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CASE

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PROJECT

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IMPACT ASSESSMENT STUDY ON THE GABČÍKOVO-NAGYMAROS BARRAGE SYSTEM
SURFACE WATERS

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I. Location

In order to evaluate the full effect of the Gabčíkovo-Nagymaros Barrage System on the biological condition and processes of surface waters, the entire area influenced must be considered. This area includes a 200 km stretch of the Danube between Bratislava (Rajka on the Hungarian side) and Budapest, and covers an area of 2,300 km^2 not including any parts of Slovakia that are affected. It consists of three main sections:

- the Hrušov-Dunakiliti Reservoir;
- the abandoned "Old Danube" stretch from 1,842 to 1,811 river km;
- the power canal (17 km upstream and 8 km downstream of the hydroelectric plant).

Other areas affected by the construction or the operation of the Gabčíkovo-Nagymaros Barrage System are:

- the side arm systems of the Szigetköz region, both in the active floodplain and in the protected area;
- other water bodies in the protected area;
- lower stretches of tributaries to the Danube between Rajka and Nagymaros affected by damming.

Budapest marks the downstream limit of the affected area, though water level fluctuations and water quality changes on the stretch below the Hungarian capital should be considered as well.

II. Topical Classification

The chapter attempts to give an introduction to ecology (especially hydrology and water chemistry), freshwater life and the biological processes of surface waters that are necessary to describe and evaluate the likely effects of the construction and operation of the Gabčíkovo-Nagymaros Barrage System. However, this is only a basic outline for the understanding of the above mentioned relationships. The extensive scientific findings on this 200 km stretch and its backwaters are not presented here.

Certain water bodies are described and evaluated from varying points of view. Stretches of the Danube are primarily assessed on water quality measurements, whereas branch systems are evaluated on criteria for nature conservation.

Drinking water supplies, fishery, biology and ichthyology are discussed in further chapters.

III. Description of the Original Status

1. What should be regarded as the original status?

The Danube is the second largest river in Europe with a mean discharge of about 2,000 m^3/s at Bratislava. The section of the Danube affected by the Gabčíkovo-Nagymaros Barrage System has many functions. It is not only a basic feature of the landscape, a waterway with a considerable breadth, sufficient to provide a border, but it also supplies 3 million (potentially 5 million) people with drinking water, as well as a nearly inexhaustible water supply for irrigation and industry. Furthermore, it receives, carries, and purifies waste water to a considerable extent and regulates the groundwater resources of lowland areas.

Downstream of Bratislava, the Danube entering the Carpathian Basin has formed a 100 km long, gravel-sand alluvial cone which at some points reaches 35-40 km in width and 300 km in length. This is the "Kisalföld", with the Danube in its longitudinal axis. The area on the right side of the river belongs to Hungary, the area on the left side belongs to Slovakia. The Gabčíkovo Power Plant, the reservoir and the power canal are situated in this "inner delta" area.

The hydrological effects of the Danube on the alluvial cone is very particular. The "inner delta" has not only formed greatly interlaced side arm systems but it also had a dynamic interrelation with neighbouring surface and groundwater resources through the permeable alluvial cone. Through both these connections the Danube has become a dominant factor in determining the ecological value, economical potential and social development in the region. It is especially true of the Szigetköz, an area with extensive natural and economic resources.

The determination of the "original status" is necessary for the evaluation of the effects of the Gabčíkovo-Nagymaros Barrage System. It can only be done by describing the river regulation modifications to the alluvial cone.

The Danube in the Kisalföld, had at one time, several branches on the large alluvial cone which thickens in the direction of the water flow. It formed islands (sand banks) and the side arm systems in the Szigetköz and the Žitný Ostrov . Comprehensive regulation works to increase flood protection and alleviate navigation began on this section in the middle of the last century. The present 300-360 m wide "Old Danube" was constructed at that time to ensure mean-water levels. Several side arms were already 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 to five years ago, was indeed the result of the extensive regulations which occurred between 1966 and 1983. The number of dykes and crest of previously existing dykes were increased, such that the Old Danube conveyed approximately 90% of the water at low or mean flow levels. Consequently, at several points in the side arm systems, sedimentation increased with the decrease in the intensity and annual duration of the inflow from the Danube. However, an important element of the water regime - the position of the water table - did not change as a result of these works, with the exception of some small local deviations.

Natural connections and interactions had weakened between the main arm and the side arm systems in the Szigetköz because of river regulation works. However, in many respects, semi-natural conditions characterised the area before more intensive water engineering work associated with the Gabčíkovo-Nagymaros Barrage System. Natural conditions had survived and was a healthy and intensive material transport between the main arm and the side arms. Side arms with different hydro-morphologies were supplied by the Danube. The period, length and time and quantity of flow was mainly related to their links with the main branch. The great variety of abiotic and biotic factors, e.g. the retention time of the water, led to extremely variable habitats and communities. This system was also enriched by old side arm sections which had been separated from the Old Danube by flood protection dykes. Water level fluctuations affected them only indirectly, through the groundwater. Together, these water bodies formed a unique, mosaic wetland area, providing suitable habitats for a great variety of plants and animals. All these natural and aesthetic values made the area significant throughout Europe.

The conditions in the first 70 km section of the area investigated before the intensive river regulation work began in the 1960s, are considered as the original and those just before the diversion of the Danube should be considered only moderately altered. In the 130 km long section downstream, on the other hand, the conditions before the diversion could be regarded as the original state though in many ways it is advisable to consider the situation before the 1960s.

2. *THE HYDROGRAPHICAL AND HYDROLOGICAL CHARACTERISTICS OF THE ORIGINAL STATUS*

The aquatic life and biological processes in rivers interact in a complex and dynamic way with the physical and chemical properties of the water. The continuously changing hydrological conditions are important in determining the biological conditions of rivers. The necessary characterisation of the most important hydrological features of the area are given below.

In the upper 56 km long section of the affected area (Rajka-Szap), the gradient of the Danube bed is 30-40 cm/km and the velocity is 2-3 m/s. The average water discharge is about 2,000 m^3/sec. Also flowing in the Szigetköz is the 120 km long Mosoni Danube with a guaranteed minimal discharge of 20 m^3/s, into which flow the rivers Lajta, Rába and Rábca.

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

There are five important side arm systems on the floodplain

Name	River-km
Dobörgas side arm system	1,848-1,837.2
Cikolaszigeti side arm system	1,837.2-1,832.4
Bodaki side arm system	1,832.4-1,827.7
Ásványi side arm system	1,823.9-1,816
Bagaméri side arm system	1,816-1,809.8

When the Danube is at mean flow levels, the surface area of the side arm systems and the Old Danube are 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 Cikolasziget side arm system and the lowest (2.2 to 1) in the Bagamér side arm system. The branches from the side arms were dammed by levees. When the water level is lower than crest of the levees, the side arms only receive their water supply from seepage. The heights of the levees are different, consequently the Old Danube-side arm connection is restored at different water levels.

The gradient of the river bed decreases to only 6-7 cm/km on the approximately 160 km long section of the Danube from Szap to Budapest; the velocity is only 1.0-1.2 m/sec with the exception of the Danube Bend at Visegrád. Downstream of the Mosoni Danube, three major tributaries join from the Slovak side: the Kis Duna (Maly Dunaj) which is fed by Váh, the Garam (Hron) and the Ipoly (Ipel). There are two biologically important seasonal floods in the region. One of them is caused by melting snow at the end of winter or beginning of spring. The other is the result of snow thawing at high altitudes in addition to maximal precipitation in June. The water level is at its lowest in October and November.

3. BIOLOGICAL ASSESSMENT AND WATER QUALITY EVALUATIONS IN THE PLANNING AND THE CONSTRUCTION PHASE

Biological conditions and processes are less able to be mathematically modelled than chemical, and physical (technical) processes. Consequently a descriptive characterisation can be sufficient to determine the biological status or to set up a prognosis. Nevertheless, mathematical methods and descriptions should be used in order to produce a scientifically valid study.

The mathematical formulation of hydrobiological processes is quite difficult. Unlike air, water is not only a medium but a solvent as well and the prognosis of processes in weak solutions, changing in quantity and concentration is even more difficult. Similarly, differences between the actual and predicted weather conditions and other environmental parameters which can considerably change the functioning of the system (i.e. cold summer, drought, mild winter) further complicate matters.

There was no investigation into the biological status of the surface waters and the water quality in the impact area of the Gabčíkovo-Nagymaros Barrage System either in the planning phase of the project or during construction. No answers were given to such questions, no investigations could be carried out as a result of the slowly growing social pressure and the professional concern of several scientific institutes, including the Hungarian Academy of Sciences, the Budapest Waterworks, and the Hungarian Institute for Town and Regional Planning, in 1985, seven years after the interstate treaty was signed for the implementation of the project, an environmental study was quickly produced. Surprisingly, the study hardly contained any data on the water quality and outlined no problems to be solved or any that could not be solved easily during the construction. In part, water quality seems to have been the focus of interest mainly by the organisations within the water authorities, but research was only carried out later by the water authorities laboratories. In spite of the environmental study, the planners seemed to become uncertain. Due to adverse criticism, the peak operation plan was rejected and an intensive regional sewage treatment project was developed. A water supply system in the Szigetköz was conceived to reduce the effect of the water level decrease in the area. The management of the would-be-abandoned 31 km long Old Danube section and the resulting water table decrease was also planned to be minimised. Another problem was the probable effect of the water table increase, up to nearly 70 km upstream of Nagymaros, on the local agriculture, forestry and towns. With the exception of the damages to the villages and towns, all the above mentioned problems affected the water quality.

The lecture of the academic. Imrich Daubner (Bratislava), held at the Hungarian Academy of Sciences in 1979, October 11th on the "Biological aspects of the hydropower plant constructions on the Danube" should be mentioned here[1] The former director of the Limnological Institute of Centre for Experimental Biology and Ecology of the Slovak Academy of Sciences, a well-known hydrobacteriologist throughout Europe, indicated a few possible water quality problems in his obviously moderate speech. Some remarkable citations from that work are listed below.

> "A construction of such size radically disrupts the environmental conditions of the surrounding areas"
>
> "rich and typical riparian forests are going to be destroyed"
>
> "The total forested area will decrease by 28%. The area between the power canal and the old river bed will be inadequate for forest ecosystems because of the 1 to 3 m decrease of the water table along the diversion canal. An important effect of the construction on the riparian forests will be the absence of the regular floods, which enrich the nutrient content of the soil."
>
> "isolation of game species will decrease their genetic diversity"
>
> "the decline of birds of prey could lead to the proliferation of rodents"
>
> "the area of cultivated land will decrease by 4,762 hectares"
>
> "Unique side arms will disappear. They function as a trophical basis for many main arm species and serve most fish species in the Danube as the main breeding habitat in the region and a refuge during floods."
>
> "98% of the zooplankton and 97% of the zoobenthos of the entire Czechoslovak Danube reach inhabit the area affected by the Barrage System. 92% of the annual fish catch and nearly 99% of the annual fish production comes from here. The predictable decrease in the ichthyofauna, the potential fish production and fishery between Bratislava and Nagymaros will be 57%, 69% and 89%, respectively."
>
> "The construction of the Barrage System will obviously affect landscape protection areas and nature conservation sites. The structure and overall picture of the landscape will also change."
>
> "The mass proliferation of infectious and facultative agents (including viruses) in the Danube and its tributaries should also be taken into consideration. These agents, constantly present in the Czechoslovak section of the Danube are important health hazards for humans and animals."
>
> "The estimated enormous, 10-12 billion m^3 healthy drinking water reserve is threatened not only by the pollution of the Danube water but also by the increasing pollution of the river bed."
>
> "The prognosis, that after completion of the project, polluting agents will infiltrate more intensively along the dyke at Hrušov because of the greater pressure in the reservoir due to the 1-3 m increase in the water level is scientifically well established. This will be seriously detrimental to the quality of the groundwater."

[1] Published in 1981 as: "Biological aspects of dams in the Danube." In Hungarian. MTA Biol. Oszt. Közl.24, pp.57-65.

"Based on our previous experiences the water quality will worsen in the reservoirs even if the pollution level of the Danube and the human activity in the catchment area do not change. This will be true of basic chemical, microbiological parameters and the oxygen balance, too."

The Hungarian and Slovak Academies of Sciences within the framework of the co-operation treaty worked for nine years on a joint research project considering the ecological, biological and water quality propels posed by the Gabčíkovo-Nagymaros Barrage System. With thematic consultations held continually there was practically no opportunity to discuss the results of the research.

It was also remarkable that during the bilateral consultations of governmental expert panels in 1989, there was no argument over several potential water quality hazards, even though the two parties recommended different solutions. The Slovak side did not consider a delay in the construction necessary to resolve the debated problems, in their view these problems could be solved during construction and operation.

IV. Changes in the Original Status

This chapter summarises the most easily recognisable changes caused by the construction and the partial operation of the Gabčíkovo-Nagymaros Barrage System with the diversion of the Danube. It includes and evaluates the existing and probable changes. In spite of the obviously close interrelations between the Old Danube, the side arm systems and the Mosoni Danube, they are discussed separately as individual hydro graphical units.

1) MAIN ARM

The 200 km stretch of the Danube between Rajka and Budapest has two different parts. The upstream 40 km reach flows faster as the slope of the river bed is greater. This upper section, called the "Hungarian Upper Danube", is the main stretch in the Szigetköz (Kisalföld) region. Its was formed by water regulation works last century. Previously, there had been several large Danube branches on the alluvial cone but then the water flow was modified by embankments. The habitats in the Danube, were determined by three main factors: flow velocity, suspended sediment load (during most of the year) and the connections with the side arm system. Despite the river training works, the main arm-side arm link remained quite active.

The principal parts of the Gabčíkovo-Nagymaros Barrage System which need to be considered when evaluating its effect on the Old Danube are the Dunakiliti Reservoir and the bypass canal. The total area of the reservoir would have been 52 km^2 with an average depth of 3.3 m and a volume of 243 million m^3. These parameters all decreased in the actual reservoir constructed as part of Variant C. The hydrobiological conditions of the reservoir are mostly determined by the surface area, the reduced and variable flow velocity (due to the morphology of the reservoir) and the partial deposition of the suspended sediments. The 17 km headrace canal which has an inner cover of asphalt, raises the water above the ground and takes it straight to the power plant. The 8 km tailrace canal has a more natural form and bed material.

The river section between Szap and Budapest, the Hungarian Middle Danube is characterised by a considerably lower river slope and flow velocity and a regulated river bank. The grain size of the bed sediment is smaller than in the upstream section. Floods carry the smaller sized particles downstream. The aquatic life is more diverse in this section because of the slower flow and greater nutrient content of the water, nonetheless, in some areas the diversity is reduces by pollution. Several tributaries flow into the Danube in this section (Rába, Váh, Garam, Ipoly etc.), some of which are quite polluted. There are also parts of this section that are affected by the industrial waste waters of Győr and Esztergom. As there are bank filtered wells along the river banks, the biological condition of the Danube affects the region's drinking water sources.

The hydrobiological status of the main arm of the Danube in the Szigetköz is basically determined by that of the section upstream. Along the regulated main arm between Rajka and Szap, it changes only moderately. This was especially true before the side arm systems were more intensively separated. Hungary hardly pollutes the Upper Danube, however it does deposit urban and industrial waste in the Middle Danube, downstream to Szap. Moreover, some Slovak tributaries to this section (Váh, Ipoly), also carry pollution.

Chemically the Danube can be characterised as a calcium-hydrogen carbonate dominated β-α oligotrophic water, with a mean salt concentration of 240-350 mg/l and a specific conductivity or 250-500 µs/cm. The usual dissolved oxygen concentration of the river varies between 8 and 10 mg/l although it is occasionally higher. This is a sufficient concentration for the aquatic biological communities and the degradation processes. The chemical oxygen demand is not too high (COD_{5Mn}: 4-6 mg/l; COD_{Cr}: 10-16 mg/l). It is within the β-mesosaprobic, β-α mesosaprobic range. According to the data series at Rajka for the last 20 years, the main arm water quality has deteriorated over this period with respect to several parameters (specific conductivity, COD_p, BOD_5, ammonium, nitrite, chloride, sulphate). The greatest increase was detected in the concentration of different forms of nitrogen and that of orthophosphate.

The quantity and quality of suspended sediments is important for the biological production of the Danube. In recent years, there has been around 10 mg/l of suspended solids at low flow levels. During floods the suspended load can reach 100-200 mg/l . A comparison between data collected in the late 1950s and that of late 1980s shows a reduction by a half in the suspended sediment load. The primary cause of these significant changes are the Austrian dams constructed on the Danube during this 30 year period.

The Danube continuously carries heavy metals in two forms: either dissolved or bound to solid particles. The concentration of heavy metals in both phases considerably fluctuates and the maximal values are in some cases, near to the maximal acceptable concentrations. The heavy metals absorbed on the surface of suspended solids are deposited and then reductive processes release them. In the Szigetköz, the heavy metal concentration of molluscs originating from side arms which often have reductive beds, was two to three times higher than the concentration of molluscs from the Old Danube.

The nutrient supply of plants in the Danube is a basic biological feature. The current average concentration of inorganic nitrogen is 2.5 mg/l of which 85-96% is nitrate. The nitrite concentration can be neglected. The concentration of ammonium ions is between 0.2 and 0.25 mg/l. Variations in the total concentration of inorganic nitrogen follow a typical annual cycle: lowest in summer and early autumn and reaches its peak in winter and early spring. There can be a 100% difference between the annual minimal and maximal values. In the vegetation period, when the phytoplankton production is the most intensive, nitrogen binding is considerable.

The total phosphorus, especially the orthophosphate, 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 cultivation period when the phytoplankton is in abundance, the concentration decreases, but only to 0.04-0.05 mg/l. It is still significantly above a concentration which could restrict an increase in the water trophity. In 25 years, the average inorganic nitrogen concentration has increased by nearly 56%, and that of orthophosphate phosphorus by approximately 100%. Even 25 or 35 years ago, before this increase, the Danube was potentially politrophic.

The oxygen production/consumption balance changed significantly in the mid 1980s. Up until the beginning of the 1980s the side arms perceptibly affected the oxygen cycle of the Szigetköz section of the Danube. This was due to the direct links between the main arm and some large side arms. The phytoplankton production in the slow moving water of the side arms was considerably higher than that in the main arm. As there was a nearly continuous connection, the oxygen rich inflow from the side arms regularly increased (often significantly) the primary production downstream. As a result, the side arm systems in the Szigetköz used to play an important and advantageous role in the oxygen cycle of the main arm. Erosion of the riverbed and the subsequent isolation of the main arm, 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 classification was based on the presence and quantity of Protozoa species. In other studies, centrifuged dipped samples were saprobiologically analysed. The saprobiological status of the Danube and the side arms are generally acceptable with rare exceptions. Between 1976 and 1980 the average saprobity index in the main arm reached the α-mesosaprobic range (>2.9) in winter, while it approached β-mesosaprobic (around 2.2) in summer. There was a small decrease of 2-3% between Rajka and Medve.

The trophity of a water body is the quantity of organic nutrients for algae and macrophytes in the water, and indicates eutrophication. As mentioned earlier, the Danube and the side arms are potentially politrophic. They contain enough nutrients for extensive algae growth if the environmental conditions are favourable. The actual trophity of the Danube, which can be measured by determining either the number of algae, the biomass of the phytoplankton, the chlorophyll-a concentration or the primary production, changes throughout the year. From November to February it is oligotrophic. At low water levels, the Danube was mesotrophic even in March. From spring to autumn it is oligo-mesotrophic during floods and eutrophic or eu-polytrophic in low flow periods. In some years it became eutrophic in March and it remained that way until as late as October.

By the end of the 1970s both the average and the maximum number of algae increased by a factor of 3-5 in the Szigetköz region. The nutrient supply of the Danube could have been sufficient to attain an eutrophic or eu-polytrophic status as early as the end of the 1950s or the beginning of the 1960s. Meteorological conditions and several hydrological parameters (flow velocity, water level fluctuations) can be neglected as possible causes of the tropic changes because they changed little in the Hungarian section. According to our present knowledge, the decrease in the quantity of the transported sediment resulted in better light conditions which affected the reproduction of phytoplankton.

First of all the quantity and quality of suspended solids and the depth of the illuminated water column in flowing waters, determine the light conditions for the phytoplankton. The quantity of suspended solids in the Danube between Rajka and Budapest, as previously mentioned, decreased by half from the late 1950s to the late 1970s, especially when the water level was low or average. The main reason for the decrease in suspended solids was the sediment retention effect of the German and Austrian barrage systems constructed during that period. This decrease in suspended solids, considerably increased the transparency of the water. It was two or three times higher at the end of the 1970s than at the end of the 1950s. Now the percentage of the total water body illuminated in normal flow conditions is 75-90%, and during floods is 20-30%. Consequently, at low flow levels, algae proliferate in nearly all of the Danube, whilst during floods their reproduction is restricted to a shallower, upper layer. In contrast, at the end of the 1950s, there was enough light for algal reproduction in 20-40% of the Danube water column only at low flow levels and 10-15% during floods.

Reservoirs provide good habitats for euplankton algae. Those proliferating in the reservoirs on the Upper Danube are then carried to the Danube, where they find appropriate conditions for their existence and reproduction. This process continues along the Austrian section of the Danube. By the time the Danube reaches Hungary at Rajka it has a rich planktonic algal flora, which would not normally be expected in this section.

From among the nearly 200 zooplanktonic ciliates, β-mesosaprobic species dominate the Danubian communities in the Szigetköz region. 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 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 several weeds and water mosses could survive in the constantly water covered zone of transverse dykes and embankments. Macrophyte stands could develop along the Middle Danube because of the slower flow velocity. They are usually found around transverse dykes and riversides, where floods do not dislodge them. In general, fluctuations in the water level and floods strongly inhibit the distribution and development of macrophytes along the Middle Danube.

Pollution of the sediment differs in each Danube section. It is difficult to detect accurately the load in the often moving bed sediments of the Upper Danube. At certain sections, it is possible to collect fine sediment samples near the bank and investigate their pollutant load. Samples taken, together with others from the Hungarian Middle Danube, were analysed for nine heavy metals (Hg, Cd, As, Cu, Pb, Cr, Mn, Zn, Fe). All heavy metals were detected in the sediment. Their average concentrations were below the maximal acceptable heavy metal concentrations of soils (the maximum tolerated by plants). However, with the exception of Cu, the maximal concentrations were greater than the acceptable standards. These sediment samples were collected from the upper 5 cm layer. Bank filtered water wells are important for certain regions along the Hungarian Middle Danube. Sediment samples were collected in those areas at different depths from the surface to the confining layer (the fine sediment can be several metres thick at slow flowing sections). The samples were investigated for organic pollution, oils and fats. In each case the finest grain size sediment contained the greatest quantity of polluting agents. Consequently, the deposition of fine particles causes the accumulation of pollutants in the Danube.

The original status of the Hrušov-Dunakiliti reservoir and the diversion canal is not dealt with here. There was no water in the area where the diversion canal is now constructed (at least not in the upstream part) while a discussion of the former Danube section within the reservoir is irrelevant. These areas are considered later with regards to their hydrobiological effects and changes.

2. *Side arm systems*

In this chapter, only the side arm systems of the Szigetköz are discussed. Neither the side arms of small islands in the Hungarian Upper Danube nor the 31 km long side arm of the Szentendre Island upstream of Budapest will be described. (They do not differ greatly from the main arm - there are only minor differences in their size and water discharge.) They are also continuously connected to the Danube at both ends. The Slovak side arm systems (on the left side of the river) are not considered here, either. The Szigetköz side arm systems are described here in their historical complexity. Besides the water bodies in the floodplain, the waters within the protected area are also discussed.

Originally the side arm systems and the main arm of the Danube were integral parts of a complex system. This included water bodies within the protected area even if they were only fed through the groundwater. If the water discharge of the Danube was not greater than 1,800 m^3/sec, i.e., at low-flow levels, there was no direct side arm-main arm connection. Subsurface inflow and outflow was the sole link with the water supply and so, the side arms became lentic. This 'still water' period used to last for approximately half of the year (170-180 days). During roughly 90 days each year, the system could be described as being supplied by seepage. Direct connection only occurred when the water discharge was above 2,500 m^3/sec (60-70 days per year) the quantity flowing into the system depended on the actual water level.

Each side arm system can differ enormously from another, because of its different shape, size and water regime. In low water periods, when the water hardly flows or even stands, they generally manifest lemnic hydrobiological features, usually accompanied with a high trophity. This is due to the high inorganic nutrient content (phosphorus) of the Danube and the lack of currents in the water body.

During floods, the <u>phytoplankton</u> in the floodplain side arms and the main arm are identical. Following the separation of the side arms from the main arm in the cultivation period, the composition of aquatic biological communities and the phytoplankton population change rapidly, i.e., certain species occur in abundance. The new, dominant phytoplankton develops within a few days in small arms. A similar process occurs in large side arms, but sometimes takes several weeks to complete.

The abundance of phytoplankton can vary greatly in each side arms in the cultivation period. The number of individuals is usually around several tens of thousands of individuals/ml, the chlorophyll-a concentration is between 50 and 200 mg/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 blooms even along certain sections of the main arm, but it is more typical in the side arms. Small side arms usually have low concentrations of chlorophyll-a as they get their continuous water supply from filtered Danube water. In other cases, the intensive grazing of zooplankton reduces the population of phytoplankton.

The trophity of the side arms can rapidly increase in the vegetation period, especially between May and September. After great floods, the phytoplankton of the Danube remaining in the side arms begins to reproduce rapidly. In 24 to 48 hours the number of individuals can increase two to four times. The zooplankton reaches its maximal population after 5 to 10 days. The great abundance of phytoplankton can remain even after the vegetation period. In large side arms, if the nutrient concentration is high, a maximum population of winter plankton algae can be detected under the ice leading to eutrophic conditions. In February 1993, for example, the chlorophyll concentration under the ice was 30-50 mg/m^3 in a side arm of the Ásványváró branch system.

The differences between the composition of aquatic biological communities and the number of individuals in the Danube from that of other water bodies, is particularly notable in the water bodies within the protected area.

The connection to the main arm is a crucial factor in the species composition of zooplankton in the side arms. After floods, when the side arms are disconnected from the main arm and their flow velocity reduces, the structure of the zooplankton population radically changes. In a couple of days the number of species and their volume significantly increases. The predominant species however, remain more or less the same in the main arm and the side arms.

In the Ásványváró side arm system, zooplankton samples were collected every day between 20 June and 17 September, 1985. At Rajka, the water discharge of the Danube changed between 1,530 and 7,090 m^3/sec in the given period. Lemnic conditions prevailed, the number of aquatic communities and their populations were high when the water was stagnant. The structure of the zooplankton community is mainly determined by meterological (seasonal) changes and fluctuations in the discharge. Nonetheless, most species found in the side arms, are common to slow flowing eutrophic waters.

Oxygen production is considerable in the near lentic conditions. Following floods, the side arms are subject to a strong flushing effect dislodging many communities and transporting its sediments; before the side arms were closed, they considerably and significantly increased the oxygen concentration in the main arm.

The saprobiological status of the side arms is usually better than it is in the Danube; the saprobic index is often higher by 0.2-0.3. However, saprobity increases occur in stagnant side if there is a high abundance of phytoplankton and only little or no oxygen in the lower water layers.

There is no macrophyton stand in the main arm because of its high flow velocity. In contrast, rich and variable communities develop in small side arms and oxbow lakes on both sides of the flood protection dikes, with the exception of deep, gravel bedded side arms in the active floodplain. Rich macrophyte vegetation is typical of shallow arms which are not, or only to a limited degree, flushed by floods and have a nutrient rich sediment. The actual state of macrophyte stands depends on the water discharge, hydro-meteorological conditions and the development of phytoplankton. In general, the richest macrophyte vegetation is found in oxbow lakes and shallow waters in the protected area. It can spread over the entire water body.

There is a great variety of bed sediment characteristics in the side arms due to differences in the grain size and organic matter content. It is worth recalling here the higher heavy metal concentration of molluscs living in the Szigetköz side arms compared to that of the molluscs in the main arm.

This chapter does not cover fish biology or fishery, even so, the importance of this area for fish reproduction should be emphasised. Fish migrate here, often covering more than several hundred kilometres, to spawn from the Danube. In addition, the side arms produce more than half of the total fish in the Hungarian section of the Danube.

In the old floodplain there are some small semi-natural water bodies of great ecological value. The fate of these side arm system remnants, e.g., the strictly protected bog at Arak and the mortlake at Lipót, should be taken into special consideration.

Strictly speaking, nature conservation is also outside the scope of this chapter, however, the survival of protected areas and other natural values in the Szigetköz depend on the presence of the water. The most valuable areas are elements of the side arm systems on both sides of the flood protection dikes, which form a unique region of great ecological importance. Prominent international and national organisations evidently share this opinion.

3. Mosoni Danube

This 120 km long river is supplied by various sources. Its water discharge is relatively small compared its pollution load. The Mosoni Danube gets an internationally guaranteed 20 m^3/sec from the Danube and the water of its tributaries, the Lajta, Rába and Rábca.

The first section of the Moson Reach, from the beginning of the branch to Mosonmagyaróvár, is fast flowing with a significant bed gradient. The second section is slow flowing, and resembles the lower section of the main river. In recent decades, changes in the water supply from the Danube have caused some problems: the discharge has decreased while the two developing cities on the river, Mosonmagyaróvár and Győr, have produced an increasing amount of pollution. Consequently, the water quality has deteriorated. Downstream of the cities, the river became extremely polluted. For example, above the weir at Mosonmagyaróvár, a considerable amount of the suspended load is sedimented. Further downstream, partly as an effect of the urban sewage from Mosonmagyaróvár, the nutrient supply of algae and the self-purification capacity of the river increase. A constant problem besides the waste water of Mosonmagyaróvár, is the effect of the polluted waters of the Rába and the Rábca and the untreated sewage of Győr. During floods, the Danube dams back the Rába causing serious problems even upstream of Győr.

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

4. Effected, current and predicted changes

Hydrobiological changes are discussed in geographical units, but processes in one unit obviously have an effect downstream. With regards to the Gabčíkovo-Nagymaros Project, a considerable number of changes to the original status occur after a some time and cannot or can hardly be detected immediately after the diversion.

a) Dunakiliti (Hrušov) Reservoir

This reservoir differs morphologically and hydrologically from upstream German and Austrian reservoirs, and so cannot be compared. In this chapter, the effects of the original reservoir and not the effects of the 30% smaller Variant C reservoir are evaluated. Nonetheless, the observed changes are practically the same as those predicted, only a little less intensive due to the smaller size of the reservoir.

For a mean water discharge (Rotschein 1976), the average depth would have been 3.3 m, the volume 243 million m^3 and the water surface 52 km^2, according to the original plans. The water would have passed through the reservoir at a constant rate, but the retention time and the average flow velocity would have varied in different parts of the reservoir. They would have had the following values in the original reservoir according to Rotschein (1976):

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 of the original, average flow velocity at this section (higher than 2.0 m/sec) with the planned decrease to 0.11 m/sec. This change is the basis of all alterations to the original biological and physicochemical conditions. The suspended sediment load of the water entering the reservoir is already reduced because of the retaining effect of the upstream barrages, however, intensive sedimentation occurs in the reservoir due to the reduced flow velocity. Several mathematical models were created to describe the process (VIZITERV 1985, VITUKI 1978, 1987a, Komora and Sumbal 1965). Eight centimetres of sediment was predicted as an annual average, but under certain meteorological conditions, annual deposition can reach 30 cm. The spatial variation in sediment deposition was calculated to be between 2 and 44 cm. More than 50% of the sediment has a smaller grain size than 50μm, which can form bonds with organic matter. The continuous movement of the stream line constantly modifies the stream profile of the reservoir. As a result, the location of stagnant water areas, which adversely effect the water quality, is unpredictable. Water quality changes are more dangerous in winter when the reservoir is covered by ice, the solid surface prevents the aeration of stagnant water, accelerating anaerobic processes.

The acceleration of eutrophication depends on the availability of nutrients for algae and plants, the light conditions and temperature. In the Danube at Bratislava, there is more phosphorus and nitrogen than the phytoplankton can reproduce in. As a result, planktonic eutrophication is only limited in this section, by the lack of adequate light conditions, temperature and by the effects of the flow. In the reservoir, light conditions improve because of increased sedimentation, and the temperature increases by several degrees centigrade in the main vegetation period. The storage of the water provides an opportunity for the algae to use up the greater part of the practically unlimited phosphorus and nitrogen supply. As a result, an algal bloom is inevitable. At the same time, self-purification processes become more intensive too, but the produced organic matter burdens the downstream sections for the next couple of hundred kms. This can cause problems e.g., for the drinking water supply in certain areas. This theory was proved earlier by an Austrian-Slovak-Hungarian joint research project, along the 420 km long Hungarian section of the Danube considering effects of Austrian Danube reservoirs on the water quality. Both the number of algae and the chlorophyll concentration had increased along the entire stretch (VGI 1985, VIZITERV 1985, VITUKI 1987b). To return to the effects of the Dunakiliti weir, even if all sewage in the affected area were biologically treated, the COD and BOD_5 concentrations which indicate the organic matter load, would increase.

The quality of the bed sediment in the reservoir is also significant. Its organic matter content is estimated to be between 13-15%, primarily consisting of decayed plankton and sedimented organic pollutants. Rotschein (1976) also estimated an increase in oil pollution from the more intensive navigation. Anaerobic areas, producing hydrogen sulphur and methane can form, 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 could decrease to zero because of the humic alluvial soil and decomposing vegetation remaining in the impounded area (according to a VITUKI report in 1988). As a result, iron and manganese could be released into the ground water.

The construction of the reservoir led to the nearly complete deterioration of the Doborgazsziget side arm system. It used to be situated in the area, now covered by the reservoir, and was important in terms of nature preservation and water quality protection.

Present and future processes in and around the reservoir are the results of a dynamic, interrelated system. Their intensity and timing is extremely difficult to forecast. Nevertheless, all of the above processes will probably occur.

b) Diversion canal

Two important changes can be predicted for this 25 km canal. In the first 17 km long, completely artificial section the number of algae (and the a-chlorophyll concentration) will probably increase only slightly if the oxygen content is sufficient. However, plankton algae, sensitive to the higher flow velocity than that in the reservoir, could begin to die. A certain amount of the phytoplankton (according to some estimates, as great as 30% of the community), is mechanically killed by the turbines of the Barrage System. The water flowing through the turbines is physically enriched by a considerable amount of oxygen. Although the oxygen cannot be detected for several km downstream, it still speeds up the oxygen consuming degradation processes over a short section. The tailrace canal, downstream from the power plant, is relatively fast flowing and resembles natural conditions. No great changes occur in this section though, plankton organisms, originating from the reservoir, continue to die.

c) Old Danube

The discharge of the Old Danube decreases along the 37 km (rather than the planned 31 km). The water discharge is nearly always below 1% at the staff gauge at Dunaremete. Sudden flood flows (up to 2,000 m^3/sec) were released so far when the discharge into the reservoir was very high (4,000-5,000 m^3/sec). Those only lasted for a short period and were subject to unilateral Slovak decisions, about which no previous warnings were sent to the Hungarian authorities.

The bilateral treaty specified a 50-200 m^3/sec water supply for the upper section of the Old Danube. This is not enough for the basic biological (and non-biological) functioning of the river. The reservoir water, which already has a higher trophic level than further upstream, becomes even more eutrophic here, stagnant water areas are formed, etc.

The diversion had several effects on the Old Danube: the area and volume of the aquatic environment decreased, the semi-natural water level fluctuations have stopped, and there scarcely remains any connections with the Szigetköz side arm systems. As a result, they have lost their function as fish spawning areas which is essential for the fish fauna and fisheries of the main arm section in the Szigetköz and further downstream. In addition, the plankton communities have lost their nutrient supply from the side arm systems, which is has an adverse effect on the river's oxygen budget and capacity for self-purification. The now permanently dry areas of the river bed are being overgrown by woody plants, primarily willow bushes.

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 worsens because of the high fine sediment and pollution concentration of the water arriving from the reservoir and occasionally from other sources, too. Changes in the water quality depend on the duration of the high water level and meteorological conditions.

d) Side arm systems of the Szigetköz

The first damage to the side arm was caused by the acceleration of their separation from the main arm. This activity which began approximately 25 years ago, led to the increased silting up of the side arm systems. Their water level fluctuations only moderately followed the changes in the main arm and the biological side arm-main arm connections began to disappear.

After the diversion, the side arm systems in the floodplain lost most of its water, and large areas became dry or stagnant. This was followed by an considerable loss of fish in the area. Without doubt, Hungarian measures to alleviate the damage in the area, "brought back" the water to several areas. However, natural fluctuations in the water level and the intensive metabolic connection with the main arm could not be restored or compensated by the fraction of the original amount of water that was delivered.

The loss of invaluable biodiversity is a separate, yet important issue; a variety of habitats and niches is fundamental for biodiversity. The richness of the side arm systems is unique in this sense along the Danube.

We have already referred to the connection of the main arm to the side arm systems in the description of the main arm. Here we discuss the reciprocity: damage to the side arm system because of its separation from the main arm.

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

The water loss of side arm system elements and ox-bow lakes within the old floodplain have also been extensive. Water was conveyed to many areas, but the dynamics and quality was completely different. It is certainly not an adequate solution for the reconstitution of the desiccated sites and their vegetation and wildlife. These measures could only help in the short-term survival of the existing aquatic communities.

Two water bodies within the old floodplain, the mortlake at Lipót and the Arak bog, are of special natural value and are strictly protected. However, soon after the diversion of the main arm, the mortlake at Lipót completely dried out. As a result, its vegetation and wildlife were spoiled. After a dry period lasting several months, water was pumped into the area from the main arm when flood waters were suddenly directed along it. Since then, a constant water pump has been put into operation to provide a continuous water supply in order to revitalise the mortlake. The Arak bog was damaged similarly but to a lesser extent.

Both sides of the flood protection dykes used to have extensive wetlands which are among the most important habitats for the protection of biodiversity; they are listed in international conventions with the strictest obligations for their protection. Unfortunately, these areas have almost disappeared completely from the Szígetköz because of the decrease of the water table.

We should recognise the occurred and expected damage to the side arms system of the Szigetköz. The Žitný Ostrov on the Slovak side of the Old Danube, is an area similar to the Szigetköz. There are similarities in the side arm systems, the hydrographical conditions and in the fact that it is also situated on the alluvial cone of the Danube. The problems caused by the Gabčíkovo-Nagymaros Barrage System are very alike, too. However, the restoration opportunities are much better in Slovakia because they can provide much more water for their side arm systems from the diversion canal and avoid short-term damage to a certain extent. While Hungary could only utilise 50-150 m^3/sec water discharge of the Old Danube and 3-5 m^3/sec water (with a maximum of 10-20 m^3/sec) from the water supply system.

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

The water quality and the biological status of the water on the 17 km stretch between Szap and Vének is determined by the water arriving from the diversion canal when the discharge is below 4,000 m^3/sec. At a higher discharge, water is directed along the abandoned Old Danube. This has an unpredictable effect on the water quality, especially at the beginning of the flood, as the waters can flush eutrophic stagnant waters and fill up the previous water bed washing away the willow shrubs, both of which will probably lower the water quality considerably.

The exactly 100 km long flow-through Nagymaros Reservoir would have been 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	0.70	1.10	1.41

At present the average flow velocity is 1.00-1.10 m/sec, at an average water discharge of 2,000 m^3/sec at the side of the Nagymaros Barrage System. The dam would decrease the flow velocity by 30%, which would considerably improve the conditions for plankton organisms (both phyto- and zooplankton). This would result in an enrichment of the plankton community originating from the Dunakiliti Reservoir; the plankton biomass would be even higher than that upstream.

25-30 km upstream of Nagymaros, between Lábatlan and Esztergom, intensive sedimentation would have been expected. Polluting agents, bonded to the suspended solids would be deposited too, just as in the Dunakiliti (Hrušov) Reservoir

The number of living and dead algae and the pollution load would increase along the entire section. Unsatisfactorily purified sewage entering the river adds to the load of this stretch. The main sources of pollution are the Mosoni Danube, the Váh, Hron, Ipoly and the waste water of Győr, Komárom, Sturovo, Dorog, Esztergom and a number of small towns and villages. The large-scale sewage purification project that was launched, is far from complete. We must emphasise that the proposed 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, degrades consuming the oxygen content of the water in the bed sediment. Iron, manganese, ammonium and carbonic acid are accumulated in the reductive medium and organic molecules having a bad odour or taste are formed. Heavy metals can also be released (VITUKI 1985, VGI 1985).

The existing and potential bank filtered wells in the area deteriorate because of pollution and also because the fine grained bed sediment prevents the Danube water from flowing towards the bank filtered wells.

Along the Nagymaros-Budapest section, the effect of the Barrage System is twofold. Firstly, as the water flows through the turbines, its oxygen content physically increases. This produces an advantageous effect over a short section. However, at the same time, the amount of dead algae also increases spoiling the water quality for most of the year.

There is no accurate data on the effect of the increasing number of algae and chlorophyll-a quantity, the organic load caused by dead plankton, compounds having a bad odour or taste in either surface water or in the bank filtered drinking water extraction. Nearly 3 million people are supplied with drinking water from these sources. Dredging downstream of Nagymaros, planned before, would destroy the natural filter layer of several wells of the Waterworks of Budapest. Subsequently, further dredging was cancelled along that section.

V. Conclusion

The evaluation and prediction of biological processes and their interrelationships with watercourses such as rivers, is an extremely difficult task because they are multivariable, dynamic systems. Hence it is particularly unfortunate that the biological status of the water, the water quality and their possible changes were not assessed adequately in the planning phase of the Gabčíkovo-Nagymaros Barrage System by the countries concerned with the construction. That statement still stands even though the awareness of environmental and water quality protection, nature conservation and their social importance greatly increased between the planning phase and the beginning of the construction. The political situation, and, in certain periods, economical problems, continuously created obstacles for a comprehensive study based on a general concept. It is really unfortunate that a comprehensive joint research project and evaluation was not carried out by Hungarian and Slovak experts.

Nevertheless, none of the above-mentioned facts entitles anybody to ignore the modern ecological-economical approach and the real long-term benefits to society, when the decision on the fate of the Gabčíkovo-Nagymaros Barrage System is to be made.

References.

Komora, J., J. Sumbal. 1965. Áramlások és szabályozások a Hrušov-Dunakiliti tározóban. Összefoglaló jelentés, kézirat S-1. 13-1/18. VUVH, Bratislava.

Rotschein, J. 1976. Prognoza smien kvalitativnevo rezimu Dunaja po vystavbe vodnych diel. Prace a Studie, VUVH, Bratislava.

VGI. 1985. A BNV környezeti hatásai, különös tekintettel a vizellátásra és szennyviztisztitásra. (Environmental effects of G/N Project in particular with respect to water supply and waste water treatment).

VITUKI. 1978. A GNV várható vizminőségi kihatása. (Probable effect of the G/N Project on water quality.)

VITUKI. 1987a. A Duna komplex vizsgálata. 2. A vizminőség változása. (Complex Investigation of the Danube. 2.Changes in the water quality.)

VITUKI. 1987b. GNV területi megfigyelőrendszer (vizminőségi állapot felmérés). (The territorial water quality monitoring system of the G/N Project and water quality assessment.)

VITUKI 1988. A régi Dunaümeder szabályozása érdekében létesitendő gázlóbiztositás kismintavizgálata. (Water sediment and hydrobiological examination of the Danube, its tributaries and its side branches.)

VIZITERV. 1985. A Gabčíkovo-Nagymarosi Vizlépcsőrendszer környezeti hatástanulmánya. (Environmental impact assessment of the G/N System.) Budapest.

VITUKI. 1985. A Gabčíkovo-Nagymarosi Vizlépcsőrendszer hatása a hordalékjátásra. (Effects of the G/N System on the transport of sediments). Report no. 7623/2-801, Budapest.

VITUKI. 1985. A Gabčíkovo-Nagymarosi Vizlépcsőrendszer vizminőségi hatásának vizsgálata. (Effects of the G/N System on water quality). Report no. 7623/2-801, Budapest.

Annex 11

"DANUBIAN LOWLAND – GROUND WATER MODEL"

(Annex 2 from PHARE)

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GROUND WATER PROBLEMS IN SLOVAK DANUBIAN LOWLAND

1. Introduction

Until recently (in most countries) the main object of ground water research was no more than exploring ground water resources for water supply and the lowering of the water table for construction. Later however, other problems came into prominence, namely, that ground water should be protected from pollution, restoration of polluted groundwater, and, for instance in arid zones, protection from overuse. Nowadays ground water deserves attention since it is a basis for social, agricultural and industrial development everywhere, and a precondition for human hygiene and health. The quality of ground water, its presence or absence, is also a decisive ecological factor. As can often be seen, the ground water may be the only steady natural water resource, at least on our territory.

Ground water cannot be observed directly, because it migrates through the rock. In Slovakia more than 99% of the entire water volume can be regarded as ground water. Most of this can be found in river sediments, especially in the alluvial deposits of the Danube below Bratislava, and the depth of these deposits may be more than 300m (Fig.1). The construction of hydroelectric power plants in this region causes new problems for Slovakia because they affect the quality of ground water. The problem is new because till now all the power plants were established in mountain districts.

Therefore our attention has to be directed to the future alteration of flow conditions in ground water owing to the Hrušov-Dunakiliti Reservoir and power plant at Gabčíkovo (Fig.2). Besides that, ecological changes will occur in the Danube branches, the floodplain and the wetland forest, as well as in the cultivated area (Fig.3). Professional dialogues on all issues more or less related to ground water problems have taken place. Many problems in this area are as yet untouched; the answers are completely open.

One characteristic feature of rock and ground water is that they are subject to self-purification. However, this is not self-purification in reality, but physiochemical and microbiological processes that can be observed under certain circumstances which are able to preserve the good quality of ground water and reverse pollution. On the other hand, such conditions may occur which would make ground water unsuitable for certain purposes. The pattern and rules of this complicated ecosystem is still hidden behind a veil of mysteries. This system is susceptible to physical influences such as heat, light, flow and to chemical substances such as nitrogen, oxygen, phosphorus, organic matters. It can be affected by the physicochemical properties of rock such as absorption, ion exchange, porosity, mineral composition and by hydrodynamic parameters for example permeability, anisotropy, hydrodynamic dispersion, river and ground water level fluctuation etc.

In addition, biological and microbiological activity plays a decisive role in the game of ground water quality considering the whole system from rainfall to the rivers, soil, and the ground water itself. Man begins and ends this ecological system, while nature prevails in the middle. We must admit that this system and the processes occurring in it are not fully understood. It is an unquestionable fact, however, that such a complex system can be examined only by means of models, which nevertheless are still far from simulating the real complexity of the process. Last but not least, we are not even able to define our common understanding of nature conservancy and groundwater protection.

It is a fact that protection of ground water is closely connected with the protection of the environment. If we carefully protect our natural environment, the ground water also will be protected, and vice versa. For this reason, ground water quality is an important criterion for efficient nature and environment protection.

2. Ecological Problems Relating to Groundwater

In the region below Bratislava, the Danube flows on an alluvial cone (Fig.4). The riverbed of the Danube shows some displacements and a lot of side arms and floodplain features developed (Fig.3). Fig.5 shows low groundwater levels and it is clear that the Danube drains into the quaternary sediments all along the area below Bratislava and in the region of the hydroelectric power plant at Gabčíkovo. The permeability is very high: between $1x10^{-3}$ m/s and $1x10^{-2}$ m/s (average $3.8x10^{-3}$ m/s). The depth of the sediment layers reaches approx. 10m at Bratislava, 120m at Samorin, more than 300m at Gabčíkovo, and then it falls again to 10m. By the side of Žitný Ostrov island and up to the Dunakiliti weir the ground water table is more than 3m below the surface, not reaching the soil by capillary rise. The fluctuation of ground water level depends on the water level of the Danube and this alters quite significantly. Fig 7 shows the amplitude of this fluctuation in the middle of Žitný Ostrov island as a function of the distance from the Danube. In the lower part of the island, the ground water level is closer to the surface (Fig.6) and it is drained by many canals. The Danube, the side branches, irrigation and drainage canals, as well as rainfall and evaporation rates determine the characteristic flow of the ground water. In this environment the hydroelectric power plant, Gabčíkovo, was built, which has been debated so much.

Parts of the problems of Žitný Ostrov island can be studied in comparison with other Danube countries.

For example, the continuous sinking of the Danube river bed, causes a gradual drop in the ground water level at the riverside as well as a gradual desiccation of the flood plain. Under Vienna, Kresser (1988) observed a degradation of the river bed owing to a detention of bedload. Between Hainburg and Bratislava the sinking of river bed is up to 10cm/year. Schiel (1988) reports on a ground water level drop of 2-3m in the Vienna area in the last 30 years. It goes without saying that the termination of bedload supply from Austria affects the region of Žitný Ostrov island too. At the same time gravel mining in the Danube and dredging for navigation is further lowering the riverbed and the levels of the surface and ground water respectively.

The Austrian power plants affect the flow conditions of the Danube. The water level and flowing peak value sank especially during the summer. The consequences on the ground water are obvious. Fluctuation of ground water level decreased. This also affects the groundwater quality since in the upper part of Žitný Ostrov island, the ground water is continuously supplied by the Danube. The flow regime of the Danube as well as the particle size distribution of deposits has changed towards sand and silt. Therefore the content of organic matter becomes higher (absorption occurs at a particle size under 1mm or rather 0.1mm particle size) in the river bed. The importance of this alteration and its effects on ground water quality were explained by László *et al.* (1987) regarding the consequences on bank filtration. Similar results were observed at the Altenwörth dam above Vienna by Nachtnebel and Haider (1988). Owing to increased organic load of the sediments and lower oxygen exchanges between air of the unsaturated zone and the ground water, a gradual decline in the oxygen content can be expected. Higher ammonium (up to 1 mg/l), dissolved iron and manganese (up to 2 mg/l) content will occur. The concentration of organic matter increases to a large extent. Water soluble heavy metal complexes can develop, too. Obviously all these factors will affect the ground water quality, depending on the extent of change and the time [incorrect German text].

River regulation, various construction works, the hydroelectric power plants above Žitný Ostrov island, agricultural activity etc., caused a significant water and ground water level sinking so that, the still existing (not yet extinct) wetland forests will be subject to desiccation. Woodlands and flood plains are very important, not only for establishing a national park below Bratislava, but also for the improvement or protection of ground water quality. Their existence depends on a dynamic regime and on regularly high water level of the Danube. This territory eliminates the organic matter remaining in river branches, and in doing so for a renewable life, namely for an aerobic self-purification capacity. It provides good quality water for infiltration and the conservation of the flooded woodlands' character. In addition, at the riverside of the Danube, the ground water level used to fluctuate (Fig.7), since this happened in the deep layers of gravel-sand-sediments, the oxygen supply was quite good.

Under these natural conditions the Gabčíkovo power plant with the Dunakiliti Reservoir were built. The Gabčíkovo-Nagymaros power plant system was inserted in the program for the utilisation of the Danube from Bratislava to the Black Sea. In the upper reach, this system connects with the Austrian development projects for the Danube. The water impounded in the river is directed to Gabčíkovo power plant by a canal 17km long. A part of the water (50-200 m^3/s) should be drained into the old river bed of the Danube through the Dunakiliti weir. In the original bed a few little weirs should be constructed which would be able to control the water level in the original bed and in the side branches and adjust it more or less to the previous level.

Considering ground water quality the following facts seem to be important:

– Between Bratislava and the supply canal there will be a reservoir with a level of 131.2 m. a.s.l. It may be supposed that ground water is infiltrated through the sediment, without dissolved oxygen and with dissolved organic matter. Fluctuation of ground water level is smaller. Non-steady clogging of the river bed will develop.

– In the stretch of the supply canal, the ground water level will change, therefore the water level in the old bed of Danube will drop according to a secured level [incorrect German text].

– If dams are constructed in the old Danube bed, the water is infiltrated in anaerobic conditions through sedimented sand and silt.

–The situation of the side branches depends on the water regime. Without regulation adverse effects will occur.

– The ground water level and flow direction of ground water will be altered.

– Owing to altered ground water levels, previously filled branches of the Danube as well as waste deposits can be negatively activated.

– With a higher ground water level the oxygen supply through the capillary zone could decrease.

In the area of Žitný Ostrov island several water-works of great capacity can be found. For instance the well at Samorin gives 2000 l/s according to the plan. In Fig. 8 and 9 a model shows the ground water flow in a vertical section, and the flow alterations caused by the Dunakiliti Reservoir can be seen.

3. Possible Solutions

To utilise ground water or to develop protection measures, the flow conditions of ground water should be thoroughly understood. The water flow determines the transport of pollutants, oxygen etc., which are responsible for self-purification. It should be emphasised that this flow and material transport, as well as the alteration in the chemical composition and properties of ground water are characterised spatially. In the Danubian lowland this phenomenon is more distinct as the depth of Quaternary gravel changes from 10m (on the edge) to 300m (in the middle).

Transport and dispersion processes occurring in ground water are based on various physiochemical reactions and the biological activity of micro-organisms. To solve any problem these processes should be considered. At the same time the transport and dispersion are slow, and so it is difficult to perform experiments in situ. The most suitable solution can be found by means of numerical models which are able to describe volumetric flow and delivery (not only alteration of ground water level and level line) and the accompanying physiochemical and microbiological processes. For this model, however, the main correlation and parameters should be known. The model should be spatial and complex enough in order to include the most important processes, but also pragmatic enough as a "Use of models in decision-making" for both designers and politicians.

4. An Outline of the Present State of Solutions by Means of Models

In the area of Žitný Ostrov island early data on ground water can be found in the monograph of Duba (1968) and Mucha V. *et al.* (1966). First of all, Duba (1968), reported on the hydrogeological methods available to solve problems associated with flow, forecasts of changes in groundwater regime and also on first steps of modelling.

Numerical models of ground water flow and simulation models of material transport have been used since the seventies. These models give a flow scheme for ground water and dissolved substances, hydrodynamic dispersion and molecular diffusion. Various manuals (e.g. Kinzelbach 1986) describe these models, too.

To explain transport of non-conservative substances, chemical and biological processes, as well as physical conditions, have to be considered. This is done by the incorporation of chemical reaction in the transport models as well as additional equilibrium boundary conditions. A combination of chemical reaction and transportation equations is demonstrated by Kinzelbach and Schäfer (1989). They give a method which is based on two separate steps to break up physical and chemical equations.

A simulation model for the biological decomposition of organic matter in ground water is described by MacQuarrie *et al.* (1990) in the form of a numerical solution.

Jousma *et al.* (1989), as well as Kobus *et al.* (1989) reported on the present state of ground water models, suitable to solve water quality problems.

5. Definition of Ground Water Problems Existing in Žitný Ostrov Island Area

The main problem is that in Žitný Ostrov island physicochemical and microbiological processes are in connection with redox-processes. These reactions may be influenced by dissolved oxygen, dissolved organic carbon and other substances which promote or restrain microbiological activity.

These processes can be ranked on the basis of the consumption of dissolved oxygen or organic matter as follows:

Consumption of oxygen: Oxidation medium	Consumption of organic matter: Transition to a reduction medium
Oxidation of organic matter	Oxidation of organic matter
Oxidation of sulphides	Denitrification
Oxidation of Fe(II)	Reduction of Mn(IV)
Nitrification	Reduction of Fe(III)
Oxidation of Mn(II)	Reduction of sulphate
	Fermentation of methane

In both cases the oxidation of organic matter is predominant. If a suitable proportion of dissolved oxygen with water soluble organic matter is introduced into ground water, the oxidation of organic matter will start. This reaction is promoted by bacteria. Should the proportion of dissolved oxygen exceed the organic matter, the additional oxygen is consumed in the oxidative environment. In the case of a higher organic matter volume, reduction conditions prevail again supported by bacteria. There is no more dissolved oxygen, but is obtained from nitrates by redacting manganese, iron, etc. The transition from oxidation to reduction is very important since the degradation ability of organic matter switches from aerobic to anaerobic bacteria. At that moment, the microbiological decomposition of nitrate starts.

In the ground water of Žitný Ostrov island, a high oxygen content and high nitrate content (over 100 mg/l) were observed. The latter caused methemoglobinemia in babies.

The relation of oxygen, organic matter and nitrate content is the basis for the control of ground water quality on this island. A ground water sample of good quality must contain at least 1 mg/l oxygen and should not include any dissolved organic matter. In this case, however, the decomposition of nitrate is minimal. In order to protect groundwater, nitrate input should be minimised, for instance, by using an up-to-date agricultural technology (not only control nitrate fertiliser). The problem of introducing dissolved organic matter is also important, e.g. by oil pollution, but also in the case of regulation of the side arms and the Hrušov reservoir. Surface water quality as well as technology in agriculture is also important in this respect [incorrect German]. The unfavourable depth of the ground water level, capillary rise, mode and intensity of irrigation should also be considered.

The oxygen content of ground water will be higher when water is infiltrated from rain and snow. Most of this oxygen is, however, consumed in the oxidation of organic matter at the surface. Under the conditions prevailing at Žitný Ostrov island one part of the oxygen was infiltrated from the Danube directly into the ground water. This proportion of oxygen is used up in the Hrušov-

Reservoir during sediment transition, and it is predicted that the alluvial deposits contain organic matter to a large extent. Sudicky and MacQuarrie (1989) demonstrated that oxygen would be introduced into ground water by diffusion at the surface. In the Žitný Ostrov island area, the fluctuation of ground water level caused by Danube water level fluctuations was responsible for the input of oxygen (Fig.7). This fluctuation reached several meters near the riverside. The ground water level was far below the soil level. Nachtnebel and Haider (1988) reported on the worsening quality of ground water at the Altenwörth dam because of the infiltration of water with a high organic sedimentation load. Resulting from stagnant ground water levels, the gas exchange between the unsaturated zone and the ground water is reduced.

To model these processes, the mobile nitrate, mobile organic carbon in ground water, and bound substances which are associated with bacteriological phase were described by Kinzelbach and Schafer (1989). Obviously the ground water flow at the Žitný Ostrov island is three dimensional and unsteady. The three main components of the process (oxygen, nitrate and carbon) can be influenced by human activity. These parameters are the boundary conditions of the model, and they have never been studied. Other factors affecting the process can be found in the Table of redox-processes.

Parameters and conditions relating to oxidation and reduction indicate the factors to be determined through examinations in situ.

Input parameters of the models for ground water flow are as follows:

- separation of media; [Incorrect German]
- permeability and capacity, as well as its spatial distribution;
- definition of boundary conditions such as infiltration, rainfall, rivers, canals, water pumping etc.;
- parameters of longitudinal and transversal dispersal, absorption properties;
- temporal changes in parameters.

The starting input parameters and boundary conditions are:

- concentration of organic carbon, input of carbon compounds at the boundary of water, soil (e.g. on the basis of ground water level etc.);
- nitrate concentration and its input at the boundary;
- oxygen concentration and its transfer into the aquifer.

The starting physicochemical and microbiological parameters are:

- maximal natural increase of denitrifying bacteria;
- maximal natural increase of aerobic bacteria;
- proportion of dead micro-organisms related to the carbon content;
- carbon yield factor related to denitrifying bacteria;
- carbon yield factor related to aerobic bacteria;

– half-life of organic carbon (denitrification);

– half-life of organic carbon under aerobic respiration conditions;

– half-life of nitrogen compounds under denitrification;

– half-life of nitrate compounds under aerobic respiration conditions;

– half-life of oxygen under aerobic respiration conditions;

– concentration of bacteria;

– upper limit in oxygen concentration under denitrification.

The parameters above show the difficulty to elaborate a model and use it. Kinzelbach and Schafer (1989) describe a one-dimensional model with such parameters.

The basis for healthy ground water and a subsequently healthy environment related to groundwater is an adequate oxygen supply, limiting organic matter and the control of nitrate content. The latter means that the Mn and Fe content should be minimised in a reducing medium. For instance, in the territory of Žitný Ostrov island the low or nearly zero values of oxygen in lower layers of the aquifer without increased Mn and Fe content may be considered. The control of nitrate input is proposed in order to utilise ground water through the capillary zone, too. Obviously, this process can be affected by other substances which promote biological degradation [incorrect German].

For good quality ground water, additional oxygen should be supplied through unsaturated water and capillary zones, as demonstrated by Sudicky and MacQuarrie (1989). An even better solution is the variation of the ground water level in appropriate depths. If the oxygen content decreases at ground water level, a reducing environment could be generated. Such experiments have never been performed at Žitný Ostrov island. In a model, the vertical change of ground water level generated by the river (no fluctuation owing to rain, evaporation, etc.) should also be considered. We do not know the dispersion factor responsible for oxygen transfer in the vertical direction.

6. Conclusion

With regard to the ground water problems in Slovak Danubian lowland, from the point of view of natural science and ecology, an abundance of problems arise not only in theory but especially from a practical point of view. The object of our work is to find a model which is able to answer questions related to flow regime, the protection and the control of ground water quality, which also solves ecological problems and which allows forecasts. We understand the importance of this problem and would highly appreciate the development of a wider co-operation.

Literature

Duba, D. 1968. Hydrologia podzemnych vod (Ground Water Hydrology) - SAV, Bratislava, 349 pp.

Jousma, G., J. Bear, Y.Y. Haimes, F. Walter, (eds). 1989. Groundwater contamination: Use of Models in Decision-making. -IGWC Kluwer Acad. Publ. Dordrecht, 656 pp.

Kinzelbach, W. 1986. Groundwater Modelling. – Elsevier, 333 pp.

Kinzelbach, W., W. Schafer. 1989. Coupling of chemistry and transport. – Groundwater Management: Quantity and Quality. Proceedings of the Benidorm Symposium, Oct. 1989. IAHS publ. no.188: pp. 237-259.

Kobus, H., Kinzelbach, W. (eds.). 1989. Contaminant Transport in Groundwater, Balkema, Rotterdam.

Kresser, W. 1988. Die Eintiefung der Donau unterhalb von Wien. – Perspektiven. Heft 9/10: pp. 41-43.

László, F., Zs.Homonnay, M. Zimonyi. 1987. The effects of river-regulation and industrial dredging on the hydraulic establishments of bank-filtered water resources along rivers. – Vizügyi Közlemények LXIX/3: pp. 378-410.

Macquarrie, K.T.B., E.A. Sudicky, E.O. Frind. 1990. Simulation of Biodegradable Organic Contaminants in Groundwater. – Water Res. Vol.26. No.2: pp. 207-222.

Mucha, V., O. Dub (eds.). 1986. Limnológia ceskoslovenskeho úseku Dunaja (Limnology of the Czechoslovak Section of River Danube) SAV, m Bratislava, 326 pp.

Nachtnebel, P. S. Haider. 1988. Auswirkungen von Flusstauhaltungen auf das Grundwasser, Fallstudie Altenwörth. Perspektiven. Heft 9/10: pp. 52-57.

Schiel, W. 1988. Staustufe Freudenau – wasserwirtschaftliche Perspektiven – Perspektiven. Heft 9/10: pp. 20-25.

Sudicky, E.A., K.T.B. Macquarrie. 1989. Behaviour of Biodegradable Organic Contaminants in Random Stationary Hydraulic Conductivity Fields. – In: Kobus & Kinzelbach (eds): Contaminant transport in Groundwater. – Balkema Rotterdam. pp. 307-315.

Fig.1: Žitný Ostrov – Danubian lowland under Bratislava

Fig.2: Hrušov-Reservoir – Power plant Dunakiliti-Gabčíkovo-Nagymaros

1 – reservoir
2 – power plant
3 – deepening of river bed

Fig.3: Flood area and flood woodland at supplying canal

1 – supplying canal
2 – power plant

Fig.4: Danube flows in a convergent conical formation (higher, average and lower ground water level)

Fig.5: Level line of low ground water level (Duba, 1968)

Fig.6: Depth of ground water level (higher, average and lower ground water level)

Fig.7: Amplitude of fluctuation of ground water level as a function of distance from Danube (Duba, 1968)

Fig.8: Scheme of hydroelectric power plant at Samorin – before starting of Hrušov-Dunakiliti Reservoir

1 – Danube
2 – distance from Danube
3 – hydroelectric power plant at Samorin
4 – clay, thickness 2m
5 – gravel
6 – time interval

Fig.9: Scheme of power plant at Samorin – before starting of Hrušov-Dunakiliti Reservoir

1 – infiltration through cover layer
2 – water level high
3 – distance from Danube
4 – infiltration from reservoir per 1m dam
5 – inflow at canal per 1m length
6 – pumping from well per 1m length of well 1.0 litr./s
7 – inflow from area per 1m length of well 0.07 litr./s
8 – gravel
9 – time interval ....days
10 – clay, thickness 2m.

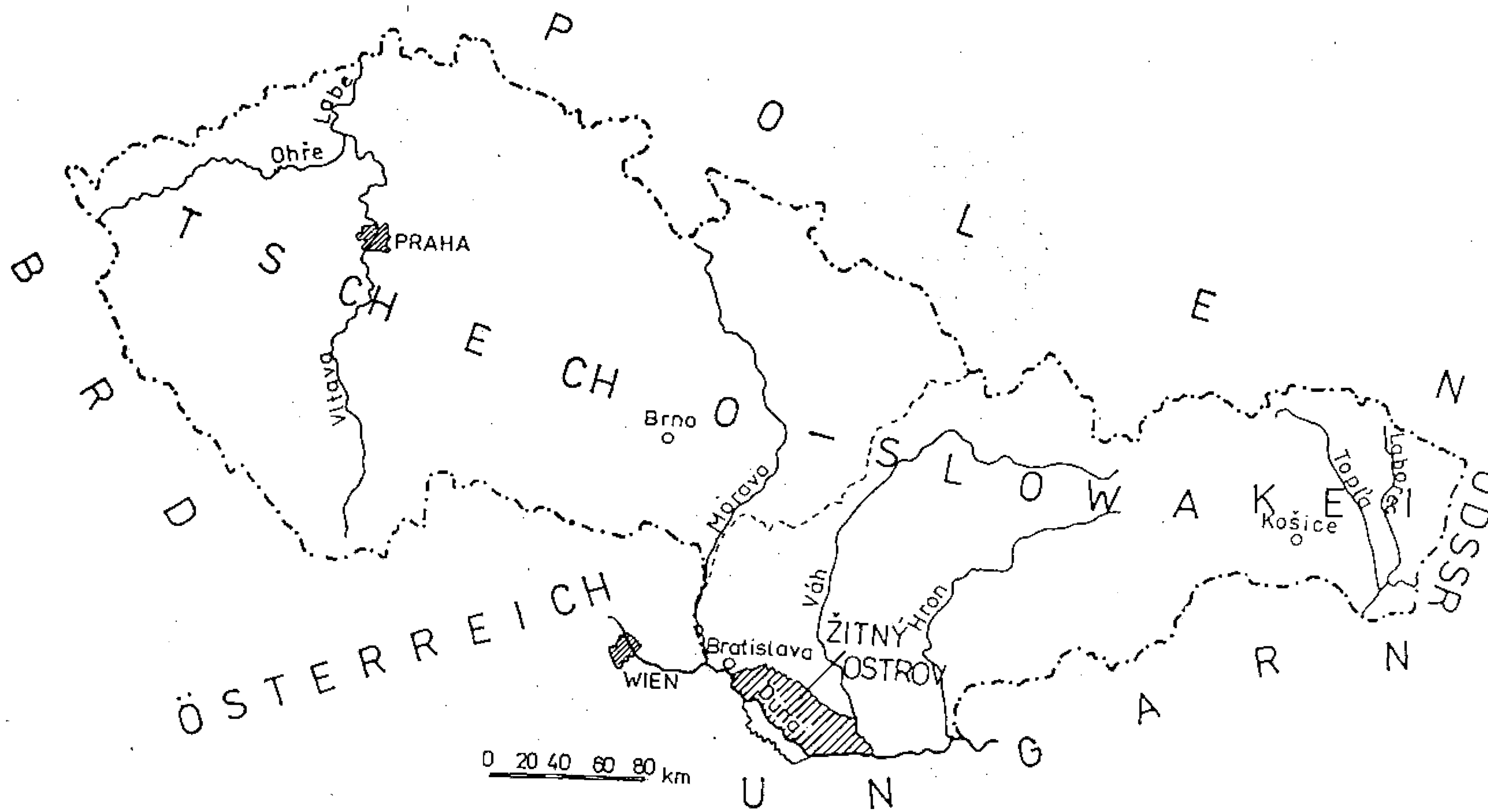

Abb. 1. Žitný ostrov - das Donaugebiet unterhalbe von Bratislava

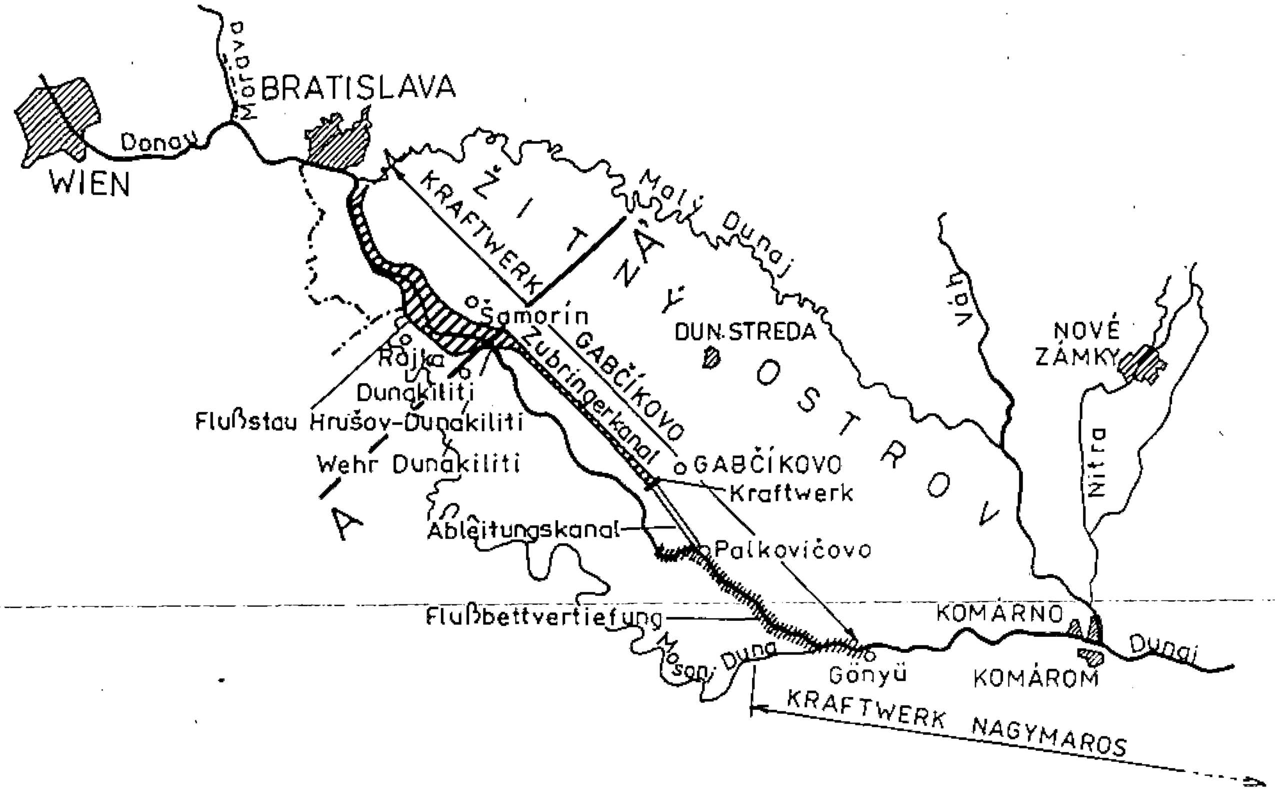

Abb. 2. Stauwerk Hrušov - Dunakility und Kraftwerk Gabčikovo - Nagymaros

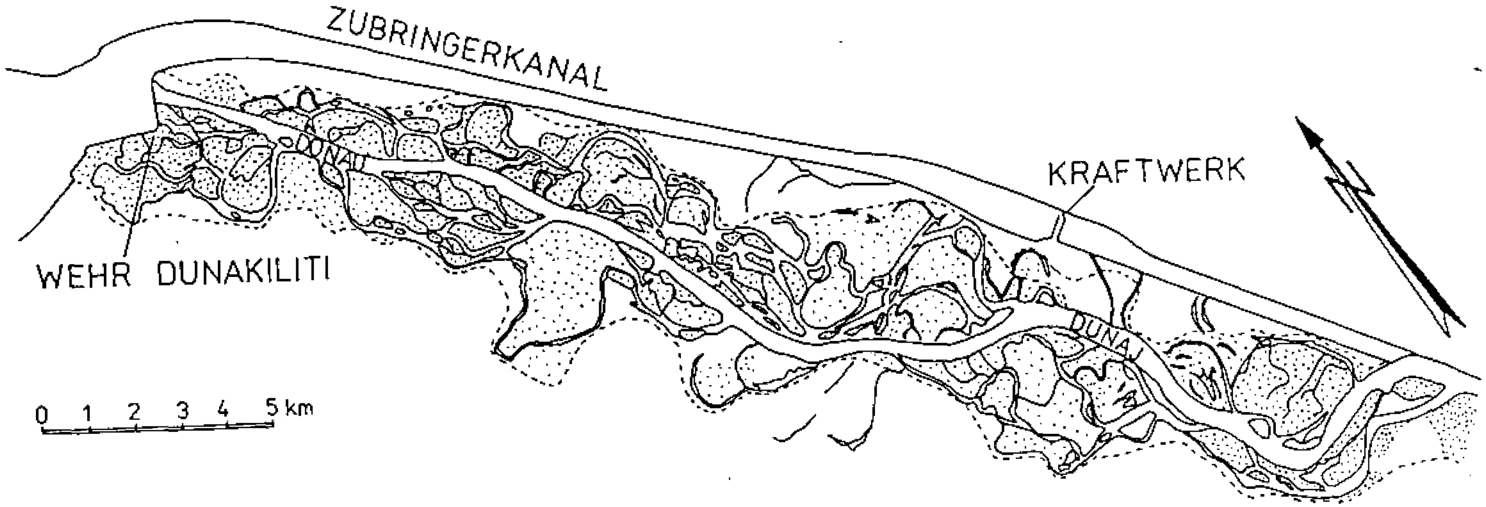

Abb. 3. Auen und Auwälder am Zubringerkanal

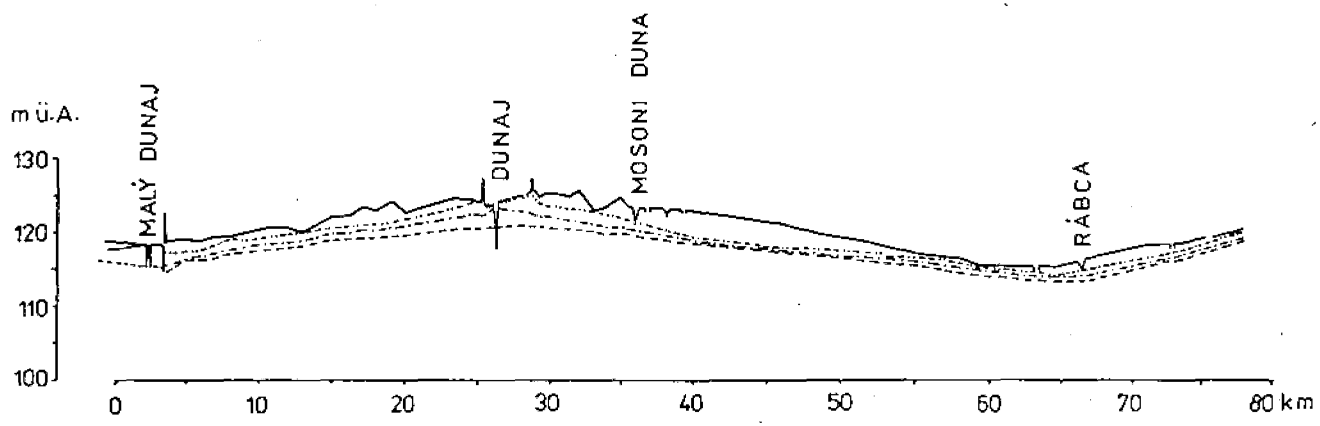

Abb. 4. Die Donau fließt auf einem von ihr zusammengetragenen Kegel (hoher, mittlerer und niedriger Grundwasserstand)

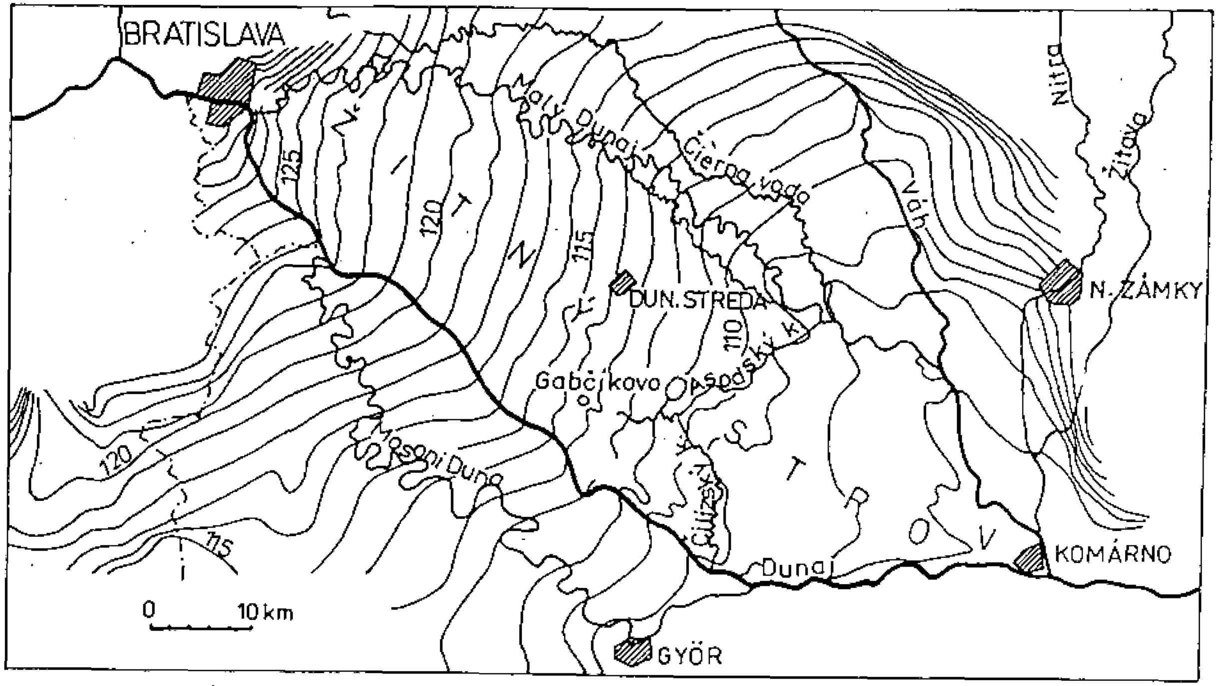

Abb. 5. Hydroisohypsen des niedrigen Grundwasserstandes (Duba, 1968)

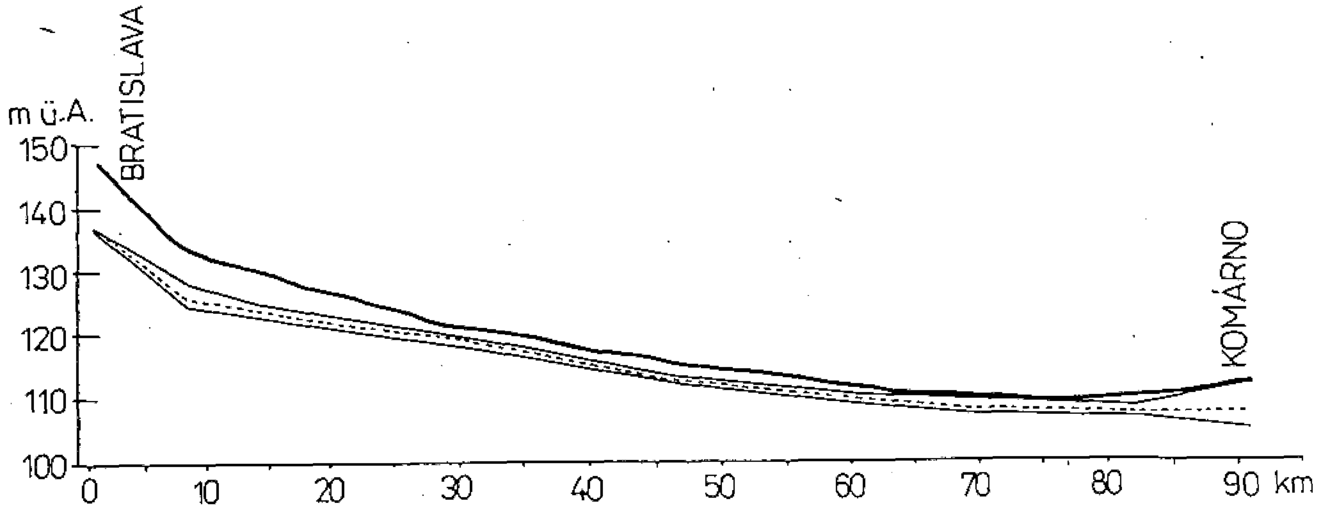

Abb. 6. Die Tiefe des Grundwasserspiegels (hoher, mittlerer und niedriger Grundwasserstand)

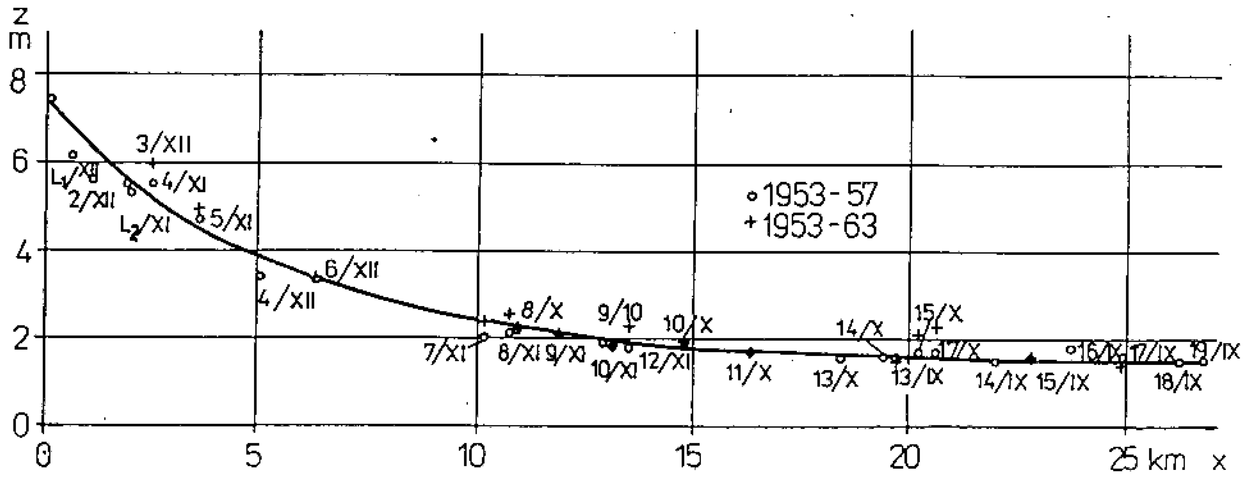

Abb. 7. Die Amplitude der Grundwasserspiegelschwankung als unction der Entfernung von der Donau (Duba, 1968)

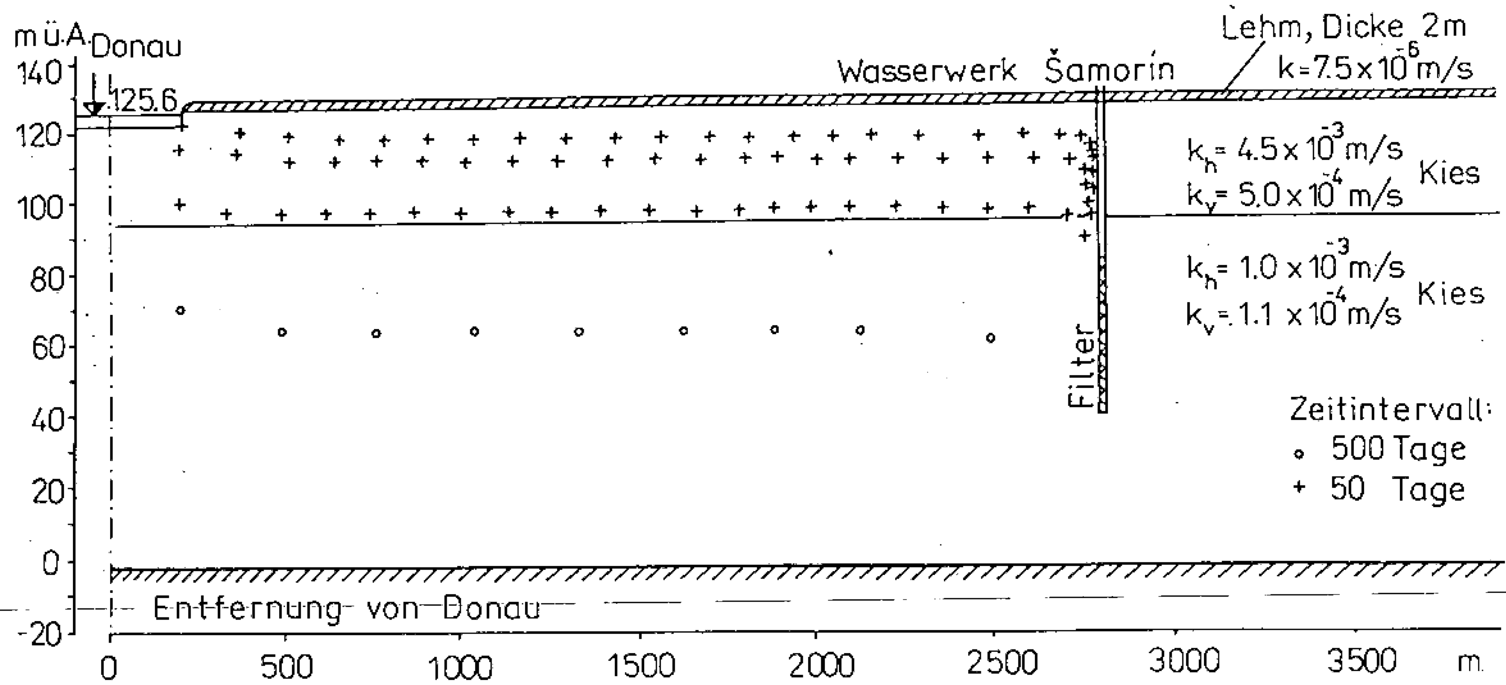

Abb. 8. Schematische Darstellung des Šamorín - Wasserwerkes vor Anlassen des Stauwerkes Hrušov - DUnakility

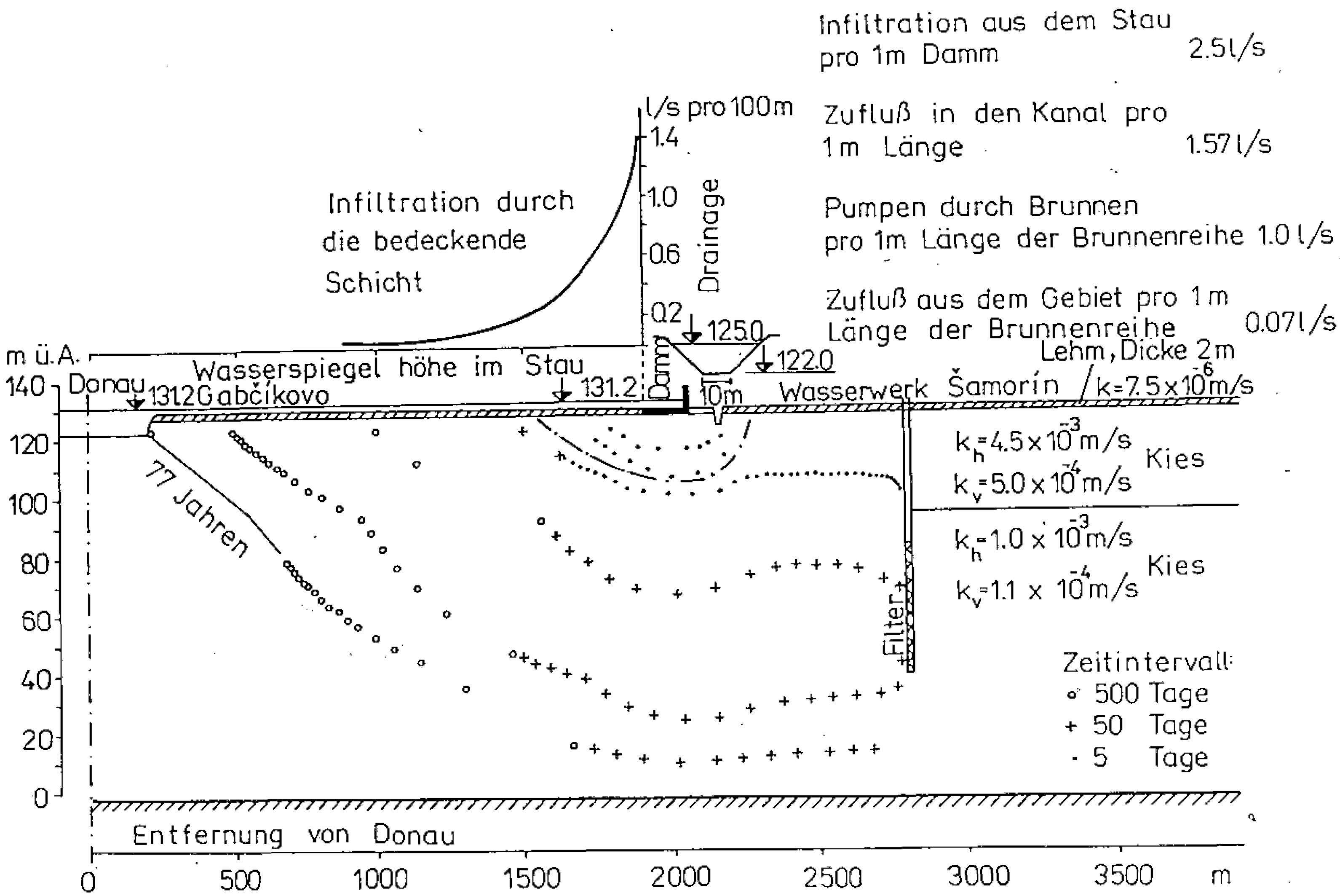

Abb. 9. Schematische Darstellung des Šamorín - Wasserwerkes nach Anlassen des Stauwerkes Hrušov - Dunakility

Annex 12

AN INTEGRATED ECO AND HYDRODYNAMIC MODEL FOR PREDICTION OF WETLAND REGIME IN THE DANUBIAN LOWLAND UNDER ALTERNATIVE OPERATION STRATEGIES FOR THE GABCIKOVO HYDROPOWER PLANT

by

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Jorgen Krogsgaard Jensen, M. Sc.,
Senior Biologist, Danish Water Quality Institute.

(Paper for presentation at CONFERENCE - WETLAND MANAGEMENT,
2-3 June 1994, London)

Paper for presentation on
CONFERENCE - WETLAND MANAGEMENT, 2-3 June 1994, London

An integrated eco and hydrodynamic model for prediction of wetland regime in the Danubian Lowland under alternative operation strategies for the Gabcikovo hydropower plant

by

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Karsten Havnø, M.Sc., Head of River Hydraulics Division, Danish Hydraulic Institute

Jørgen Krogsgaard Jensen, M.Sc., Senior Biologist, Danish Water Quality Institute.

SYNOPSIS. An integrated mathematical modelling system describing flows, water quality processes, sediment transport/erosion in river, flood plain, reservoir and ground water system is being developed and fully coupled with a large data base and GIS system. The modelling and information system is being established in an ongoing project "Danubian Lowland - Ground Water Model". The system will be applied for assessing environmental impacts on eg ground water and floodplains of alternative water management strategies in the area, including alternative operation plans for the Gabcikovo hydropower scheme. The present paper gives a brief description of the established modelling and information system with special emphasis on the coupling between MIKE SHE and MIKE 11 and of the plans for model application during the project with special emphasis on aspects relating to wetland hydrology.

DANUBIAN LOWLAND - BACKGROUND

1. The Danubian Lowland between Bratislava and Komárno is an inland delta formed in the past by river sediments from the Danube. The entire area forms an alluvial aquifer, which throughout the year receives in the order of 25 m^3/s infiltration water from the Danube in the upper parts of the area and returns it into the Danube and the drainage channels in the downstream part. The aquifer is an important water resource for municipal and agricultural water supply.

2. Human influence has gradually changed the hydrological regime in the area. Construction of dams upstream of Bratislava together with exploitation of river sediments has significantly deepened the river bed and lowered the water level in the river. These changes have had a significant influence on the conditions of the ground water regime as well as the sensitive riverside forests downstream of Bratislava. In spite of this basically negative trend the floodplain area with its alluvial forests and the associated ecosystems still represents a very unique landscape of outstanding importance.

3. The construction of the hydraulic structures in connection with the hydropower plant at Gabcikovo also significantly affects the hydrological regime and the ecosystem of the region.

4. Industrial waste and municipal sewage from Bratislava and its surroundings together with the diffuse sources of agricultural fertilizers and agrochemicals are polluting the rivers, soil and ground water.

5. These physical and biochemical changes may reduce the atmospheric oxygen transport to the ground water and at the

same time increase the supply of organic matter which will change the oxidizing conditions to reducing conditions and thereby seriously deteriorate the ground water quality.

6. Due to the economical and ecological importance of the area comprehensive data collection programmes have been carried out for many years and a large number of studies have been made in the past. Some of the present environmental problems are published in (ref 1-2).

7. To utilize state-of-the-art modelling technology for addressing the water resources problems in the area the project "Danubian Lowland - Ground Water Model" has been defined within the PHARE programme agreed upon between the Commission of the European Communities and the Government of the Slovak Republic.

OBJECTIVE AND FRAMEWORK OF THE PHARE PROJECT

8. To understand and analyze the complex relationships between physical, chemical and biological changes in the surface- and subsurface water regimes requires multidisciplinary expertise in combination with advanced mathematical modelling techniques.

9. The overall project objective is to establish a reliable impact assessment model for the Danubian Lowland area, which enables the authorities to formulate optimal management strategies leading to a protection of the water resource and a sound ecological development for the area.

10. The PHARE project is being executed by the Slovak Ministry of the Environment. Specialists from the following Slovakian organisations are involved in various aspects of the project implementation:

* Comenius University, Faculty of Natural Science (PRIF UK)
* Water Research Institute (VUVH)
* Irrigation Research Institute (VUZH)

A Danish-Dutch consortium of six organisations was selected as consultant for the project.

11. The project was initiated in the beginning of 1992 and will be completed by the end of 1995. At present the necessary equipment has been delivered to the project in Bratislava and the modelling and information system has been installed on computer workstations. The modelling work has been initiated; however no final model calibrations nor predictions have been carried out at this stage.

ESTABLISHMENT OF DANUBIAN LOWLAND INFORMATION SYSTEM (DLIS)

12. An automated system is presently being developed to support the modelling activities. The integrated modelling system will be interfaced to a central information system. The central information system, called Danubian Lowland Information System (DLIS), will provide the different models with the necessary data and functionality to elaborate further on the modelling results.

13. Because of the complexity and the amount of data involved - first estimates indicate about 2 Gbyte of data - major attention has been paid to the development of the underlying data model. The information needed for the modelling originates from different monitoring networks, which are maintained and observed by different institutes. The larger part of the data is available from automated archives and can be loaded into the system from magnetic medium.

14. The information to be incorporated in DLIS has a pronounced spatial character. The two main components of the GIS are a geographical information system (GIS), for which ARC/INFO has been selected, and a relational data base management system (RDBMS), for which INFORMIX has been selected.

ESTABLISHMENT OF INTEGRATED MODELLING SYSTEM

15. The integrated modelling tool, which will form the basis for all the modelling activities, is based on the following packages which can be used individually or brought together in an integrated manner:

* **MIKE SHE** which, on catchment scale, can simulate the major flow and transport processes of the hydrological cycle which are traditionally divided in separate components:
  - 1-D flow and transport in the unsaturated zone
  - 3-D flow and transport in the ground water zone
  - 2-D flow and transport on the ground surface
  - 1-D flow and transport in the river.

  All the above processes are fully coupled allowing for feedbacks and interactions between components. In addition to the above mentioned components, MIKE SHE includes modules for multi-component chemical reactions in the unsaturated and saturated zone as well as a component for oxygen consumption and transport in the unsaturated zone.
* **MIKE 11**, which is a one-dimensional river modelling system. MIKE 11 is used for hydraulics, sediment transport and morphology, and water quality. The modules for sediment transport and morphology are able to deal with cohesive and non-cohesive sediment transport, as well as the accompanying morphological changes of the river bed. The non-cohesive model will operate on a number of different grain sizes, taking into account shielding effects. The cohesive model deals both with consolidation of the river bed and flocculation.
* **MIKE 21**, which is a two-dimensional hydrodynamic modelling system. MIKE 21 is used for reservoir modelling, including hydrodynamics, sediment transport and water quality. The sediment transport modules deals with both cohesive and non-cohesive sediment, and the non-cohesive module will operate on a number of different grain size fractions.
* Both of the above mentioned models include **River/Reservoir Water Quality (WQ) and Eutrophication** (EU) modules to describe oxygen, ammonium, nitrate and phosphorus concentrations and oxygen demands as well as eutrophication issues.
* **DAISY** is a one-dimensional root zone model for simulation of crop production, soil water dynamics, and nitrogen dynamics in crop production for various agricultural management practices and strategies. The particular processes considered include transformation and transport involving water, heat, carbon and nitrogen.

16. The above mentioned models are all generalized tools with comprehensive applicability ranges, and they are well proven in a large number of international projects. In addition, some model modifications are being carried out during the project in order to accommodate the very special

environment and problems observed in the area.

17. With regard to simulation of floodplain hydrology and ecology the core of the integrated modelling system is constituted by the MIKE SHE, the MIKE 11 and a newly developed, full coupling of the two systems as described in the following three sections.

MIKE SHE

18. The European Hydrological System - SHE was developed in a joint effort by Institute of Hydrology (UK), SOGREAH (France) and Danish Hydraulic Institute. It is a deterministic, fully-distributed and physically-based modelling system for describing the major flow processes of the entire land phase of the hydrological cycle. A description of the SHE is given in (Ref. 3-4). Since 1987 the SHE has been further developed independently by the three respective organizations which now are University of Newcastle (UK), Laboratoire d'Hydraulique de France and DHI. DHI's version of the SHE, known as the MIKE SHE, represents significant new developments with respect to user interface, computational efficiency and process descriptions.

19. MIKE SHE solves the partial differential equations for the processes of overland and channel flow, unsaturated and saturated subsurface flow. The model is completed by a description of the processes of snow melt, interception and evapotranspiration. The flow equations are solved numerically using finite difference methods.

