Expert Group of the
Hungarian Academy of Science

Environmental Risks and Impact associated with the Gabcikovo–Nagymaros Project

Budapest, 1994

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Summary of the Main Results of the Environmental Research Activities

Budapest, April, 1994

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Preface

Diverting most of the discharge of the river Danube to Slovakian territory through the unilateral action of the Czech and Slovak Federative Republic (CSFR) on 25 th October 1992 created considerable tension between Hungary and CSFR (from 1993 onwards Republic of Slovakia). The reason of this is manifold. Most of the affected river section forms the state frontier between these countries; a major part of the international navigation route has been thereby taken away from Hungary; and most importantly, this action actually stimulated a series of very complex environmental processes resulting pre- dominantly negative, degradative changes in the area.

These unfavourable effects were already predicted by many experts of various nationality several years before. In fact, the Hungarian decision on termination of the treaty for the construction of the Gabcicovo-Nagymaros Project was based upon this awareness.

Unfortunately, in the period of planning and signing the treaty, very little if any attention was paid to the environment. Hungary's first non-communist govern- ment, being conscious of his responsibility for the future of the country, could not accept a blind "do it first and correct it later" strategy. In order to make a sound scientific basis for the evaluation of the actual and potential effects of the barrage system, a concerted multidisciplinary study was organized by the Hungarian Academy of Sciences in 1990. The unilateral damming of the Danube in the autumn of 1992 by the CSFR radically changed both the time table and directions of this study. International negotiations, missions and working group meetings of experts were frequently held necessitating more and more data. In this regard, a very significant impetus was given by the European Commission which nominated four experts to the Working Group of independent experts (from Denmark, The Netherlands, Germany and Austria). Their work is reflected by the high standard of the reports the Group presented, confirming the reliability of the account on the damage caused by the so called variant C (damming at Cunovo).

The present small volume is a summary of the several technical and scientific papers and manuscripts written on the same topics. The chapters are believed to be understandable by the non expert reader. Although most of the negative effects of the disturbed water system will only show up later as indirect consequences, and even at the time of writing of this introduction new "unexpected" problems turn up (such as the complete blocking of the navigation at Gabcikovo), I believe that enough data have already been collected and presented in the following chapters to justify the Hungarian decision to terminate the treaty.

Executive Summary of the Environmental Problems

*Situation prior to the 1977 Treaty**

The Governments of the two countries concluded an interstate treaty in 1977 on the implementation of the Bős-Nagymaros Barrage System. It took years to get to the completion of the final version of the plans. Hence it seems correct to state that views of the early 70s characterize the conception of this project. The following traits were characteristic of this period:

Subsequently to the second oil-price explosion which set in unexpectedly in 1973–74, interest in new sources of energy greatly increased. Renewable energies became more esteemed, hence the utilization of hydro-power seemed to have a perspective.

Environment protection as a new economic and social trend and movement was still in its infancy in these years. Society was hardly sensitive to environmental problems. The legal regulation system of environment protection was underdeveloped. Higher-level resolutions did not make it obligatory to assess environmental impacts prior to a construction.

The dominant approach among technical experts was that though environmental hazards were possible, the unwanted negative effects could either be eliminated through proper technological procedures and well chosen system of operation or at least be reduced to a satisfactory degree in the course of construction or after it. It was held that the possible damage would be far less than the expectable profit.

Hungarian society was very insufficiently informed about the planned construction in the second half of the 70s. The centrally controlled propaganda emphasized only the expectable positive effects: cheap energy will be produced in an environmentally safe way, the proper depth of water recommended by the Danube Commission can be secured for navigation, and also flood control will be safer.

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[1] In full: Treaty Concluded between the People's Republic of Hungary and the Socialist Republic of Czechoslovakia on the Construction and Joint Operation of the Gabcikovo–Nagymaros Barrage System, Signed in Budapest on 16 September 1977.

The possible negative effects were either not mentioned at all or only in a simplified form, which thus by-passed the risks. Critical views (like e.g. articles by János Vargha) published in the late 70s and the early 80s were restricted administratively.

No cost-benefit analysis was allowed to be made either in the planning stage or as a result of the growing criticisms following the conclusion of the 1977 Treaty.

Environment protection as a new element of politics

The UN Human Environment Conference was held in 1972 in Stockholm. This was the first world conference, which called the attention of governments to the importance of environment protection. Principle 13 in the "Declaration of Principles" document stated the following:. "In order to achieve a more rational management of resources and thus to improve the environment, States should adopt an integrated and coordinated approach to their development planning so as to ensure that development is compatible with the need to protect and improve the human environment for the benefit of their population."

Principle 24 provided a new approach concerning international cooperation:

"International matters concerning the protection and improvement of the environment should be handled in a cooperative spirit by all countries, big or small, on an equal footing. Cooperation through multilateral or bilateral arrangements or other appropriate means is essential to effectively control, prevent, reduce and eliminate adverse environmental effects resulting from activities conducted in all spheres, in such a way that due account is taken of the sovereignty and interests of all States."

As it is well known neither Czechoslovakia nor Hungary participated at the Stockholm conference — being under pressure by the Sovietunion. The reason was not an aversion from environment protection but the non-recognition of the German Democratic Republic and the resulting omission of invitation to the conference by UN. It should be stressed, that during the early seventies the member states of the CMEA (thus among them Czechoslovakia and Hungary as well) accepted the appearance of environment protection at the international fora. They had also responded to this new trend. In November 1972 the Scientific-Technical Cooperation Committee of CMEA paid special attention to scientific issues concerning the protection of the environment. A standing task force was established, named Environment Protection Council.

The Environment Protection Council developed a diverse program of scientific cooperation for the protection and improvement of the environment, which was approved in 1974. The program comprised 12 complex tasks. One of them bore the title "The protection of waters from pollution". This cooperation was essentially implemented in the work program of the Water Management Conference of CMEA member states. Research tasks included the establishment of new waste water treatment equipment, the development of new test methods of water quality. Research work also covered the assay of surface and subterranean waters. Another task envisaged was the elaboration of mathematical methods to protect the purity of water reservoirs, with which the eutrophication capacity of a reservoir or lake can be determined. All these may help in developing measures to reduce harmful effects.

Thus the idea of environment protection had been known in the leading circles of ex CMEA states. It followed, however, from the essence of the central planning ideology, that all harmful consequences can be eliminated with technical and organizational procedures and this caused a belittling of the problem. According to the information supplied about the tasks of water quality protection the whole issue was entrusted to the Water Management Conference, where certainly the priority was given to production interests and not to the protection of the environment.

The Hungarian political leaders were late in responding to the challenges presented by environment protection.

The resolutions passed by the Xth Congress of the Hungarian Socialist Workers' Party held in the autumn of 1970 had not yet included any references to environment protection.

The amendment of the Constitution of the Republic of Hungary enacted in 1972 included under Paragraph 57 on the implementation of civil rights the principle of protecting the human environment. The Patriotic People's Front organized in March 1973 the first national conference on environment protection and the social program on environment protection was adopted.

The resolutions of the XIth Congress of the HSWP held in the spring of 1875 and the program statement accepted here already contain environment protection tasks. It is essentially from this point of time, that we can see issues dealing with the protection of the environment appearing in the most important Hungarian party and state documents.

The comprehensive act on the protection of the human environment was passed by Parliament in the spring of 1976.

The Council of Ministers resolved in 1977 on the further development of the organization for environment and nature protection.

As a result of this the National Environment and Nature Protection Council, as a coordinating, commenting and supervising agent of the Council of Ministers, was established, and also the National Environment and Nature protection Office as a national authority was formed, to perform a coordinating and supervising task in specific areas.

It can be seen, that the political leadership in Hungary was late and slow in responding to the international trends of environment protection. All this caused, that in the preparation and drafting of the "Interstate Treaty" not even the international environment protection principles characterizing the mid sixties were realized fully, and also — as it will be demonstrated later — they lagged far behind the environment protection principles evolved by the late eighties.

During the eighties major changes in the attitude toward environment protection evolved worldwide, which had their impact on the modification of national policies as well. With some simplification we may say, that earlier environment protection had been a local or at the most a regional problem, and had been treated as a short term or possibly medium term task, also there was a widely accepted view, that through properly selected technical solutions all environmental damages can either be prevented or eliminated or reduced to a socially acceptable minimum.

On the other hand the new trend of environment protection, which is characteristic even today, gradually developed, namely: instead of regional problems global problems were highlighted, the short term approach was replaced by a long term approach and instead of the one-sided technical preventive options a complex social-economic response became prevalent.

During the last decade the concept of sustainable development evolved gradually, which does not deny the necessity of economic growth, where it is necessary for the satisfying of fundamental human necessities, but urges for a substantial reduction of material and energy consumption, and also the changing of consumption habits in the industrially developed countries. Sustainable development integrates economic policy and environmental policy, but in the case of conflicts of interests declares the priority of ecological interests.

The UN Conference on Environment and Development was held in 1992 in Rio de Janeiro. One of the accepted documents was the "Rio Declaration on Environment and Development". Among the 27 Principles there are some, which can be taken into account also for the case of the Gabcikovo-Nagymaros project:

"Principle 2
States have, in accordance with the Charter of the United Nations and the principles of international law the sovereign right to exploit their own

resources pursuant to their own environmental and developmental policies, and the responsibility to ensure, that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.

Principle 15
In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

Principle 17
Environmental impact assessment, as a national instrument, shall be undertaken for proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a competent national authority.

Principle 26
States shall resolve all their environmental disputes peacefully and by appropriate means in accordance with the Charter of the United Nations."

First of all "precautionary principle" is a new element in environmental policy. This expression was developed at the Bergen Conference of European environmental ministers, which was held in Norway, in May 1990. The precautionary principle obliges the decision makers to make their decisions in due time, otherwise, by the time everything would have become certain in respect of an environmental risk it may be too late, because an irreversible situation may have occurred.

The relevant statements of the Executive Summary of Final Statement from the Conference on Sustainable Development, Science and Policy accepted at the Science Section of the Bergen Conference (Bergen, 8–12 May, 1990) were as follows:

(2) As in many other areas of uncertainty in policy matters, after taking into account the possible consequences for being wrong, it will be better to find out we have been roughly right in due time than to be precisely right too late.

(3) When dealing with uncertainty, it must be realized that global environmental change inherently involves scientific uncertainty. Moreover, our understanding of these risks changes over time. Because of this, institutions and legal regimes must be developed that can be responsive to changes and scientific knowledge. The natural and social

sciences have an important role to play in identifying and clarifying the risks and in relating the risks to costs and benefits of intervention. Where the environmental changes are global in scale, irreversible and transgenerational, anticipatory assessments aimed at narrowing uncertainties and estimating types and magnitudes of effects are particularly needed. In such cases, early intervention by policy-makers may be crucial to prevent costly harms."

We can find AGENDA 21 among the documents of the UN Conference on Environment and Development, which is a collection of recommendation and proposals for national governments and international organizations. AGENDA-21 comprises a total of 40 chapters.

Chapter 39 has the following title: International legal instruments and mechanisms. Within this the issues of Dispute Settlement are also tackled, and AGENDA-21 suggests the following in this context:

"In the area of settlement of disputes, States should further study and consider methods to broaden and make more effective the range of techniques available at present, taking into account, among others, relevant experience under existing international agreements or instruments and, when appropriate, their implementing mechanisms, such as modalities for dispute settlement. This may include mechanism and procedures for the exchange of data and information regarding situations that might lead to disputes with other States in the field of sustainable development, and consideration of the inclusion in treaties relating to sustainable development of clauses providing for the effective peaceful settlement of disputes. Existing institutions, in particular the International Court of Justice, should also play a role in this field."

In order to illustrate to what a large extent had the worldwide approach to environment altered I list below the key words, which were extensively used in the documents of the Rio Conference (1992), and were not yet applied at the Stockholm Conference (1972):

- Sustainable development;
- States have common, but differentiated responsibilities;
- Appropriate access to information;
- Public awareness and participation;
- Precautionary approach
- Polluter should bear the cost of pollution;
- Environmental impact assessment.

The growing criticism of the scientific circles

There were no open scientific discussions on the conception and designs of this construction in the 70s. To establish their work, the designers had ordered several dozens of background studies to be written by researchers and university teachers. Most of these, however, dealt with individual issues. No comprehensive system analyses of the risks were made.

The first worries and reservations in the scientific circles concerning the possible environmental hazards appeared around 1979–1981. News about them got to the Science Policy Committee of the Government, which resulted in resolutions to commission an expert group to examine in 1982 the expectable environmental hazards emanating from the given technological implementation. The commission related to the "given technological implementation", that is, politics lim- ited the examinations, and such changes like e.g. the rejection of peak power production could not be imagined. The commissioned report had been completed by April 30, 1983.

The report stated that after 1975 about 60 studies had been written on the expectable environmental hazards and their consequences. However, these were not discussed in a wider circle of experts. Neither these studies, nor the examinations of the past few years gave unambiguous answers to the disputed issues which arose between hydrologists and ecologists concerning the expectable environmental consequences of the GabcikovoNagymaros Project. The lack of complex studies assessing the environmental impacts was partly the cause, partly the effect of the clashes of opinions. Thus the report proposed to have such a study made in two years' time.

The National Water Authority was assigned to co-ordinate this project. The study became completed, but was primarily written by people who were interested in the implementation of the project. The conclusion of this study assessing the environmental impacts was that through additional investments, proper technological procedures and correct operation of the barrage system, the environmental hazards can be prevented or be reduced to an acceptable degree. The preconception of the study assessing the environmental impacts is clearly indicated by the surface and underground waters having been mentioned only in a few sentences, stating that significant problems in this area cannot be expected. Ecologists did not hold these statements satisfactory and well founded. Since 1985, the date when the study assessing the environmental impacts was made public, a permanent debate has been carried on between the various expert groups about the expectable environmental consequences.

In December 1983 the Presidium of the Hungarian Academy of Sciences discussed the situation of the GabcikovoNagymaros Project. There were two core issues in this discussion, namely, what will be the long-term environmental risks involved in this investment, and what economic advantages can be expected and how do they relate to the costs. As a result of the discussion, the Presidium took a very reserved stand. Namely, it stated that based on economic and environ- mental considerations, the right attitude would be either to suspend or to postpone the investment for a longer time.

To make the picture complete, it should also be told that there were also several scientists who though with lesser or greater reservations did support the idea of this investment. Those who opposed it belonged to different branches of science, the most critical ones having been the ecologists and the economists.

Periods of the events of the last 15 years The history of the Bős-Nagymaros Barrage System after the conclusion of the Treaty, the preparation of which lasted for about two decades, can be divided into four characteristic periods.

1. From 1977 to May 1989 when the investment was started, and carried out with changing intensity.
2. From May 1989 to May 1992 when the Hungarian party suspended the construction, while the Slovak party continued it.
3. From May 1992 to October 1992, which started with the termination of the 1977 Treaty by the Hungarian party and ended with the diversion of the Danube a one-sided step by the Slovak party.
4. Since 24th October 1992, the date of the diversion of the Danube.

We are giving here a possible classification of the environmental impacts:

a. Effects advantageous or disadvantageous which had already been presupposed in the original plans and to the minimization of the disadvantageous ones of which there had been measures planned.

b. Factual damage which could not be foreseen but has become clear by now.

c. Future damages which are now already sure to happen.

d. Risks which are highly probable to occur.

We have examined the following fields from the aspect of environmental impacts:

— earth sciences,
— soil resources,
— surface waters,

— underground waters,
— agriculture,
— forestry,
— fish biology, fishing,
— nature conservation,
— public health.

We are summarizing below the most important elements of knowledge related to the various periods, the various types of environmental impacts and the individual factors.

The period from 1977 to May 1989

As we have already mentioned, disadvantageous environmental impacts had already been considered in the course of planning, however, these were limited. The greatest danger was considered to be likely in changes in the water table balance, but it was thought that additional procedures, like for example systems of seepage canals, could counterbalance the negative effects. The investors painted a calming picture for the state leadership, and the modest information provided for society arouse the same feelings. The following statements can be made in connection with the individual factors:

Geology

From the point of view of geology, the greatest risk has been the lack of detailed knowledge of the area; under such circumstances, a number of preparatory and planning tasks (e.g. environmental impact assessment, technical planning) cannot reach well-founded results. Safe prognoses can only be made on the basis of systematic studies revealing the geological background conditions.

The planning of the Danube dams was not preceded by a detailed geological survey of the region. It was a serious mistake that there were no structure-exploring deep drillings in the impact area of the dams. It well demonstrates the insufficiencies of planning that the contractors did not even have the necessary permit of the geological authorities.

It is a further problem that the research results obtained separately in Hungary and the Czech and the Slovak Republic have never been integrated. For example, the so-called Gabcikovo fault line discovered in the territory of Slovakia has not been traced further in Hungary. This fault was the reason why the site of the Gabcikovo dam was changed in the early 70s, although by not more than 600 metres with respect to the original plan. Thus, as is admitted by some Slovak experts, this dam has been built in the neighbourhood of a geologically young fault.

The most important element of the deep structure in the impact area of the Gabcikovo dam is the Rába line, the border of the Alpine and the Transdanubian tectonic units.

Its position is highly uncertain, at present it can be traced in two alternative variants. Structural exploration by means of drillings in the young sediment has not been carried out; satellite photos which may be interpreted in several possible ways do not allow to form a unanimous and profound opinion. Consequently, a clear structural view cannot be constructed yet.

Another set of problems concerns the seismology of the area of the Bős-Nagymaros Barrage System. The seismicity values of the Joint Agreed Plan cannot be accepted; the seismicity problem cannot be answered with a reliability required by international norms, since the necessary studies are lacking. The seriousness of the problem is shown by the fact that the expected intensity estimated for the Dunakiliti area on the basis of historical earthquakes is 8.7–9.0 MSK at the usual security threshold, while the original plans were prepared by assuming 6.0 MCS.

From among the uncertainties of planning, the sizing of the embankment is an especially grave problem, owing again to insufficiencies of prior investigations. The weakest point of the Dunakiliti reservoir is the embankment: it is the largest structure regarding its volume, while at the same time it is the most heterogeneous in its structural constitution, material and quality. The stability of certain parts of the embankment cannot be considered safe against earthquakes that are likely here. This especially applies to the stability of the bank higher than 7 metres, as they are not sufficiently safe against sliding. Security tests along the Dunakiliti reservoir show that the safety characteristics of the embankment do not fit the international standards. The risk level taken into consideration in the plans actually applies to common buildings where environmental effects can be excluded.

Soil resources

The original plan reckoned with significant changes in the water table balance and the substance regime of soils in the affected areas after the system has been put into operation. Depending on changes in the water table balance, the following four basic cases were prognosticated by the designers.

1. Groundwater is in the gravel layer and its changes will remain therein. In these areas (i.e. about 30% of the total territory, primarily in the north-western part of Szigetköz), there will be no changes in the water table balance.

2. Groundwater is in the fine topsoil and its changes will remain therein. In these areas (about 30% of the total territory, primarily in the lower lying areas and in the south-eastern part of Szigetköz), it is prognosticated that (a) a rise (of 20%) in the groundwater level will be followed by a little increase (2 mm/year) of the capillary water supply originating thereof; (b) a (10%) fall in the groundwater level will be followed by a small (2 mm/year) decrease of the capillary water supply.

3. Groundwater is in the fine topsoil, but as a result of the operation of the barrage system, it will go down into the underlying gravel layer. (This means about 30% of the total territory, primarily the north-western part of Szigetköz, from Ásványráró to the country border.) In these areas, the about 100–150 mm/year capillary water supply will completely cease to exist, greatly increasing the territory's sensitivity to droughts, with all its negative consequences for the natural and agro-ecosystems.

4. Groundwater is in the underlying gravel layer, but as a result of the operation of the barrage system, it will rise into the fine topsoil. In these areas (about 10% of the total territory, primarily the area south-east to Ásványráró), we have a situation opposite to the one described above.

These changes in the water table balance will also change the substance regime of the soil. The following important changes can be prognosticated: (a) Formation of lime accumulation layers, petrocalcic horizons, limestone pads at the edge surface of the underlying gravel layer and the fine topsoil, as a consequence of the effect of groundwater containing much carbonate. This will make the soil become of a shallow depth and also become sensitive to droughts.

(b) In areas of sinking groundwater levels, the soil's sensitivity to droughts will increase, crop yield security will decrease and become more dependent on precipitation; decomposition of organic matter and the leaching out of nutrients will increase, while the hydromorphic characteristics of the soil, its moisture content will decrease. (c) In areas with rising groundwater levels, the danger of inland waters will increase, and overmoisturing will lead to detrimental anaerobic processes. The probability of the formation of limestone pads, which make the topsoil shallow, will become higher; moreover, in undrainable, lower lying areas, alkalization and salt accumulation processes might occur. The probability of the latter is not significant in those areas of Szigetköz which has good natural drainage conditions, but on the Slovakian side, especially east to the middle of Csallóköz, it means a serious environmental hazard.

(d) If the groundwater becomes polluted from various sources, the accumulated pollutants might get into the plant-animal-human being nutrient chain through the soil, thus causing direct health hazards.

The original plan intended to prevent the prognosticated detrimental effects by constructing seepage and draining canal systems. However, their water demand and costs were greatly underestimated in the plans. Their absolute necessity was clearly proven by the drought in 1992, by the low water level of the Danube due to natural causes, and by the drastic decrease in the groundwater level as a consequence of the construction of Variant C (together with its already manifesting ecological effects).

Surface waters

In case of the implementation of the original plan, the eutrophication process — resulting from the slowing down of the velocity of water due to damming up and from the several days' long cycle of the exchange of water in the reservoir — would have been much faster and had more deleterious effects than originally expected. The prevailing idea was that by changing the mode of operation of the reservoir and building additional objects which would change the flow conditions, no harmful processes would develop or they would be so minimal that they would not cause any trouble. This optimistic view could hardly be supported by anything.

It is highly probable that the nutrition content of the sediment accumulating in the reservoir over the years would have raised the degree of eutrophication. This would have worsened the quality of surface waters especially in the warm summer periods in dry years. This process would have had its greatest effects on Hungarian territory, i.e. the detrimental effects would have primarily affected this area.

The sediment accumulating in the reservoir, the dynamism of its heavy metal content, its sudden and intensive appearance, would also have deteriorated the quality of surface waters. Besides the advantageous self-purification processes taking place in the reservoir, a significant growth of algas must also be reckoned with, which when getting into the lower sections of the river might lead to a problematic load of organic matter.

Underground waters

In Szigetköz and its adjoining territories, the valuable and good quality underground water stock which is stored and moves in the gravelly alluvial fan of the Danube would have been detrimentally affected by the barrage system.

The fine sediment accumulating in the Dunakiliti reservoir, the possible toxic materials contained in it might have worsened the quality of underground waters through the reduction processes that happen in the course of seeping through the sediment. (Earlier the underground waters were supplied directly from the main branch of the Danube with good quality water.) The deterioration of quality of the underground waters would have occurred in a significant part of the several hundred metre thick gavel complex in a few years or decades. The original plan did not reckon with the pollution of the significant potential drinking water reserve of Szigetköz-Csallóköz, estimated to be about 10 km^3. The capacity of this potential water reserve is estimated to be 0.5–1.0 million m3/day on the Hungarian side.

In the case of the artificial recharge systems planned for later years on the protected side and in the side-branch system of the flood-plain, the deterioration of the quality of water is also imminent. In the vicinity of the reservoir a rise in the groundwater level was reckoned with, and the surplus water was planned to be drained through seeping canals. With the progress of kolmatation, infiltration would have decreased both from the reservoir and in the case of the water supply systems. This could have been helped by dredging, which, however, raises newer water quality problems.

In the old Danube bed, letting 50–200 m^3/s water run in it, the planned bottom dykes — owing to the little amount of water dammed up — would have increased kolmatation and, as a consequence, also the risk of the deterioration of water quality in case the Danube's water seeps into the groundwater.

Along the river section below the Dunakiliti dam, a 3–4 metre decrease in the groundwater level was calculated (lessening towards the Moson branch of the Danube), which could have been eased through the planned additional water supply and the bottom dykes. The most significant decrease would have occurred on the flood-plain below Dunakiliti and in Central Szigetköz. In many places the water supply from below of the fine topsoil would have ceased; in years of drought this supplements precipitation. Irrigation was planned in these areas, but even so, decay of part of the alluvial forests had to be reckoned with. In the eastern part of Szigetköz — where the quality of underground waters is less favourable — no essential changes had been expected.

In the dammed up section between Gönyű and Nagymaros, silt deposition had to be reckoned with owing to the lower velocity of the water, especially in the section below Nyergesújfalu. Silt deposition and the reduction processes developing in it, the possible toxic sediments would have threatened the bank filtrated water stocks along this section, which would have added to the water quality problem already present in this area.

The karst water reservoir of the Transdanubian Central Mountains is in direct hydraulic connection with the Danube bed at Dunaalmás and Esztergom. The risk of the Danube water's seeping into the karst water reservoir, the pressure in which decreased due to mine-drainage, is present even without damming up; however, damming up would have increased this risk in case the depression of the karst system remains.

Below Nagymaros it was primarily the bank filtrated water stock of the Budapest Municipal Waterworks at Szentendre Island that was threatened by the downstream effects of the Nagymaros damming up. Dredgings planned in connection with the construction of the barrage system, but serving also industrial purposes, reduced the yields of the bank filtrated drinking water resources, which secure a greater part of the supply of Budapest, by about 25%. In the down- stream sections of the Nagymaros dam, the minor erosion and the insecure silt deposition would have meant inadmissible risks to the bank filtrated system which is anyway sensitive owing to the reasons given above and in which most of the natural filtering process is taking place in the few centimetre thick upper layer of the river-bed.

Agriculture

Intensive agricultural production is carried out in this region. The crop yields of the major plants (wheat, maize, sugar beet, spring barley, fodder maize) were about 15–20% higher here than the national averages. Plant growing is primarily based on the utilization of natural precipitation which is supplemented in an advantageous way by groundwaters. Irrigation is usually not economical due to its high costs and is thus only applied in the case of plants of great value (sugar beet, vegetable crops, etc.). The ratio of irrigated territories in Hungarian agriculture is about 4–5%, in Szigetköz it is minimum 8–13%. The original plan reckoned with the disadvantageous effects along the Old Danube, caused by the diversion of 90-95% of the river's water into the power canal.

Forestry

The alluvial forests, primarily poplars, represent a great economic value. This area constitutes one of the important raw material resources of cellulose production. Beside the forests for industrial utilization, the ecosystems of the indigenous species of the alluvial forests, which characterize this area, also occupy a significant territory. Changes in the groundwater table would have influenced both the wood volume growth and the yield in value of all the forests in a disadvantageous way. Species requiring less water could have been planted instead, but both their biomass production and the value of their yields per year would have been significantly less than those of the present species.

In the course of construction, 1200 hectares of high-yielding alluvial forests were cleared on Hungarian territory, while in Slovakia 3180 hectares of similarly valuable woods had to be cleared. It seems justified to suppose that had the barrage system been built according to the original plans, much more at least a further 3500 hectares of alluvial forests (on the flood-plain and the protected side) would have decayed and died out in 5–15 years than was originally reckoned with. That is, about half of the forests of Szigetköz would have become victim of the construction and operation of the barrage system.

Fish biology fishing

As a consequence of the work done at the Dunakiliti reservoir, the flood-plain section of Szigetköz from Rajka to Dunakiliti was practically abolished, which entailed a proportionate decrease in the fish population of the area. The water level fluctuation due to the originally planned peak power production would have caused serious troubles in the daily life-cycle of fish. In spawning season, this would have either prevented the fish in the area along the bank from spawning (pike, carp, most of the bream species, etc.), or millions of roes would have got on dry territory and thus perished. Peak power operation would have had its effect on an over 100 kilometre long section of the Danube, together with the mouth sections of the affluents (the Rába, the Moson branch of the Danube, the Garam, Rábca, Lajta and Ipoly rivers) on a water area of about 140 kilometres.

The Szigetköz section of the Danube is the most important spawning and fry breeding area of the Danube in the Carpathian Basin; in the case of some migrating fish (e.g. Vimba vimba), the reproduction effect of the area covers several hundred kilometres. Peak power operation, by way of the faster passing of floodwaves, would have caused reproduction problems in the affected areas. In the case of fish species spawning in the side branches, there would have been no possibility for spawning (which is dependent on very strict physico-chemical parameters), for the hatching of the roes and the development of the fries, owing to the shorter flood period of the flood-plains. This means an especial hazard for the protected and endangered species, in the case of which no man-made stocking can take place.

Reproduction problems would have entailed serious losses in both nature protection values and in fishing performance. As a result of the water kept in the reservoir, the Danube loses its sub-mountain character, which entails the transformation of the fish population, leading necessarily to a degradation in natural values. Although a significant decrease in the stock of fish was reckoned with in the original plan, its impacts on fishing, nature conservation and ecology were greatly simplified.

To sum up, implementation of the original plan would have been detrimental in respect of both fish biology and fishing.

Nature conservation

The territorial situation of Szigetköz, its geological, geomorphological, climatic and hydrographic properties, the mosaic-like arrangement of biota in it, provide living conditions for a variety of species and ecosystems. The flora of higher plants of the area is well known; it has 900 species, which means more than one third of this flora in Hungary. There are 67 plant communities known in Szigetköz (2 relicts, 10 protected, 25 semi-natural, 6 pioneer, 6 disturbance resistant, and 18 weed communities). There are 60 protected plant species in this area. Between 30 and 80 per cent of the animal species living in Hungary can be found here. For example, 116 species of mollusks live in the area, meaning 48 per cent of the Hungarian fauna. There are 96 species of crabs known in Szigetköz, which means two thirds of the Hungarian fauna. 50% of the of dragon-fly species known in Hungary can be found here. Out of the 80 species of fish in Hungary, 65 live in the waters of Szigetköz. 57% of the Hungarian bird fauna, i.e. 206 species, can be seen in this area. The number of protected animal species living here is about 300. Some remnants of alluvial forests, the mortlake of Lipót and the marshland of Arak are specially protected nature conservation areas.

Those who made the original plans were not sensitive to nature conservation. The dominance of the one-sided economic interests (e.g. gaining energy, improving the navigation conditions) was so strong that they paid practically no attention to the conservation of natural values.

The ecosystems in Szigetköz are still in a natural or almost natural condition and they occupy a significant area of the flood-plain and the territory on the protected side outside the flood-plain. These ecosystems have accustomed themselves to the centuries-long dynamics of the river. In the continuously changing side branch system of Szigetköz, the ecosystems can slowly follow the processes taking place (this is called: coenological succession). In the case of forests, the process is slower, it can only be measured on a scale of centuries. If there are quick, drastic changes, the answer is degradation and decay. It would take the nearly natural forests several centuries to recover even if there were advantageous conditions.

The original plan would have essentially sacrificed the existing ecosystems of Szigetköz and would have thus drastically decreased the biological values of this region.

Public health

Damming back, in line with the original investment plan, would have resulted in a different situation in respect of the self-purification of the sewage getting into the Danube from the settlements along the river. The construction of sewage treatment plants — involved in the original plan — would have solved the majority of the problems, but, most probably, this would not have been realized in time, owing to the lack of resources. Changes in the water table in areas without a sewerage system would have greatly affected groundwater pollution resulting from the use of cesspools. A decrease in the water table would have improved self-pu- rification in the soil, whereas an increase in the water table would have deteriorated it.

By raising the groundwater level, damming up would have caused significant deterioration in the bank filtrated waters in the upstream area, for example, at Dömös and Esztergom in the case of Nagymaros. As a result of the reduction effect, manganese, iron, ammonium would have appeared in the waters, which would have necessitated the application of new purification technologies. Increasing eutrophication, as a result of the proliferation of algas and masses of cells owing to the slowing down of the velocity of the river, would have entailed an increase of the by-products due to chlorination in the purified surface waters (namely, in the case of Lábatlan and Budapest). As the majority of these compounds are mutagenic, some of them carcinogenic, water purification technologies should have been improved considerably to prevent the health hazards.

The lower velocity of the river and the eutrophication process would have improved the quality of water in the Danube from a bacteriological point of view, so the risk of contamination in case of bathing (which is today a real risk even in the section above Budapest) would have decreased.

The period from May 1989 to May 1992

Owing to the risks shown by analyses and environmental impact assessments, the Hungarian party suspended con- struction in this period, while the Slovak party continued it on its own territory. From the point of view of additional environmental hazards, this period is indifferent. No new dangers or risks were involved in the Slovak construction, that is, nothing new compared to the original plans had emerged.

Earthquake

Intensive professional discussions commenced in 1989-1990, ending in the conclusion that the planned investment had not been studied properly from the geological and seismological points of view, and this lack of information might mean serious risks. In 1991–1992 there were possibilities to make detailed and comprehensive analyses in some fields (e.g. in that of seismic risks). These examinations led to the conclusion that the basic seismological data used in the course of planning were not correct, the value of the expectable effect (horizontal acceleration) of an earthquake in this territory would be about 5-10 times higher than reckoned with in the plan.

The period from May 1992 to October 1992

This period started with the termination of the 1977 Treaty by the Hungarian party and ended with the diversion of the Danube by the Slovak party. Neither in this period were there any new developments in respect of environmental hazards. The extra warm and dry (droughty) summer of that year and the consequently low water levels in the catchment area of the Danube above Szigetköz practically prognosticated the expectable consequences of a possible diversion of the Danube — even if not in a quantitative, but in a qualitative respect (i.e. in respect of the kinds of damage). As a result of the Slovak construction, damaging the landscape in the area continued. However, these activities had no direct effect on natural resources and on nature conservation values on the Hungarian side.

The period after 24th October 1992

The Slovak party diverted the Danube. Except for floods, only 150–350 m^3/sec water reached the old river-bed. This caused drastic changes in the hydrological conditions of the area. The reservoir became filled up to about two thirds of its originally planned surface, the turbines of the power plant started to work, the navigation route was diverted. It was primarily the following impacts that could be felt after half a year:

Surface waters

After the diversion of the Danube at Dunacsúny, instead of the earlier about 2000 m^3 water per second, some 150–300 m^3/s was let into the former mainstream bed, except for the flood periods. At Rajka, the reduced water flow caused an immediate over two metre fall in the water level of the mainstream of the Danube, whereas compared to the average conditions, it meant a decrease of four metres. Above Szap, where the downstream canal flows back into the river, damming back showed different values depending on the amount of water diverted toward Gabcikovo. The discharge and the water level of the Danube in this section have greatly changed: except for the dammed back section, lasting low water level is characteristic with slight fluctuations. The fluctuations become great in flood periods for a short while. At the outlet of the downstream canal, also great daily fluctuations have been noticed, depending on the operation of the reservoir.

After the diversion of the Danube, the otherwise little water in the side-branch system of Szigetköz has completely disappeared in most parts of the area in autumn. In spring and summer, the earlier high water levels were missing, which had had the function of supplying the side-branch system by way of the spillovers also from above. In August 1993 part of the water in the Moson branch of the Danube was used to supply some — about 10 m^3/s — additional water into the side-branch system. This could only slightly alleviate the damage. Since spring 1993 the artificial recharge system on the protected side has received about 5 m^3/s additional water supply from the same source.

Occasionally oxygen supply significantly decreased in the water originating mostly from the reservoir and let, as an additional amount, into the Moson branch of the Danube. Between late summer and early autumn of 1993, water quality in the side-branch system was better in some places than in the previous years, owing to recharging.

Underground waters

As regards underground waters, changes so far could only be measured in the water tables. We are going to express the changes with the difference between the water levels earlier and now at the Danube section where it arrives on Hungarian territory after Bratislava (Pozsony).

As a consequence of the dammed up water level at the reservoir at Dunacsúny, at the western end of Szigetköz (i.e. near the reservoir) the water table rose about 0.5–1 metre. Along the mainstream of the Danube, where the water level became lower, the water table decreased by about 3–4 metres. Farther away from the Danube, the decrease is more moderate, on the average it is about 1 metre along the whole section with lower water level. On the flood-plain, the decrease in the water table usually exceeded 1 metre, while on the protected side, it was smaller than this on the average. In this respect, we also have to take into account that the already mentioned recharging on both the protected side and the flood-plain reduced the decrease of the water table by about 1 metre as compared to the originally envisaged one. Moisturing of the fine topsoil failed to occur — compared to the earlier situation — on a great part of the flood-plain and on some parts of Central Szigetköz.

There were no significant changes expected — neither noticed — in the quality of the underground waters in the examined period. As a consequence of the mentioned decreases of different degrees in the water table, the changed place of the additional supply as well as artificial recharging, the flow directions of the underground waters have changed significantly. Earlier the underground waters generally moved from the Danube towards the Moson branch of the Danube (and even over it). Now they move in a north-west to south-east direction, i.e. more or less parallel with the Danube, in most parts of Szigetköz. The water seeping in the additional supply systems seeps into the Danube bed which has a lower water level now. Also here is seeping most of the underground water of unknown quality originating from the Dunacsúny reservoir.

Agriculture

There was drought in Hungary all over the country in 1993. In the first half of the year there was exceptionally little precipitation. In April and May 1993 there was very little precipitation also in Szigetköz, which from 22nd April was coupled with lasting warm weather. In June precipitation was very different in the various territories of the region, but on the whole it was little and the moisture content of the soil became minimal. The rainfall in July (varying by territories between 48.6 and

102 mm) improved the yields of plants to be harvested in autumn. In each part of the vegetation period precipitation was less than the average of the former seven years. (During the 1993 vegetation period, the rainfall was lower at Mosonmagyaróvár by 87 mm and at Győr by 118 mm than the average of the last 40 years.)

There were significant differences in the quantity of precipitation in the various parts of the region during the vegetation period. (For instance, at Rajka in Upper Szigetköz 240 mm, at Ásványráró in Central Szigetköz 286 mm and at Győr-Bácsa in Lower Szigetköz 153 mm were registered.)

The decrease of the water table came in addition to this situation. There was a significant decrease from Tejfalusziget to Ásványráró, due to the diversion of the Danube. On a territory of 1900 hectares of arable land previously characterized by a high level of groundwater, the water level decreased by 100–150 cm on the average during the vegetation period. On a further 2100 hectares of land, the level of groundwater decreased by 60–100 cm compared to the previous level. On these territories, the level of groundwater used to fluctuate permanently or occasionally in the top layer, whereas with the mentioned decrease it moved into the gravel layer and thus ceased to function as a moisture supplier. (According to measurements made in March, 20–50 mm were lacking out of the useful water content of the soil of 150 cm on these territories, due to the lack of groundwater supply.)

In 1993 the yields of crops lagged behind the average of the region.

Data on the most significant crops of Szigetköz are as follows:

		Yields		
	Area ha	t/ha	average of the last 13 years, t/ha	difference (%)
Wheat	6118	3.98	5.50	–27.6
Spring barley	1772	3.25	5.06	–35.8
Maize	3631	5.24	6.75	–22.4
Fodder maize	1420	26.72	26.72	—
Sugar beet	1734	37.82	40.68	–7.0

The loss of yields in the case of 11 species having been analysed amounted to 20.5%. The decrease in yields was primarily caused by water deficiency. Half of the yield decline in Szigetköz was due to the scarcity of precipitation, while one quarter could be attributed to the decrease in the groundwater level.

Both the natural endowments and the level of production differ from one part of the region to the other. The farms in Lower Szigetköz (at Dunaszeg, Győrzámoly, Győr-Bácsa) produce under better conditions and at a higher level. In the majority of the region, the level of groundwater remained sufficient in spite of the diversion of the Danube. Deficiency in precipitation was significant (79–93 mm) in 1993. Although the decline in yields was primarily due to this deficiency, it was of a smaller degree (on the average 14.4%).

The endowments of the farms located in Central Szigetköz (at Ásványráró, Hédervár, Darnózseli, Lipót, Püski, Dunasziget, Halászi) vary significantly. There is usually more precipitation here. They had had a significant territory with high groundwater level, which declined into the gravel layer as a consequence of the diversion of the Danube. The relative precipitation surplus could not counterbalance the groundwater deficiency. Level of production here was around the average of Szigetköz. The decline in yields in 1993 was of medium degree (23.3% on the average), caused mainly by deficiency in the moisture content of the soil, due about equally to the smaller amount of precipitation and of groundwater. The endowments of the farms in Upper Szigetköz (at Rajka, Bezenye, Dunakiliti, Máriakálnok) are less favourable. Their level of production is below the average of Szigetköz. Decline in yields here was significant in 1993 (31%, out of which 20% was caused by water deficiency, for three fourths of which the smaller amount of precipitation, while for one fourth the decrease in the water table was responsible).

Forestry

After June 1993 partial water deficiency could already be visually seen in the case of the alluvial forests. Patches, mostly yellow, appeared on the leaves. Some branches shrivelled up. It was a general phenomenon from June on that the trees started to lose their leaves. They tried to counterbalance water deficiency by reducing their foliage (i.e. by a smaller transpiration surface).

By mid-June 3% of the alluvial forests had to be qualified as decayed. In July there was some more significant precipitation, the side-branches also became filled up for a short time, thus the rate of deterioration slowed down. From the second half of August and the beginning of September the loss of foliage and decay continued. At the end of 1993, 5% of the trees have to be qualified as decayed.

The 1993 decrease in the size of the spring-early summer timber, which has the greatest water demand, can be best characterized by the decline in the girth increment measured by the Research Institute of

Forestry every week with 0.1 mm accuracy in several sample fields of the Szigetköz flood-plain. The data, compared to the averages of 1991–1992 (calculated from the beginning of vegetation to July 31st) are as follows:

— near the bank of the mainstream, e.g.

Dunasziget, plot no. 15/A 12-year-old I–214 poplar clone, 95 cm thick topsoil: 65% decrease in the girth increment;

Dunasziget, plot no. 15/B 13-year-old white (grey) poplar sprout, 180 cm thick topsoil: 70% decrease in the girth increment;

— in usual flood-plain situation, e.g.

