# A GEOECOLOGICAL SURVEY OF GROUNDWATER SYSTEM AND SURFACE PATTERN ON AN ALLUVIAL FAN IN THE SZIGETKÖZ AREA

# GEOEKOLOŠKO PROUČEVANJE PODTALNICE IN POVRŠINSKIH OBLIK NA ALUVIALNEM VRŠAJU V OBMOČJU SZIGETKÖZ

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**Abstract** UDC 55 (282.1)(439 "Szigetköz")

**A geoecological survey of groundwater system and surface pattern on an alluvial fan in the Szigetköz area**

As a consequence of setting the Gabčikovo Barrage and the Čunovo Reservoir into operation, a profound environmental transformation is taking place in the area under investigation. Several scenarios have been proposed to predict changes in the position of groundwater table. The detailed mapping of geoecological units indicates that groundwater lowering affects 83.2 per cent of the Szigetköz area. The knowledge on the geomorphic pattern of the alluvial fan allows the evaluation of the complex system of groundwater recharge.

**Izvleček** UDK 55 (282.1)(439 "Szigetköz")

**Geoekološko proučevanje podtalnice in površinskih oblik na aluvialnem vršaju v območju Szigetköz**

Na področju proučevanja se dogajajo velike spremembe v okolju kot posledica začetka delovanja pregrade Gabčikovo in Čunovskega umetnega jezera. Za napovedovanje sprememb v podtalnici so bili predlagani različni scenariji. Detajlno kartiranje geoekoloških enot je pokazalo, da je znižanje gladine podtalnice prizadelo 83,2 % območja Szigetköz. Poznavanje geomorfne izoblikovanosti aluvialnega vršaja omogoča ovrednotenje kompleksnega sistema za napajanje podtalnice.

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## INTRODUCTION

Extensive alluvial fans are common landscape types along the margins of mountain ranges. In the central part of the Carpathian Basin these landforms are rather flat and grade unobserved into alluvial plains of very subdued relief. The accumulation from braided channels on the alluvial fans of big rivers, however, created an extraordinary richness of microforms: natural levees, bar-and swale systems, sand splays, backswamps, ox-bows and other microfeatures.

The ecological significance of alluvial fans lies first of all in the abundance of water, providing ample sources for drinking water supply from confined groundwater as well as surface waters for fishing, transportation, water sports and other recreational purposes. Because of their characteristic flora and fauna (K e v e y - A l e x a y, 1992) parts of riverside environments are often declared nature reserves or national parks.

Alluvial fans are not at all unique, however, in respect of human interventions. Their surfaces are preferred by human settlement, arable, meadow and forest economies. The impacts of these activities are increasingly observed in several factors of the physical environment of alluvial fans.

## TEST AREA

Most of the above statements apply to the Szigetköz landscape, the youngest part of the Little Hungarian Plain (Kisalföld) alluvial plain (Fig. 1), where the richness in microforms is represented by a complex system of point-bars and filled oxbows with backswamps and minor depressions (P é c s i, 1975; G ö c s e i, 1979). Cutting across between the Alps and the Carpathians in the Dévény (Devín) Gap, the Danube braids into three main channels: the northernmost Mali Dunaj (Csallóközi-Duna) and the main Danube embrace the Žitni ostrov (Csallóköz) in Slovakia, while on the right bank of the hydrological axis of the alluvial fan, the Moson-Danube surrounds the smaller (375 km²) Szigetköz. Its surface was shaped in Holocene fine fluvial sand and sandy silt deposited on gravel beds. Soils are of variable fertility and arranged in a secquence: raw alluvium, humic alluvial soil, meadow alluvial soil, meadow soil, meadow and calcareous chernozems (the latter only in minor patches; V á r a l l y a y, 1992). Over this spindle-shaped fan stream gradient along the main Danube decreases from 30 cm per km at the apex at 128 m above sea level (Dunacsún / Čunovo/ on the Slovak side of the border) to 20 cm per km at Vének (112 m elevation), the


Fig. 1: Location of the Szigetköz alluvial fan.
Slika 1: Lega aluvialnega vršaja Szigetköz.

lowermost tip of the 'island'. Before the Austrian hydroelectric plants were constructed, the Danube had carried gravels of 5-7 cm maximum diameter until the upper section, while it deposited bedload of 2-3 cm size in the lower part (P é c s i, 1959).