20. In the horizontal plane the catchment is discretized in a network of grid squares. The river system is assumed to run along the boundaries of these. Within each square the soil profile is described in a number of nodes, which above the groundwater table may become partly saturated. Lateral subsurface flow is only considered in the saturated part of the profile. Fig. 1 illustrates the structure of the MIKE SHE. A description of the methodology and some experiences of model application are presented in (Ref. 5-8).

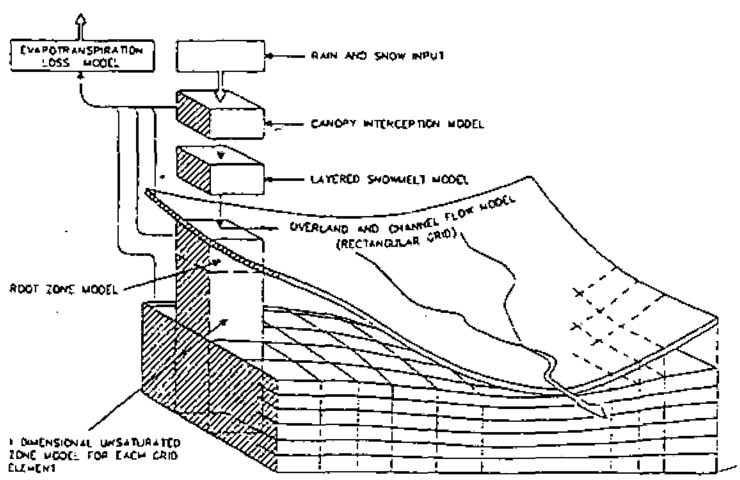

Fig. 1. Schematic presentation of the MIKE SHE.

21. The spatial and temporal variations in the catchment characteristics and meteorological input are provided in a series of two-dimensional matrices of grid square codes. To each code is further attached a number of attributes describing either parametric data or input data.

22. The distributed description in the MIKE SHE allows the user to include and test against spatially varying data. MIKE SHE is a multi output model which besides discharge in any river link also produces information about e.g. water table elevations, soil moisture contents, infiltration rates, evapotranspiration, etc. in each grid square.

MIKE 11

23. MIKE 11 is a comprehensive, one-dimensional modelling system for the simulation of flows, sediment transport and water quality in estuaries, rivers, irrigation systems and other water bodies. It is a 4th generation modelling package designed for micro-computers with DOS or UNIX operating systems and provides the user with an efficient interactive menu and graphical support system with logical and systematic layouts and sequencing in the menus. The package was introduced in 1989 and today the number of installations world-wide exceeds 300. The modular structure of MIKE 11 is illustrated in Fig. 2.

24. The hydrodynamic module of MIKE 11 is based on the complete partial differential equations of open channel flow (Saint Venant). The equations are solved by implicit, finite difference techniques. The formulations can be applied to branched and looped networks and quasi two-dimensional flow simulations on floodplains.

25. MIKE 11 operates on the basis of information about the river and the floodplain topography, including man-made hydraulic structures such as embankments, weirs, gates, dredging schemes and flood retention basins. The hydrodynamic module forms the basis for morphological and water quality studies by means of add-on modules.

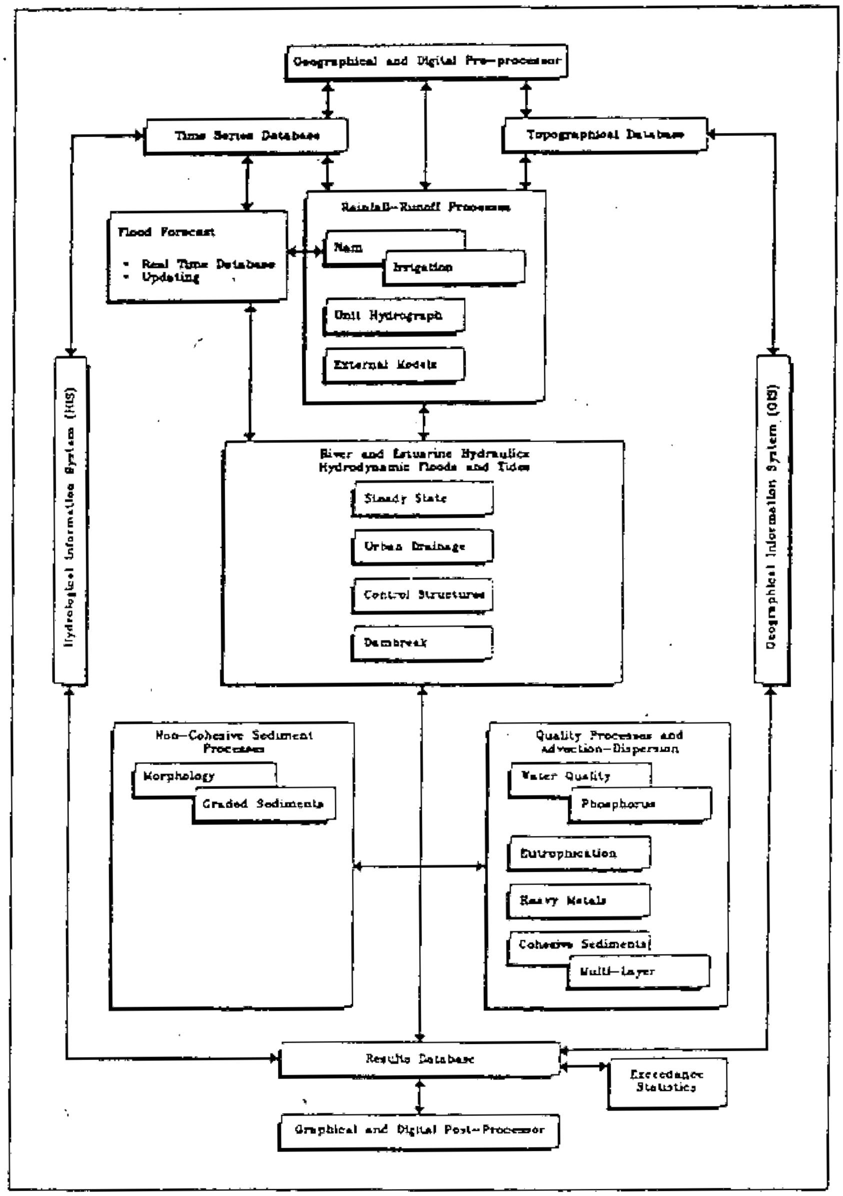

Fig. 2. Modular structure of MIKE 11

A COUPLING OF MIKE SHE AND MIKE 11

26. The focus in MIKE SHE lies on catchment processes with a comparatively less advanced description of river processes. In contrary MIKE 11 has a more advanced description of river processes and a simpler catchment description than MIKE SHE. Hence, for cases where full emphasis is needed for both river and catchment processes a coupling of the two modelling systems is required.

27. A full coupling between MIKE SHE and MIKE 11 has been developed. MIKE 11 computes water levels and flows in the river and floodplain system. The water levels, flows and flooded areas from MIKE 11 are then used as boundary conditions in MIKE SHE for calculation of the remaining parts of the hydrological cycle. The interactions between the river and the other components (aquifer, overland flow, etc) computed in MIKE SHE are then in turn transmitted back to MIKE 11.

28. The two systems are run simultaneously with full exchange of data. Numerically, the two systems may utilize different time steps. The data transfer between the two systems takes place through shared memory.

29. The MIKE SHE-MIKE 11 coupling is crucial for a correct description of the dynamics of the river-aquifer interaction. Firstly, the river width is larger than one MIKE SHE grid, in which case the MIKE SHE river-aquifer description is no longer valid. Secondly, the river/reservoir system comprises a large number of hydraulic structures, the operation of which cannot be accounted for in MIKE SHE. Thirdly, the very complex branch system with loops and flood cells needs a very efficient hydrodynamic formulation such as MIKE 11's.

30. The complexity of the floodplain with its river branch system is shown in Fig. 3. for the 20 km reach downstream the reservoir on the Slovakian side where alluvial forest occurs. In order to enable predictions of possible changes in floodplain ecology it is crucial to provide a detailed description of both the surface water and the groundwater systems in this area as well as of their interaction. For this purpose the MIKE SHE-MIKE 11 coupling is required.

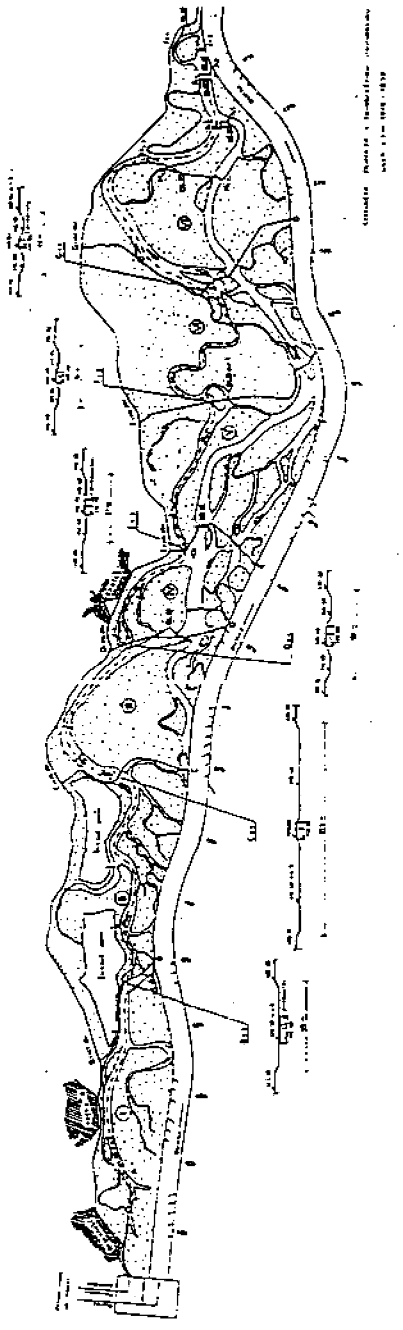

Fig. 3. Sketch of river branch system on the Slovakian floodplain for a reach of 20 km downstream the reservoir.

MODELLING STUDIES IN THE DANUBIAN LOWLAND

31. The modelling studies initiated and planned under the PHARE project involve a number of disciplines and processes with different space and time scales as outlined below. An index map also illustrating the different spatial scales is shown in Fig. 4.

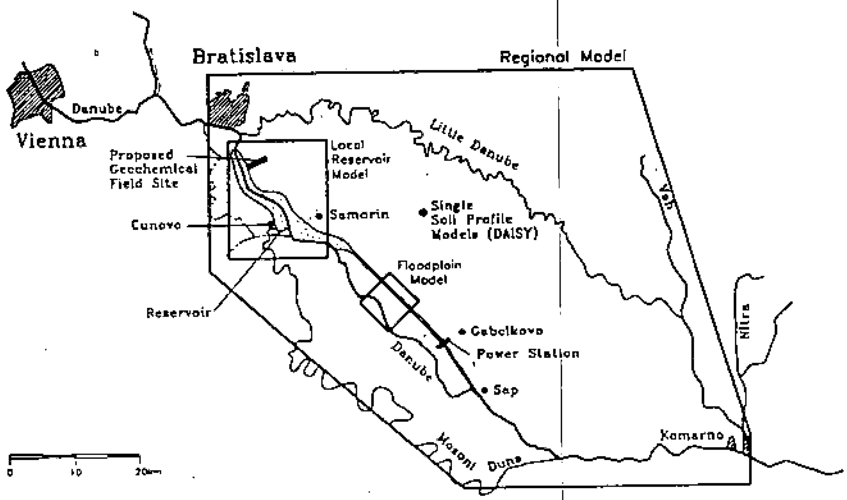

Fig. 4. Index map of the Danubian Lowland with indications of various spatial modelling scales.

32. River and Reservoir Flow and Sediment Transport. For the simulations of flows and sediment transport in the reservoir and the old Danube a combination of one and two-dimensional numerical models is applied.

33. MIKE 11 is being established for the Danube from a point within Austria to Komárno. It includes possibilities for imposing specific operation of the structures in connection with the hydropower plant at Gabcikovo and the reservoir weir at Cunovo. For the old Danube reach between Cunovo and Sap the complex channel branch system with all its internal regulating structures is included together with possibilities for directly describing inundation depths and coverage of the flood plains in between the branches. Thus the model is able to describe both low and high flow conditions as well as all possible regulation possibilities.

34. For the regional ground water studies the Little Danube and the irrigation and drainage systems are also included in the model setup.

35. The model will be calibrated on conditions from the 1960's as well as on the present conditions.

36. Long term morphological simulations will be carried out in order to assess bed level changes and composition of sediment in the backwater zone of the reservoir and in the old Danube (due to e.g. flushing of sediment from the reservoir and possible dumping of dredged material).

37. Hydrodynamic modelling with MIKE 21 has already been carried out for different options of reservoir alignments and deflecting structure designs, see Fig 5.

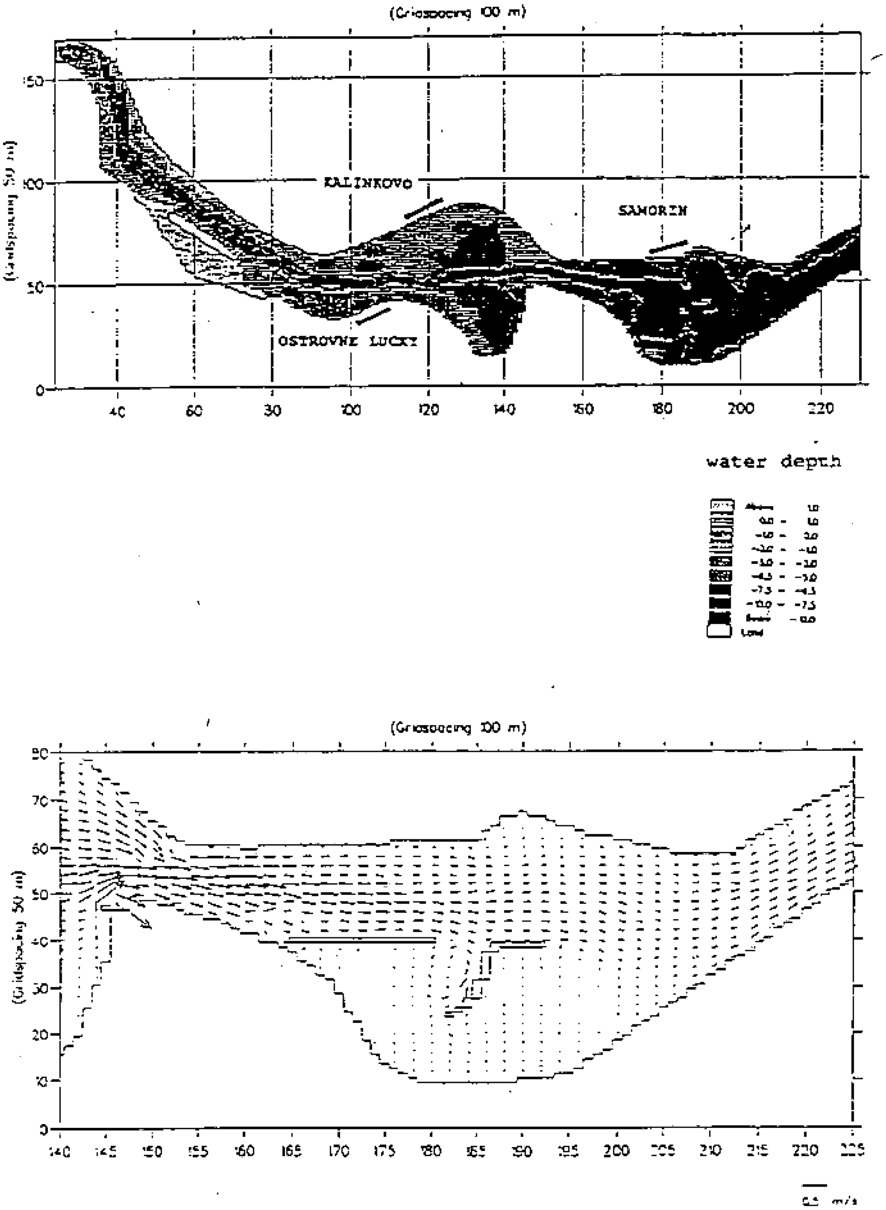

Fig. 5. Example of MIKE 21 model prediction of flow pattern in the Samorin reservoir with the designed reservoir alignment and deflecting structures. On the upper figure the bathymetry for the entire reservoir is shown together with the location of three major well fields for water supply. The lower figure shows the simulated velocities corresponding to a discharge of 1400 m3/s into the reservoir and power canal.

38. The sediment transport modelling of suspended load will include both cohesive and non-cohesive transport. Also resuspension during flood of sediment deposited in periods with low flow will be accounted for. The boundary conditions in terms of flux and sediment transport at the upstream boundary, water level/flux at the entrance to the power channel, water level/flux at the weir will be provided from the MIKE 11 simulations. Sediment transport boundary conditions will consist of grain size distributions and suspended sediment concentration for each fraction.

39. The predictions will provide information about flows, water levels, grain size distributions and depths of the deposited suspended sediments in the reservoir. These results will be used both in the surface water quality modelling as well as in the ground water quality and quantity modelling. For assessment of the morphological consequences of different flushing schemes, the MIKE 21 non-cohesive sediment transport module will be applied.

40. Surface Water Quality. In order to highlight the oxygen status of the surface water, particularly during low flow situations and in slow flowing branches of the Danube, MIKE 11WQ is applied. The MIKE 11WQ describes the diurnal variation in the water quality parameters, i.e. the concentration of organic matter, oxygen, ammonium and nitrate in the water. The diurnal variation is especially important in the branches of the old Danube with a significant macrovegetation, in areas where severe eutrophication occurs and in periods with relatively low flow velocities.

41. The model will be used both in the old Danube with its branches as well as in the reservoir (here as a submodel to MIKE 21). Output from the eutrophication model, (which describes the daily average production), with respect to levels of oxygen production from primary producers, can be used in these calculations.

42. A description of the horizontal differences in the algae growth and the possible sedimentation of organic matter in the reservoir will be carried out by using the two-dimensional MIKE 21EU. Because of the relatively shallow areas in the reservoir macrophytes should be included in the future eutrophication modelling.

43. The eutrophication effect in the old Danube and the branch system will be most severe in periods with low flow. In these periods the system can be described by a branched 1-D system because the old Danube will be described by a branched/looped MIKE 11 model. The eutrophication effects can also be described by the one dimensional MIKE 11EU-model including macrophytes.

44. Ground water flow modelling. The application of MIKE SHE at three spatial scales, see Fig. 3, will support different types of modelling studies:

* **Regional scale.** The aim at this scale is to provide a framework for regional predictions and provide realistic boundary conditions (usually head boundaries) for local models. Some management options could have subregional or even regional implications requiring a reliable model on this scale. For the purposes of detailed modelling in local areas, where a very detailed description is required, it is only necessary and only technically feasible to establish a model for a smaller area. If the exact boundary conditions are not easily established, the regional model can provide the dynamic boundary conditions

which may account for the conditions outside the model area.

The regional model includes the entire Zitny Ostrov area and cover approximately 3000 km^2. The overall hydrological regime will be simulated taking into account all the major surface water systems.

* **Local scale.** For studies of the local conditions MIKE SHE will be set up in small areas to describe the flow and transport conditions with a high degree of detail both in horizontal and vertical directions (a fully 3-D description). These models will serve as a basis for the detailed description of different aspects, e.g.:
  - Geochemical processes around the reservoir area; and
  - ecological effects in the Danubian flood plain area.
* **Transect/Plot scale.** Model simulations on this scale will basically serve to study specific processes which either require a very fine spatial resolution or which can be described by one-dimensional flows, e.g.:
  - Geochemical processes (e.g. along a transect in connection with field investigations);
  - flow and solute (e.g. nitrate) processes in the unsaturated zone (soil columns); and
  - analysis of oxygen transport from the atmosphere through the unsaturated zone to the water table (transect or soil column).

45. Geochemical modelling. The hydrogeochemical modelling focuses on the part of the aquifer system in the vicinity (2-3 km) of the Danube river.

46. The infiltration of oxygen and nitrate through river (and reservoir) beds with different compositions, e.g. fine sediments rich in organic material and gravel sediments with a small amount of organic material, will result in different supplies of oxidation capacity to the aquifer system at the different river-aquifer interfaces. In some parts of the interface between river and aquifer, water with a low oxidation capacity and perhaps even anoxic will infiltrate due to the build up of a low permeable layer of fine sediment in the river after the completion of the reservoir. It is therefore important to handle the transfer of oxidation capacity through various river bed systems correctly in order to be able to characterize the supply of oxidation capacity to the aquifer system. Oxidation capacity can also be added to the system through infiltration from the unsaturated zone. Further, the effects of a fluctuating water table in the riverine area in bringing oxygen (and nitrate) to the aquifer will be studied. 47. The hydrogeochemical modelling will focus on the oxidation/reduction processes in the river bed and aquifer systems. The total amount of oxygen and nitrate is equal to the oxidation capacity added to the systems through the river and unsaturated zone (SO_4-reduction has not been considered here). Bulk organic matter, either in dissolved or solid form, is the reduction capacity. The hydrogeochemical situation will be that of a reduction of oxygen and nitrate by kinetically-controlled oxidation of organic matter. Oxygen must be consumed first before nitrate is reduced.

48. Unsaturated zone and agrochemical modelling. The effect of the reservoir on the productivity in the Zitny Ostrov is of direct concern. From the calibrated regional

model the present and future ground water levels will be simulated and the area can be classified according to its water supply for crops in the growing season.

49. Combining these predictions with the DAISY agricultural model the productivity and the irrigation needs before and after implementation of a given management scenario for the dam can be simulated for selected classes of water table depths and crops.

50. Although the amounts of nitrate leached are not extremely large, they are a problem for the general quality of the ground water. The losses can be reduced through changes in amounts of N applied, timing of application, optimal use of manure, and by optimal irrigation practices. Different scenarios can be analyzed through modelling.

51. Simulation with DAISY (Ref.9) can provide estimates of former and future nitrate loads leaching from the root zone under different conditions and to map "leaching hazard". Through discussions with the relevant agricultural institutions a number of scenarios can be defined with improved agricultural systems/protected areas and they can analyze how this would influence the leaching losses and ground water quality.

52. Modelling Ecological Effects in the Flood Plain. The ecological functioning of the floodplain is governed by the dynamics of inundation, flushing and ground water level fluctuations. These factors will form part of the modelling of the floodplain area.

53. The MIKE SHE/MIKE 11 model will be set up for an area which forms part of the existing monitoring system (for biomonitoring and forestry).

54. The model will be given sufficient detail in order to simulate the inundation and flushing regime at various discharges in the old Danube in order to predict changes in ecotype diversity. The horizontal model discretization is envisaged to be in the order of 50 m. The model will also allow the prediction of ground water levels, soil moisture regime of the floodplain in relation to channel and river branch development (e.g. morphology and sedimentation).

55. Water quality aspects will be considered as being included using MIKE 11 WQ/EU, thus enabling predictions of the water quality and eventually macrophyte growth.

CONCLUSIONS

56. The ecological system of the Danubian Lowland is so complex with so many interactions between the surface and the subsurface water regimes and between physical, chemical and biological changes that a comprehensive mathematical modelling system is required in order to provide quantitative assessments of environmental impacts.

57. Such modelling system coupled with a comprehensive data base/GIS system is being developed under the PHARE project. When finally calibrated and verified this modelling and information system will provide the best available tool for providing assessments of the impacts on surface and ground water quantity and quality of alternative water management schemes.

58. In addition, the integrated system will enable detailed, quantitive predictions of surface and ground water regime in the floodplain area, including e.g. frequency, magnitude and duration of inundations. Such information constitutes a necessary basis for subsequent analysis of flora and fauna in the floodplain.

ACKNOWLEDGEMENT

59. The PHARE project is being executed by the Slovak Ministry of the Environment.The Project Manager is Professor Igor Mucha from the Ground Water Consultants, Faculty of Natural Science, Comenius University (PRIF UK). A Danish-Dutch consortium of six organizations was selected as Consultant for the project. The Consultant is headed by Danish Hydraulic Institute (DHI) and comprises the following associated partners: DHV Consultants BV, The Netherlands; TNO-Applied Institute of Geoscience, The Netherlands; Water Quality Institute (VKI), Denmark; I Krüger Consult AS, Denmark; and the Royal Veterinary and Agricultural University, Denmark. The author of the present paper is the Team Leader for the Consultant.

REFERENCES

1. MUCHA I. and PAULIKOVA E. "Ground water quality in the Danubian lowland downwards from Bratislava". European Water Pollution Control, Vol 1, 5, 13-16, 1991.
2. SOMLYODY L. and HOCK B. " State of the water environment in Hungary". European Water Pollution Control, Vol 1, 1, 43-52, 1991.
3. ABBOTT M.B., BATHURST J.C., CUNGE J.A., O'CONNELL P.E. and RASMUSSEN J. "An Introduction to the European Hydrological System - Système Hydrologique Européen "SHE" 1: History and philosophy of a physically based distributed modelling system". Journal of Hydrology, 87, 45-59, 1986.
4. ABBOTT M.B., BATHURST J.C., CUNGE J.A., O'CONNELL P.E. and RASMUSSEN J. "An Introduction to the European Hydrological System - Système Hydrologique Européen "SHE" 2: "Structure of a physically based distributed modelling system". Journal of Hydrology, 87, 61-77, 1986.
5. REFSGAARD J.C., SETH S.M., BATHURST J.C., ERLICH M., STORM B., JØRGENSEN G.H. and CHANDRA S. "Application of the SHE to catchment in India - Part 1: General results". Journal of Hydrology, 140, 1-23, 1992.
6. JAIN S.K., STORM B., BATHURST J.C., REFSGAARD J.C. and SINGH R.D. "Application of the SHE to catchments in India - Part 2: Field experiments and simulation studies on the Kolar Subcatchment of the Narmada River". Journal of Hydrology, 140, 25-47, 1992.
7. LOHANI V.K., REFSGAARD J.C., CLAUSEN T., ERLICH M. and STORM B. "Application of the SHE for irrigation command area studies in India". Journal of Irrigation and Drainage Engineering, 119 (1), 34-49, 1993.
8. STYCZEN M. and STORM B. "Modelling of N-movements on catchment scale - a tool for analysis and decision making. 1. Model description & 2. A case study". Fertilizer Research, 36, 1-6, 7-17, 1993.
9. HANSEN S., JENSEN H.E., NIELSEN N.E. and SVENDSEN H. "Simulation of nitrogen dynamics and biomass production in winter wheat using the Danish simulation model DAISY". Fertilizer Research, 27, 245-259, 1991.

Annex 13

WATER QUALITY ISSUES CONCERNING THE GNBS: MODELS AND APPLICABILITY

VÍZMINŐSÉGVÉDELMI INTÉZET

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Budapest, 1989

Contents

Introduction

The report deals with water quality issues related to GNBS and the extent to which water quality (ecological) modelling would contribute to a solution, and points out the experimental and data-collecting prerequisites for their implementation.

The material is divided into four units. The first chapter gives an outline of the water quality conditions in the Hungarian impact area of the GNBS (with special regard to the Danube section between Rajka and Budapest) and the expected trends (if the GNBS is not built). The second chapter deals with expected water quality problems caused by the establishment of the power plant system, as they manifest in the direction of water-flow. The third chapter analyses the possibilities and limits of modelling, then provides the preliminary results of models developed for three different problems and areas (the results for which had to be based primarily on professional literature data since we had no/little experimental data). Finally, the closing chapter considers a monitoring system serving research purposes; the required experiments and the database, which are prerequisites for the further modelling work are also detailed.

1. Identification of Conditions, and Expected Trends on the Hungarian Impact Area of the GNBS

The water quality inspections on the Danube – presented in the literature – date back to 1953 (VITUKI, 1957). Originally, these were to identify the conditions on the Danube and its river branch system, and had no connection whatsoever with the construction of the GNBS. From 1973, either explicitly or implicitly, the purpose of the examinations was the canalisation of the Danube.

Hereinafter, a brief summary shall be presented on the result of these examinations. Completeness is not the central issue, and only the most significant materials will be discussed, that is primarily those that have been compiled by institutions – rather than annually repeated national surveys or those concentrating on issues other than the GNBS.

The chapter is divided as follows: water quality problems associated with traditional chemical components, heavy metals, organic micropollutants, hydrobiology, bacteriology, sediments, pollutant load and bank filtered water.

Due to the lack of time, trend-examinations taken in their classical sense could be performed only in relation to traditional chemical components. Thus, these assessments refer to conditions supposing that the GNBS is not built.

1.1 TRADITIONAL CHEMICAL COMPONENTS AND THEIR CHANGES

A number of studies have dealt with water quality conditions on the Hungarian Danube section affected by the GNBS (VITUKI, 1957, 1963, 1973; WHO-VITUKI, 1976; VGI, 1976; Ábrahám and Várday, 1977; VITUKI, 1978, 1981; Horváth, Pannonhalmi and Várday, 1981; VITUKI, 1984; VGI, 1985; VIZITERV, 1985; VITUKI, 1987a, 1988b; KVM, 1988). *Table 1.1* contains the branches, years, cross section numbers, sample-taking frequency, and the examined components covered by the studies, as well as the presentation of the results, and the evaluated statistical parameters. – Following are some supplementary remarks:

– Although the measurements were usually made in the same cross sections and in several of them the frequency of sample-taking was also similar (main network examinations with prescribed regularity), there were major differences in the presentation of the evaluated statistical parameters and the results. From this point of view, only three materials are similar in character (VITUKI, 1984, 1987a; KVM, 1988).

– With the exception of only one study (VITUKI, 1987a), each of the studies deal exclusively with the quality of the Hungarian Danube section.

– "Classical chemical components" in most cases mean the components of oxygen-, nitrogen– and phosphorous management, and other properties (specific conductivity,, hardness, dissolved and suspended debris, pH value, etc.), which, however, hardly reflect the material transport connections.

– Unfortunately, all the N and P data – significant with regards to the expected eutrophication of the reservoir (see Chapter 3) – are only available in the form of statistically useless sporadic data. Thus, we do not even have approximate data on their seasonal change.

***Table 1.1**: Water quality examinations on the impact area of the GNBS on the Danube and its river branch system in the professional literature*

No.	Author (year)	Examined: years	Examined: water branches	Examined: No. of cross sections	Examined: frequency of sample-taking sample/year	Components	Evaluated statistical parameters, the way of putting forward the results
1.	VITUKI (1957)	1953-1955	The Danube and all Hungarian branches	147 mouth sections of all Danube branches	1-2	Q, t, 22 classical chemical components, saprobiology	measurement data in tables, without statistical valuation
2.	VITUKI (1963)	1958-1960	Budapest section of the Danube (long and cross section examinations)	8 (in long section) 2 (in cross section) 11 sections	2/71	Q, t, 22 classical chemical components, saprobiology,	measurement data in tables, without statistical valuation, written cross sections
3.	VITUKI (1973)	1970-1972	Danube	8	12-52	COD_p, O_2, BOD_5	minimum, maximum, COMECON standard
4.	WHO-VITUKI (1976)	1974 1975	Danube	8 1 5 cross sections	12 52 1-4	a./ COD_d, extractable material, phenols, ana.det., pesticides, heavy metals (Hg, Zn, Mg, Mn) b./ 11 chemical components c./ NH_4^+, Hg	minimum, maximum, average, cross section iso-concentration graphs
5.	VGI (1976)	1974	Danube	8	12-52	COD_d, extractable materials, phenols, ana.det., heavy metals (Hg, Zn, Mn)	minimum, maximum, average
6.	Ábrahám-Várday (1977)	1967-1975	Danube	7	26-52	t, 5 classical chemical components, saprobity index,	Cross section examinations: Rajka, Komárom, Dunaalmás; material flow in the function of water delivery, monthly averages

No.	Author (year)	Examined				Components	Evaluated statistical parameters, the way of putting forward the results
		years	water branches	No. of cross sections	frequency of sample-taking sample/year		
7.	VITUKI (1978)	1968-1976	Danube	1	52	Q, t, $COD_{d,p}$ P, O_2, BOD_5, total dissolved material, suspended solids	minimum, maximum, average distribution (annual), concentration trend
8.	VITUKI (1981)	1971-1980	Danube	12	26-52	Q, t, 19 classical chemical components, Hg, Cd, Pb, organic coal	n, minimum, maximum, average, distribution, relative distribution, concentration trend, material flow trend, long sections (quarterly, 1971, 1980, ten-year average)
9.	Horváth-Pannonhalmi -Várday (1981)	1968-1978	Danube	6	26-52	COD, conductivity, anions, cations, NH_4^+, NO_3^-, PO_3^{4+}	five-year material flow in the length section
10.	VITUKI (1984)	1979-1983 1974-1983	Danube Mosoni-D., Rába, Rábca, Concó, Altalér, Ipoly	4 (Danube) 1-1 (branches)	26-52	16 classical chemical components	80%, 95% duration values, duration graphs, concentration trend (1974-1983)
11.	VGI (1985)	1970-1984	Danube, Vág Danube	9	26-52	Q, 20 classical chemical components, saprobity index	graphical long sections for concentration (1984), graphical length sections on material flow (1977-1984), time lines for material flow (1977-1984), annual average concentrations (1970-1984)
12.	VIZITERV (1985)			see 10.			

No.	Author (year)	Examined				Components	Evaluated statistical parameters, the way of putting forward the results
		years	water branches	No. of cross sections	frequency of sample-taking sample/year		
13.	VITUKI (1987a)	1976-1985	Duna, Morava, Mosoni D., Rába, Cuhai Bakonyér, Concó, Altalér, Kenyérmezői patak, Ipoly, Szentendre Dunaág	5+8 (Danube) 1-1 (branches)	12-52	t, 22 classical chemical components, saprobity index	average, 80%, 95% duration values, in annual and twice in five years division, concentration trends, Austrian-Hungarian length sections
14.	VITUKI (1988b)	1988	Danube	12	1	12 classical chemical components, 9 heavy metals, 5 microbiology	presentation of the measurement data in tables
15.	KVM (1988)	1983-1987, and 1971-1987	Danube, Mosoni D., Lajta, Rába, Marcal, Cuhai-Bakonyér, Concó, Altalér, Vág Danube, Kenyérmezei patak, Ipoly	6, 1-1 branches	52	24 classical chemical components, 6 heavy metals, 9 chlorinated paraffin, 8 bacteriology	maximum, 80%, 95% duration (1983-1987); written long section, concentration trend, monthly averages: 3x5 years in division; changes during the year; concentration trends; heavy metals, chlorinated paraffin, bacteriology, biology

Hereinafter, a brief outline will be provided on water quality conditions on the basis of some classical components (VITUKI, 1987a). Six of the 25 sections evaluated in Tables 1.2 in Annex No.1 are sections of the Danube, two are in Austria, the measurement sites are located where the river enters and leaves Austria, and six are in Hungarian side branches with 80% duration values in 1981-1985. The following supplementary remarks are made to the tables:

– As regards the majority of the components, the Danube has 1st class water quality. The components not included in this group on the Hungarian section are: pH, COD_p, BOD_5, nitrite, ortho phosphate, oil, phenols, biological conditions.

– A striking difference can be observed in pollution levels between the Szob (left side bank) and Szob (right side bank). This relates to the polluting effect of the Vág (and in part the Ipoly).

– The tributaries of the Danube show rather diverse water quality values. In general it can be said that their water quality is worse than the Danube's.

– In spite of the above, the tributaries of the Danube usually cause no more than localised pollution in the Danube as a result of its great dissolving effect. The only exceptions are in the vicinity of Morava, the Vág, and the Ipoly, as they have a relatively larger water delivery (VITUKI, 1987a).

In possession of the evaluated data, water quality long sections were prepared, where the five-year minimum, maximum, average, 80% and 95% duration values, and in the case of Szob, left side bank and right side bank average values were specified. *Figure 1.1* shows a COD_p long section drawn up this way. The following general remarks (which also characterise the other components not presented here) can be made from the figure:

– The extremes (minimum, maximum), although interesting, should not be accepted as characteristic because they occasionally represent exceptional circumstances. Moreover, at places where samples are taken more frequently (Hungarian section), there is a greater chance of measuring such values. The greatest cause of the scatter in the results, however, is the fact that the samples are taken from different streamlines (different parts of the cross-section).

– The Austrian data are not appropriate conclusions to be drawn on the local effect of Austrian barrage systems on water quality. This would require at least two sample-taking sites per barrage system (tail water, head water), that is 18 measurement sections as opposed to the existing five sections.

– The Wien-Nussdorf sample-taking site is located at the northern part of Vienna and thus it can hardly characterise the effect of the Austrian Capital on water quality. The Wolfsthal section serves this purpose better.

– The sudden increase between Wolfsthal and Rajka relates to the polluting effect of the Morava, but – according to our assumptions – it may also result from analytical differences, at least concerning ammonia, nitrite and BOD_5.

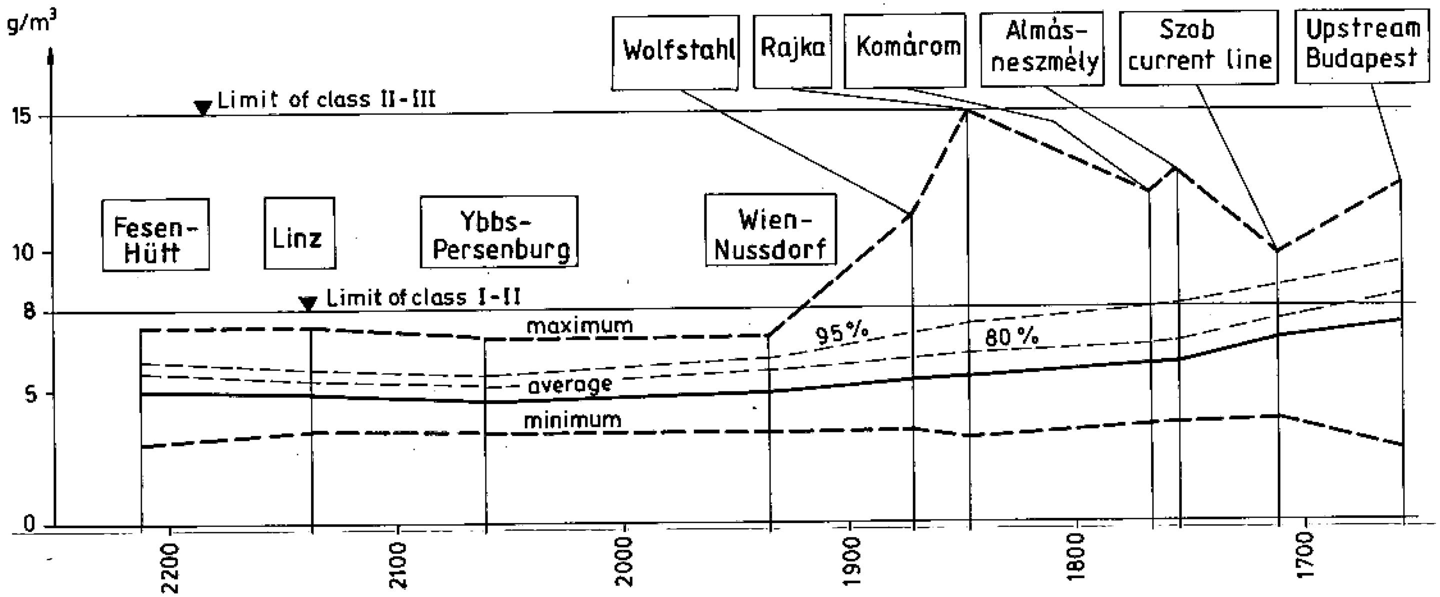


Figure 1.1: *COD_p long section based on tests 1981-1985 (VITUKI, 1987a)*

(9)

– The polluting effect of the Vág and to a certain degree of the Ipoly can be determined in part by comparing the average data of the left side bank, the current, and the right side bank, and the results of the sample-taking site above Budapest.

– The values of 80% and 95% duration are appropriate for ruling out exceptional values and more or less follow the long section of average results.

– Out of the presented 15 components, the following show a definite deterioration in the long section on the evaluated Austrian-Hungarian section: conductivity, COD_p, BOD_5, ammonium, nitrite, chloride, sulphate. The major sources of pollution are Vienna, Morava and Vác (VITUKI, 1987a).

The evaluation of changes in water quality in function of time was carried out according to the stipulations of MSZ-10-172/1-83 on the basis of annual average data (1976-1985). The examined components also comply with the standard's specifications except for two differences: on the Austrian section the changes of COD_p were provided instead of COD_d (due to the lack of measurements), and instead of all dissolved material (also due to the lack of data) the changes in the proportionate conductivity was examined.

Part of the results are presented in *Table 1.2*, which demonstrates the rate of change of water quality on four Danube sections (two Austrian and two Hungarian), and six Hungarian side branches. The following remarks are made from the tables:

– Similar basic direction changes can be observed on the entire examined section of the Danube, with improvements in the case of COD_p, COD_d and dissolved O_2, and deterioration in the case of BOD_5, nitrate, conductivity, as well as all dissolved material (we are unable to comprehend the contradiction within the oxygen management).

– In the case of ammonium, the change in the Hungarian section is opposite to that of the Austrian section.

– In time, the changes on the evaluated branch rivers of the Danube show a rather diverse picture according to the waterway and the components. Almost each water quality component shows deteriorating tendencies at the following locations: Mosoni Danube(Győr), Rába (Győr), Concó (Ács), Általér (Tata), Ipoly (Letkés) (VITUKI, 1987a).

We were unable to carry out trend-calculations reaching far back in the past (several decades) – although valuable source works are at our disposal (e.g. VITUKI, 1957, 1963) – because in part the old examinations were done at a lower frequency, and in part they do not (evenly) cover the whole year. Nonetheless, it is worthwhile to show some minimum and maximum values from an annual data-line measured in the early sixties in the Rajka section of the Danube, in order to compare those to the minimum and maximum values of the 1981-1985 main network examinations (*Table 1.3*).

***Table 1.2**: Tendencies in the change of water quality on the Danube 1978-1985 (Austrian section), 1976-1985 (Hungarian section), and in the tributaries of the Danube on the basis of 1976-1985 data (%/year) (VITUKI, 1987a)*

Section	Components						
	COD_p* COD_d*	BOD_5	Dis-solved O_2	Ammo-nium	Nitrate	Ortho phos-phate	Conductivity ** tot. dissolved mat. **
Felsen-Hütt	-2.5	+1.0	+0.4	+4.4	+1.1	+0.2	+0.2
Wolfsthal	-1.6	+3.4	+1.7	+3.9	+0.1	+1.7	+0.4
Szob (current)	-0.7	+0.1	+0.5	-0.7	+2.3	+0.0	+0.4
Above Budapest	-1.7	+1.3	+0.8	-3.4	+2.3	+1.7	+0.1
Mosoni Danube, Győr	+2.2	+2.7	-1.1	+1.8	+2.9	+0.1	-0.5
Rába, Győr	+2.8	+1.4	-0.0	+0.4	+3.2	-0.2	+1.1
Kenyérmezői patak, Dorog	+0.4	+2.2	-8.0	-7.6	-2.8	+5.4	+1.1
Concó, Ács	+0.1	-3.7	+0.1	+1.9	+0.2	+9.4	+0.4
Általér, Tata	+8.6	+2.5	-2.9	+11.3	+2.4	+12.3	+2.2
Ipoly, Letkés	+2.3	+2.7	+0.2	+2.6	+3.4	-1.8	+1.0

* On the basis of COD_p on the Austrian section, and on the basis of COD_d on the Hungarian section

** On the basis of conductivity on the Austrian section, and on the basis of the (proportionate) total dissolved material on the Hungarian section.

The table shows that in the course of approximately 20 years:

– with the exception of pH, all the measured maximum values have greatly increased; the growth is especially apparent in the case of the different nitrogen forms, while there is a large-scale change in ortho phosphate;

– in the case of nitrate and ortho phosphate the measured minimum values have also shown a great increase.

A number of studies have examined the seasonal periodicity of water quality components (VITUKI, 1981; OMFB, 1984; VITUKI, 1987b, KVM, 1988). This component-related fluctuation is especially outstanding for the components of the nitrogen management (Table No. 1 Annex No. 1), and in the case of dissolved O_2.

The saturation values of oxygen have been fluctuating within ever wider ranges the past years. During vegetation periods rather high and increasingly so saturation and over-saturation values can be observed, while in the other parts of the year dissolved oxygen content and saturation is low compared to previous measures, and it shows a decreasing tendency.

As has been justified by the results of other examinations , the reason for the above phenomenon is the following: during the vegetation period, and especially when water levels are lower than average, the alga-population develops in numbers 5-10 times higher than 10-15 years ago. The greater over-saturation is caused by the increased oxygen-producing activity of this population (OMFB, 1984).

The day-to-day changes of dissolved O_2 were examined in detail by Dváhally (1977). *Table 1.2* includes some of the results, which make clear that in case of the Danube

– when the volume of dissolved O_2 is low, daytime fluctuation is also low;

– when the volume of dissolved oxygen is high, the daily fluctuation is also high,

– the minimum values of daily fluctuation are also quite favourable (Hock, 1982).

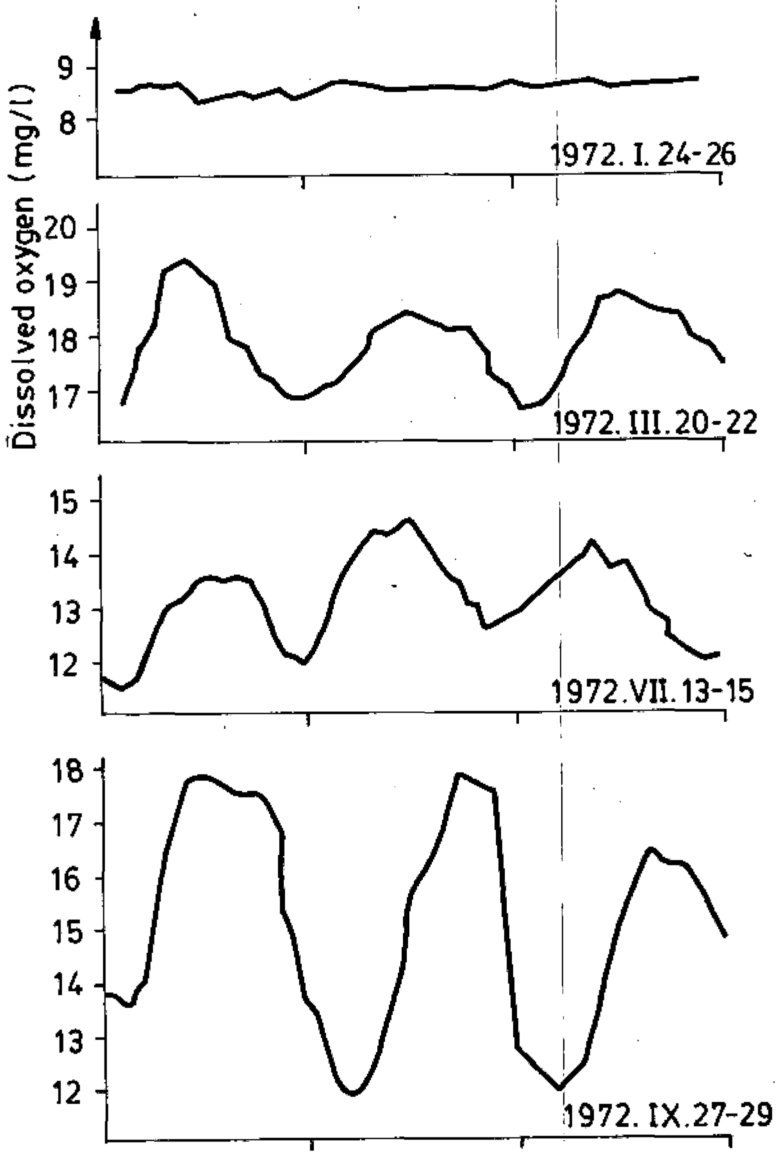


Figure 1.2: *Daily changes of the dissolved oxygen concentration in the main branch of the Danube (rkm 1531) on the Hungarian Section (Dváhally, 1977)*

***Table 1.3**: Changes in water quality on the Danube at Rajka (Liepolt, 1965; VITUKI, 1987a)*

		1960 (Liepolt 1965)		1981-1985	
Component	Dimension	Min.	Max.	Min.	Max.
Total dissolved material	mg/l	183	272	181	380
pH	-	7.5	7.9	7.3	8.9
COD_p	mg/l	4.4	9.3	3.2	15.2
BOD_5	mg/l	0.6	5.3	1.0	9.8
Total hardness	mg/l	99	126	78	143
NH_4^-	mg/l	0.12	0.40	0.10	1.70
NO_2^-	mg/l	0.03	0.10	0.04	0.26
NO_3^-	mg/l	0.6	5.0	4.4	17.0
PO_3^{4-}	mg/l	0.00	0.16	0.12	1.46

1.2 Heavy metals

The examination of the heavy metals is necessary not so much because of their concentration measurable in water, but rather due to their willingness to be deposited and to enrich in the sediment.

Their examination reaches back to the early 1970s. The first comprehensive evaluation was carried out in the WHO-VITUKI (1976) study. Out of the assessments performed we shall be mentioning those carried out in 1974-1975 in the Szob section of the Danube, where the cross section distribution of mercury was examined. The results of the four measurement series are presented in *Figure 1.3* by iso-concentration graphs. The figure shows that the measured values exceeded the limits (0.5 and 1.0 μg/l) at a number of places.

The long section distribution of three heavy metals (mercury, cadmium, lead) was examined on a regular (monthly) basis in the Danube section between Rajka and Mohasco in 1977-1979, . In case of mercury, even the average concentrations approached the limit, while the maximum values exceeded the limits almost everywhere. In the Rajka section, the annual average values showed a gradual increase during the period examined. With regards to the long sections, the Szob-Budapest and Dunaujváros-Dunaföldvár sections had the highest pollution levels. The average concentrations of cadmium were far below the desired limits, while in several places the maximum values exceeded the tolerable limits. In the case of lead, the average concentrations were much lower than the desired level, and maximum levels far below the tolerated limits (VITUKI, 1981).

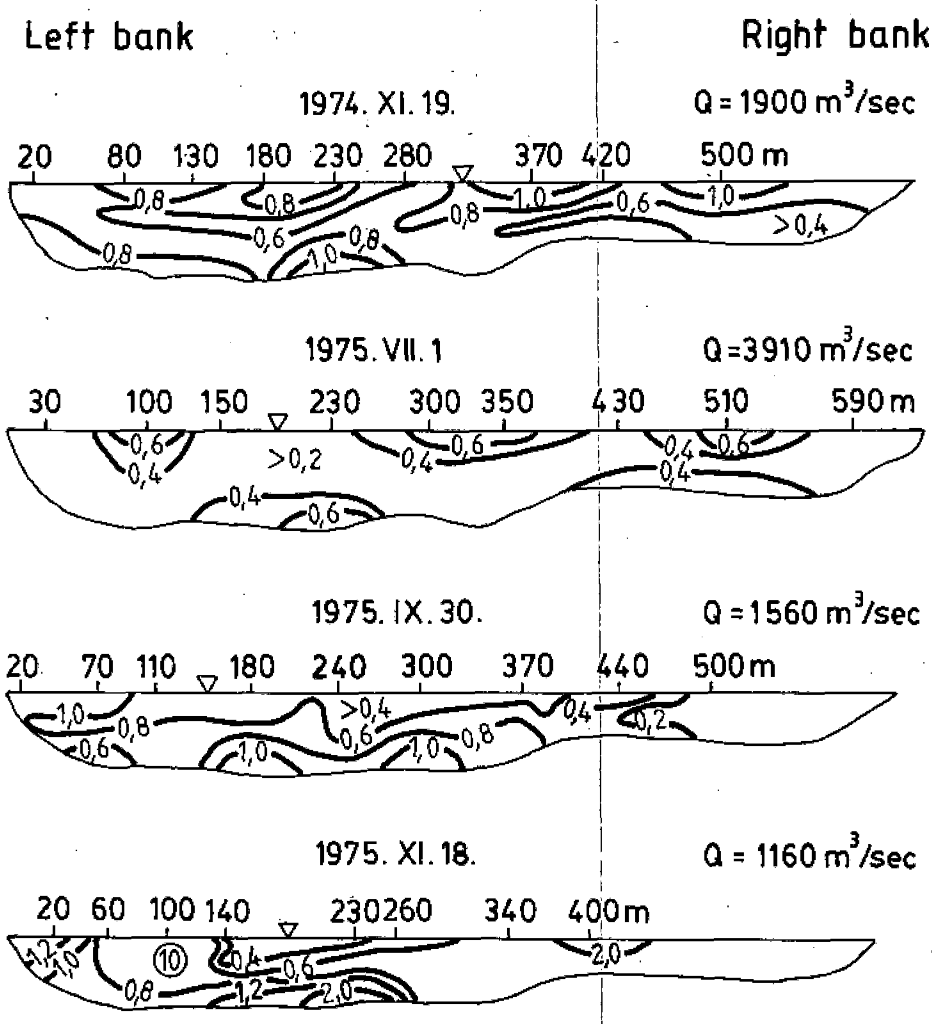


Figure 1.3: Distribution of Hg concentration in the Szob section of the Danube (μg/l) (WHO-VITUKI, 1976)

In addition to the above a series of further examinations were carried out to detect heavy metal pollution in the Danube (VGI, 1976; VITUKI, 1987a, 1988b; KVM, 1988). However, these more detailed examinations shall not be covered in this report. The water courses and sections, and heavy metals, where the maximum values of the above-mentioned measurements exceeded the desirable limits and the limits tolerated by MI-10-172-/3-85 shall be put forward in two summarising tables. The "+" and "⊕" signs in Tables 4 and 5 in Annex No.1 refer to this fact, the "-" sign refers to its opposite, and if the appropriate box is not filled, the component in question was not measured in the given case.

It has to be mentioned that the maximum was chosen as a typical parameter because when dealing with (partly) toxic materials an average value cannot form the basis of classification.

The following remarks can be made from the tables:

- the worst conditions were shown by mercury;
- the measurements of various institutions contradict each other with regards to cadmium and lead;
- only sporadic data are available with respect to total iron;
- the manganese results from 1974 do not correspond to the main network examination data.

1.3 ORGANIC MICRO-POLLUTANTS

In the upper section of the Danube regular measurement values are available for linden, metoxichlorine, aldrin, dieldrin, DDT, heptachlorine, heptachlorine-peroxide, endosulphane, hexachlorine-benzol from among the compounds posing the greatest threat to drinking water supply, water wildlife, and other uses of water. Carbon tetrachloride, chloroform, tetrachloride-ethylene and trichlorine-ethylene measurements have also been carried out in the section above Budapest.

Classification can be performed on the basis of "desired" limits permissible in surface and drinking water.

From among the listed and examined components only hexachlorine-benzol and linden could be observed on the upper Danube (Table 6. Annex No.1).

In the section above Budapest chloroform was detectable in 40% of the samples in 0.3-0.8 μg/l concentration (the limit for both drinking water and surface water is 30 μg/l); carbon tetrachloride was detected in all samples in 0.1-1.1 μg/l (the limit is 3 μg/l); trichlorine-ethylene was found in 10% of the samples in 0.1-0.2 μg/l concentration (the limit stands at 30μg/l); and tetrachloride-ethylene was observed in 80% of the samples in 0.1-0.6 μg/l (the limit is 20 μg/l).

On the basis of the above it is evident that the presence and concentration of the examined organic micro-pollutants is rather low in the Danube (KVM, 1988).

1.4 HYDROBIOLOGY

A number of studies have dealt with the hydrobiological conditions of the Danube section (and connected branch system) affected by the GNBS. The results of the examinations, based on a high number of measurements, will be summarised in the following order:

- hydrochemical characteristics and hydrobiological conditions,
- dissolved O_2 transport,
- trophity,
- saprobity,
- zooplankton,
- fish population.

1.4.1 Hydrochemical characteristics and hydrobiological conditions

Oertel (1982) examined the relation between the main and side-branch of the Danube with hydrochemical tests. He came to the conclusion that the hydrochemical values (oxygen-concentration, electric conductivity, pH, redox potential) measured during through-flow do not show major differences between the main and the side branch. Following the termination of the through-flow, however, there are significant hydrochemical differences, and characteristic horizontal and vertical variations appear within the side branch. The hydrochemical conditions of the side branch which is gradually becoming stagnant is effected by aquatic biological communities within them. These are different both in their composition and volume to those of the main branch.

The studies of Dváhally and Kozma (1964) show that the enclosing side branch has increasing electrolyte content, which is followed by the increase of the population of water, associations.

1.4.2 Dissolved O_2 transport

The dissolved O_2 conditions on the Danube and its tributaries have already been mentioned in Chapter 1.1 on the classical components. However, that should be supplemented with the values of oxygen production measured on-site (dark-light glass method), which showed a high fluctuation in the Göd section: surface O_2 values were 0-14.0, medium depth 0-11.8, and near the riverbed 0-2.0 mg/l. At the same time the respiration values were identical in all three depths: 0-7.9, 0-7.9, 0-8.4 mg/l O_2, respectively (Dváhally, 1962, 1977).

The relation between the main and the side branches is also clearly reflected by the changes in oxygen production (Dváhally, 1977a). At the time of the through-flow of the Danube water, the oxygen producing capabilities of the main and the side branch are identical. Following the enclosing of the side branch, larger oxygen production can be measured in the created still water environment, which is connected to the differences in the physical (temperature) and chemical characteristics.

The optimum capability for oxygen production – measured in laboratory conditions – has characteristic seasonal variance. During the winter it is at a minimum – frequently there is no oxygen production at all. The values reach a peak in spring (April and May), but they decrease in the summer flood periods. In autumn, the values rise again to a peak which is usually even higher than the spring peak. The outlined annual dynamics of oxygen production corresponds to the volume changes of the phyto-plankton in time (Dváhally, 1977; VITUKI, 1984).

1.4.3 Trophity

The degree of trophity is measured either by determining the volume of photosynthetic oxygen produced, as discussed in the previous chapter, or by determining the algae participating in the process and their a-chlorophyll content. The a-chlorophyll, the algae count, and the represented biomass show regular seasonal changes. The relevant data of the Rajka section of the Danube is shown in Table 7 of Annex No.1 (KVM, 1988). In addition to the seasonal change, variances along the long individual section are also evident (Bartalis, 1978; Németh, 1971), these are shown in *Table 1.4*, and in Table 8 of Annex No.1.

Several indices of the degree of trophity, e.g. the close relation of the volume of phyto-plankton, a-chlorophyll content, photosynthetic oxygen production and hydrobiological conditions became especially evident in 1983 (Bartalis and colleagues 1984; Dváhally, 1984; Dváhally and colleagues, 1984; Kiss, K., 1984). In the second half of the year – parallel with the long-lasting low water level – the algae count was 16-57% higher in the Göd section in comparison with similar periods of the past five years. This coincided with a consequential volume increase in photosynthetic oxygen production. These new findings also prove that hydrological conditions play a major role in the hydrobiological conditions of the Danube. The most direct hydrobiological effect of the decrease in flow-velocity is the increase of volume of planktonic algae during the vegetation period, and an increase in the intensity of related processes.

***Table 1.4**: The seasonal average values of a-chlorophyll (A) (mg/m^3) and the algae count (A*) (10^6 individual/l) in 1975 (Bartalis, 1978)*

Season	RAJKA 1,848 rkm)		GYŐRZÁMOLY (1,806 rkm)		DUNAALMÁS (1,752 rkm)		ESZTERGOM (1,717 rkm)	
	A	A*	A	A*	A	A*	A	A*
Spring	33.1	13.8	40.7	18.1	39.5	18.3	51.9	22.8
Summer	22.7	6.4	27.4	7.5	27.2	6.5	34.5	7.9
Autumn	23.5	7.0	34.3	8.3	31.0	8.7	40.5	11.4
Winter	5.5	1.1	6.0	1.2	4.8	1.2	7.5	1.3

1.4.4 Saprobity

The results of the routine saprobity tests carried out between 1974-1983 on the Danube section affected by the GNBS are summarised in Table 9 of Annex No.1. The duration graphs of the PANTLE-BUCK index (*Figure 1.4*) provide information on the degree of organic pollution on four sections on the basis of examination carried out between 1979-1983. The two upper sections (Rajka, above Vác) and the two lower sections (Szob, above Budapest) show strikingly different graphs. The river sections above and below the Vác definitely vary from each other, and the greater saprobity degree of the lower section is caused by the effect of the organic pollution transported by the Vác. Although water quality improves between Szob and Budapest in the case of all components, the annual average values of saprobity are the highest upstream of Budapest, in each of the examined 10 years. On basis of ten years' data it can be said that the saprobity degree shows a small but definite increase in all sections, which is caused by the growing organic pollution of the river (VITUKI, 1984).

1.4.5 Zoo-plankton

Since the middle of the 1960s regular examinations were performed on the small crab fauna of the Danube at the MTA ÖBKI Dunakutató Állomás (Danube-research Station) from both a systematic and ecological point of view.(Bothár, 1966, 1982, 1982a; Bothár, Ponyi, 1968; Bothár, Dváhally, Kozma, 1971). On the basis of the tests it was determined that:

– the population density and species composition of the small crab plankton is closely related with the hydrological changes in the river. The increasing flow-speed and turbulence, decreases the individual number per volume unit. Larger amounts of suspended sediments destroy the living conditions of numerous species.

– The natural bank, and the secondary branch system connected to the main branch serve as an important reproduction and protection site, in addition to being the place where the small crab plankton spend the winter. Thus, maintaining the original conditions of the natural banks, and the relation between the main and the secondary branches is highly important.

– The numbers of rotifera (Kertész, 1963) and small crab plankton (Bothnár, 1974) increase on the domestic Danube section in the direction of the flow.

– On the basis of the comparative zoo-plankton examination on the Rajka (1,848 rkm) and the Esztergom (1,717 rkm) sections, increasing numbers of small crab and rotifera plankton volumes were again observed in the direction of the water flow. It was also pointed out that the maximal population density develop from spring to fall, in the periods of low water level (Bartalis, 1978).

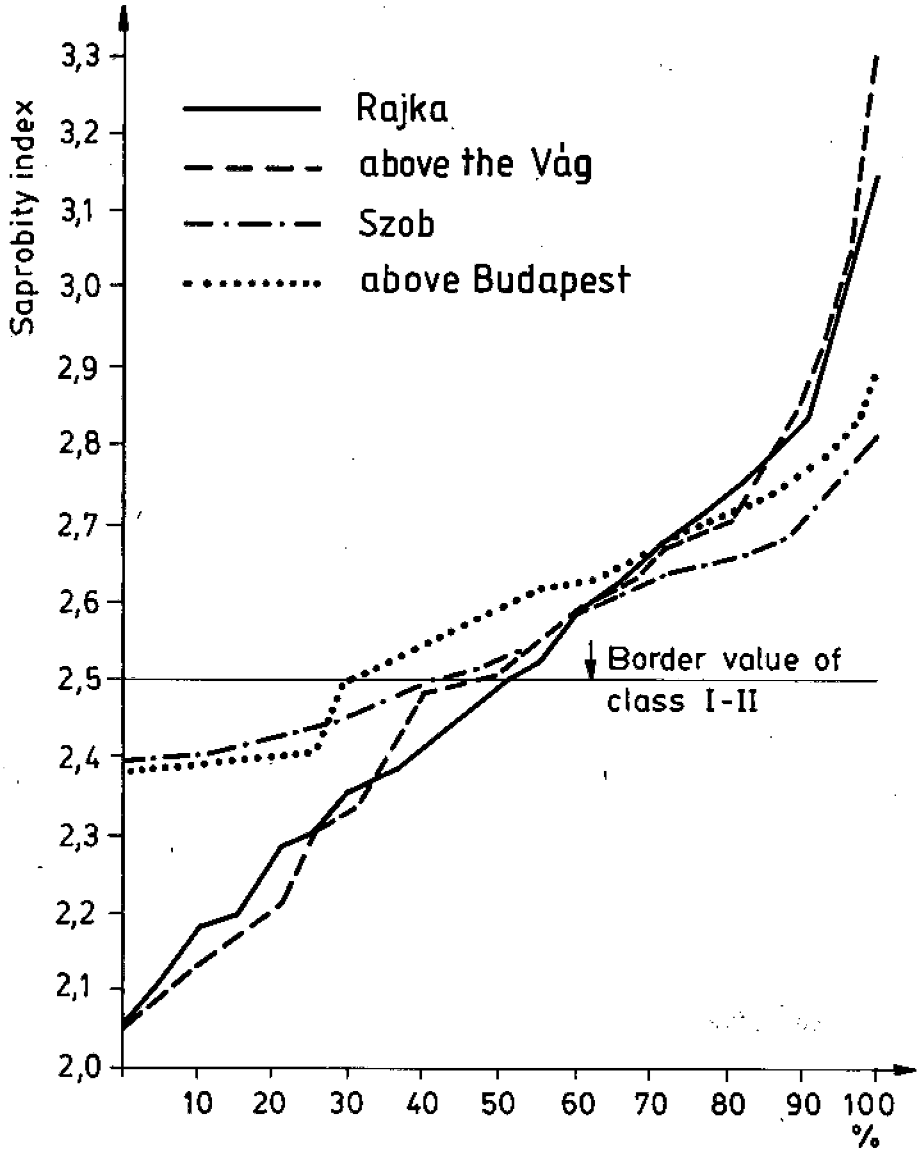


***Figure 1.4**: Saprobity index duration graphs based on 1979-1983 examinations (VITUKI, 1984)*

1.4.6 Fish population

The changes that have taken place in the volume and species composition of the fish population of the domestic Danube section can be traced back to the 1950s. In a number of studies, Tóth (1962, 1982) dealt with these changes and their links with the water quality, based primarily on the statistical evaluation of fish-catching data. The following should be noted in order to characterise the hydrobiological conditions of the Hungarian section of the Danube:

– The results of fish-catching on the Hungarian Danube section tended to increase between 1950-1981. However, this seemingly favourable change arises from increasing volumes of small-sized species in the catch, which are less important economically. This change has the following main nutrition-biology and reproduction-biology causes;

– the changes in volume and species composition reflect the effects of planktonic eutrophication that has occurred in the past 25 years. The increased plankton volumes served as a larger, natural food base for above all small-sized fish;

– the environmental conditions necessary for the reproduction of large-bodied fish have deteriorated, primarily by the restriction of the connection between the main and the side branches in space and time: the effect of hydrological technical intervention (Tóth, 1960, 1982).

1.5 Bacteriology

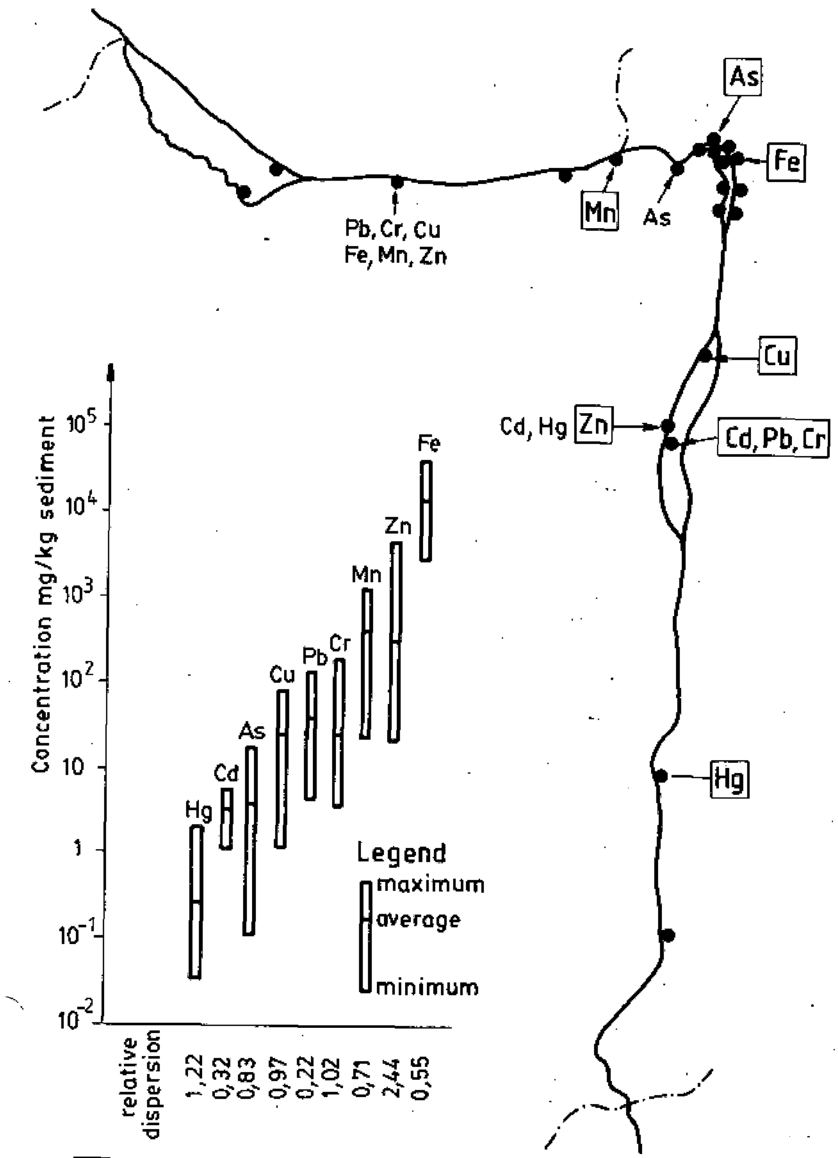
According to the classification of all inspecting organs (Komárom County KÖJÁL, regional VIZIGs, Székesfehérvári VIZIG regional laboratory) the section of the Danube above Budapest and the Mosoni Danube fall into categories III (polluted) and IV (severely polluted) (KVM, 1988). The minimum and maximum values of the 1987 tests are included in Tables 10 and 11 of Annex No.1.

It is worth comparing the above results with the results of the 1973-1975 OKI tests, which classified the given section of the Danube as II-III category from a bacteriological point of view (WHO-VITUKI, 1976; Deák, 1977).

1.6 Sediment tests

The tests relating to the pollution level of the bedsediments of the Danube reach back to 1977, but only a few useful data are available from the early periods (VITUKI, 1981). In 1983 a detailed survey was carried out at 22 major, bank filtered waterworks plants of the Hungarian Danube section, to identify heavy metal pollution- of the waterbed material (VITUKI, 1983).

The test was carried out on two occasions under small and mean water flow; 45 different sediment samples were taken from the upper 5 cm of the suspended sediment covered by water at the bank. *Figure 1.5* shows the results of the analysis giving the minimum and maximum concentration of the components, the average value, the relative dispersion, as well as the sites of the smallest and largest concentrations. The smallest measured concentrations of the polluting materials, comply with the naturally occurring background concentrations.



Cr → sample-taking place linked to the highest chrome concentration

Cr → sample-taking place linked to the lowest chrome concentration

***Figure 1.5**: Pollution level of the waterbed sediment on the examined Danube section (VITUKI, 1985)*

In addition to a comparison with the natural background concentrations, the pollution-level of the sediment can also be classified by the concentration of certain elements in the soil, permissible from the point tolerated by plants. (Table 12 Annex No.1). The average heavy metal concentrations of the examined sediments from the Danube did not exceed the permissible heavy metal content of soils, while the highest concentrations measured exceeded the limits in all cases of toxic elements with the exception of copper.

From among the components, the concentration of cadmium changed within the narrowest margins: the cadmium contents were within one order of power. Cadmium also proved to be the most stable component, when testing variability on the basis of dispersion, the other extreme was represented by zinc.

It should be mentioned here that the sediment analyses carried out quarterly over three years at a chosen, permanent sample-taking location (1,659 rkm) also demonstrated the stability of the cadmium concentration in time, compared to the variability of mercury, lead and zinc.

The presented results refer to the upper 5cm thick layer of the sediment. At the same time a riverbed material examination (drilling near the sounding plummet to the water sealing layer) was conducted on the Danube section with bank filtered wells. It demonstrated that in the sections rapidly becoming silty, the relatively polluted layer may reach a depth of several metre (VITUKI, 1985).

In order to determine the concentration of heavy metals solids accumulated, four sediment-chemistry measurement series were carried out in 1987 at a total of 25 sample-taking sites on both the riverbed sections of the major bank filtered water-bases in the Szigetköz Danube branches, and in the impact area of the GNBS. The tests were conducted on the less-than-1 mm granule fraction, of the upper 5 cm layer, of the riverbed by the edge of the bank.

Figure 1.6 shows the smallest and largest concentration, average value, and the permissible heavy metal content of the soil.

Once again, the maximum polluting material concentrations permissible in soils from is the value at the points of the plants' tolerance (specified in Technical Directives MI-10-420-83) This was regarded as principal in judging the pollution-level of the sediment. The highest average concentrations of toxic heavy metals, exceeding the limit, occurred on the Tát-Göd Danube section, and the smallest averages were found on the upper Danube section (VITUKI, 1988b).

The test results are coherent with the findings of the sediment analysis carried out in 1983 on Hungarian Danube sections used for bank filtration (VITUKI, 1983), there again, the smallest concentrations characterised the upper Danube section and the highest, the middle Danube section. However, the 1983 survey did not observe any average concentrations exceeding the limit values.

The changes in the pollution level of the sediment are also affected by the flow conditions and within this the granule size conditions. For this reason we decided to find out whether there exists a relationship between the pollution material distribution in the suspended sediment of the Danube, of and the granule size (VITUKI, 1987).

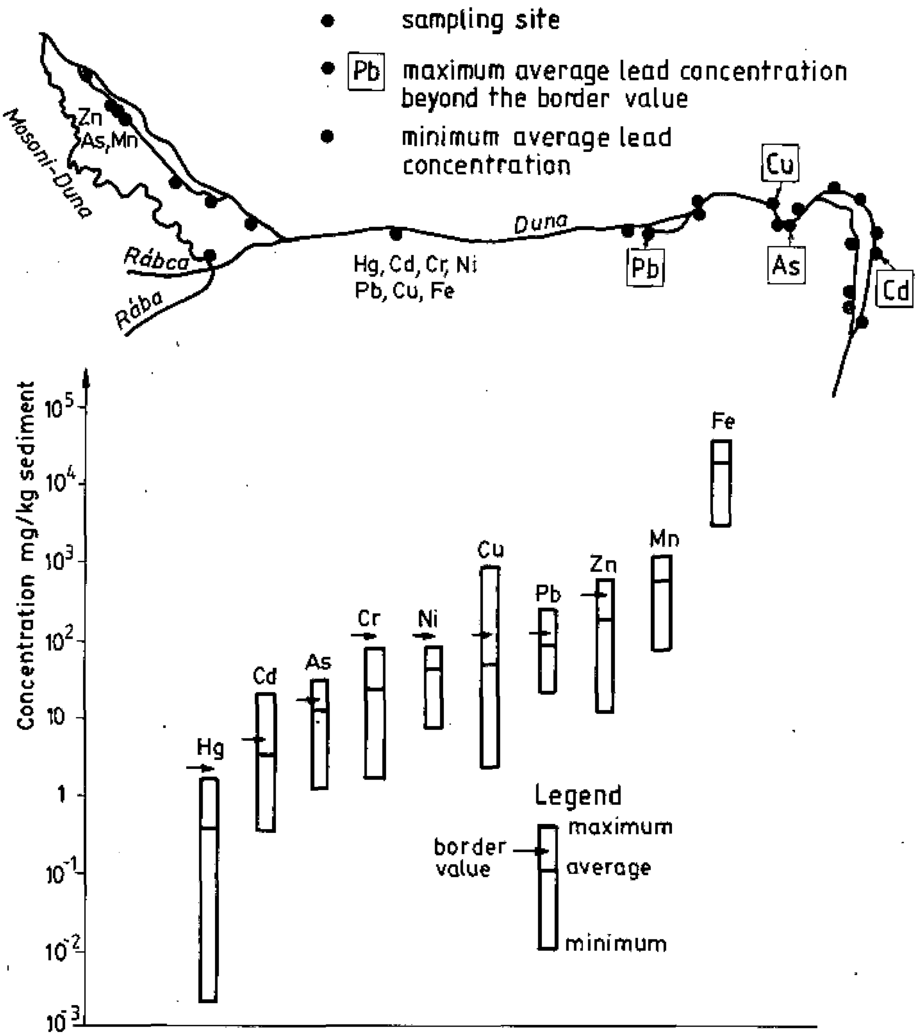


Figure 1.6: Pollution level of the bed sediment on the examined Danube section (VITUKI, 1986)

The annual depth should be determined as the increased deposition of fine-granule sediments sections with a slow flow velocity is considered to be one of the results of waterbed regulation and dredging. This phenomenon affects the bank filtered water supply.

We assume that the small granule-size usually accounts for higher pollution in the sediment (e.g. higher organic material concentration). Unfavourable hydrochemical changes can take place in the more polluted filtering layer because on its changed composition.

In order to prove this hypothesis, the chemical analysis, for each granule size. (d<90 μm, 90<d<250 μm, 250<d<1000 μm fractions) of riverbed samples taken from the Danube section Budapest – Rácalmás, started in 1986 for mercury, cadmium, lead, chrome, arsenic, copper, nickel, iron, manganese, and zinc inorganic pollutants, total organic material and hydrocarbon organic components. In 1987, the examination was expanded to the Nagymaros – Budapest, Táti, Bajai, and Mohácsi sections of the Danube each were characterised from one sample the results of which are included in *Table 1.5* (VITUKI, 1983).

The primary conclusion that can be drawn from the tests: typically, the concentration of toxic solids in the smallest granule-size sediment-fraction pollution material is the highest for all the examined pollutants. Although there are some local exceptions, the average concentrations reflect well the general tendency. The test results supported the supposition that the sedimentation of fine-granule sediments in the Danube coincides with pollutant concentration.

With regards to the VO section surveys performed on the Komárom-Nagymaros Danube section in 1988, the pollution-level of the riverbed material was examined at 14 sample-taking sites in three fractions of the sediment (d<90 μm, 90<d<200 μm, 200<d<1,000 μm) concerning various heavy metals and organic materials. *Table 1.6* shows the average concentration of pollutants in the examined sediment fractions. Again, the pollutant concentration of the smallest granule sediment fraction is the highest in the case of all examined components. In the smallest granule-size fraction, the average concentration of lead, arsenic, copper, and zinc exceeds the permissible values for soils (MI-10-420-83).

Table 13 of Annex 1 provides the heavy metal pollution level of the sediment in the tributaries of the Danube.

Table 1.5: *Average concentration of pollutant in the examined sediment fraction (mg/kg) (VITUKI, 1988b) (Budapest-Rácalmás)*

	d < 90 µm	90 µm < d < 250 µm	250 µm < d < 1,000 µm
Mercury	1.00	0.15	0.16
Cadmium	2.78	1.33	0.94
Lead	105	42.7	51.1
Chrome	50.9	15.1	15.4
Arsenic	9.6	2.5	3.2
Copper	228	34.3	30.5
Nickel	58.0	25.9	21.1
Iron	20,600	8,630	7,830
Manganese	782	291	232
Zinc	381	77.0	85.9
Total organic material	49,700	20,200	27,400
Oil + fat	1,050	428	477

***Table 1.6**: Average concentration of pollutants in the examined sediment fraction (mg/kg) (VITUKI, 1988b) (Komárom-Nagymaros)*

	d < 90 μm	90 μm < d < 250 μm	250 μm < d < 1,000 μm
Mercury	0.51	0.08	0.29
Cadmium	3.90	1.85	1.17
Lead	126	14.9	19.0
Chrome	34.3	12.5	15.7
Arsenic	16.0	2.7	5.3
Copper	248	9.7	18.2
Nickel	52.4	19.3	19.1
Iron	20,112	6,210	6,953
Manganese	1768	268	294
Zinc	436	45.3	63.9
Total organic material	40,957	8,107	34,600
Oil + fat	352	187	275

1.7 POLLUTANT LOADS

A number of studies have dealt with the pollutant load of the Hungarian section of the Danube, affected by the GNBS (VITUKI, 1973; WHO-VITUKI, 1976; VGI, 1976; VITUKI, 1978; VITUKI, 1984, 1985b; VGI, 1985; VIZITERV, 1985; KVM, 1988). On the one hand, these studies include quantitative and qualitative data on the waste water inlets, and on the other the pollutant load of the effected Danube section originating from the tributaries. The evaluated components, waste water inlets and tributaries are summarised in *Table 1.7*, which however, requires the following supplementary remarks (the number in the table is in brackets):

– The data are more or less outdated (especially the ones preceding 1984: 1, 2, 3, 4).

– In part, the data are integrated for the entire region (1, 4, 6), that is they are not broken down according to pollution sources, and they consider both the Danube and its tributaries.

– The data are heterogeneous from the point of water quality components, and in some cases they are not identifiable (3, 6).

– The data consider different impact areas, in other words they are not unified on the width of the impact area.

– The data are not homogeneous in space either: even the most up-to-date material (8) only includes the Rajka-Almásfüzitő section, although for this section it specifies the material-flow data of waste water inlets for four components, it does not offer any data on sewage water volumes.

Table 1.7: Dot-like pollutants of the Danube and tributaries on the impact area of the GNBS in the professional literature

No.	Author (year)	Danube and its tributaries	Waste water inlets	Components
1.	VITUKI (1973)	Duna, Vác, Nyitra, Garam, Ipoly, Rába,	"Waste water inlets on the Hungarian section"	COD_p, BOD_5, NO_3^-, total dissolved mat.
2.	WHO-VITUKI (1976)	Mosoni Danube, Cuhai Bakonyér, Concó, Áltatér, Táti-Dunaág, Szilas p.,	17 Hungarian pollution sources	Q, COD_d, BOD_5, CCl_4, MSS, NH_4^+ (only at the 17 Hungarian pollution sources)
3.	VGI (1976)	Mosoni Danube, Cuhai Bakonyér, Concó, Általér, Táti-Dunaág, Szilas p., Czechoslovakian side tributaries	12 Hungarian pollution sources, 10 regions	Q, COD_d, NH_4^+, oil(?), Q, COD_d
4.	VITUKI (1978)	Concó, Általér, Ipoly, Vác, Nyitra, Garam	19 Hungarian pollution sources, 3 Czechoslovakian pollution sources	Q, COD_d
5.	VITUKI (1984, 1985b)	-	20+23 Hungarian pollution sources	Q, COD_d
6.	VGI (1985)	Duna, Mosoni Danube, Cuhai Bakonyér, Concó, Általér, Kenyérmezei p.	31 Hungarian pollution sources	Q, COD_d, fats+ oils, toxic materials, Nitrogen , phosphorous, NO_3, total dissolved mat., Na, SS
7.	VIZITERV (1985)	-	26 Hungarian, 23 Czechoslovakian pollution sources	Q
8.	KVM (1988)	-	48 Hungarian pollution sources	COD_k, SZOE, NH_3^- NH_4, total dissolved. mat.

The data are (almost) exclusively of Hungarian origin. No useful data could be obtained on pollution of the Czechoslovakian side. Material (7) contains only waste water data.

– Only one study (6), deals with non-dot-like pollution sources, but that too only specifies on a map, the Hungarian communal, agricultural, industrial and toxic waste material storage sites. Their number of each is shown in *Table 1.8.*

For information, we shall present the list of the main Hungarian pollution sources affecting the given Danube section: the quantity, COD concentration and material-flow data – which are (partly) outdated today (5) (Tables 14 and 15 of Annex No.1).

The distribution of the waste water load between the two countries (Czechoslovakia and Hungary) is a separate problem. Lacking concrete Czechoslovakian data, this issue is either ignored by the evaluated studies (1, 2, 6) or avoided by making assumptions from the effects of the tributaries calculable from the Danube (3, 4, 5). Note that these three calculations, made on three different occasions, involving slightly different databases and methods, projected the ratio of waste water load between the two countries as 8.3; 7.6 and 9.1 to 1.0 as regards their COD_d according to the respective literature 3, 4, 5 of *Table 1.7* (taking Hungarian pollution as 1.0). It has to be mentioned here that the Morava pollution load was not considerate in the above calculations.

Only one of the studies dealt with the effects of the waste water load coming from the Morava (VITUKI, 1987b), but without Czechoslovakian data the only conclusion it could reach was that this water course – similar in size to the Vág – is classified category IV by Austrian regulations as one of Austria's most seriously polluted watercourse.

Two of the above studies (2, 6) recommended the construction of waste water treatment plants. Document (2) gave concrete proposals for the treatment level of four components (COD, BOD_5, MSS, CCl_4), (2, 3) outline waste water treatment plans, while the proposal (6) prepared nine years later, additionally emphasises that "denitrification should also be performed in each case at waste water treatment plants".

***Table 1.8**: Waste material dumps on the impact area (ŤGI, 1985)*

Waste material dump sites	Number of sites
communal	58
agricultural	97
industrial	33
toxic material	30

Table 16 of Annex No.1 details the capacity of the planned and operating waste water treatment plants in the Vác-Nyitra water system (7). No information was found in the literature on waste water coming from the Czechoslovakian side and directly affecting the Danube, and incoming waste water affecting the Morava.

On the basis of the above and other information the following statements can be made:

– The available data are only suitable for performing informative classification calculations (e.g. test-runs in the case of models).

– Up-to-date Hungarian data can be collected from regional KÖVIZIGs (presently, however, there is no unified computer database).

– In the past, the collecting of quantity and quality data on Czechoslovakian incoming waste waters – highly important from the point of the waste water load of the Danube section – was not successful.

To conclude, it can be stated that no database is available, which would allow a comprehensive material transport evaluation on the longer effected sections of the Danube.

1.8 CLASSIFICATION OF BANK FILTERED WATERS

The alluvial, sand-gravel layers beside the Danube, offer a valuable opportunity to establish bank filtered water bases. The section of the Danube effected by the GNBS is of utmost importance, primarily because it supplies the water for settlements bordering the Danube and therefore the impact area.

The quality of the water drawn from bank filtered wells has two characteristics. One is the change in the water quality during the year: When the water levels in the Danube are high, (e.g. in case of a small flood) the quality of the water is good, as the water level decreases, the water quality of the wells slowly deteriorates, and more nitrate etc. appears. This phenomenon is caused by the fact that, the wells mainly draw water from the Danube when the water level is high, while in the case of low water levels, other waters from the surrounding area dominate, whose quality is much worse as a result of industrial, communal and agricultural pollution. This can be observed at the water works of Visegrád, where the surrounding area includes the village and the connected forest (VIZITERV, 1985). The other phenomenon noted is the increased pollution of waters drawn from wells within decades. The tendency is demonstrated by *Figures 1.7* and *1.8* on the basis of five water quality components, at the tested right and left hand side bank water base of the Dunakanyar (operated by DmRV). The figure was prepared with the average data of the 105 wells in 14 waterworks. In the Danube, the deterioration of the examined water quality components was smaller in the same time period (VITUKI, 1987b).

The above circumstances refer to the increase of background pollution and project the necessity of introducing costly technologies that go beyond chlorination.

Special emphasis should be given to the water supply underlying the Szigetköz. This gravel-bed is supplied in part by the Danube, and in part by the waters coming from the Lajta-mountains. The surface of the water located in the gravel has a gradient of $0.5\text{-}1.0 \times 10^{-3}$, and thus it moves towards the Rába – Mosoni Danube. Basically, the water-mass forms a connected whole, it is not divided into layers by connected horizontal barriers. This practically unified water-mass is continuously polluted from above as a result of human activities (communal, industrial and agricultural pollution). The wells of the operating water works draw the water from a depth of 80-100 metres (VIZITERV, 1985).

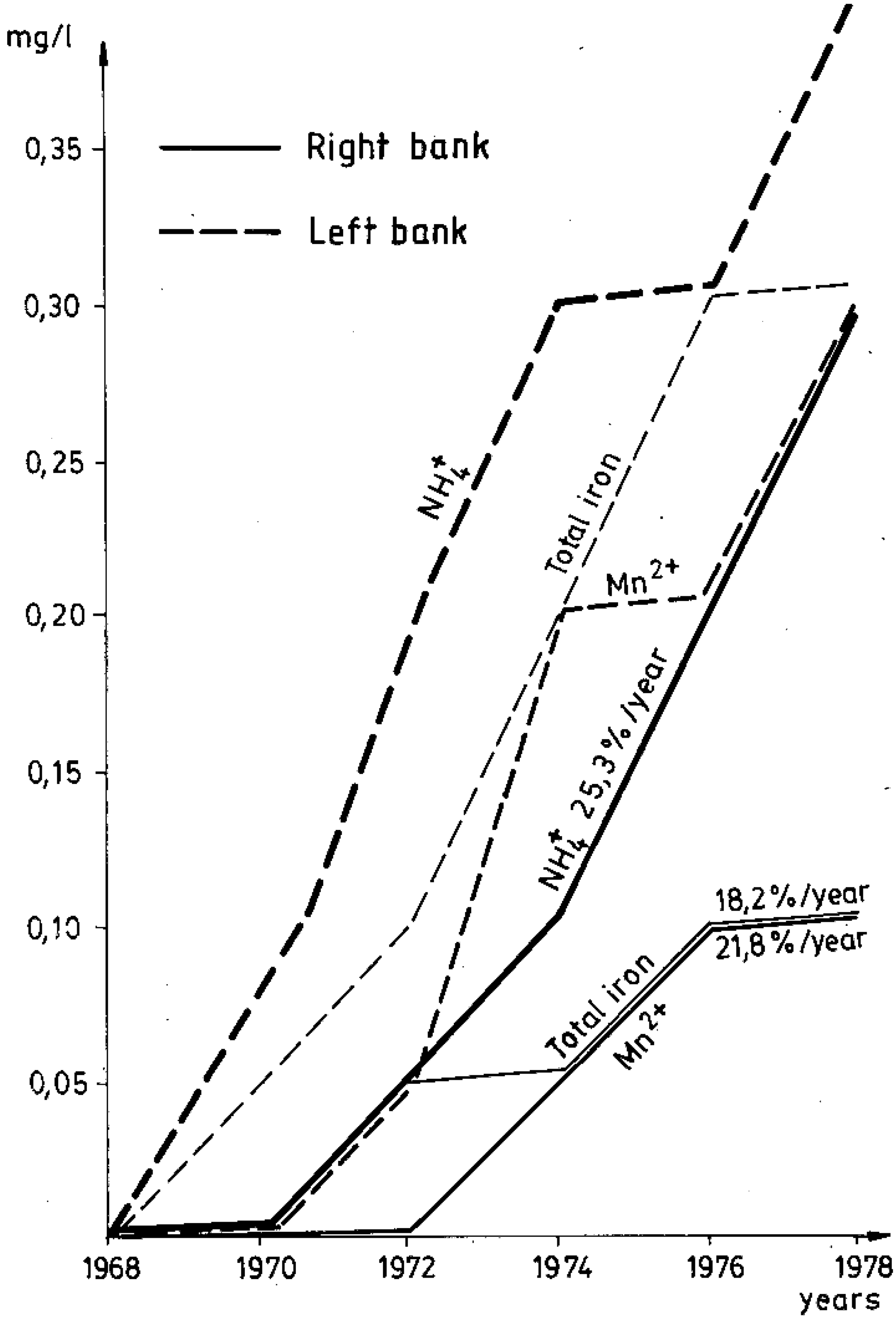


***Figure 1.7**: Changes in the average water quality of the right and left bank water works of the Danube, based on NH_4^+, Fe, and Mn^{2+} values*

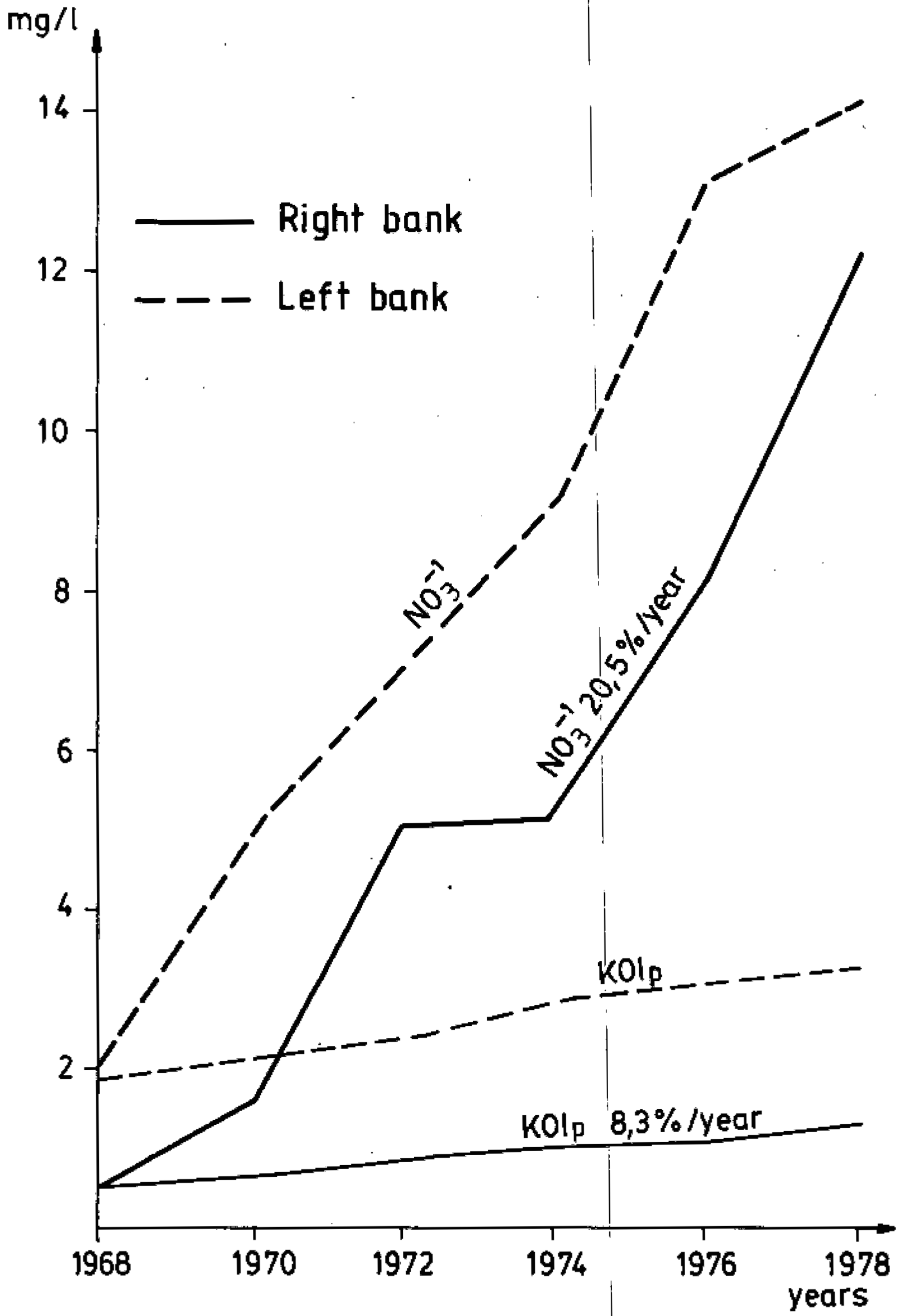


Figure 1.8: Changes in the average water quality of the right and left bank water works of the Danube, based on COD_p and NO_3^{-1} values (VITUKI, 1987b)

***Table 1.9**: Water works allocated on bank filtered water based (VGI, 1985)*

Name of waterworks	Monitoring wells	Waterworks capacity (10^3 m^3/d)	Waterworks production (10^3 m^3/day)	areas++ internal	areas++ external	areas++ hydro-geological	Water quality parameters mg/l	Pollution sources	Note
Kisbajcs-Szőgye	+	25,0	20,0-25,0	+	-	-	Fe + Mn = 1.4-1.6	Danube, Szőgye, Nagybajcs	can be developed
Révfalu	-	45,0	22,0-23,0	+	-	-	Fe = 1.5-2.5 Mn = 0.2-0.6 NH_4 = 0.2-0.9	Győr, industrial waste dump site	the riverbed has clogged
Komárom-Koppány-monostor	-	6,5	2,8-6,5	-	-	-	Fe+Mn = 1.0-1.5 NH_4 = 0.1-0.3 NO_3 = 1.0-7.0	cottages, Holt-Duna, wetland background, silty build-up	protected by a dyke, reached by floods
Nyergesuj-falu-VISCOSA	-	10,0	6,0	+	-	-	Σ = 230 CaO SO_4 = 150-190 NO_3 = 12-25	bacterial pollution	NO_3 deteriorating
Tát	+	7,9	(2,0-5,5)	+	+	-	NH_4 = 230 NO_3 = 350 Cl = 200	background soil pollution, agricultural cultivation	drinking water quality only with enrichment
Esztergom-Prímás Sziget	-	21,0	8,0-21,0	+	+	-	general drinking water quality	wetland area, dog training site, waste dumps	expandable, protected by a dyke
Esztergom-Szentkirály	-	6,6	2,0-3,0		+	-	Σ = 300-320 CaO Mn = 0.5 NH_4 = 0.35-0.45 NO_3 = 2-15	Siltation upstream of Tat island, Kis Danube	improvable with water enrichment
Dames	-	2,1	0,65-1,0	+	+	+	NH_4 = 0.3 NO_3 = 19 NO_2 = 0.06	plant cultivation, animal breeding	expandable
Zebegény	-	0,3	0,2-0,3	-	na	na	under est.	cottages, Bőszobi-patak	-
Visegrád	+	1,2	0,8-1,2	+	na	na	NH_4 = 0.0-0.2 NO_3 = 5-100	background	terminated on the long-term

The most important characteristics of the explored areas and the areas recommended for exploration in connection with the bank filtered water works located on the Rajka-Nagymaros Danube section have been summarised in *Table 1.9* and in Tables 17 and 18 of Annex No.1 (VGI, 1985).

Communal and agricultural groundwater pollution is observable at the Szentendre Sziget too, where pollution originating from the surface appears in the water quality of wells, when the water-level of the Danube is low (VIZITERV, 1985).

Among the well-groups of the Fővárosi Vízmüvek's northern waterworks (Tahi I, Tahi II, Tahitótfalu, Szentendre Sziget I, Szentendre Sziget II, Kisoroszi, Surány) only the Kisoroszi 12 radial well and the radial wells of the Surány Water Works have serious water quality problems.

The works of the northern water works that are considered to be typical from the perspective of water-quality, are the (for short) Szigeti I and Szigeti II works. Tables 19 and 20 of Annex No.1 show that at these two location wells did not comply with the chemical standards between 1971 and 1980. The "O" in the table means that the well in question complied for all of the chemical components in the given year, while an "X" means occasional non compliance, and Mn or NH_4 would mean regular objections concerning that component. The tables show that only in a few cases does the water quality regularly breach the standards at the works representing the northern water base of Budapest (VITUKI, 1987b).

The interaction between the favourable dissolved O_2 conditions of the Danube (see the chapter dealing with classical chemical components) and the oxygen conditions measurable in bank filtered waters should be demonstrated here. VITUKI carried out a series of tests at the southern water works of Budapest to determine the effectiveness of bank filtration. Parallel to the frequent (2-3 samples/week) sample-taking performed in 1984-1985, 24 water quality components of the Danube and one radial well were examined. The results showed that during filtration, the oxygen content reduced by on average 84%, in some cases creating nearly anaerobic conditions (VITUKI, 1988b).