Dunakiliti, plot no. 14/E 18-year-old I–214 poplar clone, 145 cm thick topsoil: 59% decrease in the girth increment.

The Dunakiliti data are important, because, though the communicating-vessel effect of the reservoir raised somewhat the groundwater levels in the area relative to those that would have been in the case of such low water level of the river as it was, I–214 poplar clone would also need the additional supply of medium and high water levels.

If the water table does not change to the better in 1994, an accelerating decay of the alluvial forests can be expected.

Fish biology, fishing

As a consequence of the diversion, water has completely flown out of 72% of the flood-plain side branches. In proportion to this, the bigger part of the fish fauna moved into the mainstream where some of the typical side-branch species (e.g. pike, carp, roach, tench) do not have even their most essential living conditions. Moreover, the situation is also critical because the conditions for the overwintering of the fishes should have been established just in the period of the diversion, when they would have needed intensive nutrition. In the mainstream there was not enough and not the needed sort of nutriment. The fish that remained isolated in the shallow remnants of water in the side-branch system either fell victim to predatory animals or got frozen in the ice during winter. 150–450 thousand kilogram of fish have disappeared or perished, 30–32% of which were economically valuable fish.

The living connection between the Old Danube and the system of side branches has ceased to exist; from the 53 spawning-grounds known by fishermen 20 ceased to function in 1993. 39 kilometres of the mainstream lost its sub-mountain character, its characteristic species migrated from here. As a result of the diversion, an upper part and a lower part of the flood-plain of Szigetköz became separated from each other. In the upper part, the water table became critically low after the diversion, and the earlier big uninterrupted sections became broken up into several small water surfaces. The conditions of migrating, getting nutriment and spawning became worse. In the flood-plain of Lower Szigetköz, which was less affected, strong silt deposition can be noticed which also decreases the level of the surface waters.

The number of developed fish decreased to 65–70% of that before the diversion, within this, that of flood-plain predatory fish to 30–35% of the former number. The amount of second-summer-old fry decreased by 20–30%. The dead channels on the protected side became dry during winter, their valuable fish fauna got destroyed. (In 1992, 61% less fish was caught in Szigetköz than five years before.)

According to the original plan, it would have taken about half a year to fill up the Dunakiliti reservoir, while the waters on the flood-plain and on the protected side would have received continuous additional supply. As a result of the diversion, the loss of water took place in a few days, thus adding to the negative effects of the power plant. Hence, it can be stated that the implementation of Variant C is even more disadvantageous than the original one.

Nature conservation

Due to the diversion of the Danube, Upper and Lower Szigetköz will be more characteristically different from each other than they have been. The dividing line will most probably be situated where the damming back effect of the Danube will be felt in some form (at about the Bagaméri branch system).

In Upper Szigetköz a radical decrease in the discharge and the water level of the Danube will effect the change and transformation of the there existing plant communities and will also affect the specific animal associations living in this area. Do the surface- and the groundwaters remain on the same level as now, it will terminate in many cases slowly, but surely the greatest value and the most characteristic trait of Szigetköz in a botanical and zoological sense, namely, very great variety on a small territory, the mosaic-like arrangement of biota. If the next two-three years are the same as this year, the original water-, uliginal and marsh-plants will be durably damaged. The size of populations will significantly decrease. In the longer run a reduction in biological diversity must be reckoned with. In 1993, partly due to the disadvantageous changes in the water table balance, also the protected flora showed signs of drought of a degree never experienced before.

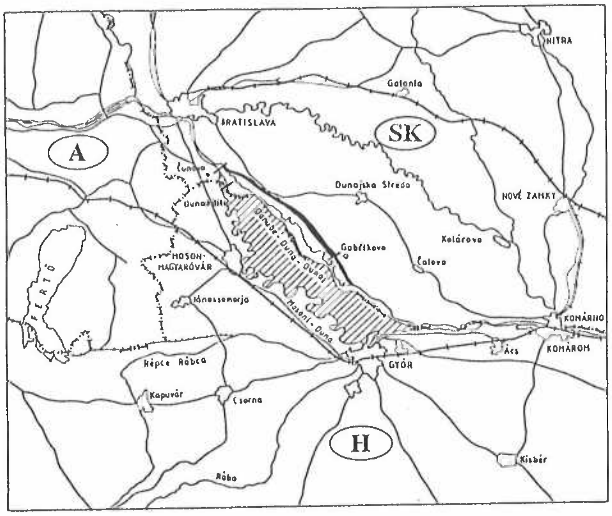
The mortlake of Lipót and the Ásványráró-Öntéssziget Lake both specially protected nature conservation areas had become dry temporarily by the beginning of summer, owing to a complete loss of water. The artificial, i.e. pumped, supply of water into the mortlake of Lipót took place in the second part of summer.

It is difficult to form an unambiguous picture of the changes in the natural values of Lower Szigetköz which constitutes about a fourth of the whole territory of Szigetköz. It is highly probable that the value of this area from the point of view of nature conservation will rise. This territory is expected to be less dry, and all those changes which are expected to occur in Upper Szigetköz will either not take place here or only to a limited extent.

The Natural Geography of Szigetköz

According to Hungary's regional grouping, the Szigetköz is a small geographical unit within the Szigetköz-Mosoni Plain unit group of the Győr Basin sub region of the Small Plains region.

The Szigetköz is situated in the plain created by the Quaternary alluvial cone of the Danube, bounded by the main arm of the river, the Old-Danube and the Mosoni-Danube, thus it is essentially an island that is 52 km long and, on average, 7–8 km wide. Its surface area is 375 sq.km.



THE SZIGETKÖZ AND ITS SURROUNDINGS

Its surface is a perfect plain with a slight north-east — south-west slant, with a few meter high outcrops. The highest point is 127 mBf, its deepest point is 110 mBf. The surface of the alluvial cone is higher along the Old-Danube (owing to the Holocene sedimentation of the alluvial deposit) than in the vicinity of the Mosoni-Danube. The surface, showing only little level differences, can be divided into lower and higher river flood plain. The height of the lower one reaches 1–2 m above the medium water level of the Danube, that of the higher one, 4–6 m. The lower flood plain is mainly covered by woods and meadows, the higher one by plough land.

Climate

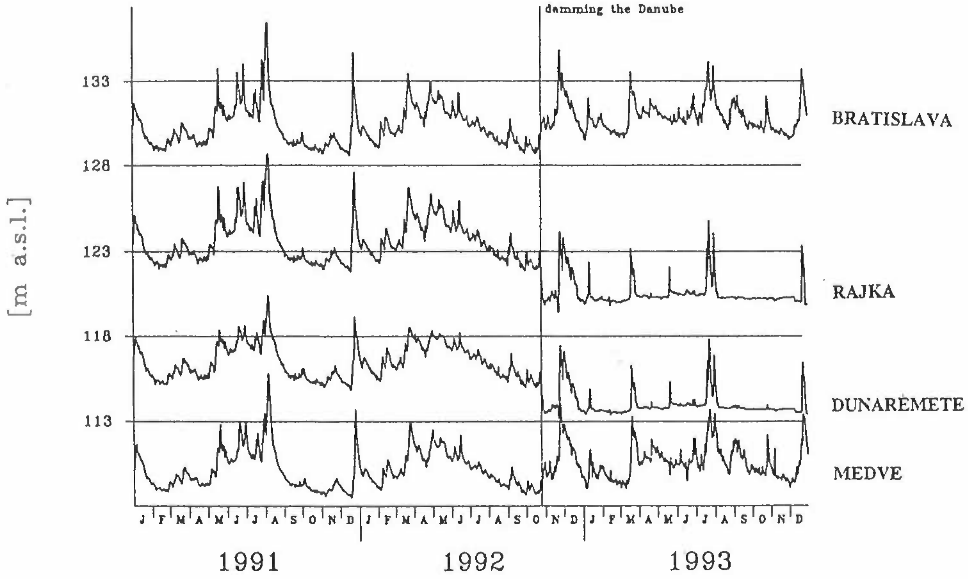
Climatic conditions are determined mainly by the humid air masses arriving from the north-west, the Atlantic Ocean, through the Dévényi-Gate. Their impact balances the climate. The relative humidity of the air is high at 75% on average. The ratio of cloudy days is at around 60%; nevertheless, the number of sunny hours is high, 1900–2000 a year. The seventy years average of the quantity of precipitation is 649 mm, higher than the national average. Over the last 40 years, the maximum annual precipitation was 800 mm, its minimum, 350 mm. On average, precipitation exceeding 1 mm comes on 85-90 days a year

The annual average temperature is 10 °C. The average of the winter period is 3.9 °C, that of the summer, 19.3 °C. The highest temperature (38.5 °C) as well as the lowest (–28.5 °C) were measured at Mosonmagyaróvár.

Hydrography

The Szigetköz evolved on the alluvial cone of the Danube below the bank of Dévény. The ancient Danube had covered virtually the entire area of the alluvial cone with its smaller and larger arms for many thousands of years. The line of the main river bed changed after every single flood. Finally, the Danube broke into three branches south of Bratislava: Small-Danube, Old-Danube, Mosoni-Danube. The Szigetköz part of the Old-Danube is 52 km long, that of the Mosoni-Danube, 120 km. The rivers received their present profiles as a result of the river control activities of the end of the past century, when the fixed main river channel and the system of side-branches of the flood plain were developed.

The level difference of the medium water level of the Danube (Old-Danube) along the Szigetköz is 15 m, representing a drop of 20–40 cm per kilometre. The current of the Danube is determined primarily by the climatic conditions of the Alps. Late in the winter or early in the spring, a rapid warm-up from the west following prolonged period of cold weather can cause icy floods. The other flood period frequently can be expected from the end of May till the end of July. In this period, the green flood appears virtually every year. These early summer floods arise as a result of the combined effect of ample rainfall and the melting of snow in the Alps. The period of low water level extends from October to February. Floods can, however, occur in any period. The floods alter the river profile: in the course of the 1965 flood, for instance, gradient values of 47–50 cm/km were measured on the right side flood plain. A major flood can alter the condition of the river bed of the Upper Danube in an extraordinary manner. The alluvium deposited by the river is at first very loose, therefore the medium and small waters are efficiently able, to re-establish the drainage conditions disturbed by the flood.



WATER LEVEL OF THE DANUBE
AT THE VICINITY OF SZIGETKÖZ REGION

The current of the Danube is exceedingly capricious; the table below shows the volatility of the annual average water output values at Pozsony over the past 7 years:

1986	2033
1987	2371
1988	2372
1989	1986
1990	1715
1991	1782
1992	1970

The Mosoni-Danube receives water through the Rajka lock, Of its three tributaries, the Lajta enters the Danube at Mosonmagyaróvár, the Rába and the Rábca at Győr.

The flood protecting dike of the Danube divides the Szigetköz into two parts, the flood plain and the so-called protected side. The protected side is covered by a network of internal canals of a total length of 157 km, most of these were implemented in the period between 1986 and 1990. Their tracks mostly follow the old riverbeds. The internal canals contain water only for some parts of the year, most of the time their beds are dry.

There are five significant branch system located in the flood plain. Their locations, according to the river kilometres of the Danube are as follows:

Branch system of Doborgazsziget	1848.0–1837.2 km
Branch system of Cikolasziget	1837.2–1832.4 km
Branch system of Bodak	1832.4–1827.7 km
Branch system of Ásvány	1823.9–1816.0 km
Branch system of Bagomér	1816.0–1809.8 km

The medium water level beds of the branch system an area almost the same as the medium water level bed of the Danube. The length of the branch system is a multiple of the part of the Danube effected by the branch system. The network of branch system is the most dense in the Cikolasziget system, here an average of 5 km branch length falls to each km of the main arm of the river. The lowest number of branch system is found in the Bagomér system, with 2.2 km of tributary length for each km of the main bed. Dykes are installed at the junctions so branch system; so long as the water level of the main river bed does not reach the crown level of the dykes, the branch system are only fed by water seeping through the dykes. The dykes are installed at different levels, hence the individual branch system join in the water supply at different water levels of the main bed.

River regulations

Regulations began in the 1830s. At first, interventions were made to facilitate navigation, mainly in various reaches of the river.

Medium water level regulation began, as the first step of the comprehensive control of the Upper Danube, in the 1880s. With the works performed between 1886–1896, the river was walled in between stone dykes in the part between the 1880–1790 river kilometres. A new, permanent river channel was established, led through long, straight parts and slight meanders.

High water level regulation consisted of the building of flood protecting dikes, with a somewhat capricious profile along both banks, implemented between 1900–1904. The Rajka (Csúny) lock was built in 1907, which excluded the Danube floods from the Mosoni-Danube once for all.

Low-water level regulation initiated in 1899 continued until 1940, with some interruptions. Together with low water level regulation, the partial separation of the branch system on both sides of the river was also accomplished. The purpose of these action was to prevent the degeneration of the river bed. With the same end in view, the height of the medium water dykes was increased and the river bed was dredged. These works were successful as far as the improvement of the navigation rout was concerned, but were unable to solve the crucial problem of the Upper-Danube, the geological process of river bed rise.

Owing to the reduction and even lack of controlling and maintenance work at the part of the river between Rajka and Gönyü in the 1950s, the efficiency of a significant part of the dikes and dams deteriorated substantially. Based on the joint evaluation of the Hungarian Czechoslovakian Joint Technical Committee, a great deal of controlling work was carried out between 1963 and 1975: altogether 580.000 cu. m of stones were built into the dams and 6.0 million cu. m of gravel was dredged. The objective of this work was to facilitate the favourable carrying of the alluvium and the establishment of a hydraulically favourable river bed section, also taking into account the implementation of a 25 dm deep and 120 m wide navigation route. Consequently, be means of stones and dredging a uniform river channel was created with controlled branch system.

After this, mainly dredging was performed in the main river bed, to prevent the depositing of alluvium, in the branch system further separating structures were created according to the plans of the Gabcikovo-Nagymaros Barrage Project.

The regulation resulted in a slowly deepening river bed, between Rajka and Gönyü by 3 cm a year. The natural tendency between Rajka and Sap would be 1.5 cm a years rise, and 8 cm a year between Sap and Gönyü.

Impact Assessment Study on the Gabcikovo-Nagymaros Water Power Plant

Surface Waters

1. Description of the original status

1.1 What shall be regarded as the original status?

The Danube is the second largest river in Europe carrying 2100 m^3 water in a second at Bratislava. The section of the Danube within the area affected by the Gabcikovo-Nagymaros Water Power Plant has got a lot of functions. It is not only a basic feature of the landscape, a waterway and a considerable stretch of at providing the means of a border, but even today it supplies 3 million (potentially 5 million) people with drinking water, as well as a nearly inexhaustible water basis for irrigation and industry. It also receives, carries and purifies water to a considerable extent and regulates the groundwater resources of lowland areas.

The determination of the "original status" is necessary for the evaluation of the effects of the Gabcikovo-Nagymaros Water Power Plant. It can be done only with the description of river regulation manipulations on the inland delta of the gravel.

The Danube had at one time several arms in the Kisalföld section on the large gravel cone which get thicker as the water flows downstream. It formed islands (sand banks) and the side arm systems in the Szigetköz and the Csallóköz. Regulation works began on this section with flood protection and navigation problems as early as the middle of the last century. The present 300–360 m wide main arm (Öreg Duna) was constructed at that time due to mean-water regulations. Already in that period several side arms were separated from the main arm. A nearly 75 km long, 2–4 km wide flood plain was created containing most of the side arm systems of the Szigetköz region. These regulations resulted in semi-natural conditions as most water bodies resembled to a great extent, their previous status.

The conditions of the Szigetköz three-five years ago was indeed the result of extensive regulations between 1966 and 1983. The number of dikes and the height of earlier constructed ones was increased, which made the main arm to carry approximately 90% of the water when there was a low or mean water discharge. Consequently a fast silting up process began at several points in the side arm systems together with a decrease in the intensity and the annual duration of the inflow from the Danube. An important element of the water regime, the position, of the water table still did not change at that time with the exception of some small local alterations.

Natural connections and interactions have weakened between the main arm and the side arm systems in the Szigetköz because of a more than a hundred year long river regulation activity. However, in many respects semi-natural conditions had characterized the area before more intensive water engineering work in connection with the Gabcikovo-Nagymaros Water Power Plant began in 1960. Natural values survived and there had been a healthy and intensive material cycling between the main arm and the side arms. Side arms with different hydro-morphology had got their water supply from the Danube in different periods, and at varying lengths and quantity with variable dynamic effects according to their connections with the main arm. The great variety of abiotic and biotic factors, i.e. the retention time of the water, led to spatially and temporarily extremely variable life conditions and communities. This system was also enriched by old side arm sections which had been cut away from the main arm by flood protection dikes. Water level fluctuations affected them only indirectly, through the groundwater. All these water bodies together formed a unique, mosaic patterned wetland area providing suitable habitats for a great variety of plants and animals. All these natural and scenic values made the area significant throughout Europe.

On the basis of the above described processes along the first 70 km section of the area affected by the Gabcikovo-Nagymaros Water Power Plant the conditions before the beginning of the intensive river regulation work in the 1960's are considered as the original status and the conditions just before the diversion of the Danube should be considered only moderately in this sense. The situation concerning the downstream 130 km long section, on the other hand, is just the opposite where the conditions before the diversion could be regarded as the original status through in many ways it is also advisable to look back to previous to the 1960's.

1.2. *The hydrographical and hydrological characteristics of the original status*

The aquatic life and biological processes in rivers are in sophisticated and dynamic interactions with the physical and chemical characteristics of the water being their medium. The dynamically changing hydrological conditions are important in the determination of the biological conditions of rivers. The necessary characterization of the most important hydrological features of the area are given below.

The slope of the Danube bed is 30–40 cm/km, the velocity is 2–3 m/sec in the upper 56 km long section of the area affected by the Gabcikovo-Nagymaros Water Power Plant till Sap at 1810 river km. The average water discharge is 2100 m^3/sec on the right side of the 56 km long section of the Danube in the Szigetköz region. There is the 120 km long Mosoni-Danube with an internationally guaranteed 20 m^3/sec minimal water discharge. It also gets its water supply from the rivers Lajta, Rába and Rábca.

The Szigetköz is divided into two parts by the flood-protection dikes of the Danube, the floodplain and the protected area. There is a 157 km long drainage canal system created mostly between 1886 and 1900 following more or less old abandoned river beds on the protected side. They are usually intermittent running waters with long dry periods. Oxbow lakes on the protected side have considerable nature conservation values.

There are five important side arm systems on the floodplain between the following river km-s.

Name	*River-km*
Doborgazi side arm system	1848–1837.2
Cikolaszigeti side arm system	1837.2–1832.4
Bodaki side arm system	1832.4–1827.7
Ásványi side arm system	1823.9–1816
Bagaméri side arm system	1816–1809.8

When there is a mean water level the surface area of the side arm systems and the main arm is nearly equal. The total length of the side arms is much greater then the length of the main arm. This ratio is the highest [5 to 1] in the Cikolaszigeti side arm system and the lowest [2.2 to 1] in the Bagaméri side arm system. The branching out of the side arms was dammed up by longitudinal river walls. When the water level is lower than crest of the river walls the side arms get their water supply only from the seepage. The heights of the river walls are different, the main arm-side arm connection is restored at different water levels.

The slope of the river bed decreases to only 6–7 cm/km on the approximately 160 km long section of the Danube from Sap to Budapest and its velocity is only 1.–1.2 m/sec with the exception of the Danube Bend gorge at Visegrád. Downstream to the Mosoni-Danube main tributaries come from the Slovakian side, the Maly Dunaj also taking the water of the Vág, the Garam (Hron) and the Ipoly (Ipel). There are two biologically important seasonal floods in the region. One of them is a caused by snowmelting at the end of winter or at the beginning of spring, the other is the result of snowmelting at high elevations and maximal precipitation in June. The water level is at its lowest in October and November.

1.3 Biological assessment and water quality evaluations in the planning and the construction phase

There was no investigation into the *biological status* of the surface waters and the water quality in the area affected by the Gabcikovo-Nagymaros Water Power Plant in the planning phase of the project nor during the construction. No answers were given to such questions, no investigations could be carried out. Thanks to the slowly growing social pressure and the professional concern of several scientific institutes, among others, these being the Hungarian Academy of Sciences, the Waterworks of Budapest, and Hungarian Institute for Town and Regional Planning an environmental impact assessment study was compiled on the Gabcikovo-Nagymaros Water Power Plant in 1985, seven years after the ratification of the Hungarian-Slovakian bilateral treaty. Surprisingly the environmental impact assessment study hardly contained any data on the water quality and outlined no problems to be solved or any which could not be solved easily during the construction. Water quality was indicated to be researched mostly by the laboratories of the water authorities only in later years. Due to the adverse criticism the peak load operation plan was rejected. An intensive, regional, sewage treatment programme was developed and a water supply system in the Szigetköz was planned to reduce the effect of the water level decrease in the area. Another problem to solve was the probable affect of the water table increase up to nearly 70 km upstream from Nagymaros on the local agriculture, forestry and settlements. With the exception of the damage to the villages and towns all the above mentioned problems had a water quality element.

2. Original status — changes and their assessment

This chapter summarizes the most easily — recognizable changes caused by the construction and the partial operation of the Gabcikovo-Nagymaros Water Power Plant and the diversion of the Danube. It includes both existing and predictable changes and their evaluations. In spite of the obviously close connections between the main arm, the side arm systems and the Mosoni-Danube they are discussed separately as hydrological-geographical units.

2.1 Main channel

The hydrobiological status of the main arm of the Danube in the Szigetköz is basically determined by the section upstream. Along the regulated main arm with the great slope between Rajka and Sap it has only moderately changed. This was especially true before the side arm systems were more intensively dammed up. The Upper Danube did not get much pollution from the Hungarian side. The Middle Danube downstream to Sap gets industrial and urban pollution from the Hungarian side. Moreover, some branches (Vág, Ipoly) also carry some pollution from Slovakia.

Chemically the Danube can be characterized as a calcium-hydrogen carbonate dominated ß-oligohalobic water (body) with total salt concentration of 240–350 mg/l and a conductivity of 250–500 us/cm. The usual dissolved oxygen concentration of the river varies between 8 and 10 mg/l with occasional higher values. This is an adequate concentration for the organisms and the degradative processes. The chemical oxygen demand is not too high (COD5Mn : 4–6 mg/l, CODCl : 10–16 mg/l). It is in the ß-mesosaprobic, ß-mesosaprobic range.

On the basis of a 20 year long data series at Rajka the quality of the water in the main arm has become worse during the study period in several parameters (conductivity, CODp, BOD_5, ammonium, nitrite, chloride, sulphate). The highest increase was detected in the concentration of different nitrogen forms and the orthophosphate.

The quantity and quality of suspended solids is important in *sedimentation* and in the biological production of the Danube.

There has been around 10 mg/l of suspended solids during low water periods in recent years. During floods the suspended load can increase to 100–200 mg/l. In looking at the comparison between data collected in the late 1950's and late 1980's a decrease in the carried suspended solids can be recognized. There is only half the amount of suspended solids in the Danube at Rajka than there was thirty years ago, this being mostly due to the effect of Austrian dams on the Danube constructed during this 30 year period.

The Danube continuously carries *heavy metals* in two forms. They are either dissolved or bound to solid particles. The concentration of heavy metals in both phases considerably fluctuates and the maximal values are near to the maximal acceptable concentrations in some cases. A part of the heavy metal content absorbed on the surface of suspended solids precipitates is deposited and reductive processes dissolves it. This way benthic or periphytic organisms can incorporate it. In the Szigetköz the heavy metal concentration of molluscs originating from side arms with often reductive bottoms was two to three times higher than the heavy metal concentration of molluscs from the main channel.

The *nutrient supply of plants* in the Danube is a basic biological feature. At the moment the average concentration of inorganic nitrogen consists of 2.5 mg/l with 85–96% nitrate dominance. The nitrite concentration can be neglected, the concentration of ammonium ion is between 0.2 and 0.25 mg/l. The concentration of the total inorganic nitrogen changes in a typical annual cycle. It is at its lowest in summer and early autumn and reaches its peak in winter and early spring. There can be a 100% difference between the minimal and maximal values in a year. In the vegetation period, when the phytoplankton production is the most intensive, nitrogen binding is considerable.

The total phosphorus and especially the orthophosphate phosphorus concentration of the Danube is extremely high compared with other surface waters. The average fluctuates between 0.1 and 0.2 mg/l. During the vegetation period when the phytoplankton is present in large quantities the concentration decreases but only to 0.04 to 0.05 mg/l. It is still well above a concentration which could limit the increase in the trophic condition of the water.

The inorganic nitrogen concentration has increased by nearly 50%, the orthophosphate phosphorus concentration by approximately 100% (average values) in 25 years. The Danube was potentially polytrophic even 25 or 35 years ago before this increase occurred.

An important change in the *oxygen production-consumption balance* in the mid 1980's is worth mentioning. Up until the beginning of the 1980's the side arms had a detectable affect on the oxygen cycle of the section of the Danube in the Szigetköz. This was due to the direct connection of the main channel and some large side arms. The phytoplankton production in the slow moving water of the side arms was considerably higher than in the main channel. As there was a nearly continuous connection between them the oxygen rich inflow from the side arms regularly increased the primary production of the downstream section. Not rarely it was a significant increase. The side arm systems in the Szigetköz used to play an important and favourable role in the oxygen cycle of the main downstream arm. The erosion of the riverbed and the isolation of the main channel nearly halted this beneficial input of the side arms making it almost undetectable.

Saprobiological investigations provide information on the extent of *organic pollution*. In some cases the categorization was carried out according to the presence of Protozoa species and individual numbers. In other studies centrifuged dipped samples were saprobiologically analyzed. The saprobiological status of the Danube and the side arms is generally acceptable with rare exceptions. Between 1976 and 1980 the average saprobity index in the main arm reached the β-mesosaprobic range (>2.9) in winter, while it was rather ß-mesosaprobic (around 2.2) in summer. There was a 2–3% decrease between Rajka and Medve.

The continuously increasing organic matter decreases the self-purification capacity of the river.

The *trophic status* of a water body indicates the quantity of nutrients for algae and macrophytes in the water, an indication of eutrophication.

As mentioned above the trophic status of the Danube and the side arms is potentially polytrophic. They contain enough nutrients for extensive algal growth if the environmental conditions are favourable. The actual trophic status of the Danube, which can be measured by the determination of the number of algae, the biomass of the phytoplankton, the a chlorophyll concentration, or the primary production, changes during the year. From November to February it is oligotrophic. In several years when the water level was low it was mesostrophic in March. From spring to autumn it is oligo-mesostrophic during floods and in low water periods it is eutrophic or eu-polytrophic. In some years it became eutrophic in March and it remained this way as late as October.

By the end of the 1970's both the average and the maximal number of algae increased by 200–400% in the Szigetköz region. The nutrient supply of the Danube could have been enough to reach the eutrophic or eu-polytrophic status as early as the end of the 1950's or the beginning of the 1960's.

The quantity and quality of suspended solids and the depth of the illuminated water column determine the light conditions for the phytoplankton in running waters. The quantity of suspended solids in the Danube between Rajka and Budapest decreased to half of the original amount from the end of the 1950's to the end of the 1970's especially when the water level was low or average. The main reason for the decrease in the amount of the suspended solids in the Danube was the sediment retention effect of the German and Austrian water power plants constructed during that period.

The decrease in the quantity of suspended solids considerably increased the transparency of the water. It was two or three times higher at the end of the 1970's than at the end of the 1950's. At present during low water periods 75–90%, during floods 20–30% of the total water body is transilluminated. Consequently during low water periods algae reproduce nearly throughout the complete water mass of the Danube. During floods their proliferation is restricted to a thinner upper layer. At the end of the 1950's in the Danube there was enough light for algal reproduction in 20–40% of the water column during low water periods and 10–15% during floods.

Reservoirs provide good habitats for euplanktonic algae. Planktonic algae proliferating in reservoirs on the Upper Danube are carried from the next reservoir to the Danube, where they find appropriate conditions for their existence and reproduction. This process continues along the Austrian section of the Danube. When the Danube reaches Hungary at Rajka it has got a rich planktonic algal flora, which is not a natural characteristic of the section.

From among the nearly 200 zooplanktonic Ciliates ß-mesosaprobic species dominate the Danubian community in the region of the Szigetköz. This is characteristic of moderately polluted surface waters. There is a close correlation between the individual number of zooplanktonic (lower) crustaceans and the water temperature, discharge and the flow velocity. In spring and autumn low water periods several species can be found in large numbers at certain sections. This causes eutrophic "waves" on the river.

The development of *macrophyton stands* along the Upper Danube was limited, only some water mosses and weeds could survive in the constantly water covered zone of transverse dikes, rockfill dams and revetments. Macrophyte stands could develop along the Middle Danube because of the slower flow velocity. They are usually found around transverse dikes and rivers walls, where floods do not tear them off. In general, water level fluctuations and floods strongly inhibit the distribution and development of macrophytes along the Middle Danube.

2.2 Side arm systems

Originally the *side arm systems* and the main channel of the Danube were *integral parts of a complex system.* It also included water bodies outside the flood protection dikes even if they were fed through the groundwater. If the water discharge of the Danube was not greater than 1,800 m^3/sec, which is a low water discharge, there was no direct side arm-main arm connection. Underground inflows and outflows characterized the system and the side arms became lentic. This standing water-like situation used to by typical for approximately half of the year (170–180 days). Annually approximately 90 days could be described as having a water supply from seepage. Direct connection occurred when the water discharge was above 2,500 m^3/sec (60–70 days) with different inflows according to the actual water level.

Side arm systems can be very different because of their different shape, size and water discharge. In low water periods, when their water hardly flows or stands, they can generally be characterized by limnic hydrobiological features and usually with high trophic values. It is due to the high inorganic nutrient content (phosphorus) of the Danube and the lack of the currents, a selective agent.

During floods the *phytoplankton* of the floodplain side arms and the main channel are identical. Following the separation of the side arms from the main arm in the vegetation period the species composition and the individual number of the phytoplankton change rapidly. Certain species occur in large abundance. The new, characteristic phytoplankton develops over a few days in small arms. A similar process sometimes took several weeks in large side arms.

The abundance of phytoplankton can greatly vary between the side arms in the vegetation period. The individual number is usually around a several tens of thousands of individuals/ml, the a- chlorophyll concentration is between 50 and 200/m^3. The maximal concentrations can reach a hundred thousand individuals/ml and 800–1.000 mg/m^3, respectively. Maximal phytoplankton production can lead to water blooms even along certain sections of the main arm, but it is more typical in the side arms. Low concentrations are characteristic of small arms, which get their continuous water supply from filtered Danube water. In other cases the intensive grazing of planktonivorous *zooplankton* causes the low individual number of the phytoplankton.

The trophic status of the side arms can rapidly increase in the vegetation period especially between May and September. After great floods the phytoplankton of the Danube remained in the side arms begins to reproduce rapidly. In 24 or 48 hours the individual number can increase two to four times. The zooplankton reaches its maximal individual number after 5 to 10 days.

The abundance of phytoplankton can remain high even after the vegetation period. In large side arms, if the nutrient concentration is high a winter planktonic algae maximum can be detected under the ice leading to eutrophic conditions. In February, 1993 the chlorophyll concentration was 30–50 mg/m^3 in a side arm in the Ásványráró side arm system under the ice.

The difference in the species composition and individual numbers from the Danube and between the water bodies is especially characteristic of the area outside the flood protection dikes.

The connection to the main arm is a crucial determinant in the species composition of the zooplankton in the side arms. After floods, when the side arms get disconnected from the main arm and the flow velocity slows down the structure of the zooplankton radically changes. In a couple of days both the number of species and the abundance significantly increases. The predominant species are more or less the same in the main arm and the side arms.

In the Ásványráró side arm system zooplankton samples were collected every day between 20.6. and 17.9. 1985. At Rajka the water discharge of the Danube changed between 1530 and 7090 m^3/sec in the given period. Limnic conditions were typical, the species and individual numbers were high when there was no direct in or outflow. The structure of the zooplankton community is mainly determined by seasonal changes and the effect of water discharge fluctuations. Most species found in the side arms are common in slow flowing eutrophic waters.

Following floods, when there is a strong flush in the side arms, the oxygen production is considerable under the near lentic conditions. Before the side arms were dammed up they considerably and significantly increased the oxygen concentration in the main arm.

The saprobiological status of the side arms is usually better then it is in the Danube. The saprobic index is often higher with 0.2–0.3 in the side arms. However, saprobity increase occurs in side arms with standing water if the abundance of phytoplankton is high and there is only a little amount or no oxygen in the lower water layers.

There is no macrophyton stand in the main channel because of high flow velocity. On the contrary, rich and variable communities develop in small side arms and oxbow lakes on both sides of the flood protection dikes. The appearance of macrophytes in deep side arms with gravel beds in the floodplain is rather exceptional. Rich macrophyte vegetation is characteristic of shallow arms which are not or only to a limited degree flushed by floods and have a rich sediment. The actual status of macrophyte stands depends on the water discharge, hydrometeorological conditions and the actual development of phytoplankton. In general oxbow lakes and shallow waters outside the flood protection dikes have the richest macrophyte vegetation. It can spread over the whole water body competing out the phytoplankton.

2.3 Mosoni-Danube

This 120 km long river, which also forms the southwestern border of the Szigetköz, gets its water supply from different sources. Its water discharge is relatively small compared with the amount of pollution. The Mosoni-Danube gets an internationally guaranteed 20 m^3/sec from the Danube and the water of is tributaries, the Lajta, Rába and Rábca.

The first section of the Mosoni-Danube from its branching out to Mosonmagyaróvár is fast flowing with a significant slope. The second section is slow flowing, and resembles the lower section of the river. Changes in the water supply from the Danube have caused some problems in recent decades.

From a biological point of view the lower section of the Mosoni-Danube is an important migratory route of the spawning fish stock.

2.4 Past, present and predictable future changes

Hydrobiological changes are discussed in geographical units. Processes in one unit obviously affect downstream changes. A considerable number of changes in the original status occurs with a time gap and cannot or only very slightly be detected immediately after the diversion of the Danube.

a) Dunakiliti-Körtvélyesi (Hrusov) Reservoir

Two characteristics should be mentioned first. This reservoir differs morphologically and hydrologically from upstream German and Austrian reservoirs. That is why there is no point in their comparison. Besides, the effects of the original reservoir and not the effects of the 30% smaller reservoir of the C variant is evaluated here. However, the experienced changes are practically the same just not as intensive due to the smaller size of the reservoir.

If the water discharge was around the average the mean depth would have been 3.3 m, the volume 2.43 million m^3, the water surface 52 km according to the original plans.

The water would have flowed through the reservoir but the retention time and the average flow velocity would have been different in different parts of the reservoir. They would have had the following values in the original reservoir:

Water discharge of the Danube m^3/sec	1,000	2,000	3,000	4,000
Retention time (hr)	67.5	33.8	22.5	16.9
Average flow velocity (m/sec)	0.05	0.11	0.16	0.21

The extent of the changes can be demonstrated with a comparison. The average flow velocity used to be higher than 2.0 m/sec at this section of the Danube before the reservoir was created. It was planned to decrease to 0.11 m/sec. This change is the basis of alterations to the original status. The suspended solid content of the water entering the reservoir is already smaller than it used to be before upstream reservoirs were created. It also decreases in this reservoir because of intensive sedimentation due to the slowing down of the current. Several mathematical models were created to describe the process. 8 cm sediment was predicted as an annual average, but it can also be 30 cm under certain meteorological conditions. The spatial variation in sediment deposition was calculated to be between 2 and 44 cm. More than 50% of the sediment is with a grain size below 50 um binding organic matters. The continuous translocation of the streamline constantly modifies the stream profile of the reservoir. It makes the location of stagnant water areas, which have a negative effect on the water quality, unpredictable. Water quality changes are more dangerous in winter under the ice, which prevents the aeration of stagnant water accelerating anaerobic processes.

Eutrophication depends on the nutrient availability for algae and plants, light conditions and temperature. There is more phosphorus and nitrogen in the Danube at Bratislava than the phytoplankton can build in. As a result, at this section, planktonic eutrophication is limited by not having adequate light conditions, temperature and by the effect of the current. In the reservoir light conditions improve due to sedimentation, and the temperature increases by several degrees centigrade in the main vegetation period due to the retention of the water providing an opportunity for the algae to use up a greater part of the practically unlimited phosphorus and nitrogen supply.

As a result a great increase in the abundance of algae is inevitable. At the same time self-purification processes become more intensive as well but the produced organic matter burdens the downstream sections for a couple of hundred kms. This can cause problems i.e. in the drinking water supply in some areas. This theory was proved earlier by an Austrian-Slovakian-Hungarian joint research project along he 420 km long Hungarian section of the Danube on the water quality effects of

Austrian Danube dams and reservoirs. Both the number of algae and the chlorophyll concentration increased all the way along the stretch. Even if all sewage in the affected area were biologically treated the COD and BOD5 concentrations indicating the organic matter load would increase because of the Dunakiliti-Körtvélyesi reservoir.

The quality of the sediment in the reservoir has also got noteworthy significance. Its organic matter content is estimated to be between 13–15%. It mostly originates from decayed planktonic organisms and sedimented organic pollutants. There is also estimated an increased oil pollution due to more intensive navigation. Anaerobic areas with hydrogen sulphur and methane production can be formed especially in warm shallow parts of the reservoir, where the decomposition rate of the organic matter is high.

The oxygen concentration in the seepage from the reservoir after the inundation could decrease to zero because of the decomposition of the vegetation remaining in the area and the humic alluvial soil according to a VITUKI report in 1988. As a result, iron and manganese could be resolved.

Though it is not a surface water hazard the uncertain, yet potential threat to the Hungarian-Slovakian groundwater reservoir which, at present, has an excellent water quality should be mentioned here as well.

Present and future processes in and around the reservoir are the results of a dynamic multivariant system. Their intensity and timing is extremely difficult to forecast. The above outlined processes will all probably take place in the future.

b) Diversion canal

Two important changes are predictable along this 25 km long section. In the first 17 km long completely artificial section the number of algae (and the a chlorophyll concentration) will probably increase slightly if the oxygen concentration is sufficient. Planktonic algae sensitive to higher flow velocity than in the reservoir could begin to die even in this section. A certain amount of the phytoplankton (according to some estimates it can be as great as of 30% of the community) is mechanically killed by the turbines of the water power plant. The water flowing through the turbines is physically enriched by a considerable amount of oxygen. It can not be detected several km downstream but it speeds up oxygen consuming degradative processes in a short section. The second section of the diversion canal downstream from the power plant, is relatively fast flowing resembling natural conditions. Planktonic organisms from the reservoir continue to die in this section.

c) Main channel

The original water discharge of the main channel has been last along 37 km instead of the planned 31 km. The water discharge is nearly always below 1% at the staff gauge at Dunaremete. Important increases (up to 2,000 m^3/sec) have occurred so far only when the water level was very high (4,000–5,000 m^3/sec). Those were only short periods dependent on one sided Slovakian decisions, about which no previous accounts were sent to the Hungarian authorities.

The bilateral treaty specified a 50–200 m^3/sec water supply for the upper section of the main channel. This is not enough for the basic biological (and non-biological) functioning of the river.

The diversion had several effects on the main channel. The area and volume of the aquatic environment decreased, there is no semi-natural water level fluctuation and there are hardly any connections with the side arms systems in the Szigetköz. In this way they lost their function as fish spawning areas, which was essential for the fish fauna and fishery of the main arm section in the Szigetköz and downstream. The planktonic communities also lost their supply from the side arm systems, which is also deleterious to the oxygen budget and the self-purification capacity of the river.

The lower 15 km section of the abandoned river bed is dammed back from downstream if the water discharge of the Danube is above 4,000 m^3/sec. The water quality becomes worse because of the high fine sediment and pollution concentration of the water originating from the reservoir and sometimes from other sections, too. Changes in water quality depend on the duration of the high water level and meteorological conditions.

d) Side arm systems in the Szigetköz

The first damage to the side arm systems in connection with the construction of the Gabcikovo-Nagymaros Water Power Plant was caused by the acceleration of their separation from the main channel. This activity began approximately 25 years ago and led to the increasing silting up of the side arm systems. Their water level fluctuations have only moderately followed the changes in the main arm and the biological side arm-main channel connections have begun to disappear.

After the diversion (damming at Cunovo) the side arm systems in the floodplain lost most of their water and large areas became dry or stagnant. It was also followed by intensive loss of fish in the area. Although the Hungarian measures to decrease the damage brought back some water to several areas, the natural water level fluctuations and the intensive metabolic connection with the main channel could not be compensated by a fraction of the original amount of water.

The efficiency, permanence and the water quality stability of the water supply of inevitably reduced value cannot be judged at the moment (i.e. the probability of eutrophication is unknown).

The water loss of side arm system elements and ox-bow lakes outside the flood protection dikes had also been extensive. Water was conducted to a lot of areas later but the dynamics and the water quality was completely different. It is certainly not an adequate solution for the reconstruction of the dried out sites and their vegetation and wildlife. These measures could only help in the short-term survival of the original aquatic communities.

Two sites, the bog Arak and the oxbow-lake at Lipót from among the bodies of water outside the flood protection dikes are of special natural value. (They are also strictly protected.) The oxbow-lake at Lipót completely dried out soon after the diversion of the main arm. Its vegetation and wildlife got spoiled. After dry period lasting several months water a constant water pump was put into operation to provide a continuous water supply for the revitalization of the oxbow-lake. The bog at Arak had a smaller-scale damage.

There used to be extensive wetlands on both sides of the flood protection dikes. Wetlands are among the most important habitats for the protection of biodiversity also listed in international conventions with the strictest restrictions for their protection. These areas have nearly completely disappeared from the Szigetköz because of the water table decrease.

e) The Sap-Vének-Nagymaros-Budapest section of the Middle Danube

The analysis does not include any aspects of the peak power operations as it was rejected mostly for ecological reasons.