The deposits of the Szigetköz fan store large amounts of groundwater. Groundwater flow takes considerable dimensions and is subparallel to the surface. This results in uniform water quality throughout the region (E r d é l y i, 1990).

The Szigetköz is an important agricultural area of Hungary. Most of the main crops grown here (wheat, maize, sugar-beet, vegetables like cabbage and green peas) require much water. Over more than half of the area a hundred years of arable farming has obscured or partly obliterated the traces of old meanders, but differences in the distribution of fine cover deposits – which control the availability of moisture – survived.

## GROUNDWATER FLOW PATTERNS: PAST, PRESENT AND FUTURE

On an alluvial fan the main source of groundwater recharge is naturally the principal river, which usually occupies an axial position on the fan and flows at higher elevation than other channels of the braided system. However, the storage of water in these by-channels is also of major importance in keeping groundwater at a constantly high level.

This was the situation along the Szigetköz section of the Danube until the end of last century, when increasing steam-boat traffic called for river regulation (acccomplished between 1886 – 1896). Through dredging more water was concentrated into the main channel

and by-channels were closed by bank-protection structures. The drainage of waterlogged meadows beyond the flood-control levees also promoted a major change in land utilisation: between the canalised former meanders large fields were created for farming. The post-war collectivisation of agriculture also favoured large-scale crop cultivation, which required a lower groundwater table. The recharge of groundwater was far from uniform in time since the fluctuation of discharge on the Danube was great: flood levels exceeding low water stages more than 10-fold. Water amounts coming along the Moson–Danube and its table had been more balanced until very recently along the main Danube bed than along the Moson branch, where sinking to under 3 m below the surface was not uncommon.

Since the Hungarian government showed no readiness to complete the Dunakiliti barrage and fill the reservoir beyond it with water, the Dunacsún (Čunovo) barrage with 20 flood-gates was built on the Slovak side and in this way the size of the projected reservoir was one-third reduced (Fig. 2). The key of water supply to the Szigetköz, however, is in the hands of the Slovak Republic now.

There are several forecasts to predict changes in groundwater table for the Szigetköz area. The researchers of the Research Centre for Water Resources Management (VITUKI), Budapest, have proposed a variant for low water conditions and another for high water level on the Danube (C s o m a, 1975).

It is estimated that discharges above 1500 $m^3$/sec are necessary for the Danube to be effective in groundwater recharge. Since the navigation canal has to be supplied with 4,000 $m^3$/sec discharge to operate the Bős (Gabčíkovo) hydroelectric station, this can only be expected for about one week a year, during the early spring flood.

Consequently, the second – high-water – variety (Fig. 3) is analysed here (Attention has to be paid to the fact that both variants had been elaborated before the substitution of the Dunakiliti dam with the Dunacsún one, and this may be responsible for minor modifications. Another point to be made here is that water management experts raise doubts about the probability of groundwater table drops of more than 3 m.). Along some sections of the present-day active flood plain groundwater levels may sink deeper than 2 m below the surface causing already visible damage to poplar and willow stands and this would also affect arable land. With the general flow direction of groundwater from the Old Danube towards the Moson-Danube remaining unaltered, locally it is possible that flow reverses, even in the lower portion of the Szigetköz (to the influence of the Rába river), as presented on the map. Although, since February 1993 the operation of the Dunacsún barrage controls the water supply of the Szigetköz, no direct observation of the impact on the value of agricultural habitats can be made. Only after the beginning of the growing season the consequences can be evaluated, the spatial distribution of the damage surveyed and the efficiency of groundwater recharge devices (see below) established.