From relevant foreign examples the experience gained at the Linz waterworks within the retained water area shall be mentioned. One of the control wells in pre-dam conditions showed an oxygen content of 2.4-5.2 mg/l O_2, while in post-dam conditions it was within the 0.0-1.3 mg/l O_2 range depending on the temperature; both measurements were taken when oxygen conditions in the Danube were near saturation (8.4-12.1 mg/l O_2). Among the reductive circumstances approaching anaerobic conditions, the mobilisation of iron and manganese had started. The cause of this phenomenon is the fine sediment deposited in the dammed area (VITUKI, 1988c).

In the followings, Table 21 of Annex No. 1 shows the extreme values measured by eight subsurface main network points in the course of five years. The water quality of the wells, located between Rajka and Dömös, is rather diverse. At some the iron and manganese content (and in certain cases the ammonium ion content) is objectionable. In other cases, the maximum nitrate concentration approaches or exceeds the limit (KVM, 1988).

To summarise the water quality of the bank filtered wells has recently seriously deteriorated. This has been caused by the coinciding effects of a number of factors: the deterioration of the Danube's ecologically sound water body; inappropriate specification of the water bases' protection area;

inappropriate location of water bases; background pollution due to excessive use of agricultural pesticide; waterbed regulation work and dredging (VGI, 1985).

2. Future Water Quality Problems Caused by the GNBS

Hereinafter, the future water quality problems related to the implementation of the GNBS, will be subdivided geographically. It cannot be stated that each and every one of the listed problems will manifest (and especially not with the mentioned weight and probability) but we do believe that each issue is based on true facts. It should also be understood that the majority of them (except for maybe the algae boom) are not going to appear overnight. Similarly to the Kiskörei reservoir, the new ecological "balance" will develop gradually, in several years or even nearly a decade. This applies especially to the water quality of bank filtered wells.

2.1 THE DUNAKILITI RESERVOIR

It should be emphasised that morphologically, the Dunakiliti reservoir differs totally from the riverbed reservoirs of the German-Austrian section, which means that any experience gained there cannot be applied here automatically. The planned Dunakiliti reservoir is a through-flow type reservoir, whose water flow is not equal throughout the reservoir because of its morphology. It is relatively shallow (with an average water delivery the average depth is 3.3 metres, Rotschein, 1976), and has a volume of 243 million m^3, and a water surface of 52 km^2 (VIZITERV, 1985). With the exception of the dead ground on the sides, the reservoir will have an intensive water exchange (see *Table 2.1*).

***Table 2.1**: The theoretical storage time and the average flow velocity in the Dunakiliti reservoir (Rotschein, 1976) (without peak operation)*

	Water delivery of the Danube (m^3/s)			
	1,000	2,000	3,000	4,000
Storage time (hours)	67.5	33.8	22.5	16.9
Average flow velocity	0.05	0.11	0.16	0.21

The quality of water in the Dunakiliti reservoir will basically be determined by both the quality of the arriving water and the specific properties of the reservoir resulting from complex physical and biological processes. As a result of the German and Austrian barrage systems, the water of the Danube – as characterised by the chemical parameters discussed in Chapter 1 – entering the reservoir will carry smaller volumes of rolled sediment, and will reflect the polluting effect of Vienna, and Bratislava and the Morava in its microbiological indexes. The water quality in the reservoir, which develops as a result of the above effects, plays a decisive role in the water quality of the entire Danube section affected by the GNBS (i.e. the power canal, the old riverbed, the Mosoni Danube, the drain canals, subsurface waters, etc.; see *Figure 2.1*), moreover, for certain parameters, its influence also extends to the section of the Danube below Nagymaros (e.g. degree of trophity, water temperature).

On the basis of the flow-velocity distributions, without peak mode operation (VUVH, 1965) (*Figure 2.2*), only minor changes occur in the flow in the current of the reservoir (that is in the original Danube riverbed and in its environment), thus no significant change to the water quality can be expected to take place there (Rotschein, 1976, Hock, 1982). As a function of the discharge and the geometry of the reservoir, the flow-speeds developing in the reservoir are much slower than that of the incoming water. Consequently, the quality of the incoming water, the reduced velocities, the increase of storage times and water surfaces will be vitally important in terms of the water quality of the reservoir. Naturally, the peak mode operation will modify the flow-picture demonstrated in *Figure 2.2,* and consequently the quality of the water.

The primary consequences of the new hydrological circumstances, resulting from the geometry of the reservoir, will be the following:

– the transport of suspended sediments will change;

– the transfer of rolled sediment will decrease;

– more suspended sediments will be deposited;

– the volume, granule-size, and dispersion of the bed-silt will change, just as the volume, quality, and dispersion of pollution materials bound to the granules;

– water temperatures will change;

– light conditions will modify, the water will be more transparent;

– trophity conditions will change fundamentally in the water;

– the oxygen-, phosphorous– and nitrogen management will change significantly.

The listed processes and factors are going to enter into a complex interaction with a dynamic system characterised by permanent changing water levels (1 metre water level change in peak mode operation) (VIZITERV, 1985) and constantly changing flow.

The situation is even more complex because of changes in the quality and quantity of the Danube water entering the reservoir, the water movements created by winds and in winter, the effect of the connected ice cover, developing on the reservoir.

The increased deposition of suspended sediments will have two consequences: large amounts of bed-silt will develop and the transparency of the water will increase.

There is no reliable data on the expected volume of the depositing suspended sediments. Previous estimates, which projected an annual 1.3-4.0 cm sedimentation for the entire area of the reservoir (Pirkovszky, 1966; VIZITERV, 1977; VITUKI, 1978; Hock, 1982; VIZITERV, 1985; VITUKI, 1987a) seem to be superseded by recent calculations. Sedimentation is now expected to be much greater.

The results of tests on the scale model of the reservoir (VUVH, 1965) show that in a year with average precipitation, approximately 8 cm sediment is expected to settle in the entire reservoir, (in a dry year the sedimentation is 7 cm, this, however, may reach 29 cm in a year with high precipitation).

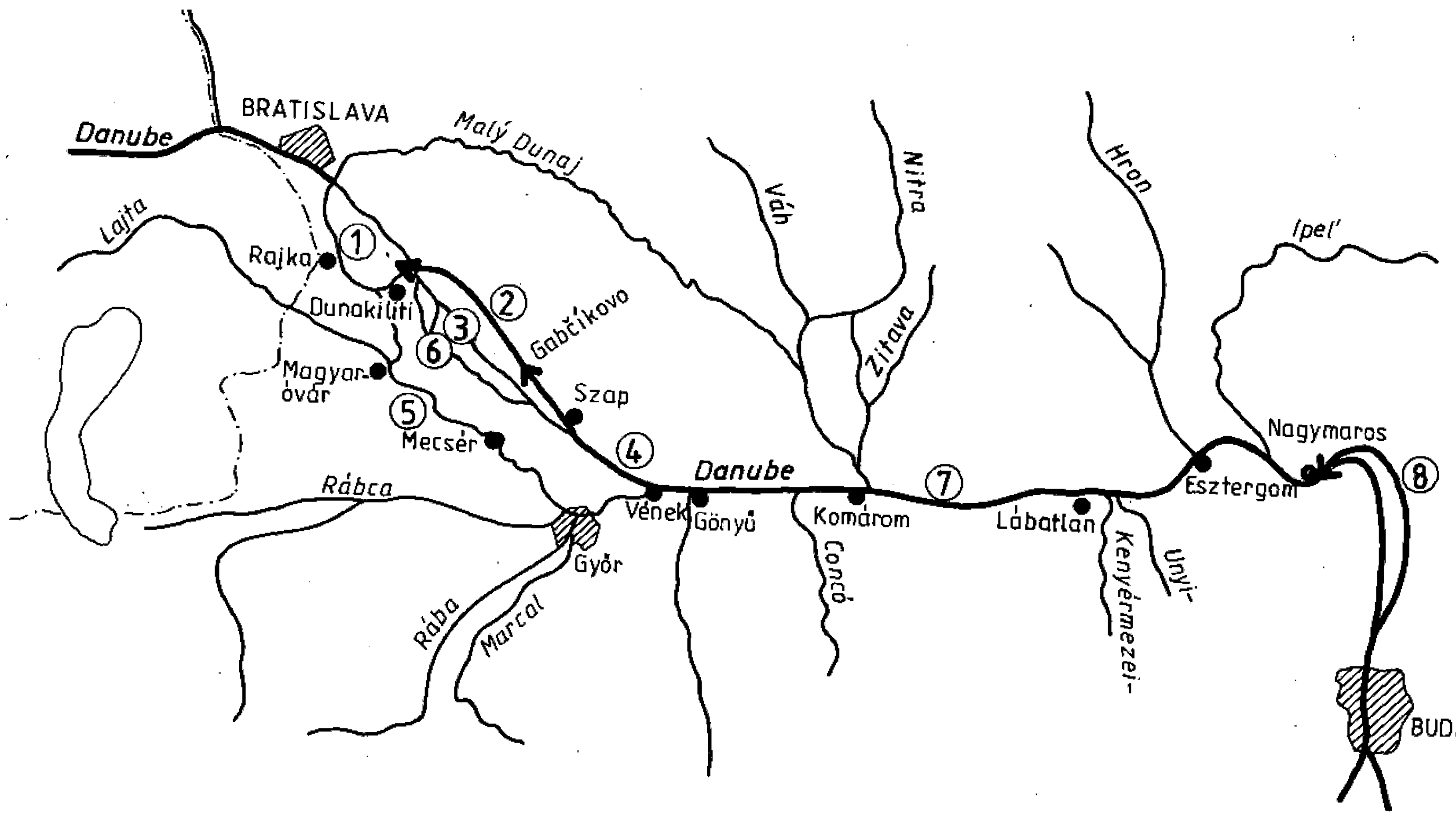


Figure 2.1: Outline of the GNBS System

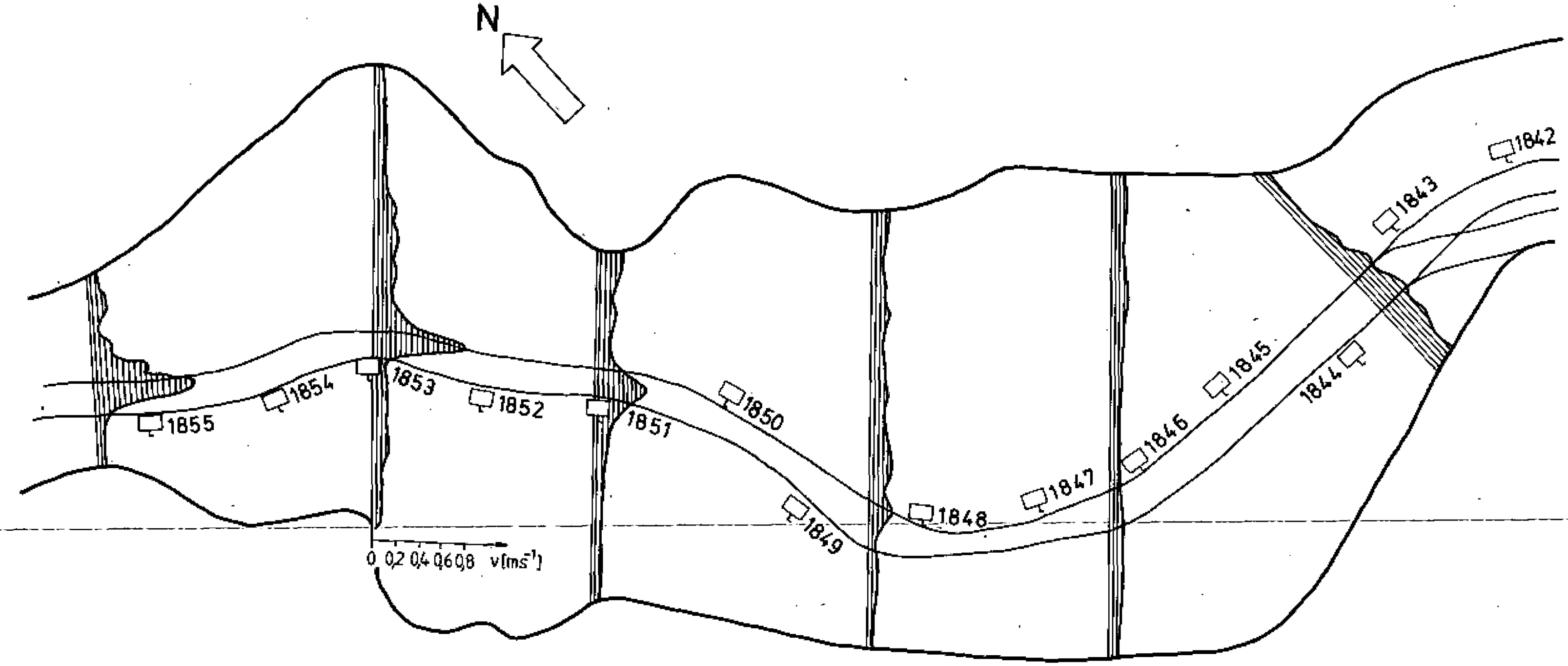


Figure 2.2: Flow speed distribution in the Dunakiliti reservoir (VUVH, 1965) precipitation the maximum levels of sedimentation may even reach 1.5 metres annually in smaller areas).

The volume of sedimentation changes greatly within the reservoir. In a year with average precipitation, annually 44 cm will be deposited by the current-line (directly at the entrance), while in other, farther parts of the reservoir 2-9 cm sedimentation can be expected. (In years with high precipitation the maximum levels of sedimentation may even reach 1.5m annually in smaller areas).

The surface load caused by the granules under 50 μm – carrying the majority of organic material connected to the suspended sediments – is 300 kg/m^2 near the entrance, and 20-100 kg/m^2 annually at other places.

Since sedimentation occurs unevenly depending on flow conditions, dredging should be considered for certain parts of the reservoir. The changes in operation and the large water discharges may cause sediment transfer on the dammed section, which will require counter measures (Benedek, 1988).

The bed-sediments will have an important role in the future water quality of surface and, subsurface water, as well as in the drain canal. A significant proportion of the water's natural and antropogen pollution organic material (deceased plankton organisms and organic pollutants connected to suspended sediments) will end up in the silt. According to Rotschein (1976) the average organic material content of the developing silt can be estimated as 13%. Increasing enrichment of oil, adhering to suspended sediments, can be expected to take place with the increasing ship traffic (Rotschein, 1976). The consequences of the oxygen-consuming mineralisation processes taking place in the silt is an increase in the vegetable nutrient content of the sediment. As a result of the rotting organic material content of the occasionally several centimetres thick bed-sediment, oxygen-poor facultative anaerobic, or anaerobic fields can develop particularly in the shallower parts of the reservoir. Coinciding with anaerobic decomposition gas is formed and large amounts of deposited vegetable nutrients can return to the water (Berczik, 1988). The mixing of anaerobic fields (e.g. during peak mode operation) could increase the toxic load of the water passing through the reservoir (Berczik, 1988). Thus, the reservoir should be formulated in such a way that the possibility to create areas with slow flow minimal (WHO-VITUKI, 1976; VITUKI, 1978; Hock, 1982; VIZITERV, 1985; VGI, 1985; VITUKI, 1985).

A relatively permanent granular bed would be favourable for the development of zoobenthos and [suspended sediments otherwise not characteristic to riverbeds.] The prevailing north-western winds carry the rising suspended debris to the right hand bank section (Rotschein, 1976), which thus requires continuous removal. Attention should also be drawn to the fact that after flooding, the dissolved oxygen concentration of water draining through the top layer, presently covered with plants and humus deposit (25-40 cm), may reduce to as low as zero even if the oxygen supply of the reservoir water is favourable. For this reason iron and manganese re-dilution may occur in the water filtered through the sediment (VITUKI, 1988b).

The majority of toxic, inorganic micro-contaminants reaches the bed-sediment via the depositing suspended sediments. Since the greater part of the heavy metals, bonds primarily to suspended sediment having a granule size smaller than 50 μm (VITUKI, 1988b), their enrichment of the bed will take place at slow flow areas, mainly in the bottom third of the reservoir.

The large vegetable nutrient content of the bed sediment and the increasing transparency of the water, create advantageous conditions for the mass reproduction of phytoplankton (VGI, 1985; VITUKI, 1985b). The water's transparency, which is 40-70 cm in the Rajka section (Dváhally, 1987) may increase significantly in the reservoir. It should be noted here that no linear connection was found in the Danube's Rajka section between the a-chlorophyll content of the water and the concentration of vegetable nutrients (nitrate and phosphate ions). The river is abundant in nutrients, so these have no limiting effect on the development of a large phytoplankton population (Bartalis, 1987).

In the right hand bank sections of the reservoir, which are more susceptible to siltation, the light may even reach the bottom and thus enable the development of vegetation characteristic to shallow waters (Rotschein, 1976). To avoid this, the reservoir should not have any parts with low flow speeds (VITUKI, 1978; VGI, 1985; VIZITERV, 1985; VITUKI, 1985b).

During the summer even blue algae may appear in the shallow, slow flow-rate and high water temperature parts of the reservoir. However, when carried to parts with higher flow-rates, these would probably die (Rotschein, 1976).

The 1-2°C average increase in water temperature, which will develop in the Dunakiliti reservoir in the summer, will effect the entire Hungarian section of the Danube.

Parallel with the increase of the phytoplankton population in the water favourable light conditions, the volume of dead algae in the water also increases, which deposits on the bed increasing the organic material content of the silt. The greater number of living and dead algae can adversely effect not only the reservoir, but also the lower, sections of the Danube (VGI, 1985; VITUKI, 1985b; VIZITERV, 1985; VITUKI, 1987). For example the COD and BOD_5 concentrations – characteristic for a given organic material content – will increase even if all waste water is 100% treated.

Another unanswered question is what procedure would be the best when faced with a possible algae boom (or other dramatic increases in e.g. oil pollution). It is by no means sure, that the proposals for quick draining are the best (VIZITERV, 1985; VITUKI, 1985b, 1987a).

The water quality of the reservoir may also be greatly effected by oxygen management. The prevailing dissolved oxygen content of the water is the result of the combined effects of a changing physical oxygen intake, turbulence conditions, the increased water surface and water temperature, in addition to the more intensive biological activity (photosynthesis - respiration) and the organic matter load (the water and sediment).

During the vegetation period the volume of oxygen created biologically grows in the water; this may even become dominant over the atmospheric oxygen intake small discharge (Rotschein, 1976; Dváhally, 1987). Rotschein (1976) dealt with the assumption of the common effects of processes influencing the oxygen management (see also Chapter 3.2).

Based on the evaluation of the expected processes outlined, Rotschein (1976) believes that if appropriately managed, the quality of the water reaching the power canal could be identical to or even better than the Danube water entering the reservoir. However, the projection of water quality conditions in the reservoir is. Complicated by the unknown volume of "self-pollution": an unfavourable side-effect of the alga population growth. Thus, the above statement of Rotschein is disputable (especially concerning the quality of the water discharged into the Old Danube).

The periodically developing unfavourable effects can be avoided the most efficiently by decreasing the pollutant load of the water entering the reservoir.

2.2 THE POWER CANAL

By way of the Dunakiliti weir, the energetically useful water-mass is led from the Dunakiliti reservoir to the 17 km long head-race canal, covered with asphalt for its whole length (VIZITERV, 1985). As a result of the rapid flow of the water, no change in water quality is expected in the head-race canal (VIZITERV, 1985).

In the course of the work-session of WHO dealing with the effects of reservoirs, the Hungarian health care authority raised the question of multinuclear aromatic hydrocarbons which might dissolve from the asphalt cover of the power canal. The Czechoslovakian investors referred to tests, according to which the asphalt used satisfies health care regulations.

After passing through the Gabčíkovo barrage system, the dissolved oxygen content of the water increases somewhat (1-2 mg/l) as a function of the prevailing dissolved oxygen saturation (VIZITERV, 1985). In saturated and over-saturated conditions this effect can be overlooked, because the excess oxygen soon returns to the atmosphere (Berczik, 1988).

The increasing discharge leads to damages on living organisms, and thus the plankton biomass. Therefore, the oxygen surplus of the water will probably be used for the decomposition of the deceased organisms. There is no available data on the volume of the biomass which expires as a result of these damaging effects (some experts estimate 25-30%).

No sedimentation can be expected in the head-race canal and the 8 kms long, semi-natural, dredged tailrace canal, because of the high flow speeds (VGI, 1985).

Another effect of high velocities and short storage times is an unchanged water quality over the entire section of the power canal and slower biological life (VGI, 1985).

2.3 THE OLD DANUBE

With the establishment of the GNBS, the majority of the discharge of the Danube will be diverted to the power canal with the assistance of the Dunakiliti weir, and only the absolutely necessary water discharge will be directed to the 30 km long Old Danube. The necessary discharge depends on the water conditions of the Danube and the hydraulic and ecological needs of the Old Danube riverbed (VIZITERV, 1985; VITUKI, 1988). As far as we know, this demand is not yet assured by the joint plan (KET, 1977). Under the operation of the GNBS, the old riverbed of the Danube will have a role in directing floods and ice (VIZITERV, 1985).

For low and medium flow water levels, the water of the Old Danube riverbed will be made up of reservoir water draining through or let through and from the draining waters coming from the drain system of the flood plain. Depending on the mix-ratio of the two different waters, the water reaching the Old Danube is expected to be of higher quality (VIZITERV, 1985).

The operation allows the flushing of the given river section with larger water discharge in case of necessity (e.g. alga boom) in order to assure an "optimum" water quality. However, the riverbed can only be rinsed with reservoir water (VIZITERV, 1985; VITUKI, 1985b, 1987b).

Professionals have had lengthy debates on the required volume of water delivery to be assured on the Szigetköz section of the Danube. The experts estimated the necessary volume of water substitution at 50 to 500 m^3/s (OMFB, 1984). Anyhow, the planned 50 m^3/s discharge makes it difficult for all the demands on the old riverbed of the Danube to be fulfilled, that is it should:

- be worthy of being a border river (that is wide enough);
- be free of dangerous water quality changes;
- maintain its wildlife character;
- satisfy other water use demands (e.g. small boating);
- be suitable for directing floods and ice (OMFB, 1984).

The satisfaction of the demands supposes the establishment of the widest possible water surface and the greatest depth. Efforts were started in 1986 to solve the problem at VITUKI (VITUKI, 1986-87;VITUKI, 1988a).

In the following paragraphs, there are clear signs of the uncertainties connected to the formulation and operation of the Danube section:

> "According to plans the Danube riverbed, having a water delivery of 50-200 m^3/s, should be maintained. No underwater weirs and structures shall be built in the riverbed" (OMFB, 1984).

At the same time tests were carried out in VITUKI (VITUKI, 1988a) in 1988 to determine the optimum location of chutes and underwater weirs for accelerating the speed of water flowing across the fords. This way the water's oxygen content could be increased and even small boat traffic could be assured. Under operating conditions the required water-depth can only be achieved by damming, that is by constructing underwater weirs. Physical model tests demonstrated that various still areas would develop with different flow levels and also, the possibility of siltation.

If structures are built, the riverbed would divide into reaches consisting of slow and rapid flow areas. The slow sections will favour sedimentation, the rapid areas, oxygen intake. The professional literature of the GNBS does not deal with the hydrobiological processes taking place in these reaches; we have only negative assumptions.

Taking into consideration the water discharge at Bratislava, it can be stated that water delivery exceeding 50 m^3/s can only be expected on average for 14 days annually in the old riverbed (VGI, 1976).

This also raises the problem of removing the macrovegetation which will flourish in the meantime; chemical treatment is out of question (VGI, 1985).

The low flow levels – characteristic to the Danube section for most of the year – assure the appropriate light climate for algae formation. This seems to be proven by the experience in the abandoned Danube riverbed by the barrage system at Melk (VITUKI, 1988c). The light reaching to the bottom (1-1.5 m) in the shallow reservoir allowed the intensive development of algae even at the end of September. Groups of algae surfaced from the bottom layer as a result of the oxygen released from the colonies.

If the discharge in the Danube exceeds 4,000 m^3/s, the tail-race canal's redamming effect manifests on the lower 15 km section of the Old Danube. This section of changing flow direction, speed and discharge will be characterised by the mixing of the two waters of different quality coming from above and below.

The plan aimed to eliminate the redammed section (VIZITERV, 1985), which also affects the water quality of lower Danube sections, which also affects by envisaging the establishment of a 1,200 m^3/s connection between the tail-race canal and the Old Danube. As far as we know, this shall not be implemented in the course of the construction. However, the above-mentioned shortening of the critical Old Danube section would offer a solution for the unfavourable water quality conditions.

In order to protect the quality of the water, special care has to be taken not to let any oil pollution from the reservoir reach the river section in question.

2.4 The Danube section between Szap and Vének (1,981-1,794 rkm)

The water of the power canal is directed back into the old Danube riverbed at Szap.

The quality of the water will be determined by the mixing ratio of the two waters, which will be dominated by the power canal under medium flow conditions. The old Danube riverbed will only take a major part in water transport under large water delivery (>4,000 m^3/s).

The water level of the nearly 20 kilometres long section is going to be slightly effected by the damming of the Nagymaros barrage system, while the daily distribution of the flow and the connected changes in water levels, will be determined by the operation of the Gabčíkovo power plant.

Under peak mode operation, the largest fluctuations in the GNBS system water levels, appear on the Danube section between Szap and Vének, and on the lower section of the power canal above that. The fluctuation of water levels with average is +/-2.3m in the tail-race canal, +/-2.3m at Szap, and +/-1.3m at Vének (VIZITERV, 1985).

It is not yet known how the fluctuation of the water level damages the living populations on the rocks of the bank and their oxygen-producing function.

According to examinations, living organisms have a minor role in determining the water's dissolved oxygen content; they account for 0.1-2.1% of biologically produced oxygen (VITUKI, 1985b). It is important, but not yet defined, what will happen if the living cover loses its habitat (VITUKI, 1985b).

2.5 The Mosoni Danube

Theimplementation of the GNBS will eliminate the present periodical water supply of the Mosoni Danube and improve the water quality of the upper section.

Improving water quality can be expected in the rapid flowing upper section, since a constant water delivery (20 m^3/s) is assured from the good quality water of the drain canal (VIZITERV, 1985). However, as colmitation progresses further in the future, water substitution from the reservoir may become necessary.

The "II." category Lajta and the waste waters of Mosonmagyaróvár will have a temporarily unfavourable effect on water quality in the middle section of the Mosoni Danube.

Part of the suspended debris deposits above the Mosonmagyaróvár weir. Underneath it, as a result of the connected industrial and communal waste waters the oxygen-need of the water and its plant nutrient concentration show a temporary increase, but the quality of the water remains acceptable because of the advantageous self-purification conditions of the middle section (Várday, 1987).

The problems, which require urgent rectification will be on the lower river section between Mecsér and Vének (the estuary). The water quality of this section already suffers from the effects of the Rába and the Rábca, and those caused by the large volume (80,000 m^3/day) of Győr's untreated waste water of (Várday, 1987). It has to be noted that the dredging (VIZITERV, 1985) of the present silty riverbed (containing organic and toxic silt) – especially under Mosonmagyaróvár and Győr (VITUKI, 1985a, 1987a) – would lead to the improvement of the water quality on the Mosoni Danube.

The water-level increase of the Danube lasting for 4-6 hours, during peak mode operation, following the installation of the GNBS, stops the flow on the lower section of the Mosoni Danube, and even back-flow may occur (VIZITERV, 1985). At the estuary, Danube water would enter the Mosoni Danube riverbed and by mixing to an ever decreasing degree with the Mosoni Danube would cause redamming. The consequential increase of water level at the estuary (Vének) will be 1.3 m, and 1 m at Győr (VIZITERV, 1985). Redamming may cause a still water section to develop under Győr for a couple of hours, which could obstruct the draining and dilution of its waste waters.

The strongly contaminated mass of water also stays together whilst flowing downstream, and as a result of biological processes, it may lose its oxygen content (see sub-chapter 3.3). The contaminated mass of water, which moves as a function of varying flow velocities – determined by the GNBS operation – passes through the section below Győr and reaches the Danube in a receding water period.

Serious deterioration of water quality and damage to wildlife can be expected on the affected section, the greatest impact will be felt by the fish population. Since the lower section of the Mosoni Danube is one of the migration routes of spawning fish (Jancsó-Tóth, 1987), it is difficult to estimate the adverse consequences to the present fish population.

If the biological cleaning and the conveying of waste water from Győr is stated not solved, it can be that the lower section of the Mosoni Danube will be the most critical section of the GNBS system with regards to water quality.

2.6 SIDE ARMS SYSTEM (RIGHT HAND SIDE)

Presently, the Szigetköz, and within that the main branch of the Danube, several flowing branches and still branches form a unified water system. If the discharge of the Danube is small (up to 1,800 m^3/s) the system is only connected to the Danube from the bed for 160-180 days per year. On such instances the majority of the side arms become still. For another 80-90 days the substitution of water only consists of infiltrating waters and the that passing small weirs. A continuous and intensive water supply from the Danube only occurs for 55-70 days per year when the discharge is greater than a 2,500 m^3/s (VITUKI, 1985b; VIZITERV, 1985). As a result of the profuse plant nutrients the compositions of the filoplankton populations in potentially politrophic waters are greatly effected by the flow-rate. (Kiss K., 1987).

Implementing the GNBS will cause a basic change in the rather diverse discharge and flow conditions of the sidearms.

The water replenishment system, established primarily to recharge the groundwater level of the Szigetköz, assures the continuous water supply of the branches with approximately 35 m^3/s (VITUKI, 1985b, 1987a; VIZITERV, 1985).

The complex structure of the system, the diverse water quality conditions, and the lack of knowledge concerning the spatial distribution of the replenishing water, does not enable any predictions on the future water quality, and especially on the degree of algae growth. Nonetheless it is possible that extensive eutrophication may occur, because of clogging in the branch system. The majority of alga and other plant over-production can be forced into the main riverbed with floods and according to some views may even reach the section of the Municipal Surface Waterworks (VGI, 1976).

2.7 THE NAGYMAROS RESERVOIR

The purpose of the Nagymaros reservoir is to balance the peak discharges arriving from the Gabčíkovo powerplant and to assure the required depth for navigation between the two barrages.

In this flow through reservoir, 95 km long, and totally different geometrically from the Dunakiliti reservoir, high flow velocities are expected to develop (*Table 2.2*) (Rotschein, 1976). As a result of its advantageous geometry there will be no still areas in the reservoir except in the depressions (VGI, 1985). The intensive water-exchange reservoir will have a relatively low (a couple of decimetres) fluctuation of water levels.

***Table 2.2**: The theoretical storage times and the average speed of the water in the Nagymaros reservoir (Rotschein, 1976) (without peak mode operation)*

	Water delivery of the Danube (m^3/s)			
	1,000	2,000	3,000	4,000
Storage time (hours)	75.0	37.5	25.0	18.7
Average water speed (m/s)	0.35	0.70	1.10	1.41

Although damming slows the flow rate, its consequences in this case will still be different (because of the constantly moving water mass) to those in the wide, relatively shallow, Dunakiliti reservoir full of slow flow-rate areas.

Although the slowing water movement allows a finer sediment fraction to deposit, the peak wave regularly mixes it up, keeping the finest sediments continuously suspended. Thus, the light climate of the reservoir will be less favourable for alga reproduction than in the Dunakiliti reservoir (VGI, 1985). As a consequence, the degree of eutrophication is not expected to exceed the amount which would reclassify the reservoir in a lower category.

The living and dead algae coming from the upper section of the GNBS system (power canal, Old Danube, Mosoni Danube) and through the branch system is superpositioned on this.

Suspended sediment can be expected to deposit directly above Nagymaros, mainly on the Lábatlan-Esztergom section (Hock, 1982; VGI, 1985). For this reason, dredging to different degrees and frequencies, will have to be carried out in the various reservoirs (VITUKI, 1985a, 1986, VIZITERV, 1985).

According to previous calculations of sediment deposition, the Dunakiliti reservoir would hardly reduce the natural suspended sediment load in the Danube (VITUKI, 1985a). However, recent hypothesis do not support this idea (see above). Moreover, without adequate information, the build-up of toxic micro-pollutants deposited in the silt with the fine suspended sediment, cannot be projected on the given section.

It is no easy task to prognose the future water quality of the Nagymaros reservoir, because four large rivers (Mosoni Danube, Vág, Garam, Ipoly) enter the area, and Győr, Komárom, Sturovo, Dorog, Esztergom and several small settlements dispose of their waste water in the Danube.

The installation of the GNBS will cause major changes in the mixing processes of the Danube and the above rivers, so the relevant examinations (flow velocity and dispersion factor) should be urgently carried out, especially in the case of the Vág (VITUKI, 1985a,b, 1987a,b).

The Tát Danube-branch is also a notable problem. This Danube branch which receives the waters of the Kenyérmezei and Unyi streams will be closed with the installation of the GNBS and the water will be pumped into the main branch. If no solution is found for the treatment of the (mainly industrial) waste waters deposited into the two streams, the water quality of the Tát affluent will quickly deteriorate, primarily due to the concentration of organic and inorganic toxic micro-pollutants (VITUKI, 1987c). Pumping the water of the side arm into the Danube might afflict the latter with a major toxic load.

Presently, the only possible prognosis on the expected water quality of the Nagymaros reservoir is that the higher population of living and dead algae will increase the organic material content of the water by about 1-2 mg/l COD. Most of the hydrochemical parameters will be determined by the amount and level of purity of the received waste waters.

The particular problem of the Nagymaros reservoir, is its effects on bank filtered water bases. These are expected to appear, primarily on the section between Lábatlan and Nagymaros, and are in relation to the regular fluctuation of the water level, its decreasing speed and the deposition of silt.

The following problems will be faced at smaller waterworks, established on bank filtered water bases in the given section:

– The regular fluctuation of water levels effects the water-supplying layers – although in a reduced and delayed form. The diurnal flow expands the ducts of the filtering layer, deteriorating the efficiency of the filtration, which in turn effects the quality of the produced water and accelerates the wear of the wells (VGI, 1985).

The constant mixing, which is characteristic of the section, inhibits the development of a biological filtration layer, and thus the possibility of bacterial contaminations in the drawn water is greatly increased (VGI, 1985). There is no information on the regeneration of the filtration layer in periods of non-peak mode operation.

– The slower of flow rate worsens the existing and potential bank filtered water supply of the region. The fine particles depositing on the slow flow areas near the banks, block the path of the water to the bank filtered wells, and may cause a fall in their productivity (WHO-VITUKI, 1976; OMFB, 1984).

– The silt with a high organic material content, deposited as a result of the slower flow velocities, starts to decompose. The oxygen content of the filtered water at first decreases, then falls to zero as a result of the several anaerobic processes linked to decomposition. Consequently, dissolved iron, manganese, carbonic acid, ammonia, hydrogen sulphide, taste and odour deteriorating organic materials, appear in the water (Hock, 1982; VITUKI, 1985b; VGI, 1985). In addition, toxic heavy metals and detergents are also expected to arise (ITUKI, 1978). The removal of the humus covering layer, which is submerged in the course of damming becoming a part of the filtration layer, might also be considered on the Danube section directly above Nagymaros (VITUKI, 1988b).

The following proposals have been made to avoid the problems which would endanger the operation and water quality of bank filtered wells:

– A solution has to be found which protects the banks by assuring both an adequate flow conditions and the decrease in sedimentation near to the water bases;

– Silt-dredging should be administered at the required sites (VIZITERV, 1985). However, this may damage the biological layer, temporarily deteriorating the water quality (Hock, 1982; VIZITERV, 1985).

One advantage is that the damming will cause a shift in the ratio of polluted ground water to cleaner water from the Danube – to the benefit of the latter. This shift will probably decrease the rate of pollution in the wells (VITUKI, 1985b; VGI, 1985; VIZITERV, 1985). Nevertheless, it is also possible that the reduction in the amount of groundwater drawn will be temporary, only to last until the new, higher, groundwater level develops.

2.8 THE DANUBE SECTION BELOW NAGYMAROS

The water quality of the Danube section below Nagymaros is determined by the quality of the water regularly passing through the GNBS. In addition, the dissolved oxygen concentration of the water increases somewhat when passing over the weir, which will most probably be used up by the decomposition of the algae (VITUKI, 1985b; VGI, 1985).

The rise in living and dead algae in the water may cause technological problems in the treatment plants for the Fővárosi Felszíni Vízművek. Some metabolism products of living algae and the metabolic materials developing with the decomposition of dead algae may result in an undesirable taste and odour in drinking water. As far as we know, no assessment has been made on the effect of the increased algae count and the secondary pollution arising from the decomposition of algae – undesirable taste and odour – on the operation of the Fővárosi Felszíni Vízmű (Budapest Water Works).

As a result of intensive dredging over the past decades, the water level of the present section comply with that planned for the GNBS system (VIZITERV, 1985). The riverbed is expected further degrade with the operation of the barrage system, which will make even thinner the filtration layer already damaged by the dredging. There are two possible solutions: the replacement of gravel on the riverbed, or the establishment of another barrage system under Budapest.

Special attention should paid to water bases in the course of waterbed regulation following start of G/N Project operations in order to maintain the present quantity and quality filtration layer VIZITERV, 1985). In addition to all this – independent to the implementation of the GNBS system – the need of further treating bank filtered water, beyond chlorination should not be forgotten(VITUKI, 1985b; VIZITERV,1985)

3. The Role and Application of Water Quality Models

First of all, this chapter will discuss the advantages and limits of modelling including methodological issues. As the next step, a brief summary will be provided on previous modest modelling attempts concerning the GNBS. Three problematic issues will then be touched: the oxygen management of the Mosoni Danube under peak mode operation, the expected eutrophication of the Dunakiliti reservoir, and the organic material decomposition processes examined in both the reservoir and the covering layer of the Mosoni river-bed. With a comparison to Chapter 2, the results give numerical data on how important the discussed issues are and at the same time lead to basic conclusions for the future experimental and modelling program (discussed in the next chapter).

3.1 THE NECESSITY AND LIMITS OF WATER QUALITY MODELLING

As has already been demonstrated, the problems raised by the GNBS can be put into three groups:

(a) design;

(b) operation management;

(c) monitoring.

The long and short term future developments in water quality – which depend mainly on material transport conditions – will be decisive for the design and operation of GNBS. This implies that the monitoring system should not only characterise the "resulting" water quality, but also the participating material transport processes too (various kinetic constants, reproduction and decease rates, etc.). In addition, it is also necessary to observe changes in the composition of aquatic biological communities of the pollution levels than integrated chemical components. There are certain cases, when the major limiting factor of the design or operation management is the "permissible" change in the composition of these communities.

Thus, the sediment transport considerations should be key issues in the preparation of the final design, the operation management and the monitoring system (which may have various levels, see chapter 4). However, without applying water quality (ecological) models these cannot be established for at least two reasons:

– the large size and complex character of the task;

– the projection are for a non-existing system.

Since modelling on the basis of similarity ("scale model tests") is not possible because of the complex interaction of physical, chemical and biological processes, the use of mathematical water quality models is necessary. These have a rather extensive literature (for example Thomann, 1972; Scavia and Robertson, 1979; Biswas, 1981; Loucks et al, 1981; Orlob, 1983; Somlyódy and van Straten, 1986; Thomann and Mueller, 1987) which is regularly applied in a number of countries. However, this does not apply in Hungary, where, from among the results of the past 15 years (Sajó, Duna, Balaton and non-point-like pollutants) only the eutrophication model of the Balaton was actually applied (Somlyódy and van Straten, 1986); the others did not go beyond methodological development. The spread of the accumulated knowledge was hindered by the low number of really important issues and the underrated role of modelling in solving environmental management problems.

The water quality and ecological models have a history of nearly two decades. The original, naive approach was to try and prepare large and complex models which can be generalised for a variety of uses. However, by the 1980s it became clear that the above goal could not be realised and now, only use-specific, small models are developed. Their design vary depending on the *in-situ* conditions (whether they are natural or modified by humans), the objective of the model (scientific exploration, planning, operation management, etc.). and its space and time scale (local, or regional; hour, day, season, year or years). Considering the practicalities of the task, we should try to limit our expectations; the comparative, relative evaluation of plan alternatives (or operation strategies) is a much more realistic goal than overall evaluation.

It was mentioned earlier, the application of water quality models is a must in our case. The next question is whether the models themselves will be capable of solving the arising problems. The answer is definitely negative, unless their development is closely linked to an appropriate data-collection and experimental program.

At the start of the modelling process, three themes are analysed:

(a) the receiver and its region;

(b) the character of the "problem" (e.g. oxygen management, or eutrophication) and;

(c) the goal (or goals).

On the basis of the above we are able to develop a model, which best suits our goals. In the development stage, two different fields of knowledge will be used (Eykhoff, 1974): theoretical and experimental. The first is based on natural laws (e.g. conservation of mass and energy), and produces the basic structure of the model. For example, the equations of Saint-Venant in hydraulics would be used to determine a one dimensional, free surface flow.

However, the basic model structure cannot always be formulated because of the very nature of the problem; this is typical of hydraulics. The situation is similar with regards to water quality, where the basic hydrochemical and hydrobiological laws are presented in such a specific, complex and under-explored way that their initial mathematical wording is frequently impossible. Of course there are cases where the model can be formulated on the basis of theoretical knowledge, but a comparison with observations often leads to major differences.

Whichever case it may be, knowledge gained from experiments should be included in the formulation process (selection of condition variables and parameters, kinetics of processes, calibration, certification of model structure, validation, etc.). The final model structure is always achieved by the synthesis of theoretical and experimental knowledge. This can only be reached if there is close co-operation between the model development and the experimental work (Beck, 1982; Somlyódy, 1982).

In this case, the primary advantage of modelling is that it allows the discussion of the sediment transport over a large area (that is why it is necessary). However, this can only be realised if adequate data-collection and experimental programs are linked to the development (otherwise, any predictions deduced from the basic model, are without any justification, or proof lacking experimental corroboration). Hereinafter, some problems – raised by the GNBS and summarised in the previous chapter – will be analysed by models with the double aim of illustrating the weight of these issues and indicating the areas of uncertainty in the deduced hypothesis. The latter arise from the determination of various processes and parameters on the basis of previous studies.

3.2 PRELIMINARY WATER QUALITY MODELLING WORK

There have been no comprehensive, water quality model developments for examining the effects of the GNBS. One can only speak of numerical assumptions and tests with occasional, simplified models. These can be summarised as follows, in chronological order:

(1) In 1964, with the methods of Natermann (1952) VITUKI examined the expected, average oxygen management conditions of the Esztergom-Nagymaros section of the Danube following the establishment of the Nagymaros weir (VITUKI, 1966). In this work, the effect of the sediment on photosynthesis, respiration, nitrification and the oxygen management was overlooked – in accordance with the contemporary level of water quality modelling. It was pointed out that if the discharge is less than 3000 m^3/s, the oxygen consummation exceeds the intake by diffusion, and that this difference grows as the discharge diminishes.

(2) The next assessments, based again on the methods of Natermann (1952), were performed nine years later on the upper reservoir. It was demonstrated that storing water in the reservoir was expected to affect favourably the oxygen conditions (to a decreasing degree as the oxygen concentration approached the maximum), because the slower flow is counterbalanced by the water surface and the wind. At the same time attention was drawn to the heterogeneity of the reservoir, and the problems arising from the shallow water and the presence of pangó areas (VITUKI, 1973).

(3) The first model-type examination of the effect of the two reservoirs on oxygen management was carried out as late as 1978. The following factors were taken into consideration by the model: BOD_5, BOD_5 decomposition factor, BOD_5 increase in the reservoirs as a result of the waste water inlets, bed-silt decomposition factor, dissolved O_2 concentration, diffusion oxygen intake, the volume and surface of the reservoirs, the inflow of the reservoir and theoretical storage time. The following approaches and assumptions were used in specifying the water quality model:

– The barrage system consists of two parts, namely the Dunakiliti reservoir and the Nagymaros reservoir;

– The waste waters entering the reservoirs mix immediately with the water;

– There is no peak mode operation;

– Oxygen transport connected to biological production can be overlooked;

– The theoretical storage times (fill-up times), calculated from the discharge and the volume of the reservoirs, can be applied in the calculations;

– Plants and humus are removed from the reservoirs.

Basically, the applied model was a Streeter-Phelps connection system in the form of a differential equation system supplemented with the decomposition in the alluvium. It considered the average monthly discharge and the dependence on the water temperature (as a monthly average). The results of the calculations can be summarised as follows:

– Damming has an advantageous effect on BOD_5 in both the Dunakiliti and Nagymaros reservoir. This is a direct consequence of the significantly increased storage time;

– Damming has an unfavourable effect on dissolved oxygen: on the one hand, the above-mentioned BOD_5 reduction consumes large volumes of oxygen, on the other, however, the oxygen intake conditions are also modified (as has been referred to in the previous point).

According to the results (VITUKI, 1978) BOD_5 values will decrease by an average 0.5-1.0 mg/l under Nagymaros, which, even in the summer months, does not lead to a dissolved oxygen concentration below 7 mg/l (with the above assumptions).

(4) In the course of the work outlined it became evident that the water quality problems of the GNBS can only be explored with a comprehensive research and experiment program, which would also set the foundations for modelling. However, the program prepared jointly in 1978 by the VITUKI and the MTA Dunakutató Állomás for the Bratislava-Budapest section (which would have included the co-operation of the regional VIZIGs) was not accepted, in spite of the fact that it could have produced solid conclusions on sediment transport.

Following the review of previous water quality models, we will introduce the procedures of the present project. Firstly, we will deal with the modification of oxygen management conditions in the Mosoni Danube.

3.3 The modification of oxygen management in the Mosoni Danube under peak mode operation

It has to be determined what effect the fluctuating water movement in the Mosoni Danube – developing as a result of peak mode operation – will have on the volume changes of dissolved oxygen concentration over time

– without the treatment of waste waters;

– with biological purification, taking into consideration both base and rainfall loads.

3.3.1 Descriptive equations

The classical Streeter-Phelps connections built into the equation of long section dispersion, allows the determination of the effect of flood-regression type water movements. The assumptions are the following:

(1) Oxygen is only absorbed by the decomposition of organic material characterised by BOD, while the role of nitrification, photosynthesis, respiration and the sediment can be overlooked;

(2) In the river, total mixing occurs immediately when a flow joins it;

(3) the coefficients of the equations are constant in space.

Thus, with

L = BOD and the lack of oxygen

$D = c_S - c$

where c is the current value of dissolved oxygen concentration, while c_S is the saturation concentration, the following

$$\frac{\partial L}{\partial t}+\frac{\partial L}{\partial x}=E\frac{\partial^2 L}{\partial x^2}-(k_1-k_3)L,\ (1)$$

and

$$\frac{\partial D}{\partial t}+\frac{\partial D}{\partial x}=E\frac{\partial^2 D}{\partial x^2}-k_2 D+k_1 L,\ (2)$$

single-dimension connective-diffuse equations can be written, where t is time, x the longitudinal co-ordinate, U the longitudinal speed, E the longitudinal dispersion factor, k_1 the decomposition factor (l/day), k_3 the sedimentation factor (l/day) and k_2 the oxygen intake factor (l/day). As a result of total mixing, the total volume in equations (1) and (2), is an integral-average referring to the cross section. The solution requires the starting conditions

$$L(0,x) \text{ and } D(0,x),\ (3)$$

and the knowledge of peripheral conditions (the domain is U-shaped because of the negative speeds (-X, X)):

$$L(t,-x),\ D(t,-x) \text{ and}$$

$$L(t,x),\ D(t,x),\ (4)$$

The solution referring to permanent conditions preceding peak mode operation can be used as a preliminary condition:

$$L(0,x)=L(0,0)\exp\left[-(k_1+k_3)t\right],\ (5)$$

$$D(0,x)=L(0,0)\exp(-k_2 t)+\frac{(k_1+k_3)L(0,0)}{k-(k_1+k_3)}\left\{\exp[-(k_1+k_3)t]-\exp(-k_2 t)\right\},$$

where x=t•U (see for example Benedek and Literáthy, 1979, Thomann and Mueller, 1987). The place of the waste water inlet is x=o, the river flow (in this case) is Q, and the waste water discharge is q

$$L(0,0)=\frac{L_{ww}q+L_r Q}{q+Q}, \quad (6)$$

$$c(0,0)=\frac{c_{ww}q+c_r Q}{q+Q}, \quad D(0,0)=c_{ww}-c(0,0),$$

and appropriately, the indexes refer to "waste water" and "river".

To continue the analysis, characterised by the relationships (1)-(4) in the (-X, X) domain, equations (6) are boundary conditions, where the concentrations of water coming from the right or the left should be used instead of the L_r and c_r background concentrations.

In relation to assumptions (1)-(3), please note that:

- nitrification may lead to a greater decrease in dissolved oxygen concentration than that calculated, but in this case the role of photosynthesis and respiration can be overlooked;
- we presume several kilometres are required for total mixing, which means that a local oxygen deficit, higher than what was calculated, may also occur;
- assumption (3) was used exclusively to check the order of magnitude of the calculation.

3.3.2 Numerical solution

The problem outlined by equations (1) and (2) can be solved to give an approximate result by the method of partial differentiation in such a way that after discretion by axis x (Δx, Δt), the solution referring to the (t+Δt) period is obtained in three subsequent steps, by applying the operator of convection, reaction and diffusion. The procedure's advantage is that in the various steps different types of solutions can be chosen according to their precision, stability, efficiency etc.

By using that in our case, velocity is assumed to be constant in x (but changing in time), the method of characteristics can be applied satisfactory, since by choosing Δt=Δx/U(t) the numerical dispersion can be ruled out fully. Thus the convection is a simple transposition from point (i, j) to point (i+l, j+l). According to the

$$L_{i+1}^{j+1,*}=L_i^j \text{ and } D_{i+1}^{j+1,*}=D_i^j,, \quad (7)$$

equation (where i is the x co-ordinate and j is the y co-ordinate), whose indexing is modified appropriately in the case of negative characteristics.

As the second step, equations (5) are applied for the $L_{i+1}^{j+1,*}$ and $L_{i+1}^{j+1,*}$ values (substituting the former for L(0, 0) and D(0, 0)) and thus, the reaction members are taken into consideration. Finally, for an interim solution of the received $L_{i+1}^{j+1,**}$ and $D_{i+1}^{j+1,**}$, we use the well-known, explicit scheme of diffusion,

$$L_i^{j+1} = aL_{i+1}^{j+1,**} + (1-2a)L_i^{j+1,**} - aL_{i+1}^{j+1,**}, \quad (8)$$

$$D_i^{j+1} = aD_{i-1}^{j+1,**} + (1-2a)D_i^{j+1,**} + aD_i^{j+1,**},$$

which is stable provided $a = E\Delta t/\Delta x^2 = 1/2$.

At the same time, equations (8) offer the final solution for the (j+1) time period.

3.3.3 The assumption of parameters

The k_1 decomposition factor is a function of the waste waters' composition, the degree of purification and the character of the water flow. In the case of communal waste waters, its value moves between 0.1/day and 0.4/day (Mills et al 1982; Benedek and Literáthy, 1979; Thomann and Mueller, 1987). The professional literature offers a number of relationships for the oxygen intake factor (see the previous references). One frequently used model comes from Churchill:

$$k_2 = 5.03\frac{U}{H^{1.67}},$$

where H is the depth of water (in the case of the present problem, the values given by the relationship for k_2 are approx. 0.5/day). The saturation concentration is determined by Henry's law. Its value is available as a function of temperature in both tables and approximating graphs. Finally, the factor of longitudinal dispersion can be projected from various empirical modelling (Somlyódy, 1985). In this case the 2-10 m^2 domain seems to be realistic.

It has to be emphasised that the above parameters are system-specific, that is their value should be determined by measurements in each case. If no measurements are available (as in our case), values taken from the professional literature should be used, and the sensitivity of the solution examined by methodically changing the parameters.

The temporal change of flow velocities and the pollution load are also necessary to perform the calculations concerning the Mosoni Danube. The former can be obtained by calculations carried out with the help of the non-permanent water movement equations of the impact section of the Danube (VITUKI, 1988a). In the case of a 20 m^3/s and 41m^3/s discharge, the 24-hour cycle can be divided into three periods, in which the velocity is approximately constant. Thus, for example with KET 2000/700 peak mode operation, the characteristic duration and velocities are as follows (negative velocities refer to reverse flow):

$20 m^3/s$ discharge		$41 m^3/s$ discharge	
Average velocity	Duration	Average velocity	Duration
V_1=0.44 m/s	T_1=8 h	V_1=0.49 m/s	T_1=8 h
V_2=-0.32 m/s	T_2=6 h	V_2=-0.44 m/s	T_2=6 h
V_3=0.35 m/s	T_3=10 h	V_3=0.48 m/s	T_3=10 h

Finally, the pollution load data and their inferences (for both dry and rainy periods) are included in Annex No.2. When the dry weather load was projected, the BOD_5 planning data of the Győr water treatment plant were used deliberately, in other words we did not take into consideration the total BOD ($BOD\infty$) which may be much higher than the five-day BOD depending on the degree of nitrification. Accordingly, the actual dissolved O_2 will be less favourable than presented below.

3.3.4 Presentation of the results

(a) Present conditions

Taking k_1=0.25/day, k_2=0.50/day, k_3=0 and E=5 m^2/s and supposing average parameters, when the discharge Q=20m^3/s, the concentration of dissolved oxygen only decreases by about 2 g/m^3 up to the estuary section of the Mosoni Danube in dry weather in dry weather conditions. However, the situation becomes much worse if the runoff load is taken into account: according to the projection of Annex No.2 there is 5 kg/s BOD load for a one-hour duration of a rainfall with a one-year return period. This creates a shock-like load which reduces the smallest dissolved 0_2 concentration to below 1 g/m^3 for an approximately 5 km long river-section for a couple of hours (see *Figure 3.1*, showing the average derived from a 24-hour simulation using the extreme values). The developing conditions are similarly detrimental if the discharge is seriously reduced, for example, anaerobic conditions develop when Q=5 m^3/s in dry weather conditions (about 6 km below the inlet).

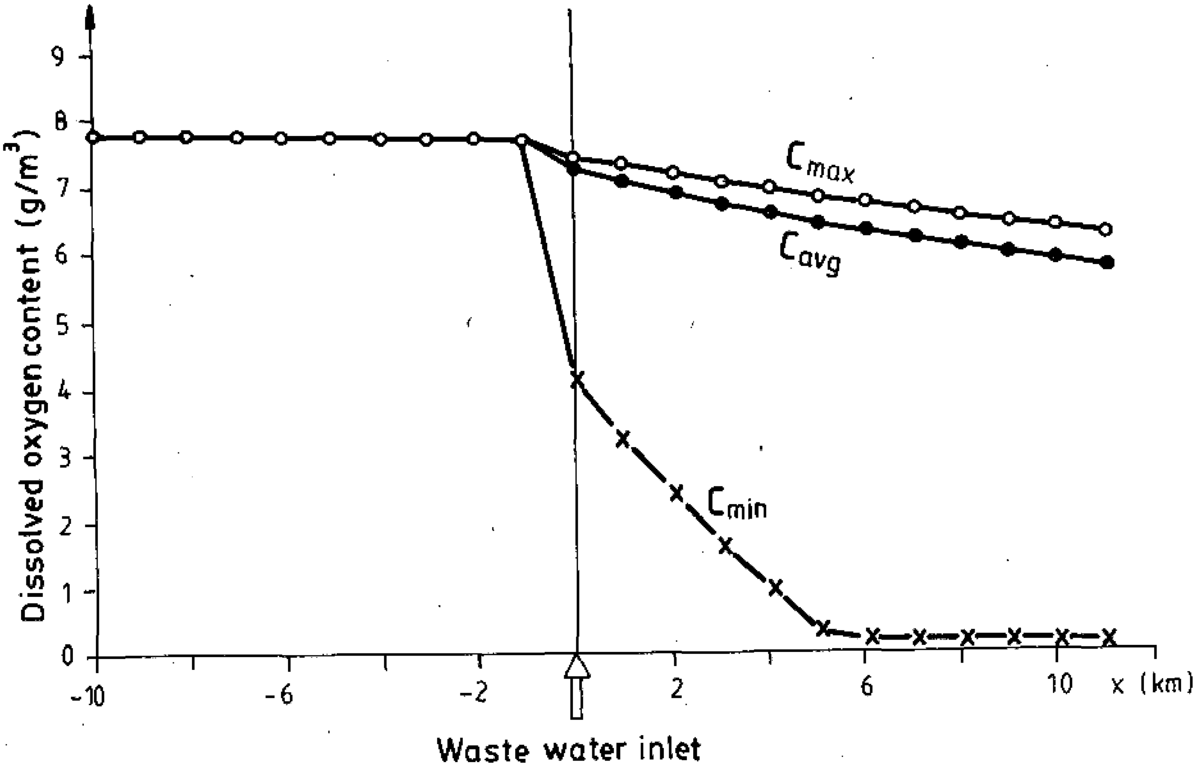


Figure 3.1: The effect of one-year frequency rainfall on the present river section ($Q = 20\ m^3/s$): changes in dissolved oxygen concentration

(b) Changed conditions

As a result of the fluctuating water movement, and higher storage times in the Mosoni Danube, the peak mode operation produces characteristically non-permanent and much worse conditions than the original, which is illustrated clearly by the *Figure series 3.2* on base load and rain water (the parameter values are identical to the previous case). According to the summarising, dry-weather Figure (3.3), the greatest decrease in dissolved O_2 reaches 5 g/m^3 (the scale differs from that of the previous figure).

Naturally, the results arrived at above, depend on the sensitivity of the solution concerning the two most important parameters, the k_1 decomposition and the k_2 oxygen intake factor. This is shown by *Figures 3.4 and 3.5*. It can be seen that the 60% increase of an average value of k_1=0.25/day, characteristic of communal waste waters, results in an approximately 80% reduction in the lowest dissolved O_2 giving a value below 1 g/m^3. The importance of the oxygen intake factor is smaller in the given area, because it only effects one of two variables (D and L). The effect of different peak mode operations is relatively unimportant if the average, daily discharge remains unchanged. The increase of the latter has a positive effect by increasing the dilution ratio (Q=41 m^3/s and 60 m^3/s were also examined).

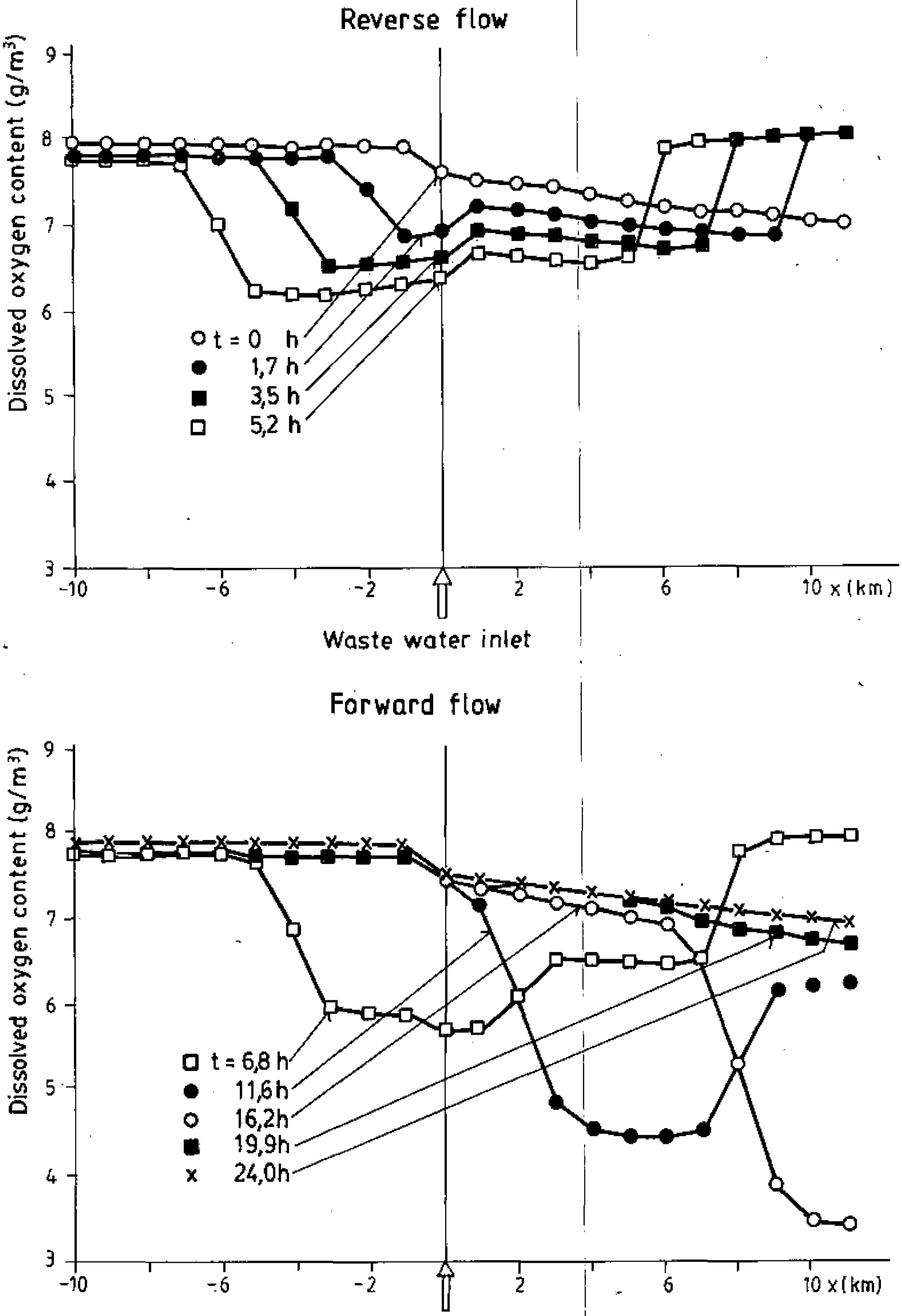
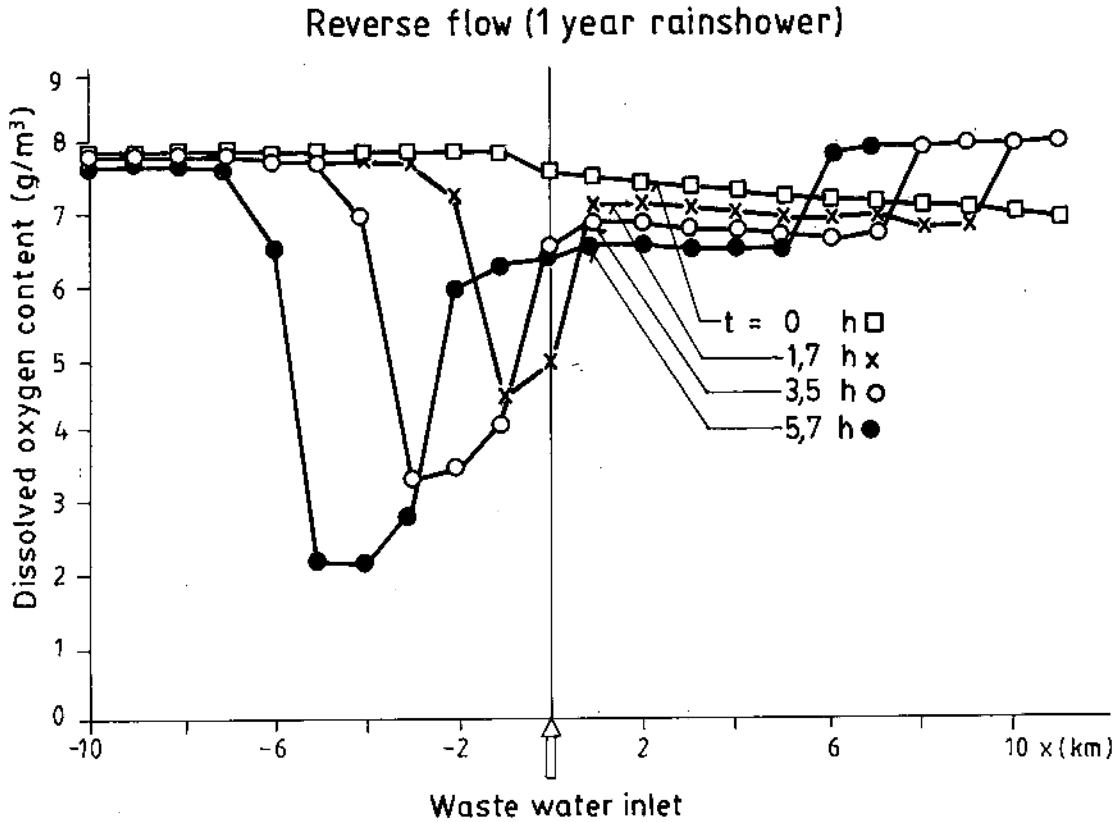


***Figure 3.2a**: The temporal and longitudinal direction change of dissolved O_2 concentration in the Mosoni Danube (basic load)*



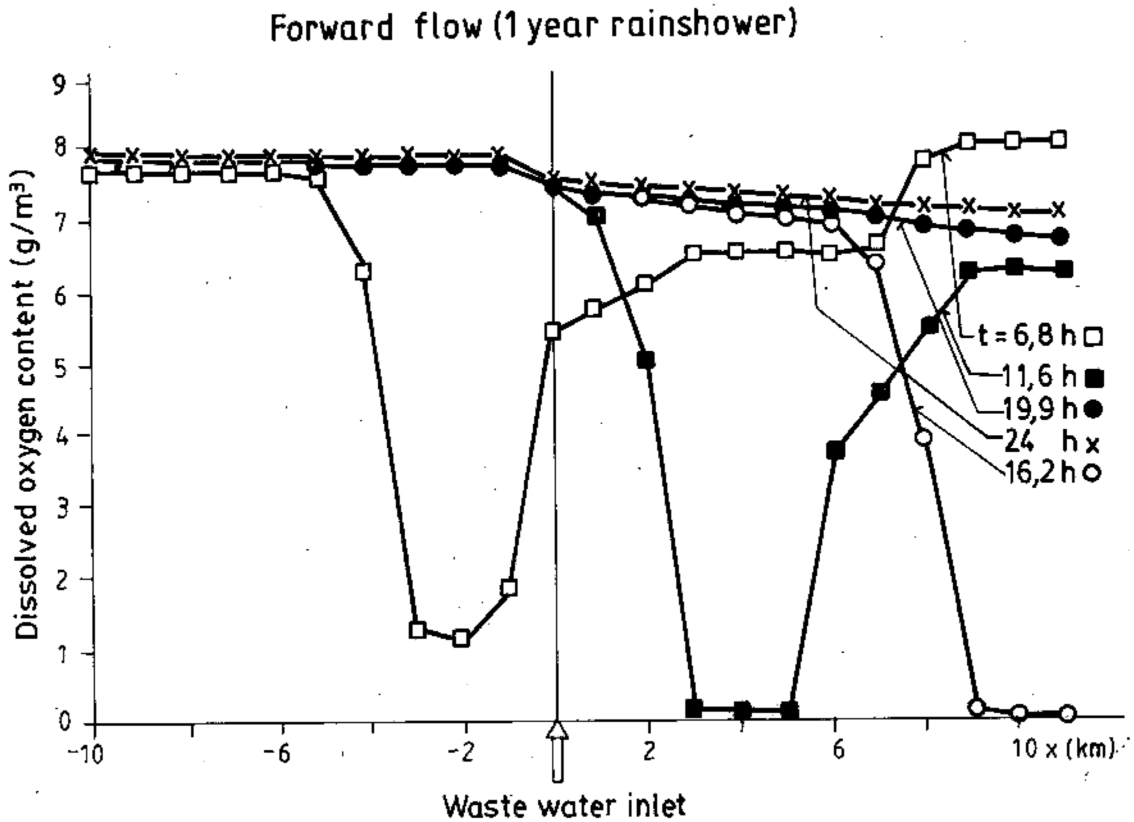


Figure 3.2b: The temporal and longitudinal change of dissolved O_2 concentration in the Mosoni Danube (pollution from basic load and one -year

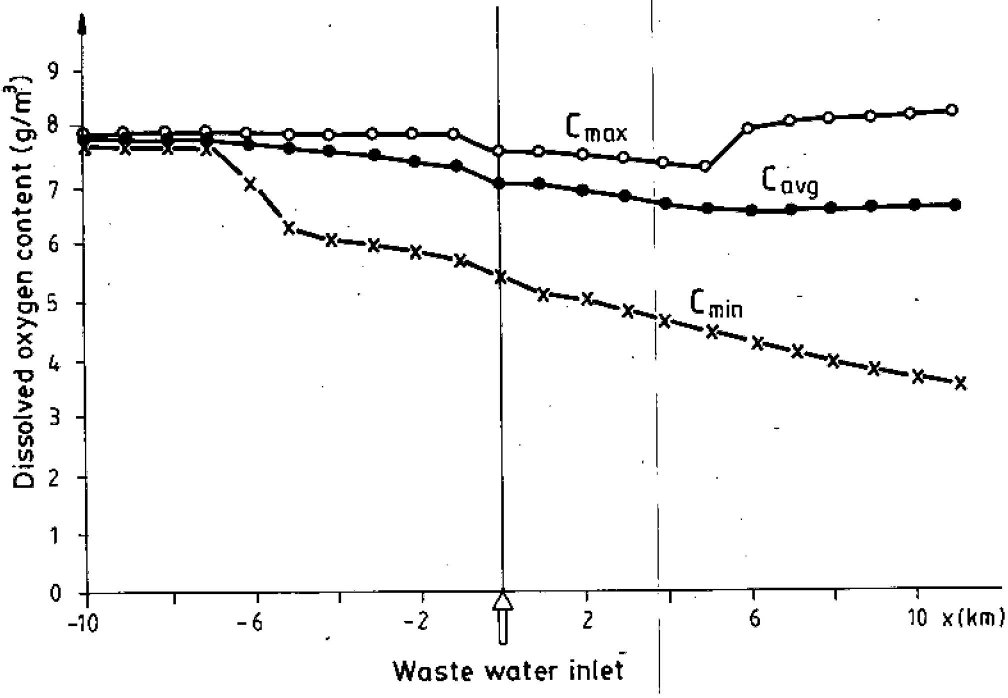


Figure 3.3: The effect of dry weather waste water inlets on the river, redammed because of peak mode operation

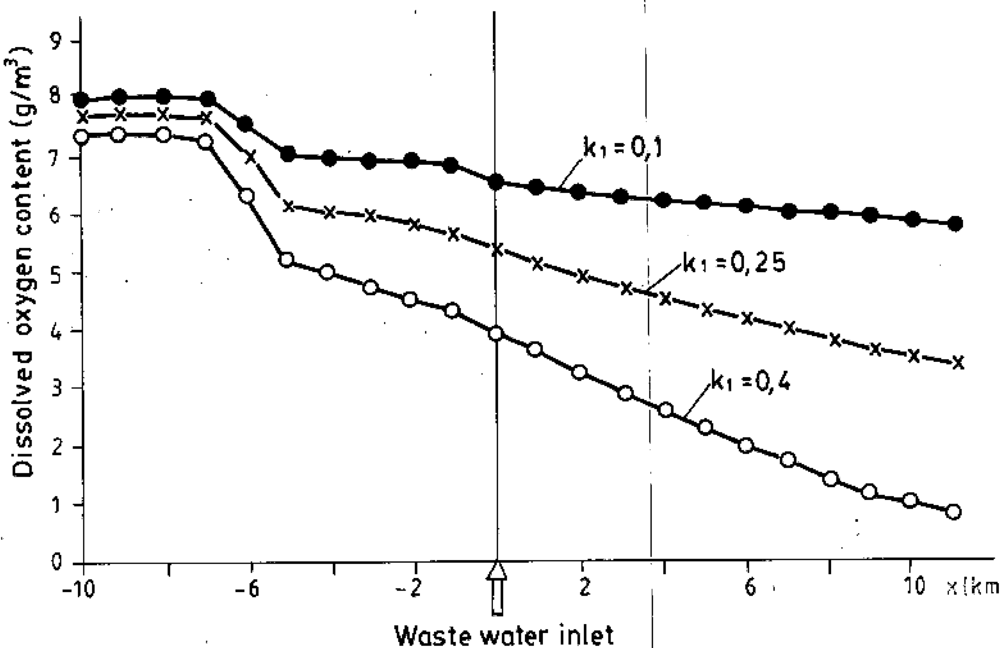


Figure 3.4: The sensitivity of the calculation to changes in the decomposition factor (1/day): changes in the daily minimum dissolved O_2 concentration

Rain water causes extremely adverse conditions (*Figures 3.6 and 3.7*) even with a 5 mm/hour intensity. This is not greatly improved even by a higher-than-average longitudinal dispersion factor (10 m^2/s).

In the above it was supposed that rain pollution load reaches the receiving water without delay, which of course, can only be regarded as an extreme case when considering the approx. 50,000 m^3 storage capacity of the reservoir. For this reason, the duration of the load will vary between 1-5 hours which is probably more realistic.

Figure 3.8 shows that oxygen-lacking/anaerobic conditions can still occur among such conditions on shorter river sections – but a longer rainfall duration was used. The increase in dilution again causes a favourable change (*Figure 3.9*), but the smallest realistic dissolved O_2 concentration is still below 2 g/m^3 even in the case where Q=41 m^3/s.

All in all it can be stated that without biological waste water treatment, anaerobic conditions can still develop on the Mosoni Danube with peak mode operation under a dry-weather basic load. Presuming an 80% efficient purification, this danger can be avoided and the decrease of dissolved oxygen would not exceed 2 g/m^3 (if the role of nitrification and cross-direction mixing is overlooked as stated at the start of the sub-chapter). However, the problem cause by rainwater is still present. One solution would be appropriate balancing or flow-through to the Danube.

As was already mentioned, the effect of primary production and respiration on the oxygen management was overlooked in point 3.3.1. However, following the implementation of biological waste water treatment, this supposition would not be valid with the changed light conditions. Thus the examination of trophity conditions in the Mosoni Danube would also become necessary.

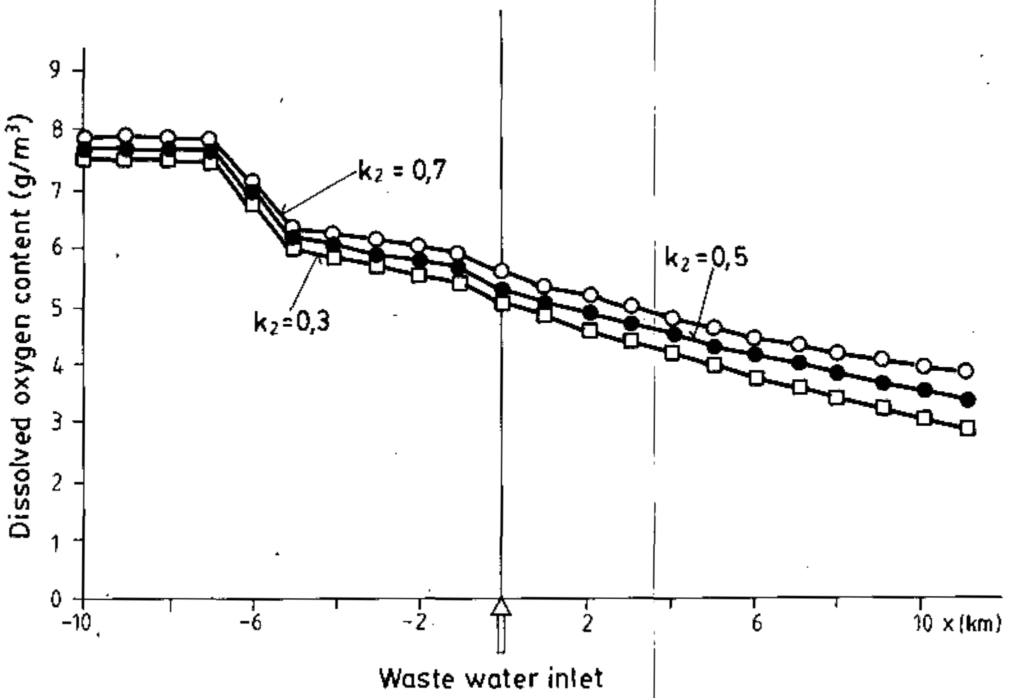


***Figure 3.5**:The sensitivity of the calculation to changes in the oxygen intake factor (1/day): C_{min}*

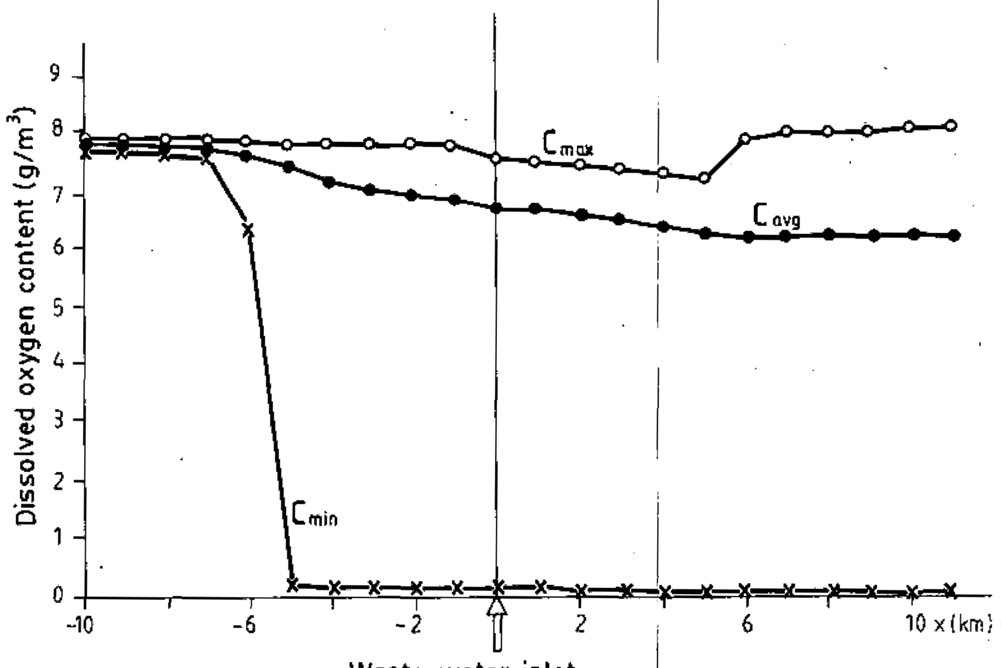


***Figure 3.6**: The effect of a one year frequency rainfall on the dissolved concentration of O_2 on the redammed river*

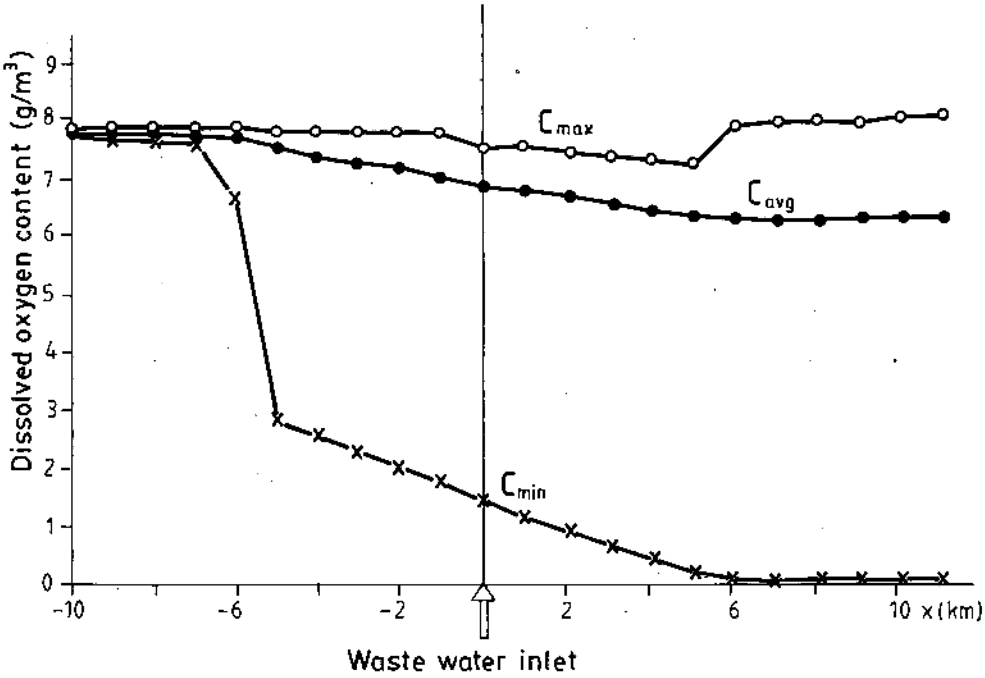


***Figure 3.7**: The effect of 5mm/h intensity precipitation on the redammed river section*

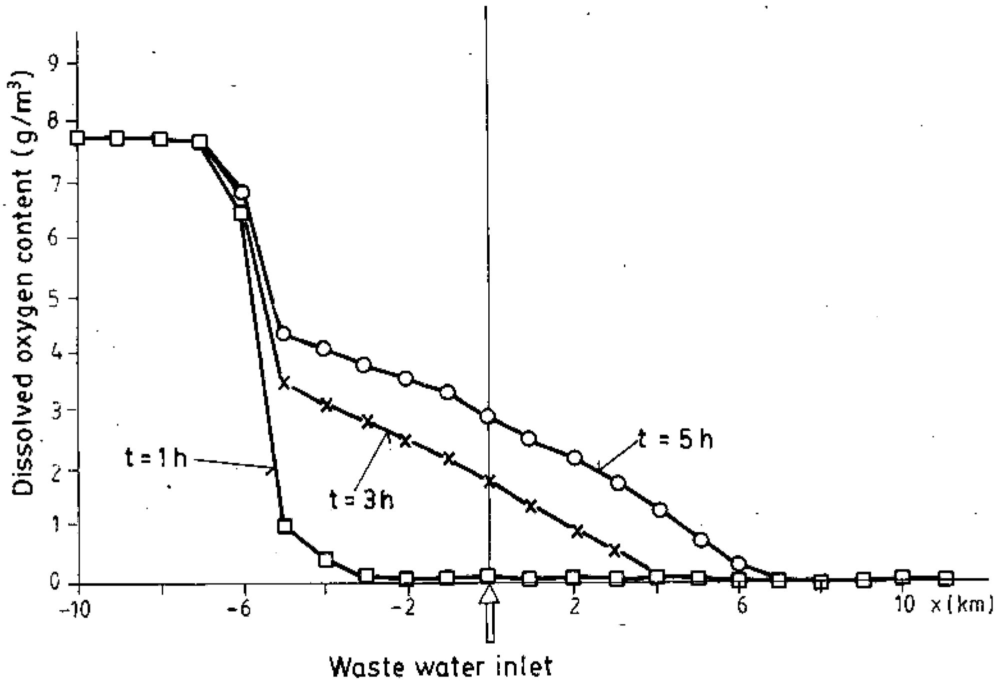


***Figure 3.8**: The duration of the shock-type load caused by rain and its effect on the dissolved O_2 concentration (C_{min}). The volume of total organic content is the same in all three cases; 20 m^3/s, JCT 2,000/700 mode, one year frequency rainfall*

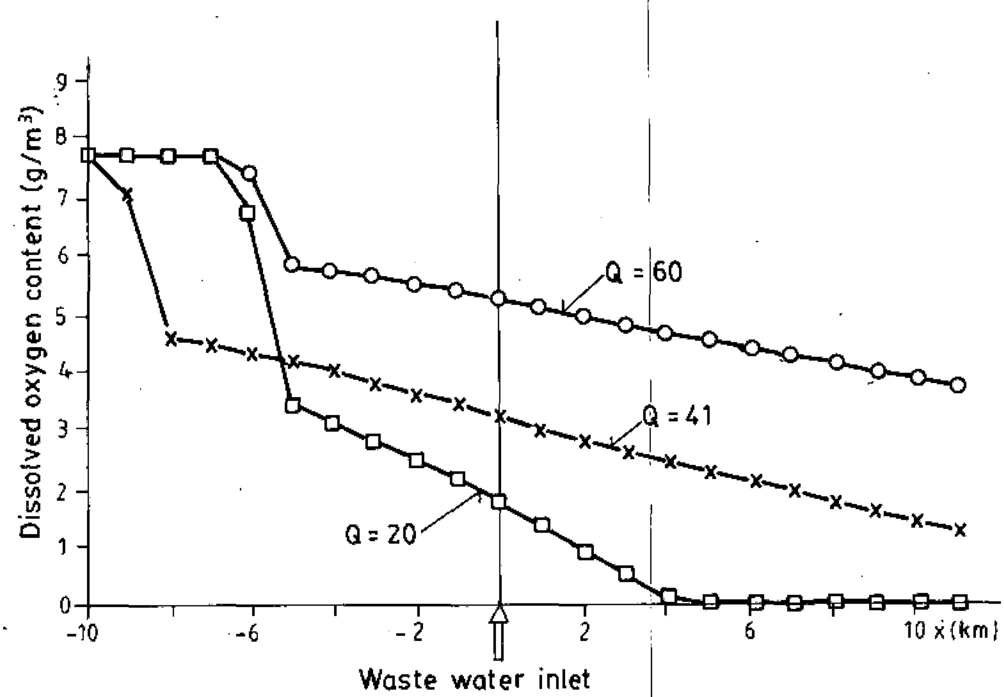


Figure 3.9: The effect of a one year frequency rainfall on dissolved O_2 concentration (C_{min}), with various nominal discharges

3.4 Expected Eutrophication in the Dunakiliti Reservoir

An average 25-30% increase in the concentration of a-chlorophyll concentration can be observed on the affected section of the Danube (see also *Table 1.4*). According to the long-section examinations, the same result is characteristic of the section between Rajka and Baja (where e.g. the algae population may quadruple) (VITUKI, 1984; ÉDUVIZIG-KÖVIZIG-ADUVIZIG, 1988), naturally as a function of meteorological conditions. All in all, it can be said that trophity is increasing on the domestic section of the Danube in the direction of the flow. In this sub-chapter we examine the role the upper reservoir will play in the modification of trophity conditions.

3.4.1 The formulation of a simple eutrophication model

By assuming permanent conditions, the equation of eutrophication in a waterway or a through-flow reservoir (that is, in our case) is

$$U\frac{dA}{dx} = \left(G_p - D_p - \frac{V_s}{H}\right), \quad (1)$$

(see e.g. Thomann and Mueller, 1987), where A is the daily average algae-biomass, expressed as a a-chlorophyll concentration, x and U are the longitudinal co-ordinate and speed (the latter shows the effect of redamming), G_p and D_p are the reproduction and decease rates (1/day) (to which photosynthetic oxygen production and respiration can be added, if the oxygen management and its daily cycle is examined), V_s is the sedimentation speed, characteristic to algae (m/day), and H is the depth of the water.

The decease rate is basically dependent on temperature

$$D_p = k_p O^{T-20}, (2)$$

where K_p is the decease rate at T=200°C, O is a constant greater than one. It has to be mentioned that the formulation of equations (1) and (2) supposes that the role of zooplancton can be overlooked.

The eutrophication factor is usually formulated as follows:

$$G_p = k_{\max}^{f(T)f(I)f(P,N)}, (3)$$

where K_{max} is the maximum reproduction speed, f(T), f(I) and f(P,N) the temperature, light, and nutrient limiting factors. These can be specified as follows:

(a) Temperature limitation

Version 1

$$f(T) = O_T^{T-20}, (4a)$$

which expresses monotonic temperature-dependence similar to equation (2).

Version 2

$$f(T) = \frac{|T_{cr} - T|}{T_{cr} - T_{opt}} \exp\left[1 - \frac{T_{cr} - T}{T_{cr} - T_{opt}}\right], \quad T \le T_{cr}, (4b)$$

$$f(T) = 0, \quad T \rangle T_c,$$

Here T_{opt} is the optimum temperature of saprobity, but reproduction stops above the T_{cr} critical value (Somlyódy and van Straten, 1986). The advantage of the second approach is demonstrated if seasonal changes are examined, because different T_{opt}, T_{cr} values can be attributed to the dominant algae species and thus in a simplified way, structural changes can also be traced.

(b) Nutrient limitation

The phosphorous and nitrogen limitation factor is defined by the usual Monod kinetics:

$$f(P) = \frac{P}{P_k + P}, f(N) = \frac{N}{N_k + N}, \quad (5)$$

where P and N are the concentrations of dissolved inorganic phosphorous and nitrogen, P_k and N_k the semi-concentration constants.

Version 1

$$f(P,N) = f(P)f(N), \quad (6a)$$

Version 2

$$f(P,N)=\min\{f(P),f(N)\},\ (6b)$$

As regards other possible formulations of limitation, we refer to the literature mentioned in sub-chapter 3.3.

(c) Light limitation

Assuming the Lambert-Beer law for light absorption in water, the Steel relationship between eutrophication and the light intensity, as well as the consistency of radiation in the photic-period (used only for simplicity), the daily and H water-depth integral average of light limitation factor can be specified with the following equation

$$f(I)=\frac{2.718f}{k_e H}\left[\exp(-a_1)-\exp(-a_0)\right],\ (7)$$

(see Straskraba and Gnauck, 1985; Thomann and Mueller, 1987; for details of the derivation) where

$$a_1=\frac{I_a}{I_{opt}}\exp(-k_e H),\ \text{and}\ a_0=\frac{I_a}{I_{opt}},$$

In the equations, I_{opt} is the intensity of optimum light (cal/cm^2/day or 3/cm^2/day), I_a the current value, which can be calculated in the knowledge of I_t total radiation and the f length of the exposure (0<f<1): $I_a=I_t/f$, finally K_e is the factor of extinction (1/m) characterising light absorption (which is inversely proportional to the Secchi depth, and according to previous studies the proportion factor is close to 2).

The extinction factor depends on the dissolved material in the water, the algae biomass and the suspended debris (SS):

$$k_e=b_0+b_1A+b_2SS,$$

where b_0 is the background extinction and in general, the linearity expressed by equation (8) can be accepted.

Supposing that the previously derived parameters of equation (1) are constant, and by introducing the t*=x/U transformation (travel time) the solution is

$$A=A_0\exp\left(G_p-D_p-\frac{V_s}{H}\right)t^*,\ (9)$$

A_0 is the starting value, and the increase, extreme value or decrease takes place as a function of the value of the $G_N=G_p-D_p-\frac{V_s}{H}$ net reproduction speed. In reality, however, $G_N(t)$ is not constant even if the hydrological and meteorological factors (Q, U, T and I_t) remain unchanged, since the extinction factor changes with modification SS and A. Furthermore, because of sediment transport reasons, eutrophication accounts for the consummation of P and N, and thus f(P, N) cannot be considered as a constant for most of the time.

The outlined characteristics can be considered by segmenting by x (and t*) and the introducting new equations. By discretion the value of k_e can be modified via equation (8) and the phenomenon of self-shadowing can be incorporated: if the supply of nutrients is profuse. The upper limit of the alga biomass will be determined by this factor through the equations (7)-(9).

The well-known, simple

$$\frac{dSS}{dt^*} = -\frac{v_{s1}}{H} SS,, \quad (10a)$$

equation can be formulated for the changes in the biomass, whose solution is

$$SS = SS_0 \exp\left(-\frac{v_{s1}}{H} t^*\right), \quad (10b)$$

where v_{s1} is the coefficient of sedimentation of suspended solids, the resulting sedimentation speed.

Including the modification of inorganic nutrients would require the application of a complex ecological model, describing the transport of both phosphorous and nitrogen. Since our primary goal is only to derive approximate models on the Dunakiliti reservoir, and to judge the importance of the problem, we are using simplifying suppositions. The two following extreme cases can be analysed follows:

(a) the sediment transport is rapid or the nutrient discharge of the sediment is constantly high, for this reason

$$f(P,N) = const., \quad (11)$$

(b) the transport (primarily the mineralisation) is slow and together with the eutrophication the nutrients are slowly "running out". Then, supposing constant stoichiometry, on the basis of material-balance considerations (see equation (1))

$$\frac{dP}{dt^*} = -a_p G_p A, \text{ and } \frac{dN}{dt^*} = -a_N G_p A, \quad (12)$$

whose solution is

$$P = P_0 + \frac{a_p G_p A_0}{G_N}\left[1 - \exp(G_N t^*)\right], \text{ and}$$

$$N = N_0 + \frac{a_N G_p A_0}{G_N}\left[1 - \exp(G_N t^*)\right], \quad (12a)$$

where

a_p and a_N are the ratio of inorganic P and inorganic N to the a-chlorophyll volume (mgP/mgCl and mgN/mgCl).

As the equation (10-12) approach their limit, the calculation is continued in such a way that the limitation factors are modified (and if necessary the hydraulic and geometry data, if they change longitudinally). After the descriptive differential equation is solved for a certain segment, we turn to the next Δx (and Δt^*) longitudinal section.

The cross-sectional differences can be taken into consideration by dividing the reservoir into adjacent segments, whose discharge is characterised by a parameter between 0 and 1 (arising from the velocity and depth distribution) and referring to Q. If no water-exchange is allowed between the neighbouring elements, the system is considered to be the combination of parallel tube-reactors. Taking the mixing between each parallel section into consideration is no mathematical problem either (although it may result in the modification of the numerical solution) if its parameters are known from measurements or a calculation carried out with a hydrodynamic model.

3.4.2 The recording of parameters and input data

There are no previous studies available concerning the parameters of sediment transport in the Danube. For this reason we used values (ranges) taken from the literature. The calculation, performed with average parameters on the given, nearly 24 km long section of the Danube, showed a 25-30% increase of the a-chlorophyll concentration By assuming August conditions (Q=1,000 m^3/s, I_t=400 cal/cm^2/day and T=20 °C), which corresponded adequately to the available information. This step means that the specification of conditions and the "calibration" of the model: starting at a 40 mg/m^3 a-chlorophyll concentration calculated for the Rajka-Baja section by the model with the received parameters may rise 4-5 times, which matches data gained during the examination of the long section (see VITUKI, 1984; ÉDUVIZIG-KÖVIZIG-ADUVIZIG, 1988). The parameter domains are summarised in *Table 3.1* (supposing the application of equation 4a). The other input data are also presented here, in some references are made to their the assumptions supposed.

The reservoir was divided into three "tube-reactors" (main riverbed and two side flood plains), and five longitudinal segments. The a_{Qb} and a_{Qj} discharge dispersion factors refer to the total discharge, and thus the main branch always has a $(1-a_{Qb}-a_{Qj})$ Q volume of water.

Similarly to sub-chapter 3.3, in addition to the simulations taken in their normal sense we again of examined the role of their sensitivity and uncertainties. Hereinafter, we shall evaluate with the evaluation the results.

3.4.3 Evaluation of the results

The following changes can be observed, based on the calculations when the discharge Q=1,000 m^3/s, with average parameters complying with the calibration in *Table 3.1*, weather conditions characteristic to August, and supposing "slow" sediment transport (and using equation 6a).

(a) Left hand side flood plain

In comparison to the original state, the travel time grows nearly ten times (approx. 4 days), as a result of which the 51 mg/m^3 a-chlorophyll value in the outgoing section of the reservoir prior to damming, changes to 190 mg/m^3 (growth is linear in the direction of the flow from the 40 mg/m^3 starting value). As a result of the mentioned modification of the biomass, the extinction factor gradually increases (to a value beyond 5/m) and reproduction is hindered by self-shadowing: f(I) decreases to about one-sixths (while f(P,N) is moderating).

(b) The main branch

No significant change can be observed when compared to the pre-dam conditions: the a-chlorophyll concentration will only increase by approx. 10%.

***Table 3.1**: Parameters and input data*

Characteristics	Unit	Range	Note
1. Geometry			On the basis of the available data in such a way that the volume, surface and storage times in the divided reservoir comply with the planning data
2. Hydrology, meteorology			
Q = discharge	m^3/s	1,000, 2,000	
T = temperature	°C	15-25	
I_t =	$cal/cm^2/day$	300-500	
f =	-	0.66	
3. Starting conditions			
A_0	mg/m^3	40	On the basis of the available
P_0	g/m^3	0.25	observations. The P_0, N_0,
N_0	g/m^3	2.5	P_{cr} and N_{cr} values lead to
SS_0	g/m^3	15	f(P,N)=1, in compliance with the profuse supply of nutrients (Bartalis, 1987).

Characteristics	Unit	Range	Note
4. Parameters			
k_{max}	1/day	1-5	See e.g. Thomann and Mueller (1987) and basic condition calibration
k_p	1/day	0.05-0.15	"
O	-	1.05-1.15	"
O_T	-	1.07-1.15	"
v_s	m/day	0.0-0.1	"
v_{s1}	m/day	5	"
P_{cr}	mg/m^3	1-5	"
N_{cr}	mg/m^3	10-20	"
b_0	1/m	0.2	"
b_1	$(mgCl/m^3)^{-1}$	0.01-0.05	Approx. on the basis of VITUKI (1988b)
b_2	$(mgSS/m^3)$	0.02	"
T_{opt}	$cal/m^2/day$	100-400	Thomann and Mueller (1987)
a_p	mgP/mgCl-a	0.5-2.0	"
a_N	mgN/mgCl-a	7.0-10.0	"
a_{Qb}	-	0.06	On the basis of speed and depth distribution (see *Figure 2.2*)
a_{Qi}	-	0.01	"

(c) The right hand side flood plain and the conditions downstream the reservoir

As the recorded input data, the flow-down time exceeds that of the left hand side flood plain, eutrophication is also different. Around the middle of the reservoir the a-chlorophyll concentration exceeds 200 mg/m^3, light limitation becomes significant, and inorganic P runs out. Consequently, the net reproduction rate becomes negative, and the value of A decreases to 140 mg/m^3 in the outgoing section. Below the reservoir, the same value is somewhat higher than 100 mg/m^3 following the mixing of waters coming from various sources, that is it doubles in comparison to the original conditions (with a 2-4 g/m^3 BOD_5 growth).

If a constant nutrient supply is assumed, somewhat higher a-chlorophyll values are attained: 195, 56, 302 and 123 mg/m^3, respectively.

The increase in discharge causes a reduction in the biomass. Thus, in case of Q=2,000 m^3/s, in the right hand side flood plain and downstream of the reservoir, the respective values are 170 mg/m^3 and 80 mg/m^3.

As we have emphasised, lacking firm sediment transport knowledge of the Danube, literature data were used for the above calculations. Thus, in the following paragraphs we shall analyse the sensitivity of the solution by methodically changing the parameters. To this purpose a single element of the parameter vector was changed in the appropriate domain of Table 3.1 in such a way that the system was otherwise typical to the nominal (calibrated) condition. The results have been summarised in *Figures 3.10a-3.10d* in a dimension-free form. No further details are needed, because

– the high sensitivity in the (-60, +120%) domain;

– the presence of great non-linearity;

– the shallow depth, long residence time areas (e.g., the right hand side flood plain) inclination to eutrophication;

– the importance of input variables (e.g. T and I_t) in the modification of trophity

are all obvious enough.