The water quality and the biological status of the water on the 17 km stretch between Sap and Vének is determined by the water coming from the diversion canal when the water discharge is below 4,000 m^3/sec. When the water discharge is higher, the abandoned main channel also carries some water, which has an unpredictable effect on the water quality especially at the beginning of the flood. They can flush eutrophicated stagnant waters and fill up the previous river bed washing away the willow shrubs, which may result in a poor water quality.

The exactly hundred km long Nagymaros Reservoir which allows water to flow through it freely is situated between Vének and Nagymaros. The calculated current velocities at different water discharges are the following:

Water discharge of the Danube (m^3/sec)	1,000	2,000	3,000	4,000
Average flow velocity (m/sec)	0.35	0.7	1.1	1.41

At present the average flow velocity is 1.0–1.1 m/sec, at an average water discharge of 2,000 m^3/sec, at the site of the Nagymaros Water Power Plant. The power plant would decrease the flow velocity by 30%, which would considerably improve the life conditions for planktonic organisms (both phyto- and zooplankton). This would result in an enrichment of the planktonic community originating from the Dunakiliti-Körtvélyesi Reservoir. The planktonic biomass would be even higher then upstream.

25–30 km upstream to Nagymaros between Lábatlan and Esztergom intensive sedimentation can be predicted. It would bind polluting agents just as in the Dunakiliti-Körtvélyes (Hrusov) Reservoir but there are no reasonable estimations on the intensity of the process.

The number of living and dead algae and the pollution load would increase along the complete section. Not satisfactorily purified sewage also burdens this section. The main sources of these pollution types are the Mosoni-Danube, the Vág, Garam, Ipoly and the urban waste water of Gyõr, Komárom, Sturovo, Dorog, Esztergom and a number of small towns and villages. The large-scale sewage purification project launched in the meantime is far from being complete. We must emphasize that the potential solution to this problem will not even slow down eutrophication because of the oversupply of inorganic phosphorus and nitrogen.

Reduced flow velocity increases sedimentation. The mud rich in organic matter begins to degrade, which consumes the oxygen content of the water in the sediment. Iron, manganese, ammonium and carbonic acid are accumulated in the reductive sediment. Organic molecules having a bad odour or taste are formed. Heavy metals can also be resolved.

The realized and possible bank filtered drinking water extraction opportunities in the area degrade because of pollution and also because the fine grain-size sediment prevents the water from flowing towards the bank filtered wells.

Along the Nagymaros-Budapest section the affect of the water power plant should be mentioned (just as at Gabcikovo). As the water flows through the turbines its oxygen content physically increases. This produces and advantageous effect for a short section. However, at the same time, the amount of dead algae also increases negatively influencing the water quality during most of the year.

There are no accurate data on the effect of the increasing number of algae and a chlorophyll quantity, the organic load caused by dead planktonic organisms and compounds having a bad odour or taste on the surface and bank-filtered drinking water extraction. Nearly 3 million people get their drinking water supply from these sources. Dredging ordered in the plan of the Gabcikovo-Nagymaros Water Power Plant downstream to Nagymaros reduced the capacity of several wells of the Waterworks of Budapest. Further dredging was cancelled along that section.

Ichthyological Aspects of the Gabcikovo-Nagymaros Project

I. Introduction

Water types of Szigetköz are of special importance when analyzing the ichthyological effects caused by the Gabcikovo River Barrage System, since these water bodies have shown the most dramatic changes so far and the expected long-term effects are also the most relevant here. For this particular reason the ichthyological analysis of the area is discussed in details.

The examined changes are presented in three chronological periods. The first period discusses the conditions prior to October 1993 and are shown here as the "initial" stage. Former Hungarian investments associated with the water dam, such as constructing the Dunakiliti reservoir, already had certain effects on the fish-fauna of the area, though of much less importance than the processes taking shape after the diversion. It resulted mainly in diminishing the size of the floodplain habitats and along with it the total stock of fish. The next period describes the changes that occurred and examined so far (between October 1992 and October 1993). Some of them are registered facts, though the probable events also belong here. While the last period gives the predictable short- and long-term changes, based on data and observations described in the previous parts, in cases of all individual water types.

II. Situation before diverting the Danube (Ichthyological values of the influenced area)

The ichthyofauna of Szigetköz is highly valuable not only for certain remarkable species but also for its special species composition and combinations. According to investigations before the diversion, the six main water types of Szigetköz sustained 65 fish species. This species diversity is outstanding not only for Hungary but for Europe as well. The ratio of floodplain — main stream system/species (6000 ha/65 species) is unique in similar European water bodies (with only fresh-water fauna). This means that 80% (!) of the native Hungarian fish species can be found in Szigetköz. These two characteristics should have been sufficient for demanding international protection to the area as one of the most important ichthyofaunistic "paradises" in Europe.

Ratio of endangered species on the European level:	22% (n = 14)
Ratio of rare species on the European level:	22% (n = 14)
Ratio of vulnerable species on the European level:	43% (n = 22)

The major reason for the richness of species (high species diversity) is the "cramming" (occurrence) of numerous habitat type mosaics in a comparatively small area.

The water bodies of Szigetköz can be classified into six main ecological categories:

- main stream,
- inundated branch system of the floodplain,
- wetlands and disconnected backwaters,
- irrigation and water-supply canals of the flood free area,
- ponds of gravel-pits,
- Mosoni-Duna.

A complete species list and the frequency of species in the water types of Szigetköz as well as the international qualification of the species are summarized in the tables of the Appendix.

1. Main stream

The main stream of Szigetköz belongs to the submontane zone of the river and its character species developed accordingly. The slope gradient (40 cm/km) and the velocity (2.5 m/s) of the Szigetköz main stream are unique in Hungary providing habitat for several rare rheophilous species, such as *Pararutilus frissii meidingeri, Gobio kessleri, Zingel streber, Gymnocephalus schraetzer* etc.

An outstanding ichtyofaunistical value is the population of *Hucho hucho* that is known to live exclusively here in our country. The population of this endemic species in the Danube system is maintained by artificial breeding and fry reintroduction in the other riparian countries. The epicentre of its occurrence is Hungary.

For the last 25 years other populations of *Cottus gobio* have not been reported elsewhere in Hungary, and it was abundant in the main stream of Szigetköz before the diversion.

The character species are Barbus barbus and *Chondrostoma nasus.* Prealpine elements: *Cottus gobio, Hucho hucho, Salmo trutta m. fario* etc.

occur here in considerable numbers. Several rare fauna elements are also found here. Migratory Ponto-Caspian species very seldom occur in Hungary and voucher specimens were found exclusively in Szigetköz; they are *Caspialosa kessleri pontica, Coregonus albula, Coregonus lavaretus.* The other species of the community are primarily Ponto-Caspian as well.

By knowing these facts, it is readily understandable, why on this 60 km long tract the number of fish species (n = 57) was so high before the diversion.

2. Floodplain

River regulation, flood control, navigation furthermore the agricultural and sylvicultural utilization of the land drastically reduced the territories of alluvial floodplains all over Europe. In Hungary, however, along the Danube floodplains of considerable size remained intact in the area of Szigetköz and Gemenc, that, together with their fish fauna represent natural values of European significance!

A characteristic feature of the floodplain branch systems is the high habitat diversity. Side-arms provide spawning sites not only for native fish species, but for those of the main stream and migrating species arriving from great distances, such as *Vimba vimba.* The high habitat diversity accounts for the high species diversity (n = 52).

Notable fish species in the floodplain are:

- *Cyprinus carpio m. hungaricus*
- *Cobitis aurata*
- *Pelecus cultratus*
- *Gymnocephalus baloni*

A special water type of the flushed floodplain branches are the permanent inner lakes. These waters have similar basic fauna to the backwaters of the flood free area. Due to seasonal water level fluctuations these lakes temporarily communicate with the side-arms providing thereby reproduction, fry development and feeding sites for other floodplain species outside the basic fauna. The most important inner lake is "Öntési-tó" lying in the Ásványi branch system.

3. Wetlands and disconnected backwaters

The draining of the wetlands decreased the surface area of marshes, moors and isolated water bodies. These — together with their extremely rich fauna and flora — should be protected worldwide as in Szigetköz.

The backwaters of the flood free area became isolated from the floodplain during former water regulations. Their ichthyofauna stabilized before the diversion. The specific physico-chemical parameters of the water are tolerated only by a few species. Due to the disappearance of similar water types most of these became endangered. A highly valuable species of these habitats is *Umbra krameri*, indigenous in the Carpathian Basin and recorded in the Hungarian Red Data Book. Its most relevant population in the world is found in Hungary. The other dominant species in the fish community of its habitat are *Misgurnus fossilis and Carassius carassius*. Further members of the community are *Proterorhinus marmoratus* and *Tinca tinca*. *Leucaspius delineatus* is a rare, protected fauna element that is abundant in some parts of Zátonyi-Duna. In the backwaters of the flood free area 23 species were recorded during sample collections before the diversion.

4. Irrigation and water-supply canals of the flood free area

Between 1896 and 1900 a drainage system was constructed in Szigetköz which, after subsequent extensions forms a nearly 300 km long canal system. Although existing river beds were also used, the majority of the canals have regulated straight banks. Ichthyologically interesting areas could only develop at points with diverse habitats (e.g. bridges, trees fallen into the water, meanders and wider parts with thick water vegetation). The outstanding, protected and endangered fish species of the canals are *Gobio albipinnatus* and *Umbra krameri*, the latter being very scarce in this water type. The total number of fish species here is 27.

5. Ponds of gravel pits

As the subsoil in Szigetköz is gravel, there has been gravel digging in the area for a long time. The high groundwater levels gave rise to lakes in the abandoned pits, which are scattered throughout the territory of Szigetköz.

Their fish fauna is the result of artificial introduction. Only a small portion of these communities, usually cyprinids, originates from natural colonization. Since their fauna does not considerably differ from other ponds managed by angler associations, it is not discussed here in details.

6. Mosoni-Duna

Similarly to the branches, Mosoni-Duna also has a flushed character, both with strong currents and stagnant water bodies. Migratory fish species move according to water fluctuations. With respect to its ichthyofauna, the branch can be divided into upper, intermediate and lower stretches. At the upper reach of Mosoni-Duna, receiving water solely through the dike of the main stream, the biggest *Gasterosteus aculeatus* population in Hungary can be found. Near the Halászi-bridge it is abundant. Two rare cyprinids, *Pararutilus frisii meidingeri* and *Rutilus pigus virgo* are assumed to occur at the mouth of Mosoni-Duna.

Rivers flowing into the intermediate part (Rába, Rábca, Lajta) have a great impact on the ichthyofauna of Mosoni–Duna. Owing to the influence of Rába, a large population of *Cobitis aurata* is found near Győr. This species turned up only on one occasion in other locations of Szigetköz (Ásványi branch system, Árvai-dam 1991). Near the delta of the rivers Rába and Lajta the occurrence of two rare zingel species *(Zingel zingel, Z. streber)* was recorded.

The hydrodynamic conditions and the fish fauna composition of the lower reach of Mosoni-Duna also have certain connections to the above mentioned rivers, but here the influence of the Main-Danube is considerable; *Acipenser ruthenus*, characteristic of the lower tracts of the main stream, is an example.

Although the habitat diversity of Mosoni-Duna is lower than that of the main stream — floodplain system, the number of species is similar (n = 54) due to the above mentioned external effects.

III. Changes resulting from the diversion of the Danube (From October 1992 to October 1993)

1. Main stream

Owing to the diversion the main stream became divided into three distinct sections. On the basis of changes in the hydrodynamic conditions and the fish fauna the three stretches are: upper reach (from Rajka roughly to the end of Ásványi branch system), intermediate reach (from the end of Ásványi branch system to the inflow of the artificial canal) and lower reach (from the inflow of the artificial canal to the mouth of Mosoni-Duna).

The existence of a connection between the various water types could have guaranteed the conservation of the ichthyofaunistic values found in the upper part. The diversion resulted in disconnecting the main stream and the floodplain almost entirely, the diversity of the latter being important for the survival of many main-stream species. Thus on the upper reach of the main stream daily and seasonal migration between the two areas became impossible. This fact will lead to a population decline mainly on the long run and to a probable decrease in the number of species at this section of the main stream. The majority of main-stream fish species spanned in the branches and the different phases of fry development also took place there, with the exception of the following rheophilous and stenoecious species: *Zingel zingel, Z. streber, Gymnocephalus sreatzer, Hucho hucho, Salmo trutta m. fario, S. gairdneri, Gobio kessleri* and *Cottus gobio* that spanned in the main channel. Streamflow and channel depth decreased considerably in the area. This narrowed habitat means reduced carrying capacity. The clearly narrowed main stream has lost most of its contacts with the tidal zone, the littoral part of which was more than indispensable for many species.

Cottus gobio living in the littoral zones is a characteristic alpine — Prealpine element in the fish fauna of the main stream. The international significance of this population is small since it is wide-spread at the Salmonid levels of Europe, but in Hungary it was its only recorded area in the last 25 years. Today a serious population loss is taking place in the upper Szigetköz tract of the main stream, where its habitats has significantly narrowed.

Specimens of *Cottus gobio* were not found at all in the medium reach of the main stream. The inflow from the diversion canal of the power plant created a submerged section in the medium reach. Consequently, it entirely lost its submontane character and thus the populations of characteristic species decreased (the majority of the individuals migrated from the territory). The main stream near Bagaméri branches became a problem area for other fish species as well. During sampling after the diversion (October 1992) the following common main-stream species could not be found:

- *Abramis ballerus*
- *Gobio albipinnatus*
- *G. kessleri*
- *Leuciscus leuciscus*
- *Pelecus cultratus*
- *Rutilus pigus virgo*
- *Vimba vimba*
- *Cobitis taenia*
- *Lota lota*

— *Cottus gobio*
— *Gymnocephalus baloni*
— *G. schraetzer*
— *Zingel zingel*
— *Z. streber*

Species less frequent than these were not found either in samples from this tract, but their absence perhaps is due to the number of samples. However, the species listed above should have occurred at any of the three sampling periods provided their frequency remained unchanged. Not only the total stock of fish, but the number of species also decreased here. The best explanation for these observations is that the main stream lost its submontane character and the individuals of the rheophilous species most probably disappeared or their number significantly diminished in that area. Compared to the other main stream tracts, changes in the fish fauna are the most relevant here. At this moment the relevance of this "barrier" for the migratory species cannot be predicted. It is important to note that the temporary water supply of the branches developed at the Hungarian side upstream of this area is connected to the main stream and thus it may hinder the above mentioned reproductional migration of main stream species.

At the tract downstream of the inflowing service water no considerable impact was observed on one year scale. Potential ichthyofaunistic changes caused by the inflow of stored water cannot be predicted at present.

Thus, the upper and the submerged tracts underwent negative changes compared to the "initial" stage. The reaches downstream of the returning diversion canal did not show considerable ichthyofaunistic changes on a one year scale.

2. Floodplain

As a result of the diversion the majority of the water flowed out of the branches. Consequently, the best part of the fish fauna entered the main stream lacking even the most elementary conditions of typically side-arm species, e.g. *Esox lucius, Cyprinus carpio, Scardinius erythrophthalmus and Tinca tinca.* Body conditions necessary for hibernation became critical for several species, as their intensive feeding was impossible at the time of the diversion. In the main stream they could not find food in satisfactory quality and amount. The quantity of fish perished or disappeared (estimated 3 to 5 fold of the annual fish catch) is 150–450 000 kg, accounting for several millions of individuals.

Species that already started hibernation, got stuck in a few remaining water bodies and eventually died due to the continued habitat loss. The inundation of late November filled up the branches with water, but was not sufficient to change the situation. Some of the individuals resettled in the side-arms, but when the flood was over, their habitats disappeared again. The water level in the water bodies of the floodplain lowered to the groundwater level and then followed its fall. During the first months after the diversion the majority of the isolated residual water bodies froze to the bottom several times. Thus the fish hibernating here could not survive the winter. In several tracts of Ásványi branches thousands of fishes were found frozen in the fragmented ice cover. As the condition of fish stuck under the ice of deeper areas was not sufficient for hibernation, the future of survivors is uncertain.

As a result of the diversion, the upper and the lower sections of the Szigetköz floodplain separated characteristically. Water levels in the upper branches were critically low before water supplementation had started. The former large and continuous water surfaces were divided into several small water bodies, which hindered migration, thereby the feeding grounds and also spawning sites became inaccessible. The populations of the rheophilous species decreased at a greater extent than the others. On the basis of collected samples it can be assumed that the number of predators older than three years was reduced to one tenth compared to similar periods in previous years. The quantity of the two-year old fries decreased only by 20–30%.

Owing to the absence of the icy flood at late winter and the green flood, the main stream species reached side-arm spawning sites only exceptionally.

Due to temporary water supplementation, several migrating, rheophilous species reappeared in the affected parts of the floodplain. The majority of these fishes returned from the main stream to the branches presumably through the connected side arms and reappeared throughout the upper floodplain.

Such recorded species are:

- Barbus barbus
- Chondrostoma nasus
- Vimba vimba
- Leuciscus leuciscus.

Nevertheless, the number of non-migrating, rheophilous species diminished compared to the initial stage. An example for that is Gymnocephalus baloni that used to be abundant in the floodplain. (It showed an average of 40 specimens on a 50 m long riprapped littoral area of high velocity in 1989, as opposed to only 1 individual on every 100–120 metres in 1993.)

The Bagaméri side-arm system is a less endangered floodplain area. In springtime the reproduction of several cyprinids (e.g. *Abramis brama, Chondrostoma nasus and Vimba vimba)* was observed. Changes in water conditions are less striking here. Owing to the main channel, migrating rheophilous species occur at the lower part of this water body from time to time and the ratio of non-migrating rheophilous species is similar to the "initial" stage. Although submerging affects this area as well, ichthyofaunistic changes cannot be observed yet.

3. Disconnected backwaters

The water disappeared practically everywhere from the backwaters of the flood free area. The remaining short tracts were so shallow that birds and other piscivores have considerably thinned the fish populations.

After the water supplementation of Zátonyi-Duna *Umbra krameri* could not be found among the character species (see Chapter II). The disappearance of this population is a serious loss in the genetic value of the species. In Austria, where even a single specimen has not captured for fifty years, it became a symbol of nature conservation. In Lipti Holt-Duna its estimated density was 3–10 individuals per square metre in 1992.

Due to the water supplementation of Zátonyi-Duna, the backwaters with stagnant water and marshes became in many parts "canals" of 40–80 cm/s current velocity. Gravity water intake from Mosoni-Duna made its fish fauna appear in Zátonyi-Duna. Consequently, the number of fish species increased, but only *Misgurnus fossilis* remained dominant from the members of the "initial" fish fauna. This seemingly positive effect meant the colonization of the euroecious, competitor species that supersede the original fauna. *Lepomis gibbosus* appeared in large numbers, a fish-egg consuming, aggressive territorial species that suppressed indigenous elements already in several water bodies.

Among the rare, protected elements of the "initial" fauna, the population of *Leucaspius delineatus* in Zátonyi-Duna decreased critically. In the last few months it could be found solely at the edge of a dike (an area with stagnant water) though it used to be abundant in several parts of Zátonyi-Duna before the diversion. Instead, *Alburnus alburnus* became abundant, a species with broader ecological tolerance, a typical pioneer of newly formed gravel ponds.

Lipóti Holt-Duna, that had prominent ichthyiofaunistic values, dried out completely after the diversion, and thus, its fish fauna perished. Water supplementation withdrawn from the main stream could not save the "initial" fish fauna. The physical, chemical and biological parameters of the water did not enable the resettlement (natural or artificial) of this fauna of European value. During sampling two pioneer species *(Carassius auratus, Alburnus alburnus)* and a one-year old specimen of *Cyprinus carpio* were collected, the latter presumably of local introduction. Species of the "initial" fish fauna did not occur at all.

4. Irrigation canals of the flood free area

Diversion brought about a significant drop in the water level of the canals, their flow was reduced or the water became stagnant. Consequently, the status of rheophilous species became critical. As the effects of the diversion are delayed through exclusive contacts with the ground water, the ultimate results became evident only a few months later. The previously dominant species in these canals, suffered significant population decrease:

- *Gobio gobio*
- *Gobio albipinnatus*
- *Leuciscus leuciscus*
- *Cobitis taenia*
- *Noemacheilus barbatulus*
-

The increasing dominance of Lepomis gibbosus and Rhodeus sericeus amarus over more valuable fauna elements is striking.

5. Mosoni-Duna

From among the water bodies of Szigetköz, it is only Mosoni-Duna that has slightly been affected, since the inflowing rivers from the Hungarian side (Lajta, Rábca, Rába) alleviate the effects of the diversion. The evaluation of data collected last year does not show any significant changes.

Note:

The majority of endangered species cannot be reproduced, because their artificial breeding is not ensured. Sufficient information enabling large-scale breeding is available only for economically important fish species. Our knowledge regarding the natural history, the reproduction and the behaviour of these rare endangered species is scanty.

IV. Long term effects of the diversion (Tendencies, prospects, problems)

1. Main stream

The river regime of this section of the Danube is of alpine character. In case this "alpine rhythm" seasonal water level fluctuation is not sustained in the floodplain — main stream system, the spawning, fry development and hibernation of main stream fish species become questionable, as these are based on cyclic hydrological conditions. The hibernation, spawning, feeding and fry development sites do not overlap, therefore isolated, mosaic-like water bodies are not convenient for these species. Migratory species living in other tracts of the Danube regularly spawned in the side branches of Szigetköz. Thus a decrease in spawning sites will affect the fish fauna of the Danube downstream the Szigetköz area.

An outstanding element of the Szigetköz main stream is the small *Hucho hucho* population. The occurrence of this species is due to the strong current, the high concentration of dissolved oxygen, the low water temperature, suitable nutrients etc. The simultaneous presence of all the optimal factors in the main stream is quite improbable, and thus, the survival of this species in Szigetköz is very unlikely.

There are several other Prealpine elements in the Szigetköz main channel of the Danube that are very sensitive to even one or two degrees of fluctuations in water temperature. The lower streamflow of the upper reach, the decreased current velocity of the intermediate reach and the re-entering of stored water into the lower part will result in an increased water temperature in all reaches in summer. The future of Prealpine elements is largely dependent on its degree.

2. Floodplain

Among the water types of Szigetköz, the floodplain is the most complex system. Therefore, the evaluation of ongoing changes is the most difficult here. Upper- and Lower–Szigetköz will be divided more characteristically. Their border will presumably be the point where the submerging effect of the Danube will spread (at Bagaméri side-arm system).

Temporary water supplementation can at best alleviate the detrimental effects of the diversion. The isolation of main stream — floodplain system decreased habitat diversity. The regular flushing of the floodplain was primarily responsible for the great variety of habitats. The stabilization of the water regime will also lead to a loss in habitat diversity. In case the fluctuating hydrodynamics of the floodplain change, reproductional and ontogenetic cycles adapted to alpine hydrodynamic conditions may suffer severely. These potential changes will lead to a decrease in species diversity in the long run.

3. Disconnected backwaters

The fish fauna of these areas was most probably completely destroyed directly after the diversion. With the exception of Lipóti Holt-Duna, temporary water supplementation comes from Mosoni-Duna, and therefore, the immigrating and recolonizing species originate from that area. The stabilization of the elements in the new community depends on the new habitats determined by the water supplementation. At present water velocities the resettlement of the "initial" community cannot be expected. Rather, the dominance of euroecious species is likely that would mean the natural devaluation of the area. However, before the establishment of a stabilized, stationary community the overdominance of certain species can be expected, as it was observed in similar, newly colonized systems.

4. Irrigation canals of the flood free area

At present it is difficult to predict the future development of the fish fauna in the irrigation canals, as temporary water supplementations may considerably modify the situation. A situation similar to Zátonyi-Duna would be favourable for the canals.

5. Mosoni-Duna

Due to the inflowing rivers mentioned above, hardly any change occurred in the fish fauna of Mosoni-Duna. The species conserving capacity of this area may become significant later regarding the ichthyofauna of the whole Szigetköz.

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Appendix

Table 1. Distribution of fishes in the Szigetköz as compared to neighbouring water bodies, their nature conservation status, and represation in our collection

Species	DISTRIBUTION					C	P	Th	Bern Conv.		Cor. B.M.
	Sz 1 2 3 4 5	II 1 2 3	SI 1 2 3	A 1 2 3	R	Sz	H		II.	III.	
Petromyzontidae											
Eudontomyzon marine (Berg, 1931)	1 ? ? – 1	0-2 + +	+ + –	– – –	2	▨	▨	V		*	*
Acipenseridne											
Aeipenser ruthenus Linnaeus, 1758	1 1 – – 1	0-2 + ?	+ + –	1 – –	1	▨		E		*	
Clupeidae											
Caspialosa kessleri pontica (Eichwald, 1838)	* – – – –	– – –	– – –	– – –	–						
Anguillidae											
Anguilla anguilla (Limnaeus, 1758)	1 1 – – 1	0-3 + +	+ + –	1 1 1	1	▨		I-V			
Esocidae											
Esox lucius Linnaeus, 1758	1 2 2 2 2	0-3 + +	+ + +	2 2 2	2	▨		I-V			
Umbridae											
Umbra krameri Walbaum, 1792	– ? 1 2 –	0-2 – –	1 ? –	– – –	–	▨	▨	V-E	*		
Coregonidae											
Coregonus allada Linnaeus, 1758	* – – – –	* * –	– – –	– – –	–			E		*	*
Coregonus lavarelus Linnaeus, 1758	* – – – –	* * –	? + –	– – –	–			E		*	*
Thymallidae											
Thymallus thymallus (Linnaeus, 1758)	? – – – –	* – –	? ? –	– – –	–		▨	V		*	*
Salmonidae											
Salmo trutta m. fario Limnaeus, 1758	1 1 – – –	0-3 * +	+ ? –	– – –	1	▨		V			
Salmo gairdneri Richardson, 1833	1 – – – –	0-3 * +	+ + –	– – –	1						
Hucho h. hucho Limnaeus, 1758	1 – – – –	0-1 – –	+ – –	1 – –	–	▨	▨	E		*	*
Cyprinidae											
Cyprinus carpio Linnaeus, 1758	1 2 1 1 2	0-3 + 1 +	+ + +	1 2 2	2	▨		V-E			
Cyprinus carpio m. hungaricus (Heckel, 1813)	1 1 – – ?	0-1 + ?			1	▨					*
Abramis brama (Linnaeus, 1758)	2 2 – – 2	0-3 + +	+ + +	3 3 3	2	▨					
Abramis bollerus (Linnaeus, 1758)	1 2 – – 1	0-2 + +	+ + +	2 3 3	1	▨		V		*	*
Abramis sapa (Linnaeus, 1758)	1 1 – – 1	0-2 + +	+ + –	1 2 2	1	▨		R-V		*	*
Alburnus alburnus (Linnaeus, 1758)	3 3 1 1 3	0-3 + +	+ + +	3 3 3	3	▨		I			
Alburnoides bipunktatus (Bloch, 1782)	1 – – – 1	0-3 – +	+ + –	– 1 –	3	▨	▨	V-E		*	*
Aspius aspius (Linnaeus, 1758)	2 2 – – 1	0-2 + +	+ + +	2 2 –	2	▨		V-E		*	*
Barbus barbus (Linnaeus, 1758)	3 2 – – 2	0-3 + +	+ + –	3 1 –	3	▨		V			
Blicon bjoerkna (Linnaeus, 1758)	3 3 2 – 3	0-3 + +	++ +	3 3 3	3	▨		I			
Carassius carassius (Linnaeus, 1758)	– 1 1 2 1	0-3 + +	+ + +	– – 1	1	▨		R-V			
Carassius auratus (Linnaeus, 1758)	2 3 1 1 3	0-3 + +	+ + ?	2 1 1	2	▨		I			
Chalcalburnus chalcoides mento (Agassiz,1832)	? – – – 1	0-1 * –	– – –	– – –	–		▨	V-E		*	*
Chondrostoma nasus (Linnaeus, 1758)	3 2 – – 2	0-3 + +	+ + +	3 3 –	3	▨		I-V		*	
Ctenopharyagodon idella (Valeneiennes, 1844)	1 1 1 1 2	0-2 + –	+ + +	– 1 1	1	▨					
Gobio albipinnatus Lukasch, 1933	2 2 3 – 2	0-3 + +	+ + –	3 1 –	3	▨	▨	R		*	
Gobio gobio (Linnacus, 1758)	2 2 3 1 2	0-3 + +	+ + +	1 – –	3	▨		I-R			
Gobio kessleri Dybowski, 1862	1 1 – – 1	0-3 + +	+ + –	1 – –	2	▨	▨	R-V		*	
Hypophthalmichthys molitrix (Valeneiennes, 1844)	1 2 – – 1	0-2 + +	+ ? –	– 1 –	1	▨					
Hypophthalmichthys nobiiis (Richardson, 1845)	1 2 – – 1	0-2 + +	+ + –	– 1 –	1	▨					
Leucaspius delineatus (Heckel, 1843)	– 1 ? 2 –	0-3 ? +	+ + +	– – 2	1	▨	▨	R-V		*	
Leucisous cephalus (Linnaeus, 1758)	3 3 3 1 3	0-3 + +	+ + +	3 2 1	3	▨					
Leucisous idus (Linnaeus, 1758)	1 2 1 1 2	0-3 + +	+ + +	2 1 –	1	▨		V-E			*

Table 1/2

Species	**DISTRIBUTION**					**C**	**P**	**Th**	**Bern Conv.**		**Cor B.M.**
	Sz 1 2 3 4 5	II 1 2 3	SI 1 2 3	A 1 2 3	R	Sz	H		**II.**	**III.**	
Leuciscus leuciscus (Linnaeus, 1758)	2 2 1 – 1	0-3 + +	+ + +	2 1 –	2	▨		I-V			
Pelecus cultratus (Linnaeus, 1758)	1 1 – – 1	0-3 + *	+ + +	1 1 –	1	▨		I-R		*	
Phoxinus phoxinus (Linnaeus, 1758)	1 – – 1	0-3 * +	+ – –	– – –	1		▨	V			
Pseudorasbora parava (Temminek et Sehlegel, 1842)	1 1 1 1 1	1 3 + +	+ + ?	– – –	2	▨					
Rhodeus sericeus amarus (Bloch, 1782)	2 2 3 1 2	0-3 + +	+ + +	– 1 3	2	▨		R-V		*	*
Rutilus rutilus (Linneus, 1758)	3 3 3 2 3	1 3 + +	+ + +	2 3 3	2	▨					
Rutilus pigus virgo (Heckel, 1858)	1 1 – – 1	0-1 + +	+ + –	1 – –	?			R		*	*
Parantilus frigii meidingeri (Heckel, 1852)	? – – – 1	0-2 – –	+ – –	– – –	–			R E		*	*
Scardinius erythrophtbalmus (Linnaeus,1758)	– 1 1 2 2	0-3 + +	+ + +	– 1 3	1	▨		V			
Tinca tinca (Linnaeus, 1758)	1 1 1 2 2	0-3 + +	+ + +	– 1 2	1	▨		I			
Vimba vimba (Linnaeus, 1758)	2 2 – – 1	0-3 + +	+ + –	1 1 –	1	▨		I-E		*	
Cobitidae											
Cobitis taenia Linnaeus, 1758	1 2 3 1 2	0-3 + +	+ + +	– 1 1	2	▨	▨	R		*	
Cobitis aurata (Filippi, 1865)	? 1 – – 1	0-2 + +	+ + –	– – –	2	▨	▨	R-V		*	
Misgurnus fossilis (Linnaeus, 1758)	– 1 2 2 1	0-3 + +	+ + +	– – –	1	▨	▨	R-V		*	*
Noemacheilus barbatulus (Linnaeus, 1758)	2 2 2 1 2	1 3 + +	+ + –	– – –	2	▨	▨	R-V			
Ictaluridae											
Ictalurus nebulosus (Le Soeur, 1819)	– 1 1 – 2	0-3 + +	+ + +	– – –	1	▨					
Siluridae											
Silurus glanis Linnaeus, 1758	1 1 – – 1	0-2 + +	+ + +	1 1 1	2	▨		R-V		*	*
Gadidae											
Lota lota (Linnaeus, 1758)	2 2 – – 1	0-2 + +	+ + +	1 1 –	2	▨		R-I			*
Gasterosteidae											
Gasterosteus aculentus Linnaeus, 1758	– – – ? 3	0-1 + –	? + –	1 – –	–	▨	▨	I-R-V			
Cottidae											
Cottus gobio Linnaeus, 1758	3 1 – – –	0-? ? –	+ + –	2 1 –	–	▨	▨	V			
Centrarchidae											
Lepomis gibbosus (Linnaeus, 1758)	– 1 2 2 2	0-3 + +	+ + +	– – 3	1	▨					
Percidae											
Perca fluviatilis Linnaeus, 1758	2 3 2 2 3	1 3 + +	+ + +	2 2 3	2	▨					
Gymnocephalus baloni Holcik et Hensel, 1974	2 3 – – –	0-2 + ?	+ + –	1 1 –	–	▨	▨	V		*	
Gymnocephalus cernuus (Linnaeus, 1758)	2 2 – – 1	0-3 + +	? + +	1 2 2	1	▨		I			
Gymnocephalus schraetzer (Linnaeus, 1758)	2 1 – – 1	0-2 + +	+ + –	1 1 –	2	▨	▨	E		*	*
Stizostedion lucioperoa (Linnaeus, 1758)	2 2 – – 2	0-3 + +	+ + +	2 2 2	2	▨		I-V			
Stizostedion volgense (Gmelin, 1788)	1 2 – – 1	0-3 + +	+ + +	1 1 –	1	▨		I-V		*	
Zingel zingel (LInneaus, 1758)	1 – – – 1	0-2 + +	+ ? –	1 – –	2	▨	▨	E		*	*
Zingel streber (Linneaus, 1758)	1 – – – 1	0-2 + +	+ + –	1 – –	2	▨	▨	E		*	*
Gobiidae											
Proterorhinus marmoratus (Pallas, 1811)	2 3 3 2 3	1 3 + +	+ + +	1 2 3	–	▨		V		*	

Legend: Sz: = Szigetköz: 1 = main channel, 2 = side-arm systems, 3 = irrigation canals, 4 = disconnected backwaters, 5 = Mosoni-Duna. H = Hungary: 1 = other parts of the country, 2 = Danube river, 3 = catchment area of the Danube reach (after Holòik *et al.* 1981): 1 = main channel 2 = side-arm systems, 3 = biotopes outside the floodplain. A: Austrian Danube reach beetwen Vienna and the Slovakian border (after Schiemer & Spindler 1989): 1 = main channel, 2 = connected backwaters, 3 = disconnected backwaters. R = Submontane zone of the Hungarian part of the Raab river. C = collected in the Szigetköz (1983–1993). P = protected by the law in Hungary. Th = threatened in Europe (after Lelek 1987). Bern Conv. II = included in Bern Convention, Appendix II. Bern Conv. III = included in Bern Convention. Appendix III. Cor. B. M. = included in Corine Biotopes Manual issued by the Comission of the European Communities. Symbols: – = absent, + = unspecified, ? = assumed occurence, * = random occurence, 1 = rare, 2 = common, 3 = abundant

Table 2. Comparison of the fish fauna of two Hungarian sub-montane zones

SUB-MONTANE ZONES		
	Szigetköz	**Rába** (above Körmend)
Total number of fish species	65	53
Protected in Hungary	20 (31%)	13 (25%)
Threatened species*	47 (82%)	36 (68%)
Endangered species*	14 (22%)	7 (13%)
Bern Convention App. II.	1	–
Bern Convention App. III.	30 (46%)	22 (42%)
Corine Biotopes Manual	21 (32%)	15 (28%)

Environmental/Ecological Effects of the Gabcikovo-Nagymaros Hydropower Project

Subsurface Waters

1. Introduction

1.1 On the effects of river barrage systems on subsurface waters;-general considerations

Construction and operation of river dams alter water levels, the hydrological regime, sediment movement and, in many cases, water quality. All of these affect those neighbouring subsurface waters which are hydraulically interconnected with the channel flow. These ground waters are mainly found in the alluvial gravel deposits of the rivers. In some situations the ground water is recharged from the river, while in others the rivers drain the shallow aquifers. In particular cases recharge and discharge conditions alternate, varying as a function of the water stage in the channel. In rare specific cases the river is interconnected not only with the ground waters of its own alluvial cone, but also with those of other geologically older formations. In such situations the rivers generally drain the ground water that flows in the older geological formations.

Effects of river barrages on the ground waters of the adjacent area include: alterations of the ground water table and hydraulic heads, changes of the velocity and direction of groundwater flow, modification of the conditions of recharge and discharge and changes of the quality of ground water.

Eventually, ground water table rises in the vicinity of impounded river reaches will occur due to increased recharge from the river. However this effect can be substantially reduced if the deposition of fine sediment particles onto the channel bed results in clogging (colmatation), thus reducing the permeability of the channel bed. Under such circumstances the quality of water recharged from the river might deteriorate, as a function of the chemical composition of the deposited material. Ground water level rise might be sufficiently high in the initial phase when the effect of colmatation is still negligible, that seepage canals (catch drains) must be constructed in order to drain excess seepage waters. However, with the increasing deposition of finer silty particles the rate of recharge of the ground water could be reduced by orders of magnitude. This process might result in substantially reduced exfiltration (groundwater recharge) which in turn could reverse the former rise of the groundwater table, causing groundwater subsidence.

One of the crucial issues of the effects of river barrage systems and river impoundments on subsurface waters is related to the quality and quantity of sediments depositing onto the channel bed due to the reduced flow velocities. The theoretical principles of sediment scour and deposition are relatively well founded, although in practice estimates of sediment behaviour are subject to high levels of uncertainity. However, the combined case of sediment deposition coupled with ex- and infiltration from/into the channel does not even have an agreed theoretical basis. Relationships of sediment movement do not, generally, consider the changes of the rate of infiltration into the channel as affected by the joint effects of scouring and deposition, although it is well known that in the case of intensive water abstraction from bank-wells, the deposition of particles and the clogging (colmatation) of the channel bed can occur even when high flow velocities would have been expected to prevent this process.

In the nineteen-sixties investigations were carried out at the Water Resources Research Centre VITUKI with respect to the questions of channel bed clogging (colmatation) (Starosolszky, 1965, 1966). In these studies colmatation was considered a favourable effect, hindering seepage, and it was found that this process takes place under conditions characteristic of the Danube,s sediment properties.

In the case of bank-filtered water abstraction schemes the fluctuation of river water levels is generally sufficiently high that some infiltration into the river occurs from time-to-time. This can have an effect similar to the wash-back or flush-back process which is applied in the case of man-made slow filters use in water and waste water treatment processes. If this process does not occur in the bank-filtered water abstraction systems problems might arise even in cases when the river flow velocity is considered high enough to prevent deposition. Consequently, if river training measures result in the elimination of this two-way flow pattern, the continuously flow towards the ground water from the river can result in the clogging of the channel bed thus causing deterioration of the hydraulic relationship between the ground water and the river flow regimes.

In places where ground water is hydraulically connected to the river, loss of head of ground waters will occur in areas adjacent to the river channels downstream of the dams and in the case of power canal type arrangement also in the river reaches of reduced flow and water level. Recharge of ground water could cease or even the flow direction reverse along river reaches where the river had formerly been feeding ground waters. In river reaches where the river had been draining ground waters the rate of flow towards the channel might be substantially increased. Along river sections and arms of reduced flow and water stage the above effects might successfully be counteracted by river training methods which reestablish or maintain previous water levels (e.g the construction of bottom dikes). These methods, however, can not be applied successfully in cases where the reduced flow is associated with the deposition of fine particle sediments, which clog the channel bed. This situation is likely to be especially serious at locations where the river had originally fed the groundwater resources. In such river reaches reduced flow velocities might also be associated with the deterioration of water quality of the river and of the pore water of the deposited sediment. Ground water subsidence can, in principle, be counteracted by the construction of infiltration (recharge) canals and basins. Nevertheless, in practice, this solution can give rise to a range of other problems as is clearly shown by the relevant literature. These include water quality deterioration due to colmatation.

The greatest problems related to the effects of river dams on subsurface water resources are likely to be associated with bank-filtered drinking water abstraction schemes and with the changes of the ground water table, with the changes of the water of shallow groundwaters, and with the associated water quality problems.

Along the impounded river reaches, some effects might be positive, since increased recharge from the river reduces the chance of ground water abstraction by wells from the usually more polluted off-river background zones. In periods of low river flow, when background water of worse quality might have been abstracted previously, improved quality of the abstracted water could result. However, negative effects can be expected in terms of the water quality of the impoundments, where deposited silt can induce undesirable changes. Chemically reductive conditions might develop, resulting in the dissolution of iron and manganese and in the increase of ammonium concentrations. Hydrogen sulphide and methane problems might arise and micropollutants could be mobilized under reductive conditions. The situation can be further worsened if dredging disturbs the bottom deposits.

The above problems can also occur in cases where impoundment does not actually increase water levels but maintains the original river water stages at reduced flow rates.

In the case of lowered water stages, along the downstream reaches, the water yielding capacity of bank-wells might be adversely affected as a function of the extent of lowering of water levels. This might be further aggravated by channel bed erosion along the downstream reaches, which could further decrease water stage, especially under mean- and low flow conditions.

Effects on the shallow ground water table and on the water balance of the phreatic aquifer are especially important from the viewpoints of nature conservation, forestry and agriculture, that is from the viewpoint of the water available for vegetation and the ecosystem as a whole. In this context, a sinking ground water table can create the most problematic situation, especially in cases when the vegetation relies, due to the lack of sufficient local precipitation, on the supply of moisture from the ground water resources. In cases where capillary rise does not reach the top soil, the location of the groundwater table becomes irrelevant from this point of view. Excessive rise of the groundwater table can also be problematic, resulting in more soil moisture than desirable and in excess water inundations. Both positive and negative effects on the soil water budget can adversely affect the salinity of the soil, sometimes to harmful extent.

