Hohlstein, R., Kämmereit, M., Klupp, R., Labatzki, P., Mau, G., Seifert K., Wondrak, P. (1997). Fischwanderhilfen, Notwendigkeit, Gestaltung, Rechtsgrunladen. Verbund Deutscher Fischerreiverwaltungsbeamter und Fischereiwissenschaftler e.V., 114 p.

Kryžanowski, A. (2000). Problematika vključevanja pregrad in hidroenergetskih objektov v prostor. Zbornik posvetovanja: Hidroelektrarne kot infrastrukturni objekti in njihov pomen pri vključevanju Slovenije v evropsko tržišče električne energije. Elektrotehnična zveza, Ljubljana.

MOPE (2003). Prostorske ureditve hidroelektrarn na spodnji Savi in urejanje prostora v vplivnem območju, Poročilo 2. faze. Ministrstvo za okolje, prostor in energijo RS, Ljubljana.

MOPE (2004). Prostorske ureditve hidroelektrarn na spodnji Savi in urejanje prostora v vplivnem območju, Poročilo 4. faze za HE Brežice in HE Mokrice. Ministrstvo za okolje, prostor in energijo RS, Ljubljana.

Sava (1994). Gumeni jezovi (prospekt). Sava Kranj, industrija gumijevih, usnjenih in kemičnih izdelkov, Kranj.

SEL (1995). Prefeasibility študija. Savske elektrarne Ljubljana, Ljubljana.

Vlada RS (1994). Appendices to the concession act for the exploitation of the lower Sava river hydro potential. Government of the Republic of Slovenia, Ljubljana.

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