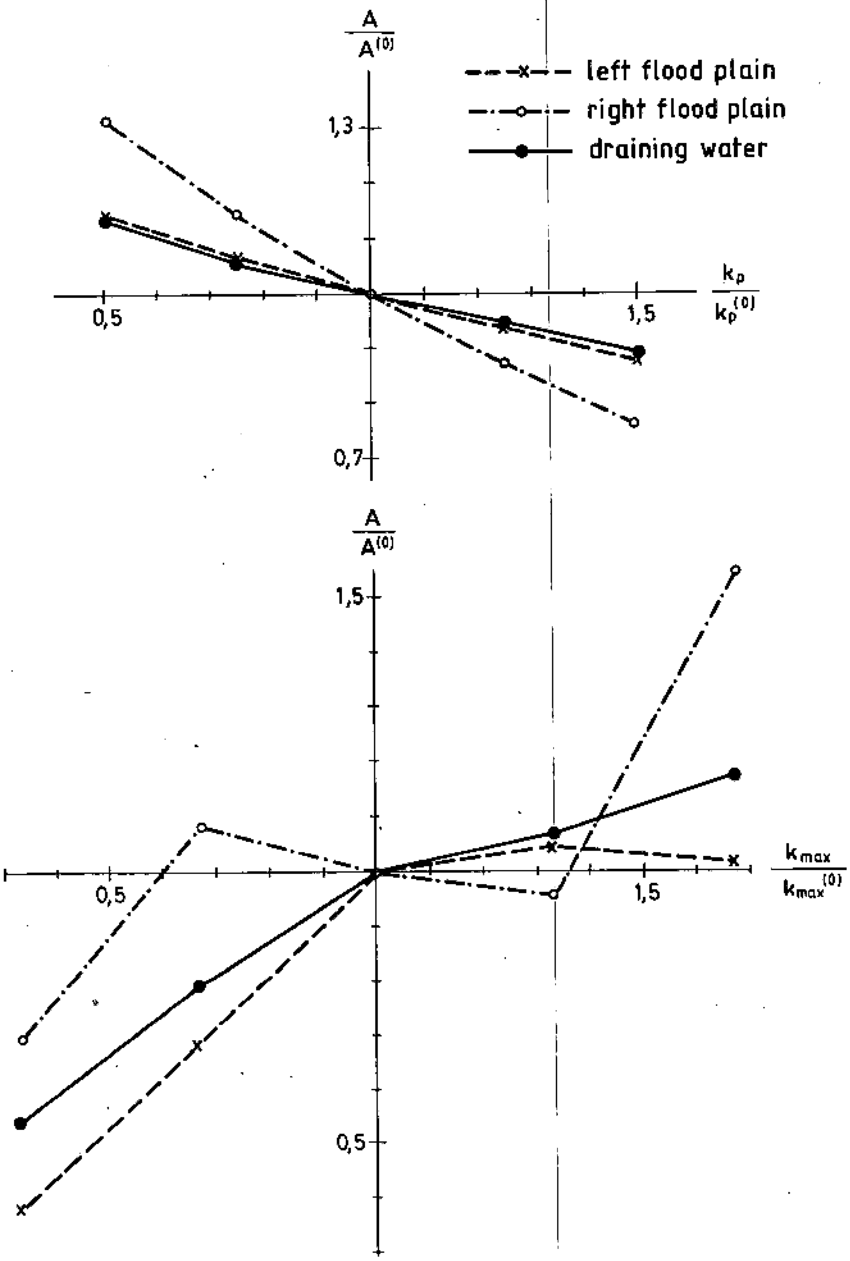


***Figure 3.10a**: Assessment of sensitivity (1): Dunakiliti reservoir, f(P,N) ≠ 1*

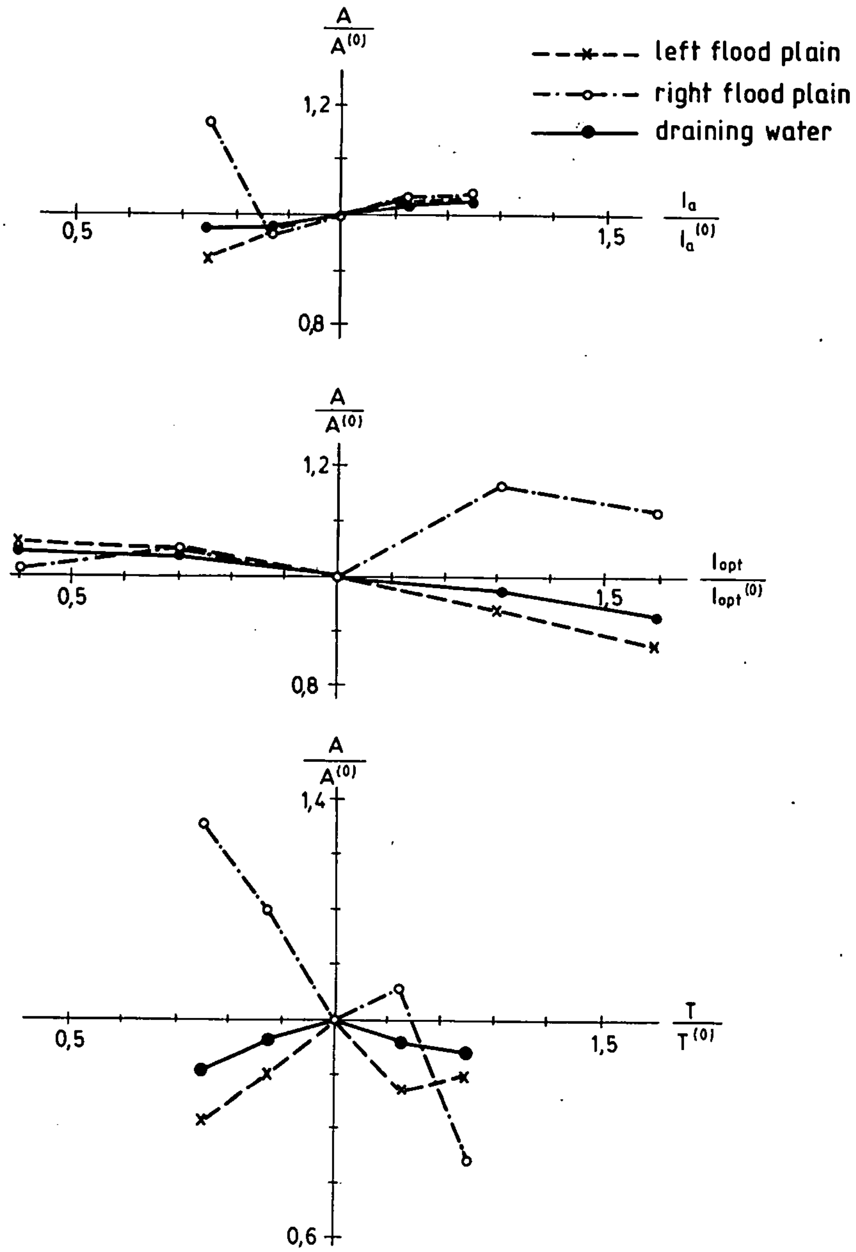


***Figure 3.10b**: Assessment of sensitivity (1): Dunakiliti reservoir, $f(P,N) \neq 1$*

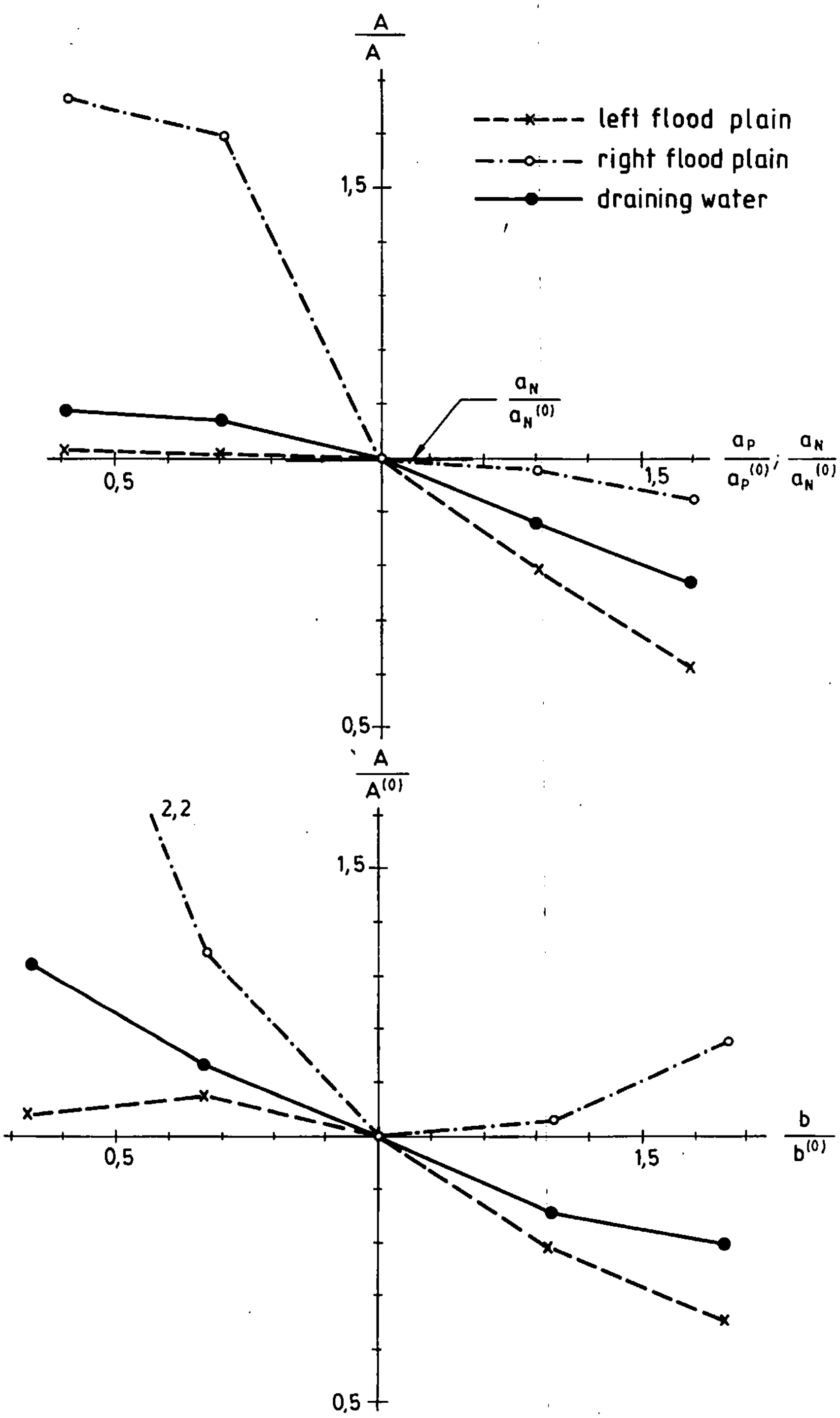


Figure 3.10c: Assessment of sensitivity (1): Dunakiliti reservoir, f(P,N) ≠ 1

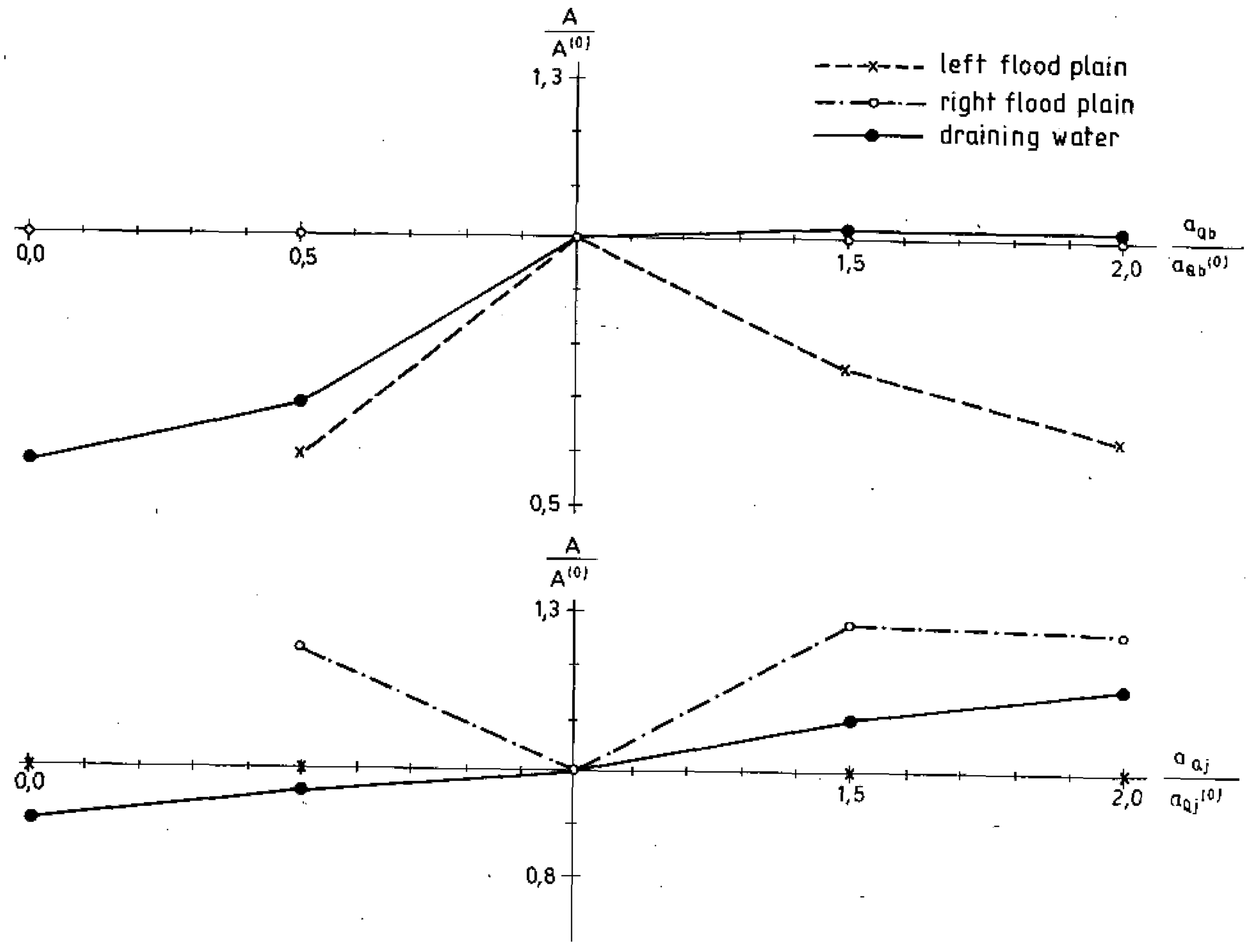
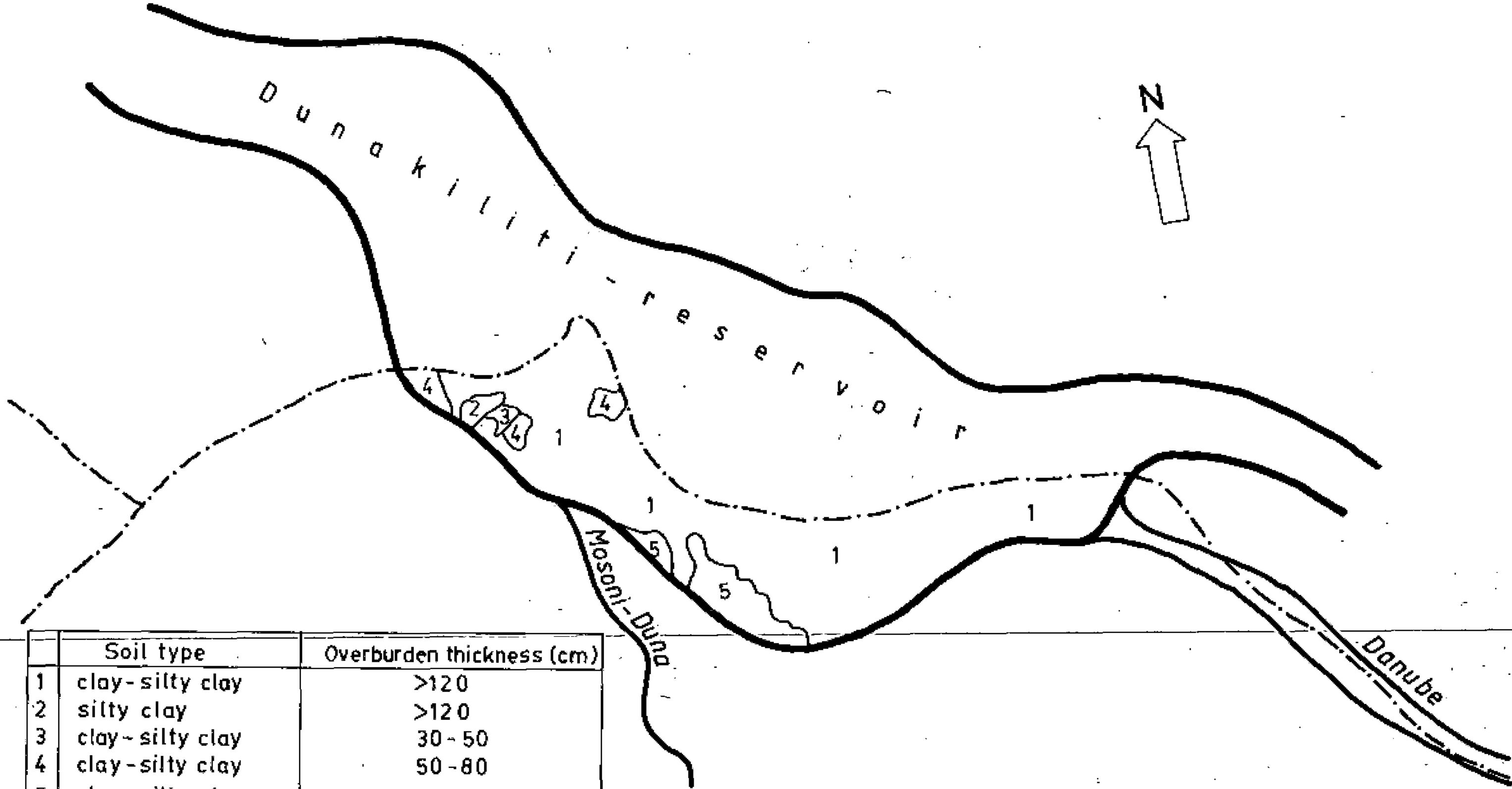


Figure 3.10d: *Examination of sensitiveness (4): Dunakiliti reservoir,* $f(P,N) \neq 1$



	Soil type	Overburden thickness (cm)
1	clay-silty clay	>120
2	silty clay	>120
3	clay-silty clay	30-50
4	clay-silty clay	50-80
5	clay-silty clay	>120

Figure 3.11: Dunakiliti reservoir, cover layer

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Naturally, the above figures only partially demonstrate the sensitivity of the solution, while the domain of uncertainty, originating from the incorrect assumption of parameters, should not be ignored. For this reason Monte Carlo simulations were carried out by random generating ecological-type parameters from within range the specified in *Table 3*, supposing an even distribution. The result of 2,000 simulations is summarised in *Table 3.2.* One favourable side of the calculations was that the various effects, arising from the incorrectness of the parameters, neutralise each other, at least in part, and the uncertainty domain is narrower than what was expected on the basis of *Figures 3.10.* For the various water areas, dispersion is around 35% and the distributions are typically elongated. The highest a-chlorophyll concentration may reach 500 mg/m^3 (for the sake of the comparison, the value of the latter rarely exceeds 100 mg/m^3 in the Kisköre reservoir, while concentrations above 400 mg/m^3 have been observed in the Kis-Balaton). The final conclusion is similar to that of the sensitivity tests: a comprehensive experimental program is needed to narrow the wide uncertainty domain.

To conclude this sub-chapter, we have to mention that the presented simple eutrophication model is not only suitable for the examination of short periods, but, by taking into consideration the changes in the input parameters (Q, T, I_t and f), it can also be used to describe seasonal changes. In a similar way, the model can be expanded in space, and following its further-development it can be used to study the different types of river sections (see chapter 2) from the point of view of phosphorous, nitrogen, oxygen management, and eutrophication (chapter 4). Naturally, the realisation of a comprehensive experimental program is again a pre-requisite.

***Table 3.2**: Summary of the results of the Monte Carlo simulations*

	Left flood plain	Main branch	Right flood plain	Resultant
Average	163	59	168	101
Dispersion	61	14	62	31
Minimum	57	40	69	48
Maximum	464	121	589	251

3.5 THE EFFECT OF THE COVER LAYER REMAINING IN THE RESERVOIR

Following the filling-up, water oozes into the gravel layer through the humus covering layer, present on nearly 80% of the reservoir. If the covering layer is not removed, two inter-linked effects should be taken into account:

– the composition of the oozing water changes as a result of the decomposition of organic material;

– if the sediment becomes low in oxygen, the material transport conditions of the reservoir (e.g. internal load), discussed in the previous chapter, will be significantly effected.

The soil science features of the Hungarian part of the planned reservoir can be characterised as follows (MTA TAKI, 1988):

– the soil of the entire area is low or high degree humus deposit;

– patches 1, 3, 4 and 5 on the attached map (*Figure 3.1/1*) are clay, clay – silty clay, and patch 2 is sandy clay;

– on patches 1, 2, and 5 the gravel is situated under a covering layer thicker than 120 cm, on patch 3 the gravel is under a 30-50cm depth and on patch 4 under a 50-80 cm depth;

– the thickness of the weakly developed, light-coloured humus layer is 25-40 cm, with the exception of patch 3, where it is 20 cm thick;

– the organic material content of the humus layer of patches 1 and 4 is 2.0-2.5%, of patches 2 and 3 is 1.5-2%, and finally of patch 5 is 2.5-3.0%.

Following the filling-up of the reservoir, the quality of the water filtering into the gravel layer, through the covering layer with an organic material content, may change significantly because of the following redox processes associated with the decomposition of microbiological organic material.

The water entering the covering layer from the reservoir contains dissolved oxygen, thus aerobic oxidation processes take place near the water-sediment surface.

If the volume of dissolved oxygen is insufficient for the oxidation of the sediment and the organic material content of the oozing water, the oxidation is continued by the transformation of the manganese(IV)-oxides to manganese (II) form, and with nitrate-reduction. In the next step the iron(III)-oxides and iron(III)-oxides and hydroxides are reduced by freeing iron(II), which – from the point of the order of redox processes – complies with the place of the sulphate reduction.

Microbiological methane formation occurs in a highly reduced environment – in a sediment extremely profuse in organic material, if no more sulphate is available. The above redox processes are completed by the reduction of elementary nitrogen into ammonium.

In summary, the redox processes associated with the decomposition of organic material, have a special role in the denitrification of subsurface waters, in the re-dilution of manganese and iron, and in the reduction of sulphate.

The equations formulated for typical forms can be incorporated into the mathematical model, describing the processes by quantity, on the basis of the order of redox potentials.

Equations suitable for the simple description of the processes:

Aerobic respiration:

$$CH_2O + O_2 \quad \Rightarrow \quad CO_2 + H_2O$$

Denitrification:

$$CH_2O + 4/5NO_3- + 4/5H^+ \quad \Rightarrow \quad CO_2 + 2/5N_2 + 7/5H_2O$$

Mn(IV)-reduction:

$$CH_2O + 2MnO_2 + 4H^+ \quad \Rightarrow \quad 2Mn_2^+ +3\ H_2O + CO_2$$

Fe(III)-reduction:

$$CH_2O + Fe(OH)_3 + 8H^+ \quad \Rightarrow \quad 4\ Fe_2^+ + 11\ H_2O + CO_2$$

Sulphate reduction:

$$CH_2O + 1/2S\ 0_4^{2-} + 1/2\ H^+ \quad \Rightarrow \quad 1/2\ HS^- + H_2O + CO_2$$

Methane-fermentation:

$$CH_2O + 1/2\ CO_2 \quad \Rightarrow \quad 1/2\ CH_4 + CO_2$$

Nitrogen-reduction:

$$CH_2O + H_2O + 2/3N_2 + 4/3H^+ \quad \Rightarrow \quad 2/3\ NH_4^+ + CO_2$$

The above reactions were given in decreasing order of redox potentials, which, at the same time determines the priority order of the reactions.

Considering the above redox reactions, and the starting conditions, it was calculated for how long the anaerobic conditions, favourable for the dilution of manganese and iron, will be dominant in the water filtering through the covering layer. The following parameter ranges were assumed originally:

– the dissolved oxygen concentration of the reservoir water	5 - 10 g/m^3
– the nitrate concentration of the reservoir water	5 - 10 g/m^3
– the thickness of the humus covering layer	0.2 - 0.4 m
– the microbiologically useful percentage of the humus covering layer	0.5 - 1%
– the density of the covering layer	1500 kg/m3
– the flow-rate of the water infiltrating in	0.02 - 0.1 m/d.

The calculations were made for two extreme cases; the slowest and fastest decomposition of organic material (the underlined values refer to the rapid decomposition of organic material).

According to the approximating model calculations, 2.5 years are necessary for the rapid decomposition of the degradable organic material content of the covering layer, and approximately 100 years are required for the slow decomposition. The specified durations also apply to the anaerobic periods favourable for the dilution of manganese and iron.

The results change if depositing suspended sediments and the dissolved organic material concentration of the reservoir's water is taken into consideration according to the following:

the volume of depositing suspended sediment:	0.01 - 0.05 m/year
the dissolvable organic material content of the suspended sediment:	0.5 - 1.0%
the BOD of the incoming water:	2 - 6 g/m^3

By this modification, the balance of organic material decomposition in the reservoir is restored (at the soonest) about 3.5 years after the reservoir is filled. Using the high load values, the organic material content of the sediment is continuously increasing, and anaerobic conditions characterise the water oozing through the bed of the reservoir. This also means that a constantly high nutrient discharge takes place from the sediment because of the anaerobic conditions, and consequently the f(P, N)=1 condition is fulfilled and alga reproduction is limited by light only (see sub-chapter 3.4). The higher alga reproduction – with increasing organic material – has a positive effect on decomposition processes in the covering layer (sediment) and their time scale. For this reason the covering layer (or at least part of it) should definitely be removed prior to the filling-up of the reservoir.

Naturally, the above rough calculations are not sufficient to provide a realistic assessment of the water quality draining out of the Dunakiliti reservoir, since the quality of water draining through a gravel riverbed and the covering layer is basically different. The two water-types mix in the drain space under the reservoir. A MULTRA transport-model (handling redox processes and hydrogeological phenomena together) is needed to calculate the resultant water quality. It has been developed to describe transport processes characteristic of bank filtered water bases (László and Székely, 1989).

In the present stage of development, the MULTRA model incorporates the following processes:

- layer-direction draining in layers with good permeability (hereinafter; water supplying), cross-flow in less permeable layers;

– external substitution and sub-irrigation from the unsaturated zone, artificial structures or through the bed-sediments of surface waters;

– advection transport by the drain tracks;

– mixing by the sounding plummet in water supply layers, as a result of which, the quality of the above layers can be specified by a sounding plummet average value;

– lateral mixing in the singular points of the water supply layers (flow saddle points, point-like absorption or sources);

– external chemical mass transport from the substitution sources and towards the tapping sources;

– the balance (reversible absorption) or time-dependent reactions of the components;

– momentary or reversible hydrochemical reactions between the dissolved components in the water phase;

– reversible hydrochemical reactions between the components dissolved in water and those in the solid phase (on the rock frame).

It has to be pointed out that the above statements refer to the quality of water draining through the cover layer. There is no accurate information on the state of the drain-picture in the cross and long section below the reservoir. Thus, at the moment, the ratio of the volume of water draining through the cover layer and the water draining through the gravel riverbed (which are basically different) cannot be projected in the drain canals, and thus, no assumption can be made on the quality of water in these canals.

4. Future Projects: Monitoring, Tests, Database and Water Quality Modelling

4.1 MONITORING

The design of any monitoring system depends upon the information to be derived from the acquired data. The most frequent goals are the following Somlyódy et al., 1987):

– to examine the processes effecting water quality, and its "self-purification" from discrete observations;

– to determine an average value (of what) for various time periods;

– to follow tendencies.

Various mathematical – statistical methods are available to determine the sample-taking frequencies in order to fulfil the different goals (Somlyódy, 1984; Somlyódy et al., 1986). For example, when considering the nutrient load of the river Zala, the reconstruction of continuous temporal changes requires day-by-day sample-taking, while the determination of monthly, yearly and four-year averages requires sample-taking every three days, every week and approximately every month (assuming 25% error and 95% probability level in general). It should also be mentioned that in many cases the detection of trends frequently requires higher frequency than the determination of averages (especially if the trend is small, and distribution is large), since the data-line usually has to be reduced significantly as a function of its auto-correlation.

Similar methods exist for the allocation of the network of specimen sites in space.

Thus, various levels of observation can be selected when designing the monitor systems, depending on the goal. In general, no conclusions can be drawn from the dynamic, non-linear and frequently stochastic processes derived from the results of a network aimed at the regular, routine-like monitoring of a large area. The complementary statement is also true, because a research-purpose monitoring network cannot be operated within large-area or nationally for financial reasons. With regards to the G/N, Project in order to answer the questions outlined in chapter 2, a research-purpose monitoring network (including the various on-site experiments) and a connected database needs to be established.

One of the primary characteristics of a research monitoring network is that it will be established for the projection of near-future conditions. According to the line of thoughts of chapter 3, this latter is based on the exploration of material transport processes and their description by models. Thus, the monitoring system has to examine, specify, and determine the connected kinetic parameters of processes outlined in points 3.3 and 3.4 (decomposition, alga reproduction and decease rates, mineralisation, nitrification, etc.).

Returning to sub-chapters 3.3-3.5, in the following sub-chapters we shall outline what experiments and tests are needed to make the above assumptions more accurate.

4.2 EXPERIMENTS

4.2.1 The problem of the Mosoni Danube

According to sub-chapter 3.3, the greatest uncertainty is in the assumption of the waste water load and the decomposition factor, overlooking nitrification and the determination of a realistic discharge (dilution). Thus, the tasks of primary importance are the following:

(a) The specification of the waste water composition in both dry and wet weather with decomposition tests (which also demonstrate the role of nitrification).

(b) The assessment of rainfall pollution loads (depending on the applied waste water treatment technology).

(c) The exploration of future discharges in order to deduce realistic water flows, flow-rates and water-depths.

(d) On-site tests for the joint assumption of k_1; k_2 and k_3 parameters in the Mosoni Danube (state specification).

In addition, a detailed examination is recommended on cross-sectional mixing and the puffer-capacity of the sewer network (see point (b)).

4.2.2 The expected eutrophication of the Dunakiliti reservoir

On the basis of point 3.4, a more comprehensive assessment of this phenomena is required in the reservoir, than in the Mosoni Danube. These can be outlined as follows:

(a) The examination of the seasonal change of associations of algae on the affected section of the Danube and in slow flowing side arms and still waters, in the form of a case study.

(b) The carrying out of primary production measurements, with the simultaneous identification of light conditions and velocities.

(c) Comprehensive analysis of the photo-climate, including the effect of suspended debris.

(d) Studying the role of the zooplankton.

(e) Examinations of the nutrient limitation, algae reproduction and decease rates in laboratory conditions, in limnocorals (where the storage time can be modified in the desired range), and in various types of branches and still waters.

(f) Examination of other processes of P and N management (mineralisation, absorption, nitrification, etc.).

(g) Assessment of the flow and suspended sediment load in the reservoir to be built (which accounts for "experiments" to be carried out with numerical models).

4.2.3 The importance of removing the covering layer in the Dunakiliti reservoir

Further information is required for a more precise estimation of the relationship between the covering layer and water quality:

(a) identification of the biochemical decomposable organic material ratio and biochemical oxygen demand of the covering layer;

(b) specification of the kinetic characteristics of the decomposing of organic material;

(c) identification of the nitrogen, phosphorous, iron, and manganese content of the covering layer;

(d) examination of the effect of transport processes between the sediment and the water body (diffusion, convection) on the components transporting oxygen;

(e) exploration of drainage conditions in and below the reservoir.

4.3 THE DATABASE

Widespread meteorological, hydrological, hydrochemical, hydrobiological and water quality information is available for the section of the Danube between Rajka and Budapest. On the basis of chapter 3.4 it can be stated that sediment transport can only be examined if the information from the various fields are evaluated jointly, according to their role. This requires data-collection, then the setting up of a simple database, which is – at the same time – the prerequisite of future modelling work, in addition to the professional co-operation of institutes concerned with the Danube (MTA ÖBKI Dunakutató Állomás, regional KÖVIZIGs and laboratories, as well as VITUKI) is also necessary.

The objective of this study is not to evaluate the water quality monitoring system introduced in Annex No.3. but to consider the proposals for the sample-taking sites. It does not deal either with the components to be examined or the frequency of sampling (VIZITERV, 1986).

4.4 WATER QUALITY MODELLING

Three water quality models were outlined in chapter 3. These are by no means all the possible models (for example one could also mention the passage of a typical pollution, risk analysis and other fields too). On the basis of the problems summarised in chapter 2 it was demonstrated that the primary goal for a model of the Hungarian section of the Danube upstream of Budapest, is to examine the oxygen, phosphorous, and nitrogen management together with the process of eutrophication. Phytoplankton and if possible, zooplankton would have to be included in the description of material transport. Basically, this requires the unification of the models of sub-chapters 3.3 and 3.4 in conjunction with the detailed observation of nitrification and phosphorous management. By segmenting in space, and taking account of the water exchange and suspended sediment transport, such a model would lead to representations of the Dunakiliti reservoir, the branches, the Old Danube, the Mosoni Danube or any of the various types of river sections further downstream.

The outlined water quality (ecological) model could fulfil a number of goals:

(a) examine daily changes in oxygen management;

(b) solve planning problems associated with the Old Danube;

(c) analyse seasonal changes in present and post-dam conditions;

(d) prepare the procedures for operation;

(e) study the changes over a period of several years (an aggregate model would probably be more suited for this purpose).

It has to be emphasised again, that the precondition of realising the above goals is the establishment of the research monitoring network outlined in the previous sub-chapters: the effecting of necessary experiments and the implementing of the database.

Conclusions and Summary

The essence of the report is centred on two metre main problems. One is the synthesis of all water quality research related to the GNBS (to identify the conditions and consider the expected water quality problems), while the other is the examination of the approachability of arising water quality problems with modelling (water quality partial models and the database necessary for their application).

Chapter 1 identifies the water quality conditions and the future trends on the Hungarian impact area of the GNBS (with special emphasis on the section of the Danube between Rajka and Budapest). It was not our intention to be comprehensive: only the issues thought to be the most important are dealt with. We left out the national surveys performed annually by institutions that were did not consider specifically GNBS. The report did not mean to dwell on the international professional literature dealing with the water quality effects of reservoirs: therefore only a couple are referred to (those linked directly to the region).

The chapter is divided as follows: classical chemical components, heavy metals, organic micro-pollutants, hydrobiology, bacteriology, sediment, waste material loads, and the water quality problems of bank filtered wells. Lacking experimental data, trend-examinations taken in their classical sense, could only be applied with regards to the traditional chemical components. Of course, these relate to conditions without the construction of the GNBS.

Chapter 2 deals with the expected water quality problems in different geographical units, which have been raised among Hungarian professional circles in connection to the implementation of the GNBS. The majority (with the exception of e.g. algae-boom) will not appear overnight. The new ecological balance will develop gradually over several years or maybe even decades (particularly the changes in the water quality of bank filtered wells).

The geographical division is as follows: Dunakiliti reservoir, power canal, Old Danube (Old Danube), Danube section between Szap and Vének, Mosoni Danube, branch system, Nagymaros reservoir, Danube section below Nagymaros.

The flow rate, arising from the geometry of the reservoir, has an especially important role within the Dunakiliti reservoir. Its primary consequences are expected to be the following:

– suspended sediment transport changes and within that, a decrease in the transport of rolled sediment, and an increase in the depositing ratio of suspended debris;

– change in the volume, granule-size, and distribution of bed-silt , and also the volume, quality and distribution of pollutants bonding to the granules;

– a change in water temperature;

– light conditions change, the water's transparency increases;

– a basic change in trophity conditions;

– oxygen management is greatly modified.

As result of the above effects, unfavourable changes to the water quality are expected to take place in the shallow parts of the reservoir, and periodical dredging will be necessary. Efforts have to be made to find an appropriate storage place for the silt, greatly polluted with heavy metals and possibly other toxic materials. The most evident form of the change in water quality will be an explosion of phytoplankton in the shallow parts of the reservoir. These changes may also adversely affect the water quality conditions of the Old Danube (in the upstream section), and the quality of drainage waters.

It has to be emphasised that morphologically, the Dunakiliti reservoir completely differs from the reservoirs of the German-Austrian section, which means that any experience gained there does not apply.

The quality of water is not expected to undergo any major change while passing through the power canal and the Gabčíkovo barrage system.

The water quality of the Old Danube, supplied from the congestive parts of the Dunakiliti reservoir and the drain waters, is uncertain at the present. This section of the Danube has to fulfil a rather diverse set of requirements:

– it should be worthy of being a border-river (wide-enough);

– it should be suitable for small boating;

– it should maintain its characteristic wildlife;

– the water quality should not deteriorate (deep enough);

– and it should be able to direct away floods and ice.

From the perspective of water quality it should be pointed out that for most of the year, the available planned discharges (50-100 m^3/s) assure an excellent photo-climate for eutrophication, and therefore, secondary pollution of the water on lower Danube sections. For this very reason, it is extremely important that the prevailing discharge be determined by the ecological needs.

The quality of the Mosoni Danube – with the exception of the section by Győr – will probably improve. If, however, the biological treatment of the waste waters of Győr and the run off of rainwater is not solved, the section below the waste water inlets will be one of the most critical points of the GNBS.

The professional literature is in dispute over the future water quality conditions in the Hungarian side arms system. According to one extreme, the replacement of the periodical water supply with a continuous one will improve water quality conditions, while the other expects a great degree of eutrophication, algae growth, together with their consequences.

The future water quality parameters of the Nagymaros reservoir will be determined by the conditions which have developed on upper sections, and the geometry of the reservoir. The eutrophication of the reservoir is not expected to exceed the amount that would normally occur in a river section downstream of a reservoir. The living and dead algae quantities, arriving from the upper section of the system, will be superpositioned there. The most of the sedimentation is expected to take place above Nagymaros. This, however, can be counterbalanced with varying intensity and frequency dredging (otherwise the water quality of the area's bank filtered water bases will deteriorate indefinitely).

The major problems for Fővárosi Felszíni Vízmű (Budapest Waterworks) occurring on the Danube section downstream of Nagymaros, are the greater volumes of living and dead algae from the upper sections and the degradation of the riverbed under the reservoir The latter may decrease the thickness of the filtration layer in the long term, which could effect the water quality of bank filtered wells again in the long term.

Chapter 3 deals with the role and application of water quality (ecological) models. The main point was that one necessary (but not sufficient by itself) method of solving planning and operational problems of the GNBS, both now and the future, is water quality modelling. The future changes of water quality (both long and short term) are important for both problems. These changes depend first of all on the modification of material transport conditions, not identifiable with a classical monitoring system. The task is further complicated by its large size and complexity, and by the fact that the projection has to be made for a system not yet existing. The water quality modelling can only be successful if the theoretical approach of the issue is linked to an appropriate data-collection and experimental program in such a way that they are closely interconnected (chapter 3.1).

Only modest steps have been taken towards the above water quality model; they are summarised in chapter 3.2.

Three examples of water quality models are presented to demonstrate their possibilities : the examination of the oxygen management of the Mosoni Danube under peak mode operation, the evaluation of expected eutrophication conditions in the Dunakiliti reservoir, and the effect of the organic covering layer remaining in the Dunakiliti reservoir. Their common characteristic is the lack of measurements on kinetic or other parameters (classical monitoring cannot supply such data). For this reason, the values (and their ranges) were taken from the literature, thus, the results are primarily demonstrative. However, they are suitable for drawing attention to the importance of the issues raised, the wide practical uses of water quality modelling, and to prove that without, targeted experiments and monitoring, models can only supply unreliable results.

In examining the oxygen management of the Mosoni Danube, our task was to identify the effect of the fluctuating water movement – developing as a result of peak mode operation – on the temporal and longitudinal change of O_2 concentration. This was considered both without waste water treatment and with biological treatment conditions, taking into account both dry and rainwater loads, and calculations form one given waste water inlet (chapter 3.3). The applied single-dimension dispersion model – supplemented with reaction members – incorporates diffused O_2 intake, BOD_5 decomposition, sedimentation, longitudinal dispersion, and various velocities (for different peak mode operations). The following conclusions can be drawn from the results obtained (estimated parameters):

– intolerable O_2 conditions develop under peak mode operation, dry weather waste water, without biological waste water treatment;

– biological waste water treatment solves the above problem even in the case of dry weather waste water;

– with the addition of precipitation loads, even biological waste water treatment is insufficient. For this reason other regulation possibilities have to be examined (e.g. storage or rainwater conveyed directly into the Danube).

The eutrophication conditions expected in the Dunakiliti reservoir were demonstrated by a simple model which incorporates temperature, light, and nutrient limitation, the eutrophication, and in a simplified form the changing of the storage time space. The results are presented in a-chlorophyll values (proportionate to the algae volumes) (sub-chapter 3.4). As for the spatial distribution of the problem, the reservoir was divided into three "tube-reactors" (main branch and two flood plains) with five longitudinal segments. Two extreme cases were examined from the point of view of nutrient supply: "fast" and "slow" material transport. In the first case, the nutrient element discharge of the sediment is high, while in the second case the nutrients gradually run out with the growth of the alga population. Of course, here too, we used parameter data (more precisely, the averages of data lines) taken from previous studies, which were calibrated for August in pre-dam conditions. The following conclusions can be drawn from the results obtained (estimated parameters):

– no major change in a-chlorophyll can be expected in the main branch;

– 170-200 mg/m^3 a–chlorophyll values may occur in the flood plains because of the higher storage times (depending on water discharge);

– as a result of the above, the biomass can be expected to double on the section below the Dunakiliti reservoir.

It was examined how methodically changing individual parameters effected the results. Thus, it was determined that the parameter sensitivity is high (-60, +120%), it changes non-linearly, and which variables have a major effect on trophity. The inclination of high storage time spaces (like the right side flood plain) could be demonstrated. The domain of uncertainty, arising from the errors in estimating the parameters was evaluated using a Monte Carlo simulation. It can be characterised by an elongated distribution and approximately 35% dispersion.

The calculations on the effect of the cover layer remaining in the Dunakiliti reservoir are included in chapter 3.5. The quality of the water draining into the gravel layer, through the organic cover layer containing material, may change significantly as a result of the redox processes of microbiological decomposition of organic materials. Following their introduction, we estimated the extreme parameter values effecting the process (dissolved O^2 and nitrate ion concentrations, thickness of the humus cover layer, its organic material content, density, the flow rate of draining water). The calculations were made for two cases, the fastest and the slowest decomposition of organic material. According to the approximating model calculations, the decomposition time may change between 2.5 to 100 years. The assumptions refer to the quality of the water draining through the cover layer. There is no accurate information as to what the longitudinal and cross-sectional flow diagram will be under the reservoir. Thus, it is not possible to determine the ratio of water draining through the cover layer to water draining through the gravel river-bed (basically different water qualities) will be in the drain canals, and hence their expected water quality.

Chapter 4 deals with future tasks in the field of water quality modelling. The model-developments demonstrated in chapter 3 clearly showed that the results of routine assessments are not suitable for solving such tasks. The precondition for any further modelling work, is the establishment of a research-centred monitoring system (laboratory experiments, on-site experiments, measurement of components outside the main network). The processes of the oxygen, nitrogen, phosphorous management, and eutrophication in the different areas of the Danube section affected by the GNBS, can only be described by such monitoring. Only with the establishment of such a system can the daily, seasonal and long-term changes be prognosed, and the various issues of operational management examined. In relation to this, we have outlined (without trying to be complete), the experiments and examination necessary to making more accurate the assumptions on the oxygen management of the Mosoni Danube, the eutrophication of the Dunakiliti reservoir and the effects of its cover layer.

References

Ábrahám, M., Várday, M.: A Rajka-Esztergom közötti Dunaszakasz vízminőségi problémái. (Water quality problems of the Danube section between Rajka and Esztergom). Hidrológiai Közlöny, 2., 1977

Avakjan, A.A.: Znacsenievodohraniliscs ulja vodosznabzsejije I ih vlijanie na kacsestvo recsnoj vodü. Gidrotechnicseszkoe Sztoitelsztvo 3., 1967

Bartalis, É.T.: A Duna Rajka-Nagymaros közötti szakaszának biológiai vízminősége. (Biological water quality of the Danube section between Rajka and Nagymaros) Hidrológiai Közlöny, 58/7., 1978

Bartalis, É.T., Dváhally, Zs.T., Kiss, K.T. und Schmidt, A.: Mit dem Sauerstoffgehalt zusammenhängende Untersuchungen in der mittleren Donau III. 24. Arbeitstagung der IAD, Szentendre-Ungarn, I.1-4., 1984

Bartalis, É.: A Duna Szigetköz szakaszának és hullámtéri vizeinek biológiai vízminősége, (Biological water quality of the Szigetköz section of the Danube and its flood plain waters) VEAB, A Kisalföldi Duna-szakasz ökológiája,(The ecology of the Kisalföld Danube section) Szerk. Dváhally Zs., 1987

Beck, M.B.: A procedure for modelling, In. G.T. Orlob (Editor), 1982, Mathematical Modelling of Water Quality, Wiley, Chichester, 1983.

Benedek, P., Literáthy, P.: Vízminőségszabályozás a környezet-védelemben. (Water quality regulation in environmental protection) Műszaki Könyvkiadó, Budapest, 1979.

Benedek, P., Valló, I.: Víztisztítás – szennyvíztisztítás. (Water treatment - waste water treatment), Zsebkönyv, 1976

Benedek, P.: A dunai vízlépcsőkből erredő környezeti kockázatok becslése. (Assumption of environmental risks caused by the barrage systems of the Danube) Kézirat, 1988

Berczik, Á.: A biológiai állapotváltozás néhány alapvető kérdése a GNV áhatásterületén. (Some basic issues of biological status change on the impact area of the GNB) MHT, Győr, Kézirat, 1988

Biswas, A.K. (Ed.): Models for Water Quality Management (New York: McGraw-Hill), 1981

Bothár, A.: Beiträge zur Kenntnis der Weichtierfauna der ungarischen Donau, Opusc. Zool. Budapest, 6, 1966

Bothár, A.: Horizontale Planktonuntersuchungen an der Donau von Rajka bis Turnu Severin (Stromkm 1850-930). Ann. Univ. Sci. Budapest, Sect. Biol. 16, 1974

Bothár, A.,: Die Entwicklung des Zooplanktons und -benthos unter dem Einfluss des Abwassers. Übersichtereferatum, 22, 1982, Arbeitstagung der IAD, Basel, Schweiz. Z. Hidrol. 44-2, 1981

Bothár, A., 1982a: Tiefenbhängige Verteilung der planktonischer Crustacean in 1980-1981. Kurzreferatum, 23. Arbeitstagung der IAD, Wien, 1982

Bothár, A. and Ponyi, E.J.: Informatory investigations about qualitative and quantitative conditions of the crustacean plankton of the Danube Section near Alsógöd (Hungary). Ann. Biol. Tihany, 35, 1968

Bothár, A., Dváhally, Zs.T. und Kozma, E.V.: Hydrobiologische Untersuchungen im Donauabschnitt zwischen Nagymaros und Magyar (Stromkm 1695-1956): Ann. Univ. Sci. Budapest, Sect. Biol. 13, 1971

Deák, Zs.: Bakteriológiai vizsgálatok a Duna Rajka-Budapest közötti szakaszán. (Bacteriological examinations on the Danube section between Rajka and Budapest) Hidrológiai Közlöny, 2, 1977

Dváhally, Zs. T. und Kozma, E.V.: Jahresuntersuchung der chemischen Milieufaktoren des Donauwasser im Bereich der ungarischen Donauforschungstation Alsógöd. Danubialia Hungarica XXI. Arch. Hydrobiol. Suppl. 27, 1964

Dváhally, Zs. T.: Tájékoztató jelentés a Duna magyar szakaszán 1966-ban végzett vizsgálatokról. (Informatory report on examinations carried out on the Hungarian section of the Danube in 1966) Kézirat, 1977

Dváhally, Zs. T.: Folyóvizek elsődleges termelése és a biológiai szellőzés. (The primary production of rivers and the biological respiration) pp. 148-173. A Duna. pp. 246-264. In: Felföldy L. (szerk.) Elsődleges termelés. Hidrológiai továbbképző tanfolyam, Tihany 1977. 1-321, 1977a

Dváhally, Zs. T., Ertl, M., Kiss, K.T. und Schmidt, A.: Mit dem Sauerstoffgehalt zusammenhängende Untersuchungen in der mittleren Donau II. 24. Arbeitstagung der IAD, Szentendre-Ungarn, I. 9-12, 1984

Dváhally, Zs. T.: A Kisalföldi Duna-szakasz oxigénviszonyainak néhány sajátossága, (Some characteristics of the oxygen conditions on the Kisalföld Danube section) VEAB A Kisalföld Duna-szakasz ökológiája. Szerk. Tamásné Dváhally Zs, 1987

ÉDUVIZIG-KÖVIZIG-ADUVIZIG: A Duna magyarországi szakaszának vízminősége a hossz-szelvény vizsgálatok tükrében. (The water quality of the Hungarian section of the Danube as reflected by long section examinations), 1988

Eykhoff, P.: Systems Identification – Parameter and State Estimation. Wiley, Chichester, 1974

Hock, B.: Szakvélemény a "Duna komplex hasznosítása" c. OMFB tanulmányhoz. (Expert's opinion to the "Complex utilization of the Danube" OMFB study), 1982

Horváth, L, Pannonhalmi, M., Várday, N.: A Duna magyarországi szakaszának szennyezettsége és vízminőségváltozása. (The pollution-level and water quality change of the Hungarian section of the Danube) Vízügyi Közlemények. 4, 1981

Jancsó, K., Tóth, J.: A Kisalföldi Duna-szakasz és a kapcsolódó mellékvizek halai és halászata. (Fish and fishing on the Kisalföld Danube section and its branches) VEAB A Kisalföldi Duna-szakasz ökológiája. Szerk. Tamásné dváhally Zs., 1987

Kertész, Gy.: Vizsgálatok a Duna magyarországi szakaszának Rotatoria planktonján. (Examinations on the rotatoria plankton of the Hungarian section of the Danube) Állattani Közlemények, 50, 1963

KET: Gabčíkovo-Nagymaros Vízlépcsőrendszer Közös Egyezményes Terv. Gabčíkovo-Nagymaros Barrage System Common Agreed Plan), 1975

Kiss, K.T.: Die Eutrophisation des Donauabschnittes bei Göd. 22. Arbeitstagung der IAD, Basel, 1981

Kiss, K.T.: Phytoplanktonuntersuchungen in den Donauabschnitten oberhalb und unterhalb von Budapest, im Jahre 1983, 1984

Kiss, K.T.: Fitoplankton vizsgálatok a Duna Kisalföldi szakaszán 1981-1982-ben. (Phylo-plankton examinations on the Kisalföld section of the Danube in 1981-1982) VEAB A Kisalföldi Duna-szakasz ökológiája. Szerk. Tamásné Dváhally Zs., 1987

KVM: Tájékoztató a Duna felsö szakaszának vízminőségi helyzetéről. (Information on the water quality of the upper section of the Danube) Kézirat, 1988

László, F., Székely, F.: Partiszűrésű vízbázisok redoxi folyamatainak modellezése. (Modeling of the redox processes of bank filtered water bases) Hidrológiai Közlöny (megjelenés alatt), 1989

Liepolt, R.: Limnologie der Donau. Stuttgart, 1965

Loucks, D.P. et al.: Water Resources Systems Planning and Analysis (Englewood Cliffs, NJ: Prentice-Hall), 1981

MÉLYÉPTERV: szóbeli közlés. (Oral report)

Mills, W.B. et al.: Hand Held Calculator Programs for Analysis of River Quality Interactions. Supplemental Volume to: Water Quality Assessment, A Screening Method for Nondesignated 208 Areas, 1979

MTA TAKI: A Dunakiliti-tározó magyarországi területén a fedőréteg jellemzői (Várallyay György személyes közlése) (Characteristics of the cover layer on the Hungarian area of the Dunakiliti reservoir), 1988

Natermann, E.: Eine neue Berechnungsweise des Sauerstoffhaushaltes verunreinigter Flüsse nebst einiger Folgerungen. GWF, 93, 16, 1952

Németh, J.: A fitoplankton mennyiségi változásai a Duna magyarországi szakaszán. (The quantitative changes of the phylo-plankton on the Hungarian section of the Danube) OVH VIKÖZ Vízminőségi Felügyelet (kézirat), 1971

Oertel, N.: A Duna fő- és mellékágának kapcsolata Gödnél néhány vízkémiai komponens alapján. (The relation of the main and side branches of the Danube at Göd on the basis of some hydrochemistry components) Hidrológiai Közlöny, 62/10, 1982

OMFB: A Duna távlati komplex hasznosítása. (The complex future utilization of the Danube) Elemző tanulmány 9-8204-ET, 1984

Orlob, G.T. (Ed.): Mathematical Modelling of Water Quality: Streams, Lakes and Reservoirs. Wiley-IIASA International Series on Applied Systems Analysis, Vol. 12, 1983

Rotschein, J.: Prognoza zmien kvalitativnevo rezimu Dunaja po vystavbe vodnych diel. Prace a Studie, VUVH, Bratislava, 1976

Scavia, D. and Robertson, A.: Perspectives on Lake Ecosystem Modeling (Ann Arbor, MI: An Arbor Science Publishers), 1979

Somlyódy, L.: Water-quality modelling: A Comparison of transport-oriented and ecology-oriented approaches. Ecological Modelling 17, 1982

Somlyódy, L.: Sekély tavak vízminőségszabályozása. (Water quality regulation of shallow lakes) Doktori értekezés, 1984

Somlyódy, L.: A szennyezőanyagok elkeveredésének meghatározása vízfolyásokban. (Determination of the mixing of pollutants in waterways) Vízügyi Közlemények. 1985. 2. füzet, 1985

Somlyódy, L. and van Straten, G.: Modeling and Managing Shallow Lake Eutrophication. With Application to Lake Balaton Springer-Verlag, 1986

Somlyódy, L. et al.: Water Quality Monitoring in Lakes and Tributaries, IAHS-AISH Publ. No. 158, 1986

Straskraba, M. and Gnauck, A.: Freshwater Ecosystems. Modelling and Simulation. Elsevier, 1985

Thomann, R.V.: Systems Analysis and Water Quality Management (New York: McGraw-Hill), 1972

Thomann, R.V. and Mueller, J.A.: Principles of Surface Water Quality Modeling and Control. Harper & Row, Publ., 1987

Tóth, J.: Einige Veränderungen in der Fischfauna der ungarischen Donaustrecke in der vergangenen Dekade. Ann. Univ. Sci. Budapest, Sect. Biol. 3, 1960

Tóth, J.: Antropogén hatások a Duna biológiai állapotváltozásaiban. (Antropogen effects in the biological condition changes of the Danube) MTA Biol. Oszt. Közl. 25, 1982

Várday, N.: A Kisalföldi Duna-szakasz hidrológiai, hidrográfiai és vízkémiai viszonyai, (The hydrological, hydrographic and hydrochemical conditions of the Kisalföld Danube section) VEAB A Kisalföldi Duna-szakasz ökológiája, Szerk. Tamásné dváhally Zs., 1987

VGI: A magyarországi Felső-Duna térség összefoglaló vízminőségvédelmi regionális terve. (The summarising regional water quality protection plan of the Hungarian Upper-Duna region), 1976

VGI: Felmérés a Duna-menti partiszűrésű vízbázisra telepített vízművekben termelt víz minőségének alakulásáról. (Survey on the quality of water produced in waterworks established on the bank filtered of the Danube), 1980

VGI: A BNV környezeti hatásai, különös tekintettel a vízellátásra és szennyvíztisztításra. (The environmental effects of the GNB, with special regard to water supply and waste water treatment), 1985

VITUKI: Magyarország vízkészlete. II. Vízfolyásaink minőségi számbavétele. (Hungary's water supply. II. Qualitative classification of the waterways), 1957

VITUKI: Duna vízminősége. A nemzetközi Dunakutatás keretében végzett vizsgálatok 1958-1960. Tanulmányok és kutatási eredmények 12. (The water quality of the Danube: Examination performed in 1958-1960 in the frames of the international Danube -research. Studies and research results 12.), 1963

VITUKI: Esztergom város szennyvizeinek hatása a Duna vízminőségére és a Duna vízminőségváltozása a Nagymaros Duzzasztómű megépítése után. Beszámoló a VITUKI 1964. évi munkájáról. (The effect of the waste water of Esztergom on the water quality of the Danube and the changes in the water quality of the Danube after the establishment of the Nagymaros weir.), 1966

VITUKI: A magyarországi Felső-Duna-szakasz szintezésének várható vízminőségi kihatása. (The expected water quality effects of the levelling of the Hungarian Upper-Danube section). Közirat, 1973

VITUKI: A Gabčíkovo-Nagymaros vízlépcsőrendszer hatása a partiszűrés vízminőségére. (The effect of the Gabčíkovo-Nagymaros Barrage on the water quality of bank filtration) 7787/4/123 VITUKI jelentés, 1976

VITUKI: A GNV várható vízminőségi kihatása. (The expected effects of the GNB on water quality) III.4.3.42. VITUKI jelentés, 1978

VITUKI: A Duna hatása a partiszűrésű területek vízháztartási viszonyaira. (The effect of the Danube on the water management conditions of bank filtered areas) 722/3/29 VITUKI jelentés, 1981

VITUKI: Gabčíkovo-Nagymaros Vízlépcsőrendszer vízminőségi hatásainak vizsgálata. (Examination of the water quality effects of the GNB) 7623/3/142 VITUKI jelentés, 1984

VITUKI: A Gabčíkovo-Nagymaros Vízlépcsőrendszer hatása a hordalékjárásra. (The effect of the GNB on the movement of sediments) 7623/2/801 VITUKI jelentés, 1985a

VITUKI: A Gabčíkovo-Nagymaros Vízlépcsőrendszer vízminőségi hatásának vizsgálata. (Examination of the effects of the GNB on water quality) 7623/3/142 VITUKI jelentés, 1985b

VITUKI: Partiszűrésű vízkészletek állapotvédelme és fejlesztése. (The maintenance and development of bank filtered water supplies) 7619/3/29 VITUKI jelentés, 1985c

VITUKI: Öreg-Duna meder szabályozásával kapcsolatos vizsgálatok. (Examinations connected to the regulation of the Öreg-Duna riverbed) 7622/1/58 VITUKI jelentés, 1986-'87

VITUKI: GNV területi megfigyelőrendszer (vízminőségi állapot felmérés). (GNB regional monitoring system (identification of water quality conditions) 7623/3/163 VITUKI jelentés, 1987a .

VITUKI: A Duna komplex vizsgálata. 2. A vízminőség változása. (Complex examination of the Danube. 2. Changes in water quality.) 7611/3/27 VITUKI jelentés, 1987b

VITUKI: A Táti Duna-ág és a Prépost-szigeti Duna-ág mederüledékének vizsgálata. (Examination of the bottom sediment of the Táti Duna-branch and the Prépost-szigeti Duna-branch) 7622/3/15 VITUKI jelentés, 1987c

VITUKI: A régi Duna-meder szabályozása érdekében létesítendő gázlóbiztosítás kismintavizsgálata. (Small model examination of wade security to be established for the regulation of the old riverbed of the Danube) 7612/2781 VITUKI jelentés, 1988a

VITUKI: Víz- és üledék, valamint hidrobiológiai vizsgálatok a Dunán, a mellékvízfolyásokon és a mellékágakon. (Water and sediment, and hydrobiological examinations on the Danube, the affluents and the branches) 7612/3/970 VITUKI jelentés, 1988b ..

VITUKI: Beszámoló külföldi tanulmányútról (Report on a professional foreign visit) (Hock B. - Gulyás P.) , 1988c

VITUKI: A Fe szennyvízbevezetések elkeveredési viszonyai. Vizsgálatok numerikus modellezéssel. (Mixing characteristics of major waste water inlets. Examinations with numerical Modeling). 7623/2/482 VITUKI jelentés, 1988d

VIZITERV: A Gabčíkovo-Nagymaros Vízlépcsőrendszer környezeti hatástanulmánya. (The environmental impact study of the GNB), 1985

VIZITERV: Merő-és megfigyelő Berendezések. I. ütem (Measurement and monitoring equipment. Phase I., 1986

VUVH: Áramlások és szabályozások a Hrušov-Dunakiliti tározóban. (Currents and regulations in the Hrušov-Dunakiliti reservoir) Összefoglaló jelentés, kézirat S-1.13-1/18. VUVH, Bratislava, 1965

WHO-VITUKI: Vízminőségszabályozási mintaterületek Magyarországon. (Water quality regulation sample areas in Hungary) Projekt zárójelentés. UNDP/WHO HUN/71/505 - HUN/-PIP/001, 1976

Wisnovszky, I.: Települések csapadékcsatornázása. (VMGT 96. VIZDOK. (The rainwater sewer system of settlements) , 1978

Annex No.1

Table No.1: 80% duration water quality values on the Danube (1981-1985) (VITUKI, 1987a)

Component	**Unit**	**Felsen-Hütt 2210.0 rkm**	**Wolfsthal 1873.9 rkm**	**Szob (left bank) 1708.0 rkm**	**Szob (current) 1708.0 rkm**	**Szob (right bank) 1708.0 rkm**	**above Budapest 1659.0 rkm**
1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**
Water temperature	°C	15.4	16.4	17.7	17.7	17.7	17.9
Specific conductivity	µS/cm	410	417	456	438	430	440
Total dissolved material	mg/l	-	-	334	321	319	327
pH	-	8.1	8.1	8.1	8.2	8.2	8.2
Dissolved O_2	mg/l	8.9	8.9	8.3	9.0	9.1	8.8
COD_d	mg/l	-	-	29.6	24.1	23.2	25.2
COD_p	mg/l	5.6	5.3	9.4	7.7	7.5	8.5
BOD_5	mg/l	2.6	4.5	7.3	6.8	6.4	7.7
Total pH	nko	11.9	12.0	12.2	12.0	12.1	12.0
AlKališe	mmol/l	3.4	3.3	3.7	3.6	3.6	3.5
Magnesium	mg/l	12.0	13.0	16.7	15.7	15.7	15.2
Ammonium	mg/l	0.40	0.59	1.22	0.89	0.68	0.85
Nitrite	mg/l	0.07	0.11	0.19	0.16	0.15	0.16
Nitrate	mg/l	12.6	12.8	13.0	13.2	13.7	13.0
Orthophosphate	mg/l	0.52	0.70	0.62	0.66	0.65	0.59

Component	Unit	Felsen-Hütt 2210.0 rkm	Wolfsthal 1873.9 rkm	Szob (left bank) 1708.0 rkm	Szob (current) 1708.0 rkm	Szob (right bank) 1708.0 rkm	above Budapest 1659.0 rkm
1.	2.	3.	4.	5.	6.	7.	8.
Chloride	mg/l	20.0	21.0	29.3	28.9	28.0	27.3
Sulphate	mg/l	31.0	35.0	56.7	48.1	51.3	52.4
Oil (uv)	mg/l	-	-	0.28	0.26	0.19	0.24
Phenols	mg/l	-	-	0.006	0.004	0.004	0.007
Ana.det.	mg/l	-	-	0.23	0.19	0.19	0.20
Natrium%	%	-	-	15.1	14.0	14.4	13.2
Biological condition	-	-	-	-	2.63	-	2.64
Manganese	mg/l	-	-	0.04	0.04	0.03	0.04

+: 20% duration index

-: five-year measurement data were not available

___: 2. class

===: 3. class

Table 2

Component	Unit	Mosoni-Danube Győr 2.4 rkm	Rába Győr 2.0 rkm	Concó Ács 5.0 rkm	Általér Tata 10.5 rkm	Kenyérmezöi patak. Dorog 2.1 rkm	Ipoly Letkés 14.0 rkm
Water temperature	°C	18.3	19.0	18.6	21.2	20.7	18.3
Specific conductivity	µs/cm	543	486	1238	943	1700	616
Total dissolved material	mg/l	361	318	920	682	1204	452
pH	-	8.1	8.3	8.0	8.6	7.9	8.1
Dissolved 0_2	mg/l	6.1	7.9	2.0	7.7	0.0	8.0
COD_d	mg/l	29.2	22.2	186.3	52.2	698.4	28.7
COD_p	mg/l	8.6	7.4	70.2	15.5	259.1	8.5
BOD_5	mg/l	8.4	6.2	49.3	11.6	316.9	7.6
Total pH	nko	15.0	13.8	37.5	27.8	36.7	15.4
AlKališe	mmol/l	4.2	3.8	9.0	6.7	8.0	4.8
Magnesium	mg/l	21.6	20.2	96.2	54.4	59.1	22.7
Ammonium	mg/l	1.36	1.11	15.66	4.97	38.80	1.47
Nitrite	mg/l	0.25	0.23	1.31	0.49	0.23	0..18
Nitrate	mg/l	10.1	12.9	10.3	8.4	0.6	14.9
Orthophosphate	mg/l	0.66	0.58	8.75	2.60	5.59	0.69
Chloride	mg/l	30.8	28.2	75.2	54.1	221.3	40.2

Component	Unit	Mosoni-Danube Győr 2.4 rkm	Rába Győr 2.0 rkm	Concó Ács 5.0 rkm	Általér Tata 10.5 rkm	Kenyérmezöi patak. Dorog 2.1 rkm	Ipoly Letkés 14.0 rkm
Sulphate	mg/l	75.2	62.6	296.9	217.3	419.7	86.4
Oil (uv)	mg/l	0.45	0.36	0.90	0.49	15.1	0.29
Phenols	mg/l	0.011	0.006	0.009	0.006	0.190	0.006
Ana.det.	mg/l	0.18	0.11	0.15	0.27	0.58	0.20
Natrium %	%	16.9	16.3	14.7	18.0	34.0	20.5
Biological conditions	-	2.99	2.87	3.96	2.60	-	2.58
Manganese	mg/l	0.18	0.20	0.18	0.22	0.02	0.07

+: 20% duration index
-: five-year measurement data were not available
___: 2. class
===: 3. class

Table 3: Annual fluctuation on two components of the Nitrogen management (monthly averages) (KVM, 1988)

Danube 1. 1848.4 rkm (Rajka)
2. 1479.7 rkm (Baja)

	01.	02.	03.	04.	05.	06.	07.	08.	09.	10.	11.	12.
NO^{-3} (mg/l)												
1.												
1971-75	7.5	9.0	8.6	6.5	5.2	4.6	4.6	4.8	5.5	6.9	6.9	6.5
1976-80	10.3	12.3	12.0	9.7	7.3	6.5	5.9	6.1	6.8	7.9	9.1	9.8
1981-85	12.1	13.6	13.4	9.8	7.4	7.2	6.0	6.3	6.8	8.8	10.2	11.5
2.												
1971-75	9.2	9.4	9.6	7.1	5.7	5.2	5.0	4.4	4.7	6.1	7.6	8.1
1976-80	10.8	12.9	11.9	9.9	8.2	6.2	6.0	5.8	6.3	7.7	9.3	9.7
1981-85	10.9	11.5	12.2	9.6	7.8	6.9	5.7	6.7	6.3	7.6	9.5	10.4
NH^{+4} (mg/l)												
1.												
1971-75	0.93	0.97	0.62	0.42	0.39	0.25	0.42	0.47	0.47	0.53	0.82	0.99
1976-80	0.93	0.90	0.62	0.51	0.44	0.44	0.51	0.58	0.24	0.35	0.47	0.68
1981-85	0.93	1.00	0.80	0.45	0.52	0.45	0.39	0.45	0.37	0.53	0.61	0.80
2.												
1971-75	0.93	0.96	0.68	0.38	0.33	0.37	0.38	0.42	0.37	0.48	0.82	0.78
1976-80	1.19	1.14	0.69	0.38	0.31	0.40	0.35	0.26	0.31	0.40	0.98	1.00
1981-85	1.14	1.17	0.78	0.37	0.38	0.34	0.35	0.37	0.34	0.47	0.79	0.97

Table 4: Maximum values of heavy metal concentration tests in the Danube

Component	Unit	Rajka			Medve		Komárom			Almásneszmély	
		1977/79	1987	1986/88	1974	1977/79	1974	1977/79	1986/88	1977/79	1986/88
Arsenic	mg/l		-								
Zinc	mg/l		+	+	+		+				
Silver	mg/l		-							++	
Mercury	mg/l	++	++		++	++	++	++	-	-	-
Cadmium	mg/l	-	-	-		++		++			
Cobalt	mg/l		-								
Chrome	mg/l		-	-							
Manganese	mg/l		-		+		-				
Nickel	mg/l		-	-							
Lead	mg/l	-	-	+		-		-	-	-	-
Copper	mg/l	-		-					-		-
Selenium	mg/l		-								
Iron (total)	mg/l		++								

Component	Unit	Esztergom		Szob		Nagymaros		Above Budapest /Felsz.v.m./		Above Budapest At railroad bridge	
		1974	1977/79	1974	1986/88	1974	1977/79	1974	1977/79	1977/79	1986/88
Arsenic	mg/l										
Zinc	mg/l	+		+		+		+			
Silver	mg/l										
Mercury	mg/l	++	++	++		++	++	++		++	
Cadmium	mg/l		+	-			++	++		+	-
Cobalt	mg/l										
Chrome	mg/l										
Manganese	mg/l	+		+		+		-			
Nickel	mg/l										
Lead	mg/l		-		+		+		+	-	+
Copper	mg/l				-						-
Selenium	mg/l										
Iron (total)	mg/l										

1974 VGI (1976)　　1977/79 VITUKI (1981)　　1987 VITUKI (1987a)　　1986/88 KVM (1988)

+ the maximums exceed the desired limit　　++ the maximums exceed the tolerable limit　　+ the maximums do not reach the desired limit

Table 5: The maximum values of heavy metal concentration tests in the river branches of the Danube

Component	Unit	Mosoni-Danube Mecsér 1986/88	Mosoni-Danube Győr 1986/88	Lajta 1986/88	Szigeti Danube 1987	Zátonyi Danube 1 1987	Zátonyi Danube 2 1987	Görbe Danube 1987	Ásványi Danube 1987
Arsenic	mg/l				-	-	-	-	-
Zinc	mg/l	+	++	+	+	-	-	+	+
Silver	mg/l				-	-	-	-	-
Mercury	mg/l				+	+	-	+	+
Cadmium	mg/l	-	-	-	-	--	-	-	-
Cobalt	mg/l				-	-	-	-	-
Chrome (total)	mg/l	-	-	-	-	-	-	-	-
Manganese	mg/l				-	-	-	-	-
Nickel	mg/l	-	-	-	-	-	-	-	-
Lead	mg/l	+	-	+	-	-	-	-	-
Copper	mg/l	-	-	-	-	-	-	-	-
Selenium	mg/l				-	-	-	-	-
Iron (total)	mg/l	-	-	-	+	-	+	+	+

Continuation of **Table 5.**

Component	Unit	Bagaméri Danube 1987	Rábca 1987	Általér 1986/88	Kenyérmezöi p. 1986/88	Vág Danube 1986/88	Unyi p. 1986/88	Táti Dunaág 1987	Táti p. 1987	Szentendre Danubeág 1987
Arsenic	mg/l	-	-					-	-	-
Zinc	mg/l	+	+	+	+	+	+	+	++	+
Silver	mg/l	-	-					-	-	-
Mercury	mg/l	+	+					-	+	-
Cadmium	mg/l	-	-	-	-	-	++	-	-	-
Cobalt	mg/l	-	-					-	-	-
Chrome (total)	mg/l	-	-	-	-	-	++	-	++	-
Manganese	mg/l	-	-					-	-	-
Nickel	mg/l	-	-	-	-	-	++	-	++	-
Lead	mg/l	-	-	-	+	+	+	+	-	-
Copper	mg/l	-	-	-	-	-	+	-	+	-
Selenium	mg/l	-	-					-	-	-
Iron (total)	mg/l	+	+	-	-	-	-	+	++	++

1986/88 KVM (1988)

1987 VITUKI (1987a)

\+ the maximums exceed the desired limit

\+ the maximums exceed the tolerable limit

++ the maximums do not reach the desirable limit

***Table 6**: The chlorinated hydrocarbon content of the Rajka-Budapest section of the Danube (KVM, 1988) (nanogram/l)*

Place	linden	metoxi-chlorine	aldrin	diedrin	DDT	hepta-chlorine	heptachlorine epoxid	endosulphate	hexachlorine benzol
Rajka	20	nd	nd	nd	nd	nd	nd	nd	2
	26	nd	nd	nd	nd	nd	nd	nd	nd
	31	nd	nd	nd	nd	nd	nd	nd	5
	15	nd	nd	nd	nd	nd	nd	nd	nd
Szob	24	nd	nd	nd	nd	nd	nd	nd	2
	31	nd	nd	nd	nd	nd	nd	nd	nd
	28	nd	nd	nd	nd	nd	nd	nd	nd
	42	nd	nd	nd	nd	nd	nd	nd	nd
Budapest	42	nd	nd	nd	nd	nd	nd	nd	5
	32	nd	nd	nd	nd	nd	nd	nd	4
	30	nd	nd	nd	nd	nd	nd	nd	5
	21	nd	nd	nd	nd	nd	nd	nd	nd

nd = not detectable

Table 7: The results of hydrobiological tests (KVM, 1988) (Danube, Rajka)

a-chlorophyll (mg/l)													
Years	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**October**	**Nov.**	**Dec.**	**Average**
'76-'80	5.1	10.7	35.1	59.8	54.1	46.0	35.5	29.2	47.3	30.9	7.4	5.8	30.5
'81-'85	6.3	10.1	32.4	70.9	77.8	41.0	43.2	34.1	39.6	26.0	21.9	7.3	34.2
'83-'87	5.5	16.8	28.9	50.4	52.7	35.5	37.6	30.7	29.7	41.2	24.3	8.4	29.3

Algae number (10^3 ind/l)													
Years	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**October**	**Nov.**	**Dec.**	**Average**
'83-'87	1,013	1,750	11,935	15,190	12,073	5,809	7,124	5,700	5,292	6,087	2,621	837	

Biomass (mg/l)													
Years	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**October**	**Nov.**	**Dec.**	**Average**
'83-'87	0.76	**0.74**	**4.09**	**9.05**	**9.86**	**4.64**	**6.07**	**4.42**	**5.48**	**6.32**	**3.96**	**0.92**	

Table 8: Changes in the quantity of PHYTO PLANKTON among the long-section of the Hungarian Danube section in Autumn 1971 (Németh, 1971)

Sample-taking site	rkm	Algae count (10^6 individual/l)
Rajka	1,848	3.1
Cikola sziget	1,837	3.4
Danuberemete	1,825	2.9
Jánosmarosi pump site	1,815	4.4
Györzámoly, Medvejhid	1,806	5.6
Vének (above the estuary of the Mosoni-Danube)	1,796	4.9
Gönyü	1,791	4.6
Ács (above the estuary of the Concó)	1,777	4.9
Komárom traffic bridge	1,767	5.7
Komárom (under the Vág-Danube)	1,765	8.7
Szöny	1,761	5.6
Danubealmás	1,752	6.6
Above Lábatlan	1,735	6.6
Above Sturovo	1,723	8.4
Below Sturovo	1,721	6.5
Below Esztergom (above the estuary of the Garam)	1,717	7.0
Below the estuary of the Garam)	1,710	10.9
Nagymaros, ferry	1,694	9.0
Above Vág	1,691	9.9
Below Vág	1,677	7.8
Large surface waterworks, Budapest northern railroad bridge	1,655	8.8
Budapest, Háros sziget	1,635	12.8
Nagytétény	1,629	8.4
Százhalombatta	1,622	8.9
Below Százhalombatta	1,618	8.8
Adony, ferry	1,598	9.0
Danubeujváros, ferry	1,581	11.1
Danubevecse	1,569	10.6
Danubeföldvár, bridge	1,560	11.4
Below Paks	1,528	10.6
Below the estuary of the Sió	1,496	13.2
Baja, bridge	1,480	14.8
Mohács	1,452	13.7
Below Mohács, border	1,434	12.7

Table 9: Typical SAPROBITY values on the basis of 1974-1983 tests (VITUKI, 1984)

Waterway	Sample-taking place	Parameters	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Danube	Rajka	min.	2.12	1.98	2.05	2.10	2.11	2.10	2.16	2.18	2.05	2.14
		average	2.51	2.45	2.45	2.47	2.62	2.53	2.48	2.57	2.08	2.56
		max.	3.05	3.03	2.93	3.25	3.35	3.21	3.23	3.07	3.09	2.93
Danube	above Vág	min.	2.00	2.14	2.02	2.14	2.17	2.11	2.07	2.15	2.08	2.05
		average	2.43	2.51	2.40	2.44	2.61	2.57	2.55	2.50	2.07	2.54
		max.	2.91	3.06	2.93	3.06	3.35	3.20	3.31	2.86	2.94	3.05
Danube	Szob	min.	2.40	2.30	2.00	2.30	2.40	2.40	2.40	2.40	2.40	2.40
		average	2.53	2.51	2.49	2.59	2.60	2.54	2.56	2.57	2.62	2.58
		max.	2.80	2.70	2.80	2.80	2.80	2.70	2.80	2.70	2.80	2.70
Danube	above Budapest	min.	2.05	2.40	2.40	2.40	2.50	2.50	2.50	2.50	2.40	2.40
		average	2.62	2.55	2.60	2.64	2.72	2.64	2.64	2.63	2.64	2.64
		max.	3.00	2.80	3.00	2.90	2.90	2.90	2.90	2.80	2.90	2.80

***Table 10**: Bacterial contamination of the Rajka-Budapest section of the Danube and its affluents (KVM, 1988)*

	Danube, Rajka		**Danube, Komárom**		**Danube, Almásneszmély**		**Danube, Esztergom**	
	min.	max	min.	max.	min.	max.	min.	max.
Total germ count/1 cm^3 20 °C	1,400	18,000	100	180,000	700	240,000	3,500	46,000
Total germ count/1 cm^3 37 °C	300	10,000	800	80,000	550	180,000	2,800	45,000
Coliform count/1 cm^3	1.3	170	17	2,400	23	920	7.8	170
Fecal coliform count/1 cm^3	0.49	160	7.9	160	0.78	350	1.7	11
Fecal streptococcus/1 cm^3	0.6	20	0	16	0.1	14	0.1	0.3
Salmonella/1,000 cm^3	71% positive		75% positive		62% positive		33% positive	
Clostridium count/40 cm^3	25	120	15	1,100	30	1,500	10	70
Fungus count/1 cm^3	2	80	2	65	5	110	16	40

	Danube, Szob		Danube, Visegrád		Danube, Negyfelszíni waterworks		Danube, above Budapest (northern railroad bridge)	
	min.	max.	min.	max.	min.	max.	min.	max.
Total germ count/1 cm^3 20 °C	1,400	18,000	3,000	22,000	2,300	32,000	1,100	15,000
Total germ count/1 cm^3 37 °C	900	15,000	1,500	16,000	1,800	80,000	900	29,000
Coliform count/1 cm^3	27	1,600	4.5	1,600	11	240	14	350
Fecal coliform count/1 cm^3	1.0	92	2.7	160	2.3	160	2.3	35
Fecal streptococcus/1 cm^3	0	7	0.2	5	0.3	27	0.2	3
Salmonella/1,000 cm^3	86% positive		75% positive		67% positive		71% positive	
Clostridium count/40 cm^3	30	950	20	220	10	120	30	360
Fungus count/1 cm^3	10	70	6	75	0	31	10	73

Table 11.

	Mosoni Danube, Mecsér		Mosoni Danube, Vének		Lajta, Hegyeshalom		Rába, Győr	
	min.	max	min.	max.	min.	max.	min.	max.
Total germ count/1 cm^3 20 °C	3,000	9,600	88,000	210,000	1,100	6,000	700	15,000
Total germ count/1 cm^3 37 °C	1,800	16,000	34,000	150,000	680	10,000	110	8,000
Coliform count/1 cm^3	2	33	540	3,500	7.8	110	0	33
Fecal coliform count/1 cm^3	0.45	7.9	13	1,600	0.45	13	0	11
Fecal streptococcus/1 cm^3	0	2	8.7	190	0	1.8	0	6.8
Salmonella/1,000 cm^3	60% positive		80% positive		29% positive		38% positive	
Clostridium count/40 cm^3	23	190	40	2,600	58	140	20	1,150
Fungus count/1 cm^3	10	40	20	60	10	90	20	70

Table 12: Maximum element concentrations in the soil permissible form the point of plants' tolerance (MI-10-420-83)

	Maximum concentration (mg/kg air dried soil)
Sb	5
As	15
Be	10
B	100
Br	10
Zn	300
F	500
Hg	2
Cd	5
Co	50
Cr	100
Mo	10
Ni	100
Pb	100
Sn	50
Cu	100
Se	10
V	50

***Table 13**: Typical values of heavy metal contamination in the sediment of affluents (mg/kg) (KVM, 1988)*

	Mosoni-Danube Mecsér	**Mosoni-Danube Vének**	**Lajta Hegyes-halom**	**Rába Győr**	**Concó Nagy-igmánd**	**Ipoly Letkés**
Hg	1.1	0.58	0.42	0.83	0.40	1.50
Cd	2.4	4.0	3.6	2.0	2.0	0.9
Pb	192	43.8	30.4	37.6	24.0	22.5
Cu	87.9	60.1	25.7	64.0	38.3	12.0
Zn	240	212	196	116	116.1	55.0
Fe	16,800	37,200	0.4	38,800	11,600	19,500
Mn	380	632	144	905	244	190

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***Table 14**: Major waste water inlets on the Upper Danube section of Hungary (VITUKI, 1984)*

No.	Pollution source	Recipient	Waste water volume (m^3/d)	COD (mg/l)	COD load (kg/d)
1.	Mosonmagyaróvár	Mosoni D.	3,000	273	820
2.	Mosonmagyaróvár (industrial)	Mosoni D.	11,000-12,000	-	-
	1.+2. based on 1980 measurement	Mosoni D.			3,548
3.	Győr	Mosoni D.	154,100	510	79,000
4.	Győri Szeszipari V.	Mosoni D.	8,000	400	3,200
5.a	ÁTEV, Győr	Mosoni D.	400	106	42
5.b	ÁTEV, Győr	Mosoni D.	600	300	180
6.	Ácsi Cukorgyár	Concó	3,500	160	560
7.	Aszári Keményitőgyár	Concó	2,000	6,050	12,100
8.	Danubekiliti	Holt-D.	115	60	7
9.	Komárom	Danube	3,500	609	2,132
10.	KKV, Szőny	Danube	17,818	20	356
11.	KKV, Almásfüzitő	Danube	10,000	120	1,200
12.	Almásfüzitő Timföldgyár	Danube	7,516	37	278
13.	Lábatlani Vékonypapirgyár	Danube	2,000	327	654
		Danube	400	93	37
		Danube	1,100	217	239
14. 15.	Lábatlani Cement és Mészmű Nyergesújfalu Eternitgyár	Danube	2,000	300	600
	Új Csőgyár	Danube	500	28	14
	Öreg Csőgyár	Danube	225	38	9
	Palagyár	Danube	1,600	73	117
16.	Lábatlan	Danube	2,700	345	932
17.	Viscosa, Nyergesújfalu	Danube	5,000	85	425
18.	Esztergom	Danube	6,000	500	3,000
19.	Dorog	Kenyérmezei p.	8,500	350	2,975
20.	Dorogi Gyógyszergyár	Kenyérmezei p.	2,660	450	1,197

From the border to Komárom	98,637
From Komárom to Szob	14,165
Total (Hungarian from Rajka to Szob)	112,804

Table 15: Major waste water inlets on the Danube section between Szob and Budapest (VITUKI, 1985b)

No.	Pollution source	Recepient	Waste water volume (m^3/d)	COD (mg/l)	COD (mg/l)
1.	Szécsény szvtp.	Szentlélek p.	300	110	33
2.	B.gyarmat szvtp.	Ipoly	2,100	400	840
3.	Tolmács				
	Erdőkémiai Vállalat	Jenői p.	1,120	40	40
	Erdőkémiai Vállalat	Jenői p.	300	40	12
	Erdőkémiai Vállalat	Jenői p.	16	10^4	160
4.	Rétság szvtp.	Jenői p.	200	390	78
5.	MN Rétság	Jenői p.	200	200	40
6.	Romhány Kerámia	Lókos	130	140	18
	Romhány Kerámia	Lókos	40	160	6
7.	Vág DCM	Cigány p.	3,000	10	30
8.	Vág csap. csat.				
	No.1	Danube	170	200	34
	No.2	Danube	160	200	32
	No.3	Danube	150	300	45
	No.4	Danube	750	330	250
	No.5	Danube	1,400	44	62
	No.10	Danube	600	66	40
	No.14	Danube	550	190	105
	No.15	Gombás p.	800	250	200
9.	Vág szvtp.	Danube	16,000	260	4,160
10.	Danubekeszi MÁV jj.	Danube	1,300	244	312
11.	Danubekeszi Hűtőház	Óceán á.	160	65	10
12.	Danubekeszi szvtp.	Óceán á.	4,000	50	200
13.	Dunakeszi házgyár	Óceán á.	800	110	90
14.	Visegrád szvtp.	Danube	200	290	58
15.	Dobogókö szvtp.	Bükkös p.	170	52	9
16.	Szentendrei papirgyár	Danube	1,830	85	161
17.	Szentendrei szvtp.	Danube	4,500	88	396
18.	Szentendre Pevdi	Dera p.	130	55	7
19.	Budakalász Lenfonó	Barát p.	2,700	520	1,420
20.	Budakalász szvtp.	Barát p.	120	370	44
21.	Szentendrei MÁRKA	Rózsa u. á.	145	110	16
22.	Békásmegyer átemelő	Danube	7,000	300	2,160
23.	Északpesti átemelő	Danube	70,000	700	49,000
	Total (from Szob to Budapest)				**60,068**

***Table 16:** The program of the construction of waste water treatment plants under way in the Vág-Nyitra (VIZITERV, 1985)*

Name of settlement	Plant capacity (m^3/day)	Method of treatment	Premises
Komárom	30,000	mechanical	in operation
Érsekujvár	20,000	biological	in operation
Surány	10,000	biological	in operation
Nyitra	25,000	biological	in operation
Topolcsány	15,000	biological	in operation
Partizanszke	10,000	biological	in operation
Pniervidza	5,500	biological	in operation
Nováki	5,500	biological	planning
Guta	10,000	biological	planning
Galánta	10,000	biological	in operation
Szered	10,000	biological	in operation
Pöstyén	30,000	biological	in operation
Vágújhely	20,000	biological	in operation
Tencsén	80,000	biological	in operation
Dubnyica	100,000	biological	under construction
Pukov	30,000	biological	under construction
Povázsszka	15,000	biological	under construction
Zsolna	280,000	biological	under construction
Kisucke	10,000	biological	in operation
Martin	30,000	biological	in operation
Rózsahegy	280,000	biological	in operation
Lipótszentmiklós	85,000	biological	in operation
Alsókubin	8,500	biological	in operation

Table 17: Explored areas (VGI, 1985)

Name of the area	Water-acquisition possibility (10^3 m^3/day)	Water quality parameters (mg/l)	Note
Medvei-hid 1,803-1,808 rkm	60.0	Fe=0.4-1.6	-
Nagybajcs-Vének 1,796-1,798 rkm and 1,800-1,801.5 rkm	40.0	Fe=0.4-0.6	-
Koppánymonostori-sziget 1,773.3-1,774.5 rkm	16.0-20.0	Fe+Mn=1.0/1.5	8 wells have been built, they are protected by a dyke, covered by floods
Szőny-Almásfüzitő 1,764-1,766.5 rkm	5.0-7.0 + the water drain	-	water quality exploration is required
Komáro,m-Szőny 1,761.5-1763.5 rkm	6.0-7.0 + the water drain	-	water quality exploration is required
Szob 1,707.7-1,708 rkm	1.5	Fe=0.3 Σchem.=200/240 CaO	-
Szob-Zebegény 1,704.5-1,704.6 rkm	0.5	Fe=0.3 Σchem.=160 CaO	-
500 m under the Ipoly estuary, left side bank	12.0	Fe=0.0/0.35 Σchem.=160-200 CaO salt=500-700 Fe+Mn=0.0	Ca and Mg carbonate water, somewhat sulphate, if covered by water the line of wells should be raised to 100 m B.f.
Under Nagymaros 1,690-1,692.3 rkm	32.0	Fe=0.0-2.6 NO3=0-36 Σchem.=260-340 CaO	with concentration 14,000 m^3/day

Table 18: Explored areas (VGI, 1985)

Name of the area	Water-acquisition possibility (10^3 m^3/day)	Water quality parameters (mg/l)	Note
Above Nagybajcs 1,808-1,812 rkm	100.0-120.0	Fe=0.4-1.4	-
Ácsi-öblözet 1,773.8-1,782.5 rkm	40.0-45.0	Fe=0.8-1.6 NH_4=1.0-3.0	-
Above Komárom 1,770.5-1,772.5 rkm	14.0-19.0	-	-
Above Almásneszmély 17,53-1,754.5 rkm	12.0-20.0 + the water of drains	-	unfavourably affected by the regulation of the Által ér
Almásneszmély-Alsósziget 1,746-1,748 rkm	10.0		to be eliminated, the bank will be filled with the material of the island
Nyergesujfalui-sziget 1,732.8-1,733.8 rkm	5.0	background NO_3 danger	-
Above Tát 1,728.1-1,728.9 rkm	17.0-22.0	background NO_3 danger	research was abandoned
Táti szigetek	15.0-17.0	Polluted silt of the Kenyérmezei stream	protected by dyke
Above Esztergom 1,721.5-1,726 rkm	25.0 + seepage water	Polluted silt of the Kenyérmezei stream	-
Below Esztergom 1,713-1,716 rkm	10.0 + seepage water	planned waste water treatment plant, cottages, weirs	-
Pilismaróti-öblözet 1,700.8-1,707.6 rkm	20.0	-	to be submerged
Szob-Ipoly-Danube triangle	15.0	-	-
Below Nagymaros 1,692.3-1,693.0 rkm	10.0	-	-

Table 19: The water quality of the Szigeti I. plant on the basis of chemical objections between 1971-1980 (VITUKI, 1987b)

Well-number/year	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**
1. shift-like well	0	0	0	0	0	0	0	0	0	0
2. shift-like well	0	0	0	0	0	0	0	0	0	0
3. shift-like well	0	0	0	0	0	0	0	0	0	0
4. shift-like well	0	0	0	0	0	0	0	0	0	0
5. shift-like well	0	0	0	x	-	Mn	Mn	0	Mn	0
6. shift-like well	Mn	Mn	Mn	Mn	x	-	Mn	-	-	-
7. shift-like well	0	0	0	0	0	0	0	0	0	0
8. shift-like well	Mn	Mn	Mn	Mn	$Mn+NH_4$	$Mn+NH_4$	-	Mn	Mn	0
3. radial well	0	0	0	0	0	0	0	0	0	0
1. radial well	0	0	0	0	0	0	0	0	0	0

Table 20*: The water quality of the Szigeti II. plant on the basis of chemical objections between 1971-1980 (VITUKI, 1987b)*

Well-number/year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1. shift-like well	0	0	0	0	0	0	0	0	0	0
2. shift-like well	0	0	0	0	0	0	0	0	0	0
3. shift-like well	0	0	0	0	0	0	0	0	0	0
4. shift-like well	0	0	0	0	0	0	0	0	0	0
5. shift-like well	0	0		0	0	0	0	0	0	0
6. shift-like well	0	0	Mn	Mn	Mn	0	0	NH_4	0	NH_4
7. shift-like well	0	0	0	0	0	0	0	0	0	0
2. radial well	0	0	0	0	0	0	0	0	0	0
3. radial well	0	0	0	0	0	0	0	0	0	Mn
4. radial well	0	0	0	0	0	0	0	0	0	0
8. shift-like well	0	0	0	0	0	0	0	0	0	0
5. radial well	0	0	0	0	0	0	0	0	NH_4	NH_4
6. radial well	0	0	0	0	0	0	0	0	0	0
7. radial well	0	0	0	0	0	0	0	0	0	0
8. radial well	0	0	0	0	0	0	0	0	0	0
9. radial well	0	0	0	0	0	0	0	0	0	0
10. radial well	0	0	0	0	0	0	0	0	0	0
11. radial well	0	0	0	0	0	0	0	0	0	0
12. radial well	0	0	0	0	0	0	0	0	0	0
9. shift-like well	0	0	0	0	0	0	0	0	0	0
10. shift-like well	0	0	0	0	Mn	0	0	0	0	0

Table 21: Water quality data of main network underwater sample-taking points (KVM, 1988)

Components		1.		2.		3.		4.	
		min.	max.	min.	max.	min.	max.	min.	max.
COD_p	mg/l	0.7	7.4	0.4	5.3	1.1	1.6	0.6	1.9
dissolved 0_2	mg/l	1.1	11.8	1.0	8.0	2.9	6.7	3.0	9.9
pH		7.35	8.35	6.90	7.70	7.00	7.70	7.05	8.30
Specific conductivity	μs	416	568	710	764	568	598	498	612
Total dissolved material	mg/l	260	380	450	570	370	390	320	410
Ca^{2+}	mg/l	64	96	92	112	92	106	52	96
Mg^{2+}	mg/l	12.2	21.9	26	41	18	27	14.5	36.5
Na^+	mg/l	6.3	18.0	15	27	6	11	8	18
K^+	mg/l	1.6	5.0	3.2	6.5	1.5	2.5	1.1	3.0
Cl^-	mg/l	13.5	21.7	33.0	41.5	19.5	20.6	12.1	18.8
SO_4^{2-}	mg/l	31	55	77	144	36	53	36	70
HCO_3^-	mg/l	207	342	255	344	329	396	299	378
CO_3^{2-}	mg/l	∅	∅	∅	∅	∅	∅	∅	∅
Fe^{2+}	mg/l	0.00	1.03	0.00	2.64	1.32	4.60	0.10	1.45
Mn^{2+}	mg/l	0.00	0.21	0.00	1.90	0.42	0.73	0.00	0.75
NH_4^+	mg/l	0.00	1.00	0.10	1.05	0.45	1.15	0.20	1.00
NO_2^-	mg/l	0.00	0.15	0.02	0.09	0.00	0.03	0.00	0.07
$N0_3^-$	mg/l	2.0	18.0	5.5	17.5	0.0	0.9	0.0	8.5
$P0_4^{3-}$	mg/l	0.00	0.47	0.00	0.77	0.00	0.11	0.07	1.06
$Si0_2$	mg/l	12	27	-	-	-	-	24	35

1. Rajka; the well of the dam-guard's house
2. Mosonmagyaróvár; the cold-water well of the beach
3. Ásványráró; the well of the dam guard's house
4. Nagybajcs-Szőgye; the well of the waterworks

Continuation of table 21.

Components		5.		6.		7.		8.	
		min.	max.	min.	max.	min.	max.	min.	max.
COD_p	mg/l	0.1	2.7	0.6	2.4	1.0	4.4	0.2	1.8
dissolved 0_2	mg/l	1.0	7.2	1.0	7.8	2.4	9.8	3.8	11.8
pH		7.30	8.70	7.25	8.40	7.20	8.60	6.95	8.60
Specific conductivity	µs	388	516	373	577	377	560	430	654
Total dissolved material	mg/l	244	340	252	346	260	383	244	430
Ca^{2+}	mg/l	44	84	48	80	52	88	64	100
Mg^{2+}	mg/l	17	46	14.5	36.5	12.2	29.3	17	36.5
Na^+	mg/l	5.5	16.5	7.5	15.5	10	23	7.3	13
K^+	mg/l	1.0	4.0	2.1	3.0	2.0	6.0	2.0	6.0
Cl^-	mg/l	6.7	10.6	17.4	32	19.2	33.4	11.0	22.7
SO_4^{2-}	mg/l	14.5	55	36	67	31	100	34	72
HCO_3^-	mg/l	244	366	195	299	181	268	226	390
CO_3^{2-}	mg/l	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø
Fe^{2+}	mg/l	0.17	1.90	0.20	1.72	0.02	0.28	0.00	0.43
Mn^{2+}	mg/l	0.00	0.32	0.00	0.93	0.04	0.38	0.00	0.38
NH_4^+	mg/l	0.03	0.55	0.05	0.95	0.04	1.10	0.05	0.50
NO_2^-	mg/l	0.00	0.06	0.03	0.11	0.02	0.12	0.00	0.04
$N0_3^-$	mg/l	0.00	1.6	1.0	8.0	4.0	19.0	5.0	24.0
$P0_4^{3-}$	mg/l	0.00	0.79	0.02	0.79	0.16	0.44	0.08	0.86
$Si0_2$	mg/l	22	45	14	54	10	25	12	70

5. Gönyü; the well of the kindergarten
6. Komárom-Koppánymonostor; the collecting lake of the waterworks
7. Esztergom; waterworks, radial well No.3
8. Dömös; collecting well of the waterworks

Annex No.2

ORGANIC MATERIAL LOAD DUE TO WASTE WATER INLET AND RAINSHOWERS

The waste water and sewer data are based on the information service of the MÉLYÉPTERV, and the precipitation data on the information service of the National Meteorological Service.

Dry-period waste water delivery and BOD_5 concentration is as follows;

$Q_{waste\ water}$=80,000 m^3/d
Q_{24}=3,333 m^3/h=0.925 m^3/s
L_0=280 g/m^3 BOD

The BOD_5 load:

T=80,000 x 0.28=22,400 kg/d
T_{24}=933 kg/h=0.259 kg/s

In a simplified form, the load caused by precipitation can be projected as follows:

The characteristics of the reservoir (MÉLYÉPTERV)
Unified sewer network:

Water-collecting surface:954 ha
Drain factor:0.47
Reduced water collecting surface:448 ha

Area characterised by a separated sewer network:
Reservoir: 100 ha
Reduced reservoir surface: 47 ha
Total reduced reservoir: 500 ha

The amount of precipitation water and the resulting BOD_5 load:

I. In case of a two-year frequency shower (Wisnovszky, 1978):

Duration (min):	10	10	5	5	5	5	10	10	60
Intensity (mm):	1.0	1.3	0.8	1.5	10	2.3	1.2	1.0	19.1

The quality of the precipitation water (Benedek-Valló, 1976):

– under peak mode operation 350 g/m^3 BOD_5, while
– before and after the peak 100 g/m^3 BOD_5.