Many literature examples can be cited to illustrate the observed occurrence of such adverse effects. For example:

In Switzerland the oxygen content of water abstracted from a bank-filtered zone adjacent to the reservoir of a hydropower station of the *River Limmat* was decreased to zero, resulting in the appearance of iron and manganese in the abstracted ater. The reservoir is the recipient of the waste waters of Zürich. (Märki, 1971)

Black, typically anaerobic, silt of high organic matter and iron content was deposited on the bottom of the reservoir of the hydropower station of Verboi on the *River Rhone*, resulting in the appearance of high iron and manganese concentrations in the subsurface water (Märki, 1971).

At a reservoir of the *River Aaare* the oxygen content of the river dropped to appr. 4.0 mg/l and the water abstracted from bank-filtered drinking water resources became chemically aggressive with high iron and manganese content *(Schmassmann, 1959).*

In spite of having the humus removed from the filter zone rapid deterioration of the quality of well water was observed at the river barrage *Ybbs-Persenburg.* After one year substantial concentrations of iron and manganese were detected along with increased oxygen consumption and ammonium content and the presence of hydrogen sulfide. Bacterium counts had dramatically increased leading to severe operational problems for the water works *(Weber, 1961).*

In the case of the *Abwinden-Asten* hydropower station of the Austrian Danube reach rapid deterioration of the quality of water produced by the radial bank-wells of the waterworks was observed after the filling of the reservoir. Manganese appeared within a year followed one year later by ammonium and dissolved iron *(Frischherr 1986).*

In the *Altenwörth* reservoir (Danube, Austria) -where 4 million m^3 silt has been deposited over 6 years and the thickness of the sediment layer has reached 6 m- the increased transparency of the water and richer nutrient supply resulted in a 20% increase of biological activity and reduction of oxygen saturation in July to 63% *(Hary and Nachtnebel, 1989).* In the reservoir deposition of sediment particles of moderate organic matter content in the vicinity of the river dam resulted in anaerobic conditions and the concentrations of ammonium, dissolved iron and manganese in the groundwater increased. In respect to deposited toxic heavy metals the present conditions are of no appreciable hazard *(Colley, 1988).*

1.2 Affected zones along the Hungarian side of the river

The Danube reach affected by the Bős-Nagymaros hydropower scheme stretches between Rajka (the border station) and Budapest. Downstream of Budapest the effects are either negligible or indirect.

Flow in the river reach of concern is hydraulically connected to the adjacent ground waters along the full length of the reach.

Following a course downstream, the first affected area is the Szigetköz, the area between the Danube and the Mosoni-Danube. However, the affected area extends beyond the Mosoni Danube to the area between the River Lajta and the Mosoni-Danube, to the area south of the River Lajta and to the area of Hanság as far as the main canal of Hanság. This area has to be subdivided into three parts both with respect to the original conditions and to the effects of the river barrage scheme:

- In the Upper Szigetköz as far as the River Lajta and to the SW from this line the groundwater table has generally not reached the fine upper soil layer (which is missing at many locations), and the effects of the hydropower scheme can be mostly characterized in terms of the rise of the groundwater table;
- In the Middle Szigetköz the relationship between the groundwater table and the top soil is varying and the effects of the hydropower scheme can be characterized by groundwater table subsidence.

- In the Lower Szigetköz, downstream of Szap where the tailwater canal rejoins the River Danube, the groundwater table has generally reached the topsoil and the river barrage system or the diversion of Danube did not alter this situation.

The next river reach further downstream is the one spanning between *Gönyü and Nagymaros.* Along this reach, where at present hardly any effects of the hydropower scheme can be felt, due to the halting of the construction of the Nagymaros dam, the alluvial gravel deposits of the river are of lesser thickness with discontinuities. Between Dunaalmás and Esztergom, the Danube is hydraulically interconnected with the karstic water reservoir of the Dunántúli Középhegység (Middle Mountain Ranges of Transdanubia), a situation that will be discussed below in more detail.

Downstream of Nagymaros, where no impoundment had been contemplated, the effects of the hydropower scheme must be investigated from the view point of the bank-filtered drinking water resources of the Island of Szentendre, as affected by the tailwaters of the Nagymaros dam. Since this latter has not been constructed no observed effects of the hydropower scheme can be mentioned in this context.

1.3 Potential effects of various phases of the construction of the Bős-Nagymaros Hydropower Scheme BNV.

Preparatory investigations aimed at supporting the elaboration of the plans of the hydropower scheme had already been carried out in the nineteen-fifties, mainly in the research centre VITUKI.

Before the elaboration of the Mutually Agreed Plan KET the following studies were made in the field of subsurface waters:

- Prediction of groundwater level subsidence in the Szigetköz (Honti, 1953; Vargay, 1964; Csománé, 1965);
- Hydraulic scale-model studies of seepage (catch-drain) systems of the Szigetköz (Varrók, 1965, 1966);
- Laboratory analysis of colmatation (clogging of the channel bed) (Starosolszky, 1966);
- Investigations into the strengthening of dikes in the Szigetköz (Szilvássy, 1970);
- Investigation of the water budget of the topsoil in the Szigetköz (Major, 1976);
- Investigations of the groundwater basins of Komárom (Varrók, 1966), Esztergom and Pilismarót (Vargay, 1964);

- Investigation of the problems of bank-filtered drinking water resources, caused by silt deposition;
- Investigations into channel changes and sediment movement did not include questions related to groundwater recharge, but provided information for research into this subject (Csoma, 1966, 1967)

In this period VIZITERV carried out the following investigations:

- Effects on the Waterworks of Győr (VIZITERV, 1976);
- Effects of the channel dredging downstream of Nagymaros (Aujeszky, 1966; VIZITERV, 1976)

The original plans of the river barrage system were included in the Mutually Agreed Plan "KET" (VIZITERV-HYDROCONSULT). These plan considered the effects of the project on the groundwater with respect to the following aspects only:

- In the Upper Szigetköz an increase of the ground water table elevation was foreseen due to the effect of the Dunakiliti reservoir. Counter measures were contemplated in the form of catch drain canals.
- In the Middle Szigetköz, where a flow of 50–200 m^3/s was to be maintained in the old channel, ground water table subsidence of several meters magnitude was foreseen. Irrigation was planned to alleviate the adverse effects of this subsidence. The construction of bottom-dikes in the abandoned Danube channel was also contemplated along with the additional supply of water to the floodplain and to the protected side of the flood levee. However,specific plans for this latter solution had not yet been elaborated at that time.
- The plans did not consider at that time the problems of diminishing water recharge into the valuable potential subsurface drinking water resource of the gravel formations of the Szigetköz. An earlier study (1976) by the responsible planning agency VIZITERV did not consider the effects of the river barrage project on the operation of the waterworks in the vicinity of Győr to be harmful.
- For the impounded Danube reach between Szap and Nagymaros the Mutually Agreed Plan KET considered the increased exfiltration from the River Danube, only from the view point of preventing excess water inundation.
- Loss of capacity of the wells of the Island of Szentendre, abstracting water from the bank-filtered resources, was foreseen

by KET, due to the effects of the planned dredging operations along the tailwater reach of the Nagymaros dam.

On the basis of the above considerations it can be stated that the KET did not deal with the effects on subsurface water resources to a satisfactory extent, in spite of the fact that the importance and location of the already utilized and potentially utilizable bank-filtered drinking water resources was well known even at that time. Although the need for relevant investigations and remedial measures had been briefly mentioned, these were to be considered later among the national tasks.

In the period *1977–89* several studies dealt with the above mentioned problems:

The following investigations were carried out at the Water Resources Research Centre VITUKI:

— Groundwater level changes of the Szigetköz were forecast by a two-dimensional numerical computer model assuming quasi-steady flow conditions and by taking local seepage resistance into consideration too (Székely, 1977);

— An analogue model was used for studying the effectiveness of the Dunakiliti seepage canal (catch-drain) and of the infiltration (recharge) system (Varrók, 1978; Ujfaludy, 1979; Haszpra, 1979, 1983; Ujfaludy, 1984). Nevertheless the problems related to channel clogging, maintenance-type dredging and water quality were only mentioned and not evaluated, and anisotropy was only considered by estimated values. However infiltration field experiments were also carried out (Ujfaludy, 1985)

— Investigations of the water quality conditions of waterworks relying on bank-filtered drinking water resources (László, 1981). Estimation of the expected quality of Danube water was dealt with in several studies (Hock, 1985; László et al., 1987);

— The relationship between the river and the karstic reservoir system was studied for the vicinity of Dunaalmás and Esztergom (Lorberer, 1987–1989)

— Effects of the hydropower scheme on subsurface waters (Szabóné, 1985).

— Research related to the topsoil in the Szigetköz (Hutyán, 1985; Vargay, 1985), and to channel changes and sediment movement (Rákóczi, 1985, 1986, 1988; Bognár, 1987–89; Kornisné, 1986; Laczay, 1987-89) also provided information for the understanding of the problems of subsurface waters.

- This was the period when researchers (Ujfaludy, 1988) started to consider subsurface water quality problems of and surveyed the agricultural and other local sources of pollution in the Szigetköz.

The Hydraulic Design Company VIZITERV also carried out several investigations related to bank-filtered water resources in 1978 and 1984. The problems of channel bed clogging (colmatation) were mentioned, but "fine" dredging was considered an efficient tool in solving these problems.

- In 1981 a study by VIZITERV, related to the regulation of the ground water table, had been dealing primarily with the relationship between ground water, agricultural production, floodplain forests, nature- and landscape protection, and flood defence. Ground water regulation (recharge) was proposed by making use of the water (50 m^3/s) delivered by the catch-drain canals that surround the upper reservoir with the help of seepage (infiltration) canals to be constructed in the floodplain and in the protected side of the flood levee. However this study did not deal with the problems of colmatation (clogging of the bottom of infiltration canals) and neither with the potential related water quality problems. The potential value of the water resource of the gravel formations of the Szigetköz, as a drinking water resource, was not considered either.
- The Budapest University of Technology also started to study subjects related to seepage hydraulics in this period.
- Attention had been drawn to the potentially harmful effects of the Hydropower project on subsurface waters, starting in 1983, first of all by M. Erdélyi, with special respect to the Szigetköz area and to the Dunántúli Középhegység (Middle Mountain Ranges of Transdanubia). These studies were, however, professional publications only, being independent of the official reports. Some of the more important statements of these studies will be referred to below:

In 1979 a publication by Erdélyi pointed out, with respect to the effects of the hydropower scheme on the Szigetköz, that: ".As the result of the contemplated construction works the connection between the main channel and the gravel formations will be weakened and that of the side river-arms will be practically terminated. This 32 km long reach of the main channel is the most important recharge section for the ground water resources of the thick gravel basin of Gyúr. Today ground water resources are being refreshed in the down-gradient direction until the area of Hanság. As a result of the contemplated construction project the recharge into the groundwater storage basin will be substantially reduced, narrowing down the zone receiving recharge substantially too.

The ground water table will fall over a substantial area. Many plant cultures might be degraded or can be maintained by irrigation only. Due to intensified irrigation leaching of pollutants such as fertilizers might be expected to increase, since the vast coarse-particle basin of the Kisalföld is without any natural protection, and has neutral hydraulic head conditions. The highest danger is associated with nitrate leaching and downward penetration.

With the decrease of natural seepage flow velocities, deterioration of water quality might be also expected. This qualitative deterioration might be further aggravated, independently of the effects of the hydropower project, by the leaching of fertilizers, pesticides and other pollutants originating from household sewage and large-scale animal husbandry".

"It is likely that the largest subsurface drinking water resource of the nation is found in the gravels of the Kisalföld basin. A resource of similar value is found in the southern Tisza river depression only. The coarse-particle formations of the Győr Basin have a total volume of 21.8 km^3, 95% of which is gravel and rough sand. Calculating with 25% porosity the volume of water stored there amounts to 5.43 km^3.

In 1983 Mr. Erdélyi has again urged investigations into the identification of problems related the hydropower scheme:

"The concept of the Bős (Gabcikovo)-Nagymaros river barrage project is more than 30 years old. During these three decades many changes have occurred in terms of both the natural environment and the national economy. It is timely to investigate whether the original concept should be revised whether it is outdated or not and if so to what extent? Are the priorities of the objectives the same as originally se, namely: navigation, power generation, which were only then followed by the triple interrelated objective of agriculture, water supply and environmental protection?"

He considered the role of the contemplated complementary water supply scheme to the side river arms a positive one:

"Water supply (to the side arms) of increased rate and longer duration would be the most valuable for the refreshment and cleaning of ground water resources if by regulating the side arms they had also served for recharging the ground waters. In this way the channel surface that had been available before the river regulation for recharge could be reestablished, offering the largest possible surface for recharging during the shortest time large volumes of water into the gravel".

- In 1983 the Hungarian Academy of Sciences had been dealing with the scientifically disputed issues of the hydropower project BNV. It drew attention to the urgency of investigation of issues related to the hazards of pollution of the River Danube and to those threatening the drinking water supply of Budapest, which relies predominantly on bank-filtered drinking water resources. Preparation of an appropriate environmental impact assessment was proposed.
- In 1985 VIZITERV prepared a document on "the Environmental Impact Assessment of the Gabcikovó-Nagymaros Hydropower Scheme". The impacts on subsurface water resources were investigated from the point of view of the Szigetköz area, the Szap-Nagymaros Danube reach and of the karstic storage reservoir of the Dunántúli Középhegység. The need to protect both utilized and potentially utilizable subsurface drinking water resources was also mentioned in this material. The document underlines the problems existing along the Danube reach of concern, discussing the conditions prior to the establishment of the hydropower project. The potentially harmful effects of the hydropower scheme on subsurface water resources are considered, in this material, were to be either negligible or easily eliminated. Positive effects have also been mentioned as follows: The increase of the Danube water level was considered as a phenomenon counteracting colmatation. Groundwater levels were to be regulated later, -to an extent which would be better than the previous conditions-, by artificial drainage and infiltration systems.

With respect to the quality of surface water recharging subsurface waters, to channel bed alteration and in this context to the qualitative and quantitative conditions of water discharge into the ground water bearing formations the impact assessment did not go into sufficient detail (among other aspects it did not consider the partial results of the Kisalföld Research Programme of the Hungarian State Geological Institute, which were available at that time). The investigation into the impacts of ground water level changes on agriculture and forestry can be considered a well founded one.

- In the framework of an exclusive round-table conference the Hungarian Academy of Sciences made a statement, in 1985, on the content of the above mentioned impact assessment. With respect to subsurface waters the following statements were made:
    - the water yielding capacity of the bank-wells of the area surrounding the Nagymaros reservoir will decrease due to the effects of silt deposition. It must be counteracted by regular dredging,
    - unified environmental monitoring network should be established in order to be able to quantify the changes expected.
- It was also of relevance to subsurface waters that the document considered the possibility of inundating the floodplain forests of the Szigetköz. Another issue of relevance was the consideration of an improvement of the water quality of the River Danube and the reduction of pollution loads, prior to the construction of the dams.
- A report of the Hungarian Academy of Sciences to the Council of Ministers, in 1988, considered already the possibilities and consequences of not building the Nagymaros dam. Among the reasons the risks of pollution of bank-filtered groundwater resources, the loss of potential bank-filtered water abstraction capacities are mentioned.
- In the period following the preparation of the impact assessment study many such investigations were carried out, the results of which should have been available well before making the Mutually Agreed Plan KET (such as studies on surface water quality, sediment transport, supplementary water conveyance into the side-arms of Szigetköz, subsurface drinking water resources and the situation of karstic waters). In 1989 there were several questions still open, due to inadequately coordinated research in various fields and to the lack of a unified systems approach. Recognizing this a large research project to model all of the above mentioned processes, including subsurface flow and transport, had been initiated with the main tasks to be undertaken by the research centre VITUKI in close cooperation with, and supervision (and also financial support) by IIASA (the International Institute for Applied Systems Analysis,

Laxenburg, Austria) (Szöllősi-Nagy et al. 1989). Although the project was launched by the Hungarian party with a major effort, resulting in a preparatory study of seven volumes, which reviewed all former research results of the related fields, this large-scale project was never completed, due to reasons beyond the control of the research institutions involved. In the 3rd volume of the above mentioned preparatory report (Szöllősi-Nagy, Székely and Ujfaludy, 1989) the following considerations, related to the quality of subsurface waters of the Szigetköz, were made:

"Even if we make the unrealistically optimistic assumptions that

= the water quality of the reservoir will not be worse than that of the River Danube now, and that
= the recharge rates of the artificial infiltration system will not be reduced by channel clogging (colmatation), and that
= the quality of water recharged will not be worse than that of the Danube water now, and that
= the use of agricultural chemicals and the extent of pollution by communal wastes will not significantly deviate from the present circumstances, and that
= the reservoir will not operate in peaking mode,

even then we must take substantial changes of the present groundwater quality conditions into consideration. Namely, upon the effect of the operation of the hydropower scheme the groundwater flow will be substantially altered; flow pathways and their length will be altered"

"The only chances of improving the groundwater quality are
= the securing of more rational use of agricultural chemicals and
= the removal or reduction of communal pollution loads"

The authors further stated that
= The effects of the planned drainage system will be favourable along the Danube reach between Győr and Nagymaros;
= the impoundment will have some favourable effects on the bank-filtered drinking water resources: "the safety of water supply will be increased from the quantitative point of view" and "contamination from the polluted background zone will be reduced, since the ration of groundwater flow from the background towards the bank-wells will be decreasing". Nevertheless bottom deposits of rather uncertain thickness, particle size and chemical composition will "increase the

  clogging of the channel on one hand", and "can deteriorate the quality of water produced by the wells"
  - In the case of the karstic ground water reservoir in the vicinity of Esztergom the "additional exfiltration from the Danube" will be increased, by the year 2000, by 30%" and "the deterioration of karstic water quality must be taken into account at certain locations";
  - Along the Danube reach downstream of Nagymaros one must, in any case, consider substantial changes of the quantity and composition of sediments, which ,-along with further changes of water quality of the River Danube-, might further modify the quality of water of the bank-wells"

- Due to the above mentioned reasons, and associated with political changes, the Government of Hungary suspended the Nagymaros construction project in May 1989 and ordered the acceleration of additional special studies (in the fields of biology, hydrology, sewage treatment, seismology and environmental protection) along with the estimation and evaluation of the risks involved. In August 1989 the Government Commissioner of the BNV project had decision support material prepared. Following this an independent expert committee prepared a report for the Council of Ministers (September, 1989) in which the expected harmful effects on subsurface waters played a decisive role: hazards to existing water works (relying on bank-filtered drinking water resources), to the potential water resource of the gravel formations of the Szigetköz (mainly from the view point of qualitative deterioration), to the ecosystem as a whole and to the ground water regime were emphasized. Nevertheless, the document did not prove, in terms of detailed research results, the magnitude or probability of the mentioned potential hazards and damages. It mentioned, that risk analyses carried out up to that time could not be considered as to be of sufficient detail or scientific basis, since monitoring data were not available for all relevant issues (while there were possibly too many observation stations of near surface ground water established). With respect to subsurface waters it is of significance that the Committee did not consider the damming of the river an acceptable solution, owing to the lack of appropriate waste water treatment. Due to the expected environmental hazards and risks the committee suggested that the optimum decision was to terminate all construction works of the BNV project once for all. The committee also suggested that the channel-closure of the Dunakiliti-Körtvélyes reservoir be suspended until an appropriate ecological guarantee was obtained and until the optimum operating rule of the Bős hydropower station was defined. This issue also has relevance to the question of subsurface waters.

- Investigations related to problems of subsurface waters were also continued in 1989 (László and Páczayné, 1989; Motyovszky, 1989; Lorberer and Csepregi, 1989; Bognár, 1989; Laczkó, 1989)
- In 1990 the Bechtel Consulting agency of San Francisco considered "the general methods aimed at the prevention of the effects of harmful changes of the subsurface flow regime" appropriate ones and made proposals for local modifications on the basis of more detailed monitoring data.
- In 1990 Erdélyi raised again the question of the relationship between the river barrage system and the subsurface waters. He stated that after having the Bős hydropower station constructed, the following situation will be encountered:

"Recharge of ground water will be almost completely terminated. The Danube section, disconnected from the main river by the power canal, will lose its groundwater regulating function, which will be taken over by the side-arm system only" He foresaw some problems related to the contemplated artificial ground water recharge system:

"The self-purification capacity of Danube will decrease, although it is of substantial significance from the point of view of drinking water supply on the downstream side (also for Budapest)

The potential for utilizing appr. 1 million m^3 drinking water resource along the Danube reach of the Szigetköz, will be lost." "Seepage water from the Dunakiliti reservoir of 35–40 m^3/s, to be utilized by the artificial recharge (infiltration) system, will not cause any favourable changes, since most of this water will be gravitationally conveyed by the gravel after the considered loss of hydraulic head.

Channels of the side-arm system will mostly form the elements of this ground water recharge scheme. It is questionable whether or not this system will be able to maintain the contemplated recharge rate, whether the clogging of the channel beds would occur at the smaller slope and flow velocity conditions, after having the side arm channels regulated, and whether or not flow intrusion from the polluted background zones would cause the quality of the ground water resource to deteriorate?"

- In 1991 the study on "the probable effects of the Nagymaros dam on the microbiological and biochemical dynamics and water quality of Danube" (Szabó I.M., 1991) raised many disputes. This issue also relates to subsurface waters. In discussions several experts (Várday, 1991) and other authors (Várday and Tevanné, 1991) judged these anxieties to be exaggerated, but the dispute made decision makers even more uncertain.
- After the government decision mentioned above, problems of subsurface water resources have also been discussed at international Czech-Slovak-Hungarian negotiations. Solution to these problems were to be found by the joint expert committees (Intergovernmental negotiations on the 2nd of December, 1991). Subsequent intergovernmental negotiations and correspondence were inefficient in finding solutions, the Czech-Slovakian partner did not halt the construction works and wanted to carry out the contemplated investigations on the hazards involved during the period of construction and operation, with the support of the EC. In this period the Slovak party launched large-scale investigations, supported by PHARE, related to the modelling of subsurface waters. The Danish Hydraulic Institute DHI assumed a significant role in these studies (its expert participated from EC,s part in the subsequent negotiations). The results of these investigations, to be completed by 1995, have already proved the potential risks of damage to subsurface waters if the original plans of the hydropower scheme were implemented; in order to protect the waterworks of Somorja (Samorin) additional measures had to be taken to change flow pattern of the reservoir.
- Between 1989 and the summer of 1992 there were no investigations of appropriate detail into the problems related to the hydropower scheme and neither were joint projects carried out. However there were some achievements in three fields:
    - Further plans were made to find appropriate solution for the artificial recharge (infiltration) system (ÉDUVIZIG, 1989-92) although they have not been finished; the questions of colmatation (channel bed clogging) that might be expected upon prolonged recharge through the channel bed of the side arms still remains still open, along with those related to water quality deterioration;
    - Under a contract with Hungarian Academy of Sciences, detailed investigations were carried out into the state of the environment in the Szigetköz and the ecological requirements. Investigations of subsurface waters were part of this project (MÁFI 1991; Somlyódy et al. 1992). These investigations considered conditions without the existence of

the river barrage scheme and were expanded only after October 1992, after the diversion of Danube, to include conditions affected by the river project. Preliminary results of these investigations have influenced the subsequent decisions related to the river barrage project. In 1992 an *ad hoc* committee of the Hungarian Academy of Sciences prepared a Statement on the ecological risks of the Bős Hydropower Scheme, taking research results of 1991 into consideration. Statements from this study, with relevance to subsurface waters, are cited below:

"Due to the special hydrogeological conditions of the Szigetköz harmful substances, getting into the ground water, will in the course of time, during a few decades, completely pollute the subsurface water resource. Furthermore contemplated dredging of accumulated silt will not only deteriorate the quality of surface waters, but by completely removing the filter layer it will open the way for the intrusion of micropollutants and microbes into the ground water too."

"The artificial recharge system aimed at the counteraction of groundwater subsidence along the abandoned Danube channel downstream of the Dunakiliti dam will also cause, due to the inflowing raw water and also of the state of the side-arm channels which are prone to colmatation, the qualitative and quantitative deterioration of the full water resource stored there."

"In order to be able to save the function of the channel bed with respect to organic matter decomposition and filtering the present dynamics of Danube should be preserved. Without this one can not ensure simultaneously appropriate oxygen supply, favourable self purification properties of the Danube and regular renewal of the channel surface which acts as a filter layer"

"Along the Danube reach in the vicinity of Budapest there were several possibilities for investigating the effects of various river training and industrial gravel dredging operations on the conditions of drinking water production, as the country,s largest bank filtered drinking water resources are found in this region".

"According to the results of chemical, bacteriological and hydrobiological investigations the water quality (of bank-wells) was non-objectionable in periods preceding the onset of dredging operations. During and after dredging, algae, iron, sulphur bacteria, coli bacteria, streptococcus and Pseudo-monas pollution incidents were frequently detected."

"In areas with groundwater table subsidence the mineralization of plant residues is accelerated, the organic material content of the soil is decreased, the soil structure deteriorates and the danger of leaching plant nutrients from the soil is increasing. The capillary water supply to the root zone will be terminated in places, due to ground water table lowering, from the fine cover layer to the underlying gravel formations. As a consequence of this the yield of cultivated plants and the safety of crop production will be substantially decreased, the drought sensitivity of the area is increasing, the supply of water to the forests will also change and the presently interconnected floodplain communities will be split into independent patches; the organic matter production of plant communities will be decreasing."

"In places where groundwater levels are rising anaerobic processes become dominant, the danger of excess water inundation is increasing in areas with poor natural drainage conditions"

— The Committee of Water Management Sciences of the Hungarian Academy of Sciences (March-April, 1992) took a contradictory standpoint to that of the *ad hoc* Committee, also in the field of subsurface waters. The "Opinion" on the Statement of the *ad hoc* Committee of MTA (March, 1992) refers to the impounded Danube arm, the Soroksári Danube arm, as an example not verifying the above raised anxieties (actually here the conditions of bank-filtration are much more unfavourable, in terms of both quality and quantity, than in the Szigetköz or at the Island of Szentendre). Discussing bottom deposits and damages to the filter zones the study states that:

"Potential damages to the bank-filtered water production can be avoided by continuously "fine"-dredging the bottom silt or by gravel dredging concentrated at certain locations of the reservoir"

The same is repeated in relation to the planned artificial water supply and recharge system:

"If channel bed clogging affects recharge into the groundwater to undesirable extent, the clogged layer can be removed by dredging"

The opinion of the Committee for Water Management Sciences of the Hungarian Academy of Sciences, formulated in April 1992 in relation to the Bős Hydropower station and to "Alternative C" assigns less significance to the water resource of the gravel complex of the Szigetköz:

> "In this area less than 1% of the population of the country receives water supply from these resources. The National Water Management Master Plan did not make any proposal for the long term utilization of this water resource, since exhausting of the Nation,s drinking water resources is not expectable. The geographical location of the area renders, as a matter of course, the conveyance of water via water mains over long distances uneconomical".
>
> The above quotation proves that there were substantial uncertainities in judging the long term significance of these water resources.

In May 1992 the Government of the Republic of Hungary issued a statement on the termination of the contract of 1977. Parts of this statement relevant to subsurface waters include the following:

> The most significant drinking water resources of both Hungary and Slovakia can be found along the Danube reaches affected by the Bős-Nagymaros project. Almost 45% of Hungary,s total drinking water production originates from the bank-filtered drinking water resources affected by the Bős-Nagymaros Hydropower Scheme. Budapest has been supplied with drinking water for more than a century from these resources and similarly Pozsony (Bratislava) relies on the same type of drinking water resources. Most of the natural filtration processes take place in the upper few cm of the channel bed. Consequently it is a question of crucial importance to secure conditions which preserve the original state of this biologically active layer which provides physical-chemical filtration as well.
>
> The quality and quantity of water stored in the alluvial gravel cone of several hundred meters thickness of the Csallóköz-Szigetköz area are also determined by the filtration properties of the Danube channel bed. Human interventions associated with the river barrage scheme have not yet affected this continuously recharged water resource. Therefore approximately 40 km and 70 km long river reaches are available respectively in Slovakia and Hungary as drinking water reserves for later utilization, as was indicated by the results of detailed water quality and hydrogeochemical surveys. These potential resources represent for Hungary a drinking water production reserve of approximately 1 million m^3/day (being of the same order of magnitude as the present rate of drinking water supply of Budapest), and it could provide 2 million m^3/d water supply, on a continuous basis, for Slovakia. Upon the effects of the

> Dunakiliti reservoir substantial changes will occur in these resources. The most significant problem will be associated with the deposition of contaminated silt which results in anaerobic conditions and in the dissolution of iron and manganese, as well as in the infiltration of certain toxic substances. The bottom sludge will create, at the same time, permanent hazard of infection by viruses.

In relation to the effects of the Dunakiliti dam the text of the Statement is the same as that of the ad hoc Committee of the Hungarian Academy of Sciences. With respect to the lack of investigation results it states, that;

> "The extent of pollution of the groundwater resource of the Szigetköz can be but roughly estimated due to the lack of detailed long term hydrological and water quality investigations in the past.
>
> It is to be noted that the above outlined opinion of Hungarian researchers are identical with those of the Slovak experts, as expressed in their final report of February 1990. Very similar conclusions, in respect to the lack of investigations, have been drawn by the Canadian firm Hydroquebec, which was invited by the Slovak Government for consultation in the fall of 1990.
>
> Just before and after the diversion of the Danube in 1992 investigations were accelerated but they focussed mainly on the changes caused by the river diversion. Due to the relatively short duration of these investigations they can not be considered complete, although their results would be very much needed for supporting the tripartite negotiations that have been launched in the meantime (in preparing this document, which will form part of the records of the court case of Hague, increased difficulties were faced, since areas outside the Szigetköz have not been lately dealt with at a level similar to that of the Szigetköz studies)."

1.4 Development of the monitoring system of subsurface waters

In accordance with the proposals for environmental impact assessment VIZITERV prepared, in 1985, a plan for the environmental monitoring system, which, with respect to subsurface waters, meant the operation of the existing groundwater level and quality observation system of wells and the expansion of the network (VIZITERV, 1986; Mantuano, 1988)

In the nineteen-fifties approximately 200 observation wells were in operation along the Danube reach of concern, most of which formed part of the national hydrographic network. In the period 1980–86 additional wells were established in the Szigetköz and later downstream of Gönyü. Some 600 wells were drilled and this proved later to be more than was needed. In 1991 more than 100 wells were excluded from the network and subsequently the number of wells used has further decreased. Evaluations were prepared by VIZITERV also in 1987-88, dealing also with the quality and quantity of subsurface waters. Evaluation of the period of 1986–1992 was made on the basis of data of 150 selected wells, since these wells had long and reliable records. Some of the wells were equipped with data loggers, but good records were available for only those wells that are operated by the State Geological Institute MÁFI. The Budapest Waterworks has its own monitoring network on the Island of Szentendre. Water quality changes of the wells of the Budapest Waterworks were monitored at 200 wells.

With respect to deeper wells the records are less complete. 13 piezometer wells of VIZITERV and 3 deep wells of MÁFI were monitored but this provided insufficient number of data. VITUKI has proposed the extension of the monitoring system several times (Liebe et al., 1993). With respect to water quality the monitoring system should be expanded with regular water quality observation of the production wells. At the present there are nearly 50 production wells in the area of concern assigned to the subsurface water quality monitoring network.

The greatest problem is related to the inappropriate evaluation of the data of the observation network. Even the faulty data have not been screened out in due time.

2. *Summary of knowledge of subsurface waters and the impacts upon them*

2.1 The Szigetköz and its adjacent areas

2.1.1 Hydrogeology of the area

The Szigetköz is located on a plain which is formed by the Quaternary alluvial cone of the River Danube. It is bordered by the main channel of the Danube and the Mosoni-Danube and thus the area is actually an island of 52 km length and 7–8 km average width with an area of 375 km^2. The alluvial cone of the Danube extends far beyond the Szigetköz and includes areas north of Danube called the Csallóköz, partial areas lying to the W and S of the Mosoni-Danube, the area between Mosoni-Danube and the River Lajta, and parts of the area called Hanság. In this study we will be dealing with areas south of the River Danube only.

A sandy, clayey complex, storing thermal waters at larger depth, underlies the alluvial Quaternary formations which reach a thickness of 700 m at some locations. The effect of the river barrage system on these underlying deep layers is not considered to be significant and thus will not be discussed in detail.

The Quaternary complex, consisting of rough clastic formations, was first described in 1938 and river morphological, hydrological and hydrogeological studies were undertaken in the nineteen-fifties. More detailed hydrogeological evaluations were prepared in the early seventies. Geophysical studies of the thirties dealt mainly with the deep structural aspects. Geological knowledge of the Quaternary coarse clastic formations was rather sparse until the eighties and corresponded to the near surface zone only. Larger research projects, upgrading knowledge significantly, were launched in the eighties and nineties only, -that is after acceptance of the plans of the BNV project-, (the Kisalföld research programmes of the Geophysical Research Company, the Hungarian National Geological Institute and of the Eötvös Lóránd Geophysical Institute as well as programme DANREG which combined the Austrian, Slovak and Hungarian geological research results of this area). These programmes provided hydrogeological information, in addition to an improvement of geological knowledge. From these, significant information was provided in the framework of the Kisalföld Research Programme on the basis of water level observation data from wells drilled as part of the programme. These gave complementary information to the data of the earlier monitoring network which corresponded to the shallow formations only.

The upper part of the Quaternary alluvial cone consists of rough clastic formations: gravel, and gravel with medium- and rough sand. The depth of this layer reaches 250 m in the middle of the Szigetköz. The hydraulic conductivity varies between 20 and 300 m/d, with the average value of 150 m/d. The layer which had been considered homogenous one was later found to be anisotropic. The coefficient of anisotropy was estimated first as 4 then later corrected to 10. In reality one faces an inhomogeneous aquifer system, created by alluvial deposition, in which zones of good permeability provide hydraulic connection along complicated spatial pathways.

The alluvial complex is covered by a top layer of finer particles of 0–5 m depth. This layer is missing at some locations, especially in the Upper Szigetköz. The hydraulic conductivity of the top layers is estimated to be in the range of 0.02–1.00 m/d. The hydraulic conductivity of the cover layer in the floodplain was determined by *in situ* experiments, obtaining values in the range 0.08–0.4 m/d *(Újfaludi, 1986)*. The top layer was formed by the silty deposits of the floods of Danube, flowing along the ridge of the alluvial cone, and of those of the side river-arms. The surface of the alluvial cone and the pattern of the interwoven channel system have been continuously changing over the course of time. Channel regulation, started at the end of the last century, and the subsequent river training activities has substantially affected these recent geological processes, but could not halt them. Due to the confining of floods the accumulation of fine sediments has accelerated over much of the floodplain and ceased on the protected side of the flood levees. High discharges of Danube were flowing at higher levels, due to the confinement by the flood levees, while the low flows were associated with smaller water levels in the Upper and Lower Szigetköz, due to the deepening of the channel. These effects can be observed in the variation of the adjacent groundwater levels.

The Danube, having suspended channel, has always been, even before the river regulation, the main supplier of water to the aquifer of the Quaternary gravel complex. The infiltration of precipitation water has been generally insignificant in comparison to the recharge from the river. Hydraulic connection takes place mostly through the well washed gravel channel bed of the main river, while less water infiltrates over the flood plain and across the mostly sediment clogged channel beds of the side arms. According to research results the overall rate of recharge of the aquifer along the Danube reach of the Szigetköz amounts to 8–10 m^3/s. The groundwater table has a slope of 0.3–0.5 m/km towards S-SE of the Danube. Groundwater levels, slope and the direction and velocity of flow vary as a function of the water stage of the river. Groundwater levels show close correlation with the water regime of the River Danube, which also holds for the water levels of deeper wells. This effect diminishes with distance from the Danube. Depending on the distance from the river the response of the groundwater to the changes of water level of the river has a time lag of 1–8 days, but the full effect will take place after several months only.

Water originating from the Danube can be identified (on the basis of tritium and oxygen 18 isotope studies) at several hundred meters depth and also beyond the Mosoni Danube. This latter indicates that the Mosoni-Danube taps the groundwater flow only partially and the rest of the flow proceeds towards the Hanság, where it is drained by smaller canals, and by the River Rábca. This is the characteristic situation also in the south-eastern parts of the Lower Szigetköz, where waterworks are tapping the flowing groundwater. On the basis of tritium investigation the actual flow velocities vary between 250 and 400 m/year. Propagation of tritium concentration peaks which occurred in the River Danube in the early sixties was analyzed by the tritium method in the groundwater and it was found that the peak today (thirty years later) has reached the middle of the Szigetköz, 5–10 km from the Danube. Flow velocities are the highest at 50–100 m depth. Using another isotope method, the 180 method, it was found that Danube water has flushed the entire gravel complex of the Szigetköz, and moreover can be traced in the groundwater as far as areas south of the Mosoni-Danube and in the Hanság.

The quality of water in the gravel complex is good, suitable for drinking water supply. Knowledge of water quality and flow velocities has been significantly updated by research carried out in 1991/92 under a contract with the Hungarian Academy of Sciences. According to the results of isotope investigations the water of the several hundred meters thick gravel formation of the Szigetköz originates entirely from the River Danube. In spite of this it is desirable to investigate the quality of the upper 20 m deep water layer separately from those of the deeper water layers, since human activities of the area mostly pollute the near surface ground water as indicated by locally identified quality problems at several places.

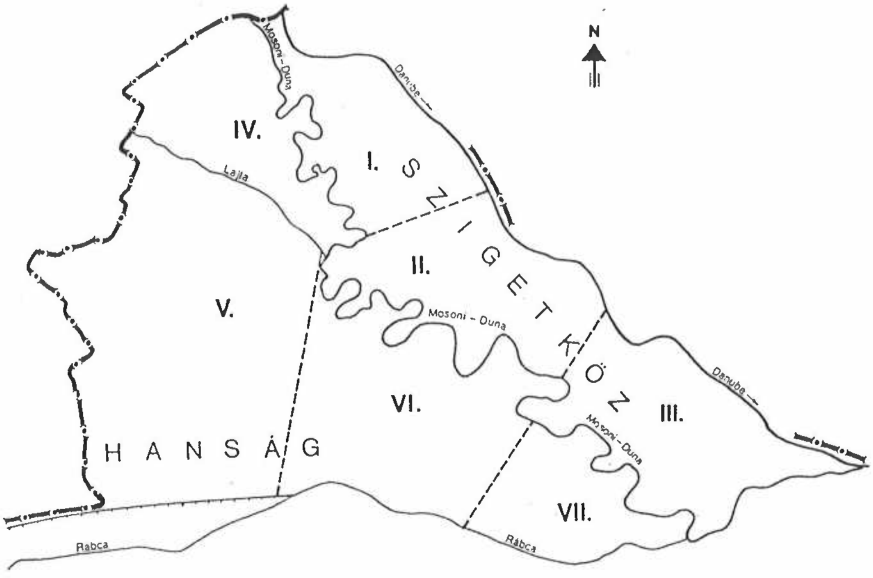
Evaluating the water quality data of water samples taken from 84 wells of the monitoring system, with respect to the quality of the upper 20 m deep layer, it is found that the concentrations of the most important quality constituents vary over wide ranges, but drinking water standard values are violated by iron, manganese and ammonium only. The relatively high average values are due to the data of a few wells only. Excessively high ammonium concentrations originate from direct local sources of pollution: open fertilizer storage, effects of animal farms, etc.

The quality of the water of layers deeper than 20 m has been regularly measured in the wells of the monitoring system. Due to sampling problems, however, these data are not suitable for the characterization of the quality of deeper aquifers. Consequently the data of 76 production wells have been used for evaluation. The quality of water of those layers of the gravel complex of the Szigetköz which are deeper than 20 m is excellent *(Table 1)* with the exception of manganese and iron in some of the wells. Even iron and manganese remain below drinking water standard values, with the exception of a few data. Nitrate is of uniform distribution. Its concentration nowhere exceeded half of the limit value (20 mg/l) in the deeper layers, and moreover it remained below 10 mg/l in the water of 90% of the samples examined. Nitrate and ammonia concentrations of samples taken from monitoring and waterworks wells did not exhibit any rising trend, which would have indicated continuing pollution. Moreover the water quality of certain wells was improving (for example in the water of well No.K1 of the Révfalu Waterworks iron content decreased from the original 3–4 mg/l to 2–2.5 mg/l during the period of 1984-90, then dropped to 1 mg/l by 1991/92. The ammonia level of the water of well No. 9/E of the Kisbajcs-Szőgye Waterworks has been continuously decreasing from the original 0.6 mg/l to the present 0.2 mg/l value).

In the neighbourhood of Szigetköz the dissolved solid content of the water of layers deeper than 20 m, which receive only partial recharge from the Danube only, is higher than that of the Szigetköz. *It is mostly characterized by the substantial increase of ammonia, iron, manganese, hydrogen carbonate and sodium as well as by that of conductivity. This might be caused by blending with the water that is rising from the deeper confined Pannonian layers. This is supported by the results of isotope investigations which indicate that in the vicinity of Szigetköz 25% of the groundwater stems from local infiltration, while 20% originates from the deeper Pannonian layers.*

Evaluating the above results with respect to their areal distribution it can be stated, although with reduced reliability due to the relatively low number of data, that in layers deeper than 20 m

- water of the best quality is found in the Upper Szigetköz (I),
- further towards the Lower Szigetköz (III) the quality of water is deteriorating (iron, manganese, ammonium), but in the Middle Szigetköz the quality is still good (II), with the exception of locally high iron content;
- in the area between rivers Mosoni-Danube and Lajta the water is generally of good quality, with the exception of higher manganese concentrations of a few wells. Nitrate attains the



INVESTIGATED SUBAREAS OF SZIGETKÖZ REGION

Fig. 1

highest values here, but nowhere exceeds the drinking water standard;

— in the area south of the River Lajta (V) the quality of water is similar; in the Hanság (VI–VII) nitrate is low but high manganese and iron concentrations are found.