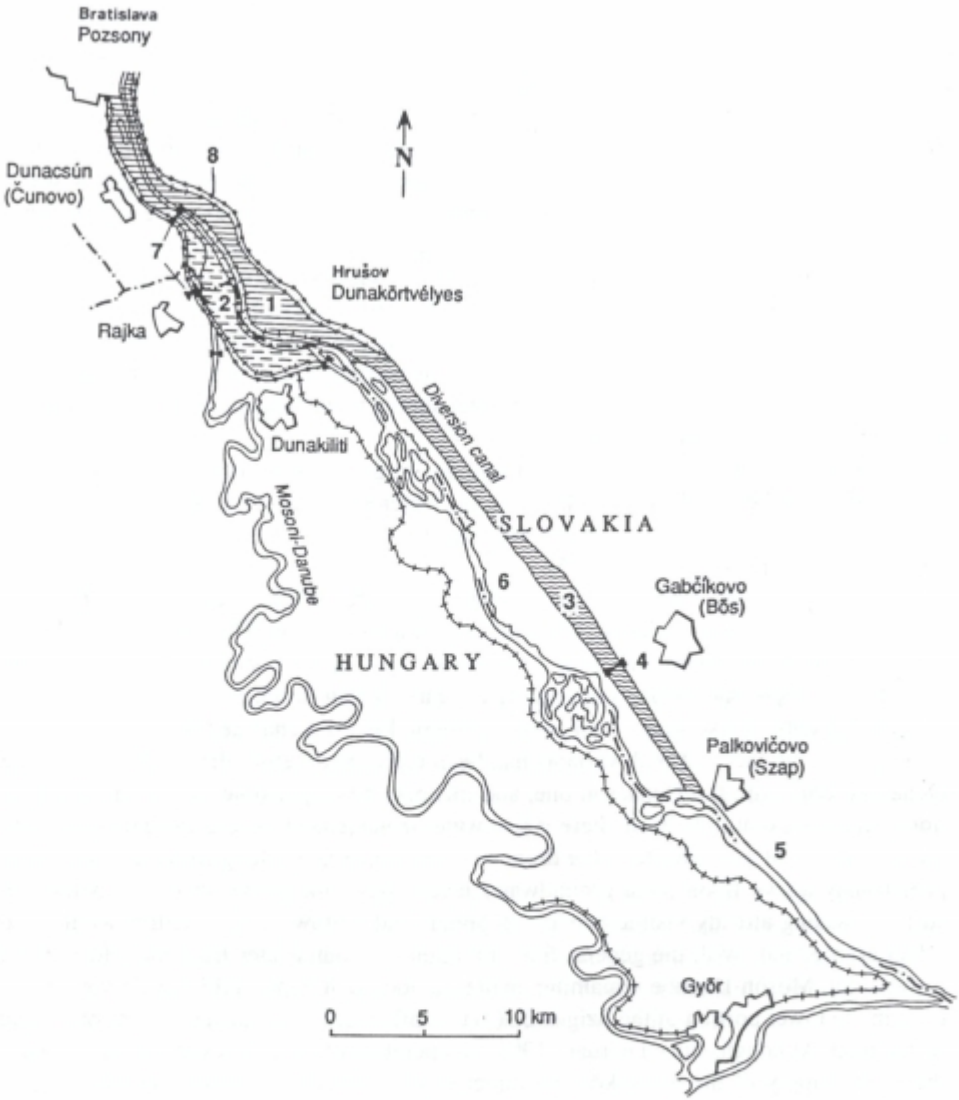


Fig. 2: The structures of the Gabčíkovo (Bős) Barrage System.
Slika 2: Zajezitveni sistem Gabčíkovo (Bős).

## GEOECOLOGICAL SURVEY

Geographical Research Institute of the Hungarian Academy of Sciences began a large-scale geomorphological mapping project under the guidance of Prof. M. P é c s i, in the Szigetköz in 1982. Within this framework the study area was divided into 9 map transects each of which can be analysed as cross-sections of the alluvial fan. The map legend was adapted from the detailed unified legend for geomorphological maps in Hungary (P é c s i et al., 1963), putting more emphasis to the morphometric parameters (particularly to depth below the general surface and to depth of fill) of one–time meanders and backswamps on the flood-free side of the levees. The landscape ecological survey relies on topographic maps at 1:10,000 scale (from 1963) to which field information on the conditions of cut-off meanders was added, aided by the interpretation of 1:50,000 scale aerial photographs (taken in 1975) and LANDSAT TM false colour composites (1984; L ó c z y - B a l o g h, 1990).