On the basis of the above the distribution of the BOD_5 load and hourly aggregate value:

Duration (min.)	Total precipitation (mm)	Q (m^3)	BOD (kg)
30	4.6	23,000	2,300
10	12.3	61,500	21,525
20	2.2	11,000	1,100
60	**19.1**	**95,500**	**24,925**

T_{24}=6.9 kg/s

II. In case of a one-year frequency shower (Wisnovszky, 1978)

Duration (min):	10	10	5	5	5	5	5	15	60
Intensity (mm):	0.8	8.0	0.7	1.1	7	1.5	0.8	2.0	14.9

The quality of the rain-water is similar to the above. Thus, the load data are as follows:

Duration (min.)	Total precipitation (mm)	Q (m^3)	BOD (kg)
30	3.6	18,000	1,800
10	8.5	42,500	14,875
20	2.8	14,000	1,400
60	**14.9**	**74,500**	**18,075**

T_{24}=5.02 kg/s

III. In case of 5 mm/h precipitation intensity

Total precipitation water amounts to 25,000 m^3, while by calculating with 200 g/m^3 average BOD_5 concentration the BOD_5 load adds up to 5,000 kg/h (1,4 kg/s).

Annex No. 3

Table 1: Proposed water quality monitoring on Hungarian areas (VIZITERV, 1986)

Test site			Water quality new	old
1-1.	Hrušov - Dunakiliti reservoir	1 + 015 rkm	1	-
		7 + 000 rkm	1	-
1-12.	Reservoir filling and drain canal	connecting canal weir No.6, ~ 4.0 rkm	1	-
1-2.	Dunakiliti weir	1,842.5 rkm	1	-
		1,841.0 rkm	1	-
1-7.	Regulation of the old riverbed of the Danube	1,825.5 rkm. Dunaremete	1	-
1.6.	Dredging in the Danube under Palkovičovo	1,809.0 rkm	-	1
	Mosoni Danube	2.4 rkm Vének	1	-
	Mosoni Danube	45.0 rkm Mecsér	-	1
	Rába	0.4 rkm Győr	-	1
		29.0 rkm Árpás	-	1
	Rábca	21.6 rkm Lébény	-	1
	Marcal	17.8 rkm Mórichida	-	1
2-26.	Komárom-Gönyű depression	Cuhai-Bakony ér 7.0 rkm	-	1
		Concó patak 6.0 rkm	-	1
		Concó patak 1,774.0 rkm	1	-
		Concó patak 1,772.7 rkm	1	-
2-25.	Komárom city and Komárom depression	1,768.3 rkm Komárom	-	1
		1,753.7 rkm	1	ü
		Általér Tata	-	1
2-24.	Nyergesujfalu-Dunaalmás depression	1,732.0 rkm	1	-
2-23.	Esztergom city and Esztergom depression	1,728.0 rkm Táti sziget. depression. weir	1	-
		1,726.5 rkm	1	-
		1,723.5 rkm	1	-
		Táti-(Unyi patak) Tokod	-	1
		Kenyérmezei patak Dorog.	-	1
		1,720.2 rkm. dock	1	-
2.22.	Pilismaróti depression, 32 VO-29 VO sz.	1,704.1 rkm	1	-
2-21.	Visegrádi-Dömösi depression	28 VO sz. 1,700,9 rkm.	1	-
		1,700.4 rkm	1	-
2-27.	Nagymaros Ipoly depression, 18,8 rkm	Ipolytölgyes	-	1
		1,708.0 rkm. Szob	-	1
2-3.	Nagymaros barrage system	1,696.0-1,695.0 rkm	1	-

Test site			Water quality new	Water quality old
		1,694.6 rkm	-	1
2-4.	Dredging on the Danube below Nagymaros	1,698.0 rkm	2	-
		1,686.5 rkm	2	-
		1,679.5 rkm. Vác	1	-
		1,676.5 rkm	2	-
		1,665.0 rkm	2	-
		Danube. Budapest	-	1
		Szentendre. Dunaág. 29.8 rkm	2	-
		27.5 rkm	2	-
		27.3 rkm Dunabogdány 19.0 rkm	1	-
		8.5 rkm Szentendre	2	-
		1.0 rkm Budapest	-	1

***Table 2**: Proposed water quality monitoring on Czechoslovakian areas (VIZITERV, 1986)*

Test site			Water quality new	Water quality old
1-7.	Regulation of the old riverbed of the Danube	1,826.000 rkm	1	-
		1,833.000 rkm	1	-
		1,839.750 rkm	1	-
2-11.	Alsó-Ipel depression	-	-	-
2-12.	Alsó-HRON depression	3.000 lkm (approx. 1,719.13 rkm)	1	-
		1.5 lkm (approx. 1,717.70 rkm)	1	-
		5.80 rkm	1	-
2-13.	KRAVANY depression	0.00 lkm (approx. 1,722.90 rkm)	1	-
		3.00 lkm (approx. 1,725.70 rkm)	1	-
		7.00 lkm (approx. 1,729.60 rkm)	1	-
		1,745.60 rkm (approx. 10.20 rkm)	1	-
2-14.	IZAI depression	5.00 lkm (approx.1,756.45 rkm)	1	-
		12.00 lkm (approx. 1,763.35 rkm)	1	-
		1764.00 rkm (approx. 12.6 lkm)	1	-
2-15.	Komárno city depression	5.00 lkm (approx. 1,766.1 rkm)	1	-
		5.00 rkm (approx. 9.70 lkm)	1	-

2-16.	Komárno-MEDVEDOV depression	VELKE KOSIHY sztp.	1	-
		34.00 lkm		
		(approx. 1,800.00 rkm)	1	-
2-17.	VÁH-Left bank depression	0.50 rkm left bank	1	-
2-18.	VÁH right bank and MALY-Dunaj depression, Cergovi sztp	20.70 rkm		
		(approx. 19.80 lkm)	1	-
		29.75 rkm	1	-
		15.30 rkm	1	-
1-11.	HRVSOV-Dunakiliti Reservoir, reservoirs 1-11	right hand side bank		
		2.000 lkm	1	-
		5.000 lkm	1	-
		8.000 lkm	1	-
		10.000 lkm	1	-
		12.000 lkm	1	-
		14.980 lkm (MS-009)	1	-
		20.000 lkm	1	-
1-3.	Head-race canal right hand side bank	1.000 lkm	1	-
		6.000 lkm	1	-
		12.000 lkm	1	-
	Drounage culvert	4.000 rkm	1	-
		0.050 lkm	-	-
		1.000 lkm	1	-
		6.000 lkm	1	-
		12.000 lkm	1	-
1-4.	Gabčíkovo barrage system	17.500 power canal km	1	-
1-5.	Tail-race canal right hand side bank			
		23.000 power canal km	1	-
	left hand side bank			
		23.000 power canal km	1	-
		24.500 power canal km	1	-
		25.000 power canal km	1	-
			1	
1.6	Dredging on the Danube under Palkovičovo	1,810.620 rkm	1	-
		(approx. 25.5 power canal km)		
		1,807.500 rkm	1	-
1.7	Regulation of the old riverbed of the Danube	1,815.000 rkm	1	-
		1,820.300 rkm	1	-

Annex 14

WHAT IS THE IMPACT OF SPECIAL WEIRS ON THE GROUNDWATER LEVELS?
PROVEN FOR THE AREA OF THE BARRAGE RHINAU

Wie wirken feste Schwellen im Rhein auf die seitlichen Grundwasserstände?
Nachgewiesen für den Bereich der Stufe Rhinau

Kalkowski,

Regierungspräsidium Freiburg

July, 1986

Enclosures:[see German text]

1. Map (1:25 000)
2. Longitudinal view of the Rhine from 249 to 268 km
3. Illustration of the progress lines
4. Map of groundwater levels (1:50 000)

In Article 8 of the Oberrhein-Treaty of 27 October 1956 the construction of special weirs is stipulated below each main weir in the river bed. The aim of these additional measures was to prevent a drastic decrease of the water levels in the Rhine. The height of the special weirs should be as high as to guarantee that the water level in the middle of the reservoir can be kept at the mean of its present level.

The question above will be answered with respect to the Barrage Rhinau. Its three special weirs have been in operation for about 20 years. Furthermore, the inland monitoring net of the groundwater monitoring sites and gauges is designed in such a way that the groundwater levels in the immediate vicinity of the Rhine can be monitored. Thus, long-term monitoring data is available allowing reliable conclusions.

The enclosed map (enclosure 1) shows topographical details. It also illustrates the location of the monitoring sites near the Rhine.

The longitudinal view (enclosure 2) between the barrages of Rhinau and Gerstheim gives an overall view of the levels along this section of the river. Currently, the water level curve is characterised by step-like pattern below a discharge of 1500 m^3. Flow gradients only occur at the 3 special weirs during mean high water levels. However, even at discharge values of more than 3000 m^3/s, the former water levels are not reached any more.

The most recent low water level measurement at a discharge value of 540 m^3/s in Basel in 1961 is noted to demonstrate the former conditions and to have a reference for the extent of the changes. In relation to this water level, the water level measured at gauge Kappel is 82 cm higher during a mean annual discharge value of 1040 m^3/s. The mean water level corresponding to $Q = 1040\ m^3/s$ was noted in the longitudinal view as provided by the Navigation Administration at Freiburg. This discharge value corresponds with average flow of 1961 at the gauge Marlen. Thus, the water level curve corresponds with the mean discharge of 1961 in this area.

Furthermore, the water level curve was illustrated which results from a flow of 600 m^3/s in the old Rhine-bed in the area of the bypass. According to experience, the Rhine begins to overflow its banks above the special weir. In that case the total discharge amounts to 2100 m^3/s. This represents a mean flood event in the winter period at the former gauge (period 1936/1965).

These notes show:

1. At total discharge values of up to 1500 m^3/s, 15 m^3/s remain in the old Rhine-bed. In this case, the water levels in the reservoir of the first and second special weirs are above the low-flow levels in 1961 but remain below the annual mean-flow levels in the upper part of the reservoir.

   However, the crest of the special weir and the impoundment level of the Barrage of Gerstheim are so low that even the upper section of the reservoir falls below the low-flow levels of 1961.

2. At higher discharge values the banks are at first only locally flooded. From the longitudinal view it can be seen, that the discharge of 600 m^3/s (= 2100 m^3/s of total discharge) is the limit above which the flood areas increasingly extend in upstream direction.

3. Considerable differences exist in the levels between the headwater and tailwater sections at the special weirs. As a consequence, these differences also persist at flood conditions with a discharge of 3000 m^3/s and lead to intense flows around the edges of the weirs. The steady level typical of the former free discharge does not occur any more, even not during the rare and high flood conditions. The step-like discharge conditions remain effective.

The conversion of a part of the river possessing a free flow gradient into a sequence of weirs has not only an impact on the drainage conditions of the waters. Changes also become apparent in the behaviour of the adjacent groundwater levels, if the river remained the receiving watercourse for the groundwater.

To show these relationships, the hydrographs of 1975/76 of the monitoring sites marked *with black arrows* are illustrated in enclosure 3.

There is no monitoring station in the Rhine above the third special weir (at 256.53 km). The tributary discharges into the Rhine below the confluence of the Leopold-channel were estimated using the water gauge at Rheinfelden (for the Rhine) and the gauge at the sluice valve (for the Leopold-channel) in order to produce a more detailed evaluation of the water levels. The upper water level was calculated and a hydrograph for 1975/76 was produced with the help of the discharge curve of the special weirs. This curve was derived from a model test. However, the curve is only valid up to a surface water level of about 163.50 m asl., above which the flooding of the adjacent area becomes effective.

Furthermore, it should be mentioned that the hydrograph of the gauge C-827 067 is similar to the water level at gauge Kappel in the Rhine. Thus, the reservoir of the barrage Gerstheim is seized in the section of the Rhine below the third special weir.

The comparison of the water levels in the Rhine (left) and the groundwater levels (right), which are illustrated in enclosure 3, show the following:

1. Between the levels of the upper water and the lower water of the third special weir is a mean difference of more than 2 metres.

2. This instability in the surface water level is not adapted by the groundwater. Its mean level still shows the steady gradient as before the construction. The break in the slope below the third weir does not contradict this statement due to the low order of magnitude of the variations.

3. The groundwater level illustrated in the longitudinal view (enclosure 2) shows the mean-flow level from 1976, i.e. a water level below the long-term average. The level pattern mainly corresponds with the pattern of the low-flow levels of 1961 in the Rhine. The permanently high water levels at the special weirs, which exceed the former water levels in the Rhine by 70 to 80 cm, have no particular impact on groundwater. In this case, the bottom water sections below the weirs take control. With their partly very low level, they form the drain for the groundwater and subsequently determine its water level near the Rhine.

4. The hydrographs of the individual groundwater gauges show a similar pattern in particular at low and mean discharges in the Rhine. Flood discharges are noticeable at all gauge sites but their variation range is different.

   The impact of the Barrage of Gerstheim becomes noticeable near monitoring site 6/16-214 067 and increases downstream. The hydrographs illustrate a more intense water level fluctuation than the impounded Rhine (see gauge C-827 067).

5. The longitudinal view illustrates those sections in the reservoir where the current mean water level in the Rhine falls below the low-flow level of 1961 and the mean-flow level of 1961 (1040 m^3/s).

– table – (not included) / see German text

Those sections, which represent a permanent drain for the groundwater due to the complete change of the water level situation in the section below the Barrage of Rhinau, fall below these low-flow values. In relation to the mean-flow level of 1961, the difference can be up to half of the length of the reservoir of a weir.

Consequently, it can be concluded that the Rhine prevents the draining of groundwater on great sections due to its damming by special weirs. However, owing to the present water level regime, there remain areas which are located below the weirs and continuously drain the groundwater. With respect to the current conditions, this effect cannot be controlled. The results of the investigations at the gauge Marlen are referred to, in order to show how the water level in the Rhine would have decreased, if there were no weirs. The comparison of the mean water levels from 1961 (138.37 m asl.) and from 1979 (135.92 m asl.) comes to a mean decrease of 2.45 m!

Surprisingly, the gradient of the groundwater level close to the Rhine does not follow the step-like pattern of the river. The groundwater level maintained its former and steady progress line, as the comparison with the low-water level of 1961 reveals. The reason for this can only be described in general terms. An important effect is the increased implication of the old water veins of the Rhine in the floodplain after the development of the Oberrhein (see enclosure 4). The comparison of the groundwater levels during mean water levels before (1946/1958) and after (1975) the construction of the Barrage of Rhinau shows that at present the slope of the groundwater thalweg is more flattened in this section of the Rhine.

Particularly, the gradient from the Rhine towards the inland decreased significantly at some locations, which results, to a certain extent, in an increase of the former low groundwater levels. Both effects are due to the higher supply of the groundwater from the inland. At the same time, the mean level adjusted to the now relatively steady conditions of the Rhine water levels.

Regierungspräsidium Freiburg — July 1986
Abt. V. Wasserwirtschaft — Kalkowski

Nr. V 52/872/86 v. 31.7.86

Wie wirken feste Schwellen im Rhein auf die seitlichen Grundwasserstände?

Nachgewiesen für den Bereich der Stufe Rhinau

Anlagen: Lageplan - 1 : 25 000,
Längsschnitt des Rheins - km 249 bis 268,
Darstellung von Ganglinien,
Grundwasserhöhenplan - 1 : 50 000

Im Oberrheinvertrag vom 27. Oktober 1956 ist in Artikel 8 der Bau von festen Schwellen im Rheinbett unterhalb jedes Hauptwehres vorgesehen. Ziel dieser den Bau der Staustufen begleitenden Maßnahme war es, den Rheinwasserstand nicht extrem absinken zu lassen. Die Oberkanten der festen Schwellen sollen so hoch gelegt werden, daß der Wasserstand in der Mitte jeder Haltung im Mittel auf seiner gegenwärtigen Höhe gehalten werden kann.

Die Antwort auf die oben gestellte Frage soll für die Staustufe Rhinau gegeben werden. Deren drei feste Schwellen sind seit rd. 20 Jahren in Betrieb. Außerdem ist das binnenseitige Meßnetz der Grundwassermeßstellen und Pegel an Gewässern so konzipiert worden, daß in unmittelbarer Nähe zum Rhein die Grundwasserstände erfaßt werden können. So liegen langjährige Beobachtungsergebnisse vor, die eine zuverlässige Schlußfolgerung ermöglichen.

Aus dem beiliegenden Lageplan (Anlage 1) gehen die topographischen Einzelheiten hervor. In ihm sind auch die rheinnahen Meßstellen eingetragen.

Der Rhein-Längsschnitt (Anlage 2) zwischen den Hauptwehren Rhinau und Gerstheim gibt einen Überblick über die Höhenverhältnisse entlang diesem Flußabschnitt. Die heutige Wasserspiegellage ist bei Abflüssen bis zu 1500 m^3/s durch einen stufenförmigen Verlauf gekennzeichnet. Erst ab mittleren Hochwasserereignissen stellen sich in den Haltungen der drei festen Schwellen Fließgefälle ein; es kommt aber selbst bei Abflüssen über 3000 m^3/s nicht mehr zu einer Wasserspiegellinie, wie sie früher bestanden hat.

-2-

Um jenen früheren Zustand zu dokumentieren und gleichzeitig einen Anhalt für das Maß der Veränderung zu geben, ist die letzte Niedrigwasserfixierung für einen Abfluß von 540 m^3/s in Basel aus dem Jahre 1961 eingetragen. Bezogen auf diesen Wasserspiegel liegt beim mittleren Jahresabfluß von 1040 m^3/s der Wasserstand um 82 cm höher. (Dieser Wert wurde für den Pegel Kappel ermittelt.) In den Längsschnitt eingezeichnet wurde nach einer Vorlage von der WSD Freiburg der mittlere Wasserstand zu $Q = 1040\ m^3/s$; dieser Abfluß entspricht dem MQ 1961 am Pegel Marlen, sodaß die Wasserstandslinie dem mittleren Abfluß des Jahres 1961 in diesem Abschnitt gleichkommt.

Ferner wurde die Wasserstandslinie eingetragen, die sich einstellt, wenn im Bereich der Kanalschlinge 600 m^3/s durch das alte Rheinbett fließen. Erfahrungsgemäß beginnt der Rhein dann oberhalb der festen Schwellen auszuufern. In diesem Falle liegt der gesamte Abfluß bei 2100 m^3/s. Am ehemaligen Rheinpegel Marlen ist dies ein mittleres Hochwasserereignis im Winterhalbjahr (WiMHQ 1936/1965).

Aus diesen Eintragungen läßt sich entnehmen:

1. Bei Abflüssen bis zu insgesamt 1500 m^3/s bleiben im alten Rheinbett 15 m^3/s. Die hierbei gegebenen Wasserstände liegen im Stau der ersten und zweiten festen Schwelle zwar über dem NW 1961, unterschreiten aber im oberen Bereich der Haltungen deutlich den mittleren Jahreswasserstand.

   Die Oberkante der dritten festen Schwelle und das Stauziel der Stufe Gerstheim sind dagegen so niedrig, daß auch das NW 1961 im oberen Teil der Haltungen deutlich unterschritten wird.

2. An den festen Schwellen kommt es bei höheren Abflüssen zunächst punktuell zu Überflutungen der Ufer. Wie aus dem Längsschnitt zu ersehen ist, stellt der Abfluß von 600 m^3/s (gleich 2100 m^3/s Gesamtabfluß) diese Grenze dar, von der an in steigendem Maße diese Überströmungsabschnitte sich flußaufwärts ausdehnen.

3. An den festen Schwellen bestehen zwischen Ober- und Unterwasser beträchtliche Höhenunterschiede. Das hat zur Folge, daß auch bei Hochwässern mit Abflüssen über 3000 m^3/s diese Spiegeldifferenzen wirksam bleiben und dazu führen, daß die Schwellen im Bereich der Uferanschlüsse scharf umströmt werden. Selbst bei seltenen großen Hochwassern stellt sich nicht

mehr ein gleichmäßiger Spiegelverlauf des früher freien Abflusses ein. Die gestuften Abflußverhältnisse bleiben wirksam.

Die Umwandlung eines Flußabschnittes mit freiem Fließgefälle in eine Folge von Stauhaltungen wirkt sich nicht nur auf die Abflußzustände im Gewässer aus. Auch im Verhalten der seitlichen Grundwasserstände zeigen sich die Veränderungen, soweit das Gewässer Vorfluter für das Grundwasser geblieben ist.

Zum Nachweis dieser Zusammenhänge sind auf Anlage 3 Ganglinien der Jahre 1975/1976 von den Meßstellen aufgetragen, die im Lageplan rot markiert sind.

Oberhalb der dritten festen Schwelle (bei Rhein-km 256,530) gibt es keine Meßstelle im Rhein. Um dennoch eine detaillierte Aussage über die Wasserspiegellage machen zu können, wurden die Zuflüsse in die Rheinstrecke unterhalb der Mündung des Leopoldskanals an Hand der Pegel Rheinfelden (für den Rhein) und Riegel (für den Leopoldskanal) abgeschätzt. Über die aus Modellversuchen bekannte Abflußkurve der festen Schwellen konnten so der Oberwasserstand berechnet und eine Ganglinie für die Jahre 1975/1976 gezeichnet werden. Diese gilt jedoch nur bis zu einer Wasserspiegellage von etwa NN + 163,50 m; von da an wirkt sich zunehmend die seitliche Beflutung des Geländes aus.

Weiter ist darauf hinzuweisen, daß die Ganglinie des Pegels C - 827 067 etwa der Wasserspiegellage im Rhein am Pegel Kappel entspricht. Damit wird der Rückstau des Hauptwehres Gerstheim in die Rheinstrecke unterhalb der dritten festen Schwelle erfaßt.

Vergleicht man nun die auf Anlage 3 dargestellten Rheinwasserstände (links) mit den Grundwasserständen (rechts), so läßt sich daraus folgendes ablesen:

1. Zwischen dem Oberwasser und dem Unterwasser an der dritten festen Schwelle besteht ein Wasserspiegelsprung von im Mittel über zwei Metern.
2. Dieser Unstetigkeit im Wasserspiegelverlauf paßt sich das Grundwasser nicht an. In seiner mittleren Spiegellage ist noch jene Gleichmäßigkeit des Gefälles erkennbar, wie sie vor dem Ausbau bestand. Der unterhalb der dritten Schwelle sich abzeichnende Gefällsknick spricht in der gegebenen Größenordnung nicht gegen diese Aussage.

3. Die im Längsschnitt (Anlage 2) eingetragene Wasserspiegellinie des Grundwassers ist das MW von 1976, also eine unterdurchschnittliche Wasserspiegellage. Es zeigt sich, daß sie überwiegend dem Verlauf des NW 1961 im Rhein folgt. Die an den festen Schwellen bestehenden hohen Dauerwasserstände, die ja das frühere mittlere Spiegelniveau im Rhein zwischen 70 und 80 cm übersteigen, haben keine besondere Wirkung auf das Grundwasser. Maßgebend sind hier die Unterwasserstrecken unterhalb der Staustellen. Mit ihrem zum Teil sehr tiefen Niveau bilden sie die Vorflut für das Grundwasser und bestimmen dann dessen rheinnahe Spiegellage.

4. Die Ganglinien der einzelnen Grundwassermeßstellen zeigen untereinander große Ähnlichkeit. Das gilt insbesondere für niedrige bis mittlere Abflüsse im Rhein. Durchlaufende Hochwasserwellen markieren sich zwar an allen Stellen deutlich; sie sind jedoch von unterschiedlicher Schwankungsweite.

   Etwa von der Meßstelle 6/16 - 214 067 an ist abwärts zunehmend der Einfluß von der Stauhaltung Gerstheim zu erkennen. Die Ganglinien zeugen von einer lebhafteren Wasserspiegelbewegung wie sie der Rhein aufweist (s. Pegel C-827 067).

5. Aus dem Längsschnitt (Anlage 2) lassen sich deutlich die Abschnitte in den einzelnen Stauhaltungen entnehmen, wo der heutige mittlere Rheinwasserstand das NW 1961 und das MW 1961 ($Q = 1040\ m^3/s$) unterschreitet:

<u>Länge der Streckenabschnitte</u>

Rhein-km	bei NW 1961 (m)	bei MW 1961 (m)	Länge der Haltung (m)
251,5 (1. Schwelle)	-	1200	2300
253,62 (2. Schwelle)	-	1050	2120
256,53 (3. Schwelle)	800	1850	2910
Stufe Gerstheim	650	1800	-

Das sind jene Flußabschnitte, die bedingt durch die totale Änderung der Wasserspiegellage in der Rheinstrecke unterhalb dem Stauwehr Rhinau eine ständige Vorflut für das Grundwasser bildon. Bezogen auf das MW 1961 ist es bis zur halben Haltungslänge einer Schwelle.

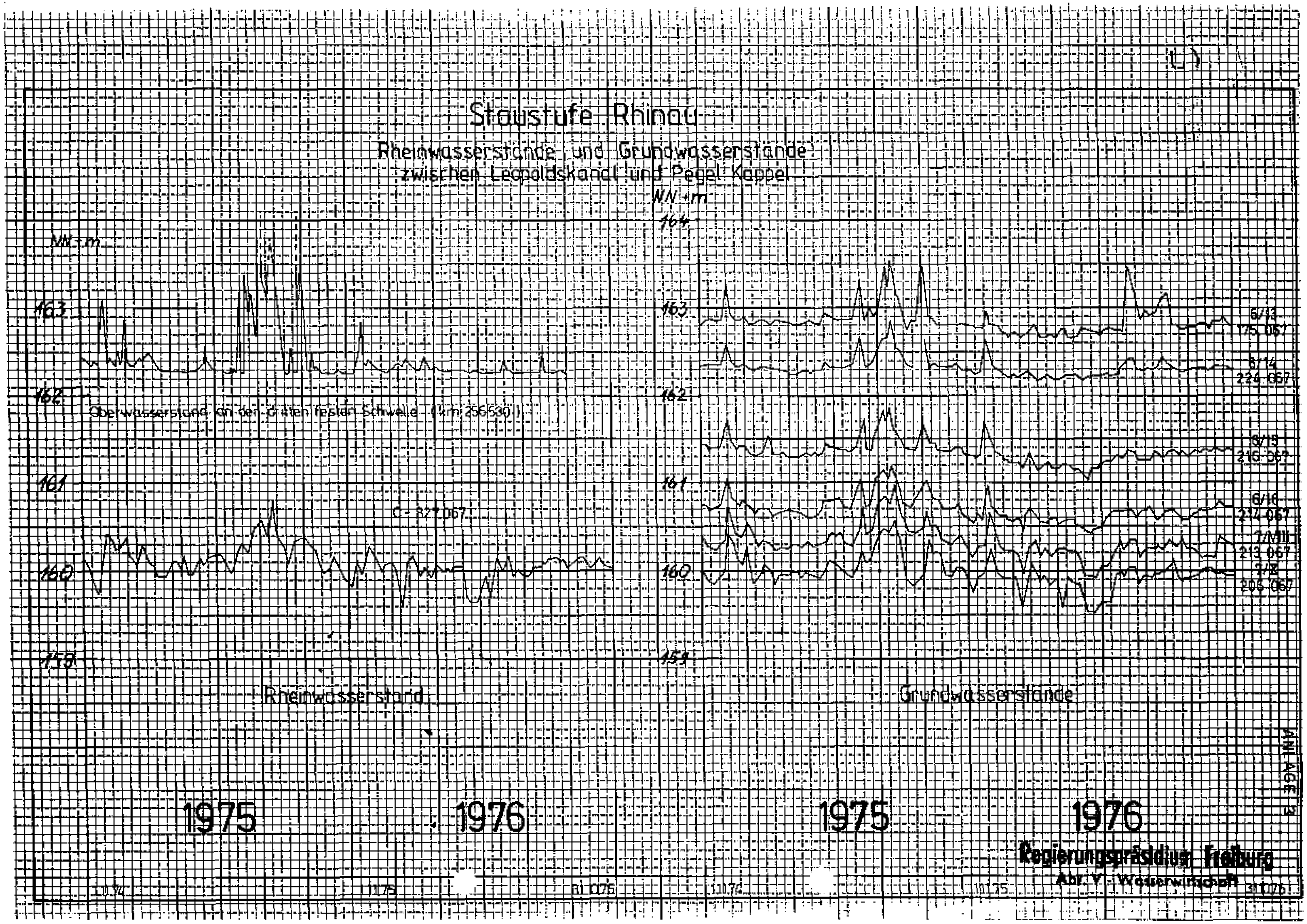
Aus diesen Tatsachen läßt sich folgern, daß auf großen Strecken der mit festen Schwellen gestaute Rhein ein Abfließen des Grundwassers verhindert. Bei den gegebenen Wasserstandsverhältnissen bleiben jedoch Bereiche, die jeweils unterhalb der Staustellen liegen, wo das Grundwasser ständig Vorflut zum Rhein findet. Hierauf kann unter den gegebenen Umständen kein Einfluß genommen werden. Um eine Vorstellung dafür zu geben, wie der Rheinwasserstand ohne Bau von Schwellen hätte absinken können, sei auf die Beobachtungsergebnisse vom Pegel Marlen verwiesen. Der Vergleich der Mittelwasserstände der Jahre 1961 (NN + 138,37 m) und 1979 (NN + 135,92 m) ergibt eine mittlere Senkung von 2,45 m!

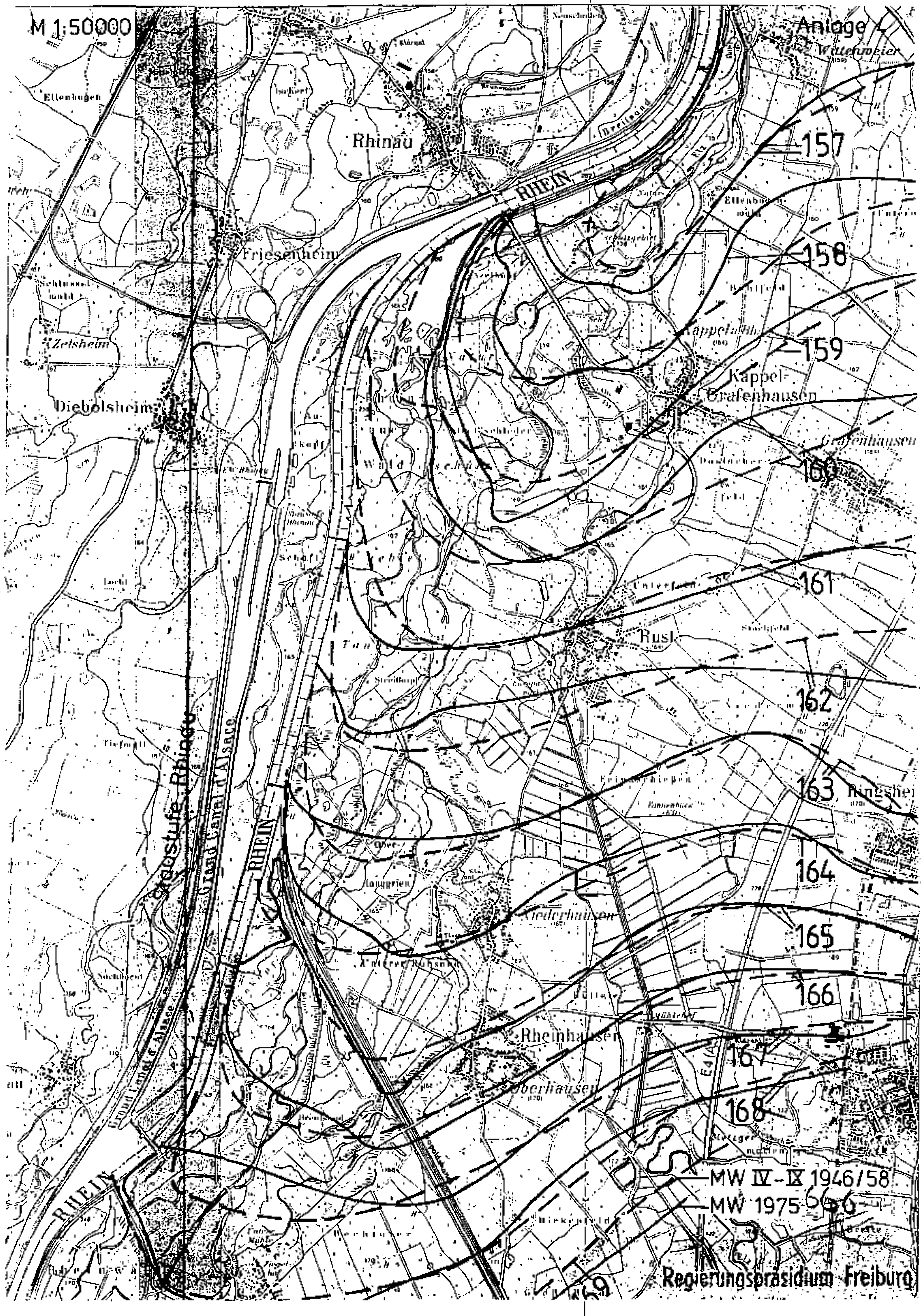
Überraschend ist, daß sich das Gefälle des Grundwasserspiegels unmittelbar seitlich vom Rhein nicht nach den stufigen Wasserständen im Fluß richtet. Es hat seinen gleichförmigen Verlauf von früher behalten, wie der Vergleich mit dem NW 1961 offenbart. Worauf das zurückzuführen ist, kann zunächst nur pauschal beschrieben werden. Dabei ist die Tatsache von Bedeutung, daß als Folge des Oberrheinausbaues die den Rheinstrom begleitende Rheinaue mit ihren zahlreichen Altwassern wasserwirtschaftlich an Gewicht gewonnen hat (vgl. Anlage 4). Der Vergleich von Grundwasserhöhenkarten für mittlere Wasserstände vor (MW IV - IX 1946/1958) und nach (MW 1975) dem Bau der Staustufe Rhinau zeigt, daß in dem hier behandelten Rheinabschnitt der sogenannte Talweg des Grundwassers heute flacher geformt ist. Insbesondere hat sich das Quergefälle vom Rhein her örtlich stark verringert, was gleichzeitig mit einer gewissen Anhebung tiefer Grundwasserstände, wie sie früher gegeben waren, verbunden ist. Beides ist eine Folge davon, daß der Grundwasserstrom binnenseits mehr gestützt wird. Dabei hat sich das mittlere Niveau auf die nunmehr bestehenden relativ gleichbleibenden Vorflutverhältnisse im Rhein eingestellt.

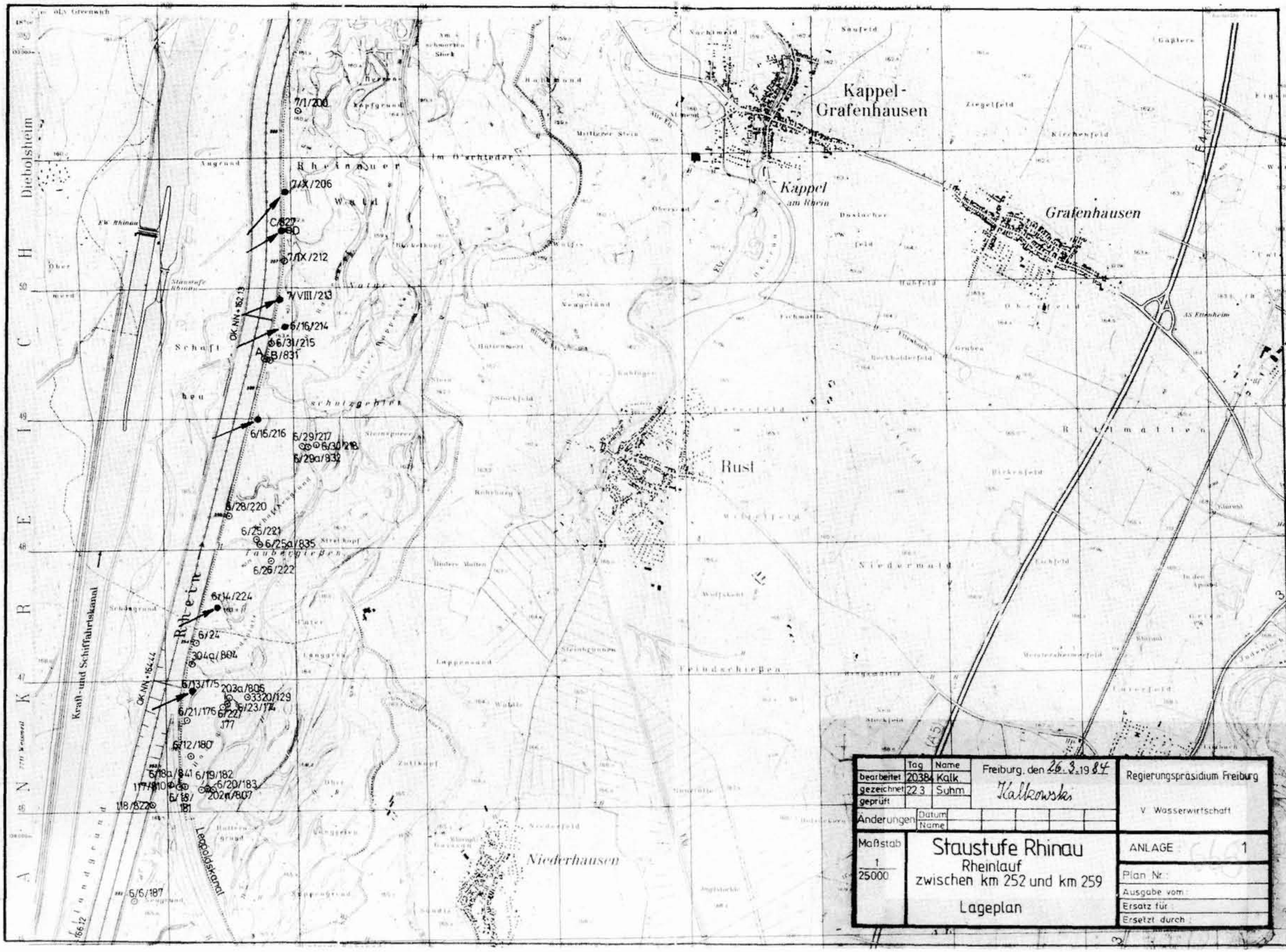
Regierungspräsidium Freiburg
- Abt. V Wasserwirtschaft -

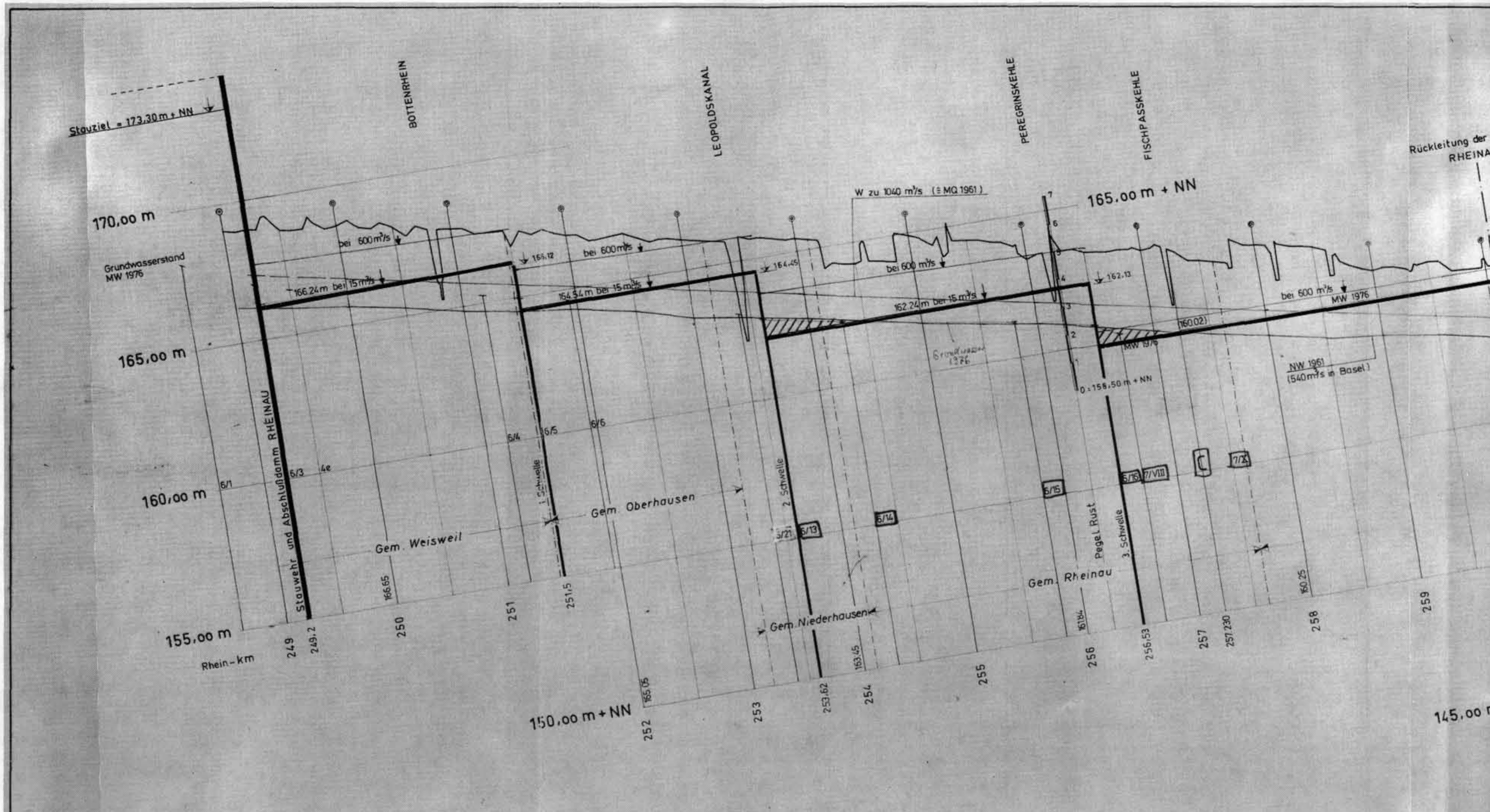
Freiburg i.Br., im Juli 1986
aufgestellt:

Kalkowski

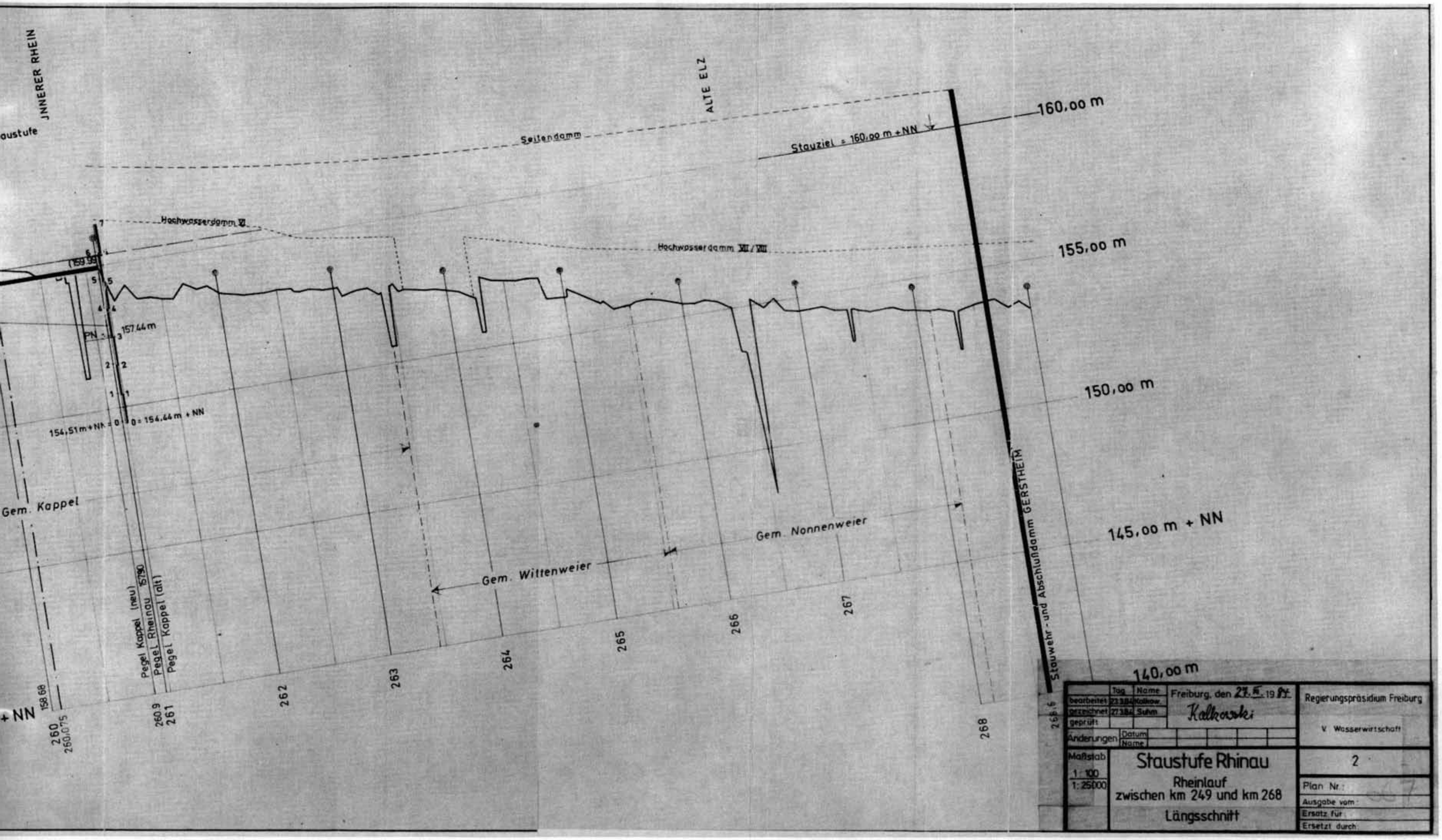

Staustufe Rhinau
Rheinwasserstände und Grundwasserstände
zwischen Leopoldskanal und Pegel Kappel
NN+m
Oberwasserstand an der dritten festen Schwelle (km 256,530)
Rheinwasserstand
Grundwasserstände
1975
1976
1975
1976
ANLAGE 3
Regierungspräsidium Freiburg
Abt. V - Wasserwirtschaft


M 1:50000
Anlage 4
Rhinau
RHEIN
Friesenheim
Zelsheim
Diebolsheim
Kappel-Grafenhausen
Grafenhausen
Rust
Niederhausen
Rheinhausen
Oberhausen
Staustufe Rhinau
Grand Canal d'Alsace
RHEIN
157
158
159
160
161
162
163
164
165
166
167
168
169
MW IV-IX 1946/58
MW 1975
Regierungspräsidium Freiburg


Kappel-
Grafenhausen
Kappel
am Rhein
Grafenhausen
Rust
Niederhausen
Diebolsheim
Rhein
Leopoldskanal
Kraft- und Schiffahrtskanal
Rheinauer Wald
Schutzgebiet
Taubergießen
7/1/200
7/X/206
C/827
7/IX/212
7/VIII/213
6/16/214
6/31/215
A,B/831
OK NN + 162,13
6/15/216
6/29/217
6/30/218
6/29a/832
6/28/220
6/25/221
6/25a/835
6/26/222
6r14/224
6/24
304a/804
6/13/175
203a/806
3320/129
6/23/174
6/21/176
6/22
177
6/12/180
6/18a/841
6/19/182
6/20/183
177/810
6/18/181
202a/807
118/822
OK NN + 164,44
6/6/187
Tag
Name
bearbeitet
20384
Kalk
gezeichnet
22.3
Suhm
geprüft
Änderungen
Datum
Name
Freiburg, den 26.3.1984
Kalkowski
Regierungspräsidium Freiburg
V. Wasserwirtschaft
Maßstab
1
25000
Staustufe Rhinau
Rheinlauf
zwischen km 252 und km 259
Lageplan
ANLAGE 1
Plan Nr.:
Ausgabe vom:
Ersatz für:
Ersetzt durch:



Stauziel = 173,30 m + NN
BOTTENRHEIN
LEOPOLDSKANAL
PEREGRINSKEHLE
FISCHPASSKEHLE
Rückleitung der St
RHEINAU
W zu 1040 m³/s (≙ MQ 1961)
165,00 m + NN
170,00 m
Grundwasserstand
MW 1976
bei 600 m³/s
166,24 m bei 15 m³/s
164,12
164,54 m bei 15 m³/s
164,45
162,24 m bei 15 m³/s
162,13
MW 1976
160,02
NW 1961
(540 m³/s in Basel)
0 = 158,50 m + NN
165,00 m
Stauwehr und Abschlußdamm RHEINAU
1. Schwelle
2. Schwelle
3. Schwelle
Pegel Rust
Gem. Oberhausen
Gem. Weisweil
Gem. Rheinau
Gem. Niederhausen
160,00 m
155,00 m
Rhein-km
150,00 m + NN
145,00 m
249
249,2
250
251
251,5
252
253
253,62
254
255
256
256,53
257
257,230
258
259
166,65
165,05
163,45
161,84
160,25



JNNERER RHEIN
ALTE ELZ
Seitendamm
Stauziel = 160,00 m + NN
160,00 m
155,00 m
150,00 m
145,00 m + NN
140,00 m
Hochwasserdamm VI
Hochwasserdamm VII / VIII
157,44 m
154,51 m + NN = 0
0 = 154,44 m + NN
Gem. Kappel
Gem. Wittenweier
Gem. Nonnenweier
Stauwehr - und Abschlußdamm GERSTHEIM
Pegel Kappel (neu)
Pegel Rheinau
Pegel Kappel (alt)
+ NN
158,68
260
260,075
260,9
261
262
263
264
265
266
267
268
268,6
Freiburg, den 27.5.1984
Kalkowski
Regierungspräsidium Freiburg
V Wasserwirtschaft
Tag
Name
bearbeitet
23.3.84
Kalkow.
gezeichnet
27.3.84
Suhm
geprüft
Änderungen
Datum
Name
Maßstab
1 : 100
1 : 25000
Staustufe Rhinau
Rheinlauf
zwischen km 249 und km 268
Längsschnitt
2
Plan Nr.:
Ausgabe vom:
Ersatz für:
Ersetzt durch:

Annex 15

ECOLOGICAL EFFECTS OF THE MANAGEMENT SYSTEM OF CONNECTED SIDE BRANCHES (DEMONSTRATED BY THE EXAMPLE OF THE REGULATION OF SIDE BRANCHES OF THE RIVER RHINE)

Werner Krause and Gerhard Hügin
and Federal Environment and Land Ecology Research Institute

Published by: W. Kohlhammer, Stuttgart

Natur und Landschaft 62 (1): 9

1987

As a result of the construction of the barrages on the Upper-Rhine, the numerous isolated side arms, which were significantly diverse and fairly abundant habitats of endangered water plants characteristic of floodplains, were interconnected through a transit water flow to form one system (irrigation canal, supply canal). The channels are supplied with water from the Rhine during the whole year which is polluted especially during low water conditions and after chemical accidents.

This technical measure was intended to protect the floodplain from the harmful effects of the drought.

In spite of the fact that the side branches are filled up during the whole year, the provision of water for the alluvial forests has not been solved. The water table is falling due to reduced water table fluctuation, low water levels in the tail water sections, lowered inland drainage levels, and significant use of ground water. Simultaneously, the clogging of the channels is apparent. The regular alternation of dry seasons and floods, which is characteristic of floodplains, is badly missing. As opposed to this situation, the floods would periodically fill the water table, which in turn, would reach the channel bed. Particularly in autumn, when the side branches would dry up, the floods would ensure the mutual exchange of surface and ground waters. Prior to the construction of the barrages, the water supply of nearly the whole area was sufficient in spring and early summer. Today, nearly half of the floodplain habitats suffer from permanent drought. The lower parts are durably moistened, but only a small portion of the area is exposed to the positive effect of the ground water.

In addition to ecological damage caused to the large forest area, the following changes in habitats also have a harmful effect on waters, vegetation, and flora:

- The water flowing through the connecting channels eliminates the individuality of the Old-Rhine branches. The clean spring water of the previously separated, short side arms is mixed with polluted water from the river and from mill-brooks. As a consequence, the oligotrophic species, such as *Chara Hispida* (in Figure), which were very wide-spread earlier, now only have a small chance for survival in a few isolated waters protected from regulation measures.

- The increased water discharge and the connection of side arms has almost fully eliminated the natural alternation of rapid flowing shallow sections and slow flowing deep sections within a short distance. For example, the gravel bed covered with shallow water, which were essential for *Hildenbrandia rivularis* (red algae, in Figure), were often graded. The other gravel beds are engulfed under deep water.

- The regular alternation of low water level and floods covering large areas has also ceased to exist. As a consequence, the plant communities characteristic of floodplains have vanished completely from those areas, which are under shallow water and dry up on a regular basis. The large mass presence of *Hippuris vulgaris* has been reduced to five populations with significantly less individuals. (in Figure)

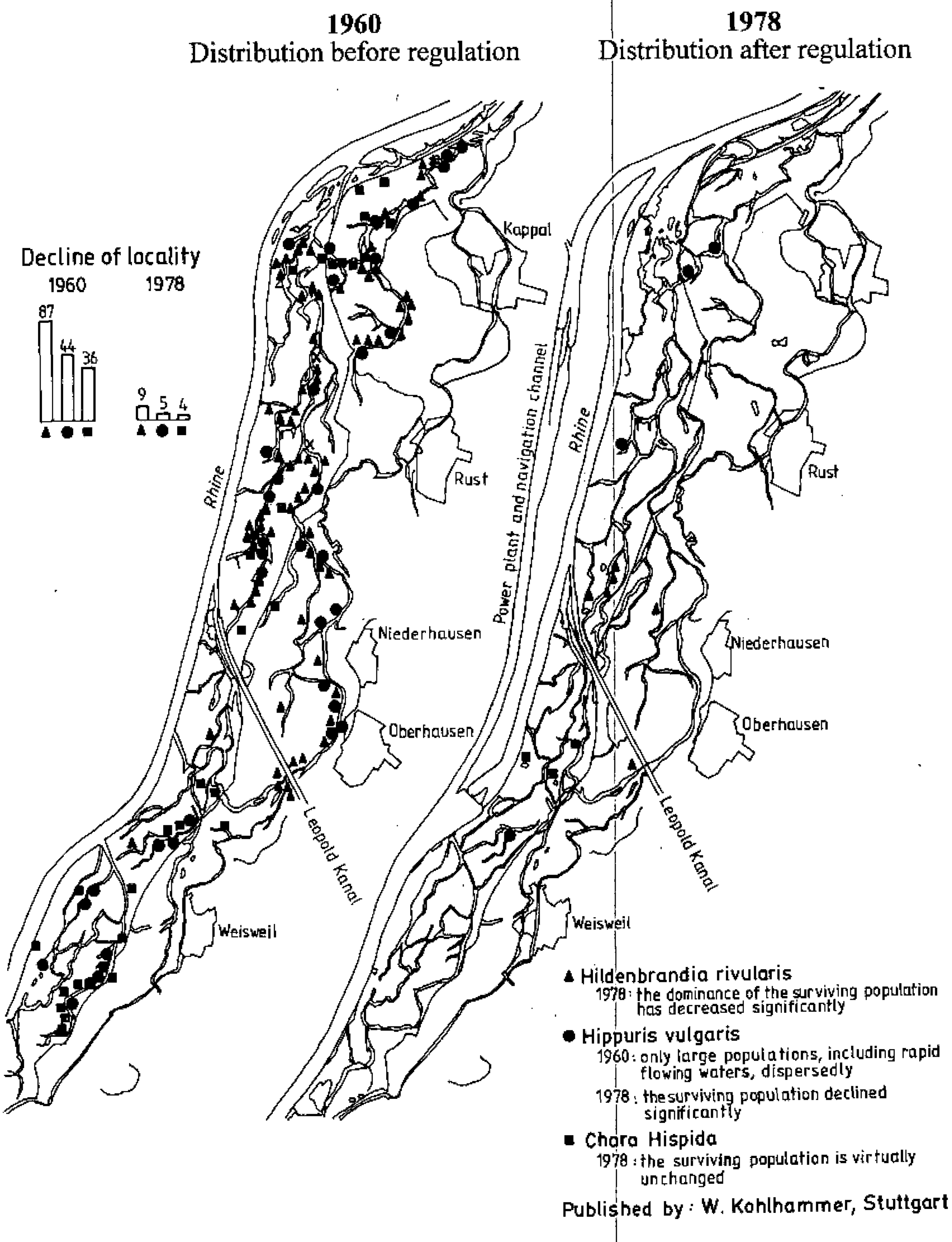
No endangered and rare species have reappeared in the connected side branches. These effects, which we have observed over decades of experience using bio-indicator organisms, can be expected to take place with the regulation of other rivers' side branches as well. As a result, the planning of management systems of connected side arms cannot be accepted any more.

The indigenous plants of the unregulated section downstream of the power plant at Iffezheim have survived. Simultaneously, the side arms within the area belonging to the special weir Breisach have remained isolated, and the regeneration of floodplain water vegetation has commenced due to the effect of the water level during the last two decades. The long-term regeneration of the floodplain and its waters would equally require the;

- restoration of the periodic alternation of falling dry and near-natural flooding,
- restoration of the isolated side arms including the natural channel morphology,
- improvement of the water quality.

The healthy ecosystem of the floodplain could be restored by retaining floods in a near-natural state. It would result in the remedy of the consequential damages, which have arisen since the regulation.

Endangered water plants before and after regulation of the backwaters of Rhine Rhine-Sundhausen weir barrage level



Annex 16

THE FUNCTIONING OF FLOODPLAIN ECOSYSTEMS: REVIEW OF THE UPPER RHINE FLOODPLAIN ECOSYSTEMS ECOLOGICAL EFFECTS OF THE BARRAGE OF ALTENWÖRTH, AUSTRIAN DANUBE

Joachim Lösing
Consulting Environmental Scientist

September 16, 1994

Table of Contents

1. The Functioning of Floodplain Ecosystems

1.1 *Introduction*

Hydro-engineering aims to improve rivers for human purposes. The changes achieved by this were at first positive: flood protection and land reclamation for cultivation, better water discharge and favourable conditions for navigation, a guarantee of national borders and the production of hydro-electric power etc.. However, in every case there were underlying negative consequences, such as increasing the threat or actual events of inundation and damages the , deepening of the riverbed and the obstruction of navigation, reductions of groundwater levels as well as in forestry and agriculture, the threat or extinction of species and biotopes, reduced capacity of self purification, unintended further measures and operational costs.

In order to understand the reasons for these unwelcome effects, this study describes and explains the functioning of floodplain ecosystems and the role of water and dynamics.

1.2 *The Position of Floodplains in the Natural Ecological System*

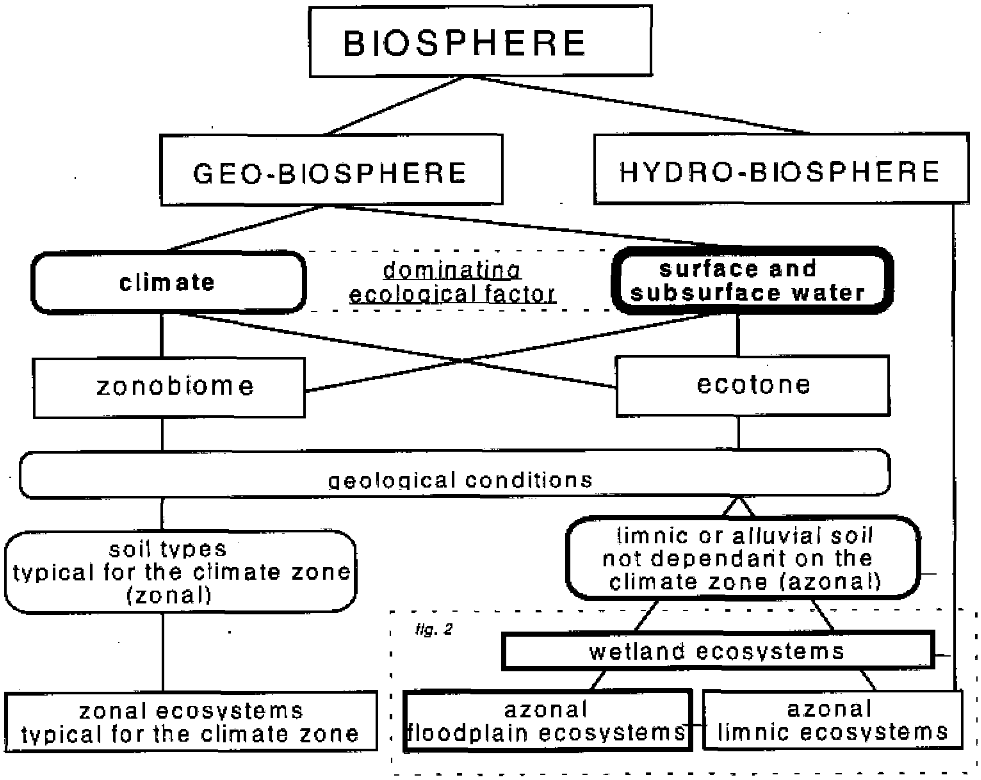


***Figure 1**: The dominant role of surface and subsurface water for the differentiation of zonal and azonal ecosystems within the ecological hierarchy. Living systems are framed in squares, abiotic elements in curves. Further explanations in the text.*

Living conditions have been established on earth by nature and floodplains have existed as long as settled land. So they are a part of nature. Nature consists of different units being distinguishable by an inner stability and similarity even in separate parts of the earth. These units are classified in ecology on different levels (Walter, 1977). It is very important to separate units which occur in a specific climate zone, from those which exist by other ecological factors (*Figure 1*).

Zonobioms and ecotones

The biosphere is the thin layer of the earth's surface to which the phenomena connected with living matter is confined (Walter, 1977). On the highest level of the ecological hierarchy they can be separated into the hydro-biosphere and the geo-biosphere. A subdivision of the latter into biomes, being large and uniform environments within it, is the scientific public domain. Biomes relating to the prevailing climate, generally being the primary independent factor of the environment (Walter, 1977), are called Zonobioms. These largely correspond to climate zones of the meteorologists. Ecotones, however, are transitional areas of ecological tension over which one type of vegetation is gradually replaced by another (Walter, 1977), e.g., littorals at sea shores with vertical zonation (Heinrich, 1990)[1].

Climate and water

Prevailing climatic conditions such as temperature, precipitation, humidity, periodicity etc. characterise the zonal vegetation which is the largest and most determining living part of the geo-biosphere. So Zonobioms largely correspond both to the zonal vegetation and to zonal soil types. If a factor other than the climate does not allow the existence of a "normal" vegetation, special sites have been established. These factors may be salt (in the sphere of marine influence at shores), unusual geological conditions (sand in dunes moved by the wind, dolomite and other special rocks) and last but not least water.

Water surpasses the role of the climate in and on stretches of water or in depressions whether on the surface, e.g., in lakes and occasionally inundated valleys, or subsurface, e.g., in formations with a high groundwater table (Horvat, 1974). All organisms living here depend on it because all those unable to survive in these extraordinary conditions are excluded by selection (see also the following chapters). On the other hand these organisms may occur in several climate zones (although the combination of species in a way reflects the predominating climate). So vegetation, fauna and the biotope (the biogeocoenoses) are not zonal but azonal.

Ecosystems

Ecology is the "understanding of the factors that determine how and where things live, how they are affected and how they interact with their physical environment and with each other" (Bradshaw, 1984). Thus an ecosystem "is always a higher unity which in general consists of the major components, living organisms and an amenable environment, operating together in some sort of functional stability" (Odum, 1959). Each possesses its own very specific climatic and soil

1 If they are broad transitional zones connecting zonobiomes they are known as zonoecotones. This study is confined to a special subject of interest, so the term ecotone will be sufficient.

conditions as well as qualities resulting from the combination of site (biotope) and organisms (the biocoenosis) (Kloetzli, 1989). The producers, plants living together as vegetation, shape the landscape. The other partners in the biocenoses are the consumers (animals or fauna) and the destruents (micro-organisms).

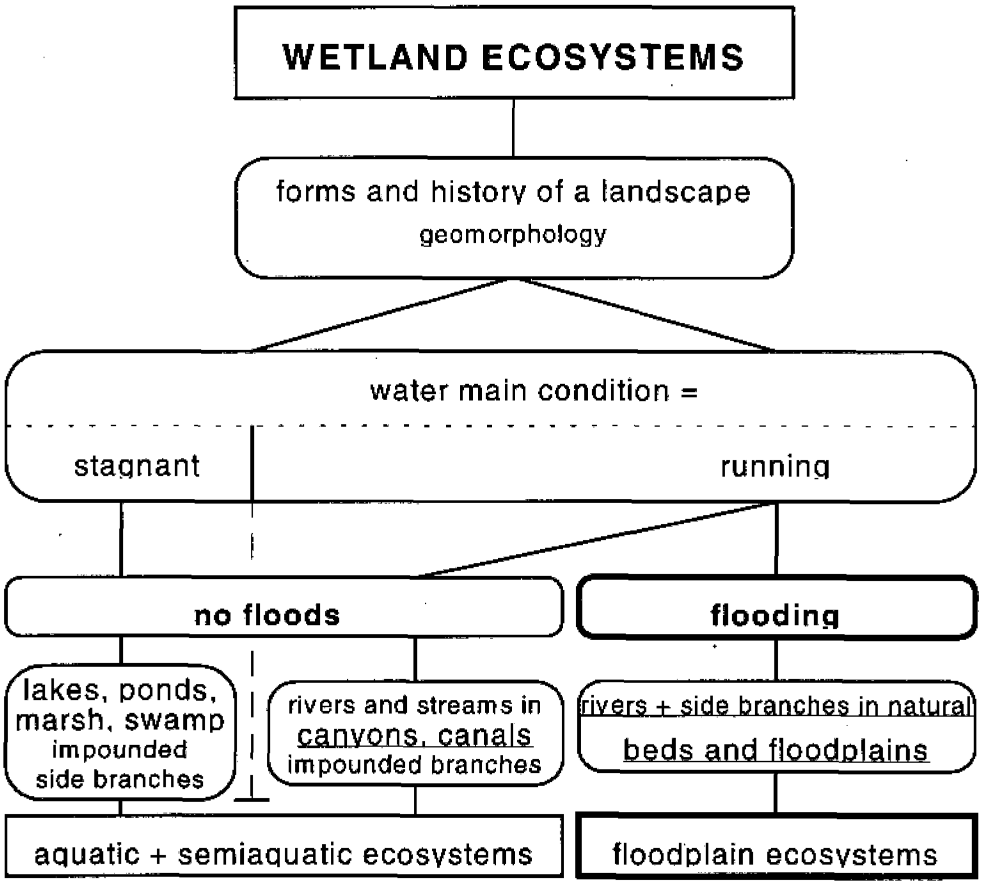


Figure 2: *The importance of flooding for the functioning of floodplain ecosystems.*

Wetlands and floodplains

Wetlands denotes all biotopes where water is the dominant abiotic factor (*Figure 1*) whether it is stagnant or running (*Figure 2*) which depends on the actual forms of the landscape and its evolution(geomorphology). Stagnant conditions result in stagnant waters, shores of lakes and other formations silting up. Groundwater tables which only rise and fall without flowing, also belong to this category. If water is mainly flowing then the category is "running waters".

Another abiotic factor necessary to distinguish within the category of running waters is to separate those with or without floodplains. Even in canyons and artificial canals water is running, but only in natural beds of rivers, in the functional system of side branches and in floodplains will there be periodic or episodic inundations. This corresponds to the most widespread and intentional simple definition that "floodplains spatially are those zones in a valley which are lying within the influence of inundations" (Gepp, 1985, cp. Gerken, 1988).

1.3 ECOLOGY OF FLOODPLAINS

The role of floods

For the existence of floodplains the alternation of flooding and drying out is the determining ecological factor (Ambühl, 1959). Otherwise no typical floodplain forests and other types of biotopes and therefore the whole ecosystem would exist, only general lowland forests etc.. So floodplains are large expansive amphibian ecosystems in contrast to other types of wetlands.

The interrelation between floods and groundwater

Increasing water discharge causes rising water levels (Landesanstalt für Umweltschutz Baden-Württemberg, 1994). The resulting inundations evoke variations of the groundwater tables. If the surface water level, and the groundwater flowing from the sides to the deepest point is unable to emerge in the riverbed then it is instead accumulated in the groundwater body, the aquifer, so the water table is rises. Extensive long-term inundations even lead to a considerable infiltration of surface water into the aquifer. Falling water levels in the riverbed have the opposite effect. An enlarged amount of groundwater is drawn off into the watercourses and the groundwater table falls accordingly (Dister, 1988).

The importance of dynamic processes

The periodicity and the amplitude of water level fluctuations in the reaches and in the inundation area are determined by the specific water discharge of a river (hydro-dynamics, *Table 1*). Running water produces erosion, transport and deposition processes (morpho-dynamics) which evoke specific processes of soil genesis, the dynamics of water and diffused air in soils (pedo-dynamics, including the dynamics of other substances like oxygen, nutrients and nowadays pollutants). Finally hydro-dynamics and morpho-dynamics control all ecological processes (Henrichfreise, 1988). Besides that, the topography of the inundation area and the permeability of all water stretches for migration and drifting of organisms are of particular importance (Landesanstalt für Umweltschutz Baden-Württemberg, 1994, Lelek, 1989).

Table 1: *Processes of natural floodplain dynamics (Henrichfreise, 1988) responsible for the variety of structures.*

hydro-dynamics	**morpho-dynamics**
periodicity and amplitude of water level and depending water table fluctuations.	series/course of erosions, transports and sedimentations (formation of bank failures, gravel banks, embankments, and loamy toplayers)

pedo-dynamics
micro relief and texture conditioning soil genesis;
dynamics of the soil water and soil air balance;
import of nutrients (and pollutants)

bio-dynamics
evolution (self-organisation) of floodplain biocoenoses and succession

The ecological zonation

The processes described above are responsible for a mosaic of structures, typical of a floodplain. This mosaic results from the combination of all processes even changing in the size of its impact from place to place. Nevertheless the structures may be differentiated following the generally agreed ecological zonation (Henrichfreise, 1988):

(a) Surface waters of the floodplain and river banks

Surface waters of the floodplain are subdivided according to the duration of the water discharge (permanently to periodically filled with water), the intensity of current (fast flowing to stagnant) and the morphology in relation to the form of surface (narrow/broad and deep/flat). River banks are subdivided by inclination (steep slope/bank failure), substratum (silt to gravel) and the duration of the terrestrial and amphibian phases.

(b) Lower zones of the floodplain (wet to moist)
Softwood[2] (Weichholzaue) and lower hardwood[3] floodplain (Hartholzaue)

The softwood floodplain is subdivided according to the intensity of hydro- and morpho-dynamics ("*dynamic* softwood floodplain" in areas near the river with strong erosion and deposition, "*wet* softwood floodplain" in areas distant from the river or situated on a higher level with little influence of erosion and deposition). The *lower* hardwood floodplain is differentiated by a shorter duration of flooding distinguished on the relief, and by granular, finer soils.

2 "Softwood" implies that all species of trees naturally growing in this zone consist of soft wood, like willow trees and bushes, poplars and alders;

3 "hardwood" of oaks, elms and ashes.

(c) Upper zones of the floodplain (fresh to moderate dry)
Upper hardwood floodplain and transition zone

Differentiation is performed firstly by the duration of floods depending on the relief, secondly by the combination of fine deposits and thirdly by the depth of the upper soil layer.

The inundation is relatively brief but periodical in the *upper* hardwood floodplain, while it is brief and episodic in the transition zone.

Current principle subdivision

Considering the human impact such as embanking and damming of rivers, another zonation has to be introduced:

(a) Recent floodplains

Nowadays human activities divide floodplain into two, ecologically very different areas. Parts of the original inundation areas which are situated within the embankments, are the real (remaining) floodplains. Fluctuations of the water level of the river with floods and a corresponding groundwater table as well as the dynamic processes, are responsible for their existence and variable change.

(b) Old floodplains

Parts of the formerly inundated area which are separated from floods by embankments or dams, are called old floodplains[4] originating from natural floodplains but without the determining factor (floods). The reduced influence of a fluctuating groundwater table corresponding to the water level of the river, is the only factor remaining. Side branch systems without flooding but with stagnant waters, also belong to this category (*Figure 2*). Spatially, i.e. from its geographical history, they are still part of the floodplain but not ecologically. Instead they correspond more to a lacustrine environment with stagnant waters like lakes, marshes and other types of wetlands or even the zonal ecosystems.

1.4 THE VARIOUS BIOCENOSES OF FLOODPLAINS

The following descriptions are based on the natural morphological formations (*Figure 3*, Henrichfreise, 1988) being easier to understand for the non-scientist; and follows the ecological classification mentioned above. However, in order to better understand the biological processes, some names of species or ecological communities are given which may be helpful.[5]

4 in French: "~ fossile")

5 General descriptions of the vegetation e.g. in Ellenberg, (1982) and Yon & Tendron (1981), for the fauna also in Gerken (1988).

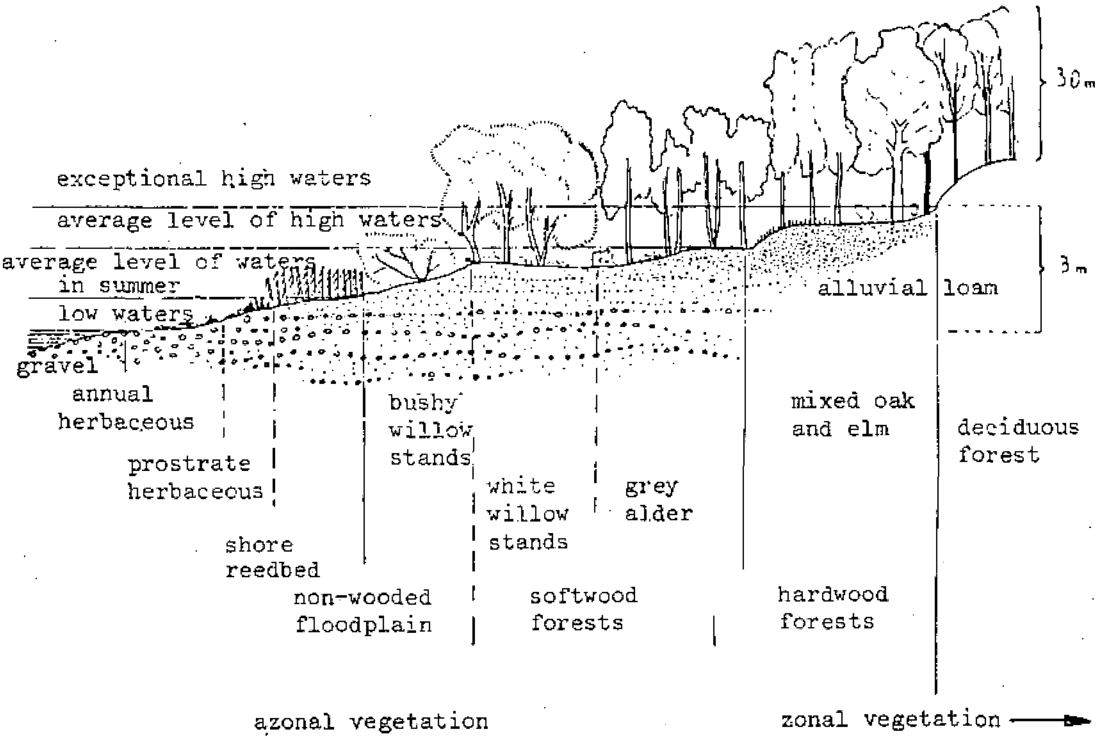


***Figure 3:** Distribution of plant formations on a cross-section of the middle reaches of an alpine foreland river (Ellenberg, 1982, Yon and Tendon, 1981.).*

Natural vegetation

In accordance with the structure of floodplains, the majority of a biocoenosis (the vegetation), corresponds to a similar terminology. You just have to replace the term "floodplain" by "riparian forests" except in "surface waters".

In open waters, flowering plants (the aquatic macrophytes), represent the vegetation, submerged or with leaves. Here the all-year-long existence of open water is required. Within the range of average water levels, pioneer formations accompany the reeds on non-wooded amphibian shores of the watercourses. Water level fluctuations are frequent and return periodically.

On the higher parts of the bars and islands, bushy willow stands grow, followed in time by willow trees and poplars, which are grouped as *dynamic* softwood riparian forests. Under typical conditions, they are localised on a low level, only a little higher than the average water level. Submersion by floods accounts for 5 months a year on average (in Central Europe), due to extreme climatic conditions this can be as little as 3 weeks or up to 9 months.

Ashes or alders are the main species of the *wet* variants of softwood and the *lower* hardwood riparian forests respectively. Elms and oaks rule in the more common, dynamic parts of the latter. They link up with the *upper* hardwood riparian forests of the higher levels, consisting of a very large variety of species but primarily elms and oaks. The transition zone to the localised, usually deciduous forests with elms, oaks and hornbeams is flooded only periodically or exceptionally for a few days in a year.

Very dry and warm, woody communities occur on the highest elevations within the inundation zone which depend on the special substratum of gravels, not common to areas outside the floodplain[6].

The most determining factor for the vegetation is the duration of inundations and the elevation of the groundwater table during the vegetation period, i.e. the growing season. It has to be remarked, that the zonation is only a relative graduation fixed on the elevations, and not an absolute one. It is subtly diversified by the different levels, frequencies and durations of floods as well as the different soil textures and the groundwater flow. It may be that only the extent of erosive and deposition processes is responsible for the evolution of softwood riparian forests and that the occurrence of the hardwood riparian forests is due to the progress in soil genesis (Dister, 1980). So several formations are to be found on the same level. This is typical of floodplain ecosystems: the natural appearance of many formations side by side in different stages of succession.

In addition, rare catastrophic events like ice drift or the sudden breaking of a meander during an extraordinary flood create formations of bare soils and rough pioneer areas on all altitudinal levels. Animals such as beavers, herds of wild cattle and ruminants such as horses and deer, keep these pioneer areas open or even produce new ones such as beaver ponds. So meadows, pastures, forest edges and bushes appeared. Man has also been part of the ecosystem since the glacial period, by cutting trees in order to gain arable land, pastures and wood (but to a lesser extent than nowadays).

However, this structure is not in evidence in a natural hardwood riparian forest: there is less than 1 % brightness on the ground; intense and impenetrable layers of shrubs and herbs and multiple structured canopies obstruct the view. Lianas are the most characteristic group, connecting all the layers. Just the number of species in the group of woody plants is unbeatable: 27 species of trees, 20 shrubs and 7 lianas in a single example at the Upper Rhine Thus, the geo-botanists are tending to describe these elm-ash-oak forests as the nearest European relatives to the tropical rainforests, in the temperate climate zone in terms of their richness of structures and species (e.g. Carbiener, 1974, p. 474).

Types of species

Due to the large number of biotopes and to the dynamics related to inundations as well as the resulting various stages of succession, floodplains contain an ecosystem, which is one of the most rich in species outside of the sea and the mountains (Hary & Nachtnebel, 1989). Typical for this diversity is the existence of many species adapted to its demands.

The most specialised species are to be found in the lower zones where an excellent adaptation to the extreme factors, is necessary to survive. Environmental conditions are changing quicker and

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6 "Heißlände" ("hot lands") or "Brennen" ("burners") as they are called in German speaking countries

more often than in other systems. That is why they use pioneer strategies to settle new sites. They are able to reach them even from a large distance either on their own or in a passive way, which may be in a stage of inactivity e.g. seeds transported by water.

Species which are unable to adapt to different conditions, need special sites for example gravel bars for tamariscs and wading birds, or bank brakes for birds who need native, steep slopes for breeding like kingfishers or sand martins. Many willows have a large spectrum of sites in theory, but in practice they are too weak to push through against other woody species except in floodplains since they can endure even long-term inundations of up to 300 days/year (on average 100-190 days) without dying (Späth, 1988).

Species with large-range habitat demands are e.g. Beaver and many birds such as Black Stork and Osprey which prefer undisturbed places for nesting on islands or in natural forests.

Another group needs accessible and undisturbed migration routes to their spawning grounds or areas of further development. Fishes, invertebrates and even plant species rely on these preconditions such as the special group which is permanently washed up from the mountains or those which live as drifters like water ferns (Landesanstalt für Umweltschutz Baden-Württemberg, 1994)

Fauna

Fish are a very important group in the fauna with regards to the proportion within their own group and from their biomass related to other groups. Conditions differ in the numerous reaches and open waters of a floodplain and offer many ecological niches for various species. Cold running waters are rich in oxygen and preferred by rheophilous fishes. Other species prefer more or less stagnant waters and another group has no special conditions and is wide-spread in almost all types of waters.

As in most of the faunistic units, a good quality environment determines the existence of the majority of dragonflies. The numerous types of wetlands in a natural floodplain offer habitats for a considerable part of the European species (cp. Gepp, 1985, Gerken, 1988, Westermann, 1987/1988). Similarly with amphibians, and on the terrestrial and amphibian areas, beetles, of which Carabids and Staphilinids are of special importance.

For birds, floodplains are the main migration routes. Floodplains supply plenty of food. Rest areas are visited by migrating birds, especially waterfowl, in such numbers that many parts of floodplains had become RAMSAR-sites (wetlands of international importance).

Even for man (and other mammals) river valleys have been the best migration routes as settlements and archaeological findings prove.

Benefits of functioning floodplains

The importance of intact floodplains was underestimated for a long time. They have important benefits when it comes to balancing out anthropogenic impacts (Dister, 1990):

The floodplains help to reduce the effect of floods by retaining large amounts of water.

Intact floodplains greatly contribute to the self-purification of the rivers.

Broad inundation areas contribute to the qualitative and quantitative regeneration of groundwater.

The near-natural floodplains have a great diversity of species and richly structured habitats and refuges for a variety of plants and animals. With their complex subsystems they offer inner stability, feasible regeneration and a remarkable genetic fund in an impoverished environment.

Recent floodplains are highly productive sites, in which forestry cultivates a number of valuable trees such as oaks, ashes, elders and poplars.

Intact floodplains and rivers have enormous merit as recreational areas offering a unique experience. The lands and the waters frequently alternate providing entertainment by their attractive combination and the multiformity of habitats and species.

2. Review of the Upper Rhine Floodplain Ecosystems

2.1 HYDROLOGY

The Rhine River has an alpine regime of discharge[7] : low water levels are typical in the late autumn and winter. Water levels rise with the beginning of thaw in the middle ranges and the Alps. Average floods appear when in the Alps precipitation falls as rain and thaw is at its maximum peak, usually in June and July. However, exceptional discharges with up to 4,500 m^3/s are recorded in winter when heavy rains fall on snow-covered, frozen ground during a warm period (Dister, 1990). Climatic conditions do not allow for comparisons between years since floods may be induced by continuous falls of rain throughout the year (Westermann, 1987/1988). A typical hydrograph in *Annex A-1* shows the variation in rainfall over three years starting with a dry (1976) and ending with a very wet year.

2.2 GEOMORPHOLOGY

The Upper Rhine rift valley subdivides into two different sections (*Figure 4, (Schäfer, 1973, 1974, 1975)*): the braided and the meander zone. They reflect the decrease of the valley slope from south to north, dropping from 0.1 % near Basel to 0.045 % at Rastatt, where the braided channel zone ends, and further to 0.0007 % at Mainz (Schäfer, 1973, 1974, 1975). The braided zone consists of numerous branches including 3,448 islands (Raabe, 1968).

7 Therefore it is very similar to the stretch of the Danube concerned with the small difference that the fluctuations are muffled by the Lake Constance.

2.3 *HISTORICAL OUTLINE OF THE REGULATION WORKS*

Nineteenth century regulation

Before 1800 the threat of catastrophic floods rose with the erection of more and more local protection measures accompanied by increasing wood cutting and farming (Hügin, 1980, 1981).

Regular river regulation on the Upper Rhine started in 1815 with TULLA's "total rectification plans". His purpose was flood protection and the drainage of wetlands his goal was to concentrate the branches into one confined channel and to straighten the meanders in order to lower water levels through bed erosion (Schäfer, 1973, 1974, 1975). The river naturally eroded its new bed guided by surface-level bank protections which did not close the side branches. TULLA did not completely cut off the floodplains from the Rhine, as his successors did. In fact he was very familiar with the principles of flow dynamics and even average water levels caused the flooding of the side branch system within the lateral main dykes (Kunz, 1975). However, the increased flow-velocity caused extraordinary channel bed erosion to almost 4 m at the beginning of the channelled section in the 19th century (Kern, 1992). The central drawing in *Figure 4* shows the degree of rectification at this time.

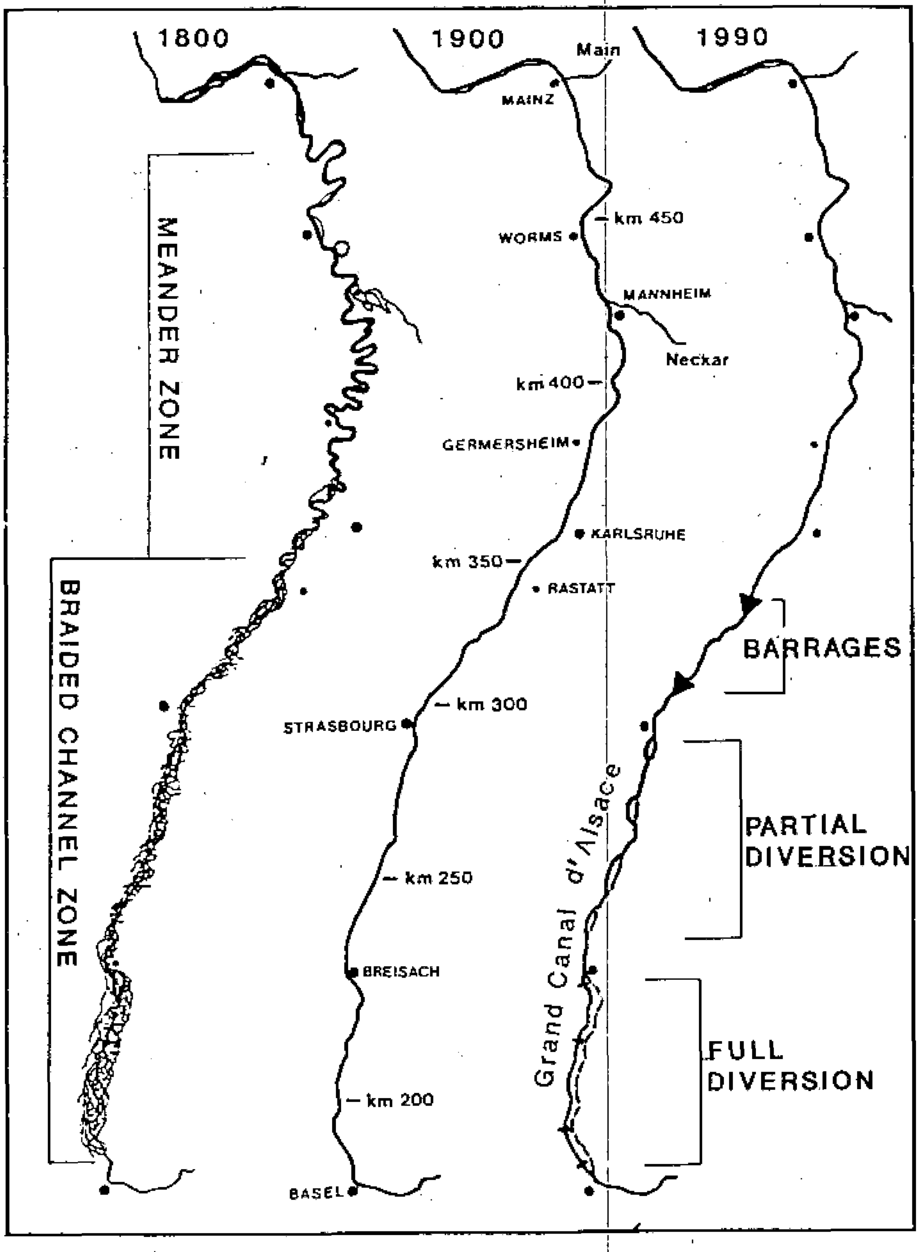

***Figure 4**: Historical development of the Upper Rhine Valley (Kern, 1992, after Dister, 1985).*

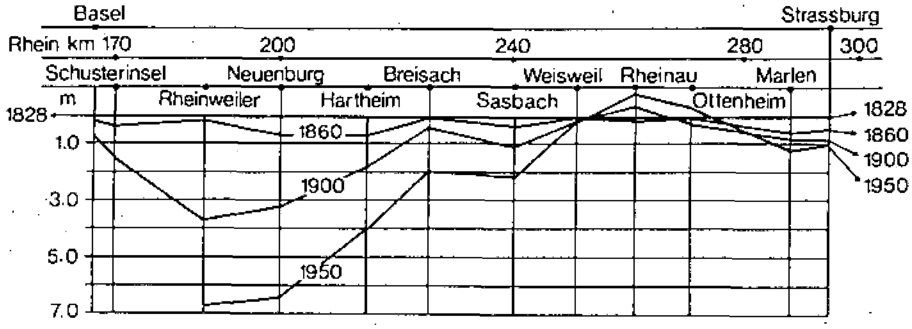

Figure 5: *Bed level development of the Upper Rhine between Basel, Switzerland, and Strasbourg, France, from the beginning of regulation up to the construction of river diversions (Rabee, 1968).*

Twentieth century regulation

"The channel bed still contained irregular gravel bars and scour holes, making the Rhine unsuitable for the recently introduced navigation". For that reason the Upper Rhine Regulation by HONSEL established a low-flow channel with a reduced width by installing groynes. Although not intended, the bed erosion increased even during periods of low discharge. Additionally a "system of levees was implemented in order to improve the flood protection. Consequently many of the diversion meanders and furcation channels were taken out of the flood regime" (Kern, 1992).

After World War I, France was given the rights to all the waterpower along the French border. They built the "Grand Canal d'Alsace", which was completed in 1959 ("full diversion" in *Figure 4*). At this time, four power stations were taking 1,200 m^3/s out of the river (today 1,400 m^3/s (Dister, 1990)) and leaving only 15-20 m^3/s in the former riverbed (today 20-30 m^3/s) (Dister, 1990))[8]. Erosion and degradation of the riverbed continued. By 1950 the bed levels had cut down to 7 m (*Figure 5*). After the German-French reconciliation, a less damaging solution was found for using the waterpower. Upstream of the next barrages built, new channels were constructed adjacent to the river[9], short sections of the main riverbed ("rest Rhine"), only affected by backwater, were included ("partial diversion" in *Figure 4*). Here up to 1,400 m^3/s (Kunz, 1975) (today 1,500 m^3/s (Westermann, 1987/1988) up to 1,600 m^3/s (Kalkowski, 1986)) were used for the production of waterpower. An additional system of artificially connected previous branches of the Rhine was built to improve groundwater conditions. The artificial supply from the Rhine is limited to a maximum of 15 m^3/s. Downstream of Strasbourg, two more dams were built in the river channel ("barrages") in the conjunction with levees on the banks. Downstream of the last dam near Rastatt (built in 1977) erosion problems have been controlled successfully by artificially adding of sediment (Raabe, 1968). *Table 2* summarises the activities and their effects. All the measures since 1927 are called the "modern Upper Rhine river training".

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8 mean discharge *ca.* 1,100 m^3/s

9 = "loops"

***Table 2:** Regulation works at the Upper Rhine (Buck, 1993, cp. 18-26).*

YEAR	RIVER SECTION	ACTIVITIES	MAIN PURPOSE(S)	EFFECTS
from 1817 until 1880	Basel/ Mannheim	*correction* according to TULLA's plans (dykes, parallel dykes in the braided zone, cuts in the meander zone	improvements: – flood protection – agriculture – human living conditions – solid riverbed (border to France) – (*not* as an original goal and not until the end of the schedule: navigation)	river-bed degradation, lowering of water- levels and groundwater tables already in 1850; + strongest change of discharge regime and floodplain morphology (Henrichfreise, 1988); reduction of ground-water table fluctuations
from 1906 until 1939	Basel/ Mannheim	*low-flow regulation* by HONSEL (groynes)	navigation with tall steam ships throughout the year	artificial agradation: cut off side branches
since 1927		*modern Upper*	*Rhine river training*	
from 1927 1932 1952 1956 1959	Basel/ Breisach	*full diversion* (Grand Canal d'Alsace) with power station barrages: – Kembs – Ottmarsheim – Fessenheim – Vogelgrün	production of waterpower by "Electricité de France" (EdF)	further lowering of water levels and groundwater tables, destruction of the riparian forest, increase of flood discharge caused by loss of natural inundation areas
from 1961 until 1970 1961 1963 1965 1967	Breisach/ Strasbourg	*partial diversion* ("loop solution") with power station barrages and weirs: – Marckolsheim – Rhinau – Gerstheim – Strasbourg	modified regulation works for navigation and waterpower for the preservation of the natural water levels and groundwater tables	partial preservation of the floodplain in this river section within the dykes; decrease of groundwater table fluctuations; increase of flood discharge
since 1970 1974 1977	Strasbourg/ Iffezheim	river regulation in the river channel (full canalisation) with *barrages*: – Gambsheim – Iffezheim	controlling of erosion, waterpower production	increase of flood discharge, cut off of the side branches, complete change of groundwater regime

Natural vegetation

The diversity of sites (cp. chapters 1.3 & 1.4) forms a variety of plant associations[10].

The most important should be mentioned according to the abbreviations used in the following (Table 3), *Figure 7,* and *Annexes A-1 to A-7* (Hügin, 1980, 1981):

Table 3: Simplified system of riverine and floodplain vegetation at the Upper Rhine.

W	areas permanently covered with water (partly with submerged Pondweed (Potamogeton sp.) and drifting (Lemna spp.) communities)
W	areas covered with water, falling dry periodically (with communities on silt (bistorts and Water Pepper (Polygonum spp.) and Limosella sp.)) typical for recent floodplains
R	communities of reeds and tall sedges (Carex spp.) of the Rhine floodplain typical for recent floodplains on sites with low flow velocity
R	communities of reed and tall sedges (Carex spp.) changed by regulation works (e.g. on former sites of S etc.)
S	softwood riparian forest (Salicetum albae) with White Willow, dynamic (recent floodplains) or wet (old floodplains, vanishing) flooding between 70 and 170 days in the growing season (Hügin, 1992)
U_1	variant of Bittercress (Cardamine sp.) of elm-ash-oak forests (Querco-Ulmetum, lower hardwood riparian forests) partly with Black Poplar (Populus nigra) and frequent floods for on average 50 (-100) days, recent floodplains Lesser Celandine (Ranunculus ficaria, 38)
U_2	variant of Ivy (Hedera helix) of elm-ash-oak forests (Querco-Ulmetum, upper hardwood riparian forests) on higher levels, regularly inundated for about 2 - 20 days/year, typical for recent floodplains
A	Black Alder forest (Alnus glutinosa) permanently wet and some decimetre above mean level, before only at the outer edges at the terraces, now established in the old floodplain
F	alder-ash forest on mostly moist calcareous soils about 40-80 cm above the groundwater table, established in the old floodplain
C_1	variant of Enchanter's Nightshade (Circea lutetiana) of the elm-oak-hornbeam forest (Querco-Carpinetum) on former sites of oak-elm forests (U) with little influence by groundwater (average depth 100-140 cm) (Hügin, 1992)
C_2	typical variant of the elm-oak-hornbeam forest on drier levels, magnitude of soil layer here 0.8-1.2 m, without contact with the groundwater
C_3	variant of White Sedge (Carex alba) of the elm-oak-hornbeam forest, soil layer only 0.4-0.6 m, without contact to the groundwater, linking up to Q
Q	White Sedge-oak forest, thermophilous on medium- to flat-sized soils, partly with dry meadows upon gravel, without contact with the groundwater (Hügin, 1992)
	surface of the ground with upper soil layer
	forested area in the lowland of the Rhine
	main dyke
	lateral dyke of an impoundment
(U_2)	evolution of this variant may not be derived exactly

10 Association is the scientific term for a unit of really existing communities with the same composition of species.

Changes of groundwater tables and fluctuations

Before the river training works, groundwater tables in the neighbourhood of the natural Rhine River corresponded to the water levels in the riverbed. Thus they were fluctuating considerably. In times of low water levels, the groundwater tables were also low, the side branches were filled only a little. At the edges of the alluvial depression where the aquifers of the floodplain and the lowest terrace ("Hochgestade") meet (Krause, 1967), fluctuations of the groundwater table always differ to a smaller extent (Schäfer 1973, 1974, 1975). Mainly in these areas special types of side branches developed which are fed completely by groundwater, except during floods (Krause, 1967). (Westermann, 1987/1988)

In the section of *full diversion* where the greatest drop of the river occurred; the bed levels as a result of the rectification in the 19th century had reduced by 4 m, and after the full diversion by up to 7 m (21, *Figure 5*). Groundwater tables followed accordingly, causing exceptional damages to the ecosystem, agriculture and forestry (Vogel, 1969).

In the downstream section of *partial diversion*, the "rest Rhine" received only 15-20 m^3/s, usually during 300 days/year (Westermann, 1987/1988). For the rest of the year a reduced effect of floods remained within the recent floodplain. Meanwhile, another agreement between France and German water management administrations allowed 30 m^3/s in summer and 20 m^3/s in winter. However, groundwater tables upstream of backwaters dropped due to the lower water levels. The infiltration of surface water to the aquifer was stopped by new drainage ditches parallel to the dykes. They collected all the water seeping through the ground (*Annex A-2*). Additionally the amount of such waters was reduced since the riverbed is self-sealing (clogging)[11] by the permanent one-way current of fine sediments through the pores of the ground (Buck, 1993). *Annex A-7* shows how the fluctuation of groundwater tables decreased.

As a *first counter measure,* weirs[12] were built in the former channel ("rest-Rhine") in order to stop further erosion and the decrease of groundwater tables, the latter then being lower in summer and higher in winter than before the river training works (Buck, 1993, Kalkowski, 1994).

As a *second counter measure,* an artificially connected system[13] of ox-bow lakes was installed (cp. Krause, 1987). Taking into account that the whole system spreads over a length of about 120 km (Buck, 1993) with a width of several km, the donation of water from the power channel is sparse and insufficient (at most 15 m^3/s) to inundate more than minimal areas within the floodplain. Groundwater tables received some reduced variable inflows to aquifer, stopped by sedimentation and clogging in the river-bed. Clogging is accelerated by the help of aquatic macrophytes (e.g. Callitriche spp.) which filter suspended load. Thus the system is now called a "gutter above the groundwater table" by the water management administration (Kalkowski, 1994).

Tests of "flooding" never reached the aims envisaged (RP Freiburg, 1976): The impoundments of several weirs of up to 140 cm increased groundwater tables only by up to 60 cm. Especially the impoundments just within the watercourses, which led to a minimal increase of 10-20 cm. Only the inundation of large parts of the area (70 % of 12 ha.) improved groundwater tables effectively.

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11 called "Kolmatierung"

12 called "Schwellen" = "thresholds" or "Sohlschwellen", a term of water-engineering in wrong use (Kern, 1994).

13 called "Altarmverbundsystem" = "system of combined ox-bow lakes"

However, this increase was less than half of the impoundments because groundwater flowed to lower watercourses downstream of the experimental area. Furthermore, the report on the experiment stated that this one-way current induced further clogging of the beds. "Infiltration of the side branches under normal discharge conditions is so little even today, that a noticeable increase of the groundwater table could not be proved" (experiment from January 12th to 16th, 1976 – one of several beginning in 1964 – in the southern part of the "Taubergiessen") (RP Freiburg, 1976).