The quality of groundwater of layers less deep than 20 m is extremely variable with differences of several orders of magnitude. The best water quality (in terms of ammonium, iron and manganese) is found in the western parts (IV–V) where flow rate is the highest of the water bearing layers of coarse particle size and good hydraulic conductivity. In the shallow zones nitrate concentrations are higher than half of the drinking water standard. The highest values are found in the western parts, due to the lack of the top cover layer (Figure 1)

In 1991 the Hungarian State Geological Institute carried out ground water surveys in the vicinity of the main Danube channel and the side river-arms. The results of chemical analyses unambiguously verified the Slovak findings (Mucha et al., 1992), according to which the water exfiltrating from the Danube through the gravel preserves its oxygenated character, thus securing good water quality in the case of the present water quality conditions of the River Danube. However,in areas, where the exfiltration occurs through silty layers of high organic matter content (for example in the side river-arms) reductive conditions are created due to the decreasing dissolved oxygen content of the groundwater. A consequence of this is the remobilization of iron, manganese and toxic metals of the aquifer, associated occasionally with the generation of ammonia and hydrogen sulphide. Deeper ground water of such origin can be found in the south-eastern part of the Szigetköz at the waterworks of Révfalu and Kisbajcs-Szőgye. The water of both waterworks is characterized by nearly zero nitrate content, less than 0.5 mg/l dissolved oxygen and high manganese, iron and ammonium concentrations which indicate a reductive environment. Similarly reductive conditions would be expected to occur in the water exfiltrating from the gravel if the organic matter content of the River Danube water was increased or its dissolved oxygen content decreased.

Organic and inorganic micropollutants were analyzed by MÁFI in samples taken from the shallow groundwater layers adjacent to the main and side branches of the River Danube. Some deeper wells of the floodplain have also been investigated in this respect. No concentrations exceeding health criteria were detected in the deeper wells, but in some of the near-bank boreholes benzopyrene, carbon tetrachloride and chloroform were observed in concentrations above the respective limit values.

The volume of the above ground water resource which is continuously recharged from the Danube is estimated as 5 km^3. It is generally of good quality and thus it forms an unique potential drinking water resource even on a European scale. The National Water Management Masterplan (1984) considers this drinking water resource as a future resource of 750,000 m^3/d water yield. Most of this resource has not yet been utilized. The water production of existing larger waterworks (Győr, Kisbajcs-Szőgye and Révfalu: 90,000 m^3/d; Mosonmagyaróvár: 17,000 m^3/d) amounts to appr. 70,000 m^3/d, together with the production of the wells of smaller settlements of the region. There are no detailed plans for the potential future utilization of this resource and neither for the potential water users involved. Earlier there had been plans made for the expansion of existing waterworks only. Investigations launched by the Hungarian Academy of Sciences in 1991–1992 (with the use of multi-layer numerical computer models) are focussed on the identification of potential sites and quantities of abstractable water (without environmental damage) for long term future development. The results, however, are not yet available, as the more detailed up-to-date modelling studies begun in 1993 only.

The location of the shallow groundwater table in the top layer of fine particle size is a very important feature from the view point of vegetation and thus agriculture. In the nineteen-eighties the mean groundwater level of the Upper Szigetköz was 4-6 m below ground level, while it was 1–3 m below the terrain in the Middle and Lower Szigetköz. As was already mentioned the area of the Szigetköz can be split into three parts from the view point of soil moisture supply from the groundwater: in the Upper Szigetköz groundwater does not generally reach the top layer. In the Middle Szigetköz it varies from time to time, while in the Lower Szigetköz capillary rise always reaches the top layer of fine particle size. These circumstance are especially important in drought years. In this context the seasonal fluctuation of groundwater level is also of importance. In the close proximity of Danube the fluctuation exceeds 2 m. while in the middle of the Szigetköz it amounts to about 1.0 m. Since the fluctuation of groundwater levels is in close relationship with the changes of the water stage of the River Danube the groundwater levels are also characterized by higher stages in the springtime, which can be considered a favourable condition since it coincides with the onset of the growing season.

2.1.2 Effects of the hydropower scheme

According to the *KET* the Danube would have been impounded at Dunakiliti. In the Dunakiliti reservoir settling of suspended solids and thus the clogging (colmatation) of the channel bed were to be expected. The infiltration capacity of the channel bed would have been thus substantially reduced, while, owing to the much larger surface and to the higher water levels in the reservoir, initially there would have been much higher infiltration rates than under the original conditions of the River Danube. A part of this excess exfiltration was to be caught by the seepage (catch-drain) canal, in order to avoid harmfully high groundwater levels in the vicinity of the reservoir. The water quality of the reservoir would have been worse, mostly in terms of the oxygen conditions, than the original quality of the Danube water. Seepage through the silt accumulating on the channel bed would have created anaerobic, reductive conditions, and thus the dissolution of manganese and iron was expected probably associated with the increase of ammonia and sulfide concentrations. In the long term the exfiltration from the reservoir would have been substantially reduced, by an order of magnitude, due to the thickening silt and to the clogging of the channel bed. Since a portion of the water exfiltrating from the reservoir into the ground water would have been rejoining the abandoned main channel downstream of the dam, it could not have substituted the missing quantities that were originally recharged by the river. According to the KET, groundwater subsidence of several meters magnitude was foreseen along the old main channel downstream of the Dunakiliti dam. In order to improve the moisture supply to the topsoil irrigation, was planned, but its effect on the properties of the soil would have been harmful ones.

After the KET had been accepted, studies on the possibilities of alleviating harmful effects have been launched. The contemplated strategies included supplementary recharge (infiltration) systems on both the floodplain and the protected side of the levee, and the construction of bottom dikes in the abandoned channel (where only 50 m^3/s flow was to be left in the channel as contrasted to the original 2000 m^3/s mean flow) in order to raise the water levels. These solutions, at their given level of elaboration, represented hazards for the subsurface waters. The channels of artificial recharge systems could be clogged and the quality of infiltrating water would be also questionable. The construction of bottom dikes would, for the low flows that were to be left in the channel, again result in the clogging of the gravel bed of the channel. Dredging of the clogged channel beds could perhaps maintain the original infiltration rates, but this would be associated with water quality problems.

Summarizing, solutions such as those contemplated in the KET would have endangered the above described drinking water resource both qualitatively and quantitatively, replacing the original, natural recharge conditions, provided by the River Danube, by an artificial system of rather uncertain character, that would create worse conditions than the original. Reduced flow velocities and changed flow directions would have increased, at some locations, the adverse effects of local sources of pollution. (Nevertheless in this latter case the solution is the elimination of these pollution sources and not the maintenance of subsurface flow at any cost). The elimination of local sources of pollution is under way and thus only the effects of earlier contamination must be taken into account.

From the view point of subsurface waters the "Variant C" strategy, that is the impoundment at Dunacsúny, is more favourable, to some extent, than the impoundment at Dunakiliti. Water of unknown quality, exfiltrating from the part of the reservoir downstream of Dunacsúny, is drained by the abandoned main channel. Consequently the main recharge area of the groundwater was shifted upstream of Dunacsúny, where the water quality and bottom sludge conditions are likely to be better than in the downstream part of the reservoir. Ground water level rise in the Upper Szigetköz was smaller in this case than it would have been in the case of the Dunakiliti impoundment, although it is still significant. Subsidence of the groundwater table of 2–3 meters occurred in the close proximity of the River Danube only, while in the Middle Szigetköz, outside the flood levee, the subsidence is 0–1 meter as compared to the earlier conditions. Groundwater level subsidence was alleviated to certain degree by the additional supply of water of 5 m^3/s ,starting in the spring of 1993, to the floodplain and to the outside of the levee. Some other, yet unknown, factors might have also contributed. A rise in the level and increase of the flow of this complementary water supply system, that was started with 10 m^3/s in August 1993, might further improve the elevation of the groundwater table by a few decimeters, but in a 0.5–1.0 km wide zone along the Danube no groundwater level rise can be induced in this manner. No qualitative changes have yet been detected upon the effect of the water exfiltrating from the reservoir and infiltrating from the water recharge system, or due to the altered groundwater flow directions. Quantitative changes are illustrated by *Figures 2–14* as a function of temporal and spatial changes of the groundwater level and also in relation to the changes of the moistened topsoil.

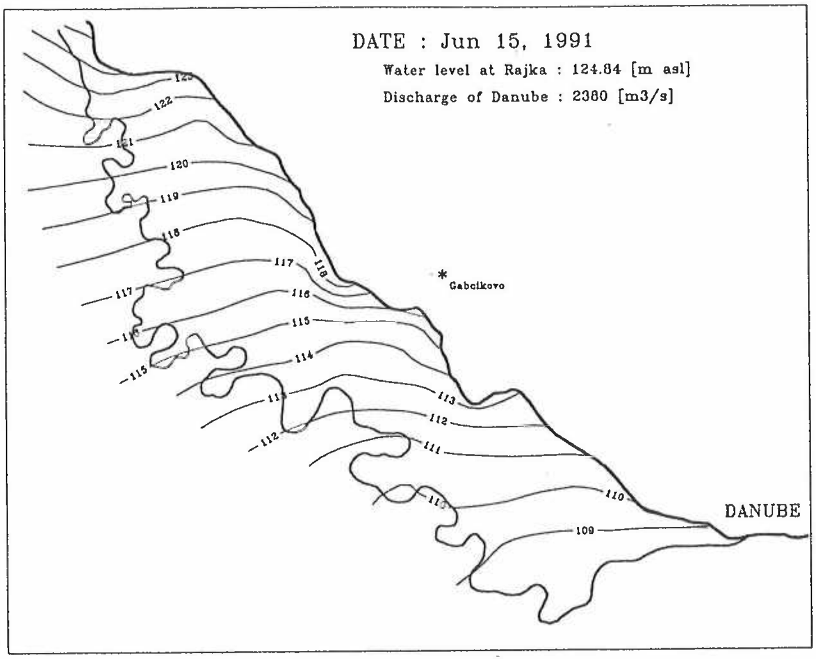

DATE : Jun 15, 1991
Water level at Rajka : 124.84 [m asl]
Discharge of Danube : 2380 [m3/s]
Gabcikovo
DANUBE
123
122
121
120
119
118
117
116
115
114
113
112
111
110
109

Fig. 2

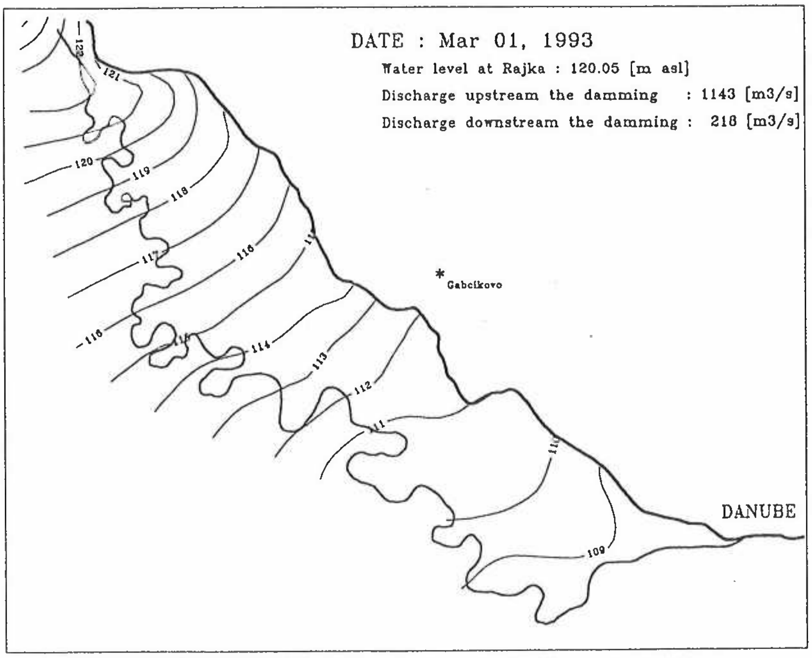
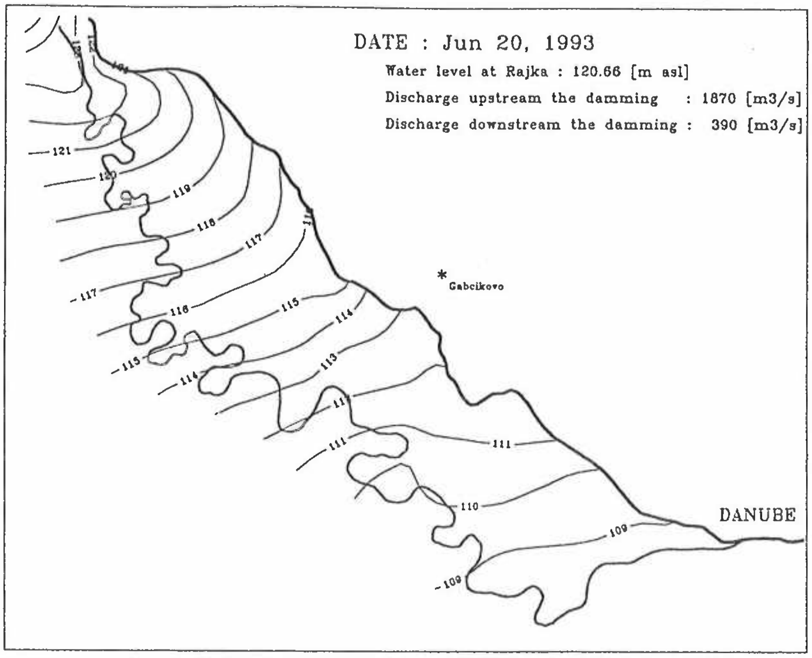

DATE : Mar 01, 1993
Water level at Rajka : 120.05 [m asl]
Discharge upstream the damming : 1143 [m3/s]
Discharge downstream the damming : 216 [m3/s]
Gabcikovo
DANUBE
121
120
119
118
117
116
115
114
113
112
111
109

Fig. 3



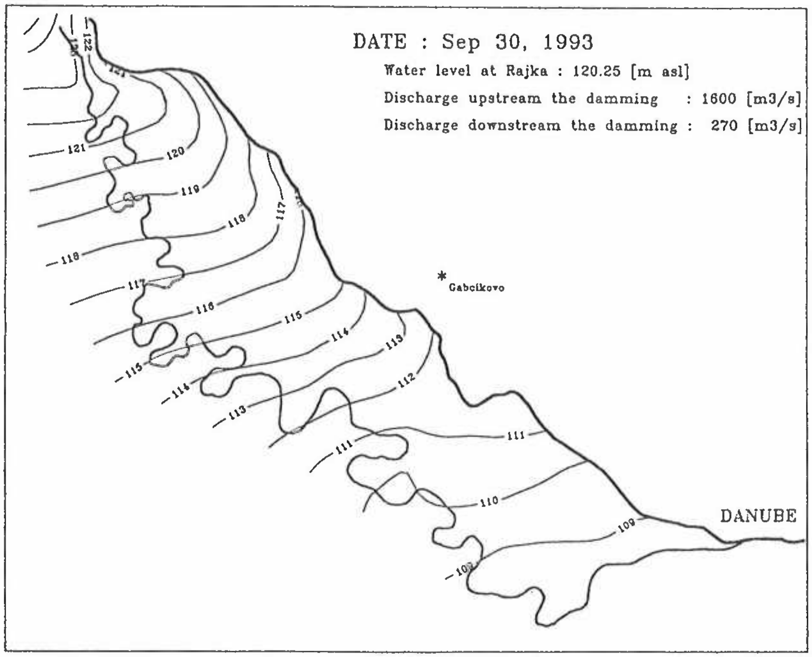
DATE : Jun 20, 1993

Water level at Rajka : 120.66 [m asl]

Discharge upstream the damming : 1870 [m3/s]

Discharge downstream the damming : 390 [m3/s]

Fig. 4



DATE : Sep 30, 1993

Water level at Rajka : 120.25 [m asl]

Discharge upstream the damming : 1600 [m3/s]

Discharge downstream the damming : 270 [m3/s]

Fig. 5

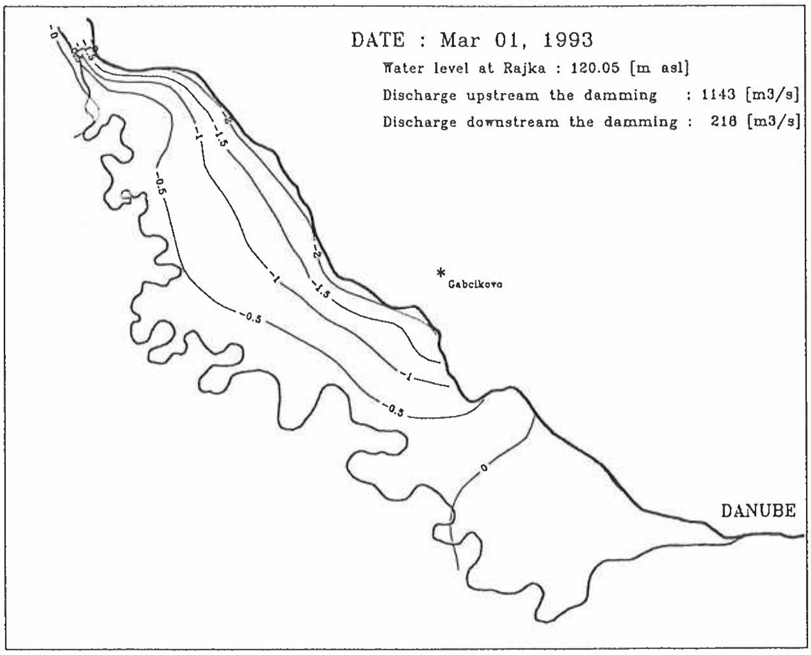

DATE : Mar 01, 1993
Water level at Rajka : 120.05 [m asl]
Discharge upstream the damming : 1143 [m3/s]
Discharge downstream the damming : 218 [m3/s]
Gabcikovo
DANUBE
-0
-0.5
-1
-1.5
-2
0

Fig. 6

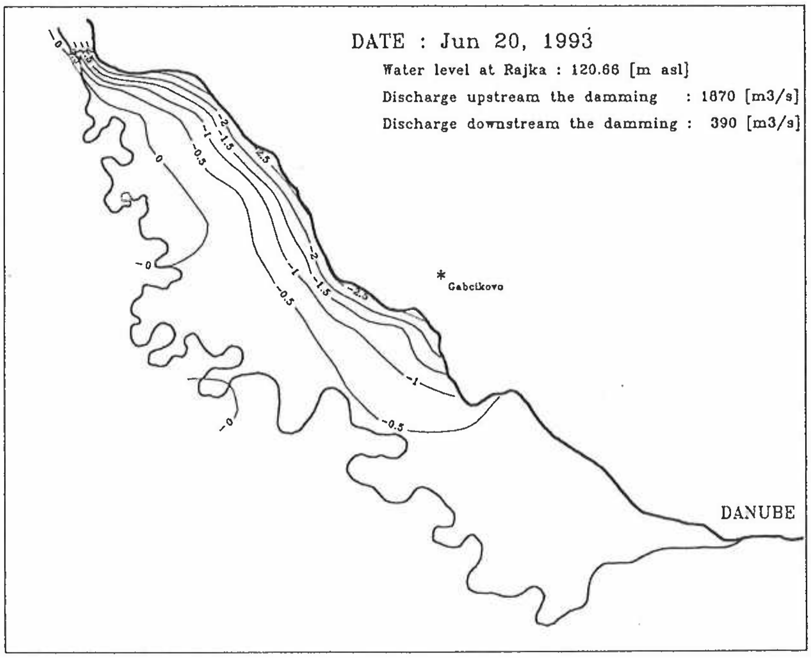

DATE : Jun 20, 1993
Water level at Rajka : 120.66 [m asl]
Discharge upstream the damming : 1870 [m3/s]
Discharge downstream the damming : 390 [m3/s]
Gabcikovo
DANUBE
-0
-0.5
-1
-1.5
-2
-2.5

Fig. 7

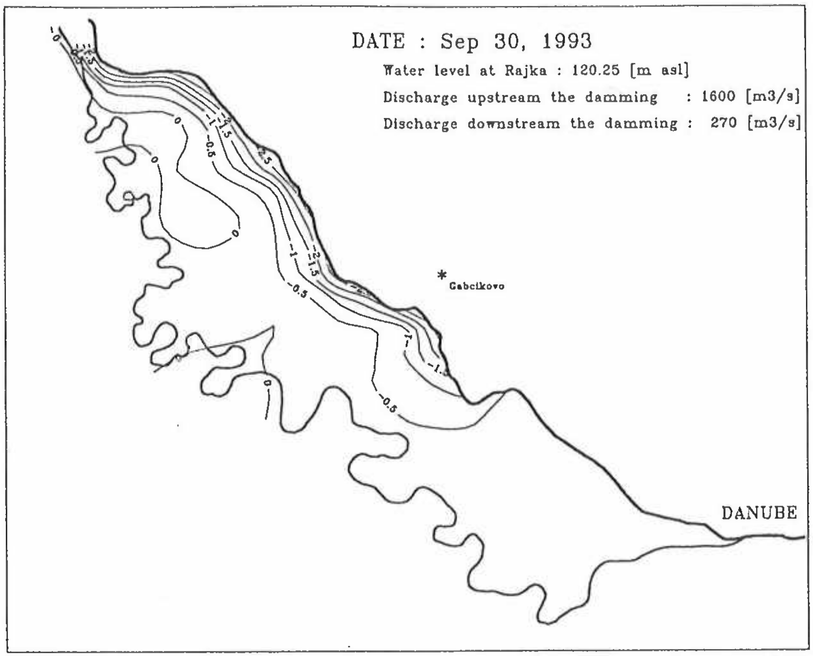


Fig. 8

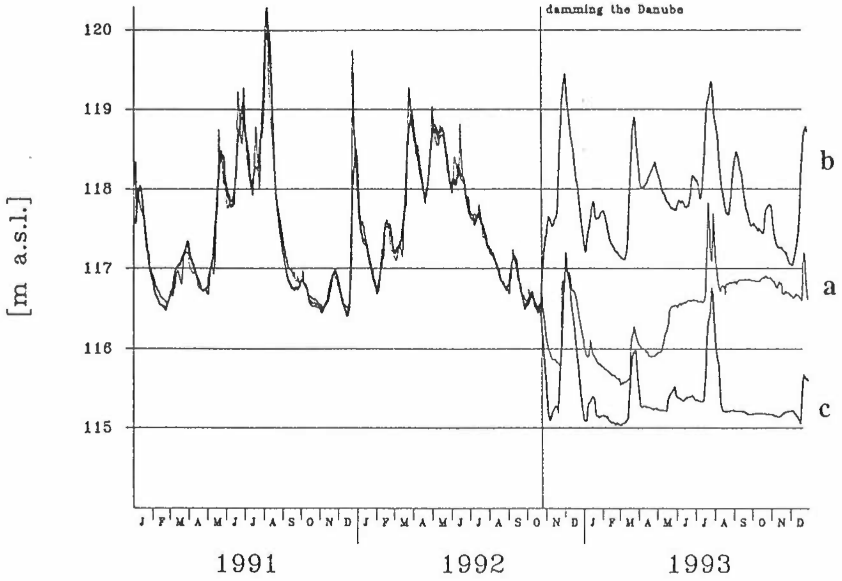
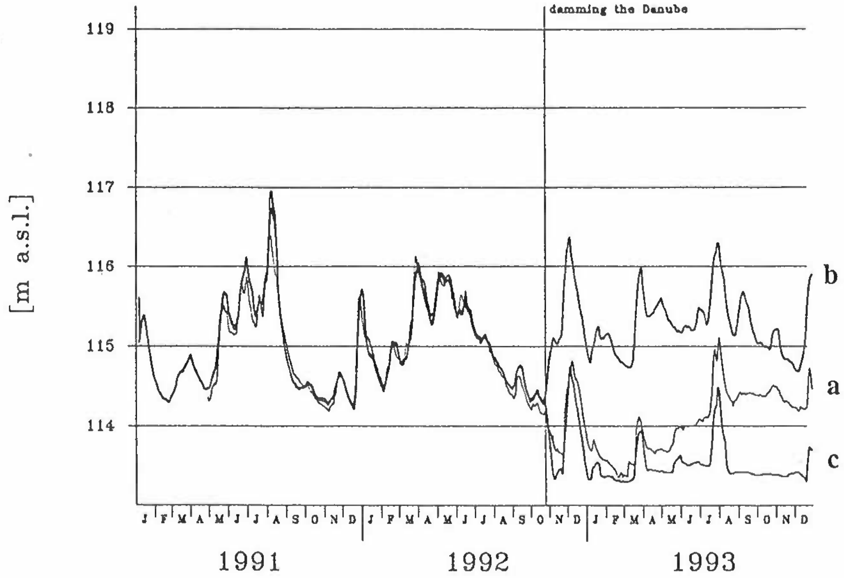


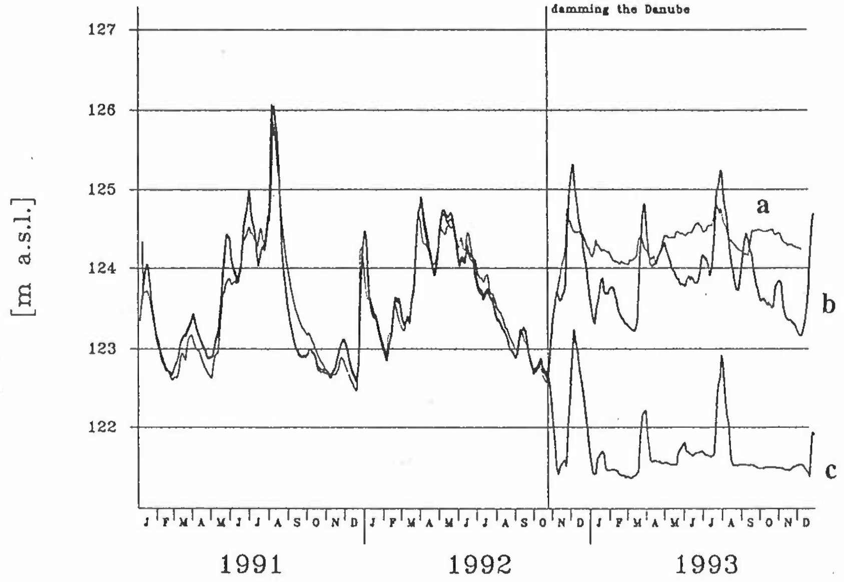
Fig. 9

9428 WELL



9442 WELL

Fig. 10



9305 WELL

Fig. 11

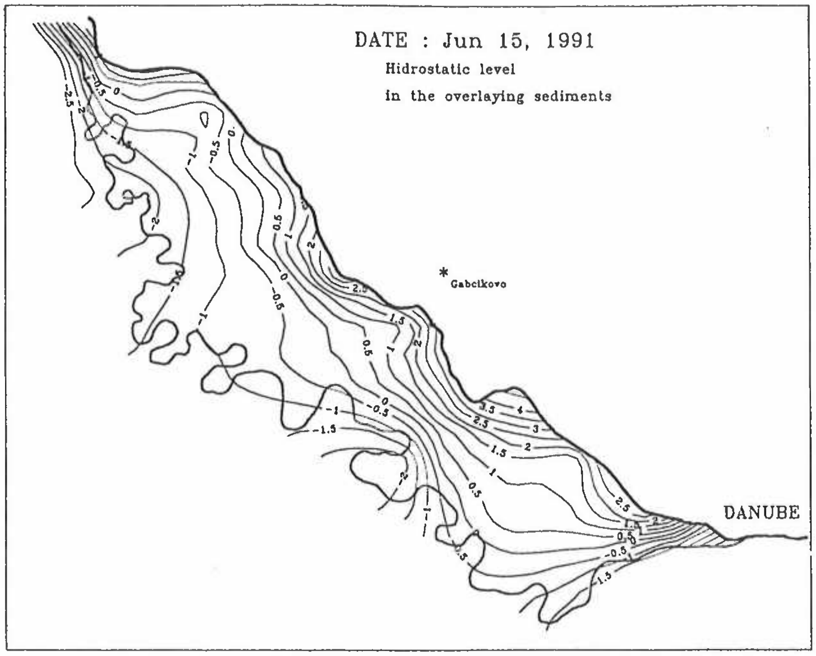

DATE : Jun 15, 1991
Hidrostatic level
in the overlaying sediments
Gabcikovo
DANUBE
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4

Fig. 12

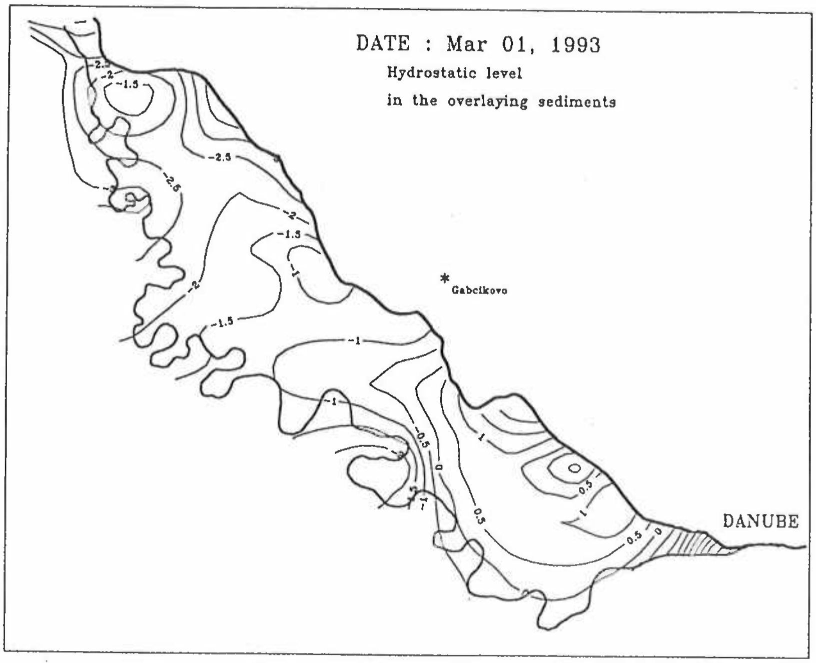

DATE : Mar 01, 1993
Hydrostatic level
in the overlaying sediments
Gabcikovo
DANUBE
-2.5
-2
-1.5
-1
-0.5
0
0.5

Fig. 13

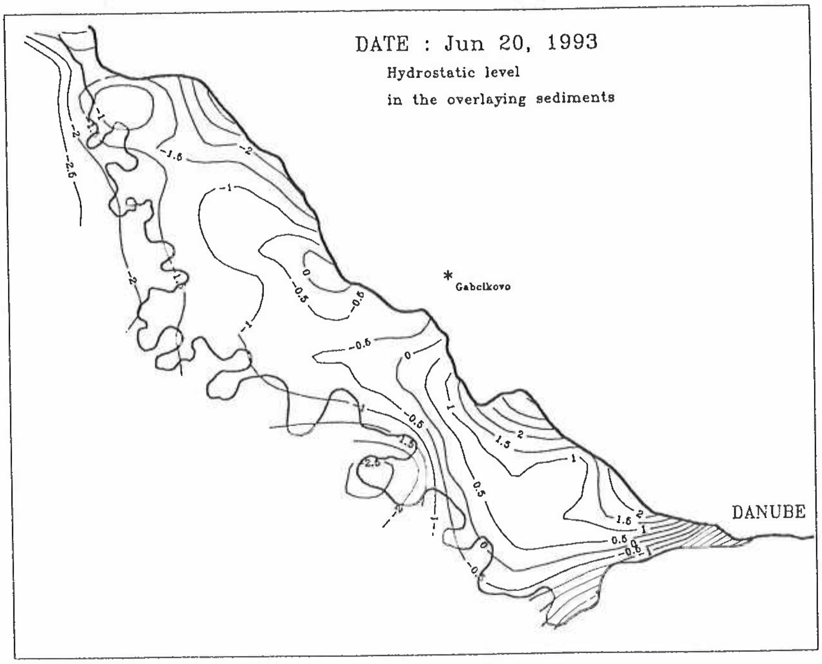

DATE : Jun 20, 1993
Hydrostatic level
in the overlaying sediments
Gabcikovo
DANUBE
-1
-2
-2.5
-1.5
-0.5
0
0.5
1
1.5
2

Fig. 14

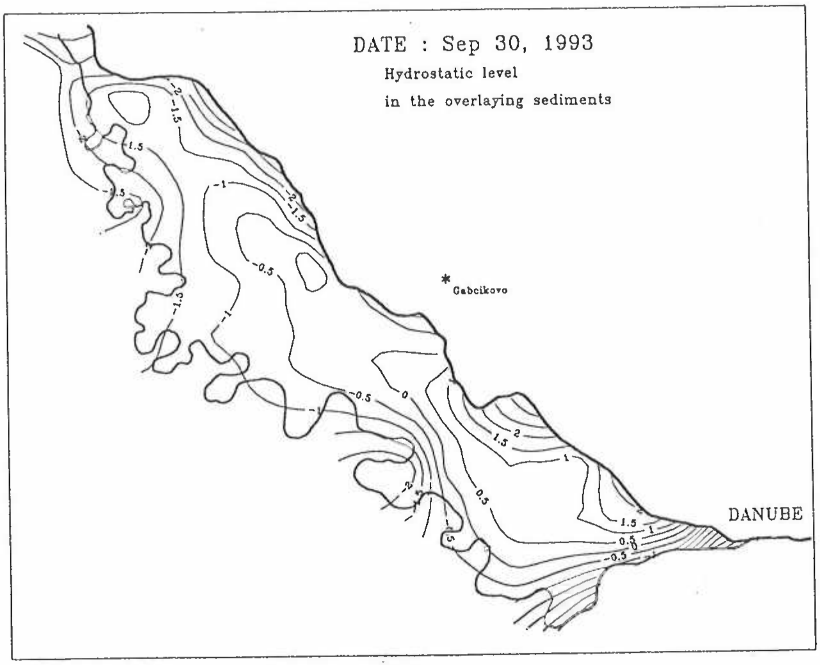

DATE : Sep 30, 1993
Hydrostatic level
in the overlaying sediments
Gabcikovo
DANUBE
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2

Fig. 15

Figures 9–11 show the typical ground water table graphs. Graphs with index "a" show the measured time series, while those with index "b" the ground water tables calculated on the basis of correlations. For periods after the diversion of the Danube the latter show the situation that would have occurred if the full discharge of the Danube (measured at Pozsony/Bratislava) was flowing in the original channel. The ground water table marked with "c" would occur when it depended only on the lowered water levels of the "abandoned" main channel. Due to the effects of the reservoir, to backwater effects and to the artificial additional supply (recharge) measures the actual groundwater table was higher, after the diversion of the river, than what is shown in the figure. The substantial groundwater table increasing effect of the reservoir is best illustrated by **Figure 11.**

Figures 2–5 illustrate the groundwater table in typical points of time:

15 June 1991: Approximate average conditions in the growing season, before the diversion of the River Danube.
01 March 1993: Typical, lowest groundwater table after the diversion of the Danube, characterizing the entire affected area, with the exception of the immediate vicinity of the reservoir.
20 June 1993: Groundwater conditions established in the first growing season, after the diversion of the Danube and before the artificial supply of water to the floodplain.
30 September 1993: End of the vegetation season with artificial supply of water to the floodplain.

Figures 6–8 show the difference between the actual groundwater table and the groundwater table that would have occurred, in the previously mentioned points of time, if the Danube was not diverted.

Figures 12–15 show the position of the groundwater table relative to the bottom of the topsoil-layer (+ when groundwater tables is in the topsoil-layer; – when the groundwater table is below the topsoil in the gravel)

Since the diversion of the Danube, that is since the implementation of "Alternative C" there have been several negotiations on the subject of sharing (distribution) of the flow of the River Danube. The solution proposed by the Hungarian partner, and supported by the EC, according to which flows varying as a function of the season of the year, but always representing more than half of the original flow, should be rediverted back to the main channel, would certainly improve both the recharge conditions of the groundwater and the stage of the groundwater table. However, this allocation pattern has not yet been agreed upon and the most recent negotiations were dealing with a scheme which would allow the release of flows somewhat larger than the present 200–300 m^3/s flow into the main channel in association with the construction of bottom dikes and with the complementary supply of water into the floodplain and to the outside areas of the levee. Although these solutions would somewhat mitigate the hazards of subsurface waters, the questions related to the quantity and quality of the water recharge to the ground water resources still remain open. Bottom dikes to be constructed in the main channel would highly endanger the possibilities of the rehabilitation of the main channel as the source of recharge of ground waters of the area. A similar problem is related to the present excessive growth of vegetation on the former, now dry, channel bed.

2.2 Areas on the Hungarian side of the Danube reach between Gönyü and Nagymaros

2.2.1 Hydrogeology

On the right bank of Danube between Gönyü and Dunaalmás, gravel layers are substantially thinner, approximately a few tens of meters deep, than those of the Szigetköz, and their connection with the Danube is discontinuous. This river reach is not characterized by steady water recharge from Danube into the gravel, but on the contrary some groundwater infiltrates into the river from the off-river background zone. From Nyergesujfalu towards Nagymaros the right bank aquifer of coarse clastic formations widens and becomes deeper in the Dorog basin. Starting at Esztergom the coarse gravel formations, which offer bank-filtered water abstraction possibilities, break up again along the right bank of the river and the next wider and deeper gravel formation is found in the Pilismarót basin. On the left bank of the Danube the only significant bank-filtered water resource is found in the vicinity of Szob.

Let us now consider, following the downstream route of Danube, the existing waterworks *(Figure 16)*. The first significant waterworks is the one of Komárom-Koppánymonostor, constructed on an island of the river. Water quality problems of the waterworks of 5,000–6,000 m^3/d production capacity are also associated with iron, manganese and ammonia. Denitrification occurs in these waters.

The waterworks of the Viscosa factory of Nyergesujfalu of a capacity of 5,000–6,000 m^3/d has problems associated mainly with

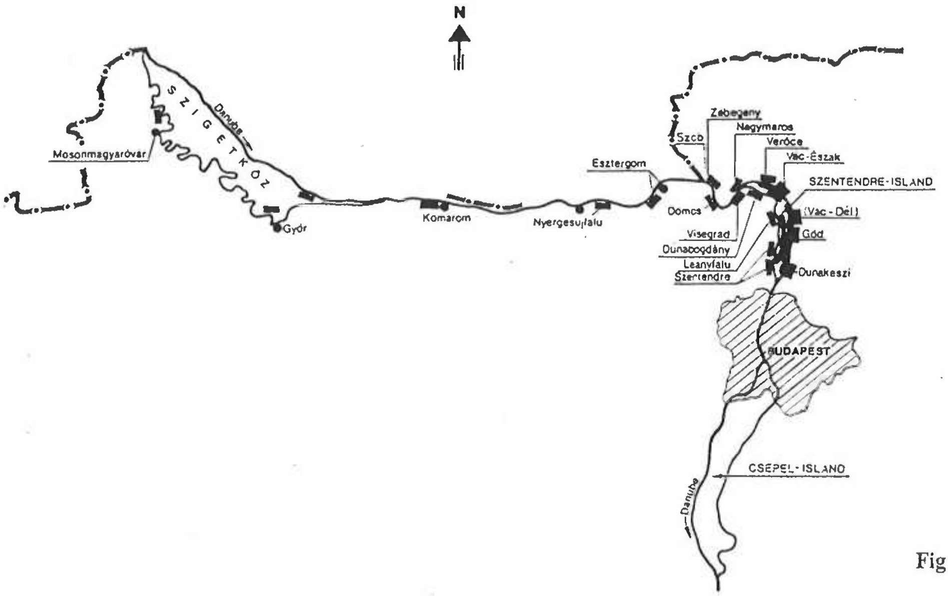


Fig. 16

WORKING BANKFILTERED WATER-WORKS ALONG THE RIVER DANUBE

contamination arriving from the off-river background zone. The same refers to the Tát waterworks of 2,000–3,000 m^3/d capacity.

The total capacity of the three radial wells of the waterworks of Esztergom Prímás Island is 12,000–13,000 m^3/d. The water quality is good here but background contamination effects occur at low water stages of the river. The capacity of the waterworks of Esztergom-Szentkirályi is about 2,000 m^3/d. The water quality is rather poor due to contamination from the off-river background zone and to the washout of pollutants from the sludge deposits in front of the islands of Tát.

Between Szob and Nagymaros waterworks of small (less than the total of 1,000 m^3/d) capacities but of good quality are found on both banks of the river (Szob, Zebegény, Dömös).

In addition to the existing waterworks there are unused bank-filtered drinking water resources "kept in stock": In the vicinity of Ács-Komárom-Almásneszmély 19,000 m^3/d, and 75,000 m^3/d at the neighbourhood of Esztergom. These potential drinking water resources have not yet been fully explored, and there might be hydrogeological and water quality problems encountered.

Here we must mention the relationship between the karstic water resources of the Dunántúli Középhegység (Middle Mountain Ranges of Transdanubia) and the Danube Hydropower scheme. The karstic water system in direct connection with the Danube at Esztergom and Dunaalmás, where, -under the original conditions-, karstic water fed into the Danube through bottom springs. Due to mine drainage operations hydraulic heads of the karst were so much decreased that the danger of Danube water intrusion into the karst has to be faced. It would have been very harmful at Esztergom, endangering both the quality and the temperature of the luke-warm karstic spring of Esztergom and also the thermal wells of the other side of the river at Párkány (Sturovo). According to the research results of VITUKI (Lorberer, 1987–89) the hydraulic connection takes place in varying forms:

- "There is direct connection between the main karstic reservoir and the Danube in Esztergom, in the vicinity of the Turkish Bath;
- Triassic-Eocene formations of the karstic storage system communicate via the gravel terraces of Danube with the river in Esztergom, at the riverside promenade, along a length of appr. 650 m;
- A more indirect relationship is found at Dunaalmás over a length of about 300 m, where among the Jurassic-Triassic limestone formations of the main karstic storage system a Pliocene (Upper Pannonian) sandy aquifer of 35–40 m depth is found (without impermeable clayey layers);-A similarly indirect relationship is found in Esztergom, in the vicinity of the lido."