In order to estimate the predictable changes due to the sinking of groundwater table, the map of geomorphological facies was overlain by that of groundwater conditions (Fig. 3). A statistical evaluation of this overlay (B a l o g h - L ó c z y, 1992) was made for generalised categories of geomorphological features: cut-off meanders in the agricultural area between the flood-control dams of the Old Danube and the Moson-Danube, point-bars in the same area and the total area on the active flood plain of the Old Danube, including shoals, backswamps, by-channels and cut-off meanders (Table 1). The column 'Reservoir' refers to the area of the planned but not completed Dunakiliti Reservoir. The table also shows the distribution by transects of the areas remaining unaffected by changes of groundwater table. These are first of all ancient point-bars lying in the lower half of the Szigetköz area.

While 22.7 per cent (49.2 km²) of the total point-bars area (217.1 km²) remains unaffected by changes, the same applies to only 14.3 per cent (14.0 km²) of the area of one-time meanders (97.6 km²). In evaluations of the individual filled meanders, the depth of fill – which may amount to 5-6 m locally (G ó c z á n, 1984) – have also to be considered. The old meanders of 1-2 m deep fill and the point-bars of locally only 0.5 m fine grained cover deposits may not be able to store sufficient amounts of moisture to ensure the water supply of agricultural crops during intervals of drought. The fertility of soils on point-bars is poor. Without capillary rise, here even a drop of 0.5 m in the level of groundwater may result in a catastrophic decrease of productivity. Table 2 proves that for 40 per cent of the Szigetköz up to 1 m sinking of groundwater table will be characteristic, in uniform distribution in all of the transects. Only 7.4 per cent of the agricultural area will experience a lowering exceeding 2 m.


Fig. 3: Geomorphological facies and areas endangered by dropping groundwater levels in the Szigetköz (B a l o g h, after C s o m a, 1975). - 1 = flood-control dyke, 2 = calculated lowering of groundwater table (m), 3 = endangered forests on the active floodplain, 4 = endangered backswamps and filled meanders, 5 = point-bars not affected by groundwater lowering, 6 = filled meanders affected by groundwater lowering, 7 = filled meanders not affected considerably by groundwater lowering, 8 = point-bars with inefficient water supply, 9 = map transects.

Slika 3: Geomorfološke enote in območja, ogrožena zaradi znižanja gladine podtalnice v območju Szigetköz (B a l o g h , after C s o m a, 1975). - 1 = protipoplavni nasip, 2 = predvideno znižanje gladine podtalnice (m), 3 = ogroženi gozdovi v recentni poplavni ravnici, 4 = ogrožena močvirja in zasuti meandri, 5 = sipine, ki jih ne bo prizadelo znižanje gladine podtalnice, 6 = zasuti meandri, prizadeti zaradi znižanja podtalnice, 7 = zasuti meandri, ki jih ne bo bistveno prizadelo znižanje gladine podtalnice, 8 = sipine z nezadostnim dotokom vode, 9 = profili.

## CONCLUSIONS AND PERSPECTIVES

In more than three quarters of the Szigetköz area higher crop yields have been attained than the national average (P a l k o v i t s - S c h u m m e l, 1992). The area is a good example for the improvement of soil productivity by the availability of capillary moisture. This favourable situation, however is bound to groundwater recharge from the Danube now endangered by the diversion of discharge into the navigation canal.

Sinking groundwater levels will exert a differential influence according to geomorphic features. In general, infilled meanders will suffer from deterioration of their moisture budget in areas with groundwater sinking more than 2 m. As it has already been mentioned, point-bar surfaces may be deleteriously affected even in the case of 0.5 m sinking. In backswamps along the Old Danube channel, where waterlogging is common, the drop of groundwater table may even be benefitial for farming.