As a *third counter measure,* the construction of two additional weirs in the "rest-Rhine" in order to support groundwater tables and to conserve the conditions for agriculture and forestry, did not improve ecological conditions in the floodplain except upstream of an additional small weir in the tributary "Möhlin" (BFANL, 1988).

The latest regulation works in the third section of *barrages* totally cut off the floodplain which now receives no more floods at all. Only downstream of the last barrage at Iffezheim (near Rastatt) do free-flow conditions still exist. Groundwater at first rose considerably in the vicinity of the dams until clogging of the reservoir bed started the clogging processes. Afterwards groundwater fell to a constant level with only small variations depending only on the water level of the surface waters downstream in the old floodplain and therefore on the precipitation rather than the water discharge regime of the river. In the vicinity of the impoundment, the average low water tables increased to about 100 cm. This effect ends at a distance of 5 to 6 km from the barrage (RP Freiburg, 1983; 1987).

Consequences for the vegetation in the three sections

The floodplain of the upper Rhine was used and influenced by man over a much longer period than records from scientists and foresters report. Undoubtedly the natural alluvial forests were used or cleared partially in the neighbourhood of settlements.

Clearings increased enormously during the *rectification* works of TULLA. Nevertheless alluvial forests were able to react very much faster than zonal forests. But meanwhile the rectification has changed the abiotic conditions: deposition changed from gravel to silt and clay as the main fractions because the dykes were so low that floods and fine sediments could pass. This was exactly the intention of TULLA for he gained new and better land for agriculture by agradation. He had counted 3,448 islands between Basel and Worms. (Almost all the islands and all of their typical shrub vegetation have vanished since that time.) Most of them were situated in the braided zone and covered with wood and pioneer vegetation stages. Some of them had typical sub-alpine characters e.g. with tamariscs. The change of deposits however caused quite another composition of alluvial forests: oaks, elms and hornbeams became dominant in the hardwood riparian forests. Softwood riparian forests diminished.

Generally, although the alluvial forests and other vegetation types changed, they remained within the functioning of the recent floodplain except for those upstream effected by the induced drop of the riverbed. Between 1880 and 1890 damages in the vegetation were observed for the first time (Vogel, 1969; Dister, 1980).

Regulation works in the 20th century caused much stronger impacts. In the section of *full diversion,* damages of the forests vegetation by desiccation were respectable. By 1959 an area of 3,755 ha. of a total of 4,608 ha. (i.e. 81 %) was devastated or dead. (The economical damages until 1950 (!) climbed to 43 million DEM at that time.) A stretch of 70 km was totally destroyed. The scarcely following vegetation was no longer typical for a recent floodplain but became a sparse desiccated forest without inundation and without contact with the groundwater. The expensive reforestation of about 1,650 ha., mostly with pines and Douglas firs was a waste of effort. Today the desiccated area is more interesting for the protection of the new flora and fauna than for its yield.

In the section of *partial diversion* the groundwater tables achieved a reduction of the altitudinal zonation of floodplain vegetation. *Annex A-2* shows the change of the abiotic factors in a typical cross-section. Damages are followed gradually by the reduction of productivity. In the small depressions, now staying continually saturated, such damages could be observed first. The positive effects of fluctuating water tables on the water supply and the content of oxygen in the soil also stopped and harmed the large areas on average and higher altitudes.

Vegetation types, typical for areas distant from the river, such as the "wet softwood riparian forests", took the place of the "dynamic" vegetation types. Sensible species and even communities specialised in the fluctuation of abiotic factors, vanished as for instance those species living in sites which fall dry periodically. Wide-spread common species and communities remained. *Annex A-3* demonstrates the effect by comparing hydrographs and totally changed natural vegetation.

The described system of ox-bow lakes connected to a new watercourse, caused only small improvements (but evident damages in the old floodplain). *Annex A-4* shows the results of controlled floods for the natural vegetation. The stretch is situated 1,200-1,700 m upstream of a weir. In this area 80 % of the vegetation is unable to profit from the groundwater in contrast to the 5-10 % under previous conditions. Artificial level increase is favourable for just 10 % of the area (A, F and U_1). Thirty percent of those parts nearer to the weir have the advantage of better water supply but 40-50 % are still without contact to the groundwater. That means that even here, the former state is no longer attainable. Ecologically important deposition of sediments as well as nutrients supply is reduced to a minimum.

Annex A-5 demonstrates the situation in the best remaining part of the recent floodplains in the two sectors of full and partial diversion: the well-known "Taubergiessen". The map on the right half of the figure shows the topography around this second diversion canal in the section of partial diversion. On the left a transsect along the right river banks (irregular line) is depicted together with the former and the recent water levels in the modern chain of weirs. It is obvious that under previous conditions even small floods could enter the floodplain behind the bank across many depressions. Today only the rare, extreme floods are able to inundate the area extensively since the weirs are at a lower altitude.

Annex A-6 shows the changes of the water regime even in the central part of this recent floodplain. The characteristic scope of water level fluctuations shrank from 3.5 to 1.5 m, i.e. almost half of the vegetation no longer have contact with groundwater table more. Thus it is changing in the direction of vegetation types (C_3, Q). Furthermore groundwater tables are 80-90 cm lower than the water level in the previous Rhine, due to the process of clogging.

In the sector with *barrages*, the recent floodplain was completely reduced. The lower parts of the now previous floodplain became continuously saturated (similar to the previous section), the higher parts permanently desiccated. The composition of species is changing from those typical for highly productive alluvial communities to those strange in a floodplain and clearly less productive. *Annex A-7* gives the example of the first barrage of this stretch. Although being extraordinarily dry (cp. A-1), the year 1976 produced larger fluctuations than the following, more humid years. The conditions of the sites changed from White Willow forests to reeds, Black Alder and Common Ash forests in the first 70 cm of altitude, the rest converted from the characteristic rich elm-oak forests to oak-hornbeam forests (Hügin, 1981). Transformation is under way as in all other old floodplains of the Upper Rhine valley (Lösing, 1989).

Figures 8 & 9 give a faunistic example of the evolution of waterfowl populations on the impoundment of the last barrage of Iffezheim. Both populations of the two main species, Tufted Duck (*Aythya fuligula* = "Reiherente") and Pochard (*Aythya ferina* = "Tafelente"), here are depending on one single species, Caspian Mussel (*Dreissena polymorpha*), in this artificial system. The mussels had grown in a massive way after the implementation of the barrage. The mass population collapsed about 10 years after when conditions normalised (Müller, 1994). The massive and unstable development of a *single parameter* is characteristic for disturbed systems.

Annex A-8 shows the different impacts of the three sections by comparing their potential natural vegetation.

General impacts on the vegetation

To summarise, the change of ecological conditions and vegetation on the whole section of the "modern Upper Rhine river training" was almost complete. HÜGIN (1981) calculated the losses of sites in the recent floodplain as shown in *Figure 6* by the help of an exact and extensive mapping of the 160 km long (smaller) right half (Hügin & Henrichfreise, 1992).

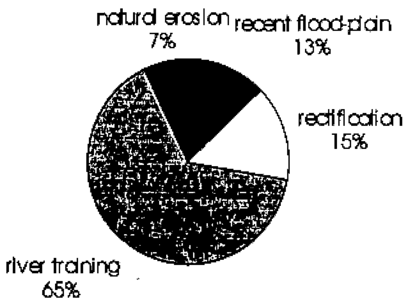


Figure 6: *Reasons for the regression of recent floodplain sites (Hügin, 1981).*

85 % of the original floodplains in 1825 have lost their character. The area of recent sites decreased to 1,400 ha. (13 %) (Hügin & Henrichfreise, 1992). From these 3 % are estimated to be intact, the rest (10 %) are spoiled by the destruction of natural vegetation (Hügin, 1981). From the riparian forests not more than about 40 ha. of elm-ash-oak forests and 50 ha. of White Willow forests have survived (Hügin & Henrichfreise, 1992).

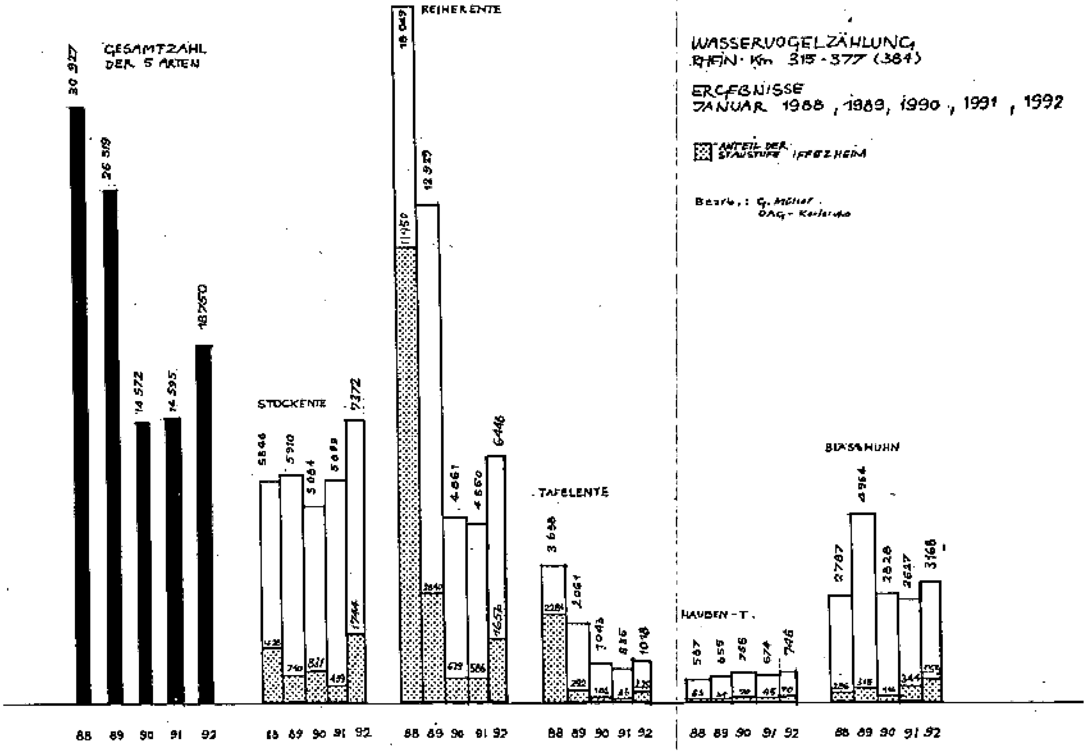


***Figure 7:** Changes of vegetation sites between Basel and Karlsruhe (right river side, shown as potential natural vegetation) (Hügin, 1980).*

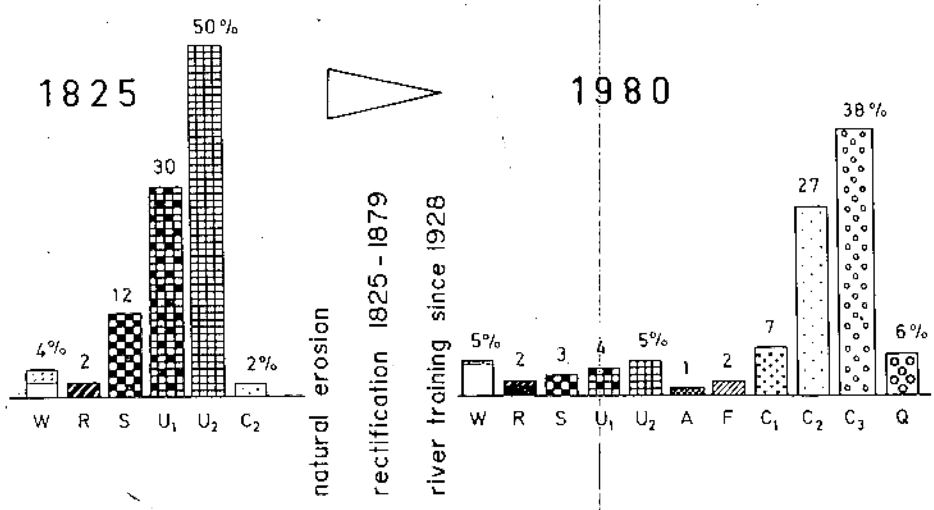


***Figure 8:** Winter counts of birds in the last barrage of Iffezheim (Müller, 1994)*

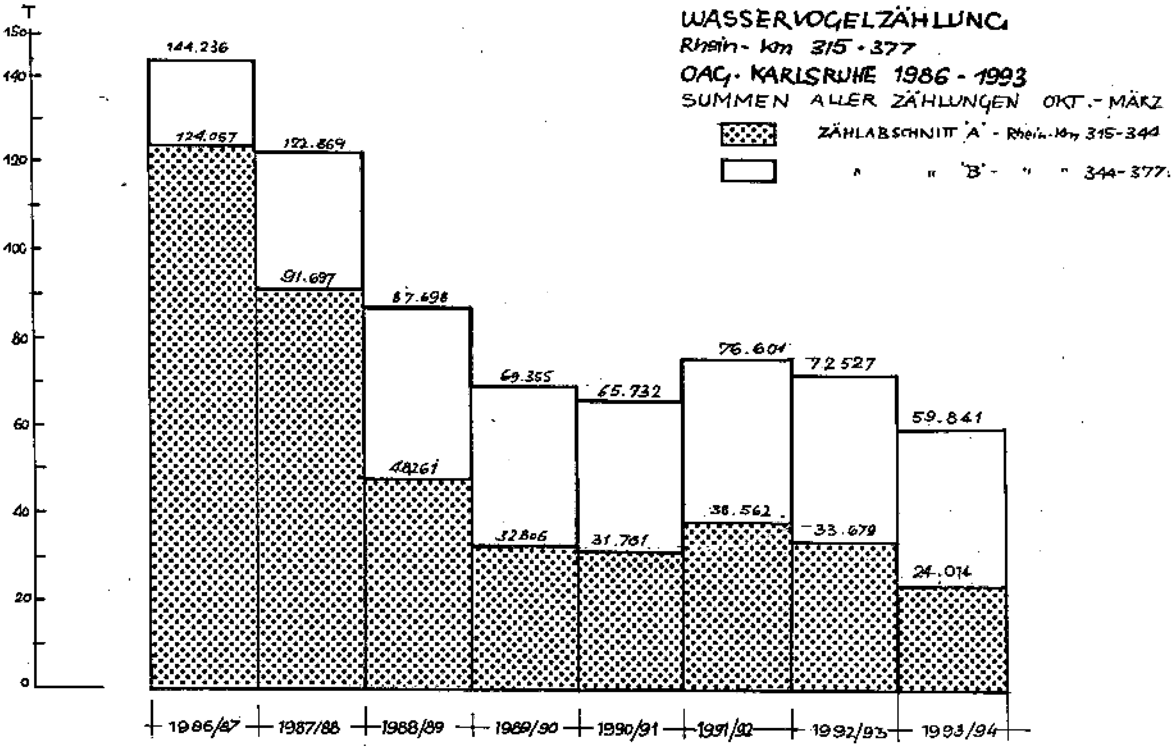


Figure 9. *Total amounts of waterfowl at, and downstream of the barrage*

Considering the French side, 270 km^2 of floodplains existed around 1800. From this whole area of the southern of the Upper Rhine, *about 6 % remain recent floodplains with 1 - 2 % functioning biocenoses.*

Both groups of numerical values in *Figures 6 and 7* differ from another because the first values express the actual condition and the second the natural potential which is a hypothesis constructed to improve ecological mapping. state of preservation

Especially between 1950 to 1977, the area of recent floodplains in the developed reach was reduced by about 130 km, (60 % of the inundation area in 1950) (Dister, 1985). Another fact underlining the losses: regulation works at the Upper Rhine reduced the side branches by 10,000 ha. (Westermann, 1987/1988).

From the qualitative point of view the natural dynamics were reduced to minimal amounts except downstream of the last barrage. First of all, the large gravel and sand bars disappeared. Furthermore, there has been no new generation of abandoned channels and, consequently, no rejuvenation of ecological succession in the last 170 years. The floods and the water level fluctuations as well as the groundwater decreased significantly (Dister, 1990). Last but not least, the regulation works provided the opportunity to massively transform the rich primeval forests into monotonous stands of a few species of trees.

3. Ecological Effects of the Barrage of Altenwörth, Austrian Danube (42)

HYDROLOGY

The Altenwörth barrage was built between 1973 and 1976. *Figure 10* shows its position in the chain of Austrian power plants on the Danube. The dykes run directly along the original bank lines and are 21.5 km long and up to 15.0 m high. The mouths of four tributaries were cut off. Instead new watercourses with an enlarged discharge capacity have been built in order to drain floodwaters to the tailwater canal of the power plant. Hence it follows that the beds of these tributaries are now deeper than in the original state.

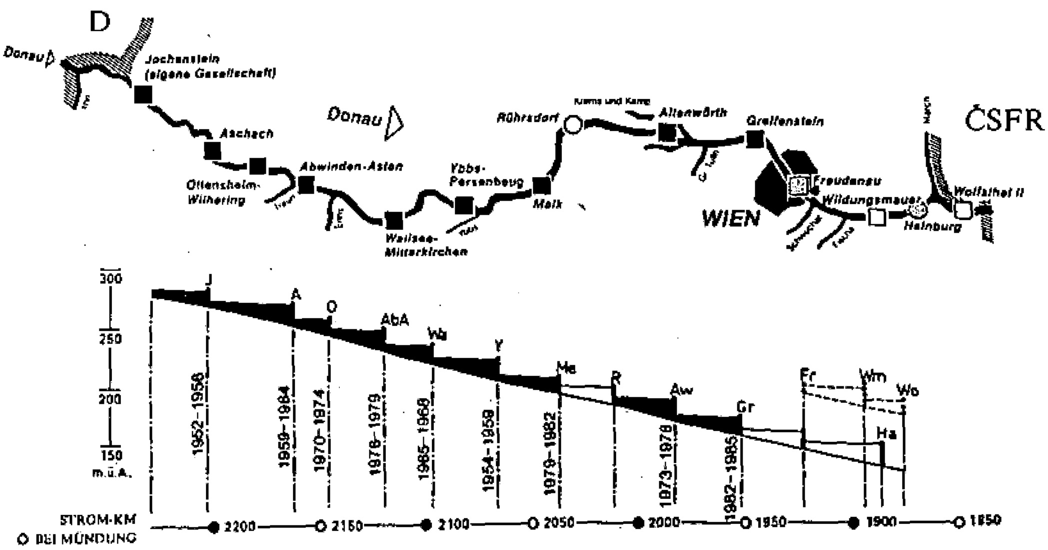


Figure 10: Schema of the Austrian hydroelectric power plants.

The regulation works have been accompanied by remedial measures ("Hinterland Project North and South") to improve the water supply of the floodplains and to strive for optimal growth conditions. Therefore the groundwater tables should be influenced by frequent controlled flooding and by raising the water levels in the ditches. For this last purpose, underwater weirs have been built in the partly diverted tributaries. In the northern half of the area, the left dyke was lowered by 0.7 m over a length of 140 m to allow flooding from a discharge of 2,200 m^3/s upwards. *Figure 11 and 12* show in detail the location of the main changes to the surface waters.

As a result of both measures, the hydrologic subsystems were equalised and *decoupled*. The original diversity of aquatic habitats characterised by different conditions of flow, depth of waters and changing substratums, was replaced by uniform structures especially in the impounded area.

The inflow and the proportions of inundations flowing into the floodplain clearly changed because of the separation of the river from the floodplain. In the southern hinterland, a large part of the upstream area became free of floods. In the northern territory, the effects of smaller flood events were reduced although the influence of floods is still present due to the lowered stretch of the embankment. High waters are drained immediately by the new broad watercourses and inundations of the plane have decreased generally.

The remedial measures of the "Hinterland Project" improved the replenishment of surface waters in the floodplain. However, the amount of water was equalised, compared to the conditions before the construction of the power plant. The same happened to the *structure of the flow* by the installation of underwater weirs. Consequently, the connection between the tailwater canal and the surface waters of the floodplain still needs to be improved.

The groundwater system shows significantly reduced dynamics. High groundwater tables decreased and low levels increased in a strip about 2,000 to 2,500 m wide along the banks with a width of while the mean values differ little as intended. The communication between the impoundment and the groundwater is almost lost. The original state cannot be restored. Now the soil-water budget is controlled by the groundwater. Before it was determined by inundations, groundwater levels and *precipitation*. The changed groundwater conditions affect substantially the soil-water budget and accordingly the vegetation of the floodplain.

LIMNOLOGY

The stretch concerned is part of the rhithron – the zone of a mountain river with low water temperatures, gravel bed and a mean flow velocity of 1.3 – 2.5 m/s. This velocity decreases in the impoundment inducing greater sedimentation, less suspended matter and a better visibility depth, (especially in the last third of the reservoir near the power plant). Here the productivity of the plankton even equals that of the Middle and Lower Danube. However, despite the more favourable conditions for production and an excellent supply of nutrients, the increase of plankton biomass is not measurable except at low water discharges. Chemical parameters react just as imperceptibly in the impoundment. Therefore, the discharge is the main factor conditioning the development of plankton at the Altenwörth barrage as the renewing the water body very fast. On the other hand, the changed qualitative and quantitative dynamics of solid matter lead to significant changes in the sediment quality of the river bed and hence the colonising animals, zoobenthos. They reflect directly the decreasing grain size from the beginning of the impoundment to the area in front of the barrage where the Tubificidae are attaining almost 100 % (> 1000 specimen per core = 27,3 cm^2 (Hary & Nachtnebel, 1989, p. 111) of the Oligochaeta (about 1 million m^{-2} (Hary & Nachtnebel, 1989, p. 112)). The second important group are the Polychaeta (≤100 specimen per core). (Investigations in floodplain waters have not been reported.) Concluding from the results, the waterbody of the impoundment is long enough to considerably affect the abiotic prerequisites but it is too narrow to allow higher plankton– biomass production. Nonetheless, the zoobenthos composition of the riverbed is changed by the different dynamics of solid matter.

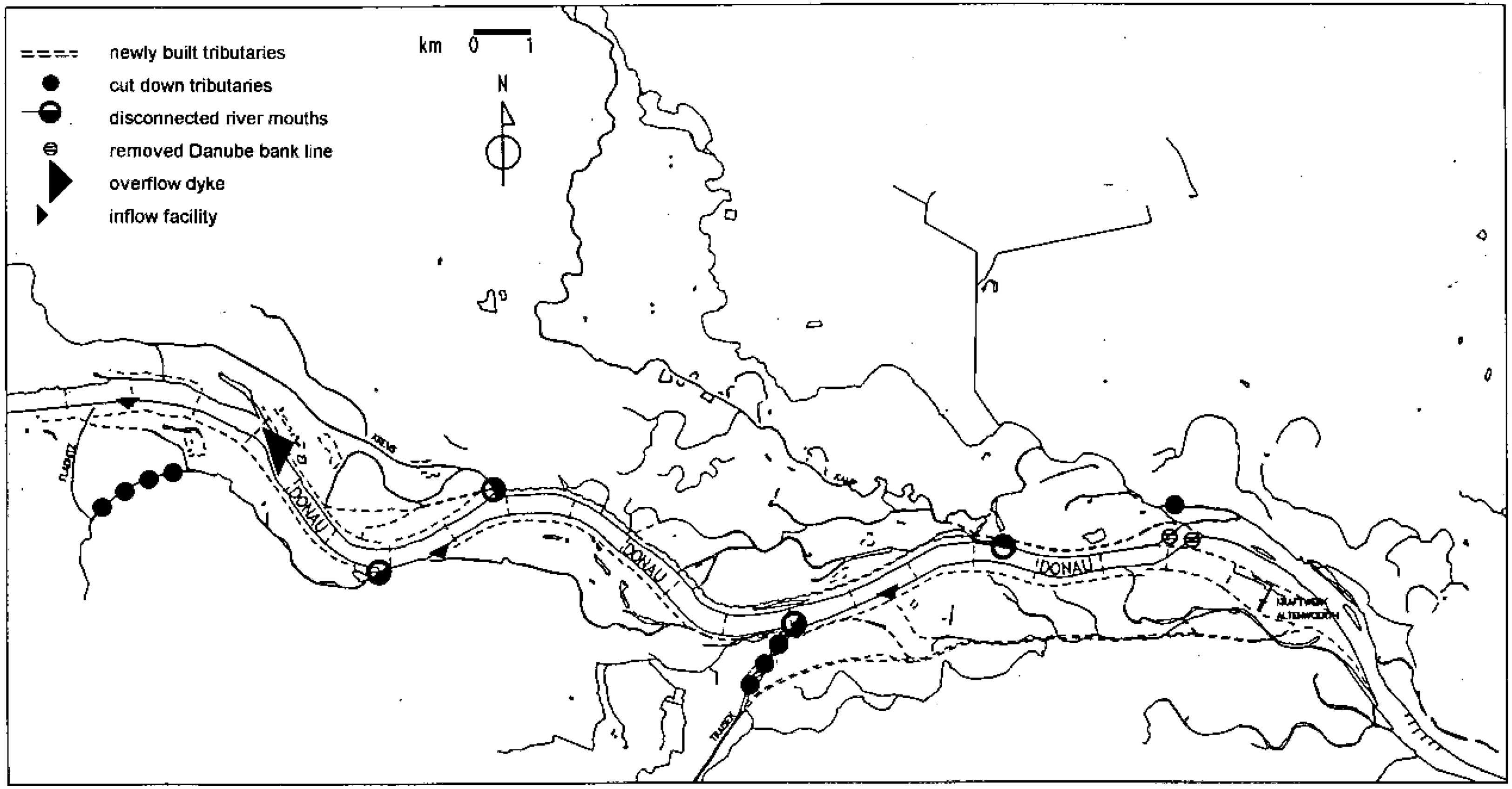


Figure 11: *Plan of the locality and the main changes of the surface water caused by building the power plant (Hary &Nachtnebel, 1989, p.32)*

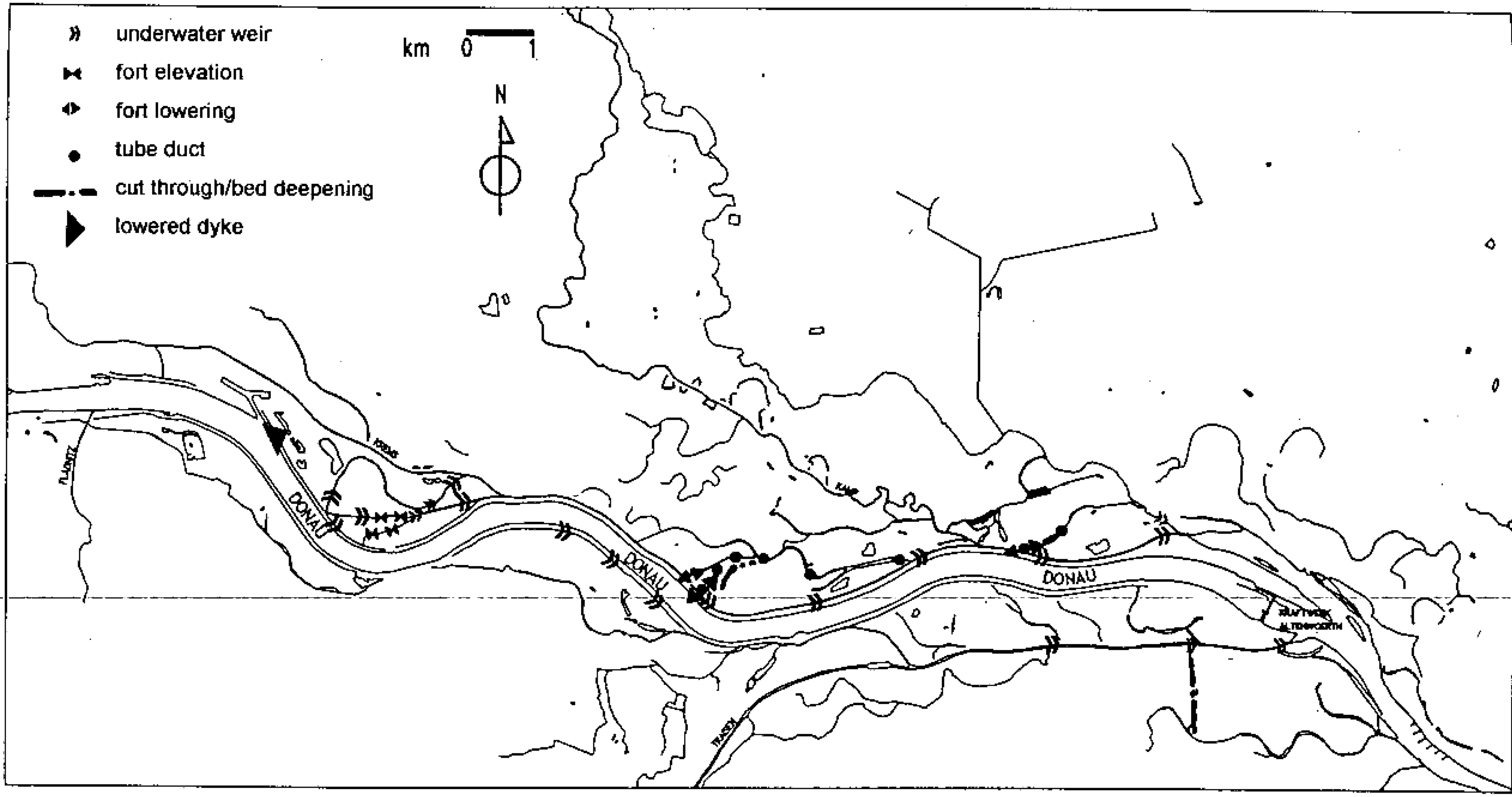


Figure 12: Changes in the flow regime caused by the 'Hinterland' preoject (Hary & Nachtnebel, 1989, p. 33)

FISH BIOLOGY

The investigation area originally showed a high structural diversity in the main channel and a strong interrelation with the surrounding floodplain and tributaries resulting in the development of various habitats with a broad spectrum of fishes. The most valuable areas were the mouths of the tributaries, the connections with stagnant waters such as oxbow-lakes, gravel banks, groynes and rocky fords.

> "Due to reduced current speed, increased depth, silty to muddy sediments and high benthic biomass, the impoundment conforms more to a habitat for limnophilic fish species. However, the relatively low average annual temperature of the Danube, the lack of shore line structure, and the low plankton density inhibit a better development of lacustrine fish associations. Distinct riparian macrophyte groups which serve as spawning ground, nursery and feeding place for juvenile fish, are seriously affected by flood events or even constant high average discharges and loose in such a case their protective functions. Due to optimal macrophyte development in 1986 as many as 14 juvenile fish species could be recorded, indifferent cyprinid species were dominant.
>
> The original dominant rheophilic fish fauna was represented in the impoundment by adult individuals only, which obviously use the rich food resources. Corresponding juvenile fish could only be detected in the free-flowing section except some few individuals also in the uppermost part of the impoundment. For typical rheophilic fish species there are no spawning grounds in the impoundment.
>
> The remaining free-flowing section upstream significantly influences the species composition of the impoundment as indicated by the unexpectedly high species number recorded" (Hary & Nachtnebel, 1989, p. 438).

Summarising the conclusions, the impounded reach is suffering from the disconnection to the floodplain waters, from the structureless banks and from the low density of plankton. Characteristic is the lack of juvenile fish.

ECO-ZOOLOGY

Based on regular waterbird counts, the report compares the situation prior and subsequent to the construction of the hydroelectric power plant. The total amount increased considerably; *Figure 13* shows the rise of wintering waterfowl, normally observed on every new large water surface. Considering the species composition, the impoundment had an opposite effect: the previously typical species decreased; "new" species supervened *being no longer typical for the Danube as a running water.* This fact is emphasised by the lower proportion of rare species. According to *Figure 14* they decreased from 10-23 % to about 5 % after the implementation. For instance the Goosander (*Mergus merganser*) reduced from 4.2 % to 0.2 % as it is specific to fast flowing and (when feeding) clear waters. Before it held 4th position within the dominant species. Similarly, the Goldeneye (*Bucephala clangula*) dropped from second position with 12.7 % to 4.2 %.

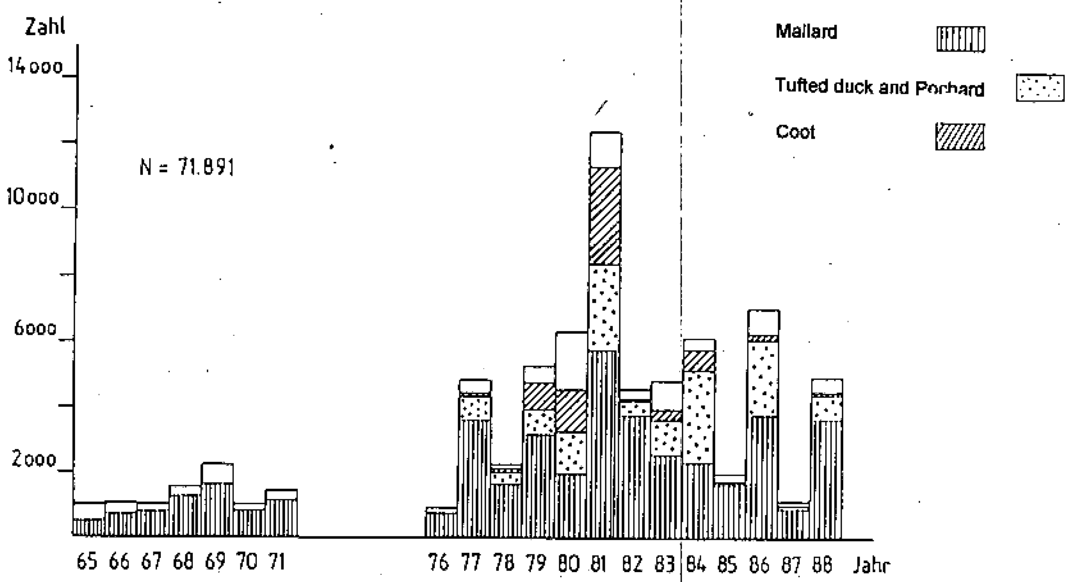


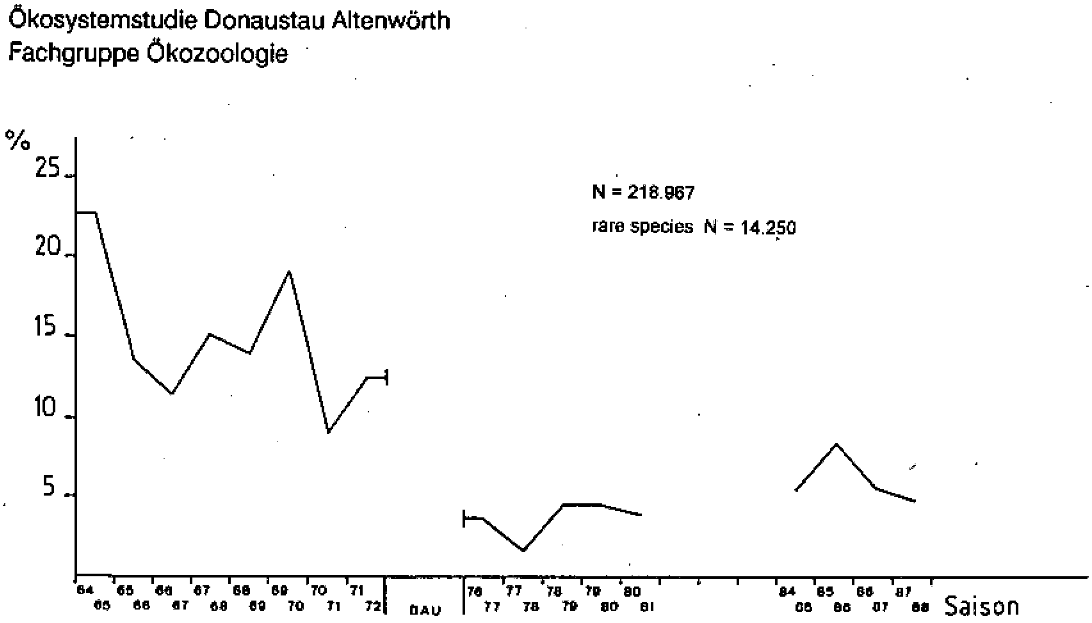
Figure 13: *Wintering water birds on the reach influenced by the Altenwörth impoundment before (1965-71) and after (1976-88) damming the river (Hary & Nachtnebel, 1989, p. 186).*

Instead, the actual situation now favours the occurrence of large concentrations of two diving ducks – Tufted Duck (*Aythya fuligula*) and Pochard (*A. ferina*) -, as well as Coot (*Fulica atra*) and Mallard (*Anas platyrhynchos*). These results are very similar to those at the Iffezheim barrage in the Upper Rhine (cp. *Figure 9*). To summarise, the following effects have been observed:

– a significant increase in the total number of wintering waterbirds;

– a change in the species composition with increase of non-specialised species and a drop in rare species;

– changes in the distribution of various species within the impoundment area.



total counts before blocking the river: N = 33 (1964 - 72), after blocking the river: N = 37 (1976 - 88).

Figure 14: *The proportion of rare species including Goldeneye and Goosander of the total number of birds counted in the winter months (November - March) from rkm 2,000 to rkm 1,980 (Hary & Nachtnebel, 1989, p. 189).*

ECO-BOTANY

This study deals with the long-term consequences of different groundwater tables in a floodplain forest ecosystem. It could not take into consideration any data from the situation prior to the construction of the barrage in contrast to the previous study. Therefore, two different stands which had always grown in the same groundwater conditions were compared. At one of these sites there was a groundwater supply over the whole vegetation period whereas at the other one groundwater was not available. The water potential was more negative at the second site although the stomata of the adult poplars (*Populus alba aff. canescens*) did not close even on warm, sunny days. The trees without available groundwater have smaller leaves, a lower leaf-area index of 4.0 (rather than 4.9 at the other site), a steeper net photosynthesis with a lighter curve and a worse biomass yield both in primary and litter production. Also the lower organic input results in a long-term deficit of organic matter in the soil. All these negative effects have been observed although the data per unit as for instance the leaf area or the decomposition rate are almost equal.

The investigation of the changes in the riparian forests is based on results gained from 1972-1976 prior to and during the construction of the barrage as well as from research carried out from 1984 to 1987. As a prerequisite, the characteristics of different alluvial soil layers are analysed in relation to the water table and to the water seeping through the rooted sphere. The standardised model characterises the different zones of soils in a floodplain:

(1) Rooted sphere with normal soil-air supply

(2) Lower interface: layer with capillary water supply supporting plant growth, adjacent to the basal boundary of the rooted sphere.

(3) Zone which is ineffective for capillary water supply due to a water table lying too deep

(4) Capillary edge with good water saturation but insufficient oxygen supply

(5) Groundwater table

The lower interface is of special ecological importance. *Figure 15* shows particularly the zone which is ineffective for capillary water supply.

The location of the basal boundary of the rooted sphere is very difficult to determine because tree roots can find its way into the soil several metres deep. They may reach the groundwater table if they are not obstructed by a gravel layer above the water table. In such an heterogeneous system the interface corresponds to the border between sand and gravel i.e. the topsoil alluvium interface. *Figure 16* shows the stratification of such a system.

Such systems with sand above gravel are found in the riparian forests of the Danube. Plants except the Black Poplar (*Populus nigra*) and Purple Willow (*Salix purpurea*) are unable to root in gravel even if the topsoil alluvium interface is only a little below the surface. Neither the immediate water supply of the roots nor capillary rise through the gravel layer are possible. At most, tree roots reach a depth of 3 to 4 m. Adding 1 m for the capillary water supply, the maximum range for the influence of groundwater ends at 5 m (Hary & Nachtnebel, 1989, p. 286). *Figure 17* shows the possible positions of the groundwater table in the simple homogenous system of *Figure 15*.

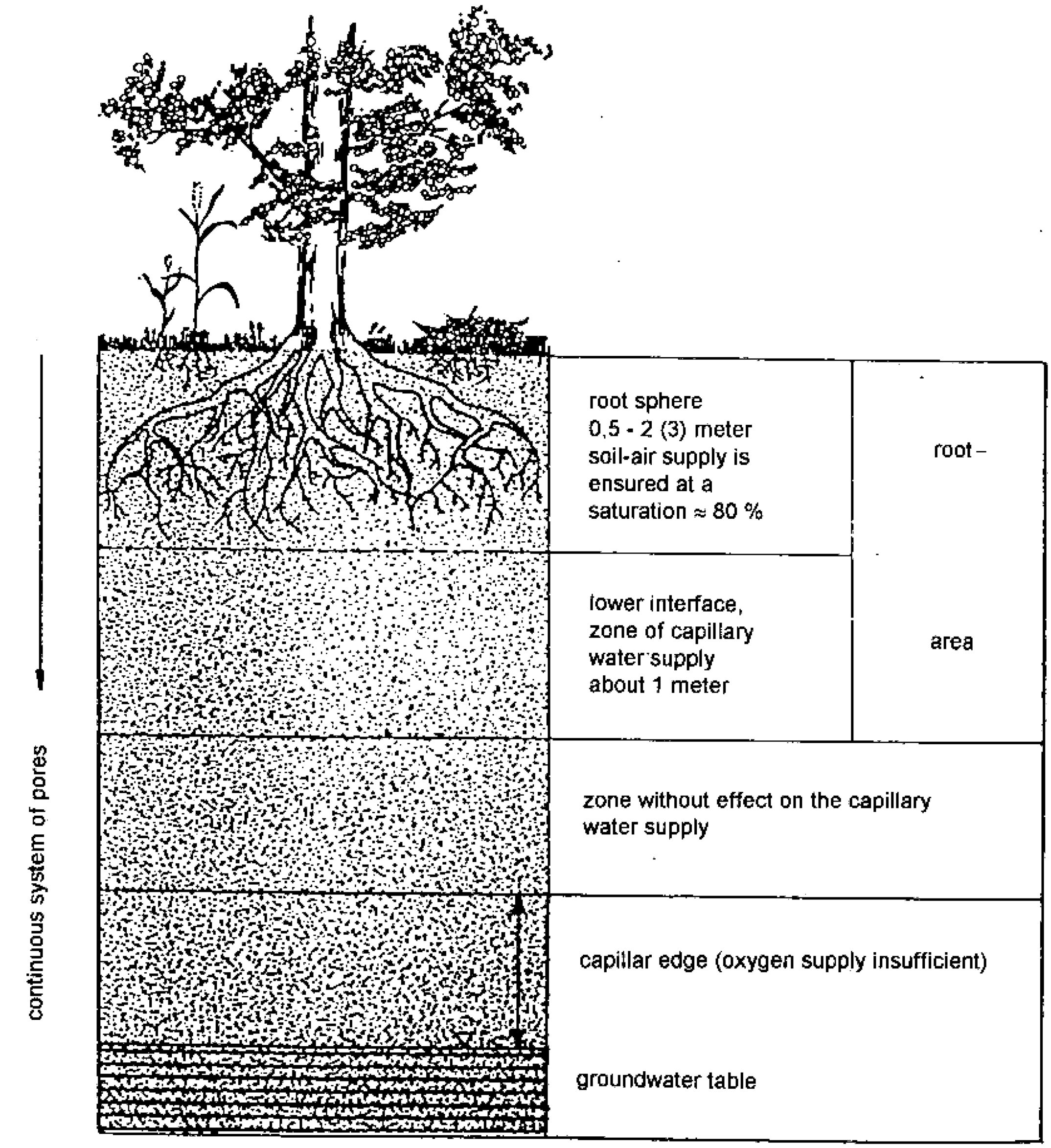


Figure 15: *Characteristics of alluvial soil layers in a rooted, sandy, porous, homogenous seeping system (without scale) (Hary & Nachtnebel, 1989, p. 272).*

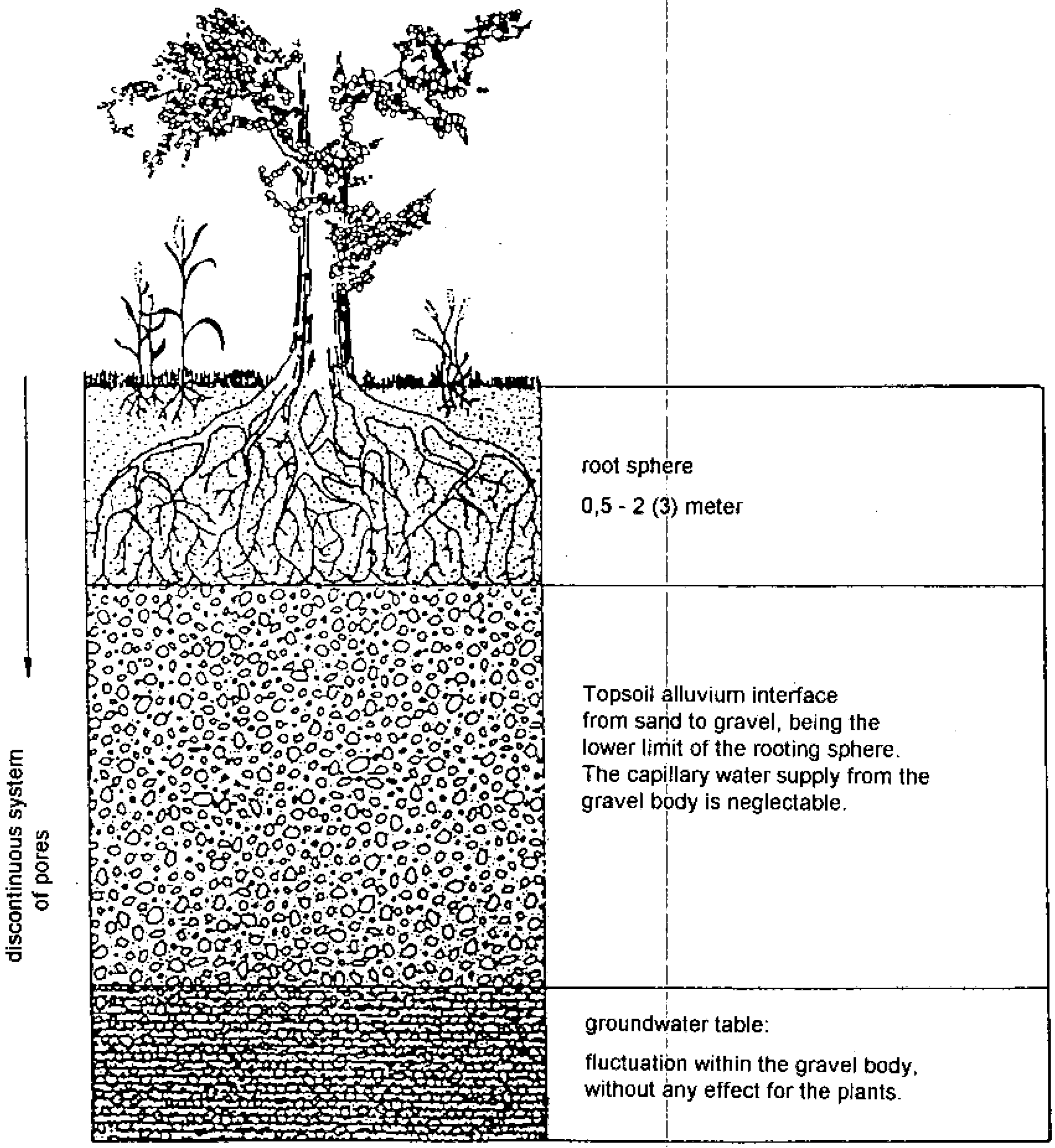


***Figure 16:** Characteristics of alluvial soil layers in an heterogeneous, two-layered seepage system of sand above gravel (Hary & Nachtnebel, 1989, p. 275).*

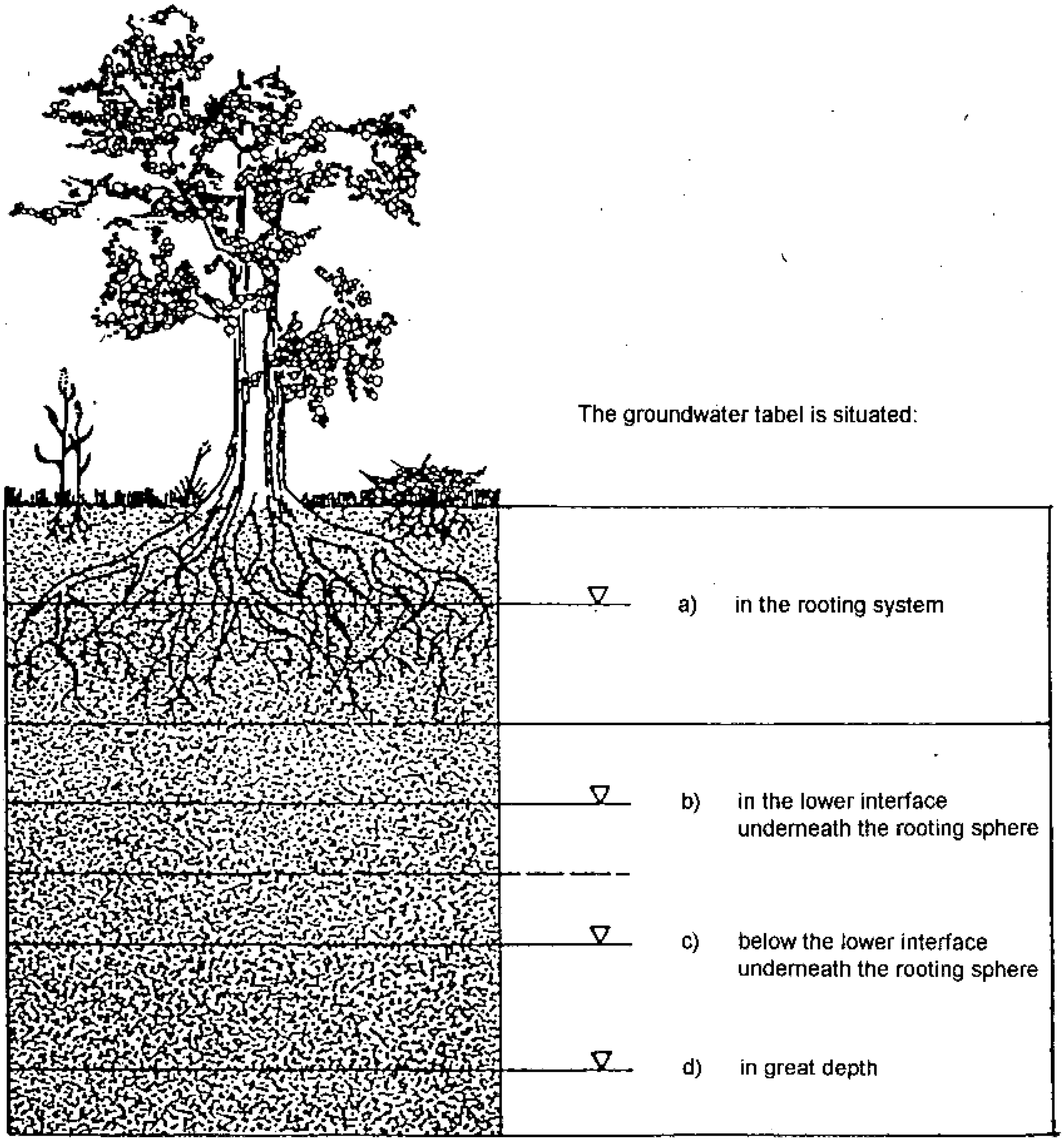


Figure 17: *Effects of drop or rise of the groundwater table on the capillary water supply in the rooted sphere within a homogenous, sandy permeable medium.*

Human impacts may lower or lift the groundwater table. Slight changes of the level influence just the vitality of the stands whereas strong changes usually modify the ecological conditions of the site.

Table 4: *Influence of groundwater table changes on woody species with special focus on forestry demands (Hary & Nachtnebel, 1989, p. 276). The influence of inundations is not considered.*

GROUNDWATER TABLE		
originally in position:	**lifted to position:**	**lowered to position:**
a) riparian forest stand		b) spoiling but gradual recovery is possible c) or d) irreversible damages are probable
b)	a) damages possible depending on wood species	c) spoiling possible depending on wood species d) irreversible damages probable
c)	a) irreversible damages probable b) advantage of tree growth possible	d) no connection with advantage of tree growth provable
d)	c) no influence on tree growth b) or a) see original position c)	

The different groundwater tables and soil sections relate to different effects:

– If the groundwater table exceeds the topsoil alluvium interface at least once per year due to flooding, the trees may get a subsidy from the groundwater to their water supply.

– If the groundwater table always rests within the gravel layer, all water supply is stopped (except to the Black Poplar and the Purple Willow).

– If the groundwater table stays in the sandy part, an intensive rooting of the well ventilated sand improves growth especially of poplars.

– If the groundwater table stays in the loamy fine-grained topsoil, the water is well stored and the roots may grow easily but processes of reduction are usual in the moistened soil.

The sites of the natural vegetation in the floodplains along the Austrian stretch of the Danube are well analysed and described (e. g. Wendelberger-Zelinka, 1952 and Margl, 1971). According to these descriptions the natural vegetation consists of: (numbers in brackets indicate the site (according to Hary & Nachtnebel, 1989, p. 321))

Initial or pioneer communities:

(1) Purple Willow shrubs

(2) Moist and wet willow forests

(3) Fresh willow forests

These sites, adjacent to the river, are directly affected by the fluctuations in the water level of the river. The groundwater table also reacts to these variations without much delay and the tree roots are able to profit from groundwater for the whole growing season. At Altenwörth, these sites are inundated for not more than 25 days on average during this season with a minimum of 8 days every 2 years.

Successive communities:

(5) Moist poplar forests

(6) Fresh poplar forests

(4) Dry poplar forests

These sites following or in contact with the previous communities, are often associated with side arms. The floods inundate at first the lower (and especially at Altenwörth) the downstream areas, later on pushing ahead to the higher and upstream sites. The groundwater table follows after some delay.

The *moist poplar forests* at Altenwörth are inundated for 75 days *annually (?)* with a minimum of 8 days every 2 years. There is a strong influence of groundwater in the silty air-poor soil.

The *fresh poplar forests* are to be found on flat or banked sites on silty or loamy sand. The roots reach the groundwater if it lies above the gravel. Inundations occur on average every 2 to 5 years for 8 to 4 days in the investigation area.

The *dry poplar forests* grow on sandy to coarse-sandy, flat soils above the gravel alluvium with little water capacity. For the most part, the trees roots do not reach the groundwater.

Permanent or continual communities:

(7) Moist hardwood riparian forests

(8) Fresh hardwood riparian forests

(9) Dry hardwood riparian forests

These sites are situated away from the side branches and cover extensive, flat areas. The groundwater table follows the river's water level with a significant delay (in its height). Nowadays at Altenwörth, they are inundated only every 2 to 5 years for 8 to 4 days.

The *moist hardwood riparian forests* are strongly influenced by the groundwater in the loamy hollows.

The *fresh hardwood riparian forests* exist on well developed loam and silt layers. The trees can use the groundwater if it lies above the gravel.

The *dry hardwood riparian forests* on thick layers of sands are not influenced by groundwater.

The *fresh linden forests* (11) are restricted to the embankments of the river being the highest elevations in the floodplain. There is no contact with the groundwater in the loamy sand but the soil has a good water content. Only catastrophic events could affect this site.

Heißlände (= hot lands) (13) represent the driest sites on shallow soil layers above gravel. The soils" water content is low and there is no influence of the groundwater.

A comparison of phyto-sociological samples from about 100 test areas taken in the years 1974-1976, 1984 and 1985, shows the *ecological decline* of the vegetation. Especially with regards to the "humidity value", which demonstrates the dependant relationship of the respective plants to site humidity,. First of all the *herb* layer indicates the lack or the significant reduction of floods on the one hand by the appearance of species which do not tolerate inundations like the Wall Lettuce (*Mycelis muralis*), the Three-nerved Sandwort (*Moehringia trinerva*) or the young specimen of the False Acacia (*Robinia pseudacacia*) and the disappearance of characteristic species such as the Lesser Celandine (*Ranunculus ficaria*) on the other hand. Although this is not a long time for plants to change, the authors notice, that the 10 years are sufficient to show the more or less far-reaching but significant shift of the species composition and distribution of plant communities (Hary & Nachtnebel, 1989, p. 320). No negative effects have only been observed at those sites, where the top soil layer is flat or where there was no influence of the groundwater prior to the works.

Due to the decrease of the groundwater table, the sites at Altenwörth tend to change in the following direction (Hary & Nachtnebel, 1989, p. 320):

(11-13) linden forest, "Heißlände"	→ +/– unchanged
(9) dry hardwood forest	→ (12, 13) dry linden forest, partly "Heißlände"
(8) fresh hardwood forest	→ (new) oak-hornbeam-linden-forest
(7) moist hardwood forest	→ (8-new) fresh hardwood forest to oak-hornbeam linden-forest
(4) dry poplar forest	→ (9-13) dry hardwood forest to "Heißlände"
(6) fresh poplar forest	→ (4 or 8) dry poplar– or fresh hardwood forest
(5) moist poplar forest	→ (6 or 8) fresh poplar– or fresh hardwood forest
(3) fresh willow forest	→ (6-4) fresh poplar– to hardwood forest
(2) moist and wet willow forest	→ (5-6) moist to fresh poplar forest
(-) reeds (of running waters)	→ partly (2) wet willow forest
(-) surface waters	→ partly (-) reeds (of stagnant waters)

Due to the *increase of the groundwater table*, the sites at Altenwörth tend to change in the following direction (Hary & Nachtnebel, 1989, p. 325):

(11,12) linden forest	→ more or less unchanged
(13,9) "Heißlände",	→ at most at the margins dry hardwood forest
(8) fresh hardwood forest	→ reconnection to groundwater table is possible
(7) moist hardwood forest	→ stabilisation; lowest parts are getting wet
(4) dry poplar forest	→ partly improved, (6) fresh poplar forest is possible
(6) fresh poplar forest	→ groundwater contact is improved, (5) moist poplar forest in the lower parts
(5) moist poplar forest	→ (2) wet willow forest partly, or permanent inundations
(2) moist and wet willow	→ (-) reeds (of stagnant waters) partly, or swamp forest

Summary

As a result of the construction of the barrage and of the remedial measures, the hydrological subsystems were equalised and decoupled. The original diversity of aquatic habitats, characterised by different conditions of flow, depth of waters and changing substratums, was replaced by uniform structures especially in the impoundment. The system shows significantly reduced dynamics: high groundwater tables decreased and low levels increased in a 2,000 to 2,500 m wide strip along the banks whereas the mean values differed little as was intended. The communication between the impoundment and the groundwater is almost lost.

From the limnological aspect, the waterbody of the impoundment is long enough to affect considerably the abiotic prerequisites but it is too narrow to allow for a higher plankton-biomass production. However, the zoobenthos composition of the river-bed has changed because of the different dynamics of solid matter. From the fishery point of view, the impounded reach is suffering because of the disconnection to the floodplain waters, the structureless banks and the low density of plankton. Characterising this is the lack of juvenile fish.

Eco-zoological observations prior to and after building the barrage showed a significant increase in the total number of wintering waterbirds, accompanied by a change in the species composition: the number of non-specialised species increased, rare species declined and the spatial distribution of various species changed within the impoundment area. The eco-botanical investigation deals with the consequences of different but unchanged groundwater tables in two poplar stands, one with supply and the other without. At the second stand, the water potential was more negative, the leaves were smaller and the biomass production was worse. The lower organic input resulted in a deficit of organic matter in the soil.

In the study on forest-ecology, the different alluvial soil layers are analysed in relation to the groundwater table with the help of models. The topsoil alluvium interface is of crucial importance. Groundwater which remains in the gravel layer cannot be reached by roots whereas water table variations within the topsoil layer may cause less damage to the vegetation. The effects on the forests depend on the different plant communities and their specific abiotic conditions. Increasing grain size and decreasing thickness of the topsoil layer exaggerates the adverse effects of dropping groundwater tables. Strong negative detrimental effects appear from a drop of 0.50 metre and more. The comparison of pytosociological samples from the years 1974 to 1985, especially the "humidity value" shows the ecological decline of the vegetation and the significant shift of the species composition and distribution of plant communities. No negative effects have only been observed at sites with shallow topsoil layers or where there was no influence from the groundwater prior to the works.

October 20, 1994

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References

Ambühl, H.: Die Bedeutung der Strömung als ökologischer Faktor. Physikalische, biologische und physiologische Untersuchungen über Wesen und Wirkung der Strömung im Fliessgewässer. (The significance of the current as ecological factor. In German). Schweizerische Zeitschrift für Hydrologie no. *21* (2): pp. 133-264., 1959

Bradshaw, A. D.: The ecological component. 19-36. In: Roberts, R. D. & T. M. Roberts (1984) Planning and ecology. New York, London, Chapman & Hall, 1984

BFANL Bundesforschungsanstalt für Naturschutz und Landschaftsökologie: Hochwasserschutzmaßnahmen am Oberrhein im Raum Breisach – Zur Prüfung der Umweltverträglichkeit. (Flood protection measures at the Upper Rhine in the area of Breisach – To the environmental impact assessment. In German). BFANL: Bonn-Bad Godesberg., *1988*

Carbiener, R.: Die linksrheinischen Naturräume und Waldungen der Schutzgebiete von Rhinau und Daubensand (Frankreich): eine pflanzensoziologische und landschafts- ökologische Studie. (The natural units and forests in the protected areas of Rhinau and Daubensand (France) on the left side of the Rhine: a study on phytosociology and landscape ecology. In German). In: Das Taubergießengebiet - eine Rheinauenlandschaft. Die Natur - und Landschaftsschutzgebiete Baden-Württembergs *7*: 438-535. (CARBIENER zB 479+524), 1974

Dister, E.: Geobotanische Untersuchungen in der hessischen Rheinaue als Grundlage für die Naturschutzarbeit. (Geo-botanical investigations in the Hessian floodplain of the Rhine as basis for the work in nature protection. In German). Doctoral thesis University of Öttingen, 1980

Dister, E.: Taschenpolder als Hochwasserschutzmaßnahme am Oberrhein. ("Pocket" polders as a flood protection measure at the Upper Rhine. In German). Geographische Rundschau 37 (5): pp. 241-247, 1985

Dister, E.: Ökologie der mitteleuropäischen Auenwälder. (Ecology of Central European riparian forests. In German). In: Die Auenwälder. Wilhelm-Münker-Stiftung (19): pp. 6-30., *1988*

Dister, E., Gomer, D., Obrdlik, P., Petermann, P. & E. Schneider: Water management and ecological perspectives of the Upper Rhine's floodplains. Regualted Rivers: Research & Management no. *5*: pp. 1-15., 1990

Ellenberg, H.: Vegetation Mitteleuropas mit den Alpen. (Vegetation of Central Europe with the Alps. In German). Stuttgart, 3rd ed. Ulmer: 1982

Gepp, J.: (ed.) Auengewässer als Ökozellen. (Floodplain waters as ecological cells. In German). Grüne Reihe des Bundesministeriums für Gesundheit und Umweltschutz no. *4*: Vienna, 1985

Gerken, B. Auen: – verborgene Lebensadern der Natur. (Floodplains – hidden lifelines of nature. In German). Freiburg, Rombach 1988

Hary, N. & H.-P. Nachtnebel: (Ed.), Österreichische Akademie der Wissenschaften:Öko-Systemstudie Donaustau Altenwörth. Teil 1. Veränderungen durch das Donaukraftwerk Altenwörth. (Eco-system study Altenwörth. Changes by the Danubian power plant Altenwörth. In German with English Summaries). Veröffentlichungen des Österreichischen MAB-Programms; Band 14. – Wagner: Innsbruck, 1989

Heinrich, D. & M. Hergt: dtv-Atlas zur Ökologie. (dtv-atlas on ecology. In German) München, Deutscher Taschenbuch Verlag, 1990

Henrichfreise, A.: (ed.) Biotopsystem Nördliche Oberrheinniederung. (Biotope system Northern Upper Rhine lowlands. In German). BFANL: Bonn, 1988

Horvat, I., Glavaç, V. & H. Ellenberg: Vegetation Südosteuropas. (Vegetation of Southeast - Europe. In German). Stuttgart, Geobotanica selecta no.4. Fischer, 1974

Hügin, G.: Die Auenwälder des südlichen Oberrheintals und ihre Veränderung durch den Rheinausbau. (The riparian forests of the southern Upper Rhine valley and their changing by the Rhine regulation works. In German with French summary). pp. 677-706. In: J.-M. Géhu (ed.) Colloques phytosociologiques *IX*. Les foręts alluviales. Strasbourg 1980. (Published 1984). Vaduz, Cramer: 1980

Hügin, G.: Die Auenwälder des südlichen Oberrheintals - ihre Veränderung und Gefährdung durch den Rheinausbau. The riparian woods of the southern Upper Rhine valley – Changing and endangering by Rhine development. (In German with English captions and summary in English + French). Landschaft + Stadt no. *13* (2): pp. 78-91, 1981

Hügin, G. & A. Henrichfreise: Vegetation und Wasserhaushalt des rheinnahen Waldes. Naturschutzbewertung der badischen Rheinaue. (Vegetation and water balance of the forest adjacent to the Rhine. Assessment for nature protection in the Baden floodplain of the Rhine. In German). Schriftenreihe für Vegetationskunde (25). BFANL: Bonn-Bad Godesberg, 1992

Internationale Kommission für die Hydrologie des Rheingebietes: Der Rhein unter der Einwirkung des Menschen - Ausbau, Schiffahrt, Wasserwirtschaft -. (The River Rhine under human impact – river training, navigation, water management -. In German). (Authors: W. Buck et al.). KHR report # I-11. KHR: Lelystad, 1993

Kalkowski: Regional Council Freiburg, dept. 5, water management: personal communication 11.7., 1994

Kalkowski: Wie wirken feste Schwellen im Rhein auf die seitlichen Grundwasser- stände? Nachgewiesen für den Bereich der Stufe Rhinau. (How do "special weirs" in the Rhine affect lateral groundwater tables? Proved for the area of the barrage Rhinau. In German). Regional council of Freiburg, dept. 5, water management. Reference # V52/872/86 v. 31.7.86., 1986

Kern, K.: Restoration of lowland rivers: the German experience. 277-297. In: P.A. Carling & G.E. Petts (ed.): Lowland floodplain rivers: geomorphological perspectives. John Wiley & Sons: Chichester, 1992

Kloetzli, F. A.: Ökosysteme. (Ecosystems. In German). Stuttgart, Fischer, 1989

Krause, W.: Zur Hydrographie der Rheinaue im nördlichen Kaiserstuhl-Vorland. (Hydrography of the Rhine floodplain in the northern forelands of the Kaiserstuhl. In German). Archiv für Hydrobiologie 63: pp. 433-476., 1967

Krause, W., Hügin, G. & Bundesforschungsanstalt für Naturschutz und Landschaftsökologie: Ökologische Auswirkungen von Altarmverbundsystemen am Beispiel des Altrheinausbaus. (Ecological impacts of systems of combined ox-bow lakes at the example of the Previous Rhine river training. In German). Natur und Landschaft, no. *62* (1): 9 + map., 1987

Kunz, E.: Von der Tullaschen Rheinkorrektion bis zum Oberrheinausbau. 150 Jahre Eingriffe in ein Naturstromregime. (From TULLA's Rhine "correction" to the Upper Rhine river training. 150 Years of interventions in the regime of a natural large river. In German). Jahrbuch für Naturschutz uns Landschaftspflege 24: pp. 59-78, 1975

Landesanstalt für Umweltschutz Baden-Württemberg: Grundsatzpapier Auenschutz und Auenrenaturierung. (Principle paper floodplain conservation and floodplain restoration. In German). Materialien zum Integrierten Rheinprogramm no. *4*., 1994

Lelek, A.: The Rine River and some of its tributaries under human impact in the last two centuries. In: D.P. Dodge (ed.) Proceedings of the international large river symposium. Canadian special publication of fisheries and aquatic sciences 106: pp. 469-487., 1989

Lösing, J.: Vegetationskundliche Untersuchungen des Gebietes Elisabethenwört und Vorland (Rußheimer Altrhein). (Geobotanical investigations of the Elisabethenwoert. In German). Integriertes Rheinprogramm, LfU Baden-Württemberg, unpublished study, 1989

Mader, K.: Veränderte Auwaldökosysteme durch wasserbauliche Maßnahmen. (Hydraulic engineering structures alter riverine woodland ecosystems. In German). Österreichische Wasserwirtschaft 41 (7/8):pp. 203 – 212., 1989

Margl, H. Die Ökologie der Donauauen und ihre naturnahen Waldgesellschaften. (The ecology of the Danubian floodplains and their near-natural forest comunities. In German). Naturgeschichte Wiens 2: 0 – 41. Jugend und Volk: Wien, 1971

Müller, G.: Winter counts of waterfowl at the River Rhine by the OAG Karlsruhe. Lecture at the Museum of Natural History, Karlsruhe 1994. Publ. in prep, 1994

Odum, E. P.: Fundamentals of ecology. London, Saunders: Philadelphia, 1959

Raabe, W.: Wasserbau und Landschaftspflege am Oberrhein. (Hydro-engineering and landscape management at the Upper Rhine. In German). Schriftenreihe des Deutschen Rates für Landespflege 10: pp. 24-31., 1968

RP Freiburg, Regional Council of Freiburg, Arbeitsgruppe für die Stauregelung in den Altrheinen: Bericht über den Stauversuch Mitte Januar 1976 auf der Rheinstraße bei Rheinhausen - Ortsteil Niederhausen. (Report on the storage experiment halfway of January 1976 on the Rhine road near Rheinhausen – district Niederhausen. In German). Regional council of Freiburg, dept. 5, water management. Reference # 52/277/77., 1976

RP Freiburg, Regional Council of Freiburg, dept. 5, water management: Wie haben sich die niedrigen und mittleren Grundwasserstände seit Inbetriebnahme der Staustufe Gambsheim geändert? (How did low and average groundwater tables change since the putting into operation of the Gambsheim barrage? In German). Reference # V52/341/83, 1983

RP Freiburg, Regional Council of Freiburg, dept. 5, water management: Veränderung der hohen Grundwasserstände entlang der Staustufe Gambsheim. (Change of high groundwater tables along the Gambsheim barrage? In German). Reference # 52/8961.23/87 v. 15.7.87., 1987

Schäfer, W.: Der Oberrhein, sterbende Landschaft?. (The Upper Rhine - a dying landscape?. In German). Natur und Museum no. *103*: pp. 1-29, 73-81, 110-123, 137-153, 177-192, 312-319; no. *104*: pp. 297-305, pp. 331-343, pp. 458-463; no. *105*: pp. 72-84, 1973, 1974, 1975

Späth, V.: Zur Hochwassertoleranz von Auwaldbäumen. (About the flooding tolerance of floodplain trees. In German). Natur und Landschaft no. *63* (7/8): pp. 312-315, 1988

Vogel, O.: Bestockungsumbau im Trockengebiet Oberrhein - eine volkswirtschaftliche und landeskulturelle Aufgabe. (Conversion of stocks in the desessicated area of the Upper Rhine – a task for national economy and land cultivation. In German). Schriftenreihe der Landesforstverwaltung Baden-Württemberg 26: pp. 1-148., 1969

Walter, H.: Vegetation of the earth and ecological systems of the geo-biosphere. New York, Springer, 1977

Wendelberger-Zelinka, E.: Die Vegetation der Donauauen bei Wallsee. (The vegetation of the Danubian floodplains at Wallsee. In German). Schriftenreihe der Oberösterreichischen Landesbaudirektion 11., 1952

Westermann, K. & G. Scharff: Auen-Renaturierung und Hochwasserrückhaltung am südlichen Oberrhein. (Floodplain restoration and flood "hold-back" at the southern Upper Rhine. In German). Naturschutzforum no. *1/2*: pp. 95-158., 1987/1988

Yon, D. & G. Tendron: Alluvial forests of Europe. (English and French versions). Council of Europe. Nature and environment series # 22. Strasbourg, 1981.

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Annexes

A-1 Hydrograph of the recent floodplain and the according plant communities at Neuburgweier downstream of Iffezheim

A-2 Cross-section of the old floodplain of the previous *Rhine* with characteristical changes caused by regulation works in the partial diversion section at Rhinau

A-3 Changes of the natural vegetation caused by modified waterlevels

A-4 Results of controlled floods for the vegetation in the connected river branch system of the old floodplain (barrage of Rhinau, section of partial diversion)

A-5 The situation of the "Taubergiessen" (barrage of Rhinau)

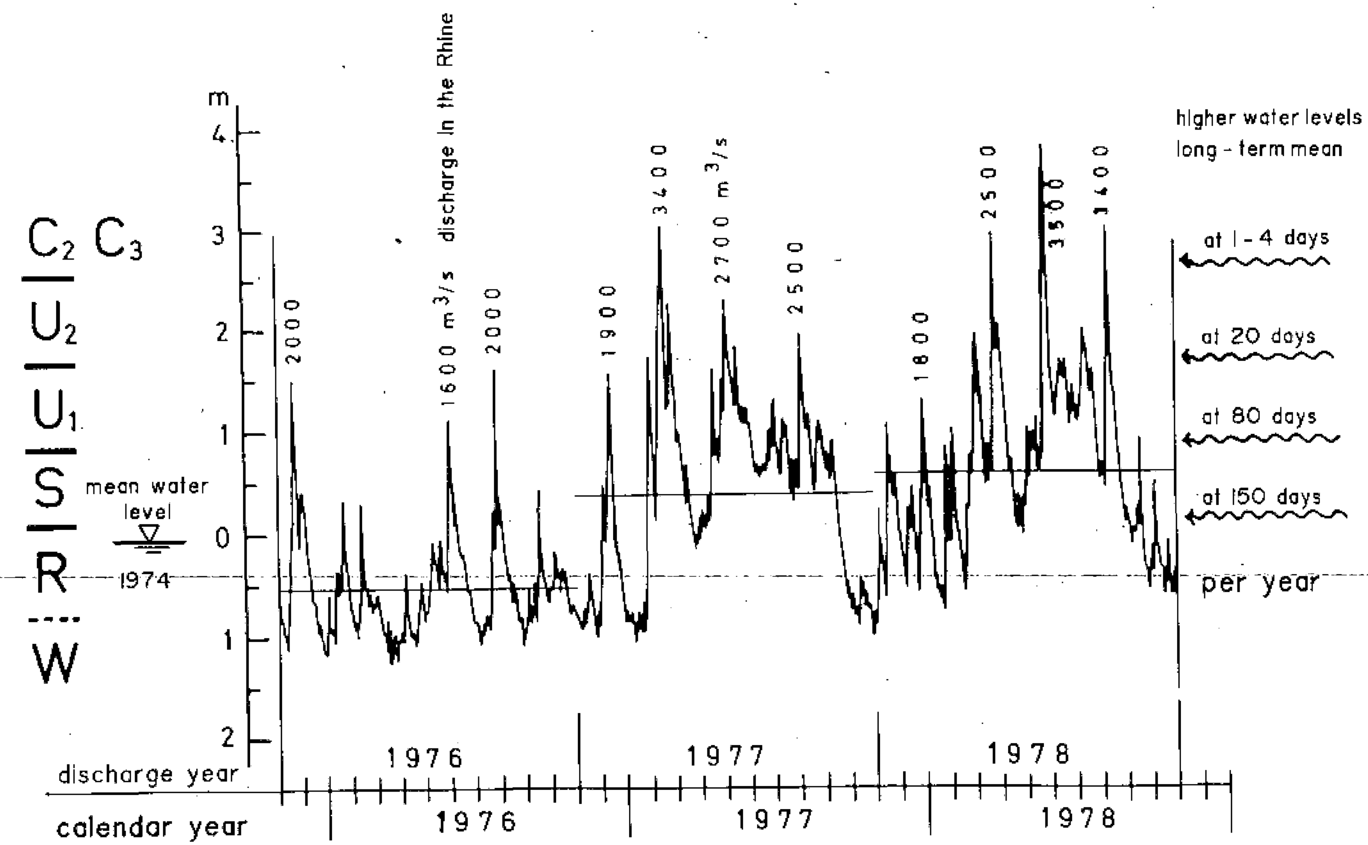
A-6 Changes of the potential natural vegetation in the central part of the recent floodplain in the "Taubergiessen" (barrage of Rhinau, section of partial diversion) caused by changes of the water regime

A-7 Changes of the vegetation and groundwater tabels in the old floodplain at the barrage of Gambsheim (section of barrages) and the effect of self-sealing

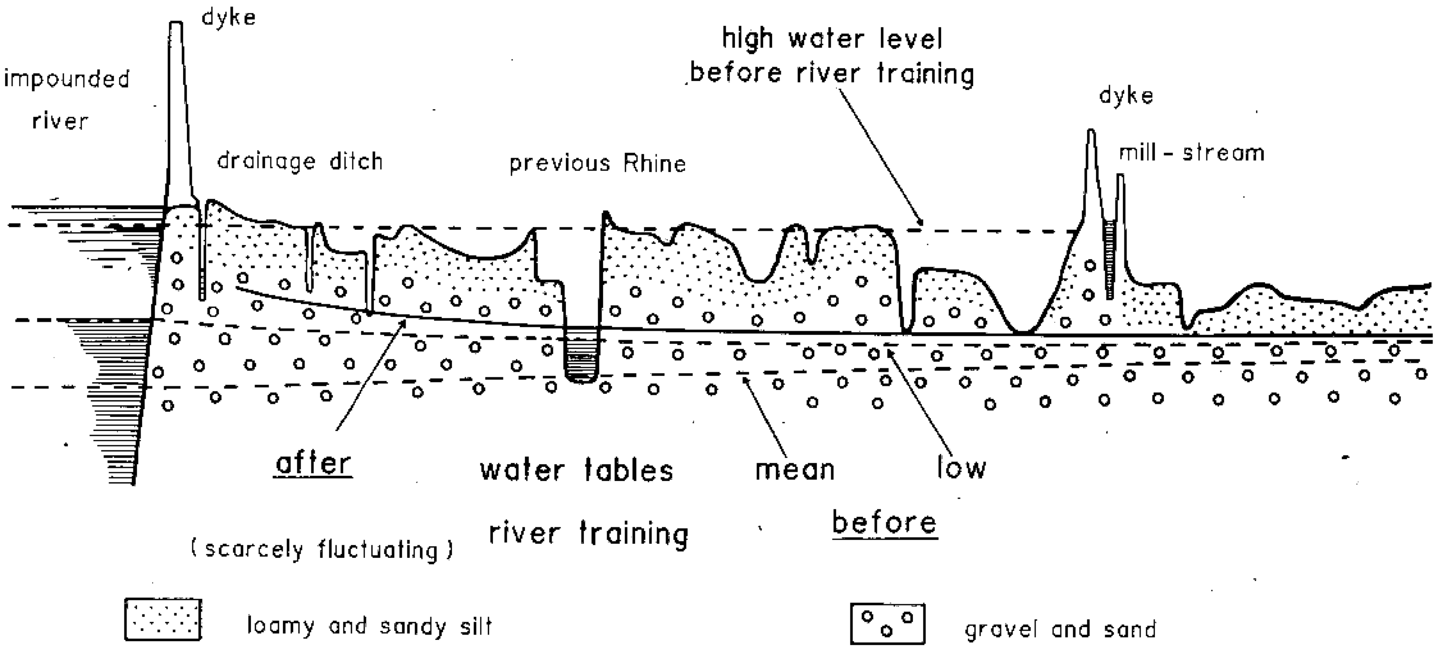
A-8 Impacts of the three regulated sections and of the strech downstream of Iffezheim on the potential natural vegetation

September 16, 1994

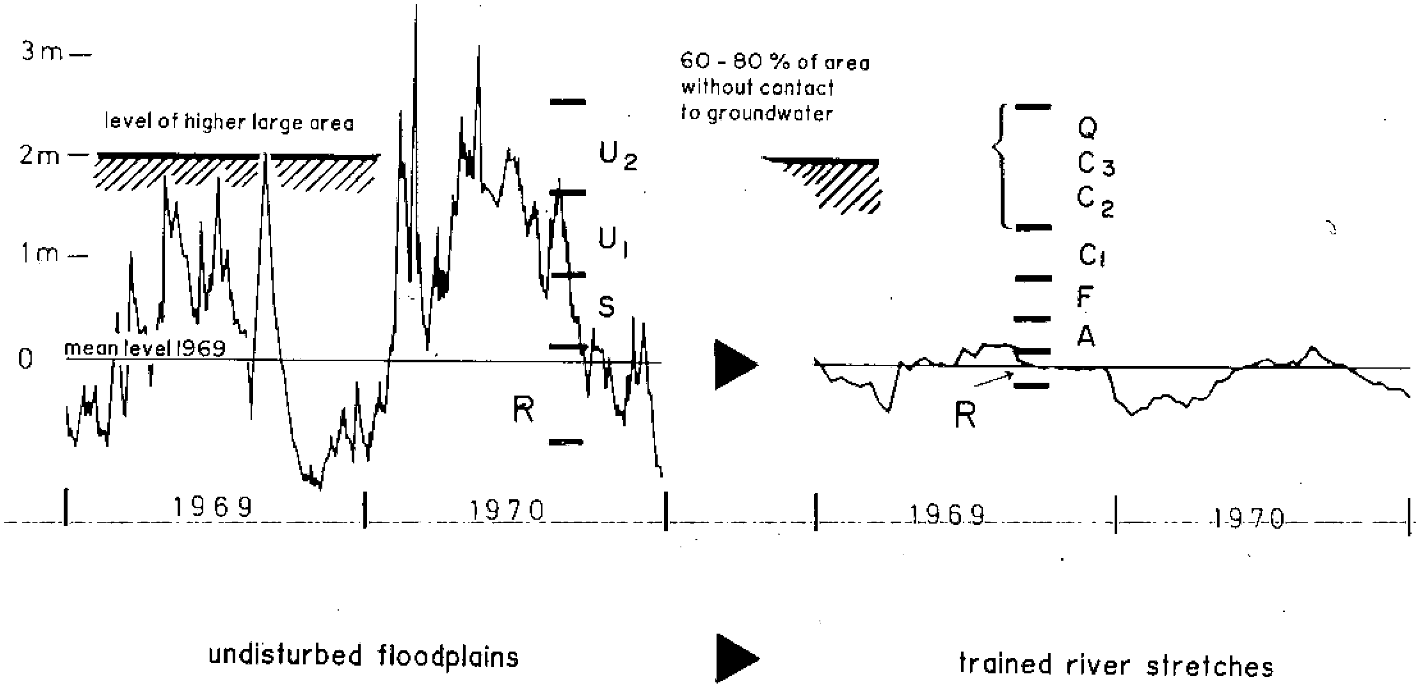
A-1 *Hydrograph of the recent floodplain and the according plant communities at Neuburgweier downstream of Iffezheim (Hügin, 1980)*



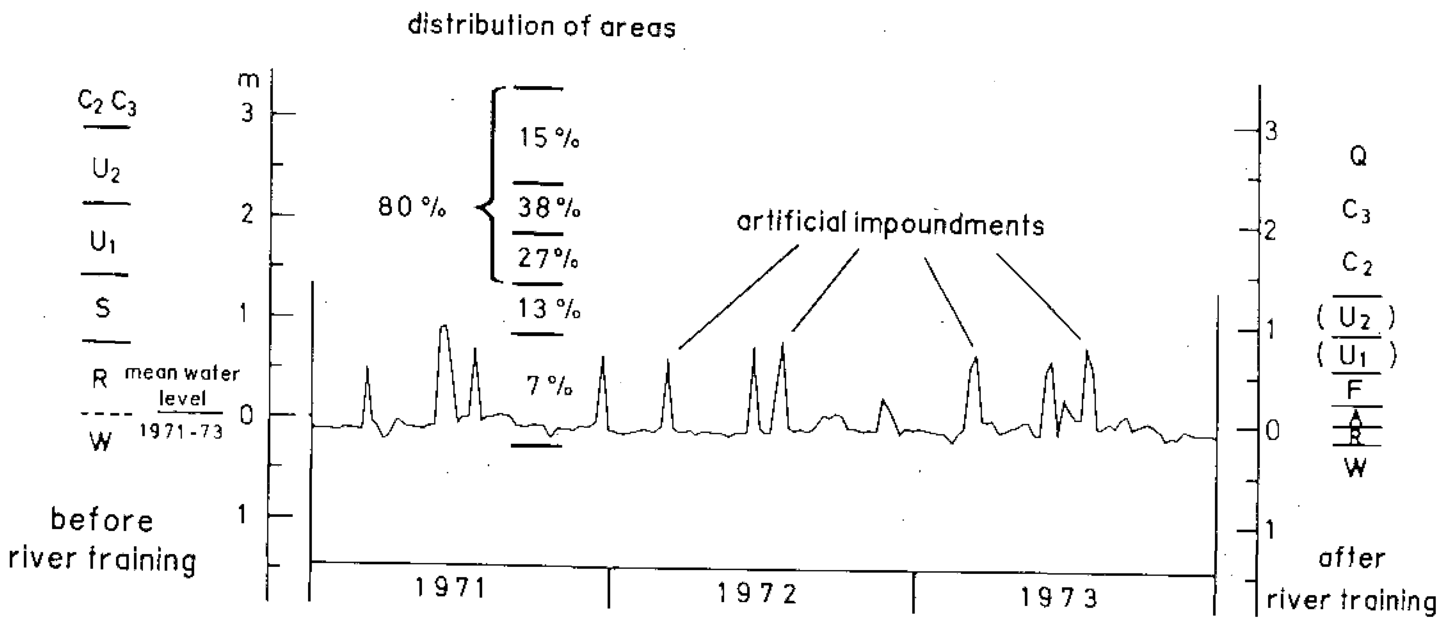
A-2 *Cross-section of the old floodplain of the previous Rhine with characteristical changes caused by regulation works in the partial diversion section at Rhinau (Hügin, 1980)*



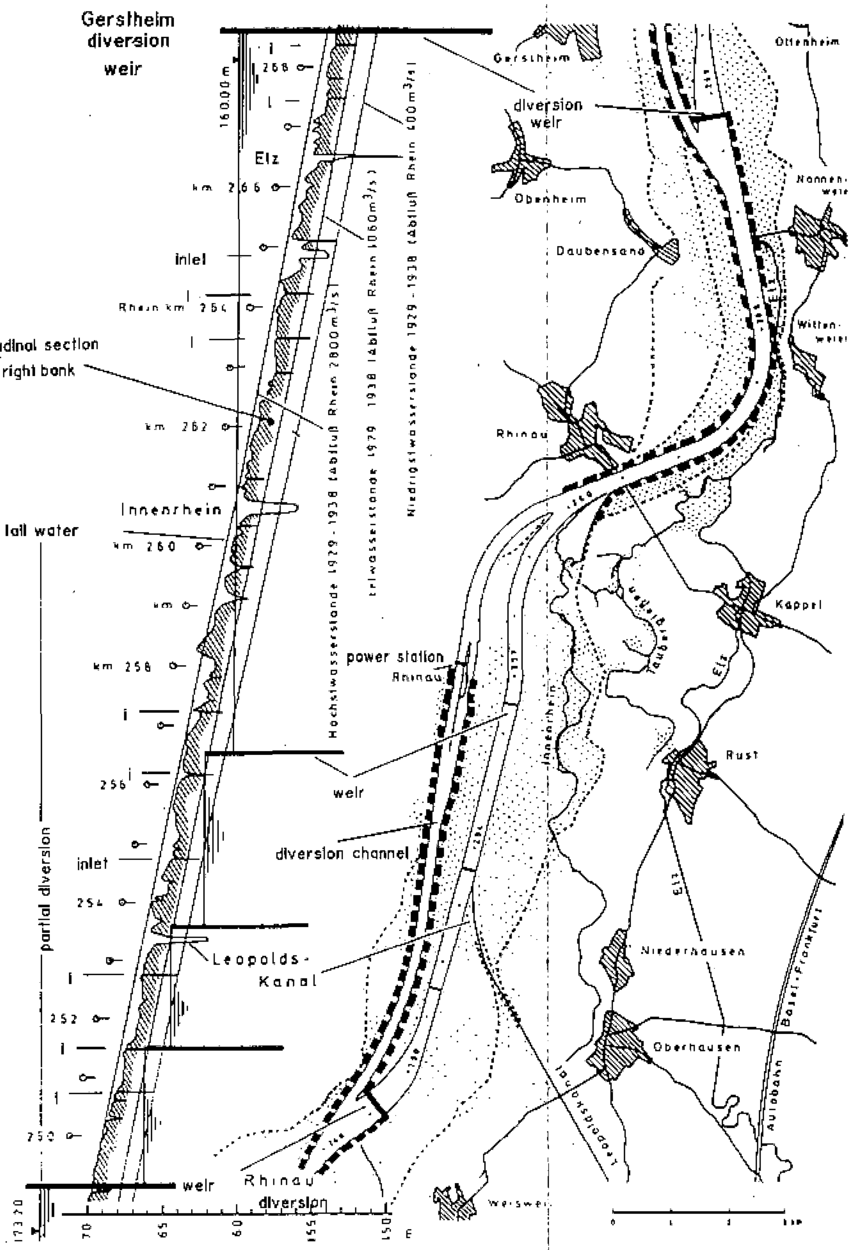
A-3 *Changes of the natural vegetation caused by modified waterlevels (Hügin, 1980)*



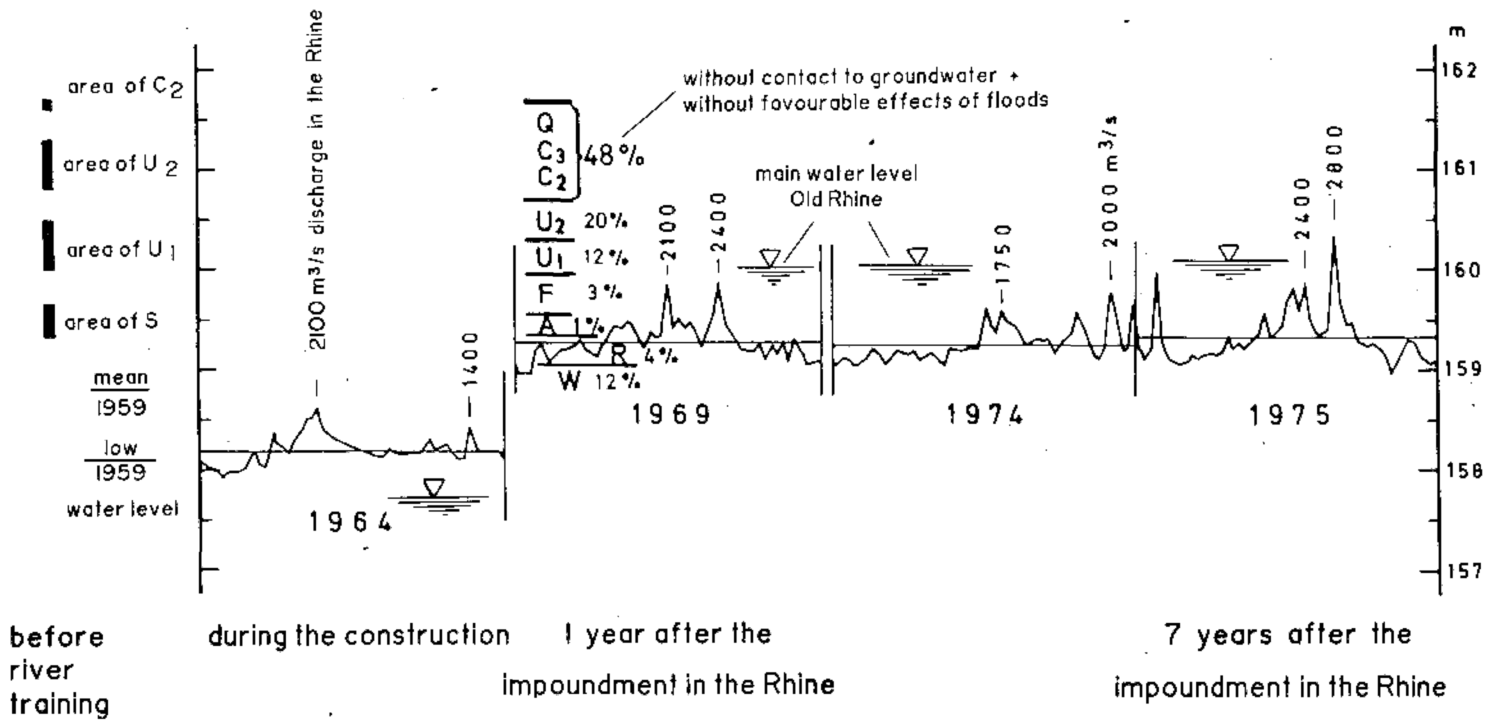
A-4 *Results of controlled floods for the vegetation in the connected river branch system of the old floodplain (barrage of Rhinau, section of partial diversion) (Hügin, 1980)*



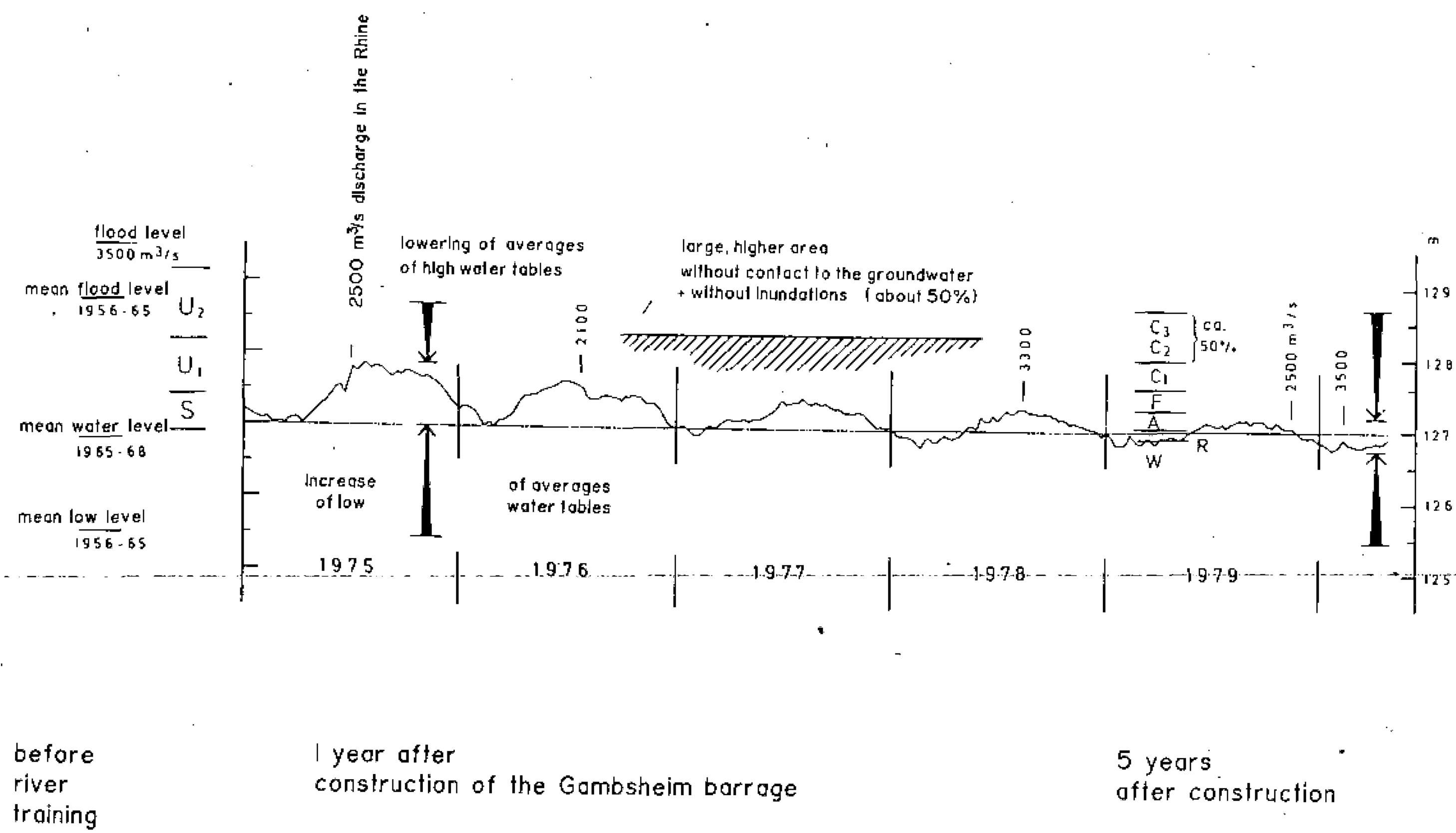
A-5 The situation of the "Taubergiessen" (barrage of Rhinau) (Hügin, 1980)



A-6 *Changes of the potential natural vegetation in the central part of the recent floodplain in the "Taubergiessen" (barrage of Rhinau, section of partial diversion) caused by changes of the water regime (Hügin, 1980)*



A-7 *Changes of the vegetation and groundwater tabels in the old floodplain at the barrage of Gambsheim (section of barrages) and the effect of self-sealing (Hügin, 1980)*



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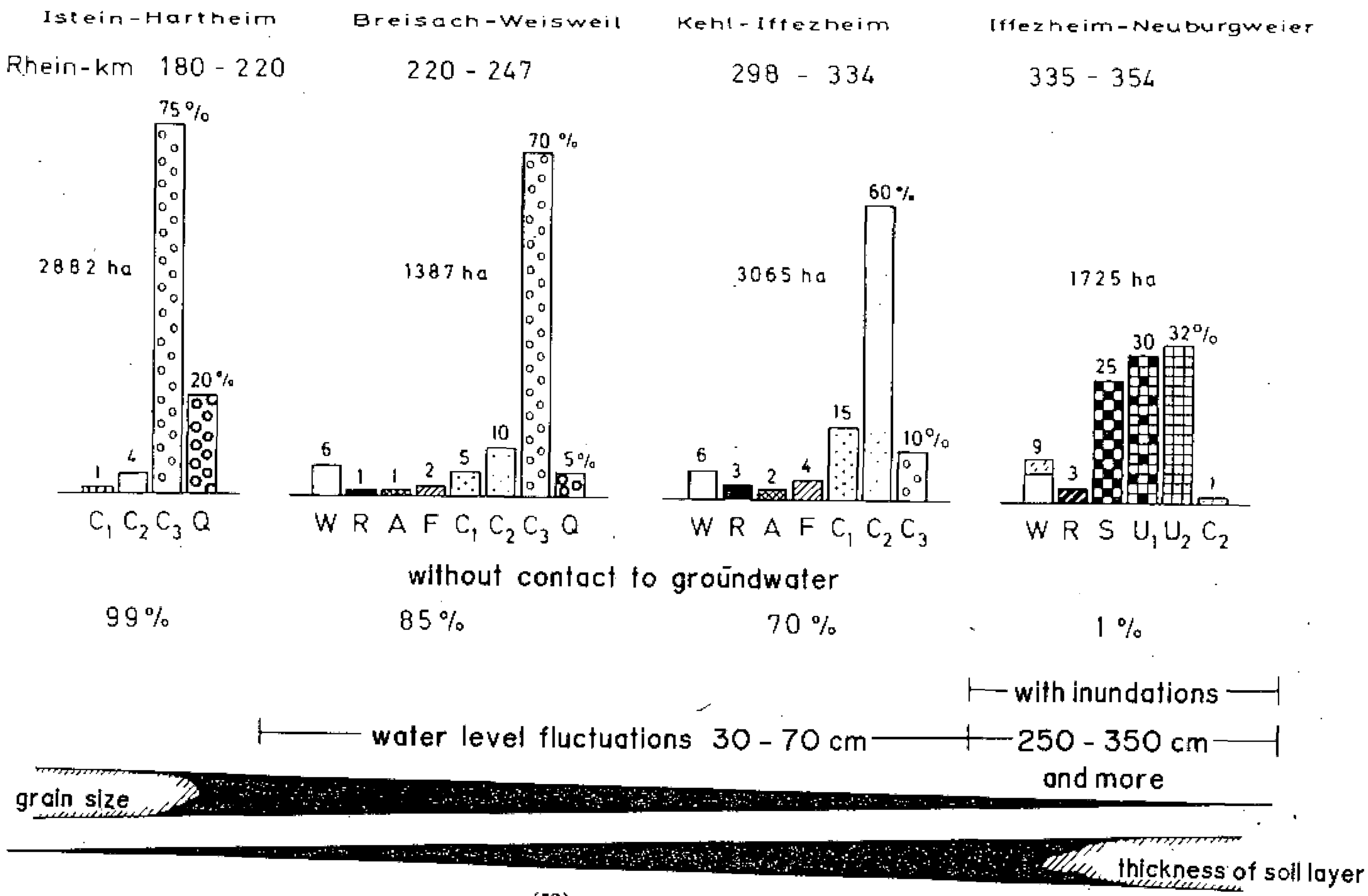
A-8 *Impacts of the three regulated sections and of the strech downstream of Iffezheim on the potential natural vegetation (Hügin, 1980)*



Annex 17

THE CHARACTERISATION OF AND THE THREAT TO TERRESTRIAL AND PARTIALLY AQUATIC HABITATS, THE IMPACT OF GNBS AND WITHIN THAT, OF VARIANT C

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Abstract

The plant communities of Szigetköz are discussed on the basis of all available data. The most important faunistic features of the aquatic and terrestrial habitats and a brief summary of the expected effects of GNBS and Variant are also given.