On the basis of computer model studies the author finds that

- "At present there is about 3 m3/min and 2 m^3/min recharge of Danube water, at Esztergom and Dunaalmás, respectively, from the gravel terrace to the main karst (these rates are decreasing due to restrictions set on mine water drainage operations since 1990)"

2.2.2 Effects of the hydropower scheme

If the plans of the KET had been implemented, this Danube reach would have been an impounded one with daily water level fluctuation due to peak operation of the Bős hydropower station. Even the KET had foreseen considerable sediment deposition along this reach, especially in the section between Nyergesujfalu and Nagymaros. Anaerobic, reductive zones would have developed in the bottom silt layer, further amplifying the problems related to iron and manganese. More pronounced reductive processes might have resulted in the generation of hydrogen sulphide and methane gases. There would have been positive effects too, in term of the quality of the groundwater resources, since the intrusion of contaminated groundwater flows from the off-river background zone, associated with low flows/water stages of Danube, would have been eliminated by the impoundment. Obviously this is not the way to eliminate pollution from the off-river background areas; but the sources of pollution must be found and removed.

With respect to the connection between the Danube and the karstic system the increase of the Danube,s water level by the impoundment would have only increased the danger of Danube water intrusion into the karstic system which has already reduced pressure heads. Nevertheless with the curtailing of mine-drainage operations this danger becomes less and less significant. Relevant research results of VITUKI (Lorberer, 1987–89) are quoted below:

- "In Esztergom, in the vicinity of the Turkish Bath, the karstic water level is 2–3 m lower than the water levels of Danube. Special local control measures (cementing, compression) would be needed because the impoundment that will increase the mean water level of the River Danube by 4.6–9.6 m would, very likely, break through the Oligocene impermeable layers which protects the spring-cave of Prímáskút. No increase of karstic water heads can be expected due to the depressions caused by the mine Lencsehegy II. in the close proximity"
- "In the vicinity of Esztergom the impoundment would (according to our calculations) result in a maximum 3.3 m pressure increase associated with excess exfiltration of Danube water of 1.5–2 m^3/min." "Exfiltration and backwaters would not cause operationaL problems either at the thermal well no. FGS-1 of Párkány (Sturovo), or at the Lencsehegy II. mine, not at the water supply systems of the Dorog basin, the latter relying on karstic water abstraction".
- "In the vicinity of Dunaalmás the impoundment will cause 1.5 m pressure head increase only, associated with transfiltration of 1.2–1.5 m^3/min".
- "Excess transfiltrations and pressure head increase, associated with the impoundment, can appreciably affect neither the head conditions nor the water budget. The maximum effects will occur along those point-like sections where the main karst communicates with Danube and here the effects are by no means negligible."
- "In the vicinity of Süttő-Lábatlan-Nyergesújfalu the channel of the Danube was cut into the Lower Cretaceous- Middle Eocene karstic formations of the Gerecse mountain. Upon the effects of the impoundment further decrease of rates lost from the karstic

reservoir to the river are to be expected in association with smaller increase of the rate of discharge of the near-bank springs."

2.3 The Danube banks downstream of Nagymaros

2.3.1 Hydrogeology

Along the Danube reach between Nagymaros and Budapest the most significant bank-filtered drinking water resource is the one of the Island of Szentendre utilized by the Waterworks of Budapest *(Figure 16)*. There is a 10–20 m deep gravel aquifer below all of the area of the Island. At mean water stages of the River the depth of ground water in the aquifer is 10–15 m, which is decreased by 2–3 m due to the depression caused by the wells. At low water stages of the river the water yielding aquifer depth is further reduced by about 2 m, and the natural filter area of the channel bed decreases accordingly.

Water is being abstracted at 17 waterworks sites from 31 shafts from 83 radial- and 439 pipe wells. The maximum capacity of the entire group of wells is 0.8 million m^{3}/d, while the annual average water production is nearly the same. This is about two-thirds of the total drinking water demand of Budapest.

In general the quality of water abstracted by the wells is directly suitable for human consumption. Average values of iron, manganese and ammonium are 0.01 mg/l, 0.04 mg/l and 0.06 mg/l respectively. In some areas nitrate contamination represents a potential hazard due to local sources of pollution (at some locations nitrate in the groundwater exceeds the health limit value of 40 mg/l, but it will not appear in the wells due to dilution water drawn from the Danube).

In the period of 1970–1987 approximately 16.5 million m^3 gravel had been dredged from the Danube channel between Budapest and Nagymaros, mostly for commercial (industrial) purposes. Three characteristic "dredging reaches" can be distinguished: the section between Nagymaros and Vác from where approximately 10 million m3 gravel had been dredged in the period of 1970–77. The section between Vác and Göd yielded four million m3 gravel in 1974–1980, while somewhat less gravel had been dredged from the channel between Göd and the downstream end of the Szentendre Island (2.4 Mm^3). In the other, the Szentendre, river arm most of the total of 4.0 million m^3 gravel that had been dredged in the period of 1970–1987 originated from the river reach between Dunabogdány and Kisoroszi and from that between Szentendre and Tahi. Commercial/industrial gravel dredging was terminated in 1980. Dredging operations in 1985 were related to the construction of the Nagymaros river dam. Dredging activities continued in the Szentendre arm also in 1987.

An R&D project on "the protection and development of bank-filtered drinking water resources" was carried out in the period of 1980–85 under the leadership of the Waterworks of Budapest. Under the framework of this programme a survey of existing waterworks and of the potentially utilizable bank-filtered drinking water resources was made. The Szentendre Island, the northern water resource of the Budapest Waterworks, was a prominent area of these studies. Some of the findings of this project will be quoted below:

> "The *water level of Danube* has decreased in the low-to-medium flow domain, both in the Main Danube and in the Szentendre arm. The water stage corresponding to the annual lowest flow has decreased, in comparison to that of 1947, by 60 cm and 123 cm at Budapest and Nagymaros, respectively. In between it might be as much as 1.5 m, due to the uneven channel bed. The duration of low flows has also been increasing. The reason is the lowering of the channel bed caused by the industrial gravel dredging activities of the past 15–20 years. The consequence is that the depressions of the production wells and the recharge to the off river background aquifers are decreasing. Both effects reduce the production capacity of the wells. The estimated capacity loss is 80,000–100,000 m^3/d. The present total capacity, withdrawn without damaging the recharge system of the water resources, of the northern bank-filtered water abstraction units can be 800,000 m^3/d at the mean water stage of the river (3.0 m at the Budapest gauge)"
>
> "The *channel of the River Danube* has changed significantly during the past 15–10 years;- it has subsided due to the effects of commercial gravel dredging (20 million m^3). The average channel subsidence amounts to 1.6 m, while in the main streamline it reaches 2.5 m. The low-flow channel cross-section area was increased and the channel bed became uneven.
>
> These changes resulted in the change of the slope and flow velocity conditions of the reach of concern. In the low flow period the slope of the water surface varies in the range of 2–28 cm/km and the mean velocity of the cross-section area remains, at some locations, below 50 cm/s.
>
> As a consequence of these features fine fractions of suspended solids, silt and organic matter have deposited onto the channel bed, and especially into the dredging pits and in the vicinity of the banks as well as in the vicinity of river training

facilities (e.g groins). Upsilted banklines were formed along about a length of 15 km.

The consequences are: The permeability of the river bed decreases; reduction processes are taking place; the iron and manganese content of the water produced increases. The production capacity involved might be as much as 100,000 m^3/d."

"The gravel terrace under the Danube channel can be divided into two parts, in terms of its water yielding function. The first is the so called filter layer which is of a few centimeters thickness and acts as an ultra-slow filter, removing 99 per cent of the contaminants. The second part is the gravel aquifer proper which conveys the infiltrated water. About 50–3000 m of the length of the wetted perimeter of the cross-section can act as a filter zone, depending on the water level of Danube and on local circumstances.

Under "natural" circumstances, in the early nineteen-sixties, the thickness of the aquifer below the Danube channel was about 4–7 m, both in the main and the Szentendre arm of the river. Due to the effect of commercial gravel dredging this thickness has decreased to 1–4 m. The area of the filterzone has decreased by about 2 km^2, and the associated capacity loss is about 200,000–300,000 m^3/d."

"The quality of the groundwater resource of the Szentendre Island is determined by the quality of the Danube water, the effectiveness of the filtration process and the activities (sources of pollution) on the off-river background zone.

Water quality processes taking place during filtration across the gravel bed are not fully known yet. Nevertheless it has been proven that most of the processes take place in the channel bed. Depending on the bed material (reductive and oxygenated zones), they exhibit spatial and temporal variation.

It follows from the above conditions that the loss of capacity will be the highest under unvafourable hydrological circumstances. The wells became sensitive to the variation of Danube water stages. There is a danger of the continuing tendency of these unfavorable effects, since in the periods of low water stages filtration velocities are accelerated to an extent which results in the increase of filter resistance.

The only remedial or control strategy that remains available for these northern subsurface drinking water resources is to maintain water recharge conditions by all means. In the opposite case, in the case of further damage to the filter zone, the deterioration of the complete drinking water resource must be

> taken into consideration in the long term, a process that might lead to the abandonment of the system. The channel regulation downstream of Nagymaros must be planned with due concern for the above hazards.
>
> The *water quality of the water withdrawal units* is determined by that of the Danube water, by the groundwater quality (sources of pollution) in the background zone, and by the mixing/blending of the above two types of water, which changes as a function of time and space and of the operational conditions of the waterworks. At present the quality of the water produced by the northern waterworks units is well below the standard limit value in terms of oxygen consumption and total hardness. The iron content regularly causes slight problems at some wells and occasionally at other ones. Manganese and ammonium tend to occur jointly, and their occurrence is usually related to the redox conditions of the infiltration zone."

In order to demonstrate the vulnerability of bank-filtered drinking water resources to river training interventions the deterioration of the quality of the water of some of the wells of the Surány Waterworks (László, 1987):

> "In the preparatory phase of the works exploratory wells were drilled in 1965 and 1966 and the water samples taken from these wells indicated good water quality free of iron, manganese and ammonia; thus proving the bankline suitable for the establishing waterworks.
>
> The waterworks of Surány is one of the best protected waterworks in the Szentendre Island, consequently the causes of water quality deterioration, should be also investigated in the main channel side.
>
> At the section of well No.7 there were two gravel dredging pits 4.5 and 1.5 m deep, respectively, filled with silt, as identified by channel survey and sediment sample data.
>
> This dredging pit continued towards wells Nos. 8. and 9. in a ditch-like fashion. Particle size, organic matter, iron, manganese, biological and bacteriological data provided an exact picture of the silt thickness and position, and provided evidence for the intrusion of manganese and iron from the sludge to the water bearing layers. The channel bed, damaged by dredging allowed the penetration of bacteria and other microorganisms into the aquifer, that is the bank-filtration function was severely damaged and its efficiency was rendered insufficient."

Along the Nagymaros-Budapest Danube reach the following bank-filtered drinking water resources can be found on the right bank of the river, in addition to the above discussed Szentendre Island resource (values in brackets indicate the average production rates):

The Dunabogdány Waterworks (700 m^3/d),
The aquifer at Leányfalu (also utilized by the Szentendre Waterworks) (14,000 m^3/d),
The Northern water resource of the Szentendre Waterworks (500 m^3/d),
The Southern water resource of the Szentendre Waterworks (2,500 m^3/d),
The Southern regional water resource of the Szentendre Waterworks (8,000 m^3/d).

These water resources are facing problems represented by contamination originating from the off-river background zones of the aquifers.

On the left bank of the Danube reach of concern the following bank-filtered drinking water resources are found:

The Verőce unit of the Vác Waterworks (22,000 m^3/d),
The Büki Island unit of the Vác Waterworks (out of operation),
The southern unit of the Vác Waterworks (out of operation),
The Felsúgöd Unit of the Göd Waterworks (800 m^3/d),
The Alsógöd Unit of the Göd Waterworks (1,600 m^3/d) and the Dunakeszi Waterworks (1,500 m^3/d).

These water resources are also characterized by the intrusion of contaminated groundwater flow from the background zone. The Souther water resource of the Vác Waterworks became fully contaminated and its operation had to be terminated. The Felsőgöd unit is utilized in peak operation mode only (e.g to be blended with other waters), due to its bad water quality. At the water resources of the Verúcemaros and Felsúgöd units water quality problems occur also at the river side: silt depositions, caused by sluggish flow behind river training structures, created iron, manganese and ammonia problems.

2.3.2 Effects of the hydropower scheme

Downstream of Nagymaros the river barrage system would have caused problems of the bank-filtered drinking water resources due to the changes of the water regime, sediment loads and the channel geometry as far downstream as Budapest.

The outstanding importance of the drinking water resource of the island of Szentendre would not have allowed the slightest increase of the risks of damage to these resources, which were to be caused by the expected changes of water- and sediment regime and of the water quality of the river.

If the facilities contemplated by KET were implemented the following risks would have been faced:

- — The water quality of the river upstream of the Nagymaros dam could have become worse than the original water quality,
- — Removal of the silt deposited upstream of the Nagymaros dam was to be facilitated by the occasional flushing of the headwater basin. Settling pattern of the thus released excess sediment loads downstream of the dam could have created rather uncertain conditions;
- — Reduced sediment content of the river, associated with the energy of the water released, could have caused channel erosion downstream of the dam. The risk of this was even higher since the channel here contains more sand than that of the gravelly channel of the Szigetköz area.

With respect to the above mentioned risks no detailed investigations that could have quantified these effects had been made. Nevertheless neither were results of investigations available to prove the insignificance of the above hazards. Research into the mechanism of the bank-filtration process of the Szentendre island has provided evidence that the process, which converts Danube water of non-potable quality into ground water of excellent quality takes place in a few cm thick layer of the river channel, where the attached ecosystem has an important biological role in this treatment process. This thin layer is very sensitive to disturbance and thus one should avoid any river training or regulation works along the Danube reach of concern, which could endanger the stability of this channel layer.

3. Summary evaluation

3.1 Summary grouping of the effects

3.1.1 Favourable and unfavorable effects of the original design, as of the KET

The problems of groundwater resources that would occur in the case of implementing the original plans of the hydropower scheme BNV (as it was contemplated in the Mutually Agreed Plan KET) can be summarized as follows:

— In the Szigetköz and the related Danube reach:

  = It is very likely that the quality of the water exfiltrating into the groundwater from the Dunakiliti reservoir through the silt deposited there will be worse than the water recharged originally by Danube through the gravel channel bed: due to anaerobic conditions dissolution of iron and manganese is to be expected, while reductive processes resulting in the generation of hydrogen sulphur or methane gasses are less probable. One might state also with lower probability that the above processes would accelerate the enrichment of organic and inorganic micropollutants. With the propagation of the channel bed clogging process (colmatation) the rate of exfiltration from the reservoir would certainly decrease but there is no reliable knowledge that would allow the estimation of the time dependence of this process.

  = It can be also stated with confidence that similar problems would occur if the water level in the abandoned Danube channel was raised by the construction of bottom dikes, since this would also be associated with decreased flow velocities. There are contradictions among the opinions of experts on the magnitude of flow velocity that would be required for avoiding the above harmful effects. The range of critical flow velocities is 0.15–0.3 m/s. At flow velocities larger than this there is less probability of the clogging of the channel bed and of the occurrence of water quality deterioration.

  = In the case of artificial recharge (infiltration) systems, aimed at the complementary supply of water into the dewatered side river arms and thus to the ground water, the clogging of channels and the deterioration of the quality of recharge waters can also be expected with great certainity, although time variation of these processes can not be estimated reliably.

  - Several meters lowering of the water level of the abandoned main channel downstream of the Dunakiliti dam would certainly result in substantial subsidence of the ground water table of the zone near to the river. Knowing the hydrogeological parameters of this gravel aquifer one is able to estimate the expected changes with 1–2 dm accuracy. Groundwater subsidence will be counteracted, moderated, by seepage flows from the reservoir and by the artificial water recharge systems. Knowledge that would allow the confident prediction of these processes is not yet available. The "topography" of the groundwater table resulting from the above processes will, at the same time, influence the recharge conditions determining the direction and velocity of subsurface flow. It is most certain that there will be changes in this field but the extent, and time variation of these changes can not be predicted in a reliable way.
  - In the light of the above considerations it is certain that damage to the potential drinking water resources of the Szigetköz will occur, but its extent or magnitude can not be predicted in a reliable manner. Among other factors there is no knowledge available about the sites and withdrawal rates of contemplated future waterworks and water abstractions.

- In the Lower Szigetköz and in the Gönyü-Nagymaros reach of the river there would certainly be sludge deposition, owing to the lower flow velocities of impounded river sections, and this would certainly be associated with water quality deterioration at the waterworks relying on bank-filtered water resources. Since the existing waterworks of this reach are in any case facing water quality problems independently of the river barrage system, the damages due to further water quality deterioration can not be quantified in a reliable way.
- The intrusion of Danube water from the impounded reach into the Karstic storage system, in the vicinity of Dunaalmás and Esztergom, would have occurred in various ways, depending of the changes of the hydraulic head conditions of the karst. Exploration of this site was insufficient in respect to the hydraulic connection between the river and the karst and neither were the effects of the banning of large-scale mine water drainage on the rate of rising of hydraulic heads in the karst known.
- In the reach downstream of Nagymaros only the effects of preliminary dredging, as contemplated by KET, on the capacity loss of existing waterworks could be forecast with reasonable

reliability. Further problems, such as the sinking of the channel downstream of the Nagymaros dam and the deposition of silt, are only estimates and there is no knowledge that would permit the confident prediction of the extent of these processes.

3.1.2 Actual damage

Damage that has certainly occurred during the construction works of the project is the loss of water production capacity of the wells of the Szentendre Island, caused by the preliminary dredging operation downstream of Nagymaros. The magnitude of this loss is still disputed, with estimates varying in the range of 70,000–300,000 m3/d. Uncertainities of judging this damage stem from the fact that dredging was made not only for the purposes of the river dam but also for commercial/industrial ones and the extent of dredging was also larger than contemplated by KET.

Following the diversion of the River Danube in 1992, that is upon the implementation of "Alternative C" the groundwater table has actually subsided, as it was discussed above. This subsidence has resulted in damage related to natural ecosystems, forestry and agriculture. The actual damage to the existing waterworks of the Szigetköz can not yet be evaluated. Damage to the potential drinking water resource of the gravel complex can not be unambiguously determined: The location , direction and magnitude of recharge into the gravel have substantially changed, but the deterioration of the quality of subsurface waters is expected to occur in the long term and can not yet be detected.

3.1.3 Expectable future damages in the case of maintaining the present conditions of water distribution

If the present conditions were maintained in the long run then damage to nature conservation, forestry and agriculture will be done, with high probability, at all those sites where the topsoil of fine particle size had earlier received moisture from the groundwater, and this supply has now been terminated.

The potential drinking water resource of the gravel complex will be most certainly damaged but this is a long process that will develop over several decades. Damage is mostly expected in terms of water quality deterioration but the form and magnitude of this deterioration can not be quantitatively estimated yet. The possibilities of establishing further water abstraction wells in this potential drinking water resource are much curtailed by the facts that the source of water recharge to the gravel was shifted from the main channel of Danube to the area of the Dunacsúny reservoir and became rather uncertain and also to the similarly uncertain source of recharge that is provided by the artificial recharge system of the floodplain and the areas outside the flood levee. It has became an urgent necessity to eliminate the local sources of pollution at an accelerated rate and by all means.

It is expected with great certainity that the impounding effects of the tailwater canal will cause the settling of considerable silt quantities in the area of the river arm system of Ásvány and Bagomér and this will influence the subsurface waters. However there is insufficient knowledge available for the estimation of the effects of the related processes.

3.1.4 Risks related to the alternatives which emerged at the tripartite negotiations

In the tripartite negotiations held in 1992-93 with the participation of Slovakia, Hungary and the EC the possibility of rediverting Danube back to its original main channel was also discussed. In this material we will not be dealing with this solution.

The EC has supported the Hungarian proposal according to which more than half of the flow of Danube would be rediverted, as a function of the season of the year, to the old channel, while keeping the establishments and structures of "Alternative C". This could, however, only be a temporary solution for a period of a few years, since groundwater subsidence would also be associated with this solution, although higher rediverted rates requested for the growing season, might reduce this subsidence to a tolerable level. Water of degraded quality, expected to infiltrate from the Dunacsúny reservoir into the gravel, will be encountered also in the case of this alternative; moreover this might become even more pronounced with the lessening of the drainage effect by the now abandoned main Danube channel.

A recent proposal supported by the EC was that more water would be discharged into the old channel than the present rate but less than that discussed above and this would be associated with the simultaneous construction of bottom dikes and with the artificial recharge system to the floodplain and to the area outside the flood levee. This could, in principle, solve the problems related to groundwater subsidence and to the damage to the potential drinking water resource. Nevertheless this plan has not been elaborated in sufficient detail. It is highly uncertain whether clogging of the channel bed (colmatation) would occur in the abandoned main channel after impoundments are created by the bottom dikes, whether it would occur in the artificial recharge system or not and whether there will be water quality changes and if so of what magnitude. The same is the case with the other complementary water supply systems which are to utilize water from the partially impounded reach upstream of the Dunakiliti dam.

3.2 Reliability of knowledge

3.2.1 Lack of knowledge in various phases of the history of the BNV system

Before the preparation of KET and before the elaboration of the impact assessment study and until the suspension of the construction works of the river barrage system, until 1989, the lack of knowledge can be summarized as follows:

- Specialists dealing with subsurface waters had no knowledge of the expected quality of water to be recharged into the groundwater resources and neither were known the extent, site and rate of accumulation of pollutants in the impoundments. This refers to the Dunakiliti reservoir as well as to the Danube reaches upstream and downstream of the Nagymaros dam;
- The above mentioned water quality and sedimentation (colmatation) problems have not yet been resolved and they also refer to the proposed artificial water supply and recharge systems too;
- Hydrogeological research into the gravel complex aimed at the more detailed exploration of the inhomogeneities of the gravel formation has not yet been completed and the same refers to the hydrogeological modelling of transport processes as well as to the actual design activities related to the protection of water withdrawal systems to be based on these resources;
- More detailed exploration of the connection between the Danube and the karstic water storage system would provide much needed further information;
- The outstanding importance and high vulnerability of the bank-filtered drinking water resource of the Island of Szentendre, downstream of Nagymaros does not allow the undertaking of risks due to the lack of knowledge of the properties of this complicated system.

Between the suspension of the construction works (1989) and the cancellation of the contract (1992) knowledge has been expanded in the following fields:

- Hydrogeological conditions of the Szigetköz;
- More detailed information on the contemplated artificial water supply and recharge systems.

After the cancellation of the contract and the diversion of Danube (1992) knowledge of the Szigetköz area has been significantly expanded:

- Ground water levels before and after the diversion of the Danube have been evaluated;
- knowledge on the efficiency of artificial complementary water supply and recharge systems has been expanded.

There is still insufficient knowledge available with respect to the following issues:

- Clogging (colmatation) of the channel by deposited sediment and the related water quality problems;
- Water movement and water quality of the deeper layers of the gravel complex of the Szigetköz;
- Concrete plans for the future utilization of the potential drinking water resource of the Szigetköz (about the construction of wells);
- Risks related to river training interventions contemplated in the area of the Island of Szentendre.

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SOILS

Contribution to the "Environment and Ecology" Chapter of the Gabcikovo-Nagymaros Project

The territory of the Gabcikovo-Nagymaros Project is a large alluvial plain of the river Danube, rich in various valuable natural ecosystems (floodplain forests, wetlands) with high diversity and beautiful landscape sceneries. At the same time the area is a traditionally important agricultural region of Hungary, a historically well-developed centre for agricultural sciences, research and high education. There is abundance of available information on the soils and other environmental factors of the region with long-term observations, field experiments and experiences in agricultural production.

The area — similarly to the Great Hungarian Plain - has continental climate: with considerable temperature extremes (cold winter, hot summer) and low precipitation with high spatial and temporal variabilities. The soils of the Danube alluvial terrace with favourable hydrophysical characteristics and moisture regime efficiently moderate these weather extremes in most part of the region. The capillary transport of water from the high quality groundwater (if it is standing and fluctuating within the medium-textured — sand/loam/silt -sediments covering the thick gravel strata of the alluvial terrace) to the overlying horizons represents a considerable contribution to the water-supply of rained natural vegetation and cultivated crops. The high geothermic gradient, the availability of good-quality "sweet" hot waters at a relatively moderate depth creates particularly favourable conditions for intensive vegetable production under controlled conditions.

Because of the characteristic geological structure of the alluvial terrace (high horizontal heterogeneity and stratification; occurrence of the loose gravel strata at a certain depth) the natural and agricultural ecosystems of the region show high spatial and temporal variabilities, and particular sensitivity to the (atmospheric precipitation-supplementing) capillary moisture supply from the groundwater to the overlying horizons, to the root zone. The possibilities of this capillary transport are determined in the area by the following factors:

- the depth, thickness and continuity of the gravel strata;
- the stratification (profile) of the medium-textured (silty sand, sandy silt, loamy silt) sediments above the gravel strata and their hydrophysical properties, especially water storage capacity, water retention, available moisture range; infiltration rate, saturated and unsaturated hydraulic conductivities;
- the depth and fluctuation of the groundwater table.

Depending on the territorial variability of these factors the soils, land-site characteristics, natural vegetation or biomass productivity of agricultural land vary considerably. There are great varieties of land-sites from the shallow, extremely drought-sensitive territories (gravel on or near to the soil surface); through the highly productive areas with thick medium-textured sediments, deep good-quality groundwater; till the low-lying, soils and considerable moisture supply from the shallow or moderately deep temporarily waterlogged wetlands or periodically flooded floodplain with repeated suspended load ("fresh silt") sedimentation. The particularly wide spectra of landscapes and land-sites in the region are the basis both of the various occurring natural ecosystems representing high, uniquely valuable species spectra and biodiversity; and of the successful and efficient biomass production agriculture and silviculture.

Any human intervention which results in changes in the above mentioned conditions will change the present equilibrium of the nature: the species spectra, the bio-diversity, the agro-ecological potential, the land productivity. And their consequences will be significant, rapid and - in many cases — irreversible (non- or hardly correctable), because of the particular sensitivity of the existing ecosystems and land-sites. This is the main reason of our personal, institutional and national public awareness concerning the future of the Bős-Nagymaros Project area.

Forecasted changes in the moisture- and substance-regimes of soils in the Gabcikovo-Nagymaros Project area

- On the basis of our investigations it can be firmly stated that the most important key-problem of the detailed soil-ecological-agricultural impact analysis of any modification in the "original" Danube (and the related surface- and subsurface hydrology) system is the regulation of groundwater conditions, including two main issues:
  - the regulation of the groundwater level (and its fluctuation); and
  - the prevention of any kind of groundwater pollution from various point and non-point sources.

The effective and efficient implementation of the actions necessary to ensure the above-mentioned two main requirements needs unavoidable large-volume investments. In the present and near-future economy situation in Hungary (and in Slovakia) there is no real guaranty for such additional large-scale investments. Without the realization of the mentioned two main preconditions the following unfavourable environmental side-effects can be forecasted with high probability:

- unfavourable changes in the substance regime of soils;
- decreasing soil fertility, problems in the main soil functions,
- simultaneously increasing hazard of over-moistening, water-logging and drought-sensitivity;
- decreasing agro-ecological potential and actual productivity of the area and increasing dependence (risk) of agricultural production from the weather conditions.

The most important factor of soil fertility, agricultural productivity and other soil functions (conditionally renewable natural resource; transformator and integrator of other natural resources, such as solar radiation, atmosphere, surface- and subsurface waters and biological resources; storage of heat, water plant nutrients and other elements, including soil pollutants; buffering of natural and anthropogeneous or human-induced stresses, such as weather extremes, atmospheric deposition, pollution; filtering function preventing subsurface water resources from pollution; gen-reservoir and important media of biodiversity) in the Gabcikovo-Nagymaros Project Area is the soil moisture regime, in which the following basic situations occur and can be forecasted :

1. The groundwater is and will be standing and fluctuating in the gravel strata. In these areas there will be no changes in the soil moisture regime: the capillary transport from the groundwater to the soil is practically zero, independently of the depth of water table in the gravel strata. These shallow soils have low fertility and particularly high drought-sensitivity, and their productivity is highly weather-dependent.

2. The groundwater is and will be standing and fluctuating in finer-textured sediments. In these territories the forecasted

(a) rise of the water table will result in a certain increase in the capillary transport of water (and soluble materials) from the groundwater to the overlying horizons;

(b) sinking of the water table will be followed by a certain decrease in the capillary transport from the groundwater to the overlying horizons.

The average change in the capillary transport is about 50 mm/year. Its exact quantity can be calculated with the application of the 4-step model presented before.

3. The groundwater is standing and fluctuating at present within finer-textured sediments, but as a direct or indirect consequence of the changes in the hydrology of the Danube-system (e.g. reduction of groundwater-supply from the original riverbed and from the connecting branches and meanders because of their reduced water quantity due to the man-controlled flow in the artificial Danube canal or due to the function of the "C-variant" established by the Slovak Republic, etc.) the groundwater table will sink to the gravel strata.

In these areas the capillary water supply from the groundwater (standing — at least periodically — in gravel strata) will completely stop (or — at least — will be radically reduced). This capillary transport reduction may reach 100–150 mm/year. Under the given climate-weather conditions (relatively low atmospheric precipitation with high spatial and temporal variability, dry vegetation period) the relatively favourable conditions for biomass production (including the traditional vegetable production) is based mainly on this capillary water supply from the good-quality groundwater, ensuring good yields and considerably reducing the weather-dependent yield fluctuations (climatic risks). The capillary water-supply is "free of charge", automatic, self-controlled, cannot lead to oversaturation and structure destruction (such as irrigation), and, so has vital importance in the given region. Consequently, the stop or radical reduction of this moisture supply (100–150 mm/year) will result in dramatic changes in the soil's moisture- and substance-regimes; in the species spectra and bioproductivity of natural ecosystems; in soil productivity; and in the yields (and yield safety) of cultivated crops. These consequences cannot be balanced simply with irrigation, because of high costs, labour requirement and potential environmental consequences (e.g. compaction and structure destruction of the soil, etc.).

4. The groundwater is standing and fluctuating at present in the gravel strata, but — as a direct or indirect consequence of hydrological changes in the Danube system — the groundwater table will rise (at least periodically) to fine-textured sediments. In such cases the moisture-regime consequences are quite opposite to the changes mentioned above (point 3). In such areas the capillary transport from the groundwater to the overlying horizons may considerably contribute to the moisture supply of the natural vegetation or cultivated crops. And this fact is favourable in most of the cases. The estimated territorial distribution of the described cases are as follows: 1. : 30% ; 2. : 30% ; 3. : 30% ; 4. : 10%.

5. The changes in the hydrological cycle of the floodplain forests and floodplain wetlands (meadows, pastures, periodically flooded or water-logged wetland ecosystems with wide species spectra and biodiversity): sinking of the water level in the small river branches and meanders or their periodical drying (in serious cases, like in 1992 and 1993) will result in dramatic (sometimes irreversible) ecological consequences: changes in their species spectra; biomass production and biodiversity.

6. Another important consequence of these hydrological changes are the serious problems in the well-developed water-tourism, hobby-angling and recreation, loosing a beautiful and romantic water and wetland "paradise 70.

The changes in the hydrological cycle of the area and in the moisture regime of soils results in considerable changes in the biogeochemical cycles of various elements and in the substance regime of soil, as well. The main prognosted changes can be summarized, as follows:

> **A.** Development of carbonate accumulation layers, lime concretions, limecoated gravels, sometimes cemented into a hard and impervious petrocalcic horizon or even into a solid "carbonate hardpan" at the boundary of the fine-textured sediments and the gravel strata under the influence of fluctuating groundwater with high carbonate content. These layers, horizons and pans make the soil shallow and sensitive for moisture extremes (drought; over-moistening and water-logging).

B. In the territories with sinking groundwater table:

- the wetting of soils is reduced, leading to the reduction of their hydromorphic features;
- the ratio between the aerobic-anaerobic decomposition of organic matter will be changed in the direction of aerobic processes, which leads to the increasing mineralization rate of plant residues and applied organic fertilizers;
- the water and solute transport will be changed in the direction of downward flow and leaching;
- the downward movement of fine mineral particles from the topsoil and from the fine-textured sediment layers will fill up the

large macropores of the loose gravel strata and leads to the development of cemented gravel layer with very low permeability and root penetrability which makes the soil shallow and particularly drought-sensitive.

C. In the territories with rising water table:

— increasing the probability of the overmoistening of the soil with its unfavourable ecological (aeration problems unfavourable changes ini the soil biota, in the microbiological processes and in the nutrient regime) and technological (problems in tillage and other agrotechnical operations) consequences; -formation of carbonate accumulation horizons (carbonate concretions, lime coated gravel layers, petrocalcic horizons or even "lime-pans") as a result of the capillary transport from the groundwater of high carbonate content to the upper boundary of the capillary fringe;

— secondary salinization/alkalization process under the influence of stagnant, shallow water table and high groundwater salinity. Salinity/alkalinity is of minor importance in the well-drained Szigetköz region, but it is a serious environmental hazard in the Slovakian side, particularly in the low lying, poorly drained areas of the Eastern Zitny Ostrove region.

D. In the case of groundwater-pollution from various sources [if the proper management — disposal, dilution, purification, etc. — of the wastes, waste-waters, sewage sludges, liquid manures from various sources (industry, concentrated dairy-farms, improper fertilizer application, rural and urban development, drinking-water supply without canalization, etc.) is not solved by considerable additional, supplementary investment] will increase, this creates a serious threat of microorganisms, animals and human-beings partly directly (as drinking water) or through the plant animal man food chain, for animal and human health and hygienic conditions.

The Nature Protection Aspects of the Gabcikovo–Nagymaros Project

I. Natural values affected by the construction of the Gabcikovo-Nagymaros Project

It is a well-known fact that the natural values of a given landscape are not restricted to the living components alone, but include inanimate formations of nature. In this study we shall examine the flora and fauna of the area affected by the diversion of the Danube, and discuss their conservation value.

The affected area may be divided into three major sections: the Szigetköz, the Danube valley (from the Szigetköz downstream to the Danube Bend) and the Danube Bend (including the northern part of Szentendre Island. The botanical assessment of these three sections was based on a uniformly distributed sampling, the zoological on less evenly distributed collecting efforts. While the flora and fauna of the Szigetköz is fairly well-known, the fauna of the Danube valley is practically unexplored, as is the zoological assessment of the Danube Bend, since it started only a year ago in 1992. We would like to emphasise though, that except for the Szigetköz, research is not exclusively focused on the dam's effect on the flora and fauna, but it is aimed to clearly show their present state.

The detailed environmental impact assessment of the flora and fauna of the Szigetköz is of paramount importance, since this region was most highly affected by the human activity arising from the bilateral treaty between Hungary and Czechoslovakia, and by continued Slovak works after the termination of the treaty by Hungary.

I. 1. General characterization of the flora and fauna of the Szigetköz (its state prior the diversion)

The Szigetköz is an unique section of the Danube valley, since a braided branch-system on a similar alluvial cone neither exists upstream nor downstream. In a relatively small area, this branch-system accommodates a wide range and an amazing diversity of habitats. Considering the size of Szigetköz, the flora and the fauna are remarkably rich.

The greatest value of the Szigetköz is the landscape itself, which was created by the Danube, with the unique geomorphological and hydrological formations and the natural values, both botanical and zoological. Because of extensive river regulations and the agricultural use of all available land, the area covered by riparian woodlands elsewhere in Europe is continuously and drastically decreasing, with alterations to their natural state and biological degradation. In contrast, significant stands of soft and hard wood riparian forest remain intact in the Szigetköz. Therefore, these riparian forests, and nearby bordering areas with their fauna, are natural values of European significance.

Owing to its special geological, geomorphological, climate and water-regime features, the Szigetköz has unique fauna. The waters arriving from the Alps constantly carry plant seeds and other reproductive components, which occasionally get stuck in the slow side branches, and when other ecological circumstances are favourable (for example cool, moist temperatures) may eventually settle in the Szigetköz. The near-natural, lowland-type forest stands owe their uniqueness to the dealpine and montane beech forest elements (for example the following species: *Selaginella helvetica, Achillea ptarmica, Lilium bulbiferum, Gentianella ciliata, G. austriaca, Carex alba, Parnassia palustris).* Although a majority of these plant associations are not rare, the species composition is peculiar. For example the diversity of orchid species is remarkable (23 species). In the maintenance of botanical diversity, the immigration of species and the repeated inundation are essential. Both of these were previously ensured by vast flow of the Danube into the side branch-system during the floods.

As a consequence of the decreased flow of the Danube, the Szigetköz has received significantly less water, resulting in a drastic decrease in the size of the wetland habitat (moors, fenwoods, marshes). Therefore, the remaining patches of these habitats with their exceptionally rich biota should be strictly protected. At higher elevations, in certain localities, the original steppe vegetation is still prevailing.

These conclusions hold true for the fauna, too. As a general rule the fauna of the great Central-European river basins are very similar, regardless to their exact geographical location. However, the fauna of the Szigetköz is unique from that of any other river basin because of its special geographical situation. Since the fauna of the Szigetköz is enriched with particular species assemblages, its species composition is unequalled (for example East-Alpean, Atlantic, lower-montane, and steppe species — beetles: *Leptura maculicornis, Acanthocinus aedilis, A. griseus; lepidopterans: Aricia artaxerxes, Scopula umbelaria, Acasis viretata, Perizoma sagittata; fishes: Cottus gobio Hucho hucho; mammals: Microtus oeconomus).*

Thus, not only the highly valuable rare species, but also the species combination and composition of the Szigetköz are unique.

The high species diversity of fauna is indicated by the fact, that 30–50% of the species of the Hungarian fauna may be found in the Szigetköz, and in the case of some taxa an even higher proportion may be established, of course, the numbers refer to the animal groups studied. These species were recorded on the 9000 hectares of the Nature Reserve. The high number of species may be explained by the presence of a large quantity of mosaic-like patches of habitat over a relatively small area. In these patches, many of the main habitat types may be found: submontane river, connected and isolated side branches, canals, moorlands, marshes, hard and soft wood riparian forests, *Convallario-Quercetum, Salicetum triandrae-purpureae associations, relict Carpino-Quercetum associations*, fens and remnant patches of forested steppe vegetation.

According to our present knowledge 57 protected and 56 Hungarian Red Data Book plant species have been ascertained in the Szigetköz. From among the animal species specifically examined by us 314 species are protected while 66 are included in the Hungarian Red Data Book. Of the animal species 159 (Appendix II) and 113 (Appendix III) are found in the Bern Convention. Furthermore, the Convention on the Conservation of Migratory Species of Wild Animals lists 2 species in Appendix I and 100 species in Appendix II. In the IUCN Red List of Threatened Animals (1994) 17 species are mentioned.

I. 2. The flora and plant associations

The vascular plants. According to botanical surveys undertaken over the last three years, the number of plant species between the Moson-Danube and the Öreg-Danube is 917. Considering the relatively small area and the high percentage of land cultivated or otherwise affected by forest management, this number is quite high, since it comprises some 42% of the total Hungarian flora. During botanical surveys a number of species were not found and considered to have disappeared during the past decades, e.g. *Selaginella helvetica, Daphne cneorum, Carlina acaulis, Centaurea arenaria, Salvia aethiopis.* Vascular plants are either somewhat rare or not always present in the flora; in other cases, their exact place of occurrence cannot be defined.

The plant associations. Approximately 25% of the 26 000 hectares of the Szigetköz is covered by near natural or semicultivated associations, such as forests, poplar and willow stands, aquatic plant associations, marshes, pastures. Although poplar and willow stands are originally cultivated plantations, they are nevertheless regarded as near natural associations because they accommodate floodplain and montane elements.

According to recent botanical assessments several floodplain associations live in the Szigetköz in a natural or near-natural state. 67 associations have already been found in this area, and the number is expected to rise. From the point of view of nature protection, 17% of these associations are highly valuable, including relicts (2 associations) and those demanding protection (10 associations); 46% are valuable, including near-natural (25 associationss) and pioneer (6 associations). 9% of these associations are disturbance tolerant and 6 are categorised as less degraded; however, 27% are highly disturbed weed association, with degradation of 18, which is the direct outcome of intense agricultural disturbance.

Vascular (flowering) plant species and plant associations of the water bodies and aquatic habitats of the Danube

The flora. The vascular flora of aquatic and marshland habitats is rich. Except for some rarities, all characteristic species of floodplains are present in the Szigetköz area. Characteristic aquatic and protected species:

Elodea canadensis, Groenlandia densa (Upper-Szigetköz), *Callitriche cophocarpa, Ceratophyllum demersum, Hippuris vulgaris, Hottonia palustris* (Lower-Szigetköz), *Hydrocharis morsus-ranae, Lemna minor, Myriophyllum spicatum, M. verticillatum, Najas minor* (Middle- and Lower-Szigetköz), *Nuphar luteum, Nymphaea alba, Nymphoides peltata, Pedicularis palustris* (Middle- and Lower-Szigetköz), *Polygonum amphibium* (Lower-Szigetköz), *Potamogeton acutifolius, P. compressus* (Atlantic species, that occur only in the Szigetköz in Hungary), *P. crispus, P. gramineus* (Lower-Szigetköz), *P. lucens, P. natans* (Upper-Szigetköz), *P. nodosus* (Upper-Szigetköz), *P. panormitanus* (Lower-Szigetköz), *P. pectinatus, P. perfoliatus, P. trichoides* (Lower-Szigetköz), *Ranunculus baudotii* (Lower-Szigetköz), *R. circinnatus* (Upper-Szigetköz), *R. fluitans* (in Hungary appears only in the Upper-Szigetköz), *R. petiveri, R. radians* (Middle-Szigetköz), *R. rionii* (Lower-Szigetköz), *R. trichophyllus, Salvinia natans, Stratiotes aloidens, Utricularia australis* (Lower-Szigetköz), *U. minor* (Upper-Szigetköz), *U. vulgaris* (Middle-Szigetköz), *Vallisneria spiralis* (Upper-Szigetköz). Further marshland vegetation elements and protected species: Epipactis palustris, Iris pseudacorus, Dactylorrhiza incarnata.