Since 66 per cent of the Szigetköz is used for farming, it is of vital importance to ensure groundwater recharge–particularly in point-bar areas - during the growing season. In knowledge of the geomorphic pattern, three ways of this are envisaged or patly also implemented:

– seepage canals,
– closing by-channels,
– floor drops in the Old Danube.

1. Seepage canals started to operate after the inauguration of the Dunacsún barrage in February 1993. They receive their water from the newly established reservoir. They are complemented by the opening-up of a by-channel, the Zátony-Danube, dredged along 29 km length and receiving 4 $m^3$/sec discharge. Since February the discharge of the Moson-Danube has not surpassed 18 $m^3$/sec, but the outflowing seepage canal should receive considerably more water (according to plans: 30-32 $m^3$/sec). As the relative relief between the new seepage canal and the Old Danube falls onto a shorter distance than the one between the canal and the Moson-Danube, groundwater flow will be directed towards the old channel instead of supplying the farmlands of the Szigetköz. The Hédervár canal, cutting across the whole Szigetköz and thus many point-bars may be more promising in this respect. Taken as a whole, the existing system of potential seepage canals is insufficient to fulfill its task.

Closing-dykes were built to the mouths of most of the by-channels on the active flood plain in the past hundred years. If these channels were filled during floods, their influence on supporting high groundwater levels would be restricted in space and time.

A rather costly solution to the water recharge problem is building (one or several) drop structure(s) on the floor of the Old Danube. Hydrobiologists consider such an intervention dangerous as far as water quality and self-purification capacity are concerned, since the drops would impound flow and create standing water conditions. All the already implemented water recharge devices are only temporary solutions.

In order to ensure a long-term water supply for devices the forests and agricultural land of the Szigetköz, concentrated research projects, a constant monitoring of changes – also paying attention to the geographical distribution of impacts – are necessary and political decisions can only be based upon the conclusions drawn from such investigations.

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## GEOEKOLOŠKO PROUČEVANJE PODTALNICE IN POVRŠINSKIH OBLIK NA ALUVIALNEM VRŠAJU V OBMOČJU SZIGETKÖZ

Povzetek

Z akumulacijo iz rečnih rokavov nastajajo na aluvialnih vršajih velikih rek izjemno pestre mikroreliefne oblike, ki imajo velik ekološki pomen. To velja tudi za Szigetköz (slika 1), najmlajši del Male madžarske ravnine (Kisalföld), kjer je kompleksen sistem nasutin, naravnih nasipov, zapolnjenih mrtvih rokavov in manjših kotanj (P é c s i, 1975; G ö c s e i, 1979).

V rečnih naplavinah Szigetköza so velike množine podtalnice. Njen tok je zelo izrazit in vzporeden s površino, kar se odraža tudi v enaki kvaliteti podtalnice v celotni pokrajini (E r d é l y i, 1990).

Najpomembnejši vir podtalnice na aluvialnem vršaju je glavna reka, ki teče običajno višje kot stranski rokavi, vendar je zadrževanje vode v njih zelo pomembno za vzdrževanja visokega nivoja podtalnice. Z regulacijo Donave za potrebe plovbe (1886-1896) so preusmerili več vode v glavno korito, saj so z utrditvijo brežin preprečili odtok vode v stranske rokave. S protipoplavnimi nasipi so pred poplavami zavarovali nekoč mokrotne travnike, kar je povzročilo velike spremembe v kmetijski rabi tal: med kanaliziranimi stranskimi rokavi so nastale obsežne njivske površine. Tudi povojna kolektivizacija kmetijstva je dala prednost velikopoteznemu poljedelstvu, kar je zahtevalo znižano gladino podtalnice.

Potem ko je madžarska vlada odstopila od izgradnje jezu Dunakiliti, je bila na slovaški strani zgrajena pregrada Čunovo, s čimer se je zmanjšala predvidena velikost umetnega jezera za tretjino (slika 2).