1. Introduction

The original flora and fauna have significantly changed in the upper reach of the Danube Valley since the beginning of this century. Although the impact area of the barrage system is rich in natural life, the vegetation and wildlife of the floodplain retained its original character in this part of Szigetköz and on the islands of the Danube. In particular, the branch system in Szigetköz and its flora and fauna are of great importance, because their richness is unique in Hungary. This area is directly threatened either by the GNBS or Variant C or any other scheme.

2. The Advance of Biological (Ecological) Research of Certain Reaches of the Upper Danube Valley

The impact area of GNBS, the Upper Danube Valley, can be divided into three reaches: Szigetköz, the reach of the Danube Valley from Szigetköz to the Danube Bend, and the Danube Bend, together with the northern part of Szentendre Island. The biological (ecological) research concerning this region, together with the information necessary for the characterisation of this habitat, varies greatly in quantity and quality. There are even differences in botanical and zoological knowledge. In a certain respect (biodiversity) Szigetköz is well known, even at the level of (plant) communities. We have a relatively large amount of data on other reaches of the impact area, but research has not advanced to the level of Szigetköz. Although there are significant amounts of data on certain wildlife groups and/or subregions, lack of concrete and focused research means that our zoological knowledge is insufficient for a profound characterisation of the habitats. Assembling fragmented data and casual observations are not enough for the characterisation of the habitats (Mészáros and Báldi, 1992). The Danube bend (Pilis Biosphere Reserve, Börzsöny Landscape Protection Area, i. e. the planned Danube-Ipoly National Park) is well explored in many respects, however, most of our knowledge does not pertain to the Danube Valley.

The noticeable differences between the approaches to habitat characterisation are a consequence of the differences methodology offered by botany and zoology. While in botany the characterisation of a habitat focuses on certain organisational levels (e.g. communities), zoology uses particular elements of the topographical space or follows the framework provided by botany (see a more detailed explanation below). To some extent, we attempted to link the two kinds of approaches when analysing the impact.

3. The Botanical Characterisation of the Habitats of the Impact Area

The plant communities of the area are fairly well described by earlier studies (Zólyomi, 1937; Kárpáti, 1957; Kárpáti, 1963) and by more recent cenological research (Simon, 1992; Simon et al., 1993; Kevey, 1993). Subsequently, communities are introduced in accordance with our home varieties, based on the Braun-Blanquet cenological system (Soó, 1964; Simon, 1992).

3.1 HERBACEOUS PLANT COMMUNITIES

1. Waterweeds (Potametea). These are communities of an ancient character growing in the ponds and slowly flowing waters of the floodplains. They preserve protected (e.g. *Salvinia* spp., *Hottonia* spp., *Nymphoides* spp., *Nymphaea alba*) and unique species (e.g. *Batrachium fluitans, Potamogeton compressus, Groenlandia densa*). There are 13, of which 3 are recommended for protection:

SPECIES	**DESCRIPTION** (place or frequency)
Lemno-Spirodeletum W. Koch 1954	common
Salvinio-Spirodeletum Slavnic 1956	sporadic, protected
Lemno-Utricularietum Soó 1928	sporadic in the oxbow lakes
Hydrochari-Stratiotetum (Langendonck 1935) Westhoff 1942	Mosonmagyaróvár: Parti-erdő
Batrachietum fluitantis Allorge 1922	in Hungary only in Szigetköz (Mosonmagyaróvár: Mosoni-Danube)
Hottonietum palustris Tüxen 1937	sporadic, protected
Elodeetum canadensis (Pign. 1953) Soó 1964	sporadic
Myriophyllo-Potamogetonetum Soó 1934	common
Potameto perfoliati-Batrachietum circinati (Sauer 1937) em. T. Simon	Mosonmagyaróvár
Potamogetonetum lucentis Hueck 1931	rarer
Potamogetonetum natantis Soó 1927	common
Nymphaeetum albo-luteae Novinszki 1928	common
subass.: *nupharetosum* Soó 1964	Magyaróvár Nydras-sziget, Keskeny Oxbow Lake, Cikolasziget
Nymphoidetum peltatae (Allorge 1922) Oberd. *et* Müller 1960	fairly common, protected

2. Marsh communities (Phragmitetea). In the area of the Danube Valley, with the exception of *Caricetum elatae* and *Carici-Menyanthetum*, these are common everywhere, harbouring protected (e.g. *Ranunculus lingua, Menyanthes trifoliata*), native (e.g. *Cirsium brachychephalum*) and rare species (e.g. *Carex pseudocyperus*) The number of communities is 11, of which 4 are to be protected, because they are of relict character and rarer (in the following, an exclamation point (!) indicates that the species is recommended for protection):

Scirpo-Phragmitetum W. Koch 1926(!), *Sparganietum erecti* Soó 1931, *Glycerietum maximae* Hueck 1931(!), *Rorippo-Oenanthetum* Lohm. 1950, *Sparganio-Glycerietum fluitantis* Soó 1931, *Caricetum elatae* (Kerner 1858) W. Koch 1926(!), *Carici-Menyanthetum* Soó 1955(!), *Carici-Phalaroidetum* Soó 1971, *Caricetum acutiformis-ripariae* Soó 1930, *Caricetum gracilis* (Graebn. f. *et* Hueck 1931) Tx. 1937, *Caricetum vulpinae* Novinszki 1927.

3. The communities of vegetation growing on silty sites (Isoeto-Nanojuncetea). There are communities of the silt of riparian zones consisting of characteristic small-sized species ("dwarf bulrush"). They typify natural conditions and are of a pioneer character:

Eleochari-Caricetum bohemicae Pietsch 1964=sporadic, *Eleochari aciculari-Schoenoplectetum supini* Soó *et* Ubrizsy 1948=sporadic, *Cypero-Juncetum bufonii* Soó *et* Csűrös 1944=quite common, *Dichostyli-Gnaphalietum uliginosi* (Horvatic 1931) Soó *et* Timár 1947=rare!

4. The communities of wet meadows (Molinio-Juncetea). The boggy meadows are rare, while the marshy meadows are common features of the Danube floodplain. They are sustained by traditional and careful meadow management.

(a) Boggy meadows: Their communities are rich in protected species (e.g. *Eriophorum angustifolium, E. latifolium, Sesleria uliginosa, Dactylorrhiza maculata, Dianthus superbus, Iris sibirica, Gentiana pneumonanthe*) and species of relict character (e.g. *Carex appropinquata, Gentianella austriaca, Succisella inflexa*). Three are known to be of relict character and thus are recommended for protection: *Seslerietum uliginosae* (Palmgren, 1915) Soó 1941=Moson-magyaróvár: Lóvári-erdő, Bezenye-Császárkaros, Feketeerdő: Házi-erdő, *Carici flavae-Eriophoretum* Soó 1944=rare and fragmented, *Succiso-Molinietum* Soó 1968=sporadic, mainly in Lower Szigetköz.

(b) Marshy meadows: Their communities preserve a number of protected species (e.g. *Achillea ptarmica, Epipactis palustris, Iris spuria, Orchis laxiflora ssp. palustris, Dactylorrhiza incarnata, Pedicularis palustris*. Six of their communities are known: *Deschampsietum caespitosae croato-pannonicum* Soó 1957=sporadic, more common in Lower Szigetköz, *Alopecuretum pratensis* Novinszki 1928 *hungaricum* Soó 1957=common *Agrostetum stoloniferae* Ujvárosi 1941 *hungaricum* Soó 1957=common, *Cirsio cani-Festucetum pratensis* M jovsky ex Ruzickov 1957=common, *Agrostio-Phalaridetum* Soó 1971=common, *Trisetetum flavescentis noricum* Soó 1964=sporadic, e.g. Dunasziget, Szőgye.

5. Hayfields (Arrhenatheretea). They are widespread in the Danube Valley, especially in Szigetköz, where their area, together with the wet meadows, cover some 10 % of the region. They are represented by one community, which includes a number of colourful flowers and, also protected plant species (e.g. *Anacamptis pyramidalis, Gentiana cruciata, Gymnadenia conopea, Ophioglossum vulgatum, Ophrys apifera, O. insectifera, O. sphegodes, O. coriophora, O. militaris, O. morio, O. purpurea, O. ustulata: Arrhenatheretum elatioris* (Br. -Bl. 1919) Scherer 1925 *et festucetosum rubrae* Tx. 1951=e.g. Dunasziget, Szőgye.

6. The vegetation of sandy sites (Festucetea vaginatae). Extensive communities can be found primarily on the sandy mounds of the Little Hungarian Plain (Kisalföld) adjacent to the Danube

Valley, but smaller patches also grow on the sandy upland sites of Szigetköz. They are embellished by a number of valuable and protected species of the Pannonian sand and steppe flora (e.g. *Onosma arenaria, Stipa borysthenica, S. joannis, Jurinea mollis, Iris variegata, Adonis vernalis, Daphne cneorum, Anemone sylvestris*) and in addition, valuable native species can also be found (e.g. *Carduus collinus, Dianthus pontederae, Erysimum odoratum*). Three are original at places: *Brometum tectorum* (Soó 1925) Bojko 1934=e.g. Győrszentiván, Püski, Kimlei-erdő, *Festucetum vaginatae arrabonicum* Borhidi 1956=Kisalföld, *Festuco vaginatae-Corynephoretum* Soó 1939=Kisalföld.

7. The communities of dry rocky and puszta grasslands (Festuco-Brometea). They are adjacent to the Danube Valley, mainly on the slopes of the Gerecse Hills and the Danube bend, but some communities can also be found in small patches in Szigetköz. These are sites of rare and protected plant species (*Adonis vernalis, Anemone sylvestris, Dianthus arenarius, Inula oculus-christi, Jurinea mollis*). In the first instance valuable, - that is recommended for protection - and of a relict character, and secondly somewhat degraded rocky and dry meadow communities are: *Poetum pannonicae* Zólyomi 1933=Danube bend, is a valuable relict in a native community that should be protected. *Potentillo-Festucetum pseudodalmaticae* Májovsky 1954=Danube bend, *Cleistogeni-Festucetum rupicolae* Zólyomi 1958=Gerecse Hills: Almásneszmély, Danube bend, *Salvio-Festucetum rupicolae* Zólyomi 1958=Gerecse Hills: Almásneszmély, *Astrogalo-Festucetum rupicolae* (Magyar 1933) Soó 1956=Kisalföld, Püski, Kimlei-erdő, *Potentillo-Festucetum pseudovinae* Soó 1936=Kisalföld, Szigetköz.

Subsequently, weed communities will be used to show that our list is far from complete: The more common communities observed by us during the exploration of the nearly natural plant communities are of hardly any value in themselves, but they do indicate the impact of human activities on the natural environment and indicate therefore a degree of degradation of the vegetation. The countrywide weed study carried out in the 1950s surveyed the nature of the weed flora in the various cultures. More recent similar surveys (Czimber, 1992) show that despite the large-scale chemical control of weeds, the rate at which the weeds have spread has not decreased but has rather increased. Only the sequence of damaging weed cover has changed, i. e. selection has taken place, during which those species tolerant to chemicals attained a greater role. In the meantime, however, the phytocenology of weed communities has hardly been studied.

8. Weed communities among green crops (Secalietea) Three common communities were observed on agricultural lands: *Amarantho-Chenopodietum* (Morariu 1943) Soó 1953=common mainly in hoed plant cultures, *Setario-Stachyetum* (Bojko 1934) Felföldy 1942=common on croplands, *Artistolochio-Convolvuletum* Ubrizsy 1967=common in vineyards and orchards.

9. Ruderal weed communities (Chenopodietea). *Rorippo austriacae-Hordeetum murini* Timár 1947=common on dykes and by the roadside, *Malvetum neglectae* Felföldy 1942=frequent, *Agropyro-Convolvuletum arvensis* Felföldy 1942=common

10. Roadside weed communities (Artemisietea). *Conietum maculati* J. Pop 1978=frequent, *Tanaceto-Artemisietum vulgaris* Br-Bl. 1949=frequent.

11. The communities of fresh edge vegetation (Galio-Urticetea). *Chaerophylletum bulbosi* Tx. 1937=common by the roadside and along the edges of forests, *Rudbeckio-Solidaginetum* (Tx. *et* Raabe 1950) em. Soó 1961=common in clearings in the active floodplain, *Astero-Rubetum caesii* I.

Kárpáti 1962=common in the more open parts of the deciduous softwood gallery forests, *Arctietum nemorosi* Tx. 1950=common in the clearcut areas of deciduous hardwood gallery forests.

12. Weed communities of marshes (Bidentetea). *Bidentetum tripartiti* W. Koch 1926=common in marshes, *Echinochloo-Polygonetum lapathifolii* Ujvárosi 1940=common on moist riparian sites and sandbanks.

13. "Trampled" weed vegetation (Plantaginetea). *Lolio-Plantaginetum majoris* (Linkola 1921) Berger 1930=common on pastures and around wells, *Sclerochloo-Polygonetum avicularis* (Gams 1927) Soó 1940=common, *Poetum annuae* Gams 1927=common along moist paths, *Lolio-Potentilletum anserinae* (Rpcs. 1927) Knapp 1946=on fresh soil close to communities, *Ranunculetum repentis* Knapp 1946 em. Oberd. 1957=common in marshes, *Rorippo sylvestri-Agrostetum stoloniferae* (Moor 1958) Oberd. *et* Müller 1961=common on marshy meadows.

THE FOREST PLANT COMMUNITIES

In the landscape of the Danube Valley the dominant role is still played by the forests, mainly by the deciduous softwood and hardwood gallery forests. On the lower parts of the floodplain, close to the riverside, the relict communities of willow, poplar and alder gallery forests are typical. The gallery forests of Szigetköz consist mainly of these communities (e.g. Dunasziget: Hajós-sziget, Öreg-sziget, the environs of the bridge at Medve) with primeval stands intertwined with *Humulus*, *Clematis* and *Vitis silvestris*. But from Gönyű downstream to Nagymaros, they are restricted to an almost homogeneous narrow strip of land with fragmented and degraded stands. A comparative phytocenological and ecological analysis of previous and present data from these willow communities showed that their species composition in the past 50 years has suffered degradation to a small degree, and also that the water regime sustaining them has become more extreme. Their development in Szigetköz has brought about valuable new cenosystematic results in several respects. Large areas are covered in Szigetköz and on the islands in the Danube by the planted forests of genetically improved poplars that are significant in terms of the landscape and also yield large profits. The size of the upland deciduous hardwood groves has significantly shrunk; there are only relict stands, mainly in Szigetköz along the Mosoni-Danube. There are smaller patches of oak stands with *Convallario-Quercetum, Festuco-Quercetum, Querco robori-Carpinetum, Calamagrosti-Salicetum cinereae, Dryopteridi-Alnetum.* With its remaining woods, marshes and meadows, Szigetköz, the Landscape Protection Area, is still the most valuable natural area of the Danube Valley in Hungary and even in Europe.

14. Marsh communities (Alnetea glutinosae). Their few stands of a relict character are known from Szigetköz. These are sites with rare and protected (e.g. *Dryopteris carthusiana, D. dilatata*) and relict species (e.g. *Thelypteris palustris*): *Calamagrosti-Salicetum cinereae* Soó *et* Zólyomi 1955(!)=e.g. Mosonmagyaróvár: Parti-erdő, Máriakálnok, Dunakiliti, Hédervár, Szőgye, *Dryopteridi-Alnetum* Klika 1940(!)=Parti-erdő, Hédervár, *Carici acutiformis-Alnetum* (Dostl 1933) Soó 1963(!)=Hédervár: Mosoni-Danube.

15. Willow stand communities (Salicetea purpureae). These are original and almost extinct pioneer communities. They preserve a number of valuable, protected species (e.g. *Arabis alpina, Cardamine amara, Leucojum aestivum, Ribes nigrum, Scilla vindobonensis, Senecio fluviatlis, Stellaria nemorum, Vitis sylvestris*), *Myricario-Epilobietum* Aich. 1933=it was sporadic on the shallow islands, its present existence is uncertain. *Hippophae-Salicetum* Br. -Bl. 1933=its presence can be expected on the sandbanks, but is not proved, *Rumici crispo-Salicetum purpureae* Kevey

1993 is mainly present on the gravelly, coarse sandy riverside and shallows, its two types at the subassociation level are: *chenopodietosum rubri, brometosum sterilis. Polygono hydropipero-Salicetum triandrae* (Timár 1950) Kevey 1993 is mainly present along the main branches and oxbow lakes, in three types: *scrophularietosum nodosi* Kevey 1993, *scirpetosum radiantis* Kevey 1993, *leucojetosum aestivi* Kevey 1993, (the latter two communities were named formerly in a contracted form: *Salicetum triandrae-purpureae* Soó 1927), *Leucojo aestivo-Salicetum albae arrabonicum* Kevey 1993 ("deciduous softwood gallery forest", formerly *Salicetum albae-fragilis* Soó 1971 p. p.), its types at the subassociation level are: *caricetosum vesicariae, humuletosum lupuli,* they are common everywhere in the floodplain. Their preservation is equally important from an ecological aspect as well as nature, landscape and water conservation. *Senecio fluviatilis-Populetum* Kevey 1993 (formerly *Salicetum albae-fragilis* Soó 1971. p. p.), its types are: *scrophularietosum nodosae, ficarietosum vernae,* they are common on the higher parts of the floodplain; its characteristic species are *Populus nigra, P. alba* and *Cornus sanguinea.*

16. The communities of fresh deciduous forests (Querco-Fagetea p. p.). Fraxino pannonicae-Ulmetum Soó 1960 (a mixed gallery forest of ash, elm and oak, or in other words, a deciduous hardwood gallery forest). Their once extensive stands were strongly depleted. In Szigetköz, the *Fraxinus excelsior* consociation is widespread, *F. angustifolia spp. pannonica* is very rare, although one of the descriptions of the species comes from Csallóköz. On the elevated parts of the floodplain, its relict stands thrive with protected species (e.g. *Lilium bulbiferum, Hemerocallis lilio-asphodelus, Dactylorrhiza fuchsii, Epipactis spp., Listera ovata, Scilla vindobonensis, Arum orientale, Primula elatior, Cephalanthera spp.*) and with montane species (e.g. *Allium ursinum, Euphorbia amygdaloides, Galium odoratum, Paris quadrifolia, Polygonatum multiflorum, Circaea lutetiana*) in a number of locations (e.g. Rajka, Dunakiliti, Feketeerdő, Magyaróvár and its surroundings, Máriakálnok, Magyarkimle, Hédervár and Ásványráró). Their more common types: *circaeaetosum lutetianae, galietosum odorati, convallarietosum, caricetosum acutiformis, aegopodietosum podagrariae* indicate slight differences in their supply of water. *Querco robori-Carpin*etum Soó et Pócs 1957 has a nice natural stand that may be considered as a relict in the Derék-erdő belonging to Halászi. A number of associated species are present under the hornbeams (e.g. *Actaea spicata, Galium odoratum, Campanula trachelium, Majanthemum bifolium, Paris quadr*ifolia). The montane element of Carex alba deserves special attention. Its only lowland site is in Derek erdo, where it has grown evenly in great quantities since the 1920s. Its special protection, preservation and introduction into a larger area would be more than desirable.

17. The communities of dry oak stands (Quercetea pubescenti-petraeae). *Festuco-Quercetum roboris arrabonicum* Soó 1957, i. e. xerothermic oak stand on sandy site. The fragments of its stands with typical steppe edge features grow in the Kimlei-erdő and close to Püski. It is most widespread on sandy highland sites between Győr and Komárom. The presence of its thermophilous species (e.g. *Brachypodium pinnatum, Silaum silaus, Heracleum flavescens, Inula salicina*), indicate a relict forest from a warm era. *Convallario-Quercetum roboris arrabonicum* Soó 1957, i. e. mesophilous forest growing on sandy sites, requiring an easy access to groundwater. The oak is associated with *Acer campestre, Fraxinus excelsior*, as well as *Corylus* spp., *Ligustrum vulgare* in the shrub layer. In the herb layer, *Brachypodium sylvaticum, Lithospermum purpureo-coeruleum, Convallaria* spp. are typical, defining at the same time the type of vegetation. Its stands can be found sporadically on slightly elevated patches of mixed ash, elm and oak gallery forest, (e.g. Rajka, Dunakiliti, Kimlei-erdő, Ásványáró, in the prettiest form in the Hédervári-erdő, and on the sandy highland sites of Kisalföld as well, e.g. acs: Herkályi-erdő).

In conclusion, it can be established that, in the region of the Upper Danube reach, there are exactly 80 plant communities. The majority, around 75%, grow in Szigetköz. Of these, 15 communities (or 19 %) are of outstanding value, with relict character, highly recommended for legal protection. Of the plant communities, 20 (or 25 %) show weed character, indicating advanced degradation. The plant communities of relict character to be protected and others indicating natural conditions represent nature values of great importance. More than 300 species are protected within the Danube Valley as well as in the entire country, for the reason that they are typical and dominant features of the surviving landscape of the ancient floodplain, a fossil delta. Their preservation is very important since the flora and fauna together with the original landscape are rapidly declining all over Europe.

4. The Habitat Types of Szigetköz from a Zoological Point of View

Animal life does not form stable structures in time and space the same way as vegetation does in a flora system, where vegetation types and well-recognisable communities exist. Anyone can easily imagine a forest, a meadow, a reedbed, and for the observer this is a system formed by the aggregate of the plants living there, with their texture and structure. The animals associated with given plant communities remain, however, almost completely hidden to the observer. In zoology there are no synonymous concepts for the units mentioned above, hence the equivalent zoological concept for forest-, meadow- and a reedbed-life would be the "fauna of the forest, the fauna of the meadow and the fauna of the reedbed".

Compared to community-forming plants, the mobility of the animals is several magnitudes greater defining their looser ties with the plant communities. We have to note the difference between the information contents of botanical and zoological data clearly. A botanical datum (presence) means that the plant species (specimen) in question is a member of a given community (zone); while zoological data proves only that an animal species has turned up at a given "point" and may be a member of a certain community. In addition, the various developmental forms of the animal species have different habitat requirements, so we may confidently state that the information content of small-scale zoological "surveys", compared to botanical surveys, reflect only a momentary situation. And since a zoological survey is a process that requires a much longer period of observation, the size of the sample needs to be increased to a level corresponding to the animal group.

Another problem is the disparity manifested in the division of the large taxonomic groups of the flora and the fauna. The point is not only that the fauna consists of a much greater number of taxonomic units than the flora, but also that the role played by these large units is a lot more diverse in comparison with the flora. The fauna has no such distinguished groups as, for example, the plants with shoots (or in a narrower category, the flowering plants) in the flora, which can clearly define the cenological framework of the individual communities.

For that very reason, our classifying system represents much larger area units, in this case major habitat types, having more or less diffuse boundaries, rather than the frequently clear-cut community types used in botany. Accordingly, the following units were distinguished:

A. Aquatic habitats

A/1. The main channel of the Danube (Old Danube)

A/2. Branch systems and ponds in the active floodplain

A/3. Oxbow lakes, canals and ponds in the protected floodplain

A/4. Mosoni-Danube

B. Terrestrial habitats

B/1. The floodplain of the Old Danube

B/1. 1. Riparian habitats under the direct influence of water

B/1. 2. Willow and poplar gallery forests in the active floodplain

B/1. 3. Deciduous hardwood gallery forests in the active floodplain

B/2. Deciduous hardwood gallery forests in the protected floodplain

B/3. Wetlands in the protected floodplain: reedbeds, marshy and boggy meadows; thickets of *Salix cinerea*

B/4. Steppe meadows and dry patches of woods

5. The Zoological Characterisation of Habitats

A/1. The Main Channel

The main channel of the Danube in Szigetköz is a river of submontane character. Its gradient (40 cm/km) and flow velocity (2. 5 m/s) are very high on a national scale. This also determines the characteristic species of the prevailing fish fauna (*Barbus barbus, Chondrostoma nasus, Zingel zingel* etc.). In addition to the characteristic species, prealpine elements can also be found in great numbers (*Cottus gobio, Hucho hucho, Salmo trutta m. fario* etc.).

The water is a periodic migrational route for the Ponto-Caspian fish species, therefore, a few rare elements also appear in the composition of the species (*Caspialosa kessleri pontica, Coregonus lavaretus, Coregonus albula* etc.). The other species of the community also possess a Ponto-Caspian range.

The high flow velocity accounts for the presence of several rare rheophilous species (*Pararutilus frisii meidingeri, Gobio kessleri, Zingel streber, Gymnocephalus schraetzer*).

In the light of these facts,, it is understandable that the number of identified fish species is very high in the approximately 60 km long stretch along rocky banks.

A/2. Branch Systems in the Active Floodplain

A fundamental limiting factor to the flora and fauna of the river branch systems is the water regime of the Danube, i. e. the periodic full flooding of the branch systems; consequently, the ecological conditions in the individual branches (and oxbow lakes) are quite variable. Between periods of flooding, these conditions may vary greatly from one place to another, creating a diverse and unique habitat typical to the area.

Each species of mollusc living in the active floodplain area is also present in the Hungarian reach of the Danube essentially in the same species composition; therefore, in the fauna of this locality they are considered to be of lesser value species, but the periodically high occurrence of individual organisms within the species, especially of mussels, clams etc. may have significant influence on the cleansing process of the water. They may serve as food for the fish, although this role is subordinate. Individual populations form temporary groupings, which frequently change their place, distribution and absolute number adjusting to flow conditions. This mollusc population is able to survive even if a major drop occurs in its numbers.

Considering their unique character, high habitat diversity and fish fauna, the branch systems in the active floodplain provide the most significant water habitat in the Szigetköz. In the currents of these waters communities of river, stream- and creek- character can equally be observed. The communities in the slowly flowing branches are frequently of a lacustrine nature. The communities of the ponds found in the interior of the islands are characteristically of a marshy nature. When the water level is high, these segregated communities are refreshed with the fauna of the main channel. The dynamic changes as well as the living connection to the main channel are the most important conservation factors here. These branch systems are regular spawning grounds not only for the local fish species, but also for the migratory species in the main channel arriving from great distances. Consequently, the number of species here is very high all year round.

In the amphibian populations in Szigetköz, the proportion of *Rana esculenta* individuals produced repeatedly through the special hybridisation (hybridogenesis) known in aquatic frogs, (*Rana lessonae, R. ridibunda, R. esculenta*) in mixed populations, is related to the impacts that influence the biotope. In habitats highly exposed to anthropogenic impacts, the proportion of *Rana esculenta* increases. Triploid forms also appear frequently.

The continuity of these populations depends, among others, on the existence of habitats suitable for reproduction. Because of the significant predation rate, the expected life span of amphibians, i. e. aquatic frogs, can be estimated as a maximum of three to four years. In addition, the time needed to reach maturity varies depending on the species. Therefore, each year may be important in the survival of the population. Amphibians select special habitats for breeding. I. e. apart from the physico-chemical condition of the water, the quantity of flora, depth of water, exposure, water supply, and the length of time during which water is present, the conditions for the nutrition of the larvae emerging from eggs, and the number of predators destroying the eggs are all determining factors. The modification of a large part of these parameters is related to the waterbalance of the area. On floodplains they are closely related to the quantity of water going down the main branch. Also, the amphibians in the area breed at different times during the year. An adequate environment for reproduction has to exist from early spring (late February) up to mid-August. That is, water bodies created from time to time and maintained for two to three months are essential for the reproduction of the individual species. The most important regulatory role can be attributed to the medium and high water levels. The shallows (40 to 80 cm deep) created by the periodical flooding of the branches that are cut off, the lower areas covered by fresh water, and the marshy vegetation developing in these areas provide a foundation for breeding sites. Their absence in the long run will lead to a significant decrease in the number of individual organisms within the populations.

Character-plant species of the habitats important for the amphibians are *Rorippa amphibia* and *Polygonum amphibium*. In the spring, the young, submerged shoots of *Rorippa amphibia* are suitable for depositing eggs. And after the withdrawal of the water, the plants with luxuriant foliage provide adequate protection and habitat, offer cover and form a special microclimate for the developing small frogs.

A/3. OXBOW LAKES, CANALS AND PONDS OUTSIDE THE DYKES

The molluscs fauna of the oxbow lakes outside the dykes is characterised primarily by pulmonate aquatic snails with a high species diversity. The oxbow lakes together with smaller canals periodically filled with water create a refuge chain of habitat and determine in a direct or indirect way the conditions for the existence of molluscs in the inner areas. This group of habitats is dominated, in general, by ubiquitous species, but it is only the rarer aquatic snails living in this place which, at least in certain cases, have a chance to form populations with high numbers. Due to technical difficulties, there is very little chance to identify rarer species living here.

For the dragonfly fauna, the most important habitats in the protected floodplain are the Holt-Danube at Gazfü and the Nováki-Canal. The Nováki-Canal is a meandering water body with relatively clean water, overgrown by aquatic plants, connecting the Old Danube with the Mosoni-Danube. Its aquatic habitats are highly diversified as it is also reflected in the case of the dragonfly fauna.

We note that in relation to the life cycle of the dragonflies, in addition to the features of the aquatic habitats the characteristics of the terrestrial habitats surrounding them are equally important. In the two areas the deciduous hardwood gallery forests adjacent to and near the water courses are also of crucial importance (as feeding grounds, as habitat for the food sources, as migration routes etc.).

The oxbow lakes in the protected floodplain were isolated from the active floodplain during previous water regulation schemes. The composition of the fish fauna indicates a typical marshy community. The special physico-chemical parameters of the water are suitable only for a few (mostly endangered) species. (*Umbra krameri*, an endemic species in the Carpathian Basin can be found here. It is listed in the Red Data Book.

Of the oxbow lakes in the protected floodplain, the fish fauna of the Holt-Danube at Lipót and the Zátonyi-Danube are of paramount importance. The oxbow lake at Lipót does not depend significantly on the motions of the flood waves of the Old Danube, therefore, its character and species composition are the most balanced among similar habitats. The fish community in the Zátonyi-Danube has a higher number of species and a much higher habitat diversity than the community in the Holt Danube. There are very slow flowing reaches and, at narrow points created along dirt roads crossing the river there are reaches with currents of a moderate strength, but without any influence on the general character of the oxbow lake. At high water levels, its aquatic fauna has occasional contact with the Mosoni-Danube and the canal system.

The canal system of the protected floodplain was developed towards the very end of the last century for the purpose of draining the excess water of the Danube during high water level periods. With subsequently built extensions, the canal network forms an almost 300-km long system today. To form the canals the isolated Danube channels were often used. Their banks for the most part are straight and regulated and their water system is regularly cleared. Therefore, interesting areas in terms of the fish fauna could develop only where there are artificial and natural obstacles in the flow and in areas overgrown by reedgrass. The reaches with currents and the ones with slow-flowing water provide a home for different communities. In the slow-water reaches, the composition of the community is similar to that of the oxbow lakes in the protected floodplain, while in the reaches with stronger currents it is similar to the gravelly reaches with stronger currents of the branch systems in the active floodplain. Its most valuable fish species is *Umbra krameri*.

The reproduction of a number of the amphibian groups (newts, brown frogs, toads, spadefoot, treefrog) takes place in large numbers in the shallow waters of the active floodplain and, to a smaller extent, in the protected floodplain. A considerable part of these animals later migrate from the sites of reproduction to relatively drier areas (both in the active floodplain and in the protected floodplain).

A/4. MOSONI-DANUBE

The Mosoni-Danube makes up the southern boundary of Szigetköz. Compared to the main channel, it flows slowly; and it has a close similarity to the branches. It is because the streams arriving from the Hungarian side (the Lajta, Rábca and Rába rivers with significant flow rates) flow into the Mosoni-Danube, that its water level and faunal composition depends also on these waters. Similar to the branch system, the Mosoni-Danube can also be described as a washed out type branch. It has reaches with both slow and rapid currents, and stagnant waters can also be seen.

Among the neuropterans developing in the water, the presence of three kinds of species representing significant natural values were successfully established (*Sialis morio, S. nigripes, Sisyra terminalis*; the only habitat of *Sialis nigripes* known in Hungary is the Danube reach at Mecsér).

The fish species migrate in the Mosoni-Danube following the changes in the water, but in this process, the role of the tributaries is more important than anything else. The canal system in Szigetköz too, has surface contact with the Mosoni-Danube alone. Therefore, the latter plays a crucial role in determining its fish fauna.

The species composition of the upper reach is influenced by the main channel of the Danube. As the river Lajta joins the Mosoni-Danube at Moson, the community is complemented at Mosonmagyaróvár Ráby fish species characteristic to creeks and streams (e.g. *Phoxinus phoxinus*). The rheophilous fish species of the fish fauna of the river Rába having adapted to narrow habitat conditions, with the fauna of the Mosoni-Danube around Győr. The species composition of the lower reach is again influenced by the Old Danube. Species typically living in the main channel, like *Acipenser ruthenus*, also appear in its community.

B/1. THE FLOODPLAIN OF THE OLD DANUBE

The floodplain, and primarily its forested form, contains the great majority of the biomass of the snail fauna of Szigetköz. Although the species are not as diverse here as in the fragmented gallery forests along the canals, the presence of snails is evidently a more important factor of the ecological balance here than it is elsewhere.

Judging by the number of broken shells, the yearly progeny of snails plays a role in the diet of the birds living here which is not to be underestimated. The snails also play a significant role in the break down of floral detritus plants. The special value of the fauna in the gallery forests is shown by the fact that the forests, for instance, at Esztergom and Budapest, sustaining large quantities of snails, are about to disappear in the downstream reach, for instance, at Esztergom and Budapest, due to the development of the riverbanks. The indicator species here are the common *Helicigona (Arianta) arbustorum* and *Cepaea hortensis* and the rarer *Aegopinella nitens* and *Trichia striolata*. The latter two could be considered to be endemic in Hungary.

Considering the number of species and their natural values, the avifauna of the active floodplain is outstanding: over one hundred species nest here and almost a hundred migratory bird species live in a relatively small area. The Szigetköz reach of the main channel is a wintering ground for the European waterfowl populations and two rarer duck and other species.

The diversity of habitats provide a home for an extremely rich and highly diverse avifauna. The species diversity of birds in the floodplain forests is also high and their intraspecific density is also higher than that of the birds in other forests in Hungary. In Hungarian terms, the strong *Parus montanus, Hippolais icterina* and *Prunella modularis* populations are almost unique. The gallery forests and the system of branches are favourable for *Ciconia nigra*, moreover, the combination of the landscape elements attract some raptor species like *Milvus migrans* and *Haliaetus albicilla*.

B/1.1. Riparian habitats under the direct influence of water

The riparian zone of the Danube is constantly flooded by fresh water. It is present along the whole Danube reach of Szigetköz changing its place and size from time to time. At low-water levels following floods, on the rough alluvium saturated with fresh water and exposed to the air, a number of rare, faunistically interesting beetle species appear. Gravelly bank sections are inhabited by *Perileptus areolatus* and *Bembidion fasciolatum*, while *Nebria livida, Bembidion modestum* and *Bleidus pallipes* are found on sandy and silty deposits. In general, the species listed are characteristic of the mountains descending to the plains only along larger rivers. *Perileptus areolatus* and *Bembidion fasciolatum* are species with a larger range; they are found in various parts of Hungary, but only a few of their localities are known in the Great Hungarian Plain. *Nebria livida, Bembidion fasciolatum* and *Bleidus Pallipes* are characteristic of Western and Northern European regions and of high mountains with a cool and wet climate. These species are known in Hungary only in Western Transdanubia and in Szigetköz.

B/1.2. Willow and poplar gallery forests in the active floodplain

Although the original willow and poplar stands survived only in small patches in the active floodplain, several elements of the original remain in some of the planted poplar stands. The forced "paper poplar stands" have to be distinguished from the surviving deciduous softwood and deciduous hardwood gallery forests which, to some extent, enjoy natural conditions and from the tiny alder, willow and small marsh patches.

As a result of regular flooding, the species diversity of the terricolous beetle fauna in the active floodplain is not too high. On the soil of marshes, meadows, willow thickets and groves, ground beetles (e.g. the protected *Carabus granulatus*) and rove beetles can be primarily found. A number of protected beetle species develop in old and rotting willows, e.g. *Megopis scabricornis* and *Osmoderma eremita.*

The butterfly fauna of the deciduous softwood gallery forests in natural or almost natural conditions is essentially different from that of the "paper poplar stands". The majority of the species living in the trees are overlapping types, but in their quantities they vary. The species diversity and density of butterflies living on herbaceous plants in natural poplar localities is greater than that of the species living in the degraded poplar stands; the natural communities are richer.

It was widely believed earlier that the soil mite fauna could hardly tolerate permanent flooding and the fauna of areas flooded with annual regularity was poor. However, our studies directed the attention to a phenomenon not yet observed elsewhere: where the floods completely wash the dry leaves away, only a few very common species can be found. On the other hand, species hitherto unknown in Hungary were discovered in the moss cover of decaying logs and stumps (*Suctobelbella messneri, S. charcharodon*).

B/1.3. Deciduous hardwood gallery forests in the active floodplain

The strongly homogenised herb layer also left its mark on the butterfly fauna of the deciduous hardwood gallery forests possessing a more diverse species composition than others in the active floodplain. The alder patches enclosed and the patches of marsh and other boggy areas are very interesting and still preserve something from what might have been Szigetköz in this millennium. The unusually high number of certain birch and alder elements and species characteristic to communities consisting of tall herbs with dry stalks is remarkable. This is all the more visible on flat land (e.g. *Plemyria bicolorata, Calospilos sylvata* etc.).

In these small habitat patches (and their environs), the general "background fauna" is enriched with local species. In addition to the alder elements living in the alder stands in Western Transdanubia, these are "montane" insects or those inhabiting boggy meadows and marshes.

The hygrophilous fauna in enclosed humid meadow patches is worth mentioning. It has a similar composition to the fauna of the *Salix cinerea* and the marsh patches in the protected floodplain. Another point of interest is worth mentioning in relation to the gallery forests of the floodplain, that is the number of common species living in the forest and/or defoliators are present only in very low numbers or may even be absent (i. e. they could not be found, indicating that these either have surprisingly low numbers or they are entirely lacking). The likely reason for this is to be sought in the behaviour of the pupation of the insects: each of these species pupates in the soil or on the ground surface and presumably they perish in floods or long-lasting inundation.

B/2. DECIDUOUS HARDWOOD GALLERY FORESTS OUTSIDE THE DYKES

The value of the *Mollusca* fauna of the deciduous hardwood gallery forests is independent of the year of planting the forest and the humidity of the environment. From a malacofaunistic aspect, the low number of alder patches, perhaps mixed with ash is the habitat that deserves the most attention.

The mixed deciduous woods may sustain a more diverse snail fauna in their moister parts at lower elevation having *Allium ursinum*, but they have no malacofaunal elements linked to plant communities. Paradoxically, a richer snail fauna can be found in the patches with elder and even with weeds, than in the more stable and more closed places exposed to slow succession, though having scattered undergrowth.

The neuropteran fauna of the mixed ash, oak and elm gallery forests in Szigetköz is very rich; 70 % of the characteristic species of the habitat type is present in forests of a nearly natural condition.

The deciduous hardwood gallery forests in the protected floodplain are the most valuable habitats from a coleopteran aspect; the species diversity is the highest here, and the majority of the protected species or those especially interesting from a faunistic aspect were found here as well. In addition to the thermophilous beetles of the plains, some characteristic species of the nearby hills (*Carabus cancellatus cancellatus, C. coriaceus coriaceus, C. scheidleri baderlei, C. ulrichii ulrichii, Cychrus caraboides, Abax parallelepipedus* etc.) can also be found in the deciduous hardwood gallery forests in Szigetköz.

From a lepidopteran aspect, the upland relict forests are the habitats having by far the highest species diversity and being the closest to the original communities, and at the same time, covering a more extensive area. Originally, these could have been deciduous hardwood forests including ash and oak, the species composition of which was altered by forest management to a greater or lesser extent. At the same time, forest management greatly promoted the spreading of weeds. In spite of this, this is hardly reflected in the faunal composition, except, to the extent that several species of the defoliators of non-local trees were also established.

The soil mite fauna of the deciduous hardwood gallery forests in Szigetköz has outstanding diversity even by Hungarian terms, with respect both to the number of species and the distribution of the individual major groups of faunal elements. The statement made above is valid primarily for the mixed ash, oak and elm gallery forests showing a close-to-natural condition in their larger stands that can be found primarily on upland sites along the Mosoni-Danube, where species diversity is unparalleled in the fauna of Hungary.

The avifauna of the fragments of deciduous hardwood gallery forests does not differ essentially from the fauna of the deciduous forests (oak stands) in Hungary. As a result of the fragmentation of the habitats, the edge effect becomes significant. In the secondary habitats created in place of the original forests, a number of general habitat species become established, as is usual in other parts of the country.

B/3. WETLANDS OUTSIDE THE DYKES: REEDBEDS, MARSHY AND BOGGY MEADOWS; THICKETS OF SALIX CINEREA

The molluscs of the reedbeds and marshes have a higher species diversity in those areas where waterlogged areas are strongly diverse and are segregated by marshes, small canals, dikes and hayfields. A valuable species of the habitat group is *Aplexa hypnorum*, and a characteristic species present in high numbers is *Lymnaea palustris*; the presence of both can be well established. Data on the butterfly fauna of the wet meadows and the connected patches of *Salix cinerea* and marshes are available primarily from more recent research. The presence of *Eulithis testata, Graphiphora* *augur* and *Diachrysia zosimi* are salient, which are shown prominently in the Red Book of the Flora and Fauna of Hungary.

There is a medium rich avifauna of reedbeds and meadows in the wet habitats of the protected floodplain, the compositions of which correspond to those experienced in similar habitats in the Carpathian Basin. The nesting *Numenius arquatus* and the occasional establishment of *Circus pygargus* are worth mentioning.

B/4. STEPPE MEADOWS AND DRY PATCHES OF WOODS

In the case of the neuropterans, patches of steppe on sandy soil provide the living conditions of two ant-lions (*Myrmeleon inconspicuus, Megistopus flavicornis*).

In the eastern end of Szigetköz (Bácsa, Győr-Ménfőcsanak, Vének), and in Kisalföld (Győr: Győrszentiván, Gonyü: Gonyüi-erdő), the remnants of the original vegetation growing on sandy sites can still be found, unfortunately in strongly degraded conditions. The peculiar transitional climatic nature of Kisalföld is characteristically reflected in the composition of the vegetation growing on sandy sites and the beetle fauna as well. There are a number of continental and Mediterranean elements among the species of the sandy puszta, but the insects of the European mesophilous forests are also present in the forests growing on sandy sites. Certain protected, rare species or those especially interesting from a faunistic aspect can be found only here in Kisalföld (*Cicindela soluta, Carabus hungaricus hungaricus, Codocera ferrugineum, Scarabaeus affinis, Gymnopleurus geofroyae, G. mopsus, Euonthophagus alces, Onthophagus furcatus, Omaloplia spireae* etc.). All these justify the conservation and a more thorough survey of the still surviving vegetation growing on sandy sites and the fauna inhabiting this area. The Gönyüi-erdő are especially interesting, where, although only in a small area, the original vegetation growing on sandy sites and the animal life have survived in their almost unchanged condition up to the present.

A number of signs indicate the survival of the zonal steppe and certain elements of the butterfly fauna linked to it in the interior of Szigetköz, on the wet meadows enclosed by agricultural lands and on the still existing but strongly degraded remnants of grasslands growing on old sandy sites. Although the species diversity of this group of the fauna falls well behind those of the areas of the Great Hungarian Plain (in Kiskunság, Békés and Csongrád Counties and the Northern Plain), it is not insignificant, particularly considering that the habitats are fragmented, small and highly degraded, and represent a very interesting species composition primarily in moths.

6. An Analysis of the Expected Changes

The original GNBS (Dunakiliti Reservoir, power canal, provision of supplementary water to the branch system, barrage at Nagymaros, managing the river for peak-flow).

The most fundamental impacts on the habitats are:

– changes in the groundwater level (primarily its decline), – a drastic reduction of the discharge in the main channel (-> 50 to 200 m3/s),

– providing supplementary water (questions of the quantitz and qualitz of the water, etc.), "trends" in the biological parameters of the water in the reservoir,

– the occasional absence of flooding in the floodplain (flood only in the case of a discharge over 4000 m3/s),

– flush flooding of the floodplain and the dry main channel with a high flow velocity,

– diurnal fluctuations of several metres in the water level primarily in the main channel due to river management of peak-flow.

Variant C (diversion at Čunovo, a smaller external reservoir, power canal, supplementary water provision for the branch system).

From a biological aspect, Szigetköz is the best known out of the various sections of the impact area; the vast majority of the research studying the impacts of the barrage system was carried out in this area. The most fundamental impacts influencing the habitats, at least in the area of Szigetköz, are practically the same in the case of operating Variant C and the complete GNB (except for the consequences of the river management for peak-flow). Therefore, it is considered reasonable to present the impacts of the two alternatives together.

The expected tendencies of the changes were summarised in our previous study ("The Nature Protection Aspects of the Gabčíkovo-Nagymaros Project, Internal Report, Hungarian Natural History Museum, Budapest, 1994). The changes in each habitat are followed up below.

A. AQUATIC HABITATS

The diversity of the former active floodplain and of part of the protected floodplain, including a great variety of aquatic habitat types will cease to exist or will shrink to critical dimensions. Consequently, the aquatic flora and fauna as well as a number of plant and animal species will become extinct due to their way of life. The size of the populations will be significantly reduced. A decline in biodiversity is imminent.

A/1. THE MAIN CHANNEL OF THE DANUBE

Both variants meant the extinction in Szigetköz of the riparian communities of vegetation growing on silty sites and yet surviving sporadically as the moss cover on the rocks along the edge of the riverbed and the willow thickets. Once exposed to the air through a drastic drop in the water level, they will be completely destroyed within a short space of time. The general decline in the water level will enhance the rapid proliferation of weed communities, being particularly striking in the dry main channel. The huge mass of weed, in which ragweed (*Ambrosia elatior*) plays a significant role, enhances pollen pollution. In the nation-wide pollen reports, the city of Győr is frequently mentioned nowadays as one of the most heavily polluted towns in Hungary with regard to pollen.

As a result of the diversion, the main channel was divided into three well separated reaches. On the basis of the changes in the water conditions and the fish fauna, we can speak about an upper (from Rajka to roughly the end of the branch system at Ásvány), a middle (from the end of the branch system at Ásvány to the inflow of the power canal) and a lower reach (from the inflow of the power canal to the inflow of the Mosoni-Danube).

As a result of the diversion, the connection between the main channel and the branch system in the active floodplain pretty much ceased to exist, the diversity of which was an important conservation factor for several species in the main channel. Thus, the diurnal and seasonal migrations between the two areas in these upper reaches of the main channel is no longer possible. This fact will cause a decline in the populations mainly in the long run. The narrow main channel in many places lost its connection with the former riparian zone, which was of outstanding importance from the aspect of fish biology (i. e. this area represented the exclusive habitat for several species in the main channel).

In the middle reach of the main channel, upstream of the return of the power canal of the power station, the water of the reach was backed up. The middle reach lost its submontane stream character as well.

Not only the total quantity of fish, but also the number of fish species decreased in this reach. An explanation lies in the fact that the main channel no longer functions as a habitat with special current conditions, and it is likely that the specimens of the rheophilous species are not present or exist only in very low numbers, in this area. From the fish faunistic perspective, the most significant change occurred in this section of the river. At present it cannot be decided how serious a "barrier" it is for the migratory species. It is important to note here that the temporary provision of supplementary water to the branch systems established on the Hungarian side is connected to the main channel just upstream of this area, thus the migration of the species in the main channel linked to the reproduction period is (possibly) limited too and may become problematic.

No significant impact has been experienced yet in studies of the main channel reach downstream of the return of the power canal.

A/2. BRANCH SYSTEMS AND PONDS IN THE ACTIVE FLOODPLAIN

Major community types: communities of waterweeds, marsh vegetation, vegetation growing on silty sites and willow thickets.

Waterweed communities grow in the aquatic sites of the floodplain, mainly in the oxbow lakes, ponds and canals in Szigetköz and as such, they reached the verge of extinction in the upper and middle parts of Szigetköz. In terms of their survival, a great deal depends on the efficiency of the provision of supplementary water.

The marsh communities are somewhat more tolerant than the waterweed communities. They diminished in numbers in the Danube Valley; their more extensive populations that are able to ensure survival and regeneration live only in the active floodplains of Szigetköz. The decline of the water table seriously threatens these in the Upper and Middle Szigetköz.

The communities of vegetation growing on silty sites, special "dashes of colour" in the vegetation, will gradually become loose together with the water bodies in a near-to-natural condition, and they will probably become locally extinct for good.

The termination of the contact of the branch systems with the main channel has entailed and will entail very serious consequences with respect to the fish fauna of the Danube in its reaches in Szigetköz and downstream.

The impact of the diversion of the Danube on the fish fauna will be felt partly immediately and partly over the long term. A number of detailed studies have been produced that show that an immediate impact would be the death of fish.

As a result of the diversion, the floodplains in the Upper and Lower Szigetköz became characteristically separated from each other. In the branch systems in Upper Szigetköz, the water level was critically low in the spring and early summer period up until the beginning of the provision of supplementary water. The formerly large and uninterrupted reaches were segregated into several tiny water bodies. The number of individuals among the rheophilous species decreased to a greater extent than those favouring stagnant waters. As a result of the temporary provision of supplementary water, several migratory rheophilous species appeared again in these areas of the active floodplain, however the numbers within non-migratory rheophilous species declined compared to the "initial" condition. In short, the order of, and the balance among, communities was upset by the drastic changes in the habitats of the active floodplain.

The Bagamér branch system is the least endangered area in the active floodplain; the changes in the water conditions are the least apparent here. The migratory rheophilous species appear periodically in the lower reach of this water body as a result of the proximity of the main channel and the proportion of non-migratory rheophilous species is similar to the "initial" condition.

A-3. OXBOW LAKES, CANALS AND PONDS OUTSIDE THE DYKES

Community types: waterweed and marsh communities.

In all likelihood, the decline and gradual disappearance of their populations will be more rapid than in the floodplain, because the effect of the provision of supplementary water may prove effective to a lesser extent in these habitats.

As a direct result of the diversion, the water practically disappeared in the oxbow lakes in the protected floodplain, therefore, their fish fauna was mostly killed. The chance for (natural) repopulation is very low.

As a result of the provision of supplementary water to the Zátonyi Danube, this marshy oxbow lake with stagnant water became a "canal" having a flow velocity of 40 to 80 cm/s at certain places. As a result of the provision of supplementary water from the Mosoni-Danube, the fish fauna of the latter was introduced into the Zátony Danube. So the number of fish species significantly increased, but only one loach species remained dominant from out of the elements of the "initial" fish fauna. This apparently positive effect introduced competitor species with a wide range of habitat tolerance, beside which the original fauna loses importance. The numbers of individuals within species with a wide range of tolerance became high and their excessive proliferation may lead to the decline of the former en masse. Similar problems occurred also in the recently established reservoirs of Kisbalaton.

Of the oxbow lakes in the protected floodplain, the Holt-Danube at Lipót was outstanding in terms of faunistic value. It dried out completely as a result of the diversion and its fish fauna was wiped out. Unfortunately, the provision of supplementary water from the main channel could not help the situation of the "initial" fish fauna either. During repeated studies, none of the species could be found from the original fish fauna.

As a result of the diversion, the water level in the canals fell significantly, their waterflow slowed down or stopped. Consequently, the situation of the rheophilous species became critical. The impact of the intervention became apparent with some delay due to the exclusive contact with the groundwater.

A/4. Mosoni-Danube

Community types: waterweed and marsh communities and willow thickets.

These communities have a chance to remain a functional part of the water regime of the Mosoni-Danube.

The fish fauna of the Mosoni-Danube downstream of Lajta (roughly east of Mosonmagyaróvár) was affected by a buffered impact and the tributaries here may accomplish repopulation. The situation of the upper reaches is still critical, owing to their exclusive dependence on the main channel.

B. Terrestrial Habitats

B/1. The floodplain of the Old Danube

B/1.1. Riparian habitats under the direct influence of water

Community types: the communities of wet meadows, hayfields and weed communities.

The decline of the water table will bring about the extinction of the boggy meadow communities. The more tolerant marshy meadows may turn into drier meadows and grasslands with a considerable decline in their yield and the quality of their hay. The hayfields rich in species (and producing valuable hay) will turn into dry meadows.

B/1.2. Willow and poplar gallery forests in the active floodplain

Community types: willow stands.

The affected stands will gradually die (within a few years) on the sites affected by the decline of the water table, primarily in the Upper and Middle Szigetköz. Since the deciduous softwood gallery forests that grow right up to the riverbanks are integral parts of the landscape of Szigetköz, as they are everywhere along the river, their absence will seriously damage the landscape and its aesthetics. Theoretically, they could redevelop if the new water level is stabilised, although in a poorer form and over a longer period of time (at least 15 to 20 years), but this process may be significantly delayed by the erosional impact of the rapid floods.

B/1.3. Deciduous hardwood gallery forests in the active floodplain

Community types: communities of fresh deciduous forests.

Striking changes are apparent even today in the old stands along the Old Danube (shedding of leaves in the summer, drying out); these stands will die out soon. Only dry wood steppe consisting of oaks and, in the best scenario, *Convallario-Quercetum* could replace them over twenty to thirty years at the earliest. The main determining factors are the groundwater conditions and the frequency and volume of floods.

B/2. DECIDUOUS HARDWOOD GALLERY FORESTS IN THE PROTECTED FLOODPLAIN

Community types: communities of fresh deciduous forests.

It is very likely that these communities may survive in an unchanged form along the Mosoni-Danube if an adequate amount of water is provided. In the upland forests (e.g. the Der,k-erdő at Halászi), however, the impact of the decline in the water level can be felt to a greater extent, mainly in the species composition and cover proportions of the undergrowth.

B/3.. WETLANDS IN THE PROTECTED FLOODPLAIN

Community types: reedbeds, marshy meadows and boggy meadows; thickets of *Salix cinerea.*

The reedbeds in the protected floodplain are sentenced to die in the upper and middle parts of Szigetköz due to the decline of the water table. Similar changes are expected in the case of the boggy meadows. The more tolerant marshy meadows and hayfields will turn into drier meadows and grasslands. The *Salix cinerea* stands are already in the process of becoming extinct. Saving and maintaining them can be ensured only by restoring their regular flooding in the summer.

B/4. STEPPE MEADOWS AND DRY PATCHES OF WOODS

Community types: grasslands growing on sandy sites, puszta grasslands and dry oak stands.

The dry grassland types will spread because of the decline of the water table in Szigetköz, however, the appearance of drought-tolerant weeds will lead to the decline of the natural communities. The rocky and puszta grasslands of the slopes adjacent to the Danube Valley will probably be left unaffected by the expected changes in the groundwater level.

In the long run, the decline of the water table in Szigetköz will cause the expansion of the drier forest types together with a fundamental change in the original landscape of this floodplain.

References

Czimber, Gy. 1992. A Szigetköz szegetális gyomvegetációja (Weed vegetation of the agricultural fields in the Szigetköz). HDSc. Thesis, Mosonmagyaróvár.

Kárpáti, I. 1957. A magyarországi Duna-ártér erdői (Gallery forests of the Hungarian Danube region). Ph. D. Thesis, Budapest.

Kárpáti, V. 1963. Die zönologischen und ökologischen Verhaltnisse der Wasservegetation des Donau-Überschwemmungsraumes in Ungarn. Acta Bot. Hung. 9: 323-385.

Kevey, B. 1993. A Szigetköz ligeterdeinek összehasonlító cönológiai vizsgálata (Comparative cenological study on the forests of Szigetköz). Ph. D. Thesis, Pécs.

Mészáros, F. and Báldi, A. (eds.) 1992. The botanical and zoological assessment of the planned Fertő-tó - Hanság - Szigetköz National Park and its recommended zonation. Unpublished Report, Hungarian Natural History Museum. (in Hungarian)

Simon, T. 1992. A Szigetköz növénytársuleásai és azok természetessége (Plant communities and their naturalness in the Szigetköz). Term. véd. Közl. 2: 43-55.

Simon, T., Szabó, M., Draskovits, R., Hahn, I., Gergely, A. 1993. Ecological and phytosociological changes in the willow woods of Szigetköz, NW Hungary, in the past 70 years. Abstr. Bot. 17: 179-186.

Soó, R. 1964. A magyar flóra és vegetáció rendszertani-növényföldrajzi kézikönyve I. (Taxonomical and phytogeographical handbook of the Hungarian flora and vegetation I.). Akadémiai Kiadó, Budapest.

Zólyomi, B. 1937. A Szigetköz növénytani kutatásának eredményei (Results of the botanical research in Szigetköz). Bot. Közl. 34: 169-192.

Annex 18

THE DESCRIPTION OF THE ECOLOGICAL VALUES OF THE SZIGETKÖZ INLAND DELTA

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Contents

Abstract

The Szigetköz region lies on part of the Danubian alluvial cone. It consists of an intricate network of backwaters, ox-bow lakes, meander remains and side arms. A large part of the Szigetköz is located in the floodplain which is almost 75 km long and a few km wide. The Szigetköz is unique because it is of "delta" character, and hence the size of the riparian habitats is very large. The specific nature of the region leads to the development of species compositions that differ from the usual fauna of European river valleys. The most important characteristics of the Szigetköz fauna are: the diversity of species and the particular combination of species which accompany the many diverse habitats. Habitats found in the Szigetköz include: marshes, canals, hard and soft woods, moors, forest steppe. So far 80 plant communities have been identified in the region. In addition to the rich flora (1000 vascular species of which 78 are protected or highly protected), 206 bird species, 65 fish species and about 3000 invertebrate species have been found. There are 17 species which are in great danger according to the IUCN Red List. Some 64% of the Szigetköz vegetation indicates quasi-natural status, hence it can be shown on a regional and possibly global scale that the region is an area of outstanding importance where the fauna and the flora are concerned. Species investigated include: molluscs, crustaceans, dragonflies, caddisflies, butterflies, fish, amphibia and birds.

Introduction

Two basic factors determining the character and structure of a landscape are its geological and geomorphological attributes. As is well known, deltas are of changing geological structure and morphology. As a consequence of this, there are many habitats of different water supply conditions, otherwise known as wetlands, where there is a huge variety of flora and fauna, in addition to the diverse species and communities found in all of the region.

The effect of the constricting GNBS is not considered in this description of the Szigetköz. Effectively, the situation described is that prior to the building work.

The Role of Riparian Habitats and Their Significance in the Survival of the Flora and Fauna

A BRIEF SURVEY OF THE INTERNATIONAL LITERATURE

The most threatened habitats on Earth are the "wetlands" (e.g. Turner, 1991; Williams, 1993). This has been recognised for example in U.S. legislation, in which the Clean Water Act ensures the protection of waters and wetlands (Steiner at al., 1994). The former President of the United States, George Bush, declared: "*My position on wetlands is straightforward: All existing wetlands no matter how small, should be preserved*". Within this category, the areas alongside watercourses are the most exposed territories, because the most densely populated and most fertile parts of the Earth are located there (Décamps, 1993). And, according to Naiman et al. (1993), riparian habitats are the most versatile and most complex habitats on lands As a result, the flora and fauna are extremely rich. For example, as much as 70% of land vertebrates use riparian habitat (Naiman et al., 1993).

By definition, riparian areas are quasi-strip habitats along water courses (Décamps, 1993), which are absolutely unique because of their location. They are known as ecotones, that is transition zones between water and land habitats, and they form an ecological corridor between two regions (Décamps, 1993; Gregory et al., 1991; Malanson, 1993).

The unique richness of riparian habitats depends upon annual floods (Gregory et al., 1991; Malanson, 1993; Naiman et al., 1993). Annual floods occurring each year create a dynamic landscape, continually changing. Consequently, the loss of floods as a result of barrage construction would destroy the most outstanding features of the riparian area which demand the highest protection available (Décamps, 1993). This is proved, for example, by the detailed ecological research carried out by Real et al. (1993), which demonstrated that a species composition, rich in amphibia, was established and maintained by regular floods.

Downstream from reservoirs the flow conditions change, heavily influencing the lower areas. On the Rhone, for example, the vegetation withered downstream of the reservoirs while plant regeneration stopped (Bravard, 1987, reference in Malanson, 1993). In sections downstream of the reservoirs there are fewer plant species than upstream of the reservoir (Nilsson et al., 1991; reference in Malanson, 1993).

Owing to global warming, the current problems (primarily the shortage of water) will eventually become of paramount importance. The volume of both surface and subsurface waters will decrease in Hungary (Somlyódy, 1989). Similar views are expressed by the World Watch Institute in Washington, which states that Hungary already suffers from a water shortage which will gradually worsen (Postal, 1993).

In the last two hundred years, more than 80% of the riparian areas have disappeared in North America and Europe. During these processes, neither the ecological nor human impacts were considered nor were the reasons for their disappearance (Naiman et al., 1993).

According to Moyle & Leidy (1992), fish are appropriate and reliable indicators of water habitats. Of the 193 fish species living in Europe, at least 80 are threatened (i.e. close to extinction), and without radical environmental intervention they will soon die out. For example, as much as 95% of the Missouri was reconstructed, losing 190,000 hectares of natural habitats in the process. In the quasi-canal reaches, fewer fish live, thus limiting the variety of species; the previously characteristic large fish are now entirely missing. Furthermore, the shallow water fish have almost totally disappeared.

Reservoirs do not promote the survival of river fish, since they establish lake conditions (Moyle & Leidy, 1992). Frequently the introduced fish species spread widely. The barrage not only prevents the migration of fish, but also the transfer of nutrients to the lower reaches, thereby reducing productivity there. The drop in the number of fish in the Caspi started after the construction of the large Volga power plants. Rehabilitation may only be successful at points where the environment is less disturbed (Moyle & Leidy, 1992).

The Geographical Characterisation of the Szigetköz

THE FORMATION OF THE DANUBE'S KISALFÖLD ALLUVIAL CONE

The River Danube appeared in the Kisalföld at the end of the Pliocene era. From that time until the mid-Pleistocene (up to the mindel-riss interglacial) a huge alluvial cone was deposited. Since the mid-Pleistocene, the middle and northern part of the alluvial cone have gradually settled further, while in the south certain parts stayed relatively loose and on the edge terraces developed. The material of the older alluvial cone remained on the Parndorf plateau (Austria) and on the highest ranges of the Győr-Tata terrace.

A further development occurred on the settled part of the alluvial cone up until the quaternary period. The youngest part is the surface of the Szigetköz, entirely covered by Holocene formations.

THE GEOGRAPHICAL LOCATION OF THE SZIGETKÖZ

The Szigetköz is a territory situated between the Old Danube and the Mosoni-Danube, along the West-East axis of the Kisalföld alluvial cone. Its length is 52 km, while its width varies between 4 and 8 km; the size of the area is 375 km^2. The surface is a perfect plain, slightly sloping from north-west to Southeast, elevated a few metres.

The highest point is 127 m and the lowest point is 110 m above sea level. The difference in height Danube's from when it first enters the Szigetköz to when it leaves is 15 m, which represents an average fall of 20 to 40 cm per kilometre.

THE GEOMORPHOLOGY OF THE SZIGETKÖZ

The surface which demonstrates very small differences in altitude can be divided into low and high floodplains. The low floodplain runs along the Old Danube in a strip of land of varying width, while by the Mosoni-Danube it can be seen along its lower course, in a strip narrowing towards the west. In the Old Danube, a series of islands with lowland forests of various width are located in the main bed. Inside the Szigetköz, the "low floodplain" is characterised by irregular spots, primarily where ox-bow lakes and old river beds have silted up. These depressions are flooded by excess ground water when the Danube has a high water level. In the vicinity of the Old Danube, owing to the higher water table, excess ground water appears earlier than along the Mosoni-Danube.

In the remaining parts of the bed protruding into the high floodplain, an intricate network of backwater, ox-bow lakes, meander remains and dummy branches developed. All the developmental stages of blocked backwater, ox-bow lakes and meander remains can be observed:

- the open water type
- the marshy reeds type
- the silted up type covered with forest
- the heavily silted up types supporting arable land cultivation.

A part of the meander remains has water streams, elsewhere a water stream is only available at the time of flood. In many cases the depressions were connected by drainage canals to remove excess groundwater

In the high floodplain, the majority of the surface is made up of an intricate network of shallow ridges overlaid and in many cases intersecting as a result of meander movement. The size of shallow ridges is associated with the water volume in the river branch having established them.

North of Győr, the sand-drift on the high floodplain covers some 5-6 km^2 of land. Small dunes and wind-blown indentations can be observed on the surface of the sand layer having an average thickness of 5 to 10 m. Most of the deflation forms are now levelled as a result of human activity; the relief raised by the sand-drift is not inundated even by the highest floods.

The regulation of the reach, problematic for flood control and navigation, had already started in the middle of last century. As a result of the medium water level regulation at the time, the main bed, 300-360 m wide (the current Danube) was created. Already at that time, numerous branches were blocked from the main branch, thereby developing a floodplain of almost 75 km in length and a few km in width, in which a large part of the side arms system of the Szigetköz is located. This regulation resulted in a quasi-natural condition, such that most of the wet areas remained in a condition very similar to that of earlier times. However, the condition in the last few years was established by a further heavy regulation work carried out between 1966 and 1983. The number and crests of side-branch barriers were increased to enforce the Old Danube to convey about 90% of the total discharge at low and medium flows. In this way, numerous parts of the branch system witnessed accelerated siltation and filling up, bringing about a significant reduction in the duration and intensity of flow. However, the groundwater conditions, involved in and related to the water system, had not yet changed, disregarding insignificant local effects.

The Botanical Importance of the Inland Delta of the Szigetköz

The alluvial cone of the river Danube is principally a fossil inland delta, which has slightly changed, only in the past million years as a result of water and wind erosion and human activity. Basically it has retained its original characteristics.

The Szigetköz includes a system of river branches consisting of water ways of various capacities and flow rates, an intricate system of valleys and ridges developed by water and wind in sand deposits. All these areas encompass a great many habitats from the very dry through dry to medium wet, and from wet to aquatic conditions. For example, in the case of plant communities, this also led to the development of dry (xero-series), medium-wet (mezo-series), wet (hygro-series) and water (aqua-series) groups of Hungarian succession which explains why there are 80 plant communities known so far in the area, in addition to the rich flora e.g. in the Szigetköz there are exactly 1000 vascular species, and fauna. There are 78 protected and highly protected plant species.

The Faunal Importance of the Szigetköz Inland Delta

The riparian areas and the floodplains in Hungary are extremely rich in animal species. They represent only 1.6% of the country's territory, but, for example, 131 birds out of the 201 nesting bird species live in them (Dobrosi et al., 1993). In addition, the frequency rate of amphibia may exceed those measured in the tropical rain forests (Dobrosi et al., 1993).

The Szigetköz is unique owing to its "delta" character, e.g. *inter alia* the width and thus the size of the riparian habitat is very large. Its fauna is basically similar to that of river valleys in Central Europe. The geographical location of the area (close to the peripheral areas of the Alps), the unique geomorphological and hydrological features and the sub-Atlantic climate lead to the development of species combinations that differ from the usual fauna of European river valleys. The most important characteristics of the Szigetköz fauna are the diversity of species and the particular combinations of species which accompany the many diverse habitats resulting from the "delta" character. Without aiming to be complete, the following main habitats may be found in the Szigetköz: sub-montane river, connected and isolated branches, canals, moors, marshes, soft woods, hard woods, oak with hornbeam, oak woods with valley lily, willow-bushes, moors, wet fields, remaining areas of forest steppe (Mészáros and Báldi, 1992).

The larger riparian area increases the richness of species in two ways. The many habitats in the area increase the number of species with associated (primarily invertebrate) animal species. On the other hand, the larger area in itself results in a greater number of species as predicted by ecological and biogeographical theories.

Presently, 1,000 vascular plant (including 78 protected or highly protected) species, 206 bird species, 65 fish species and nearly 3,000 invertebrate species are known to occur in the Szigetköz. Of the known animal species, 314 are protected or highly protected, and 66 species are featured in the Hungarian Red List. 159 species fall within the scope of Appendix II and 113 species within Appendix III in the Bern Agreement. According to the IUCN Red List (1994), there are 17 species which are internationally recognised as highly endangered.

The richness and versatility of the fauna of the Szigetköz may be amply illustrated by some animal groups.

Molluscs

In the Szigetköz, we are aware of the presence of 116 mollusks species from 74 localities (this is 48% of the total Hungarian fauna). Interestingly in addition to the recent species, many fossil shells were also discovered mainly from the sediments. On the basis of very thorough investigations we can say that the population of the species in the area is high, and in many respects it exceeds the similar zoological values of nature protection areas. It is striking that many species were only found in a few localities. A large proportion of the species in the Szigetköz are found in small isolated populations. An explanation for this can be the clear division of habitats, leading to an outstanding reservoir role.

Crustaceans

In the Szigetköz, the occurrence of 96 microcrustacean species (64 Cladocera, 32 Copepoda) is proved. The total Hungarian fauna includes 150 species (90 Cladocera and 60 Copepoda), consequently, in the relatively small area of the Szigetköz, the crustacean fauna is very rich. This is a result of several factors. The river here runs over a flat area, thus various water habitats are available within a small area. The formation of the fauna in the main branch, sub-branches, backwater canals and various stagnant waters, is decisively influenced by the dynamism's of water flow and the effect of floods. On the basis of the almost 100 species observed in the Szigetköz in recent years, this section of the Danube is exceptionally rich in crustacean taxa.

Dragonflies

There are 45 dragonfly species known in the Szigetköz (42 species as adults and 32 as larvae). This is more than 50% of the species known so far in Hungary. The rich dragonfly fauna may be explained by the slow flow rate of the Danube and its branches, depositing sediments. Dragonfly larva respire the dissolved oxygen from the water, so water quality plays a decisive role in the settlement of the species. In the Szigetköz, three areas are extremely important for fauna protection. The Mosoni-Danube, the Gazfü Backwater in the Danube (Sérfenyűsziget-Cikolasziget), and the Nováki-Canal (Halászi, Püski).

CADDISFLIES

Investigations carried out so far proved the presence of 64 caddisfly species in the area of the Szigetköz. This is a very high number when we consider the flatness of the area, since for example in the Great Hungarian Plain only 92 species are known. The 64 species living here represent about 30% of the Hungarian fauna (202 species).

The high percentual value of the caddisfly fauna in the Szigetköz is a result of the great diversity, due to the relatively clean condition of the Danube and its branches, the flow conditions (indicated by the number of rheophilous species, the higher dissolved oxygen content), the bed material, and physio-chemical processes.

BUTTERFLIES

The occurrence of about 1,150 lepidopteran species could be proved, but the actual number of species must certainly be higher, partly because of the poorly investigated seasons, partly because of the incomplete knowledge of certain groups (which frequently require special methods of observation).

The division of species into major taxons corresponds to forest areas of the middle mountains, so that there are no significant differences between the number of noctuids and that of geometrids, in favour of the former group (as there are in the drier or semi-arid regions of the continental forest steppe).

Basically the fauna is similar to that of other Central European river valleys, with two rather significant exceptions. Firstly, the greater number of species originating from the local alder woods of an Atlantic character in flat areas (or low mountain ranges). Secondly, the increased number of species arising from the markedly mosaic occurrence of various types of humid habitats. This higher versatility resulting from the sub-Atlantic climate and the relative proximity of mountains, characterises well the Szigetköz and makes it unique.

Among the macroheterocerans the number of species deserving considerable faunistic valuation is relatively low although the number of species under protection and/or listed in the Red Data Book is not low. At the same time, there are numerous species in the area of ecological importance which are generally not characteristic of the gallery forests. These elements of the fauna are typical for closed, mixed middle mountain forests or alder woods and marshy forests under Atlantic influence, occurring on the lowlands and hillsides. These elements prevail in the Szigetköz at higher elevation and partly in the small forest mosaics on the floodplain not (yet) managed; often in small, isolated population fragments.

As remnants of the former, drier forest steppe vegetation, small associations of their typical species can also be found.

FISH

The sediments carried by large water bodies from time to time refresh habitats, and ensure the constant presence of various habitats. As a result of these effects, at several points greater depths than normal develop in the side-branch. Even the bottom stratum of these deep sections is covered by less sediment, so they are more suitable habitats for large fish, as well as being excellent hiding places in winter.

The fresh sediment promotes the formation of a rich riparian vegetation which in turn favourably influences the spawning of fish species in the flooding periods.

Within the constantly changing islands, lakes are formed, the silting up of which reduces the flushing effect. These inner lakes not only yield special habitats but also provide adequate places for the fry and feeding bases.

Again it is due to the flushing effect that the system of branches are not of ordinary backwaters. As a result, several fish species (e.g. *Barbus barbus*) which normally spawn in the main river, are also able to multiply in the branch systems.

The branches of the inland delta are regularly connected. A guarantee for this is again the effect of floods and sediment deposition. Because of this "live" relationship, sub-optimal conditions develop more rarely. (In the active floodplain of the Szigetköz, hardly any constantly isolated branches or lakes can be found). These effects also reduce eutrophication.

We know several fish species which regularly migrate from the main bed and even from great distances to spawn in the Szigetköz floodplain. Of these species, many would not find the necessary reproduction conditions in an ordinary silted up backwater. The special habitat found in the floodplain not only has a favourable influence in many cases on reproduction, but also on the development of the fry.

The constantly developing reef islands represent many natural obstacles in the riparian area. This favours the development of large predatory fish populations and also ensures an appropriate feeding base. It is also true in general that in general, divided habitats can support a larger number of creatures than open waters. The constant presence of these habitats is ensured by falling trees of the floodplain forests.

AMPHIBIA

The continuity of water frog populations depends *inter alia* on the existence of suitable breeding habitats. Owing to strong predation, the expected life-time of the amphibia (and thus also of water frogs) is up to three or four years. And, what's more, the time required for sexual maturity is different for each species. Therefore each year could be important for preserving the population.

The amphibia are quite particular in their selection of breeding habitats. Factors of decisive importance are:

– the physical-chemical properties of the water (e.g. the appropriate ion concentration for the external fertilisation of the eggs,

– the appropriate oxygen concentration for egg segmentation, pH, etc.),

– vegetation cover

– water depth,

– the exposure (warming),

– the water supply of the habitat,

– the duration of water cover,

– the feeding relations of larvae from the eggs and the number of predators damaging the eggs.

The modification of a large part of these parameters is a function of the water budget in the area. In the floodplain areas, a close correlation of the water supply is demonstrated with the volume of water drained in the main bed. In addition to these factors, the amphibia breed at different times in the area. Therefore, the appropriate reproduction environment must prevail from early spring (end of February) until the middle of August. That is, for the breeding of each species, for two or three months it is essential to have constant waters and an opportunity to return from time to time.

The most important control function is played by medium and large waters. After the temporary flooding of the floodplain, the breeding amphibia rely heavily on the remaining shallow (40 to 80 cm deep) blocked branches and deeper fresh water areas as well as the marsh vegetation developing there. If these factors are lacking, this leads in the long run to a significant reduction in the number of individuals within the population.

The characteristic plants of important habitats of the amphibia are *Rorippa amphibia* and *Polygonum amphibium*. In spring, the young underwater sprouts of *Rorippa amphibia* are a suitable location for the laying of eggs. After the retreat of the water, the rich foliage of the plants create a special microclimate, providing an appropriate protection and habitat for small frogs.

The proliferation of water frogs and the change in their populations deserve special attention. As a result of hybridisation, there is one L-E (*Rana lessonae - R. esculenta*) water frog population system in the Szigetköz. The remainder of the *Rana esculenta* form is ensured by the constant back-crossing with *Rana lessonae*. Therefore breeding processes are protracted and partial spawning may be observed, until late June. The development of larvae is also continuous and lasts until autumn. The species composition of the above-mentioned populations shows differences in each area. It can be stated that large communities of *Rana lessonae* are present in the environs of Źsványráró-Patkányos, while in the Cikolasziget region, *Rana esculenta* is dominant. A similar tendency to favour change cannot be observed in the floodplain areas (nonetheless, in the vicinity of canals and side-branches, the number of *Rana esculanta* specimens has increased).

BIRDS

Altogether 206 bird species have been observed in the Szigetköz, which is 57% of our national fauna. Of these, 166 species are protected, while 134 species are nesting. Due to the mosaic nature of the area, the number of species increases because of the habitat diversity, and density primarily due to the rich shrub stratum and the edge effect. The bird communities in the Szigetköz forests are rich similarly to those in the central mountain forests, while the density of the individuals may be

1.5-2 times higher. The joint dominance of many types of habitats enables the settlement of numerous highly protected rare bird species (black stork, white-tailed eagle, etc.). The nesting of willow tit in the Szigetköz forests indicates a montane fauna relationship. The strong forest dunnock and the icterine warbler population is also worth mentioning.

Summary

In summing up, as much as 64% of the Szigetköz vegetation indicate a quasi-natural status (Simon, 1992), harbouring some 30-80% of the Hungarian fauna, many under strict protection which obviously indicates that on a regional level and probably on a global level, the Szigetköz is of exceptional importance.

Literature

Báldi, A. and T. Kisbenedek. 1994. Comparative analysis of edge effect on bird and beetle communities. Acta Zoologica Hungarica 40: 1-14.

Décamps, H. 1993. River margins and environmental change. Ecological Applications 3: 441-445.

Dobrosi, D., Haraszthy L. & G. Szabó. 1993. Magyarországi árterek természetvédelmi problémái. Nature protection problems of Hungarian floodplains. WWF, Budapest.

Gregory, K. K. and R.J. Davis. 1993. The perception of riverscape aesthetics: an example from two Hampshire Rivers. Journal of Environmental Management 39: 171-185.

Gregory, S. V., F.J. Swanson, W.A. McKee, and K.W. Cummings. 1991. An ecosystem perspective of riparian zones. BioScience 41: 540-551.

Groombrodge, B., Ed. 1994 IUCN Red List of Threatened Animals. IUCN, Gland, Switzerland Cambridge, U.K.

IUCN. 1990 United Nation list of national parks and protected areas. IUCN Gland, Switzerland and Cambridge, U.K.

László L. 1993. Megszűnt a szigetközi halbölcső. (Fish cradle in the Szigetköz no longer exists). Víztükör 33: 10-11.

Malanson, G. P. 1993. *Riparian landscapes.* Cambridge University Press, Cambridge.

Mészáros, F. and A. Báldi, Eds. 1992. The botanical and zoological assessment of the planned Fertő-tó – Hanság – Szigetköz National Park and its recommended zonation). Unpublished Report, Hungarian Natural History Museum (in Hungarian).

Moskát, C. 1985. Estimation of breeding bird densities in a beech wood in Hungary (Aves). Aquila 77: 251-261.

Moskát, C. Hraskó, G. and Z. Waliczky. 1988. Species composition and the structure of avian communities in the Pilis Mountains, North Hungary. In J. Török, Ed., *Ornithological research in the Pilis Biosphere Reserve.* Magyar Madártani Egyesület, Budapest.

Moyle, P. B. and R.A. Leidy. 1992. Loss of biodiversity in aquatic ecosystems: evidence from fish faunas. In Fiedler, P. L. and S.K. Jain, Eds., *Conservation Biology. The theory and practice of nature conservation, preservation and management.* Chapman and Hall, New York, USA

Naiman, R. J., H. Décamps & M. Pollock. 1992. The role of riparian corridors in maintaining regional biodiversity. Ecological Applications 3: 209-212.

Postal, S. 1993. Szembesülve a vízhiánnyal. (A challenge of water shortage) In: Brown L. R., Ed., A világ helyzete (The state of the world), 1992. A report by the Worldwatch Institute about the process leading to a maintainable society. Earth Day Foundation, Budapest

Real, R., J.M. Vargas, A. Antúnez. 1993. Environmental influences on local amphibian diversity: the role of floods on river basins. Biodiversity and Conservation 2: 376-399.

Simon, T. 1992. A szigetközi növénytársulások és azok természetessége. (Plant communities and their naturalness in the Szigetköz). Természetvédelmi Közlemények 2:43-57.

Somlyódi, L. 1989. Vizeink állapota. (The condition of Hungarian waters). Tudomány 5:67-69.

Steiner, F., S. Pieart, E. Cook, J. Rich, and V. Coltman. 1994. State wetlands and riparian area protection programs. Environmental Management 18: 183-201.

Turner, K. 1991. Economics and wetland management. Ambio 20:59-63.

Waliczky, Z. 1992. Különböző erdőtípusok madárközösségének vizsgálata a Szigetközben. - (Investigating the bird communities in various types of woods in the Szigetköz). – Ornis Hungarica 2: 25-31.

Williams, M. 1993. *Wetlands: a threatened landscape.* Blackwell Publishers. Oxford, U.K.

Annex 19

ECOLOGICAL AND PHYTOSOCIOLOGICAL CHANGES IN THE WILLOW WOODS OF SZIGETKÖZ, NW HUNGARY, IN THE PAST 60 YEARS

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Ecological and phytosociological changes in the willow woods of Szigetköz, NW Hungary, in the past 60 years

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Keywords: Bioindication, Diversity, Evenness, Nature conservation ranks, Water requirement spectrum, Willow forests.

Abstract: This paper is a phytosociological summary of two floodplain communities from the Szigetköz area, the willow shrubs (*Salicetum triandrae-purpureae*) and willow woods (*Salicetum albae-fragilis*). Temporal changes in these communities are evaluated through the comparison of recent data with those obtained 30 and 60 years ago. Changes in ecological characteristics are revealed by biological indication, using W(ater) indicator values and nature conservation ranks of constituting species. The W-spectrum of willow shrubs indicates a bit more extreme and drier habitat than earlier. The nature conservation ranks show a marked, but not too drastic degradation. The willow woods of the Szigetköz indicate better conditions than indicated by data collected by Kárpáti in the 1950's from willow woods outside the Szigetköz. The reason for this finding is that the Szigetköz region is fairly close to the natural conditions, especially in the Moson-Danube branch, because of the huge meanders. If one compares the present situation with that of in 1937 recorded by Zólyomi, the changes in species composition and enrichment in weeds are clearly indicated by both the W-spectrum and the nature conservation rank spectrum in the form of marked drying and degradation.

Introduction

Ecological conditions have been monitored by the qualitative and quantitative description of indicator organisms in the Szigetköz area in the framework of a monitoring system set up in the second half of the 1980's. In this paper we present the description of willow shrubs (*Salicetum triandrae-purpureae*) and willow woods (*Salicetum albae-fragilis*) on the basis of field data collected in 1991. Our data are compared with earlier descriptions (Zólyomi 1937, Kárpáti 1957). In this way not only the present state is recorded, but changes in the past three decades can also be evaluated. Special attention is paid to changes that can be interpreted in terms of water requirement of species and nature conservation values.

Materials

Most of the stands we studied are situated in the vicinity of Ásványráró - Dunasziget - Dunakiliti-Nagybajcs. Some of our samples were taken near Magyaróvár (Moson Danube branch) (Table 1). Of course, these stands are not the same as those described earlier by Zólyomi and Kárpáti, since most of the habitats have changed. They entered a seral stage of floodplain succession, they were filled up or destroyed completely. Simultaneously, on shelf islands, sand benches and low floodplain terraces, new stands have developed. The present species composition reflects the state of the 'base flora' in the area. Thus, the material for the comparisons consists of former and present day stands of willow communities.

For willow shrubs (*Salicetum triandrae-purpureae*) we use our own data ("present state") and those of collected by Kárpáti ("former state"). For willow woods (*Salicetum albae-fragilis*) we use our own data as present state and those of collected by Zólyomi as former state. In addition to these, an interesting comparison was possible using Kárpáti's data from the stands near Esztergom and Szentendre Island. This procedure proved the usefulness of our method and the results allow us

Table 1. The localities of stands with dominant or characteristic species in brackets. !: nice, seminatural, primeval-like stand

Willow shrubs - Salicetum triandrae-purpurea

1. Ásványráró, Senki-sziget (*Salix triandra*)
2. Dunasziget, Hajós-oldal (*Salix alba*)
3. Kisbodak, Kavics-sziget (*Salix purpurea*) river station 1831
4. Hédervár, Mosoni Duna (*Salix triandra*)
5. Hédervár, Mosoni Duna (*Salix triandra*)
6. Ásványráró, Öreg Árva (*Salix purpurea*) river station 1915
7. Ásványráró, Bagaméri bend (*Salix triandra*) river station 1813
8. Ásványráró, Bagaméri branch, Nagyduna torok (*Salix alba*) river station 1810
9. Ásványráró, Zátonysziget at Bagaméri dam (*Salix purpurea*)
10. Ásványráró, Zátonysziget at Bagaméri dam (*Salix purpurea*)
11. Nagybajcs, Medvei bridge, eastern side (*Salix alba*) river station 1804-1805
12. Vének, Öntésziget .(New). (*Salix alba*) river station 1799

Willow-poplar woods - Salicetum albae-fragilis

1. Hédervár, Mosoni Duna (*Calystegia, Galium odoratum*)
2. Ásványráró, Halrekesztő sziget (*Rorippa amphibia, Leucojum aestivum*)
3. Ásványráró, Szilfási channel, estuary (*Rubus caesius, Dactylis glomerata*)
4. Ásványráró, Senki-sziget (*Phalaris arundinacea*)
5. Ásványráró, Senki-sziget (*Phalaris arundinacea*)
6. Ásványráró, Kalap sziget (*Urtica dioica*) river station 1820
7. Kisbodak, Bodaki part (*Phalaris arundinacea, Aster tradescantii*) river station 1829.5
8. Dunasziget, Hajós side (*Urtica dioica, Leucojum aestivum, Ficaria*)
9. Lóvári erdő, Mosoni Duna (*Urtica dioica*)
10. Ásványráró, Ásványi branch, Árvai zárás (*Phalaris arundinacea*)
11. Ásványráró, Öreg Árva, (*Urtica dioica, Rubus caesius*) river station 1815
12. Ásványráró, Bagaméri bend (*Urtica dioica, Impatiens glandulifera*)
13. Vámosszabadi, Bagaméri branch, Nagy-Duna estuary (*Urtica dioica, Aster tradescantii*) river station 1810
14. Ásványráró, Bagaméri branch, Dani sziget (*Solidago gigantea*) !
15. Nagybajcs, Medvei bridge, eastern side (*Urtica dioica, Humulus*) river station 1804-1805 !
16. Nagybajcs, Medvei bridge, eastern side (*Urtica dioica, Humulus*) river station 1804-1805 !
17. Vének, Öntésziget .(New). (*Urtica dioica, Agrostis stolonifera*) river station 1798-1799 !
18. Kisbodak, Kavics sziget (*Dactylis glomerata*) river station 1831
19. Vámosszabadi, Kormoránoa sziget (*Phalaris arundinacea, Phragmites*) river station 1811-1812
20. Dunasziget, Hajós side (*Urtica dioica, Leucojum aestivum*)
21. Ásványráró, Bagaméri bend (*Urtica dioica, Cirsium arvense*) river station 1813-1814 !
22. Vámosszabadi, Kormoránoa sziget (*Cornus sanguinea, Urtica dioica, Rubus caesius, Impatiens glandulifera*) river station 1811-1812 !
23. Vámosszabadi, Kormoránoa sziget (*Cornus sanguinea, Urtica dioica, Phragmites*) river station 1811-1812

to emphasize the phytosociological value of willow woods in the Szigetköz.

Methods

The phytosociological description followed the standard Braun-Blanquet - Soó method. In each stratum all vascular plants were listed and their dominance was characterized by A-D values. Synthetic tables were interpreted using the constant and dominant species. We also analyzed the information of the tables in terms of W indicator (Zólyomi and Précsényi 1964) and nature conservation categories (Simon 1984, 1988). For these characteristics diversity and evenness were calculated (Slack 1977) using the Shannon formula with natural logarithm.

Results

Willow shrubs

Willow shrubs are characteristically open, loose pioneer communities, quite susceptible to the invasion of aggressive, fast spreading ruderals. The stands are regularly flooded each year, in many cases for several months. In former stands (before the 1950's) the constant and dominant species of the shrub layer were *Salix purpurea, S. triandra* and *S. alba*. In the herb layer common species (constancy from V to III) were *Ranunculus repens, Rorippa sylvestris, Myosotis palustris, Poa trivialis, Phalaris arundinacea* (facies-forming species are underlined). The dominants were *Rubus caesius, Myosotis palustris, Rorippa austriaca, Polygonum lapathifolium, Poa trivialis*. The stands dominated by *Salix triandra* were quite similar, but they were treated as a separate community by Kárpáti. *Urtica dioica* and *Solidago giganeta* occurred exclusively in this community. The constant and dominant elements of recent stands are *Salix triandra, S purpurea, S. alba. Populus nigra* has similar constancy, but low dominance. *Agrostis stolonifera, Artemisia vulgaris, Aster tradescantii, Dactylis glomerata, Phragmites, Polygonum mite, Ranunculus repens, Rorippa sylvestris, Rumex sanguineum*, and *Solidago gigantea* are common in the herb layer. The dominants are *Agrostis stolonifera, Dactylis glomerata, Phalaris arundinacea*, and *Urtica dioica*.

The basic features of former and recent stands are not the same, yet quite similar. The occurrence of the adventive weeds *Aster tradescantii* and *Phragmites* is a marked difference. In the case of other species only the importance is different (Table 2).

Table 2. Synthetic phytosociological table of willow shrubs (*Salicetum triandrae-purpureaea* Soó 1927) in Szigetköz, 1991.

Species	Sample plots 1	2	3	4	5	6	7	8	9	10	11	12	AD	K
Shrub layer:														
Acer negundo	.	.	.	.	.	.	.	.	.	.	+	.	+	I
Populus deltoides	.	.	.	.	.	.	+	.	.	.	.	.	+	I
Populus nigra	.	.	.	.	.	.	+	.	+	+-1	+-1	+	+-1	III
Salix alba	.	4	+	.	.	+	2	4	.	.	+	3	+-4	III
Salix purpurea	.	+	3	.	.	4	.	.	2-3	2	.	.	+-4	III
Salix triandra	5	.	.	4	5	.	2	.	.	1-2	.	+	+-5	III
Salix viminalis	.	.	.	.	.	.	.	.	1	+	.	.	+-1	I
Herb layer:														
Acer negundo	+	+	.	.	.	.	.	.	.	.	.	.	+	I
Achillea millefolium	.	+	.	.	.	.	.	.	.	.	.	.	+	I
Agrostis stolonifera	.	.	.	.	.	+	.	+	+-1	1-2	2-3	.	+-3	III
Alopecurus pratensis	.	.	.	.	.	.	.	.	+	.	.	.	+	I
Angelica sylvestris	.	.	.	+	.	.	.	.	.	.	.	.	+	I
Anthemis sp.	.	.	.	.	.	.	.	.	.	+	.	.	+	I
Arctium nemorosum	.	+	.	.	.	.	.	.	.	.	.	.	+	I
Artemisia vulgaris	+	+	+	.	.	.	.	.	.	+	+	+	+	III
Aster tradescantii	.	+	+	.	.	+	+	+-1	1	+-1	+	+	+-1	IV
Ballota nigra	.	+	.	.	.	.	.	.	.	.	.	.	+	I
Barbarea vulgaris	+	+	.	.	.	.	.	.	.	.	.	.	+	I
Bidens tripartitus	.	.	.	.	.	.	.	.	.	+	.	.	+	I
Cala magrastis epigeios	.	.	.	.	.	.	.	.	.	.	+-1	.	+-1	I
Calystegia sepium	.	.	.	+	1	+	.	.	.	.	.	.	+-1	II
Carduus crispus	+	.	.	.	.	.	.	.	.	.	.	.	+	I
Carex sp.	.	.	.	.	.	.	.	.	+	.	.	.	+	I
Chamaenerion palustre	.	.	.	.	.	.	.	.	.	.	+	.	+	I
Chenopodium album	.	.	.	.	.	+	.	.	.	.	.	.	+	I
Chrysanthemum vulgare	+	.	.	.	.	.	.	.	.	.	+	.	+	I
Cirsium arvense	.	+	+	.	.	.	.	.	.	+	+	.	+	II
Dactylis glomerata	2-3	2-3	1	.	.	+	.	.	+	+-1	+	.	+-3	III
Deschampsia caespitosa	+	.	.	.	.	+	.	.	.	+	+	.	+	II
Erysimum cheiranthoides	.	+	.	.	.	.	.	.	.	.	.	.	+	I
Festuca gigantea	.	.	.	.	+	.	.	.	.	.	.	.	+	I
Festuca pratensis	+	.	.	.	.	.	.	.	.	.	.	.	+	I
Galium aparine	.	.	.	+	.	+	.	+	.	.	.	.	+	II
Glechoma hederacea	.	+	+	.	.	+	.	.	.	.	.	.	+	II
Humulus lupulus	.	.	.	+	+-1	.	.	.	.	.	.	.	+-1	I
Impatiens noli-tangere	.	.	.	.	+-1	.	.	.	.	.	.	.	+-1	I
Impatiens parviflora	.	.	.	+-1	+	.	.	.	.	.	.	.	+-1	I
Iris pseudacorus	.	.	.	+	.	.	.	.	.	.	.	.	+	I
Lamium purpureum	.	+	.	.	.	.	.	.	.	.	.	.	+	I
Lycopus europeus	+	.	.	.	.	.	.	.	.	.	.	.	+	I
Matricaria inodora	+	+	.	.	.	.	.	+	.	.	+	.	+	II
Mentha aquatica	+	.	.	.	.	.	.	.	.	.	.	.	+	I
Morus alba	.	.	.	.	.	.	+	.	.	.	.	.	+	I
Myosotis palustris	.	.	.	+	.	.	.	.	.	.	.	.	+	I
Myosoton aquatica	+	2	.	.	.	.	.	.	.	.	.	.	+-2	I
Pastinaca sativa	.	+	.	.	.	.	.	.	.	.	.	.	+	I
Phalaris arundinacea	2	+	2	.	.	2-3	1	+	1-2	+-1	2	4	+-4	V
Phragmites communis	+	.	.	+-1	2	+-1	.	.	.	.	+	+	+-2	III
Plantago media	+	+	.	.	.	.	.	.	.	.	.	.	+	I
Poa annua	+	+	.	.	.	.	.	.	.	.	.	.	+	I
Poa palustris	.	.	.	.	.	.	.	.	.	.	+-1	.	+-1	I
Poa trivialis	.	.	.	+	.	.	.	.	.	.	.	.	+	I
Polygonum aviculare	.	.	.	.	.	.	.	.	+	+	.	.	+	I
Polygonum lapathifolium	.	.	.	.	.	.	+	.	.	+	+	.	+	II
Polygonum mite	.	.	+	.	.	.	.	.	+	+-1	+	+	+-1	III
Potentilla reptans	.	.	.	.	.	.	.	.	.	+	.	.	+	I
Ranunculus bulbosus	+	.	.	.	.	.	.	.	.	.	.	.	+	I
Ranunculus repens	+	+	+	.	.	.	.	.	+	+	.	.	+	III
Rorippa amphibia	.	+	.	.	.	.	.	.	.	.	.	.	+	I
Rorippa barbaroides	.	.	.	.	.	.	+	.	+	+	.	+	+	II
Rorippa islandica	.	.	.	.	.	.	+-1	.	.	.	.	+	+-1	I
Rorippa sylvetris	.	+	+	.	.	.	+-1	.	+-1	1	+	.	+-1	III
Rubus caesius	.	.	.	1	+	.	.	.	.	+	.	.	+-1	II
Rumex acetosa	+	.	.	.	.	.	.	.	.	.	.	.	+	I
Rumex crispus	.	+	+	.	.	.	.	.	+	.	.	.	+	II
Rumex sanguineus	+	.	+	.	.	.	+	+	.	+	+	+-1	+-1	III
Scrophularia nodosa	+	.	.	.	.	.	.	.	.	.	.	.	+	I
Senecio fluviatilis	.	+	.	.	.	.	.	.	.	.	.	.	+	I
Solanum dulcamara	.	+	.	.	.	+	.	.	.	.	.	+	+	II
Solidago gigantea	+	+	+	.	.	.	.	.	+	.	+-1	+	+-1	III
Stellaria media	+	+	.	.	.	.	.	.	.	.	.	.	+	I
Stenactis strigosa	+	+	.	.	.	.	.	.	.	.	.	.	+	I
Symphytum officinale	.	.	.	.	.	.	.	.	+	.	.	.	+	I
Taraxacum officinale	.	+	+	.	.	.	.	.	+	+	.	.	+	II
Thalictrum flavum	.	.	.	.	.	.	.	.	.	+	.	.	+	I
Trifolium pratense	+	.	.	.	.	.	.	.	.	.	.	.	+	I
Urtica dioica	+	3	+	+	1	+	.	+	+	.	.	+	+-3	IV
Xanthium strumarium	.	.	.	.	.	.	.	.	.	.	+	.	+	I

Regarding the W indicator spectra we can conclude that the recent W spectrum indicates a somewhat more extreme and a bit drier habitat than the former one. As Figure 1 shows some drought tolerant species occur and the importance of species that indicate wet habitats has decreased.

The nature conservation rank spectra show a slight degradation. The importance of species indicating natural state has slightly decreased, whereas disturbance tolerators have increased considerably. At the same time the importance of weeds has nearly halved. On the whole the proportion of species indicating degradation has increased from 47% to 55%, whereas that of indicating naturalness has decreased from 53% to 45% (Figure 2).