The plant associations. Widespread aquatic and marshland associations, which are classified as relicts or deserving protection:

Lemno-Spirodeletum, Salvinio-Spirodeletum, Lemno-Utricularietum, Hydrochari-Stratiotetum (Upper-Szigetköz), *Batrachietum fluitantis* (which is only found in the Upper-Szigetköz), *Hottonietum palustris* (Lower-Szigetköz), *Elodeetum canadensis, Myriophyllo-Potamogetonetum, Potamogetono perfoliati-Batrachietum circinnati* (Upper-Szigetköz), *Potamogetonetum lucentis, P. natantis, Nymphaeetum albo-luteae, Nymphoidetum peltatae, Scirpo-Phragmitetum austro-orientale, Sparganietum erecti, Glycerietum maximae, Rorippo-Oenanthetum, Sparganio-Glycerietum fluitantis, Caricetum elatae, Carici-Menyanthetum, Carici-Typhoidetum, Caricetum acutiformis-ripariae, Caricetum vulpinae, Eleochari-Caricetum bohemicae* (pioneer associations), *Calamagrosti-Salicetum cinereae, Dryopteridi-Alnetum* (willow relicts and alder marsh vegetation).

Vascular plant species and plant associations of the Szigetköz floodplain

The flora: Seriously endangered or strictly protected species: *Ophrys apifera, O. insectifera* (these two are rare in both Hungary and the Upper-Szigetköz);

Protected species include all of the further 21 species of the Orchidaceae family: *Anacamptis pyramidalis, Cephalanthera damasonium, C. longifolia, C. rubra, Epipactis atrorubens, E. helleborine, E. microphylla, E. palustris, Orchis coriophora, O. laxiflora subsp. palustris, O. militaris, O. morio, O. purpurea, O. ustulata, Dactylorrhiza incarnata, D. maculata, Neottia nidus-avis, Gymnadenia conopea, Listera ovata, Platanthera bifolia;*

Other protected species, including some montane elements: *Ophioglossum vulgatum, Dryopteris carthusiana, D. dilatata, Thelypteris palustris, Adonis vernalis, Anemone sylvestris, Clematis integrifolia, Parnassia palustris, Astragalus exscapus, Lathyrus pannonicus, Dictamnus albus, Vitis sylvestris, Gentiana cruciata, G. pneumonanthe, Gentianella ciliata, G. austriaca, Aster amellus, Inula oculus-christi, Jurinea mollis, Pyrola rotundifolia, Dianthus superbus, Primula elatior, Hemerocallis lilio-asphodelus, Lilium bulbiferum* (this species occurs in the Szigetköz plain only at low elevations, where its richest population in Hungary may be found), *Scilla vindobonensis, Leucojum aestivum, Iris pseudacorus, I. pumila, I. sibirica, I. spuria, Eriophorum angustifolium, E. latifolium, Stipa borysthenica, S. pennata;*

The *Fagetalia* species are also characteristic of the Szigetköz area: *Euphorbia amygdaloides, Majanthemum bifolium, Carex pilosa, C. alba,* *Galium odoratum, Viola sylvatica, Allium ursinum, Arum orientale, and a montane element: Pyrola rotundifolia;*

In the marshland meadows, important species include: *Sanguisorba officinalis, Sesleria uliginosa* (rare species), with the following representative endemics: *Molinia hungarica, M. arundinacea, Allium angulosum.* In the meadows and hayfield rare species include: *Achillea ptarmica, Gallium boreale.* In the fall *Colchicum autumnale* occurs in masses. Steppe elements include: *Anemone sylvestris, Festuca rupicola, Peucedanum alsaticum, Tunica saxifraga.*

The above-listed species show the diversity of the rich floodplain flora and indicate the importance of the primary and original state of the Szigetköz.

The plant associations. There are near natural associations of forests (near the villages of Feketeerdő, Halászi, Dunakiliti, Rajka and Hédervár), and Molinietalia, Molinion and Arrhenatheretalium communities are found in the Upper- and Middle-Szigetköz. The near-natural or relict associations requiring protection include:

Salicetum triandrae-purpureae, Salicetum albae-fragilis, Fraxino pannonicae-Ulmetum (in several stands, for example at Dunasziget, with the co-dominant species *Alnus incana), Querco robori-Carpinetum* (its only stand in the Szigetköz is found near Halászi in the Derék forest, the species composition of this beautiful relict forest has not changed since 1930, and similar forests are only found in Hungary on the Great Hungarian Plain), *Festuco-Quercetum roboris* (at Püski, with fragments also present in the Kimlei forest). *Deschampsietum caespitosae croato-pannonicum, Alopecuretum pratensis, Agrostetum albae, Cirsio cani-Festucetum pratensis, Agrostio-Typhoidetum, Trisetetum flavescentis, Carici flavae-Eriophoretum, Succiso-Molinietum (Lower-Szigetköz), Arrhenatheretum elatioris et subass. festucetosum rubrae, Brometum tectorum, Astragalo-Festucetum rupicolae, Potentillo-Festucetum pseudovinae.*

The relicts of alder and willow swamps (and the associations of alder and willow), which deserve protection, are of great importance because they are the last remnants of the original marshland. The *Phragmitetum* and *Glycerietum moxinae* associations cover the largest area. There are smaller fragments of *Nymphoidetum, Hottonietum,* and fragments of *Caricetum elotae* and *Seslerietum uliginosae.* Relict and protected species also occur in these associations. The high number of natural associations is a characteristic of the Szigetköz, and this mosaicity is a crucial element of the landscape. Other important elements include willow stands, *Fraxino-pannonicae-Ulmetum* riparian forests, and Potametea-, *Phragmitetea-, Molinio-Juncetea* communities. It is worth mentioning that only occurrence of *Ranunculaetum fluitans* association is in the Szigetköz. The preservation of these remnant patches is essential for the conservation of the region's original biota because these patches could serve as the starting point for reconstructing the original state of the Szigetköz. The plant associations of the meadows and pastures fortunately indicate lower level of disturbance. Several hundred years of agricultural use undoubtedly facilitated the invasion of weed associations.

I. 3. The fauna of the Szigetköz

The description of the Szigetköz fauna is more difficult than that of the flora, because animals are not as constant and clearly distinguishable, as plant associations and vegetation types. While a botanical data record (the occurrence of a certain species) shows that any given species (or individual plant) is a member of a specific association (belt, zone), a zoological reference only shows that at given animal was spotted at a particular place, and may or may not be a member of that community. Furthermore, there is not characteristic group of animals in the Szigetköz, in contrast to the vascular (flowering) plants that characterise the plant community. Therefore, the fauna of the Szigetköz is described here according to large taxonomical units.

Mollusca *(Molluscs)*

116 Mollusca species were collected from 74 localities (this constitutes 48% of all Hungarian Mollusca fauna). On the basis of detailed studies, we concluded that the number of species is very high and that the Szigetköz is of paramount importance in the preservation of Mollusca species. Several species occurred only a limited array localities. The patchiness of the Szigetköz might explain this phenomenon, and these patches are important reservoirs in some cases. The occurrence of an additional 13 species is possible and these may be introduced or rheophilous species. Specimens of *Paladilhia oshanove* were not found in the upper reaches of the Danube, although intensive research was carried out in Germany and Austria. This ground-dwelling snail has gills and lives in the ground water of the alluvial fan. It is probably an endemic species of the Szigetköz. As the *Paladilhia* species are real stygobiont organisms, they may live in holes with moving. The other molluscs are grouped according to their habitats.

Rheophilous species live in fast-flowing waterbodies, with strong current:

Gastropoda: *Theodoxus (Theodoxus) transversalis, Theodoxus (Theodoxus) danubialis, Viviparus (Viviparus) acerosus, Potamopyrgus jenkinsi, Lithoglyphus naticoides, Fagotia (Microcolpia) acicularis, Fagotia (Fagotia) esperi, Ancylus fluviatilis; Bivalvia: Unio pictorum, Unio crassus, Anodonta (Anodonta) cygnea, Pseudanodonta complanata, Dreissena polymorpha, Sphaerium (Sphaeriastrum) rivicola, Pisidium amnicum, Pisidium henslowanum, Pisidium supinum.*

Species in slowly-flowing waterbodies, including those living in canals, ponds, dead branches:

Gastropoda: *Viviparus (Viviparus) contectus, Valvata (Valvata) cristata, Valvata (Cincinna) piscinalis, Valvata (Cincinna) pulchella, Bithynia (Bythinia) tentaculata, Bithynia (Bythinia) leachi, Acroloxus lacustris, Lymnaea (Lymnaea) stagnalis, Lymnaea (Galba) truncatula, Lymnaea, (Radix) auricularia, Lymnaea (Radix) peregra, Physa fontinalis, Physella (Constatella) acuta, Planorbarius corneus, Planorbis planorbis, Planorbis carinatus, Anisus vortex, Anisus vorticulus, Bathyomphalus contortus, Gyraulus (Gyraulus) albus, Gyraulus (Torquis) laevis, Gyraulus (Lamorbis) riparius, Gyraulus (Armiger) crista, Hippeutis complanatus; Bivalvia: Sphaerium (Sphaerium) corneum, Sphaerium (Musculium) lacustre,Pisidium milium, Pisidium nitidum, Pisidium obtusale, Pisidium subtruncatum.*

Species capable of living in marshes and water accumulating in pits:

Gastropoda: *Lymnaea (Stagnicola) palustris, Aplexa hypnorum, Anisus spirorbis, Segmentina nitida and Bivalvia: Pisidium casertanum, Pisidium personatum.*

Gastropoda species characteristic of Carex vegetation and wet meadows:

Carychiumminimum, Cochlicopa nitens, Vertigo (Vertilla) angustior, Vallonia (Vallonia) enniensis, Succinea (Succinella) oblonga, Oxyloma elegans, Nesovitrea hammonis, Deroceras (Deroceras) laeve, Perforatella rubiginosa.

Snails characteristic of moist meadows and shaded places: *Cochlicopa lubrica, Vertigo (Vertigo) pygmaea, Pupilla (Pupilla) muscorum.*

Species occurring in dry grasslands or along roads: *Cochlicopa lubricella, Truncatellina cylindrica, Granaria frumentum, Vallonia (Vallonia) pulchella, Helicella (Helicella) obvia, Helicopsis (Helicopsis) striata, Monacha (Monacha) cartusiana, Cepaea vindobonensis.*

Snail species characteristic of marshlands, riparian forest:

Carychium tridentatum, Vertigo (Vertigo) antivertigo, Vertigo (Vertigo) moulinsiana, Succinea (Succinea) putris, Macrogastra (Macrogastra) ventricosa, Arion (Mesarion) subfuscus, Semilimax semilimax, Zonitoides (Zonitoides) nitidus, Vitrea (Crystallus) crystallina, Aegopinella nitens, Euconulus (Euconulus) fulvus, Trichia (Trichia) striolata, Trichia (Trichia) hispida, Helicigona (Arianta) arbustorum, Cepaea hortensis.

Snails living in moist forests: *Columella edentula, Acanthinula aculeata, Clausilia (Clausilia) pumila, Balea (Alinda) biplicata, Punctum (Punctum) pygmaeum, Discus (Discus) rotundatus, Discus (Discus) perspectivus, Bradybaena (Bradybaena) fruticum, Perforatella (Monachoides) umbrosa, Trichia (Trichia) unidentata.*

Snails living in dry deciduous forests: *Vallonia (Vallonia) costata, Chondrula (Chondrula) tridens, Cochlodina (Cochlodina) laminata, Vitrina (Vitrina) pellucida, Aegopinella minor, Limax (Limax) cinereoniger, Perforatella (Monachoides) incarnata, Euomphalia (Euomphalia) strigella, Helix (Helix) pomatia.*

Snails characteristic of the human environment, or living in cultivated lands: *Cecilioides (Cecilioides) acicula, Arion (Arion) lusitanicus, Oxychilus (Oxychilus) draparnaudi, Tandonia budapestensis, Limax (Limax) maximus, Deroceras (Agriolimax) reticulatum, Eobania vermiculata.*

Crustacea *(Microcrustaceans)*

Hungary has a total of 150 crustacean species (90 Cladocera, 60 Copepoda), 96 of which are present in the Szigetköz (64 Cladocera, 32 Copepoda), thus the Szigetköz is extremely rich in species, for several reasons. First of all, the fact that the Danube meets a plain creates a high diversity of aquatic habitats. The fauna of the main branch, side branches, dead arms, canals and stagnant water bodies is further affected by the dynamics of the water regime and by flooding. This pattern is demonstrated by material collected from the side branch-system at Ásványráró in 1991. Desiccating shallow water bodies are characterised by Daphnia magna and Moina brachiata. Samples collected near lake Öntési contain these species, as well as Chydoridae species, which are usually present in the vegetation of the littoral zone. Daphnia cucullata, which is widespread in larger stagnant water bodies, was also found in these samples. Eurytemora velox was also found, the first record of this species in Hungary. In 1992 the latter species was the most widespread crustacean in the Szigetköz, and it has colonised several water-types.

We can conclude that the Szigetköz is a very species-rich in Crustaceans.

Odonata *(Dragonflies)*

Forty-five species of Odonata were found in the Szigetköz (adults of 42 and larvae of 32 species were collected). This is more than the half of the Hungarian Odonata fauna. The high species diversity is partly maintained by the slow flowing of the Danube in the Szigetköz, which transports and accumulates sediment, as well as the well-developed side branch-system. The larvae of dragonflies breath dissolved oxygen from the water, and water quality is therefore an important factor for their survival. There are three areas in the Szigetköz that are of paramount importance for maintaining Odonata: the Moson-Danube, Gazfűi Holt-Danube (Sérfenyősziget-Cikolasziget) and the Nováki-csatorna (Halászi, Püski).

The Moson-Danube is a meandering Danube branch, which preserved its original state fairly well. Because of its different size of sediment, several habitat types have developed. These habitats, as well as the bog patches occurring in the riparian forest offer excellent conditions for the Odonata. Species living here include: Stylurus flaviceps (protected by the Bern Convention), *Aeshna cyanea* and *Sympetrum danae.*

The Gazfűi Holt-Danube and the Nováki-csatorna branching from it, are the only localities where *Epitheca bimaculata* may be found in the Little Hungarian Plain. The population of *Aeshna grandis* is remarkably strong here.

The Nováki-csatorna is the richest in Odonata species of the Szigetköz water bodies 23 species were found. The most valuable species include Somatochlora *flavomaculata, Aeshna grandis and Anax parthenope.*

Heteroptera *(Aquatic and semiaquatic bugs)*

Data on 27 species were obtained. Although Heteroptera species were absent in fast flowing river sections and lakes formed in gravel excavations, aquatic Heteroptera are rich in other localities. Interestingly, semiaquatic species are not as diverse.

Species characteristic of waterbodies partly covered by vegetation were dominant in the samples. The wide range of water and habitat types in the Szigetköz accommodate diverse species of aquatic and surface-dwelling heteropterans, comparable to that of Lake Balaton. The populations are limited by natural changes of the water-regime. Four species *(Hydrometra gracilentum, Micronecta griseola, Hesperocorixa sahlbergi and Sigara fossarum)* are interesting from faunistical point of view, and the latter species was recorded in Hungary for the first time.

Neuropteroidea *('Net-winged')*

42 species of Neuroptera, one third of all Hungarian Neuroptera, were collected at 35 localities in the Szigetköz. In addition to the characteristic species of lower montane areas, several westernly and north-westernly distributed European species were found in the Szigetköz. *Coniopteryx aspoecki* and three other Neuroptera species developing in the water along the banks of Moson-Danube *(Sialis morio, S. nigripes and Sisyra terminalis)* are of high natural values.

The Házi forest is the most natural stand of the hard wood riparian forests covering the higher elevations of the floodplain. The natural state of this forest is indicated by the fact that 7 of the 10 characteristic Neuropterans were recorded here. Four neuropteroid species living in the forest deserve protection, including *Nineta carinthiaca.*

Coleoptera *(Beetles)*

Based on our knowledge of the Coleoptera of the Carpathian Basin, the estimated number of the beetles of the Szigetköz is 2000. One third of these has already been recorded. We have provided below a list of 44 species characteristic of the areas deserving protection. The species may be grouped as:

- protected species;
- endangered species, which should be protected;
- rare, faunistically important species (characteristic for Hungarian habitats); and
- extremely rare species in Hungary (recorded only in the Szigetköz), the survival of their populations is uncertain.

List of species

Calosoma auropunctatum (Herbst, 1784) — protected, endangered species.

Calosoma reticulatum (Fabricius, 1787) — protected species, also listed in the Red Data Book.

Carabus coriaceus coriaceus Linnaeus, 1758 — protected species.

Carabus hungaricus hungaricus Fabricius, 1792 — protected species, highly endangered.

Carabus germarii exasperatus Duftschmid, 1812 — protected species.

Carabus granulatus granulatus Linnaeus, 1758 — protected species.

Carabus cancellatus cancellatus Illiger, 1798 — protected species.

Carabus ulrichii ulrichii Germar, 1824 — protected species.

Carabus scheidleri baderlei Mandl, 1965 — endangered subspecies, its protection is recommended; in Hungary it is found only in the Szigetköz.

Cychrus caraboides (Linnaeus, 1758) — protected species.

Nebria livida (Linnaeus, 1758) — rare montane species, in Hungary it occurs only along the Danube and Rába rivers; its protection is recommended.

Trechus obtusus Erichson, 1837 — rare species, occurring sporadically in the western part of Hungary.

Bembidion fasciolatum (Duftschmid, 1812) — rare montane species, in Hungary it occurs only in the Szigetköz and along the Rába river.

Bembidion modestum (Fabricius, 1801) — sporadically occurring montane species.

Perileptus areolatus (Creutzer, 1799) — rare, endangered species, occurring along good water quality rivers and clear lakes, and dwelling on soaked gravel surrounding fresh lakes.

Abax parallelepipedus (Piller et Mitterpacher, 1783) — characteristic, abundant montane species, occurring only in the Szigetköz on plain localities of low elevation.

Rantus consputus (Sturm, 1834) — a characteristic species of rivers of continental steppe or forest habitats.

Gaurodytes subtilis (Erichson, 1837) — characteristic species of cooler, moist, montane habitats.

Hydroporus rufifrons (Duftschmid, 1805) — in Hungary it occurs only in the Szigetköz.

Gyrinulus minutus (Fabricius, 1798) — one of the three known Hungarian localities of this species is in the Szigetköz.

Orectochilus villosus (O. F. Müller, 1776) — living in fast-flowing cool, clear waterbodies, in larger streams and rivers.

Bledius pallipes (Gravenhorst, 1802) — there are only two known localities of this species in Hungary, one of them is situated in the Szigetköz.

Dicerca alni (Fischer, 1823) — its occurrence is sporadic in Hungary.

Lucanus cervus cervus (Linnaeus, 1758) — protected species.

Dorcus parallelipipedus (Linnaeus, 1758) — protected species.

Odonteus armiger (Scopoli, 1772) — a widespread but rare species in the forested areas of Hungary; its protection is recommended.

Potosia aeruginosa (Drury, 1770) — protected species.

Osmoderma eremita (Scopoli, 1763) — protected species, highly endangered; throughout Europe it occurs sporadically only in old willow stands along rivers.

Megopis scabricornis (Scopoli, 1763) — protected species.

Rhamnusium bicolor (Schrank, 1781) — protected and endangered species.

Lamia textor (Linnaeus, 1758) — endangered but not yet protected species; its protection is recommended.

Obrium brunneum (Fabricius, 1792), Leptura maculicornis (De Geer, 1775), Leptura rubra (Linnaeus, 1758), Leptura sanguinolenta (Linnaeus, 1761), Monochamus galloprovincialis pistor (Germar, 1818), Acanthocinus aedilis (Linnaeus, 1758), Acanthocinus griseus (Fabricius, 1792) — are characteristic species of montane deciduous and pine forests; in the Szigetköz they live in the Pinus silvestris plantations.

Obrium bicolor Kraatz, 1862 — reaching the north-western border of its area in Hungary, it is abundant in the hard wood riparian forests of the Szigetköz.

Nathrius brevipennis (Mulsant, 1839) — occurs sporadically in Hungary.

Aromia moschata (Linnaeus, 1758) — characteristic of willow stands; deserves protection.

Calamobius filum (Rossi, 1790) — protected species.

Timarcha tenebricosa moravica Bechyně, 1949 — occurs sporadically on the plains, foothills and lower montane areas.

Sermylassa halensis (Linnaeus, 1758) occurs in a limited number of localities in Hungary.

Trichoptera *(Caddis-flies)*

64 species have been confirmed. Considering the plain character of the Szigetköz, this is a very high number. For example, on the Great Hungarian Plain, only 92 species have been recorded. The 64 species comprise some 30% of Hungarian Trichoptera (of a total of 202).

The following species are of great faunistical importance:

Ceraclea nigronervosa — a new species of the Hungarian fauna, it was recorded for the first time in 1992 in the Szigetköz; *Rhyacophila dorsalis; Agapetus laniger; Oxyethira flavicornis; Hydroptila forcipata; Polycentropus irroratus; Cyrnus trimaculatus; Lype phaeopa; Brachycentrus subnubilus* — the populations of these species were established only in the Szigetköz; *Limnephilus elegans* — rare throughout the whole of Europe, and its occurrence in the Szigetköz is important both from faunistical and ecological points of view; *Halesus radiatus; Lepidostoma hirtum; Athripsodes albifrons.*

The high species diversity of Trichoptera in the Szigetköz is maintained by the relatively clear water of the Danube and its side branch-system, as well as the current conditions, chemical characteristics and quality of the sediment.

Lepidoptera *(Butterflies and Moths)*

1124 species of Lepidoptera were identified (663 macrolepidoptera and 461 microlepidoptera). On the basis of the available knowledge, the expected number of species is probably around 1300, which is 30% of Hungarian Lepidoptera.

The distribution of species within the main taxonomical units of lepidopterans, especially the ration of species richness of Noctuidae and Geometridae, is similar to that of the lower montane forests. Namely, there is no significant difference from the ratio found in the whole Hungarian fauna (5 : 3).

Although the Lepidoptera of the Szigetköz is similar to the fauna of other Central-European river basins, the relatively higher diversity and greater number of species are directly influenced by the presence of scattered patches of Alnus stands, (which otherwise are typical of Atlantic, or lower montane areas), as well as by the mosaicity and humidity of habitats.

The Lepidoptera species composition of riparian forests in Central and South-west Europe are not exclusively determined by their exact geographical location, and are generally fairly poor in species. The difference in species assemblages is not predominantly affected by the diversity of tree canopy layer, but by the richness of the herb layer. Intense forest management or flooding can almost completely destroy the herb layer and hence facilitate the invasion of certain weed species (Impatiens, Solidago spp.), which eventually become dominant in the affected associations. This process leads to a decrease in diversity, as the invading weed associations are usually uniform.

Although these tendencies generally hold true in the Szigetköz, the area is nevertheless unique because of certain characteristic features: its sub-Atlantic climate, and the effects of the nearby Alps. Several Lepidoptera species that live here are usually absent from or rare in other riparian forests. These faunal elements are characteristic species of closed montane mixed forest stands, Atlantic plain or lower-montane alder associations, or fens and moist stream basins. In the Szigetköz they may be found in the remnant forests of higher elevation, or in the small uncultivated forest mosaics of the floodplain. Consequently, their populations are often fragmented and isolated.

The dry, sandy patches of grasslands covering the higher localities of the Szigetköz are important landscape elements, since they conserve several characteristic species of the steppe forest vegetation, although these patches are becoming increasingly disturbed.

Oribatida *(Oribatid mites)*

176 species of Oribatids were collected in the Szigetköz, which is an exceptionally high number compared to other nature reserves and national parks of Hungary. For example, 109 species of Oribatids have been found in the Hortobágy National Park, 195 in the Kiskunság National Park, 103 in the Barcs Nature Reserve and 164 in the Bátorliget Nature Reserves.

The composition of Oribatids can be characterised by chorological categorisation and ecological grouping. The size of these groups is also important.

1. Wide-spread species (48%):

cosmopolitan	(10 species)
holarctic	(40 species)
palearctic	(34 species)
for a total of	84 species (48%)

2. Species groups with smaller areas:

European	(24 species)
Central-European	(18 species)
North-West-European	(6 species)
South-western Central European	(24 species)
Mediterranean	(12 species) and
Hungarian endemic	(5 species)

3. Unidentifiable species: 3

total of 92 species (52%)

According to previous surveys, wide-spread Oribatid species are dominant elsewhere in Hungary, even at such particular places as the Bátorliget Nature Reserves (60–40%). In contrast, high numbers of Atlantic, Atlanto-Mediterranean, and even boreo-alpine faunal elements were found in the Szigetköz.

Highly valuable faunal elements of the Szigetköz: We have listed below the most important species of the area (occurring exclusively in the Szigetköz, demanding strict protection, or indicating the uniqueness and sensitivity of the area).

Brachychthonius bimaculatus Willmann, 1936
Brachychthonius impressus Moritz, 1976
Brachychochthonius hungaricus (Balogh, 1943)
Brachychochthonius suecicus (Forsslund, 1947)
Neobrachychthonius magnus Moritz, 1976
Synchthonius elegans Forsslund, 1956
Atropacarus sp. n. new species
Steganacarus brevipilus (Berlese, 1923)
Mesoplophora pulchra Sellnick, 1928
Ctenobelba pectinigera (Berlese, 1908)
Dorycranosus sp. n.? (probably a new species)
Furcoribula furcillata (Nordenskiöld, 1901)
Machuella cf. ventrisetosa Hammer, 1966
Medioppia hygrophila Mahunka, 1987
Multioppia glabra (Mihelcic, 1955)
Oxyoppioides decipiens (Paoli, 1908)
Autogneta longilamellata (Michael, 1885)
Conchogneta dalecarlica (Forsslund, 1947)
Hydrozetes parisiensis Grandjean, 1948
Suctobelbella carcharodon (Moritz, 1966)
Suctobelbella messneri Moritz, 1971
Suctobelbella palustris (Forsslund, 1953)
Oribatula pannonica Willmann, 1949
Zetomimus furcatus (Pearce & Wharburton, 1906)
Punctoribates hexagonus Berlese, 1908
Eupelops curtipilus Berlese (1916)

One of the most important results of our research is that some special Oribatids *(Suctobelbella messneri, S. charcarodon),* living in the floodplain or the moss layer covering fallen or rotten stumps or under their bark, can tolerate the repeating water cover. From the samples collected in localities (Kisbodak, Dunasziget) new species of the Hungarian fauna, or extremely rare species were collected. These habitats are undoubtedly of great importance in maintaining the

Oribatid diversity of the Szigetköz. It is highly probable that these species will be the first to disappear from the floodplain in the course of the desiccation process.

From a soil-zoological point of view, one of the most interesting and valuable areas of the Szigetköz, indeed of all Hungarian habitats is the Derék Forest. The Central-European forest fauna here enriched with Atlanto-Mediterranean and boreo-alpine species. The highest species diversity of Oribatids in Hungary has been recorded here, in a relatively small area.

Pisces *(Fishes)*

Since a separate detailed study of the fish fauna and their natural value has been prepared, we will not discuss this topic here.

Amphibia *(Amphibians)*

Eleven species of amphibians were recorded in the Szigetköz *(Triturus vulgaris, Triturus cristatus, Bombina bombina, Pelobates fuscus, Bufo bufo, Bufo viridis, Hyla arborea, Rana arvalis wolterstorffi, Rana lessonae, Rana ridibunda, Rana esculenta).*

The amphibians occurring in the Szigetköz can be divided into two major groups. The first group consists of species living permanently in the water, while the members of the second require water only temporarily. The amphibian populations of the floodplain are directly controlled through their reproductive biology by the quantity and temporal distribution of water. The repeated lack of high or medium water levels in spring will severely endanger Amphibia populations in the long term. Present hybridization conditions and changes in water regime facilitate the spread of Rana esculenta. Similarly, the size of *Rana lessonae* habitats will obviously shrink.

Aves *(Birds)*

206 species of birds were recorded in the Szigetköz, that is 57% of the Hungarian ornithofauna. 166 species are protected, of which 134 nest here. The high number of species is maintained by the mosaicity and habitat diversity of the Szigetköz, while the density of the species is increased by the dense shrub layer and the edge effect.

The species-composition of the Szigetköz is similar to that of lower montane forests, but with a higher density (150–200%). The presence and co-occurrence of diverse habitat types allow the breeding of several strictly protected species *(Ciconia ciconia, Haliaeetus albicila).*

Montane faunal influence is indicated by nesting of *Parus montanus.* The strong breeding populations of *Prunella modularis* and *Hyppolais icterina* are also worth mentioning. With regard to species richness and diversity, the Szigetköz is the most valuable floodplain in Hungary.

This area is of vital importance as an overwintering ground for wildfowl. In fact this area is one of the largest overwintering areas in Europe. Some 10–14 thousand individuals of various duck species have overwintered here in previous years. Maximum numbers were recorded in January. The main channel and the side branches provide feeding sites of different qualities and flow speeds. High number of the strictly protected white-tailed eagle *(Haliaeetus albicilla)* winters here regularly. Either because of their exceptionally high abundance (e.g. mallards *Anas platyrhynchos)* or because of their international conservation value as a threatened species, the following bird species should be mentioned (the estimated number of overwintering individuals is shown in parentheses):

Mallard — Anas platyrhynchos:	(6000–7000)
Goldeneye — Bucephala clangula:	(ca. 3000)
Pochard — Aythya ferina:	(ca. 1000)
Tufted Duck — Aythya fuligula:	(500–1000)
Goosander — Mergus merganser:	(200–250)
Smew — Mergus albellus:	(ca. 400)
White-tailed Eagle — Haliaeetus albicilla:	(ca. 15)
Kingfisher — Alcedo athis:	(500–1000)

The inclusion of the Szigetköz into the Ramsar Convention, as an important overwintering area for aquatic birds, is in progress. Similarly, the acceptance of this area into the IBA (Important Bird Areas) Project is on its way. Owing to the drop in water level, the food supply of waterfowl will probably decrease, and wintering grounds will shrink or might even disappear. This rich variety of wintering bird fauna is seriously threatened.

Mammalia *(Mammals)*

The ice-age relict *Microtus oeconomus* is a very valuable species. It is found in almost every larger reed bed of the Szigetköz, and at certain places it is a dominant species. As the areas outside the dykes dry up, this species will probably disappear entirely. From among the known mammals 16 species are protected and endangered.

II. The effects of Version C on the biota of the Szigetköz

The effects of the diversion of the Danube can be demonstrated by discussing the already detectable (1.), and the predictable long-term (2.) effects and damages.

II. 1. Damages already detectable

The immediate impact affected mainly the aquatic organisms, in some cases being disasterously. It is also clear that the effect on the terrestrial fauna will be perceptible during the next vegetation period, since most of the invertebrates were already preparing for the wintering, and their activity was lower at the time of the diversion (October).

II. 2. Predictable long-term effects: damages and changes

The natural values of the Szigetköz are maintained by the Danube river. As a consequence of the geographical and climatic characteristics of the Szigetköz it is the westernmost fragment of the zonal forest-steppe vegetation in the Carpathian Basin. If water supplementation will not be carried out, the following changes in the fauna are likely to occur.

As a consequence of the diversion, the Upper- and Lower-Szigetköz will change in character. The boundary between the two areas will probably run at around the Bagomér side branch-system, where there are already signs of impounding.

In the Upper-Szigetköz the radical change of the water discharge will transform plant associations, and it will seriously affect the fauna. If the surface- and ground-water level are stabilized at the present level, the most valuable and characteristic botanical and zoological feature of the Szigetköz will be lost: that is, the mosaicity of the landscape, and the presence of high diversity and wide range of habitats in a relatively small area.

The diversity of aquatic habitats in the floodplain, and outside the dykes will either vanish, or shrink to a critical point. Therefore, the aquatic flora and fauna and several affected terrestrial organisms may become extinct or emigrate to other locations. The size of the populations will considerably decrease. In the long-term biological diversity will decrease, although species diversity might even increase initially. We list some examples hereunder.

During the summer of 1993 rapid weed invasion with high productivity occurred in the desiccated side branch-system. Great quantities and high species diversities of weed associations were recorded. The following species were found:

Chenopodium rubrum, Polygonum mite, Artemisia annua, Sonchus asper, Plantago lanceolata, Urtica dioica, Rorippa sylvestris, R. islandica, R. amphibia, Chenopodium striatum, Aster tradescenti, Bidens tripartitus, Gnaphalium uliginosum, Polygonum persicaria, Lythrum salicaria, Potentilla supina, Polygonum lapathifolium, Juncus bufonius, Rumex conglomeratus, R. sanguineus, Matricaria inodora, Bromus tectorum, Senecio vulgaris, Solidago gigantea.

After two or three similar years the original aquatic, marshland and fen vegetation will be severely damaged. The floodplain forests cannot even endure that long and will probably be destroyed more quickly.

The desiccated gravel beds and shore lines of the Öreg-Danube have become xerotherm habitats (like a desert), where great numbers of xerophilous beetle species have recently been found *(Amara fulva, Amara similata, Anthicus schmidtii, Colotes hampei, Coccinella undecimpunctata)*, for the first time in the shore habitats of the Szigetköz.

In the stagnant waterbodies of the side branches zooplankton stocks of a very high density emerged (for example in the Sziget-Danube 6073–28368 individuals pro 20 litres). This amount of rotatorians and planktonic crustaceans is usually found in polytrophic waterbodies.

The flora and fauna preserving capacity of terrestrial mosaic patches is strongly correlated with their size and shape. As a consequence of the decrease in the ground water level and its stabilization at a significantly lower level, these mosaics will be lost or will struggle on even smaller areas, under significantly worse conditions, especially on the floodplain and localities near the Öreg-Danube. The development of hard-wood riparian forests should take place. The possibilities of ground water uptake will be both spatially and temporarily the determining factors in the development of the new biota. In this respect localities close together may vary widely.

Outside the dikes the spread and dominance of zonal forest steppe vegetation is expected. Their species composition will be greatly affected by the spreading capacity of the species living in the small fragments of present steppe patches. Perhaps the only localities where quick changes will not take place are the alluvial forests standing along the Moson-Danube. Ecologically planned water-regime regulation of the Moson-Danube and the canals outside the dikes might slow down the desiccation process.

The expected degradation will first destroy the herb species the most valuable botanical elements are within this group! Moreover, the species richness of phytophagous fauna is basically determined by the heterogeneity of the herb layer.

The mesophilization triggered off by desiccation will facilitate the spread of ubiquitous species, at the expense of stenoecious species. This process will probably initially increase the number of species, but the duration of the increase cannot be predicted. Thereafter a sharp decline in diversity will occur, as a consequence of the disappearance of the biota of the wet habitats.

The effects on the biota of the Lower-Szigetköz cannot be easily assessed. It is very probable that the value — at least the nature protection value — of this area will be more respected. This section will be less desiccated, and, therefore, the expected changes, will be less pronounced or not take place at all. The Bagomér branch-system deserves special attention, since these branches still carry water. There is not any information on the hydraulic and hydrological processes going on in these waterbodies, but we suspect that several parameters have changed since the diversion of the Danube. There is no chance that this branch system will substitute for the damaged or vanished branch systems of the Upper-Szigetköz.

In the Szigetköz an enhancement of the multidirectional migration process is expected. It is impossible to predict on the basis of our biological knowledge, which species groups will be able to establish their populations under the conditions to come.

III. Conditions of conservation and rehabilitation of the existing habitats

Under present circumstances or even with a minor water supplementation system the characteristic habitat mosaicity, sustaining the diversity and natural values of the Szigetköz, cannot be preserved. Under the conditions prior to the diversion nature protection and landscape reconstruction-rehabilitation were mainly aimed at enlarging the area of mosaic-like patches, and at creating larger zonal habitats.

Our advice concerning the rehabilitation and preservation of habitats is immediate and straight forward: the recreation of the ecological factors sustaining the original natural environment. These factors were controlled originally by the Danube itself. Therefore, the highest possible volume should be fed — without storing in the reservoir — into the Öreg-Danube. But this issue is not really a biological one, but a political and technical problem.

It is, nevertheless, possible to attempt to preserve some aquatic habitats. The price of this effort would be exceptionally high. Since the basic ecological rules predict the opposite we must bear in mind that in a considerably changed environment the long-term preservation of the biological values of these isolated small areas is almost hopeless.

IV. The flora and fauna of the middle section of the planned river barrage system (from Győr to the Danube Bend)

The particular part of the barrage system that would have fundamentally affected the ecological conditions of this river section was not constructed. Considering aspects the nature protection this river section contains the least natural values, and most of the few found here are located not directly along the shoreline of the river. The research carried out in this area is far from complete, limited to small areas and few taxa. Since 1987, botanical monitoring has only been carried out at two localities (Tát — *Molinietalia* community, Almásneszmély — riparian forest) within this river section.

V. Natural values of the Danube Bend

The landscape could itself be the target of nature protection, and valuable landscapes should be considered in their entirety when making conservation efforts. The beautiful Danube Bend is an exceptionally valuable region in both the geomorphological and aesthetic sense. A geological process lasting several millions of years was needed for the Danube to cut through the volcanic hills to form a deep and picturesque gorge. The outcome of this long and natural process is one of the most beautiful landscapes of Europe. Recent years of human interference have caused the most drastic landscape damage here, in the construction of the turbine pit for the planned power point at Nagymaros.

The World Conservation Strategy defines wetland and aquatic habitats and temperate deciduous forests as ecosystems demanding the strictest protection. The latter ecosystems are found today in the Pannonian and Kamchatkan biogeographical region. The Pannonian region is part of Hungary and of former Yugoslavia. The protection of aquatic habitats and wetlands — in Hungary several small regions belong to these categories — is of paramount importance in Europe.

site are of outstanding value and demand strict protection. As a consequence of the last regulation of the Ipoly river, these habitats were severely damaged and are presently in a critical state. Any further disturbance might entirely wipe out the biota of these wetlands.

It is very likely that the micro- and meso-climatic changes arising from the planned construction of the Nagymaros reservoir will transform these plant associations, and consequently affect the fauna living here. Before these slow-acting changes, the direct impact of the construction and the damming will heavily damage the biota. The fauna of the wet habitats (marshlands, fens, shoreline) are especially endangered by direct effects, while the animal communities of the dry-warm sand, loess-wall, and slope-steppe localities will be mainly affected by indirect effects. Consequently the future of the irreplaceable fauna elements of this region is doubtful. We must draw the attention to the fact that the populations of protected (or strictly protected) animals inhabiting the area some of which are included in the Hungarian Red Data Book — were already severely affected by the construction of the round-dam at Nagymaros, because their habitats disappeared, or were constantly disturbed by human beings. The habitat of the biggest aquatic mammal living in Hungary, the otter *(Lutra lutra)*, was almost completely destroyed around Nagymaros. Some others migrated upstream into the Ipoly river and might still be found in the mountains, but the former population focus was clearly located on the Danube.

With regard to birds, the aquatic birds and waders should be mentioned, of which most rest on the Danube during migration, or overwinter there. Both near the waterbodies and some distance away several bird species build nest: Mallard *(Anas platyrhynchos)*, Little Grebe *(Tachybaptes ruficollis)* and Moorhen *(Gallinula chloropus)*. The endangered and rare Black Stork *(Ciconia nigra)* nests in the riparian forests of the floodplain. The Little Ringed Plover *(Charadrius dubius)* nests along the Danube. During migration, many birds rest or find shelter here during the winter, including the Great White Egret *(Casmerodius albus)*, the Spoonbill *(Platalea leucorodia)*, eleven species of ducks, the Lesser White-fronted Goose *(Anser erythropus)*, the White-fronted Goose *(Anser albifrons)*, the Red-throated Diver *(Gavia stellata)* and the Black-throated Diver *(Gavia arctica)*. The larger water surface created by the damming will enhance the virtual spread of the aquatic fauna (the spread of the non-sensitive aquatic species such as swans *(Cygnus* spp.) might be expected), but the valuable sensitive species may disappear because they require not only a substantial food supply, but a peaceful habitat. The construction of the river barrage and the power station and the concomitant disturbance would probably scare away the following species of winter guests: Merlin *(Falco columbarius)*, Peregrine *(Falco peregrinus)*, Spotted eagle *(Aquila clanga)*, White-tailed Eagle *(Haliaeetus albicilla)* and Osprey *(Pandion haliaetus)*, as well as several strictly protected species that nest on the steep cliffs facing the Danube: Raven (Corvus corax) and Saker *(Falco cherrug)*, since these species are extremely sensitive to disturbance. The construction of the reservoir would surely cause their disappearance.

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Bős-Nagymaros Project from Seismological and Tectonic Aspects

I. Introduction

The man of the middle ages respected the powers of nature with a mystical fear, as he was completely ignorant of the causes behind the catastrophes. In the possession of our knowledge of natural sciences and technology today, we can follow and predict the path of hurricanes and typhoons, and, thanks to the developed health care networks, no epidemics sweeping through continents can break out, etc. There is, perhaps, one natural disaster left that cannot be forecast, and, that is earthquake. Earthquakes cannot be predicted according to human knowledge of our age, therefore, we must learn to live with it. We have to design such buildings, dwelling houses that resist earthquakes, that can withstand the impacts of tremors without damages.