Ugotovljeno je bilo, da je za uspešno napajanje podtalnice potreben pretok Donave prek 1500 $m^3$/sek. Ker je za delovanje hidroelektrarne Gabčíkovo potrebno 4000 $m^3$/sek, lahko takšen pretok pričakujemo samo teden dni v letu, ob zgodnjespomladanski visoki vodi.

Za napovedovanje sprememb v gladini talne vode je bilo predlaganih več scenarijev. Na obsežnih območjih se je gladina talne vode znižala, kar je povzročilo prestavitev tokov in mestoma tudi spremembe smeri toka. Hektarski donosi poljščin, ki so bili tod vedno nad državnim povprečjem (P a l k o v i c s - S c h u m m e l, 1992), so več kot 75 % odvisni od srednje gladine Donave v vegetacijski dobi. Kadar se gladina podtalnice zniža do prodnih plasti v podlagi finejših sedimentov, se prekine kapilarni dvig vode in v tleh na nasutinah in nekdanjih mrtvih rokavih pride do pomanjkanja vode, saj padavine ne zadoščajo (v juliju in avgustu v povprečju 60–70 mm).

Geografski inštitut Madžarske akademije znanosti je že 1982 začel z obsežnim geomorfološkim kartiranjem pod vodstvom prof. M. Pécsija. Pokrajinsko-ekološko kartiranje temelji na topografskih kartah v merilu 1 : 10 000 (iz leta 1963), terenskih podatkih ter na interpretaciji letalskih posnetkov iz 1975 v merilu 1 : 50 000 in LANDSAT TM posnetkov iz 1984 (L ó c z y - B a l o g h, 1990).

Pri proučevanju sprememb gladine podtalnice smo geomorfološko karto prekrili s karto podtalnice. Statistična analiza dobljenih enot je temeljila na poenostavljenih geomorfoloških

enotah (slika 3). Analiza je pokazala, da bo za 40 % Szigetköza značilno znižanje gladine podtalnice do 1 m, medtem ko bo na 7,4 % kmetijskih površin gladina upadla za več kot 2 m.

Ugodne hidrografske razmere v Szigetközu, ki so navezane na napajanje podtalnice iz struge Donave, so ogrožene zaradi odvajanja vode v dovodni kanal hidroelektrarne Gabčíkovo. Ker je v Szigetközu kar 66 % površin namenjenih kmetijstvu, je zagotavljanje napajanja podtalnice v vegetacijski dobi življenjskega pomena. Glede na geomorfno izoblikovanost površja obstajajo trije različni načini:

1. Kanali za napajanje podtalnice so začeli delovati po odprtju jezu Čunovo februarja 1993 in dobivajo vodo iz umetnega jezera. Dopolnjuje jih stranski rokav (Moson-Donava), ki od februarja 1993 ni imel več kot 18 $m^3$/sek pretoka (po načrtih bi moral imeti 30-32 $m^3$/sek). Ker pa površje bolj visi proti stari strugi Donave kot proti Moson-Donavi, se glavni tok podtalnice usmerja proti stari Donavi, namesto da bi obogatila podtalnico v Szigetközu. Glede tega bo pomembnejši kanal Hédervár, ki bo potekal po celotni dolžini Szigetköza in presekal številne zapolnjene stare struge. V celoti gledano ne bo mogel celoten sistem kanalov za napajanje podtalnice opraviti svoje naloge.

2. V zadnjih sto letih so z nasipi zaprli ustja večine stranskih rokavov na poplavni ravnici. Če bi te rokave ob poplavah zalila voda, bi bil njihov vpliv na višino podtalnice časovno in prostorsko omejen.

3. Strukture za upočasnitev vodnega toka v koritu Donave, ki bi omogočile dvig sedanjega nizkega vodostaja, bi bile zelo drage in nevarne s hidrobiološkega vidika, ker bi se zaradi zastajanja poslabšala kvaliteta vode in zmanjšala samočistilna sposobnost.

Da bi zagotovili dolgoročno oskrbo z vodo, je potrebno stalno spremljanje sprememb, pri čemer je pomembno tudi geografsko ugotavljanje razporeditve učinkov, politične odločitve pa morajo temeljiti samo na rezultatih takšnih proučevanj.