There are international standards and recommendations for designing facilities in areas where earthquakes may occur, prescribing that the facilities should withstand the possible earthquakes. It is especially important in the case of such buildings that the damage to which, endangers the environment too (such as nuclear power stations, dams, hazardous waste storage facilities, etc.).

From the 1960' s, UNESCO has started several research programs in order to reduce the effects of natural catastrophes. Papers on the definition and reduction of earthquake risk have been published (e.g. The assessment and mitigation of earthquake risk, UNESCO 1978). Due to the special potential danger that lies with nuclear power stations, the International Nuclear Energy Agency prepared special recommendations concerning earthquakes and associated phenomenon to be taken into consideration in the course of design and installation of nuclear powerstations. (IAEA Safety Guide 5–SG-S1).

The appropriate professional design contains three significant relevant factors:

Seismology experts study the area's subjectability to earthquakes, partly based on the analysis of past quakes, partly with the help of the instrument network, continuously registering the Earth's movements.

Geologists, geophysicists explore the tectonic conditions of the area. If, in the course of this study fracture-lines are discovered, these are rated from the aspect of earthquake incidents, i.e. the area's seismo-tectonic structure is determined.

In the possession of the findings of the research above, the design architect prepares the plans offering the optimum safety appropriate to the risk class of the facility to be built.

Every country has her own standards for determining the class of, or rating the risk, to a facility, and the associated rules of size design procedures. In Hungary, there is a relevant technical principle to be borne in mind, that distinguishes five design classes. The facilities carrying the most hazards are in the first class, damage to these may cause a catastrophe. Nuclear power stations and dams are in this class, amongst others.

The operating safety of these facilities must be designed with the minimum of risks. In view of the international practices, the main substance of determining the risks the facility may be exposed to: the historical earthquakes must be analyzed within a 150 km radius circle from the facility. Reducing the risk to the minimum is based on the assumption that if there has ever been a largest earthquake in the past, it may occur again anywhere within this circle, in the future. Therefore, the intensity value used in the design must be one range higher in the scale than the largest known past quake was. Hence, one large earthquake in the past, ab ovo, determines the whole area.

From the aspects of seismology, Bős-Nagymaros Project may be divided into three phases:

— research carried out in the first phase — i.e. from the preparation of design up to 1989 — were in-coherent and of occasional nature. No synthesis of the findings was concluded. The technical publicity was characteristically lacking, large part of the research was carried out by the designer's own experts, often short of professionalism, occasionally based on pre-conceptions. Also the solution of lesser or greater hitches occurring even amongst these circumstances (such as the case of the Bős seismic fracture-line, see later) has demonstrated a lack of professionalism.

- simultaneously with the social changes, in the 1989-90 phase, technical documents, preparatory material for decision-making have become publicly known, an intensive expert's discussion has started and reached the conclusion: the geological and seismological research of the planned investment's area has not been satisfactory, the shortfall in the information presents a risk.
- in 1991–92, under the coordination of the Ad Hoc Committee of the Hungarian Academy of Sciences, within the framework of the Hungarian-Czechoslovak research program on the development and rehabilitation of regions of the common section of the Danube, a detailed and comprehensive analysis became possible in certain technical fields (such as the determination of seismic risk exposure). The research concluded that the seismological base data used in the course of the facility's design work were not correct, the impact that would be made by an earthquake in the region is 5–10 greater than the value assumed in the design.

II. From the preparation of design up to 1989

The investor did undertake the arrangement for geological survey, and commissioned participants to carry out the part tasks involved. Thus, no summary conclusion report (a synthesis of the part reports) has been prepared on the findings of geological, geophysical and seismological survey of the Hungarian section of the Bős-Nagymaros Dams. Due to the lack of a joint seismological monitoring system, a well founded evaluation of the region's exposure to seismic effects cannot be made. (This is the Expert Committee's view, expressed by the Chairman of KFH in accordance with Resolution of the Council of Ministers No. MT 1071/1989. (VI. 15.) on the geological-geophysical issues concerning the construction of the Bős-Nagymaros Dams).

The design-geological exploration of the region surrounding the dams started in 1951. The findings of the multi-phase survey were summarised by VIZITERV in two conclusive expert opinion documents. These reports serve as a base, primarily for architectural and civil engineering design, to be expanded and completed in the course of actual design and implementation.

In June 1973, OVIBER, VIZITERV (Budapest) and VVIP HYDROCONSULT (Bratislava) prepared the paper, titled *Support*

Documents Gabcikovo-Nagymaros Dams Investment Program, in which the question of exposure to seismic effects was dealt with as:

'A large part of the areas concerned belong to the more quiet parts of the Carpathian Basin, it is especially true in the case of the Kisalföld, where, due to the simple geological structure, no quakes have occurred. Tremors could only be noticed here that started from the rims or further areas, and that followed the fracture-lines of the palaeozoic foundations.

Between 23–25 November 1965, the experts from Czechoslovakia and Hungary discussed the issue of the region's exposure to seismic effects, with special attention to the data to be provided for the hydro-electric power station's design work.

Having taken the Komárom earthquake in 1763 into account, the experts concluded that the Komárom area is to be treated as a potentially active region. The value of exposure of this region's epicentre to seismic effects was determined as 8.5 (±0.5) MCS, whilst the value of seismic intensity in Győr was 7 MCS.

Besides the above values, the iso-seismic lines in the environment of the Komárom epicentre were also determined — having taken the average ground conditions into consideration — based on the assumption that the quakes spread mainly following the tectonic lines in NW-SE direction.

For the purpose of design work, the following seismic zones were determined according to flow-kilometres:

from the in-flow of Morva river to 1861	*7*	*MCS*	*a = 0.025 g*
1861–1823	*6*	*MCS*	*a = 0.010 g*
1823–1808	*7*	*MCS*	*a = 0.025 g*
1808–1797	*8*	*MCS*	*a = 0.050 g*
1797–1770	*8.5*	*MCS*	*a = 0.080 g*
1770–1764	*9*	*MCS*	*a = 0.100 g*
1764–1752	*8.5*	*MCS*	*a = 0.080 g*
1752–1740	*8*	*MCS*	*a = 0.050 g*
1740–1720	*7*	*MCS*	*a = 0.025 g*
1861–National Border	*6*	*MCS*	*a = 0.010 g*

In spite of the fact that the survey was carried out within the designer's arrangement and the research documents have not been presented to the public, the internal critical statements of the expert team have occasionally have been heard occasionally. An expert team of Czechoslovakia attached the following comments to the Gabcikovo-Nagymaros Dams Joint Agreement Plan:

"Tectonic survey was carried out in the environment of the Gabcikovo Dams between 1964-66. The findings of the survey were published in 1971 (Dr. J. Janácek: Plioceneous tectonic structure of the central part of Kisalföld, Geological Research, Report no. 55, Bratislava, 1971), thus those findings could not have been incorporated in the investment program incepted in 1967.

The object of the survey was the exploration of the geological structure of the area where the Gabcikovo working water dam is to be built, taking the region's significant exposure to seismic effect and sensitivity to seismic tremors of the dykes locking the raised water level.

The survey explored two tectonic cracks in Gabcikovo, one in the East, the other in the West, both running parallel with the Carpathian mountains. Both cracks extend to the youngest pleistoceneous sedimentation. They can be followed well in three structural survey maps in three correlational horizons.

The seismic effects, according to the Czechoslovak geologists and seismologists, are asserted at an increased level on the cracks. The protection of the dykes from the effects of a possible earthquake could be increased if those did not cross the cracks so uncovered. This condition could be met by a small amount of shifting of the dam upriver.

It would also be desirable to review the engineering size of the Dykes, taking the local seismic conditions into consideration."

After this opinion came into public knowledge, the dyke in Bős was relocated 600 metres away from the original plans. Nevertheless, the dyke was still be built in the immediate vicinity of a geologically young fracture-line.

The values of seismic exposure recorded in the minutes of the Czechoslovak–Hungarian expert discussion held in Bratislava between 23–25 November 1965, constituted the basis of design and structural engineering of the facilities. These minutes forecasts a 6 MCS potential intensity with a 0.01g horizontal acceleration.

After this date, the research stopped for a while, until the last phase of preliminary explorations started again in 1986–87.

On the Hungarian side, VIZITERV was appointed to carry out the structural and earthquake-protection engineering work. A part of the results have also been published (Endre Mistéth: the Danube dam's ability to sustaining the effects of an earthquake, pp 184–205, Vízügyi Közlemények, issue LXIX. 1987.). This document, however, contains several, basic errors. Perhaps, the most significant of those is that it uses such charts for illustrating the earthquake intensity classes, that assigns 4 to 5 times lower values of horizontal acceleration than today's seismological standards assume (such as, for instance, Manual of Seismological Observatory Practice, Report SE-20, publ. by World Data Center A for solid Earth Geophysics, 1979). In other words, the paper calculates weaker shock than the true extent, consequently the facilities structurally engineered to withstand smaller earthquakes than would be appropriate.

As Chart. of the cited Mistéth paper constitute the foundation of all findings and forecasts, the precise definition of the data published here has a paramount importance. The acceleration values in Chart ii. are erroneous, they are not in harmony with the present level of our knowledge; expert literature calculates these values to be 4–5 times higher. (Just as a comparison, it is worth mentioning that in the structural engineering of the Paks nuclear power station, planted in one of the areas with the truly lowest seismic exposure in the Carpathian Basin, still assumed a 0.25–0.35 g horizontal effect!)

In Chart of the engineering paper there is not one line of entry without an error. According to the official catalogue (Hungarian Earthquake Catalog, Zsíros et. al.) the intensity of the Komárom earthquake in 1763 was not 8.5, but 9. instead, and the one in 1873 was 8.5 as opposed to 8.0. The earthquake in Mór 8.0 (not 8.5), in Jászberény 7.5 (not 8.5), in Eger 6.5 (not 8.0), in Kecskemét 8.0 (not 9.0) the on in Eger in 1925, was 7.5 (not 8.5). In 1940, There was no earthquake in Komárom, at all, as opposed to the Chart's quoted intensity of 9.0! The epicentral intensity of the earthquake in Dunaharaszti was 8.0 (not 8.5), the one in Berhida was 6.5 (not 7.0), and it was on 25th of August, as opposed to the 15th.

III. The period of expert discussions: 1989–90

On 23rd June 1989, the expert statement of the Hungarian Academy of Sciences was published with the title: "Environmental, ecological, water quality and seismological effects of the abandonment or implementation of the Bős-Nagymaros Dam". The part of this statement dealing with seismology states:

The dislocation, velocity and acceleration data applied in he course of the design and engineering significantly deviate from the levels accepted by today's experts. "Taking seismic exposure into consideration in the study on the stability of civil engineering facilities in the Danube dam system", the data of which we compare with the ones of today). The effects of these on the design and plan documentation are to be examined.

	Data used in the design (1966)			Data of present knowledge (1989)		
I_0 MSK	*acceler. cm/s^2*	*velocity cm/s*	*disloc. cm*	*accel. cm/s^2*	*velocity cm/s*	*disloc. cm*
7	*12–25*	*1,0–2,0*	*0,5–1,0*	*50–100*	*4.1–8.0*	*2.1–4.0*
8	*25–50*	*2.1–4.0*	*1.0–2.0*	*100–200*	*8.1–16.0*	*4.1–8.0*
9	*50–100*	*4.1–8.0*	*2.1–4.0*	*200–400*	*16.1–32.0*	*9.1–16.0*
10	*100–200*	*8,1–16.0*	*4.1–8.0*	*400–800*	*32.2–64.0*	*16.1–32.0*

Seismology and forecasting possible earthquakes within, have gone through significant developments since the Bratislava expert discussion nearly a quarter of a century ago. If became apparent that engineering that uses intensity and acceleration values based on historical data is simply not sufficient today. The modern seismological parameters must be founded on complex geological, geophysical and geodesical study. The time the necessary scientific Earth examinations take, can only be determined on the assessment of the information already available. Without those, the most conservative assumptions known to seismology may be used — resulting in an increase in building costs. In this case, the value of potential intensity in the Nagymaros (and Bõs) region would be between 9.0 and 10.0, according to the earthquake catalogue and the seismological maps (Hungarian Earthquake Catalog (456–1986) by Zsíros et al.; Seismic zoning map of Czechoslovakia version 1987, by Karnik et al. pp 144–150, Studia geoph. et geod. 32,1988; Scheme of earthquake provinces, by Karnik et al. Prague, 1978).

After this, the committee recommends: Consequent to the incomplete seismological survey, the estimated intensity value between 9.0–10.0 should be assumed for the region. As this assumption represents too high a value, the exposure to earthquake risks should be determined with a better precision by means of a complex geological — geophysical — geodesic examination, which shall, most probably, allow for a more favourable forecasting. Examining the possibility for a Czechoslovak-Hungarian scientific cooperation would serve the purpose.

The three possible kinds of damages to the dam that could result of an earthquake should be studied in detail:

> *The damages that may be caused by the quakes of different intensity to the facility that also reacts dynamically, and also the modifying effects of the data accepted today on the original starting assumptions of the design have to be examined.*
>
> *It is necessary to model the effects of the possible splitting of the facility and/or the neighbouring ground, taking the consequent slide off and later sedimentation of the basin*

materials following the down-river tidal waves into consideration with regards to the whole section between Nagymaros and Budapest.

The effects of a possible rise in the up-river water level resulting of the blockage of the facility must be examined and the necessary measures to deal with these effects must also be developed.

Dr. Endre Dulácska and Dr. Ferenc Hunyadi, by the appointment of the Ministry of the Environment and Water Management, are preparing an expert study on the main facilities' exposure to earthquake risks at the Bős-Nagymaros Dam (10th July 1989). The study concludes:

During the two and a half a decade passed since 1965, the engineering principles concerning earthquakes have changed. More and more expert believes that engineering must take the potentially largest quake that the geological conditions allow into account as opposed to the largest historical earthquake records, even if its return cycle is a thousand years.

Looking at the region according to this principle, the largest earthquake geological possible is M = 6 magnitude (in the Richter scale). This is equivalent of an intensity value of 8–9. I = 8.7 could be considered as the upper limit. The return cycle of an earthquake of this magnitude can beestimated to be 70–80 years in Komárom area, whilst this may be 250 years for the whole area, according to the experts.

Meanwhile, several rules and regulations have increased the acceleration values associated with the different rates of intensity (power). For instance, the Soviet Union increased these values from the bottom of the MSK (KGST) scale to its upper limit, that is exactly double of the original. These circumstances mean that, if the earthquake supervision were to be carried out today, the assumption and the associated calculation of much higher values would be considered prudent.

The tidal wave resulting from the earthquake of an intensity higher than I = 9, would be at a higher level than the safety level incorporated in the design. Its consequence may be that the mass of water flows over the dyke head, partly washing the ramps away that may lead to the collapse of the dyke locks.

The expert paper of Dr. Béla Goschy, engineering seismologist was also prepared in 1989 (on 15th August), the most important findings of which are:

The earth dykes of the Bős-Nagymaros Dam do not meet the earthquake sustaining requirements laid down for such facilities. Their ability to maintain their ramp angle is not provided, their being free from *sliding cannot be substantiated. There is a potential danger of liquidity of the central region of the dyke's sole-plate.*

This finding cannot be generalised for the total length of the dam, however, the two samples examined constitute such actual and potentially weak links in the chain that may lead to the collapse of the dyke, in extreme cases to the total destruction of total sections with all the associated consequences. The reinforcement of the insufficiently safe dykes by raising the ramp sizes and levels, improvements to the materials used (by stabilisation, injection,etc.) will not result in such improvement in the expectations that could be proportionate with the costs.

Similar findings of a series of expert opinion lead to the conclusion that the area of the planned investment had not been satisfactorily explored in line with the international norms, the base data for design and engineering are not well founded, and the lack of information represents risks. All these are collectively referred to as 'seismological risks' in the Hungarian terminology.

IV. Findings of the research program on the development and rehabilitation of the common Hungarian-Czechoslovak section of the river Danube and the associated region (1991–92)

In 1991–1992, within the framework of the above, government initiated program, both geological and geophysical surveys were carried out. We have to mention it here, that in the solution of many a task both disciplines participated during the concrete research phase.

Below, we are briefly outlining the geological, geophysical and seismological knowledge gained on the field surveyed.

1. Geological structure of the Kisalföld

From geological aspects, Szigetköz is not a separate unit, but constitutes a part of Kisalföld, which, in its present state, established as the indentation of the orogenic area between the Eastern Alps and Western Carpathians from the beginning of the miocene age and the subsequent sedimental filling up.

Kisalföld is a widening, near-triangular shaped indentation with the extending side being in NE. Its deepest part is the Győr Basin (h > 6 km) located roughly in the middle of the area, overlapping the Hungarian-Czechoslovak national borders. Towards South-East, the foundation of the basin is rising near-evenly up to the Dunántúl Central Hills. In North-West direction, Mihályi-rise is situated over a 2 km depth of the extended basin, after which another deep zone, the Csapodi range can be found. Similar "basin and range"-type morphology established at the Northern edge of the basin too, where, between the finger-like appendices of Western Carpathians (Inovec and Selmec Mountains), 3–4 km deep trench-like basins can be found.

a) The main tectonic units constituting the foundations of the Hungarian part of Kisalföld

A) The Kőszeg-Rohonc unit

Constituted from green, in places blue, slate in metamorphous face stage, Iuraic and lower Cretaceous age slates, phillits and ultrabasites. It is equivalent to the South Penninics defined in the Central Alps, representing the mesozoic Tethys internal, oceanic sediments and crust traces.

B) The Sopron-Fertőrákos unit

Constituted from heavily metamorphous old-paleo-zoic gneiss, phillitand quarzites. It represents the Hungarian continuation of the Grobgneiss developments of the Wechsel series being on large areas of the surface in the Eastern Alps, belonging to the Lower Austro-Alpsurface system.

C) The Rába-riverside unit

Built from slightly and very slightly metamorphous silur and devon age sand-stone, clay slate, vulcanite and dolomite, identifiable with the Graz Paleozoics of the Upper Austro-Alp surface system.

D) Dunántúl Centre Hills unit

It contains much younger and more varied developments than the previous ones. The oldest parts consist of Siluric age, slightly metamorphous phillit, on which the Perm age red sand-stone lies. The main mass of the unit is composed of lower Trias age lime-stone and dolomite and upper Trias age high dolomite and Dachstein lime-stone. These are followed by sedimented, in large areas partly eroded, Iuraic deep water lime-stones and radiolarite, continued in lower Cretaceous shallow sea developed lime-stone and marl. The mesozoic series isclosed — following a marked sedimentation gap and local development of bauxites — by Upper-Cretaceous marl. Developments in the North-West wing of the Hills, belonging to the new tectonic cycle are middle and upper Oceanic age lime-stones and marl, and also calcium-alkaline vulcanite. The Dunántúl Centre Hills demonstrate some relations to the Upper Austro-Alp surface systems, especially to the Periadriatic line of those.

E) The Ipoly river-side crystallised slate composite

This is a composite of green slate face, metamorphous slates, granite-gneiss, covered with new paleozoic and mesozoic sediments being the covered continuation of the West Carpathian Veporics, closing the Dunántúl Centre Hills from the North-East.

b) The primary structural lines separating the tectonic units

The structural lines are:

- — Csapod-line, bordering units A/C and B/C,
- — Rába-line, bordering units C/D,
- — Ógyalla (Hurbanovo)-Diósjenő line, bordering units E/D and, presumedly, E/C.

The issue of the structural development of Kisalföld is none other than the appreciation of the tectonic style of these lines and understanding how this style has changed over the times.

In the base of Kisalföld, the most recent tectonic activities of the *Rába-line* and the large structural lines to the North-East of this, are characterised by a combination of normal leaning and a left-side slicing. For the purpose of finding out what has remained out of these as active tectonics for the geologically recent times, the most appropriate research is the survey of earthquake activities. It can be noticed from the distribution of epicentres of the earthquakes experienced in the Kisalföld environment in a larger sense, that an active fracture-line can be identified: the Mur-Mörz line and its continuation in Slovakia. According to more detailed survey, the wide band of earthquakes really consists of activities around two, near-parallel lines. One is the Pieniny rock-belt, the other is the Semmering-Vág line going through the Kisalföld edge of the Little Carpathians. This seismo-active fracture-line is very near (10km) the Dunakiliti region. In order to explore how near this secondary lines approximate this fracture-line, thus posing a seismic risk to Szigetköz area, a detailed shallow and deep seismic section analysis would be necessary. It is not a comforting thought at all, that the pleistocene cross-section map arrived at through the geo-electric survey shows fast changes of large amplitude (several hundred meters) in this region.

c) Geological structure of Szigetköz

Two structural units can be found in Szigetköz, divided by the large structural belt of the Rába-line. This mesozoic determined the development of the basin of Szigetköz, its effects can be noticed in the geological developments of the present age.

The oldest developments known in the NW side of the structural line are paleozoic, metamorphous gneiss, mica-slates formed at different times and different extent, onto which mid-miocene rough sediments settled directly. At the other side (roughly SE from the Rába-Moson Danube-Gönyü line), the Trias age limestone and dolomite with a series of somewhat younger, miocene layers built on top. From the plateau of Baden the development circumstances of the two areas became similar. The are left in "shade" from the large structural movements as characterised by the creasing of the Carpathians, started to sink, and this sinking accelerated the erosion of the such developed mountains (Alp-Carpathian zone), resulting in continuous deposit of several thousands km^3 of broken debris in the Pannonia basin. The sinking continued inthe Quarter age too, and due to the effects of more intensive protrusion, rough pebble, pebble-sand ballast filled up the deepest part of the basin. In the filling up the Danube and other rivers, including the Rába also played a role. The creation of this ballast-cone is in progress today too, although river regulation and flood-protection activities pose certain limits to the spreading of fresh deposits. The young-age activity of the Rába river during the Quarter age is marked by the fact that the structural belt established more or less here, dividing the early pleistocene deposit-cone into two parts, a sinking basin and a zone of lifted terrace.

Due to the characteristic fauna poverty of the rough debris sediments, it appeared to be nearly impossible to classify the very thick, river carried pleistocene-holocene sediment composite containing the drinking waters of Szigetköz. The structural survey drilling carried out in Arak within the Kisalföld Research Program, having reached the bed of the Quarter age developments brought significant stratigraphic results. The reason for this was that the rough debris that had appeared to be nearly homogenous in the course of geophysical surveys, is divided by finer sediment layers of negligible thickness in comparison with the total thickness — in which layers, relatively protected from the mechanical after-effects, a fauna of vertebrate and mollusca has been preserved. The sediments were created in still waters or still branches of slow, shallowing rivers, and they divide the rough debris composite in 10 levels.

The exploration led to the surprising conclusion that large part of the matter of the deposit cone cumulated during the lower pleistocene. In this test-hole in Arak, according to the malacological survey, holocene fauna was gained from 16 m depth and lower pleistocene fauna from 71.8 metres.

The youngest development of the region is the sediment composite of the holocene low and upper inundation areas. The age of development of the upper inundation area — according to the fauna and radiocarbon tests — old holocene, that of the low inundation areas is new holocene. Prior to the river regulation, in times of flood, the low inundation areas were flooded by the Danube, in the times of more serious flood, the upper inundation area was also covered by water. Due to the flooding, muddy top sediments have covered the sandy-pebbly developments of the deposit-cone.

d) Geomorphology of Szigetköz

Three main processes influenced the establishment of the present appearance of the Szigetköz section of the Danube:

- the still not finished sinking of the Kisalföld area that has lasted for several millions of years,
- the building of the gigantic fan-shaped deposit-cone of the Danube as it leaves the Little-Carpathians,
- the flood-protection and river regulatory works that had started several hundred years ago and became more complete from 1886 onwards.

aa) Sinking of the Kisalföld

The extent of the sinking is well indicated by the fact that the upper Trias-age limestones and dolomites that are on the surface of the North Bakony and Gerecse Hills are found at 8,500 m depth in the lowest sunken part of the basin in the Győrzámoly region. The sinking itself, happens in a differentiated manner, in a few hundred square kilometres blocks-pots, thus, in the basin foundation ridges and grooves can be distinguished. Sinking became specially intensive during the last 12 million years, velocity of which has reached the 0.5mm/annum value in places.

Danube appeared in the middle part of Kisalföld 2 million years ago, in a similar to its present form. The maximum thickness of the rough pebble composite of the Danube exceeds 700 metres in the Szigetköz region. The thickness of the river deposits depends on the depth of the basin foundation, and that makes it plausible that the sinking process, having started several million years ago, is still in continuous progress. The large thickness of sediments of the last 10 thousand years — the holocene — deserves special attention, that may be explained by the — still lasting — fast sinking of the area lying NE from the Mosonmagyaróvár-Abda line.

The sinking of Kisalföld is a natural process beyond the control of man. Its actual-geological significance becomes more obvious if we consider that the area East from Vének is rising in absolute terms too. (At the surface near Gönyü, the Danube is eroding the Pannon developments that are still at 700 metres depth at Ásványráró). The Danube has only been able to maintain its Eastward flow for the last 2 million years that it filled up Kisalföld, and, with its deposits, has continuously eroded and deepened the rocks of Visegrád on the rising bed.

bb) Development of the Danube deposit-cone in Kisalföld

If waters do not carry deposits sufficient to fill in a sinking area, the area will soon develop into a lake or a swamp (this is how the lake Balaton or lake Fertő established). In these, so-called un-compensated sinking muddy bog-lake sediments are deposited. In the Szigetköz area, however, the river pebbly-sandy filling has always been dominant duringthe last 2 million years. In the filled-up areas there are no large claywater retention layers.

The deposit carrying power and the fall in the Danube entering Kisalföld is significantly reduced, depositing large part of the debris carried. The river bed, due to the continuous cumulation of debris deposits is becoming always higher, growing above its environment. In the course of a few floods at catastrophic extent, the Danube, having suddenly changed its course, was in search of discharging route towards the lower areas, continuing the filling up in those parts. This is how the Danube's large sized, fan-shaped deposit-cone. The most recent times' large-scale changes of the river's course can be followed in the maps of historic times too.

In today's hydrographic image of Szigetköz, the difference between the character of Danube and the Mosoni-Danube deserves the attention. While the pre-regulation Danube had a full of deposits, reef-forming, bed dividing into branches in a woven shape, the Mosoni-Danube has been running through the deposit-cone via sharp bends and meandering. The character of the river sections are determined by the deposit-management of the section. Reef-forming, woven river-bed sections develop in areas where the rolled debris deposited is more than the debris carried away. However, the bending, meandering rivers flowing in their own established beds have a near zero balance of deposits. That, nevertheless, does not exclude significant deposit-replacements within the meandering sections, resulting in the continuous relocations of the bends.

In the filling up of the deposit-cone in Kisalföld, the largest water carrier has the primary role, the woven main river bed carries out the filling up of the sinking area. The smaller water carrying branches flowing on the sides of the deposit-cone even out the deposits left by the main river-bed. Consequent to this rule, the Danube is flowing higher today than the Mosoni-Danube and the Rábca. The Hanság and Gitai swamps lying at the feet of the deposit-cone are uncompensated sunken areas, not centres of the sinking. Thus, the ground water in Szigetköz region is fed by the high-bed Danube through its river-bed deposits, and the ground-waters flow South, with a significant fall, towards the river Rábca.

c) River regulation's impact on the development of the deposit-cone

As a result of river-bed regulation civil engineering started in the 80's of the last century, the so-called mid-water Danube bed became a 300–380 metres wide channel squeezed in between the parallel works built. The shipping and flowing conditions improved in the main river bed, but it did not lead to an equilibrium: the river, due to the too wide mid-water river bed size, could not carry further the deposits arriving from further up. Hence the bed continued to be filled up, reeves developed and moved along. Little-water regulation civil engineering started at the beginning of this century. Boot-straps, side-branch locks were built, large-scale river bottom excavations commenced, but even these were not able to stop the process of the rise of the river bed.

The emphasis of further river regulation civil engineering was put on the main bed's regulation, on the development of deposit-traps in the system of side-branches, on the raising of the mid-water works, on building new boot-straps and intensive bottom excavation. Between 1946 and 1963, 850 thousand m^3 stone was built in and 6.4 million m^3 ballast was excavated. Starting from the mid-sixties, in recognition of the failure of regulation up to that time, the development of the 'river regulation principles associated with hydro-electric utilisation' came into the forefront.

From an actual-geological aspect, the 'chaining down' of the main river bed, the prevention of its changes of direction in the last century upset the balance of Kisalföld prevailing for the last 2 million years. Since the river regulation works started, the size of sunken areas un-compensated by filling up. Due to the prevention of the spreading effects of flood, the concentration of deposits on a smaller area, the river section between Rajka-Szap filled up too high, and became deformed.

2. *Geophysical research*

The and financial resources and the time given did not allow for carrying out an exhaustive research satisfying all international standards in certain disciplines (e.g. tectonics, engineering seismology), structural survey deep drilling being the most critical shortfall. In these questions the primary objectives could only have been a critical review of the research carried out so far and the development of an action program for the future.

The research program provided, however, a more detailed and comprehensive analysis in a few disciplines, than had been possible ever before (such as, for instance, seismic risk, vibration modifying characteristics of the loose sub-soil, estimation of expected maximum horizontal accelerations).

The geophysical research covered five subjects:

- determining the region's seismic risk,
- a survey on the status of the earth dykes of the Dunakiliti reservoir,
- clarification of the tectonic conditions of the area,
- structural survey on the dykes and ramps,
- creation of a geodesic database, inputting the available and accessible data.

a) Determining the region's seismic risk

The method (Cornell, 1968) used in determining the area's exposure to the risk of an earthquake gives the result of the danger factor of a probable earthquake. Let's assume that the earthquakes are independent from each other within the studied set of data, their distribution over time constitute a Poisson process, and also that the frequency of earthquakes experienced is stationary. In the application 4 main tasks are to be solved:

1. marking the earthquake source areas
2. determination of frequency of earthquakes in every single source area
3. determination of the decrease in intensity according to distance
4. calculation of the exposure

The comprehensiveness and completeness of the catalogues used have a cardinal importance. We have, with the involvement of archaeologists and ethnographic researchers, re-interpreted and reviewed the parameters of the earthquakes in the region over historic times.

Having used the distribution of source areas, the frequency of quakes, and the intensity decrease relationships, we have determined the expected annual frequency of quakes (N) at Dunakiliti (47.97N, 17.30E), and the exposure for 1000 years (P(I>I',t=1000)), in the 4<I<9 intensity interval.

In the region of the facility, at 30%, 10% and 5% risk level, earthquakes of the following intensity shall occur within 100, 500, 1000 and 10000 years:

Time period (years)	Risk level		
	30%	10%	5%
100	6.4	7.0	7.3
500	7.1	7.7	8.0
1 000	7.5	8.0	8.2
10 000	8.3	8.7	9.0

That is, for instance, the occurrence of an earthquake of an intensity greater than 8.0 within 1000 years, has a probability of 10%.

An essential element in the study of the determination of seismic risks, according to international practice, is an instrumental survey on the micro-seismic activities in the region under scrutiny. This is a known fact, that the logarithm of the number of earthquakes is inversely proportionate to the magnitude. If we monitor the minute micro-tremors for a while — usually for 2–3 years — then, from the number of these, we can guess the occurrence of expected larger quakes too.

Since the region of the planned dam system can be considered as seismically active, the seismic monitoring would have been even more justified, before the period preparing the planning activity. This could have been carried out jointly, utilising a monitoring network located in the territories of both countries. In 1990, long after the start of the building works, a joint plan was prepared for the seismological monitoring of the area of the dam system (Detailné seizmické rajónovanie v oblasti Gabickovo práce v rokoch 1990–1991), coordinated by Geofyzika Brno. It, however, remained a plan only.

b) Survey on the status of the earth dykes of the Dunakiliti reservoir

Our task was to examine, using applied geophysical methods, the physical state and structure of the reservoir barrier (61+799 – 52+983 kilometres) built in the 1980's and also the structure of the flood protection dyke body (52+983 – 51+000 km), earlier built and reinforced also in the eighties. In the main protection line segment marked out for our survey, we also examined the lithological structure of the sub-soil. The geo-electric segments planted for surveying the class and layers of the sub-soil and the electric segment determining the reservoir barrier water retention nucleus were completed before the passing down of the Summer tidal wave. From the measurements repeated after the flood it could be found that the humidity of the composite along the segment within the reservoir increased, or the few decimeter thick layer on the top became muddy. The developments examined on the reservoir side, did not saturate either on the reservoir's sub-soil or from the reservoir water gained through the body of the barrier.

We have carried out our sub-soil measurements along the track of the geo-electric segments monitored at the feet of the ramps. The dominant layer of the diametric composite: sand and pebble, or, on the top of themixed versions of these, half water retaining, half water permeable developments settled, and, on the surface, these bound developments arecovered with sandy pebbles again. We have not hit the ground waterlevel down to the depth of sampling (7.0 m) during the period of explorations.

A significant information we gained from the horizontal resistance segments that we found several proto-river beds under the barrier.

These, few hundred meters wide, high resistance (pebble) river beds led to break through at the watergate, flood in the Körös' rivers.

The virtual unit resistance values of the electromagnetic segment planted over the water retaining core on the barrier-head refer to the significant inhomogeneity and draw the attention to the thinning of the built-in water close at places. It is likely that too much rough pebble was built into this section of the dyke's body. This is proven by the engineering geophysical samples taken from the deep samplers at the reservoir side of the dyke, that could only span the dyke body diametrically at the minima of resistance.

We have built sampling points on the edge of the reservoir side of the barrier-head, for the determination of the matter and physical state of the reservoir barrier. We found that the verticuum of the nearly 7 metres thick earth engineering work is definitely layered according to grain composition, nevertheless, it is very dense in structure. The fine sand and pebble have both been built in, the weight per volume is, however, in excess of $2.0 t/m^3$.

On the 52+938 – 51+000 section of the connecting, old barrier, we have examined the structure of the dyke body and the layers of the sub-soil by means of four cross-sections. We have carried out geo-electric resistance segmentation at the feet of the ramps too. We have determined the leakage factor in 13 explorations.

We have taken a total of 68 samples on 11 sampling occasions. The soil mechanical characteristics were determined by the North-Danube Water Board.

c) The region's tectonic conditions

The most important element of Kisalföld's deep structure is the Rába line, being the border between the Alps and Central Mountains. Its position has always been uncertain. It is interpreted both as a covering border of seismic sections and as a steep break line. From magneto-telluric data, a few kilometres under the SE wing well conducting deep developments have been assumed, however these developments are completely missing on the NW side. The Rába line extends to Slovakia in the NE, following it further is possible in two directions. On is the straight continuation of the Rába line further NE, but this is only a formal, design desk solution. The Rába line interpreted as the 'border between the Alps and the Central Mountains' should be continued in the Ógyalla-Diósjenő line at a sharp angle from it. Three groups of developments are known in the foundation of the Alpine part of Kisalföld: (1) The Sopron series consisting of gneiss and crystallised slate that could be treated as analogous to the rough gneiss covering the Lower

Eastern Alps. The Southern and South-Eastern borders of its extension are unknown. (2) The Kőszeg series consists of epi- metamorphous, mesozoic sediments accompanied by basites and ultrabasites, and can be correlated with the Penninicum. On the North, it probably borders the Sopron series, its S and E borders are unclear. (3) The Mihályi series consists of the sediments that metamorphosed on the border of the epi/anchizones, together with different kinds of magmatites. Based on lithologic analogies, they are assumed to be parallel with the Graz paleozoics, which are parts of the East Alps surface cover.

From the seismic sections and the gravity model calculations it appears that the Sopron series is laid over the Mihályi series, and there is no data to support the presence of the Sopron series between the Kőszeg and Mihályi series. Thus, the expected structural order of 'Kőszeg-Mihályi-Sopron' is not proven, and the structural face is not clear.

In the Central Mountains foundation of Kisalföld, there are metamorphous paleozoics and dislocated perm-mesozoic developments. These latter constitute a large synclinal, thus the perm and paleozoic developments noticed South of Gyúr could be located as the base layer of the series. The perm and trias sediments drilled further North may be constituents either of an anticlinal wing in the NW, or, equally, of a more complex surface cover structure.

In the ridges of the basin foundation, NW from the Rába line NNE-SSW structures, SE from it, on the other hand, NW-SE structures can be found. The settlement depth of the basin foundation may even be 9–10 km in the Győr area. The thickness of the upper Pannonian sediments is 2500 metres here, of the ones of lower Pannonian age is 1200 metres, thus there is 5-6 km for miocenic sediments. The miocene composites are concentrated in grooves, the Pannonian composites are slightly reminiscent of the trench-eagle cliff structure. The of Pannonian composites are of inner-basin development, disregarding the 10–20 km wide rim faces.

In the structure of the neogenic basin sediments lystric and other slopes can be demonstrated in the interpretation of specific seismic segments. At a model level, the sinking could be retraced to a left cut in a NE-S Wdirection.

At the end of the pliocene age part protruded, with basalt volcanic effects in places. In the Quarter age, river water dying and cumulation happened, mainly affected by the Danube, already. We may form an opinion of the face image of the sediments from the geo-electrical measuring. No structural examination on the cenozoic developments have been carried out, the evaluation version of the large number of satellite pictures do not give sufficient base for the establishment of a consistent and convincing picture.

d) Structural examination of barriers, dykes

The weakest link in the facility of the Dunakiliti Reservoir is the earth dyke sub-system surrounding the reservoir, because it is the largest, hence the probability of error sources is proportionately increased with the size, and also it is the most heterogenous construction in respect of its size, structural construction, its matter and quality.

The standing power of certain sections of the barrier system cannot be considered secure to sustain expected earthquakes during the 100 years planned life cycle period. The barriers with a height in excess of 7 meters are similarly exposed in their positional power; the safety of protection against sliding off is not satisfactory. On the contact between the sub- and super-structures the phenomenon of liquidity may occur in the places where more than 50% of the barrier's granular structure is composed of smaller than 2 mm diameter grains.

Factors increasing the probability of the processes occurring:

- a significant degradation of the internal friction angle
- an increase in the porous water pressure
- quality shortcomings of the implementation works
- change in the state of the abandoned, un-maintained earth engineering works

The study on the reliability of the reservoir prove unambiguously that the reliability characteristics of the barriers surrounding the Dunakiliti reservoir are not in harmony with the requirements of the international rules. In the course of planning, the risk levels considered were those only relevant to public and residential buildings, where no environmental consequences have to be taken into account. In the design of a power station, the expected environmental damage within the impact area have to be considered over and above the local structural damages, and that is a huge risk increasing factor.

The quality of the structural sub-system (the barriers), which is unsatisfactory and different from the assumed level, shall reduce the planned life cycle down by half.

The extent of the damage to the barrier and within this, the exposure examined taking the probability calculations into account, it is clear that during the planned 100 years of life cycle, as a result of an earthquake of I = 7.3 occurring of which there is a 5% probability, a consequent 38% damage will be caused to the barrier system. There is a higher than 10% risk of joint damage to the associated structure — the environment system — and the expected damage shall be a multiple of the damage to the water barrier.

The projected ecological damage or destruction — that can be treated as actual value by our knowledge today — could be considered as a factual event with a damage rate of 10–10-fold of the investment (building) costs.

Since the safety, risk and quality requirements are not met, the barrier system is unsuitable for fulfilling its function at the prescribed safety level.

V. Conclusion

The planning of the Danube dams had not been preceded by geological survey at the necessary extent. This serious shortcoming is signified by the fact that the research program, aiming to gain general geological knowledge on Kisalföld, the geological unit that includes the Szigetköz region, only started in 1982, in spite of the fact that the planning and design process started back in the 1960's. The shortcomings are also shown by the fact that no structural survey test drilling was carried out within the impact area, during the period of preparation. It is also reflected in the volume titled 'Conclusion of the surveys carried out in connection with the Danube dam system 1951-1988 (VIZITERV, 1989), in which, there is no such entry as 'geology', 'geophysics' at all, the whole of the discipline of the Earth is narrowed down to 'topography' and 'engineering geology'. In the light of these shortcomings, it is understandable that the developers have not possessed a licence to be issued by the Hungarian geological authority.

The building firms undertook the organisation and arrangements for the geological research, they subcontracted geologists, geophysicists for part tasks only. Thus, there was nothing to guarantee that the planning and design had been preceded by the gathering of the necessary amount and quality of data. The lack of professional preparation is demonstrated by the fact that no concluding geological, geophysical, seismological summary report has been prepared on the Hungarian section of the Bős-Nagymaros Project (i.e. a synthesis of the reports on the part surveys, an evaluation, accepted by an expert Jury, in compliance with the requirements recorded in a rule of law), as a significant part of the research necessary for this summary was lacking.

A further problem was caused by the fact that the synthesis of the geological knowledge of the Hungarian and Slovak sides have never been attempted to date. (For instance, the Bős fracture, line famous in Slovakia, is un-explored at the Hungarian end. In spite of the fact, that it was exactly the reason why the location of the Bős dyke was changed at the beginning of the seventies, but only by a distance of 600 m from the original location planned, which is not a meaningful distance froma geological aspect. The dyke was built - according to the Slovak experts' opinion, in the region of a young fracture line.)

From a geological aspect, the lack of knowledge relevant to the region has presented and still presents an exposure to risks, as a number of preparatory and planning tasks — such as an environmental impact study, or the technical design — can only be well founded and conclusive in the possession of geological-geophysical knowledge of the impact area.

The outstandingly relevant findings of the geophysical examinations:

- One of the questions argued in connection with the planning of the Danube dam system was the determination of earthquake risks and the consequent engineering problems. According to our examination, at the usual risk levels, the intensity of the earthquake occurring within 10,000 years, shall be 8–9 MSK.
- Although the survey started, no concise and conclusive picture can be made of the tectonic conditions of the area, based on the findings to date.
- One of the significant information obtained from the horizontal resistance segments in the course of examining the state of the earth dykes of the Dunakiliti reservoir was the finding of such pebble river bed structures under the water barriers that similar structures in the case of other rivers led to a break through of the dyke and became the source of consequent inundations.