We note here a striking phenomenon observed in the study area. On young islands the river bank weed community is characterized by the presence of tomato (*Lycopersicon esculentum*). The possible reason for this is the release of waste waters from canning factories in Vienna or in Bős (Gabčíkovo, Slovakia) into the Danube.

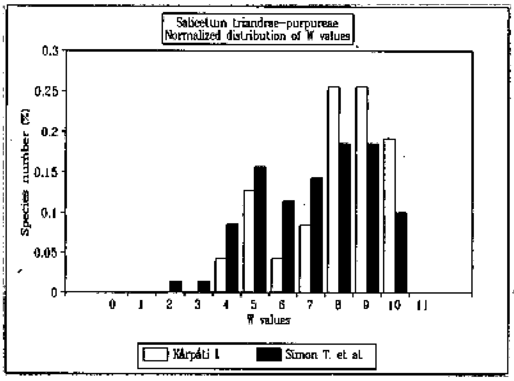

Figure 1.

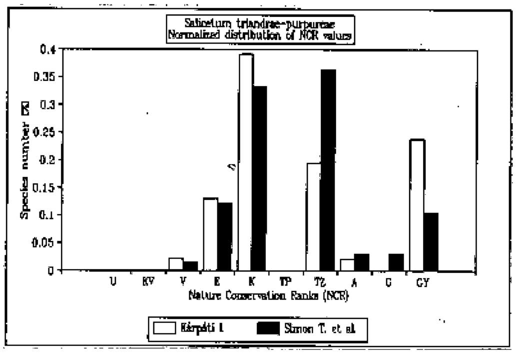

Figure 2.

Willow woods

Willow woods are the fast-growing softwood gallery groves of the low floodplain (*Salicetum albae-fragilis*). They are closed, forest-like communities, usually flooded by several meters of water during inundation. The characteristic structure with two canopy layers and dense, several meters high herb layer and veil-like liane cover of trees and shrubs develop quite fast after the retreat of water. Their stands used to give a nearly continuous cover on the islands of the Szigetköz-Danube labyrinth until the 1920's. It was Zólyomi (1937), who first described this community. *Salix alba* and *Salix fragilis* consociations were the most common, but stands with *Alnus glutinosa, A. incana, Populus nigra* and *P. alba* also occurred. The common species of the shrub layer were *Cornus sanguinea, Corylus avellana, Sambucus nigra.* The field layer was characterized by *Carex acutiformis, Impatiens noli-tangere, Agrostis stolonifera, Urtica dioica, Galium aparine,* sometimes by *Aegopodium podagraria, Convallaria majalis* and *Circaea lutetiana.*

Constant, subconstant (V-IV) species: *Salix alba, S. fragilis, Alnus incana, Cornus sanguinea, Rubus caesius, Glechoma hederacea, Galium aparine.* Common (III) species: *Populus nigra, Alnus glutinosa, Padus avium, Humulus lupulus, Agrostis stolonifera, Brachypodium sylvaticum, Urtica dioica, Ficaria verna, Angelica sylvestris, Symphytum officinale, Solidago gigantea.* Characteristic species (partly in common with hardwood gallery forests - *Populetalia*): *Alnus incana, Ulmus laevis, Padus avium, Vitis sylvestris, Leucojum aestivum, Cardamine pratensis ssp. dentata, C. impatiens, Pimpinella major, Carduus crispus, Senecio fluviatilis.* Additional mesophytic deciduous forest plants: *Clematis vitalba, Scilla vindobonensis, Paris quadrifolia, Galanthus nivalis, Stachys sylvatica, Galeopsis speciosa.*

There are fewer softwood groves near the upper Danube East of Vének. Those stands (Táti-sziget, Körtvélyesi-sziget, Nyáras-sziget, Szentendrei-sziget) were described by Kárpáti (1957). They were similar to the stands in the Szigetköz regarding the main types (*Rubus caesius, Urtica dioica, Agrostis stolonifera, Glechoma hederacea, Solidago gigantea*), but contained less species and more weeds. Several natural species e.g. *Alnus incana, Circaea lutetiana, Pimpinella major, Vitis sylvestris* were missing.

In the Szigetköz willow woods have preserved the former vegetation quite well by now (1991). About one-third of the stands we studied have semi-natural structure. In the canopy layer *Salix alba* is the most dominant with *S. fragilis, Populus nigra, P. alba, Ulmus laevis* as codominants. *Alnus incana* has become rare. The common species (constancy V-III) in the field layer are *Rubus caesius, Phalaris arundinacea, Solanum dulcamara, Phragmites, Humulus lupulus, Urtica dioica, Solidago gigantea, Galium aparine, Aster tradescantii, Impatiens glandulifera.* Some montane rarities, like *Galium odoratum, Circaea lute-tiana, Carex sylvatica, Senecio fluviatilis, Cardamine amara, Veronica beccabunga* are also present. Dominant species are: *Populus alba, P. nigra, Salix alba,* *Rubus caesius, Dactylis glomerata, Phalaris arundinacea, Calystegia sepium, Urtica dioica, Aster tradescantii* (Table 3).

By assessing the W-spectra of past and today's stands we can state that all of them indicate typical wet, floodplain circumstances. Former stands indicate more even water levels (W-range = 4-10, dominant categories = 5-8; cf. Figure 3). The present situation indicates a more extreme water regime (W-range = 1-10, dominant categories = 5-9).

The comparison of the two spectra shows that both the dry and the wet ends of the spectrum increased in importance, which indicates the more extreme water regime of the area. In the mid-range (5-8) no considerable change occurred (only the importance of group W7 decreased slightly).

If we compare the recent stands in the Szigetköz with those of described by Kárpáti (1957) outside the Szigetköz, we find that the W-spectrum of the Szigetköz stands indicates wetter habitats (Figure 5). The only decrease in species number occurs in categories 9-10, as a result of narrower floodplains of the upper Danube with longer inundation.

As Figure 4 shows the nature conservation rank spectra of the Szigetköz stands indicate a marked degradation (e.g. an increase in the number of weeds) since 1937. The proportion of species indicating natural state decreased from 84.5% to 57%, whereas the proportion of species indicating disturbance increased from 15.5% to 43%.

In Figure 6 we compare our stands with those of Kárpáti (1957). The willow woods outside Szigetköz were in a worse condition at that time (48% natural species) than they are in the Szigetköz now (57% natural species).

All these results, based on W indicator values and nature conservation ranks, confirm the semi-natural state of the softwood groves and the possibility of forest reconstruction in the protected areas of the Szigetköz. The most beautiful willow wood stands (e.g. Senki-sziget, Hajós-side, Öreg-Árva, Nagybajcs: east of Medvei bridge) could be

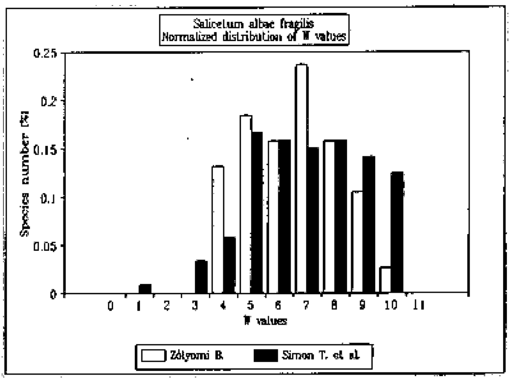

Figure 3.

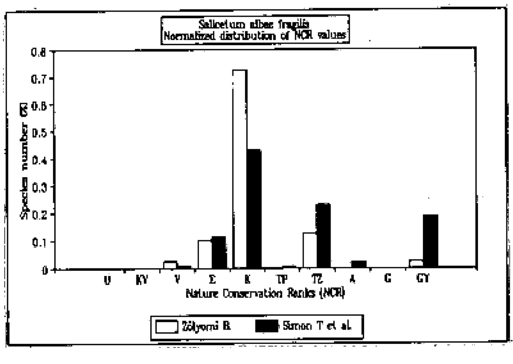

Figure 4.

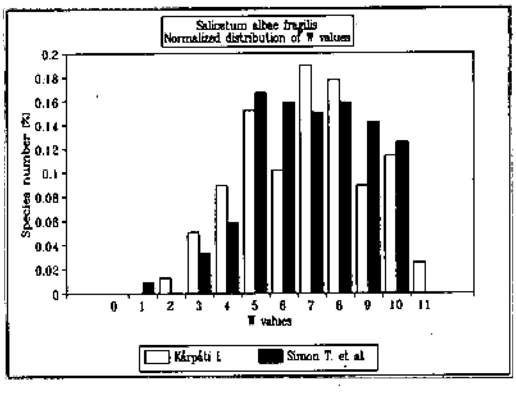

Figure 5.

Table 3. Synthetic phytosociological table of willow woods (*Salicetum albae-fragilis* Issler 1926) in Szigetköz, 1991

	Sampling plots																								
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	AD	K
Canopy layer:																									
Acer negundo	.	.	.	.	.	.	.	+-1	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	I.
Alnus incana	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	I.
Populus alba	.	.	.	.	.	.	.	+-1	.	.	.	.	.	.	.	.	.	.	.	4-5	.	.	.	+-5	I.
Populus canescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	.	.	.	.	.	.	.	.	+-1	I.
Populus nigra	.	.	.	.	.	.	.	.	.	1-2	3-4	.	.	.	.	+	1	.	.	.	4	.	.	+-4	I.
Prunus padus	.	.	.	.	.	.	.	.	+-1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	II.
Salix alba	2-3	2	2-3	2-3	4	4	2	2	3	4	2-3	2-3	.	4	2-3	4	3-4	3-4	4	1	+	2-3	3	1-4	V.
Salix cinerea	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Salix fragilis	.	2	.	.	.	.	2-3	.	1	.	.	1-2	.	.	.	.	.	.	.	.	.	.	.	+-3	I.
Salix purpurea	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	I.
Salix triandra	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	I.
Salix viminalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	I.
Ulmus laevis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2	I.
Ulmus minor	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	I.
Shrub layer:																									
Acer negundo	.	.	.	.	.	.	.	+-1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+-1	I.
Acer pseudoplatanus	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Alnus glutinosa	+-1	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	I.
Crataegus monogyna	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1-2	.	+	1-2	+-2	I.
Crataegus oxyacantha	.	.	.	.	.	.	.	+-1	+	.	.	.	.	.	.	.	.	.	.	+-1	.	.	.	+-1	I.
Cornus sanguinea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	.	1-2	1	+-2	I.
Fraxinus excelsior	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Fraxinus pennsylvanica	1-2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1-2	I.
Salix alba	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	I.
Salix purpurea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	I.
Sambucus nigra	.	.	.	.	.	.	.	.	+-1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	I.
Ulmus procera	+-1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	I.
Herb layer:																									
Acer negundo	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	+	I.
Achillea millefolium	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Agrostis stolonifera	.	.	.	.	.	.	.	.	.	.	+	+	+-1	+	.	.	+-1	.	+	.	.	+	.	+-1	II.
Alliaria petiolata	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Angelica sylvestris	.	+-1	.	+-1	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	+-1	II.
Arctium nemorosum	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	I.
Arenaria serpyllifolia	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Artemisia absinthum	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Artemisia vulgaris	.	.	.	+-1	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+-1	I.
Asperula odorata	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	I.
Aster tradescantii	.	1	1	+-1	+	.	2-3	+-1	.	.	.	+	2	.	.	.	+-1	.	+-1	+	.	.	.	+-3	III.
Ballota nigra	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Barbarea vulgaris	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Bidens tripartitus	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	I.
Calystegia sepium	3	.	.	.	.	.	.	.	.	1	+	.	.	+	+-1	+	.	.	.	.	.	+	.	+-3	II.
Capsella bursa-pastoris	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Cardamine amara	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	I.
Cardamine impatiens	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Carduus crispus	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Carex elata	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Carex riparia	+	+	.	.	.	.	+	+-1	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+-1	II.
Carex sylvatica	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Carex sp.	+-1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	I.
Chaerophyllum bulbosum	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Chenopodium album	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	I.
Chrysanthemum vulgare	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	+	I.
Circea lutetiana	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Cirsium arvense	1	.	.	+-1	.	.	.	+-1	.	.	+	.	.	.	.	.	.	+	.	.	2	.	.	+-2	II.
Clematis vitalba	.	.	.	+-1	.	.	.	.	+	.	+	.	.	.	.	+	.	.	.	.	.	.	.	+-1	I.
Dactylis glomerata	.	+	1-2	+	1	+	.	.	.	.	+	.	.	.	.	.	.	4	.	+	.	.	.	+-4	II.
Deschampsia caespitosa	.	+	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	+	+	.	.	.	.	+	II.
Equisetum arvense	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Festuca gigantea	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Ficaria verna	.	.	.	.	.	.	+	+-1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	I.
Fraxinus pennsylvanica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	I.
Galium aparine	+	1	1	1	.	+	+	.	.	1-2	1-2	+	+	.	1	1-2	+-1	.	.	+	+	+	+	+-2	V.
Galium palustre	.	.	.	.	.	.	+	+-1	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+-1	I.
Geranium robertianum	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Glechoma hederacea	.	.	+-1	+-1	.	.	.	.	.	.	+	.	+	.	+	+	.	.	.	.	+	+	+	+-1	II.
Heracleum sphondylium	.	.	.	+-1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	I.
Humulus lupulus	+-1	.	.	.	.	+	.	.	+	+	+-1	+	.	.	+	2	.	.	.	.	.	.	.	+-2	II.
Impatiens glandulifera	.	1	1	1	+	1-2	+-1	.	.	.	.	+	.	.	.	.	.	1	.	.	.	+	+	+-2	III.
Impatiens noli-tangere	1	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+-1	I.
Impatiens parviflora	+	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	+-1	.	.	.	+-1	I.
Iris pseudacorus	+	+-1	.	.	.	.	.	+-1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	I.
Lamium maculatum	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Leucojum aestivum	.	+-1	.	.	.	.	+	+-1	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	I.
Lycopus europeus	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Lycopus intermedius	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Lysimachia nummularia	.	.	.	.	.	.	.	+-1	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+-1	I.
Lysimachia vulgaris	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Lythrum salicaria	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Matricaria inodora	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Myosotis palustris	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	I.
Myosoton aquatica	.	+	.	+	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Parietaria officinale	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Pastinaca sativa	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Phalaris arundinacea	.	1	1	1	1	+	4	+-1	+	+-1	2-3	+	1	+	+	.	+	1	2	+	.	+	+	+-4	V.
Phragmites communis	+	+	+	.	.	.	+-1	+	+	+	+	.	.	+	.	.	.	+	+-1	.	.	+	+-1	+-1	III.
Pimpinella saxifraga	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Plantago major	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Plantago media	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Poa annua	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	I.
Poa palustris	.	.	.	.	.	.	+	+-1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	I.

Table 4. (Continued)

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	AD	K
Poa trivialis	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Polygonum lapathifolium	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Polygonum minus	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Polygonum mite	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	+	.	+	.	.	.	.	+	I.
Populus alba	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	+-1	I.
Ranunculus bulbosus	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Ranunculus repens	.	+	+-1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+-1	II.
Rorippa amphibia	.	2	+-1	+-1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-2	I.
Rorippa armoracioides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	I.
Roribba barbaroides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	+	I.
Rorippa islandica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	I.
Rorippa sylvestris	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	+	I.
Rubus caesius	3	+-1	1	.	+	+	+	.	+	+	2	+	+	+	+	+-1	.	.	+	+	1	2	+	+-3	V.
Rubus idaeus	.	.	.	+-1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	I.
Rumex crispus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	.	.	.	.	.	+-1	I.
Rumex obtusifolius	.	+	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Rumex sanguineus	.	.	+	.	+	.	+	.	+	.	+	+	+	+	.	.	.	.	+	.	.	.	.	+	II.
Scrophularia nodosa	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Scrophularia umbrosa	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Senecio fluviatilis	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	I.
Senecio paludosus	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Solanum dulcamara	.	.	+-1	+-1	.	.	.	+	.	+	+	+	+	+	.	.	.	+	+	.	+	+	.	+-1	III.
Solanum nigrum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	I.
Solidago gigantea	.	+-1	+-1	+-1	+	.	.	.	+	.	+	.	+	+-1	.	.	1	1	.	.	.	.	.	+-1	III.
Stachys palustris	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	I.
Stachys sylvatica	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Stellaria media	.	.	.	+-1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	I.
Stenactis strigosa	.	+-1	+-1	+-1	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	.	.	.	.	.	+-1	I.
Symphytum inundatum	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Symphytum officinale	+	.	.	+-1	.	.	+	+-1	.	.	+	.	.	+	.	+	+	+-1	.	.	.	.	.	+-1	II.
Tanacetum vulgare	.	.	.	+-1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+-1	I.
Taraxacum officinale	.	.	+	+	+	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	+	II.
Tussilago farfara	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.
Urtica dioica	.	.	+	+-1	+	5	+	1	2-3	5	4	4	2-3	+	5	4	2-3	1	.	+-1	4	2-3	5	+-5	V.
Ulmus minor	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	2	I.
Veronica beccabunga	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	I.
Viburnum opulus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	I.
Xanthium ithalicum	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I.

the starting point of the reconstruction of these woods and of preserving compositional and habitat diversity. Their structure with multiple canopy layers, with veil-like "skirts" of the trees (*Clematis vitalba, Humulus lupulus, Solanum dulcamara, Calystegia sepium*) and with the dense, several meters high field layer proves the primeval character of the community.

Results of diversity and evenness analyses

The diversity and evenness values presented in the tables represent the distribution of species numbers among the classes. Here the classes are W indicator and nature conservation rank classes. Based on nature conservation values, Table 4 shows a slight increase in diversity and decrease of evenness in *Salicetum triandrae-purpurea.* There is a considerable increase of diversity and a slight decrease in evenness in *Salicetum albae-fragilis* between 1937 and 1991. The comparison of the 1937 and 1957 data shows a marked increase in both diversity and evenness, which is in good agreement with our conclusions on the phytosociological degradation of the area.

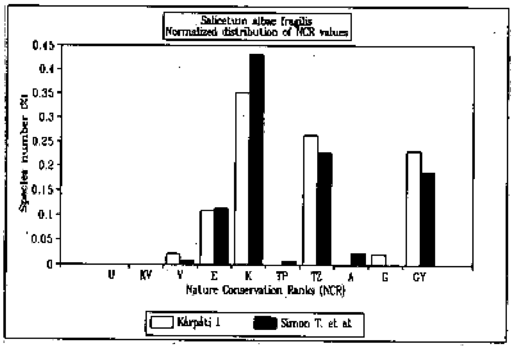

Figure 6.

Table 4. Diversity (D) and evenness (E) of nature conservation ranks (1937: Zólyomi - Szigetköz; 1957: Kárpáti - *Salicetum triandrae - purpurea* - Szigetköz, *Salicetum albae - fragilis* - Esztergom-Szentendrei-sziget; 1991: Simon et al.-Szigetköz)

Community	1937		1957		1991	
	D	E	D	E	D	E
Salicetum triandrae-purpurea	-	-	1.46	0.81	1.50	0.77
Salicetum albae-fragilis	0.91	0.56	1.46	0.91	1.42	0.73

Table 5. Diversity (D) and evenness (E) of W indicator values (1937: Zólyomi - Szigetköz; 1957: Kárpáti - *Salicetum triandrae - purpurea* - Szigetköz, *Salicetum albae - fragilis* - Esztergom-Szentendrei-sziget; 1991: Simon et al.-Szigetköz)

Community	1937		1957		1991	
	D	E	D	E	D	E
Salicetum triandrae-purpurea	-	-	1.75	0.90	2.0	0.92
Salicetum albae-fragilis	1.83	0.94	2.11	0.91	2.02	0.92

Table 5 shows that the diversity for W indicator categories increased in both associations. Evenness has not changed. All these facts support our statements about the more extreme ecological characteristics of the habitats

References

Kárpáti, I. 1957. A magyarországi Duna-ártér erdői. (The forests of the floodplains of the River Danube in Hungary.) Dissertatio ad canditaturam (ined.)

Simon, T. 1984. A Bugaci Bioszféra Rezervátum edényes flórájának természetvédelmi értékelése. (Nature conservational assessment of the vascular flora of the Bugac Biosphere Reserve.) Abstracta Botanica 9:95-100.

Simon, T. 1988. A hazai edényes flóra természetvédelmi-érték besorolása. (Nature conservation ranks of the Hungarian vascular flora.) Abstracta Botanica 12:1-23.

Slack, N.G. 1977. Species diversity and community structure in Bryophytes. New York State Museum Bulletin 428:70

Zólyomi, B. 1937. A Szigetköz növénytani kutatásainak eredményei. (Botanical researches in the Szigetköz.) Bot. Közl. 34:169-192.

Zólyomi, B. and Précsényi, I. 1964. Methode zur ökologischen charakterisierung der Vegetationseinheiten und zum Vergleich der Standorte. Acta Bot. Acad. Sci. Hung. 10:377-416

Zólyomi, B. et al. 1967. Einreinhung von 1400 Arten der Ungarischen Flora in ökologischen Gruppen nach TWR-Zahlen. Fragmenta Botanica 4:101-142.

Annex 20

DAMAGE AND RISKS TO AGRICULTURAL PRODUCTIVITY IN THE SZIGETKÖZ DUE TO THE DIVERSION OF THE DANUBE

Summary based on: Palkovits (1994 a, b, c)

November, 1994
Budapest

Chief Factors Affecting the Yield of Arable Crops – An Evaluation of Changing Patterns

The data on agricultural production in the Szigetköz region has been systematicly evaluated since 1980. The size of farmland in the regional public agricultural enterprises amounts to an estimated 22,000 hectares. Data-collection covers the area, producing the most important 11 field crops of the region, including cc. 8-900 fields totaling 20,000 hectares.

Agricultural productivity is determined by a number of factors. A full survey of environmental conditions, agrotechnological infrastructure and farm management will be made on the basis of the data collected.

Such data-bases that can be generated with reasonably high precision will be evaluated on a field-based analysis. Field-based analyses provide an enormous amount of vital information for long-term assessment projects and may lead to important conclusions.

The Szigetköz region is identified as a distinctly fertile agricultural area. The average yield of crops is 8-12% higher than the regional average of Győr-Moson-Sopron county. As a result, intensive agricultural production is carried out on the farmland of the region. This observation can be verified in the context of environmental and agrotechnological conditions.

These conditions can be classified into the following three groups:

- precipitation and weather conditions
- location and flow of ground water
- applied agrotechnology

PRECIPITATION AND WEATHER CONDITIONS

The fluctuations of moisture content greatly influence agricultural productivity. The amount and periodicity of rainfall (especially during the growing season) are key factors. The related thermal conditions provide additional important data. (Data on the quantity and distribution of rainfall are evaluated on a farm-average basis and not through field-based analyses. The reason for this is that the rain-gauges operate at production centres and precipitation is unevenly spread.)

The annual average rainfall for the period 1951-1990 stood at 573 mm and 548 mm for Mosonmagyaróvár and Győr respectively. In the course of the last 7 years rainfall dropped by 65 mm (Mosonmagyaróvár) and 63 mm (Győr). The 40-years-average of the respective growing season values were as follows: 332 mm (Mosonmagyaróvár) and 322 mm (Győr). In the course of the last 7 years there was a drop of 47 mm (Mosonmagyaróvár) and 39 mm (Győr).

Rain-gauge monitoring at the production centres reveal that the Middle-Szigetköz is more abundant in rainfall than the rest of the region. Recorded data shows that rainfall values drop near the edges of the Szigetköz: the average annual rainfall in the last 7 year period had dropped to 450 mm at Rajka and Győr-Bácsa.

As a basis for comparison, a similar investigation revealed that in the period 1980-1992 there were three years with high precipitation (i.e. min. 500-550 mm/year or min. 300 mm/growing season), five years gave standard values and five years had scant rainfall, (i.e. max. 450 mm/year or max.240 mm/growing season), three of which were counted as dry years.

THE LOCAL SPREAD OF GROUND WATER

There are over 200 observation wells in the Szigetköz region. The observation wells provide reliable data that enables the researchers to interpolate estimates for the ground water level in the areas between the monitoring posts.

Field-based data provide the values for the ground water table during the growing season. These are subject to further analysis.

The average values for the ground water table during the growing season in the Szigetköz region (1980-1992) show that 53% of farmland possessed sufficient available ground water for the crops. The data reflects the patterns in the topsoil layer.

According to measurements made where the ground water table is closer to the surface than 200cms (23% of the monitored planting fields had the water table near the surface), there was a direct supply of moisture. Where the water table is between 200-300 cms from the surface (30%) of the moisture supply was either constant or temporary, depending on the topsoil features. Where the ground water level was between 300-500 cms from the surface moisture supply was limited, and below 500 cms moisture was absent.

AGROTECHNOLOGY

Agrotechnology has a number of elements (crop-rotation, cultivation, seed-bed preparation, nutrient supply, utilisation, provision of high biological fertility, weeding, pest-control, irrigation, harvesting etc.). The quality of each technological element has a direct impact on agricultural productivity, which in turn is linked with environmental conditions. Each technological step has an important function and any defect in their use will put optimum yields at risk. In the past few years of the period researched, it may be pointed out that the standard agrotechnological management usually fulfilled the basic requirements of cropping. The first sign of technical faults began in 1992 when the implementation of some technological elements was not fully accomplished. (Deficient fertilisation already had some effects on the average registered yield.)

ANALYTICAL METHODS

In the pilot-phase of data-processing analysis was focused on the contents of professional programmes. The current annual reports still follow this pattern. At a later stage of the investigations, time-lag analyses came into use as well. In order to understand the impact of the key conditional factors upon productivity, we introduced the techniques of multi-factor impact analysis. All species of crops and soil-types were cross-referenced against the various water table categories and yield-trends for dry, average and wet years alike. The impact of technological methods (especially nutrient re-charge techniques) were also examined.

It was clear that crops with a low territorial proportion (i.e. less than 1000 ha/year) did not provide statistically sufficient data for such multi-factor analyses.

CONCLUSIONS OF THE ANALYSES

Areas of any soil-type for all categories of relatively high water table level had a significant yield-growth for all investigated species in the wet years.

Any reductions of water level led to a loss of yield at the lower ground water table sections.

The same tendency prevails in the years of average precipitation, though it must be added that meadow soils give a slightly higher yield output than the average regional values.

In seasonal cycles with a dry or drought precipitation regime meadow soils give higher yields in all cross-functional analyses. Water tables near the surface provide all soil-types with a significantly higher yield for each category. (Irrigated sugar beet produced less divergence in yield values.)

Cross-factor analyses were conducted to produce the following weighted average figures for the 11 crops investigated (1980-1992):

Compared to the average figures of the Szigetköz-region, wet years brought 9% yield increase, dry years produced 9.5% yield loss.

According to measurements made in max. 200 cms of ground water table (direct supply area) the calculated average for the 13 year period corresponds to a yield increase of 10.8% (direct supply area) and 7.4% (indirect supply area). These positive effects are based on the moisture supply capacity of the ground water. The corresponding figures for dry years are as follows: 15-19% yield increase (direct supply area) and 10.0-10.8% yield increase (indirect supply area)

The 13-year period investigated did not bring about any significant technological changes, the use of modern know-how secured the maintenance of relatively high productivity.

To verify the above observations and to understand the effects of single conditional factors the project extended its focus to the systematic data-collection and evaluation of the sample areas around the observation wells. In these sample areas we carried out a number of soil profile analyses on the most significant physical, chemical and hydrological features of the different surface layers. In 1985 phenological observations also started in the sample areas. 1989 saw the start of relative moisture content observations. The SSM-001 moisture gauge equipment functions on the capacity principle and provides realistic data on the changing moisture content. The moisture content observations are adjusted to the relevant phenological phases and changing weather conditions. These observations take place on arable land, in forests, both on the protected side and on the floodplain. The results support the previous conclusions concerning the relationship between water table fluctuations and their impact on soil moisture content.

CONDITIONAL FACTOR MODIFICATIONS FOLLOWING THE DIVERSION OF THE DANUBE

When compared to the average data-output of the 1980-1992 period, the year 1993 brought some significant changes.

1993 was the driest and hottest of all the years investigated, and can be regarded as a drought year. In the first half of the year precipitation was unusually scarce, which greatly influenced the low yield values of summer-harvest crops. Heavy rainfall in the second half of July improved yield-potentials for autumn-harvest crops, further rainfall in September and October put another limit to yield loss.

In the growing seasons of 1993, the rain gauges in the Mosonmagyaróvár-Gy¦r area registered a 87-118 mm 40-years-low. Although the total annual figures for precipitation were not low, it is important to note that nearly half fell during the last three months of the year.

Following the diversion of the Danube, ground water level had greatly reduced in the reach between Tejfalusziget and Ásványráró. In a number of areas ground water left the topsoil layer and passed into the gravel layer, thus ceasing its moisture-recharge functions. Of all the area investigated there was about 1,800 ha, where the ground water table had dropped by 100-150 cms in the average growing season. A further 2,100 ha area saw a reduction in its ground water table by 60-100 cms. If one relates this data to the decrease in the sample areas, the Szigetköz region had lost its ground water recharge capacity on 4,200 ha of the arable land. There were some further areas in the Upper and Middle Szigetköz, which suffered reductions in ground water table. However, these never exceeded 50 cms and were located in such layers which had scarcely had the capacity for moisture recharge.

The level of fertilisation capacity deteriorated at a different rate between farms. The amount of fertiliser-supply (per/1ha) was only 24.8% of the 1989 yearly equivalent (average in the Szigetköz-region: 82.4 kg/ha). Some production units had given up fertilisation. Each farming cooperative had certain species or fields where no nutrient recharge was effected.

Over 23% of the wheat growing areas had late sowing. (e.g. sowing time on 140 ha: 1 December, yield: 1.8 tons/ha). The quality of biological sowing-materials had also deteriorated, a number of production units were forced to use self-cropped seeds. One quarter of the total arable area had spring ploughing only. In this year of drought all irrigation facilities should have been managed better. (Only 10% of the sowing area was irrigated.)

RESEARCH METHODS FOR MULTI-FACTOR ANALYSES

The scope of the 1993 agrotechnological modifications have been proved by a number of investigations. The most important changes took diverse shape in the various regions, fields and production units. In the Lower Szigetköz the basis for research was established by the fact that the local ground water table had negligible fluctuations (compared long-term average values to the mean of growing seasonal data).This region suffered the heaviest effects of precipitation-deficiency but technological faults were not typical.

In the Middle Szigetköz region the topsoil-layer lost ground water table on about 4,200 ha, and there was no direct moisture re-charge effect discernible.

The region had relatively more rainfall, which nevertheless was still insufficient to make up for the disappearance of the ground water supply. Of all technological elements, the lack of nutrient recharge was significantly more important than in the regions of the lower reach. The extent of rainfall-deficiency was similar in the regions of the Upper, and Lower Szigetköz. Those instances of water-supply deficiency, which were attributed to the drop of ground water level, proved to be limited to the lower parts of a few fields. The extent of nutrient recharge deficiency is high and other technological faults are also important.

The significance of the 1993 conditional changes is best understood if contrasted to the 1980-92 average values. The extent of micro-regional damages can best be analysed on the basis of weighted average data, which primarily describe the existing conditions for the dominant crops. This method enabled us to understand the interplay and sole effect of the individual technological elements. The calculations followed the principle of exclusive data-analysis, which enabled us to concentrate on the key conditional factors relevant to the environmental impact-analysis. Hence, the elements related to technological faults were practically discounted. The same principles have been applied to the measurement of the reductions in the ground water table. The results have been supplemented with some diagrams on the moisture content of the sample areas. The above methods may suggest scope for subjective interpretation on the extent of damage related to rainfall deficiency. Nevertheless, the hypothesis was verified by the curve diagrams on soil moisture content. We determined the geometric average value of regional damage in the context of conditional factors. This provided a high-probability estimate for the yield loss in all regions of the Szigetköz. The reliability of this method is based on the great diversity of available data and the provision of geometric average value.

***Chart 1**: Damage arising from yield loss*

The micro-regional and farm-based analyses traced the yield of the five dominant field-crops, which took 79-81% of the total planting acreage.			
	Average yield in 13 yrs (tons/ha)	Yield in 1993 (tons/ha)	Change (%)
Lower Szigetköz			
Wheat	6.02	5.13	-14.8
Spring barley	5.23	3.85	-26.4
Corn	7.70	6.54	-15.1
Sileage corn			
(27% broomcorn)	27.09	29.85	+12.3
Sugar beet	39.05	34.26	-12.3
(irrigated: 27%)			
AVERAGE	-	-	-14.4
Middle Szigetköz			
Wheat	5.45	3.81	-30.1
Spring barley	5.03	3.04	-39.6
Corn	6.40	5.06	-21.0
Sileage corn	27.88	25.73	-7.7
(14% broomcorn)			
Sugar beet	41.70	38.80	-7.0
(irrigated: 86%)			
AVERAGE			-23.3
Upper Szigetköz			
Wheat	5.08	3.13	-38.4
Spring barley	4.86	2.21	-54.5
Corn	6.10	4.02	-34.1
Sileage corn	24.94	25.21	+1.1
(18% broomcorn)			
Sugar beet	40.65	38.70	-2.3
(irrigated: 85%)			
AVERAGE			-31.0

Yield loss is generated by different factors and has certain regional and plant-specific features. The proportional distribution of conditional factor-analysis provides the following regional averages:

Chart 2: *Distribution of yield loss factors*

	Weather conditions (rainfall deficiency)	Ground-water deficiency	Technological faults
Lower Szigetköz	86 %	0 %	14 %
Middle Szigetköz	43 %	46 %	11 %
Upper Szigetköz	48 %	16 %	36 %

The regional yield-trend analysis enable us to conduct a closer investigation on the actual impact of the conditional factors. The following data are based on the patterns of average yield and the estimated proportion of yield loss in the Szigetköz-region.

Chart 3: *Changing patterns of average yield*

	Average of 13 yrs (tons/ha)	1993 (tons/ha)	Change (%)
Wheat	5.50	3.98	-27.6
Winter barley	4.84	3.21	-33.7
Spring barley	5.06	3.25	-35.8
Pea (sowing)	2.76	1.69	-38.8
Pea	3.49	1.80	-48.4
Sunflower	2.30	3.02	+31.3
Potatoes	28.06	23.75	-15.4
Corn	6.75	5.24	-22.4
Sileage corn	26.72	26.72	0
Sugar beet	40.68	37.82	-7.0
Alfalfa (green matter content)	32.49	28.82	-11.3

The calculated average data on yield value for the period 1980-92 suggest reasonably high standards of production but do not shed any light on the uneven spread of the annual output. It must be mentioned that – compared to the average yield values of the preceding 13 years – 1993 gave the poorest yield.

Summer-harvest crops (wheat, barley, peas) suffered considerable yield losses, which were primarily linked to soil moisture deficiency. This factor mainly affected the crops with a short growing season (110 -130 days), such as spring barley and pea. Sunflower is a rather non-fastidious crop with a potentially high yield under normal conditions. 35% of its planting acreage functioned as a replacement for such sugar beet fields, which had been discontinued due to poor germination and pests. The replacement fields of sunflower not only provided a higher rate of nutrient re-charge but also managed to take up sufficient moisture in the periods of flowering and seeding in the second half of July.

Autumn-harvest crops suffered a limited degree of yield loss, which can partly be explained with the improvement of rainfall conditions in the second half of the year. Sileage corn was jointly cropped with drought-proof broom-corn on 28% of its planting acreage. This method produced higher yield values. 73% of the sugar beet fields were irrigated (97 mm/ha average water table level): discharge resulted in some degree of yield loss.

YIELD FLUCTUATION IN 1993

The estimated average yield fluctuations of 1993 (compared with the average values of the period 1980-92) amounted to a 20.5% yield loss, i.e. in terms of the weighted average yield values of the region's dominant 11 crops. Weighted conditional factor-analyses were carried out in the contexts of field, production unit, micro-regional structure and the variety of crops.

These investigations gave the following proportions of conditional factor-distribution: of the 20.5% of total regional yield-loss, rainfall deficiency and weather conditions made up 10.5%, whereas a further 5% loss can be attributed to ground water deficiency and an additional 5% loss to technological faults.

Yield values were based on 1993 retail prices. The calculations compare some features of the two selected periods (1980-92 and 1993). (Chart IV.)

The data reflect that a certain amount of diversification took place in various cropped species in the contexts of planting acreage, average yield and retail price. This means that the actual yield loss value may amount to more than the mere difference between the estimated yield value and the realised value of production in 1993. The systematic comparative analysis between the average annual yield value of the 1980-92 period (area/ha) and of 1993 reveal that the potential average value for 1993 is 1,085 million HUF. Hence, the 1993 yield value equals about 79.4% of the average value of the 1980-92 period. Yield loss is at 20.6%. (Chart IV)

The impact of the most important influencing factors upon the 1993 yield loss is presented in (Chart V). It is clear from the data registered that the dominant 11 plants gave a yield value of 860,882,000 HUF (instead of the potential 1,085 million HUF). Hence, the sample area (18,719 ha) suffered a yield loss of 223,649,000 HUF. The total of 20.6% yield loss is made up of the following influencing factors:

Weather conditions: 11.9%, technological faults: 4.4%, diversion of the Danube: 4.3%. Ground water deficiency accounts for a loss of 46,552,000 HUF. In the Middle Szigetköz region there was a reduction of grasslands (by 690 ha), which equalled a yield loss of 2,346 t, equivalent to 3.192 million HUF.

In 1993, the total amount of agricultural damage caused by ground water deficiency amounted to 49,744,000 HUF.

The Impact of Groundwater Table Alterations on Farmland Irrigation Patterns-Environmental and Economic Considerations

Agricultural production in the Szigetköz suffered yield losses due to various factors and in all of its sub-regions. The magnitude of the loss had to be estimated by complex analytical methods. The location of significant ground water table subsidence can be determined with high precision. The investigation on irrigation pattern alterations concentrates on the areas most affected.

The registered ground water table reduction had a direct impact on the irrigation patterns of the Middle Szigetköz. In the 1980's we had processed all the available data on regional irrigation. These investigations included field-based studies on the irrigation equipment, available water resources and the actual output of irrigation. This data-base provided a useful tool for the analysis of the subsequent alterations in the system. This study is an analysis of the alterations that have occurred since 1990 and refers to the current state of affairs. The affected area, -7 production units of the Middle Szigetköz region-, comprises 9,934 ha of farmland, 8,683 ha of which is arable. In 1990, ideal irrigating conditions were provided by 156 borehole wells, 44 dug wells, 13 gravel pits and a number of natural water courses, canals, and dead stream branches. The 9,934 ha area had sufficient irrigation under such excellent conditions that 3,671 ha area (45.4% of the total) had two or more water resources. The cumulative irrigating conditions had the following spread in the region: Püski-62%, Lipót-59%, Darnózseli-85%, Hédervár-47%, Ásványráró-40%, Dunasziget-32%, Halászi-14%.

The total area of cumulative irrigating conditions covered 11,748 ha, and had the following water resource distribution: borehole wells – 45.8%, dug wells – 14.3%, Mosoni-Danube – 4.6%, canals, dead stream branches – 30.9%, gravel pit ponds – 4.4%. By practising the principles of crop-rotation, the agricultural production units (companies) made great efforts to irrigate most of their arable land. This explains the high percentage (60.1%) of well-based irrigation. In the early years of the 1980's, farming irrigation systems were based on portable (manually-operated) equipment. By 1990, the use of modern, mobile (side-branch fitted) irrigators became widespread. Because of their higher irrigation demands, farming companies still prefer the use of this equipment, while farmers tend to have the portable units. In recent years, Ásványráró made the only purchase of new irrigation equipment in the region. In the drought year of 1990 a total of 1,153 ha received irrigation to an average of 106 mm submerged cover. Irrigation was spread as follows: sugar beet-710 ha, potatoes – 181 ha, alfalfa – 130 ha, cash crops – 112 ha, sowing peas – 20 ha. With 13.1% of its arable land irrigated, Middle Szigetköz had a higher percentage value than the regional average.

Following the drastic alterations of ground water table and other vital irrigating conditions, the current data for 1994 reflect significant changes. There is a regionally important shift in the level of serviceability of the borehole wells: 28 of the 156 units have broken down completely. There are 53 high-capacity (i.e. 2 side-branches/unit) wells in service. There are 75 low-delivery borehole wells at half-capacity. In addition, it is worth mentioning that 42 of the 44 dug-wells have an insufficiently low water delivery for any use. Water-delivery on the protected side is still sufficient to secure irrigation, although this does not greatly influence the potential size of the irrigation area.

The low flow-rate canals and open drains have dried up or dropped to a minimum capacity.

The most important changes of the different areas are the following:

Ásványráró: the subsidence of the ground water table is substantial, although the tailrace-canal discharges have temporary effects on the ground water flow. Despite ground water table reduction, the borehole wells function at full capacity. In 1994 some new borehole-wells have been established, as the dug-wells, water courses, canals had become unserviceable for irrigation.

Hédervár: borehole wells function at full capacity, 2 of the deep dug wells are still fully serviceable, 3 dug wells dried up. One of the work-pits has dried up. The canals are temporarily serviceable, as pumping water discharge increases delivery.

Darnózseli: old borehole wells at half capacity, 5 dug wells are unserviceable, dug wells near the floodplain are at half capacity. One work-pit has dried up and is used as a dumping ground. The Nováki-canal provides an excellent water source.

Lipót: most borehole wells are at full service, half-capacity near the floodplain. All dug wells are unserviceable. The canals have dried up. The Lipóti- and Hédervári- canals provide temporarily sufficient conditions for irrigation.

Püski: one-third of borehole wells are at full-capacity (Nováki-canal), two-thirds at half-capacity. All dug wells (14 in total) are unserviceable for irrigation. The canals have dried up. This area suffers the heaviest damage of subsidence in the ground water table. Gravel pits provide some capacity for irrigation.

Dunasziget: 61% of the total area can be irrigated from the high capacity water supplies. Borehole wells (9 in total) are at half-capacity. Dug wells (9 in total) are unserviceable. One gravel pit pond has dried up.

Halászi: Irrigation was based mainly on borehole and dug wells. These wells have suffered the regionally highest damage: 12 borehole wells and 5 dug wells have dried up. 20% of the area can be irrigated from the Nováki-canal. 23 of the serviceable borehole wells are at half-capacity.

Due to ground water table subsidence the area of potentially irrigated area has diminished significantly, totalling 19.1 %. The area of cumulative irrigating conditions has also shrunk by 3,500 ha. There has been a 1,349 ha drop in the size of the irrigated area with low water-flow streams, canals, and dead stream branches. This damage has mainly affected the area near Ásványráró and Püski.

Dug wells are practically unserviceable: the size of the originally served area of 1,677 ha has shrunk to a mere 57 ha. The worst deterioration of irrigating conditions hits the Püski area, as it has the most dug wells established.

The alteration in the serviceability of borehole wells has partly technical reasons (corrosion, long-term lack of use) as well as direct consequence of the ground water table subsidence. Most borehole wells are old and their capacity had been based on the dynamics of ground water. They were originally designed for traditional, manually portable irrigating systems. With the spread of modern irrigating equipment some new borehole wells have been installed. Alternatively, some agricultural companies have applied the techniques of pipe-extension and notches to provide abundant water resources for irrigation.

The areas with relatively high borehole well provision experience regionally significant loss of serviceability due to the reduction of the ground water table. Borehole wells now only provide 25% of the unable water resource (original share: 66%). The water delivery of borehole wells is insufficient on 37% of the irrigated land (3,029 ha). As a result, the irrigating regime is at half capacity. The maintenance of these resources for irrigation has become very costly therefore new, more cost-effective techniques have to be explored. Discounting the damaged water-resource areas, only 64.5% of the total regional farmland area can be irrigated. The deterioration of irrigating conditions affect all agricultural production units and the proportion of unserviceable areas runs as high as 57% (Püski), 60% (Halászi), 42% (Darnózseli).

The unserviceable (or low capacity) wells may be renovated through pipe-extension, notches and well-rings, thus the abundant water resource can be reclaimed. Renovation costs almost equal installation costs. Under the pressing economic circumstances the agricultural companies have no financial resources available. Nevertheless, some renovation projects have been realised in the last two years. The cost-effectiveness of irrigation has deteriorated to such a low standard that the actual use of renovation projects may be questionable. It is clear that irrigation deficiencies are not caused by the companies' management.

The high-capacity borehole wells have to be deepened in order to compensate for the damage of the natural water resources. These include the Mosoni-Danube, gravel pit ponds, low-capacity water streams and the discharge areas of the protected side. Due to the loss of cumulative irrigating conditions in the Middle Szigetköz region, there is an urgent need for the establishment of 126 borehole wells. In order to realise this project, some new side-branches have to be established to provide sufficient water resources.

The provision of near-optimum irrigating conditions (1990 level) requires the deepening (notching) of 150 boreholes. The new borehole well at Ásványráró cost a net 80,000 HUF in April 1994. Hence, one may estimate that the cost for the recovery of the 1990 capacity level (minimum need) would be around 10.08 million HUF. The establishment of the maximum irrigating conditions would cost about 12 million HUF.

The agricultural companies of the Middle Szigetköz have 14 sets of irrigating equipment. These include 2-3 side-branches/unit. The average number of company-based irrigation equipment varies between 2 and 3. The age of the machinery varies from 3 to 9 years. The maintenance costs of the older machinery are rather high because frequent replacement of the parts is necessary. Some companies still possess old-fashioned, portable irrigating equipments (5 in total), most of which have been out of use for the last 5 years. The full capacity of an item of modern irrigating equipment covers 50-80 ha, although in some instances a 130 ha/unit output can also be reached. At present the available irrigating equipment has a capacity for 1,000-1,200 ha (100 mm depth/ha). Considering the crop-rotation systems each company requires the investment of at least 1 further item of irrigating equipment. This would facilitate the compensation irrigation of such croplands (cereals, corn etc.) where the effects of the lowering of the ground water table are present. Further losses of the ground water table will necessitate the irrigation of 2,500-3,000 ha of hydrophyte crops. The quantity of irrigating equipment will have to be doubled: 7-14 items of equipment will have to be financed to compensate for water resource losses in the region. Costs are at estimated 19-39 million HUF at 1994 prices.

The necessity for increased investment in irrigation conditions have constantly been emphasised in our annual reports. That this has not always been realised may be linked with economical factors. The agricultural production units consider irrigation as an important technological element in securing constant yield standards or the provision of yield increase.

Under present circumstances only those plants receive irrigation, where retail prices compensate for the investment costs. The dominant plants are sugar beet and potatoes. The existence of the large gap between the industrial and agricultural retail prices and the generally poor situation for agricultural marketing is only too well-known. The cost-effectiveness of sugar-beet irrigation is frequently reconsidered at the production units, because an average yield of 30 tons/ha has already been attainable with no irrigation at all. The 1993 costs of 100 mm/ha irrigating water provision stood at 14-15,000 HUF. The retail price of sugar beet stood at 2,500 HUF/tons.

This means that cost-effectiveness requires an average yield of 38-40 tons/ha. Constant pressure on costs is not easily balanced by long-term, harvest-based income. The lack of the necessary active capital forces a number of companies towards low-cost production, which implies cuts in irrigation investments and nutrient recharge technologies.

Irrigation is a rather costly technological element, which has been reduced significantly. As has been pointed out the 1990 irrigation regime served five plants in an area of 1,153 ha at an average of 110 mms depth. The amount of irrigated water amounted to 1,222,000 cubic meters. The costs stood at less than 10 HUF/cubic meter. The changing weather conditions of the previous years demanded irrigation on a 900-1,100 ha area. Until June 1994 the average moisture content of the soils remained higher than in the previous years. The irrigation output for 1994 has covered 651 ha of sugar-beet , 213 ha of potatoes, 67 ha of alfalfa, 24 ha of field crops and 8 ha of hay. A total area of 963 has been irrigated to a depth of 80 mm.

This equals 772,600 cubic meters of irrigation water. Sugar beet and potato fields received 1-3 treatments of irrigation, all other crops had single irrigation. Alfalfa has only been irrigated in the replant fields for the second cut. The total amount of irrigated water has dropped 450,000 cubic meters (in comparison to 1990), whereas irrigation costs have increased by 60-80%. Although no exact costs analyses are available for 1994, the estimated cost for irrigation lies between 15-19 HUF/cubic meter.

The currently serviceable irrigation equipment provides a capacity of 2.5-3.0 million cubic meters for 1994. Half of the incurred costs should fall on the agents, who had damaged the water regime. The provision of the minimum requirement (1.3-1.8 million cubic meters of irrigating water) costs about 22.1-30.6 million HUF. The altered water table level conditions require the following minimum compensation costs: borehole well establishments: 10.1 million HUF, new machinery and maintenance: 19 million HUF, increased irrigation demand: 22.1 million HUF. Hence, the added costs of irrigation stand at 51.2 million HUF. The provision of optimum irrigating conditions costs 81.6 million HUF. This is the total amount of the extra cost, which is incurred from the diversion of the Danube.

Chart 4: Yield of arable crops in the Szigetköz-region

	13 yrs average				1993			
Species	Szigetköz (ha)	tons/ha	tons	crop value /1000HUF	ha	tons/ha	tons	crop value /1000HUF
Wheat	5688	5.50	31284	265914	6118	3.98	24350	206975
Winter barley	752	4.84	3640	29120	562	3.21	1804	14432
Spring barley	2186	5.06	11061	88488	1772	3.25	5759	46072
Pea(sowing)	509	2.76	1405	21075	1479	1.69	2500	37500
Pea	216	3.49	754	22620	111	1.80	200	6000
Sunflower	902	2.30	2075	37350	1083	3.02	3270	58860
Potatoes	345	28.06	9681	116172	204	23.75	4845	58140
Corn	3643	6.75	24590	245900	3631	5.24	19026	190260
Sileage corn	1742	26.72	46546	69819	1420	26.72	37942	56913
Sugar beet	2703	40.68	109958	274895	1734	37.82	65580	163950
Alfalfa (green matter content)	814	8.12	6610	33050	605	7.20	4356	21780
Total	19500			1204403	18719			860882

Chart 5: Yield loss and the influential conditioning factors in 1993 compared to the average values of the period between 1980-1992

Species	Yield loss		Total		Weather conditions		Ground water		Techn.faults	
	tons/ha	%	tons	1000 HUF	tons	1000 HUF	tons	1000 HUF	tons	1000 HUF
Wheat	1.52	-27.6	9287	78940	4756	40426	2449	20816	2082	17968
Winter barley	1.63	-33.7	916	7328	733	5864	-----	------	183	1464
Spring barley	1.81	-35.8	3207	25656	2001	16008	683	5464	523	4184
Pea(sowing)	1.07	-38.8	1582	23730	1072	16080	194	2910	316	4740
Pea	1.69	-48.4	187	5610	152	4560	-----	-----	35	1050
Sunflower	----	+31.3	----	-----	-----	-----	-----	-----	----	----
Potatoes	4.31	-15.8	879	10548	578	6936	125	1500	176	2112
Corn	1.51	-22.4	5483	54830	3136	31360	1020	10200	1327	13270
Sileage corn	0	0	1217	1825	395	592	505	757	317	476
Sugar beet	2.86	-7.0	4959	12397	2370	5925	1760	4400	829	2072
Alfalfa	0.92	-11.3	557	2785	340	1700	101	505	116	580
Grass	-----	-----	2346	-----	-----	------	1064	3192	-----	-----
Total			30620	223649	15533	129451	6837	49744	5904	47646

References:

Palkovits, G. 1994a.: A növénytermesztésre ható tényezők és értékelésük módszere *(The evaluation of the plant production)* on behalf of Ministry of Foreign Affairs

Palkovits, G. 1994b.: A szigetközi növénytermesztést ért károk mértéke. *(Measured damages of plant production)* on behalf of Ministry of Foreign Affairs

Palkovits, G. 1994c.: A talajvízszint változásának hatása a mezőgazdasági hasznosítású területek öntözési körülményeire, gazdasági helyzetére. *(The impact of changing groundwater levels on irrigation economical assessment)* on behalf of Ministry of Foreign Affairs

Annex 21

DEEP STRUCTURE AND SEISMIC HAZARD OF THE GABČÍKOVO-NAGYMAROS REGION

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Budapest

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1. Introduction

In accordance with the contract between the Geological Institute of Hungary and the Department of International Justice of the Foreign Ministry, a study of deep structure and seismic hazard of the Gabčíkovo-Nagymaros region was produced. The region in question is situated within the Little Hungarian Plain (Hungary) – Danube Lowland (Slovakia), thus, it seems to be useful to extend the study over the whole of that area.

2. Deep Structure

The Little Hungarian Plain – Danube Lowland is divided by the Slovak-Hungarian border into two parts of comparable size (Figure 1). In the Southeast of both the Hungarian and Slovak parts, the pre-Tertiary basement is composed of Permian-Mesozoic and underlying Paleozoic sequences; in the remaining areas, it consists mostly of metamorphic rocks. Late Paleozoic to Mesozoic sediments are only found in the (NW-N-NE) peripheral areas (Fusán et al., 1972b, 1987b, Fülöp and Dank, 1987, Dank and Fülöp, 1990).

Tectonic qualification of the south-eastern areas – 'Transdanubian Range Unit' – is uniform in Slovakia and Hungary whereas there is a serious discrepancy in the tectonic subdivision of the areas with metamorphic basement. Subdivision in Hungary (Császár and Haas, 1984, Brezsnyánszky and Haas, 1985, Fülöp and Dank, 1987, Dank and Fülöp, 1990, Fülöp, 1990) seems to be based on clear chronological and petrographic criteria: the 'Penninic Unit' consists of metamorphosed Mesozoic, the 'Lower Austroalpine Unit', of pre-Mesozoic crystalline rocks metamorphosed in amphibolite facies, and the 'Upper Austroalpine Unit', of anchi- and epimetamorphic Paleozoic rocks. At the same time, distinction between the 'Tatric' and 'Veporic' crystalline rocks in Slovakia seems to be based primarily on the position of the boreholes in the regional tectonic structure, and not on real petrographic features.

That difference forms a barrier for tectonic correlation of the metamorphic units in the basement of the Little Hungarian Plain and Danube Lowland. As it will be demonstrated below, the barrier in question is not necessarily impassable and the correlation opens new perspectives in understanding the basement structure.

2.1. TECTONIC POSITION AND FORMULATING PROBLEMS

The major tectonic boundary within the pre-Tertiary basement of the Little Hungarian Plain – Danube Lowland is Rába Line (Scheffer and Kántás, 1949) in Hungary and Hurbanovo Line (Gaža and Beinhauerová, 1977) in Slovakia. To the southeast is the Transdanubian Range Unit while, to the north and northwest, the at least 120 km long Alpine-Carpathian transition section (Figure 1) is situated. The transition is expressed in the 'Little Carpathian' influence in the Rosalia Mountains – Leitha and Hainburg Hills (Pahr, 1980b) and in the 'East Alpine' influence in the Little Carpathians (Mahel', 1986). As a consequence, the applicability of pure Alpine or pure Carpathian terminology seems to be doubtful.

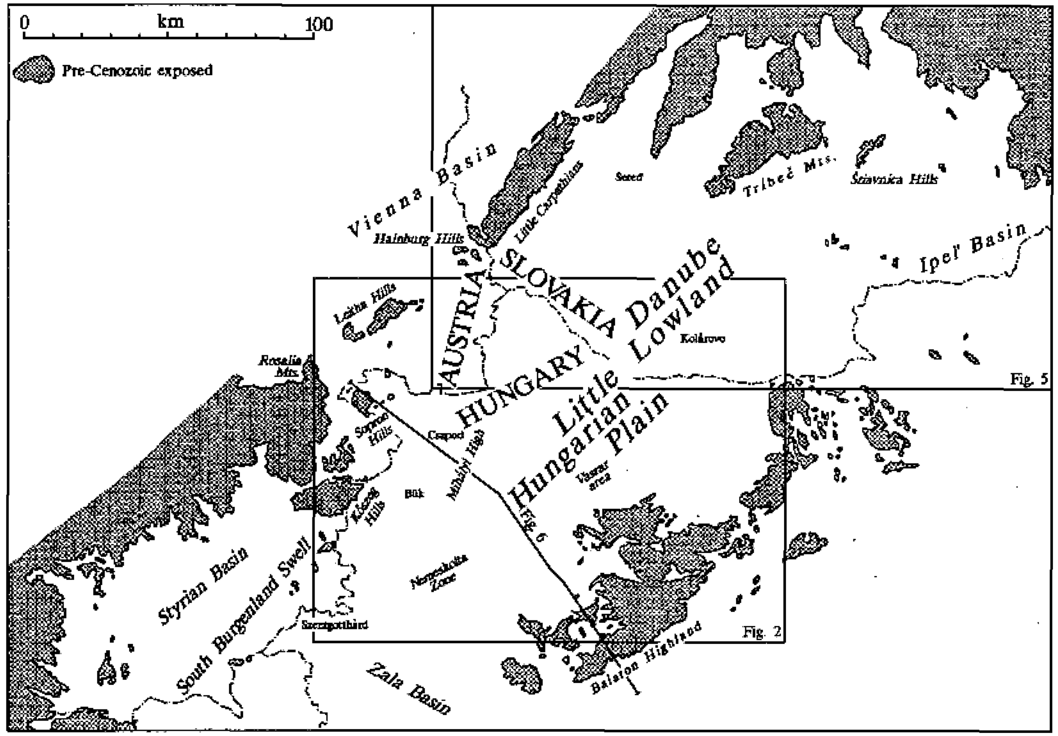

Figure 1: Index map of the Little Hungarian Plain – Danube Lowland area

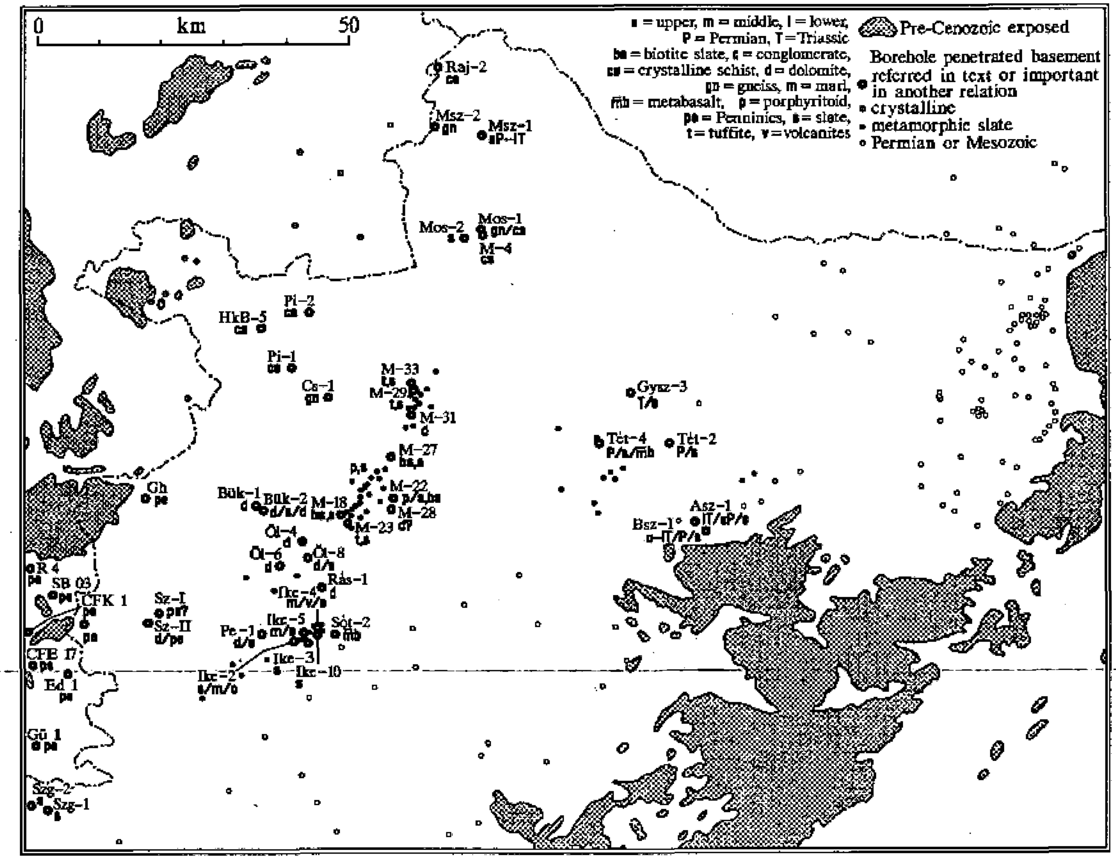

Figure 2: Boreholes with metamorphites in the basement of the Little Hungarian Plain

Characteristic of Mihályi Slate is its homogeneity. Of more than 40 boreholes, 2 penetrated dolomites (in breccias immediately below the overlying Miocene conglomerates, relationships with the slates being doubtful) and 6, mafic and/or intermediate volcanoclastic intercalations. The more than 100 cores mostly consisted of sericite to sericite-chlorite (sometimes up to chlorite) phyllites with various amounts of carbonate (calcite, dolomite, siderite) veins and infillings. In subordinated amounts, siltstones and sandstones as well as calcareous and dolomitic slates occur. Limestones are only observable as some centimetre lenses in calcareous slates. Acid volcanic influence reported by Balázs (1971) seems to be doubtful: idiomorphic albite and albite-oligoclase crystals are most probably porphyroblasts, not crystalloclasts, since the expected accompanying quartz is completely absent.

Mihályi Slate was traced for about 30 km in a SSW-NNE direction that points to its great thickness. Its metamorphism, according to Árkai et al. (1987), took place in the quartz-albite-muscovite-chlorite subfacies of the greenschist facies. In some of Mihályi phyllites, biotite was observable (e.g. in Lelkes-Felvári's photo, see Fig. 29D in Fülöp, 1990) that points to the presence of the biotite subfacies as well. Consequently, the metamorphic grade of Mihályi Slate is analogous to that of Kőszeg Slate (Lelkes-Felvári, 1982).

Árkai et al. (1987) concluded from illite-crystallinity measurements, on the high geothermal gradient during the metamorphism of Mihályi Slate, characteristic of the Variscan metamorphism and different from that of the Penninics. That conclusion, however, is invalid since measurements from Mihályi were compared with the expected value for Kőszeg (Lelkes-Felvári, 1982), not with actual results which display no significant difference.

Árkai and Balogh (1989) reported a 116±5 and a 123±5 Ma K-Ar white mica age (Early Cretaceous) that significantly differs from those for the Penninics (Tertiary). That fact was interpreted in a pure 'Alpine' framework in terms of excluding Mesozoic and confirming the Paleozoic age of Mihályi Slate. That argumentation, however, would only be valid if the Mihályi area were constituent of the Alps. As shown above (Chapter 2), it cannot be excluded that the extreme eastern Penninics extends beyond the area affected by the Tertiary metamorphism. In that aspect, it would be of interest to know the metamorphic age of the Borinka Unit of the Little Carpathians which is comparable with the Penninics (Plašienka et al., 1991)). Mihályi Slate, therefore, may represent Penninic sediments with no Tertiary, i.e. with only Cretaceous metamorphism, whatsmore this would be coherent with all data available.

Bük Dolomite was qualified as a stratigraphic unit (Fülöp, 1990) on the basis of the Bük-1 (Figure 2) borehole section with dolomites and dolomite breccias for about 200 m (9 cores). Up to 20 km south and southeast of Bük-1, 7 other boreholes also penetrated dolomites, dolomite breccias and dolomite sandstones. The maximum thickness of dolomites (280 m) was observed in the borehole Öl-6. Within the 140 m basement sequence of Bük-2, marly slates (calcareous phyllites) of about 100 m in the thickness were both covered and underlain by dolomites whereas, in boreholes Ölbő Öl-8 and Pecöl Pe-1, dolomites were underlain by calcareous sericite slates. In the area with dolomites in the basement, four boreholes only penetrated various slates in a 20-60 m thickness. As seen, dolomites both vertically and horizontally alternate with calcareous slates and are probably close to them in a stratigraphic sense. Consequently, when discussing the basement tectonics, considering a dolomite-slate sequence seems to be necessary.

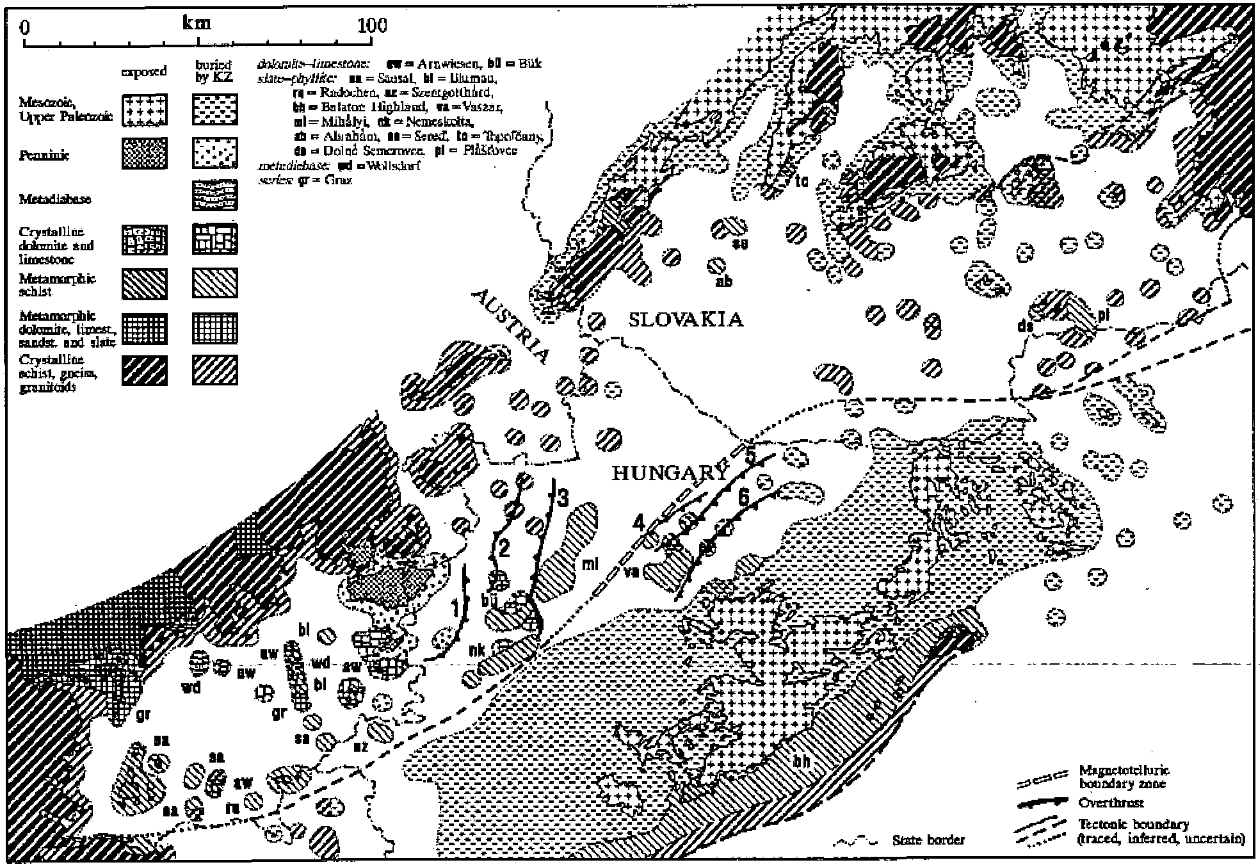

Figure 3: Pre-Cenozoic formations of the Little Hungarian Plain – Danube Lowland area and its surroundings

Sporadic b_0 values (Árkai et al., 1987) are analogous to those of Mihályi, not Nemeskolta Slate. K-Ar white mica ages, mostly for slates (140±6, 149±6, 178±7, 180±7 and 203±8, Árkai and Balogh, 1989), are significantly older than those for Mihályi Slate.

Szentgotthárd Phyllite is known from two boreholes (Figure 2) in about 25 km of the Nemeskolta and 60 km of the Mihályi area. Phyllites, sometimes with 1-2 mm calcite strips along the foliation are analogues of Mihályi rather than of Nemeskolta Slate. Illite crystallinity of a single sample (b_0=9.017 Ĺ Árkai et al., 1987) is equal to that for Kőszeg Slate (b_0=9.015 Ĺ, Lelkes-Felvári, 1982), K-Ar white mica age of the same single sample is 143±6 Ma (Árkai and Balogh, 1989), a little older than the ages for Mihályi Slate and equal to the youngest Bük Dolomite ages.

Structural relationships between the rock units outlined above can be seen in seismic sections. Pogácsás et al. (1991) presented a map of inter-basement overthrusts all over the country. For the Little Hungarian Plain, six overthrusts were displayed, three northwest and three southeast of the Rába Line (Figure 3). The latter is not visible in seismic sections, and that fact points to the steep position of the corresponding fault plane/zone. On the other hand, it is clearly detected by magnetic surveys as a zone which separates two areas of different geoelectric properties and cuts overthrusts detected in seismic sections (Figure 3).

Overthrust 1 coincides with the top of the Penninic Window at Kőszeg and can be interpreted as the base of the Austroalpine nappes. Their constituents, are not confirmed by drilling data. Overthrust 2 is in the opposite sense forming, together with Overthrust 1, something like a synform. Below it, borehole Csapod Cs-1 (Figure 2) penetrated micaschists with garnet, therefore, Overthrust 2 is not an equivalent of Overthrust 1. Farther southwards, below Overthrust 2, Bük Dolomite (and slate) appears. It is not correlatable with Csapod crystalline in a petrographic sense, but both of them may belong to the same nappe (e.g., Upper Austroalpine). Overthrust 3 separates both Csapod crystalline and Bük Dolomite from Mihályi Slate, the latter underlying them in a tectonic sense. That situation would be consistent with the correlation of Mihályi Slate with the Penninics, not Bük Dolomite. Moreover, it, in any case, contradicts the view of numerous geologists that the Csapod crystalline belongs to the Lower Austroalpine Nappe and the Mihályi Slate is part of the Upper Austroalpine Nappe. The petrographic (and stratigraphic?) heterogeneity of the Nemeskolta basement, may be due to its position within the dislocation zone of the Rába Line.

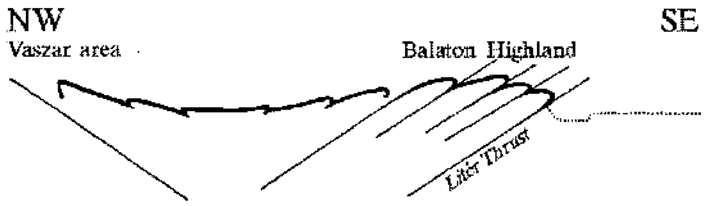

Figure 4: *The structure of the Transdanubian Range in a cross section, after Schmidt, 1961.*

Overthrusts 4-6 do not seriously influence the distribution of principal stratigraphic sequences (metamorphites, Permian sandstones and Triassic limestones), and thus, cannot bear significant magnitudes. Most probably, they are analogous to the Litér and other thrusts in the Balaton Highland, outlining the symmetry of the structure of the Transdanubian Range Syncline (Figure 4).

2.3. ALPINE AND CARPATHIAN ANALOGUES OF LOW-GRADE METAMORPHIC ROCKS

Numerous geologists regarded the Graz Paleozoic as the analogue of Mihályi Slate, Bük Dolomite and Szentgotthárd Phyllite. The Graz Paleozoic crops out in a 60×30 km area (Fritz et al., 1992) and consists of limestones and calcareous slates as well as dolomites and dolomite sandstones sometimes intercalated by mafic tuffs and lavas are characteristic. Shaly/silty sequences of sensible thickness occur in deepest horizons mostly intercalated by mafic volcanites and limestones, not dolomites.

The Graz Paleozoic is situated more than 100 km west of the Bük area, which are linked by Arnwiesen Dolomite (Flügel, 1988a-b) in the basement of the Styrian Basin. Blumau Series below Arnwiesen Dolomite consists of phyllites with limestone and dolomite intercalations, thus, may be correlated with the deeper levels of the Graz Paleozoic and, perhaps, of Bük Dolomite. Sausal Series south of Graz consists of greenschists, phyllites and sericite slates with limestone intercalations (Schönlaub, 1980). In boreholes it is traceable towards the east up to the Hungarian border (Flügel, 1988a-b). Szentgotthárd Phyllite was drilled in about 15 km of the last occurrence, and its correlation with the Graz Paleozoic is problematic.

Mihályi Slate is isolated from the Styrian Basin by the Bük-Arnwiesen series. No quasi-homogenous slate fields of comparable size exist in the area of the Graz Paleozoic on the surface. Taken in that sense, the Sausal Series would be similar, the presence of limestone intercalations in it however makes the correlation doubtful.

The metamorphism of the Graz Paleozoic ranges from late diagenetic through anchi- and up to epizonal (Hasenhüttl and Russegger, 1992). The amount of K-Ar ages is limited and ranges between 80 and 238 Ma (Becker et al., 1987, Fritz and Neubauer, 1990). Deeper nappes display younger ages(98-133 Ma in 6 samples and 80 Ma in 1 sample), than those in a higher position (150-200 Ma in 10 samples and 121, 138 and 238 Ma for three other samples) due to the increasing influence of the Alpine thermal with the burial depth (Fritz and Neubauer, 1990). From that point of view, Mihályi Slate could be correlated with the deeper nappes, and Bük Dolomite, with the higher nappes.

To summarise, Bük Dolomite is correlatable with the Graz Paleozoic through the Arnwiesen(-Blumau) link, and Szentgotthárd Phyllite, with the Sausal Series of uncertain stratigraphic and tectonic position. It is worth mentioning that both the Szentgotthárd and Bük sequences are still behind the Alpine section, not the Alpine-Carpathian transition. Correlation of Mihályi Slate (already situated behind the transition section) with any of the Austroalpine sequences, seems to be unconfirmed although not excluded.

Carpathian analogues of Mihályi Slate are difficult to find. In overviews of the Danube Lowland (Fusán et al., 1972a,, 1987a), no distinction is made between the epi- and mesozonal metamorphites, all of them being classified in the 'crystalline basement'. Since detailed petrographic descriptions are usually unavailable, the low-grade metamorphic rocks were selected mainly by names of rocks and lists of minerals (Biela, 1978a-b). 'Phyllites' and 'sericite-chlorite slates' were regarded low-grade (epizonal), although an obvious uncertainty remains with the content of the terms 'phyllite' and 'sericite', which may influence the validity of the definition 'low-grade'.

In the Danube Lowland, 'low-grade' metamorphic rocks were mentioned in three areas (Figure 5):

(1) southeastern foreland and buried southwestern continuation of the Považský Inovec Hills (biotite phyllite in Topoľčany To-1, quartz-biotite phyllite and phyllite in Sereď Se-5, phyllite and quartz phyllite in Sereď Se-6, phyllite in Sereď Se-8 and sericite phyllite in Abrahám Ab-1);

(2) Tiavnica Hills (quartz-sericite-chlorite slate in KOV-39, phyllite in KOV-40, sericite-chlorite slate in KOV-41, sericite-chlorite slate, partly influenced by contact metamorphism, and biotite slate in VŠ-1, sericite-chlorite slate with quartz lenses and greenschists in VŠ-5, sericite-chlorite slate with sillimanite, andalusite and biotite in VŠ-6 and sericite-chlorite slate with quartz lenses in VŠ-8);

(3) western Ipe Basin (sericite and sericite-chlorite phyllite with intercalations of epidote amphibolites and sericite-quartz phyllites, fine-grained quartzite and sericite-quartz phyllite, sericite, calcite-sericite and graphite-calcite-sericite phyllite in Dolnéé Semerovce ŠV-8, crystalline schist/slate in Plášovce Pl-1, phyllite with quartzite intercalations in Plášovce PU-1, phyllite in Plášovce PU-2 and sericite-chlorite and chlorite phyllite and schist in Ipeskéé Predmestie VV-5).

The Sereď area is open to the south, but, for about 80 km towards the Mihályi area, no borehole reached the basement. Four metres of brecciated 'Lower Triassic' shale and sandstone (Se-5) and 36 m 'Mesozoic' calcareous sandstone and arenaceous limestone (To-1) in the top of the metamorphites, cannot be regarded as a normal stratigraphic cover, thus, the phyllite sequence is not necessarily Paleozoic in age. Equivalents of the Alpine Penninics in the Little Carpathians (Plašienka et al., 1991) point to the need to re-evaluate the phyllite sequence, considering the possibility of its Mesozoic age and tectonic position below the surrounding crystalline and granite complexes (Senec Sn-1, Trnava Tr-1, Hlohovec Hl-2, Velké Záluie VZ-1 etc.)

The two other areas seem to be 'closed' towards the southwest by boreholes with a mesometamorphic or granite basement (Kolárovo Ko, Šurany Šu, Podhájska Podh, Pozba Po). The density of boreholes, however, is insufficient to exclude the possibility of correlation, about 80 km towards the Mihályi area still have no borehole data on the basement composition.

Presence of a distinct low-grade metamorphic sequence of Paleozoic age in the Štiavnica area is doubtful because, on one the hand there are similar names for Lower Triassic rocks (KOV-39 and -40), , and on the other gneisses, migmatites and cataclastic granitoids are present(KOV-33, -39, -41 and VŠ-1). On the contrary, biotite was not mentioned even in detailed descriptions of the basement rocks from the western Ipe Basin (ŠV-8: Reichwalder, 1981, VV-5: Klinec, 1976), thus, the presence of a low-grade metamorphic sequence in that area (3) seems to be very probable. Permian to Lower Triassic (low-metamorphic) sediments in the top (ŠV-8) confirm its Paleozoic age.

Summarising: the presence of low-grade metamorphic slate sequences can be supposed in two areas of the Slovak basement, in the Sereď area and in the western Ipeľ Basin (east of Danube Lowland). The age of the slate sequence can be both Mesozoic or Paleozoic in the first area and is Paleozoic in the second.

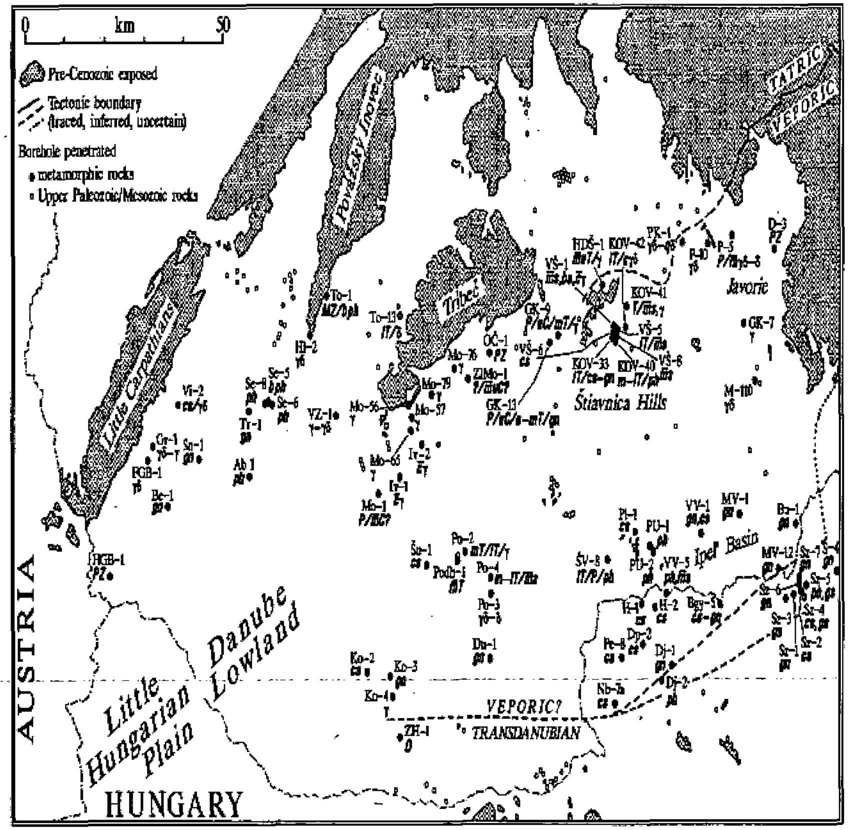

Figure 5: Boreholes with metamorphites in the basement of the Danube Lowland (Slovakia)

Taking into account the absence of any boreholes in the central Little Hungarian Plain or Danube Lowland (60×80 km) and the limited amount of them in most of basin areas, the existence of still unknown metamorphic basement sequences cannot excluded. They could partly correspond to Paleozoic slate sequences of the exposed areas (Pezinok, Pernek and Harmonia: Plašienka et al., 1991, Janov grúň: Miko, 1981, Predná hoa: Bajaník et al., 1979, Gelnica and Rakovec: Grecula, 1982), or they may be completely new.

2.4. *Crustal Structure*

Crustal structure is frequently discussed in terms of basement and Moho topography as well as fault and block delineation. Here, another aspect of the crustal structure, viz. composition heterogeneity recorded in magnetic and gravity anomaly patterns will be discussed.

Intense magnetic anomalies are characteristic of the Little Hungarian Plain (Haáz and Komáromi, 1967), the sources of them being within the pre-Cenozoic basement (Posgay, 1967a-b). They are situated in the immediate neighbourhood of the Rechnitz-Kőszeg Penninic Window, and that fact gave the idea to relate the anomalies to the mafic and ultramafic magmatites of the Rechnitz-Kőszeg series (Varrók, 1963, Balla, 1982). Magnetic anomalies were also traced in the Styrian Basin (Seiberl, 1988) and interpreted, together with those in Hungary, the same way (Hoffer et al., 1991).

It is remarkable, however, that intense magnetic anomalies both in Hungary and Austria are restricted to basins and suddenly diminish in the exposed areas of the Penninics. Moreover, mafic and ultramafic magmatites rest in nappes above the Penninic sediments (Pahr, 1980a) whereas the intense magnetic anomalies come from sources within the pre-Cenozoic basement (Posgay, 1967a-b). That is why doubts remain concerning the origin of the anomalies (Oberladstädter et al., 1979).

Gravity anomalies both in Austria and Hungary were interpreted in terms of basement and Moho topography (Renner and Stegena, 1966, Walach and Weber, 1987, Posch et al., 1989). The intense Kolárovo gravity high, primarily in Slovakia, was also related to a hypothetical basement high (Gaža and Beinhauerová, 1977), but in the light of seismic and drilling data, it was re-interpreted and connected with an intra-crustal high-density mass (Bielik et al., 1986). An analysis of gravity anomalies along a seismic section from the Sopron Hills up to Lake Balaton revealed the presence of an intra-crustal high-density mass below the Mihályi area (Figure 6), and that mass is traceable towards the southwest, across the Styrian and Zala basins (Balla, 1993). Altogether, the intra-crustal high-density mass is now traceable for more than 200 km covering the zone of the intense magnetic anomalies (Figure 7). In the first approximation, coincidence of the magnetic and gravity anomalies is explicable in terms of the mafic/ultramafic composition of the intra-crustal source.

The position of the intra-crustal high-density mass in the general structure of the Alps induced an idea to correlate it with the well-known Ivrea Zone of the Western Alps and to outline a possibility of an approximately 500 km dextral offset upon the Insubric-Periadriatic Lineament (Figure 8). The absence of high-grade metamorphism above the high-density mass, however, is a significant difference from the Ivrea Zone. It might be explained by a much deeper position of the top of the mass below the Little Hungarian Plain area compared with that in the Ivrea Zone. Unfortunately, no comparisons of the expected and observable metamorphic zonation and no computations of the corresponding thermal models were performed to support that concept.

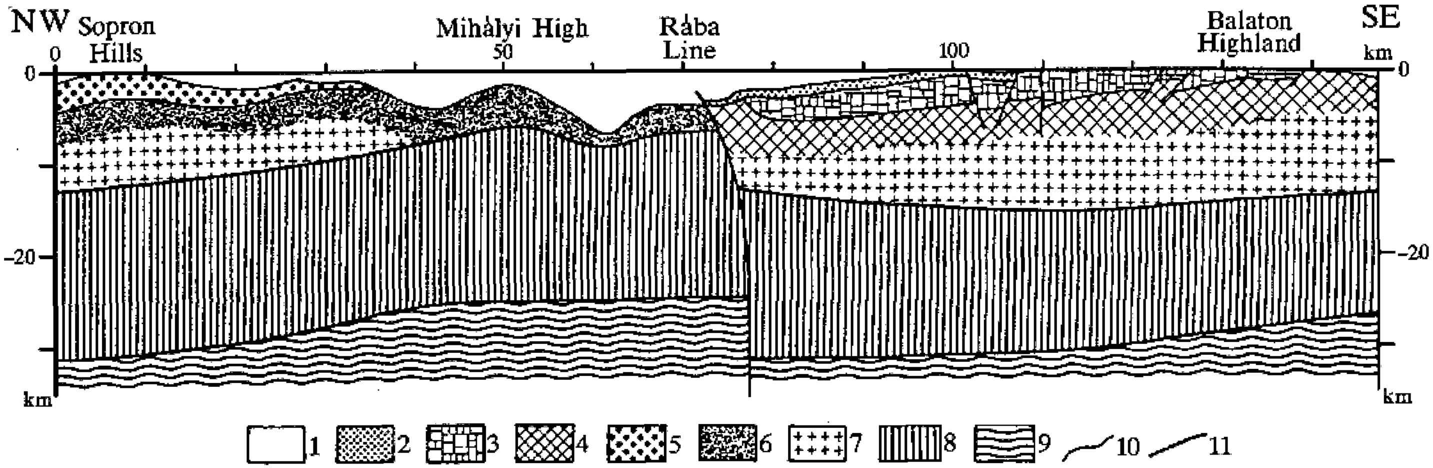

Figure 6: *Crustal section across the Little Hungarian Plain, after Balla et al., 1991 (for location, see Figure 1)*

1 = Cenozoic basin fill, 2 = Senonian sediments, 3 = Permian to Mesozoic sequence of the Transdanubian Range, 4 = Variscan basement of the Transdanubian Range, 5 = Austroalpine crystalline, 6 = Penninics, 7 = "granitic layer", 8 = "basaltic layer" or any high-density mass, 9 = upper mantle, 10 = geological boundary, 11 = fault

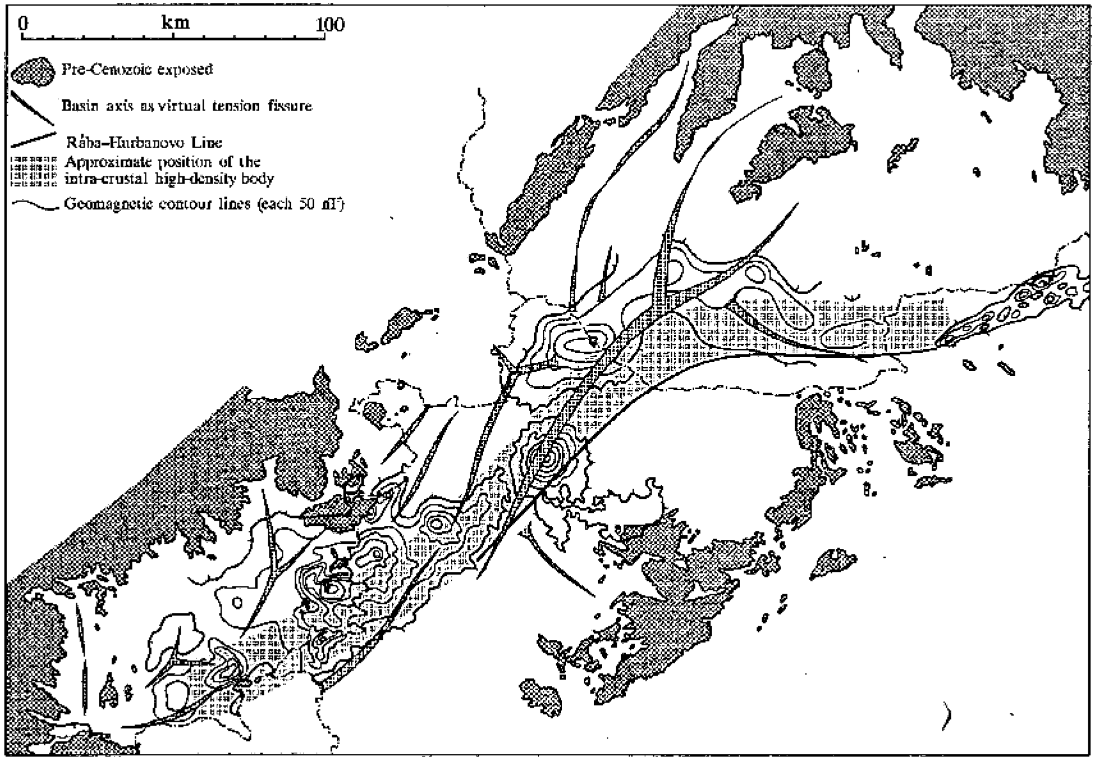

Figure 7: *High-density body, magnetic anomalies and basin axes in the Little Hungarian Plain – Danube Lowland area*

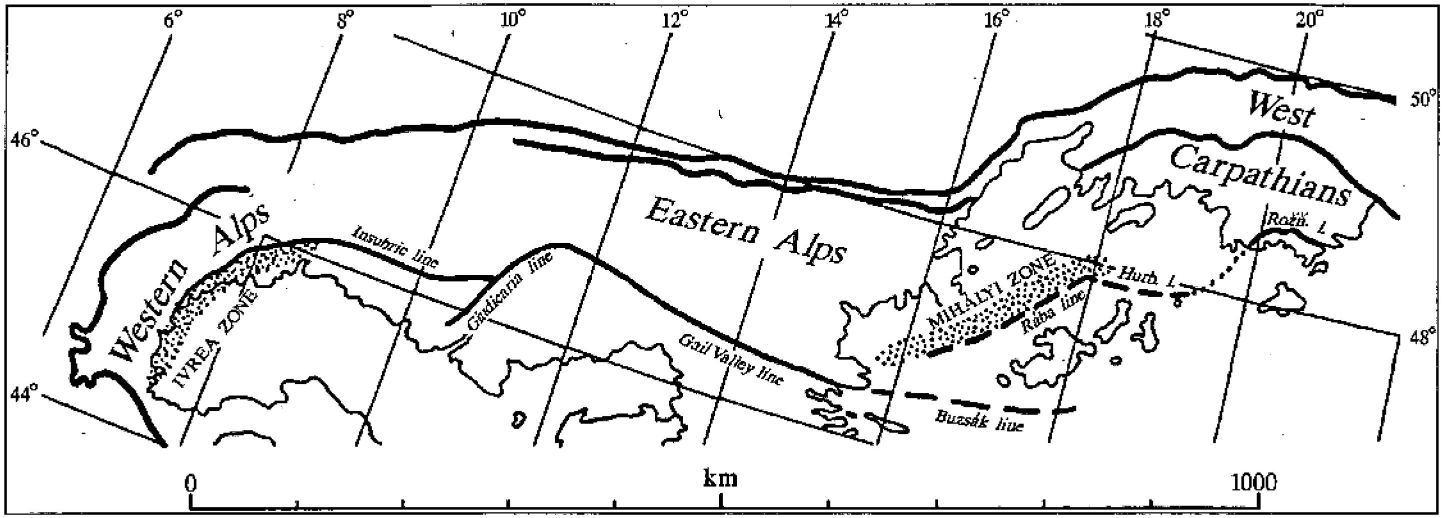

Figure 8: *Ivrea and Mihályi zones in the Alpine-Carpathian structure, after Balla, 1993.*

Three alternative explanations for the intra-crustal high-density mass can be outlined as follows:

(1) an intrusion connected with the Miocene volcanism (Bielik et al., 1986);

(2) an inclusion within the continental crust of a piece of the oceanic lithosphere which arose due to the partly open Penninic basin ;

(3) a protrusion of the upper mantle in connection with the Miocene extension.

In the intrusion model, the size of the mass in question is incomprehensible, as is its linear shape in both the intrusion and inclusion models. The inclusion and protrusion models, do not account for the vertical asymmetry of the mass (Figure 6) nor does the protrusion model explain the discordant position of the mass in maps relative to the basement topography (Figure 7). As seen, even in the first approximation, no real alternative for the Ivrea model can be offered although mantle protrusions in the axial zones of the deepest partial basins may complicate the picture due to additional high-density masses.

In the Ivrea model, the Rába Line is accompanied from the northwest by the most elevated (in a structural sense) zone, which suffered the most intense erosion before the Miocene subsidence. In other words, the deepest tectonic units, the Penninics or even its base, are expected in that zone. In the Western Alps and the Tauern Window, the base consists of continental series metamorphosed in high greenschist and/or low amphibolite facies. From that point of view, Mihályi Slate might belong to the Penninic series, and its analogues might cover large areas in the central Little Hungarian Plain – Danube Lowland where as noted earlier, there are no boreholes. The Sered' phyllites may form an apophysis of that Penninic field. Within the zone of high gravity, the continental basement of the Penninic Nappe might also occur in the base of the Miocene basin filling, the Kolárovo metamorphites and granites being possible candidates.

2.5. Summary

The pre-Cenozoic basement of the Little Hungarian Plain – Danube Lowland is divided into two parts by the Rába-Hurbanovo Line. Southeast of the Line, is the Transdanubian Range Unit (Figure 3), with Paleozoic sequences and overlying them, Permian and Triassic sediments. Northwest of the Rába Line, the pre-Cenozoic basement consists of Alpine-Carpathian metamorphic series which are only covered by Upper Paleozoic and Mesozoic sediments in the northwestern, northern and northeastern peripheral areas.

Mesozonal metamorphites belong to the Austroalpine or Tatroveporic nappes with no real possibility for further subdivision on the basis of its composition in the drill cores. As a consequence, classifying all the mesometamorphites east of the Sopron area, into the 'Lower Austroalpine Unit' in Hungary, as well as distinguishing between the 'Tatric' and 'Veporic' crystalline south of the Tribeć-Štiavnica area in Slovakia (divided by the 'Vepor Line' up to the Hungarian border) seems to be groundless.

Epi- to anchizonal Paleozoic metamorphites have been found in the vicinity of Graz, in the basement of the Styrian Basin (Arnwiesen, Blumau and Sausal series) and in southwestern Hungary (Szentgotthárd Phyllite – the probable equivalent of the Sausal series, Bük Dolomite-Slate – the probable equivalent of the Graz Paleozoic and of the Arnwiesen possibly including Blumau series). Similar rocks may also be constituents of the dislocation zone of the Rába Line (Nemeskolta area). In Slovakia, epizonal metamorphites of Paleozoic age can be assumed in the western Ipe Basin (Dolné Semerovce, Plášťovce, Ipeľské Predmestie) surrounded by boreholes containing mesometamorphic basement rocks. They are in about 280 km of the Graz Paleozoic (Upper Austroalpine) and in 160 km of its Hungarian equivalents, and are traditionally classified as Veporic crystalline.

Epizonal Mesozoic metamorphites, products of Tertiary metamorphism, crop out in the Rechnitz-Kőszeg Penninic Window. Their lithological analogues were established in the Little Carpathians, but no information is available on the presence or absence of Tertiary metamorphism. In principle, the eastern closure of the Penninic basin and eastern termination of the Tertiary metamorphism, do not necessarily coincide. Therefore it seems possible that in the Alpine-Carpathian transition zone (Rosalia Mountains through Little Carpathians and Little Hungarian Plain – Danube Lowland areas behind them, Figure 1), Penninic sediments with no Tertiary, only Cretaceous, metamorphism occur.

In the Little Hungarian Plain, Mihályi Slate emerging from below the overthrust Upper Austroalpine Bük Dolomite-Slate, is analogous to the Kőszeg series in a lithological sense, the only difference being in the Cretaceous, rather than Tertiary, age of its metamorphism. Thus, Mihályi Slate might be representative of the Penninic series with no Tertiary metamorphism. This does not exclude the possibility of its Paleozoic age. In Slovakia (80 km north of Mihályi Slate but without any borehole data on the basement between them), the Sered' phyllites emerge from below the overthrust Tatric Mesozoic. The age of them is unconstrained, thus, Mesozoic is not excluded, and an analogy with Mihályi Slate seems to be possible although as yet unconfirmed.

The Rába Line is accompanied from the northwest by a zone of intra-crustal high-density mass. This can be regarded as similar to the Ivrea Zone of the Western Alps (Figure 8), alternative explanations (Miocene volcanism-related intrusion, oceanic lithosphere inclusion and upper mantle protrusion) being inconsistent with the size, shape or position of the zone in question. In the frame of the Ivrea analogy, tectonic units of deepest position would be expected in the basement above the high-density mass. The Penninic provenance of Mihályi Slate would be compatible with that expectation, and it seems possible even without supporting borehole data, that in the central Little Hungarian Plain – Danube Lowland there are mostly Penninic sequences with no Tertiary metamorphism. This contradicts the hypothesis of 'Tatric' and 'Veporic' mesometamorphites and granites with the 'Vepor Line' between them, underlying the Neogene basin fill. Kolárovo granites and mesometamorphites do not necessarily overlie those Penninics but perhaps underlie them.

3. Seismic Hazard

The evaluation of the seismic hazard comprises of various elements, one of them being the analysis of the structural control of the earthquake distribution in space. In this study , that aspect of the seismic hazard evaluation of the Gabčíkovo-Nagymaros region will be outlined. All the other aspects, e.g. the earthquake distribution in time, the quantitative value of the seismic hazard etc., are beyond our competence and should be given by the Seismological Observatory of the Institute for Geodesy and Geophysics in the Hungarian Academy of Sciences.

For an analysis of the factors controlling the earthquake distribution in space, a great number of earthquakes is usually needed. In areas of low seismicity such as Hungary, the insufficient earthquake data can only be compensated by including large areas in the analysis. That is why the evaluation of seismic hazard for the Gabčíkovo-Nagymaros region will be preceded by a seismic hazard evaluation for the whole of Hungary. That analysis is based on four maps in scale 1:500.000 as follows:

1) faults due to Pleistocene activity from geological and geomorphic data (Jámbor et al., 1993a and Schweitzer et al., 1993),

2) geophysical lineaments (Szabó et al., 1993),

3) faults in the pre-Cenozoic basement (Fülöp and Dank, 1987),

4) spatial distribution of Hungarian earthquakes (Szeidovitz and Mónus, 1993).

The two maps indicated in 1) were compiled using for the most part similar data and similar ideas. They resulted in a picture (Figure 9) which conforms with the dominating (although not the autocratic) view for many decades in Hungarian geological and geomorphic literature, and which is the first synthesis for the neotectonics of Hungary, scale 1:500.000.

The work in 2) presents lineaments derived first of all from gravity data and connected with the basement topography and probably of fault origin. Additionally, from reflection seismic sections, some faults have been displayed. It would only be possible to better estimate the age of corresponding faults within the Pliocene-Quaternary period, by means of additional data or considerations.

The map in 3), with corrections from a new review (Figure 10), have been used primarily for checking the geological sense of geophysical lineaments.

Map 4), allowed the selection of the faults which indeed control the earthquake distribution.

Comparison of the maps (Jámbor et al., 1993b, Schweitzer et al., 1993, Szabó et al., 1993, Fülöp and Dank, 1987, Szeidovitz and Mónus, 1993) revealed certain correlations and discrepancies as follows:

1) There is no principal contradiction between the two geological-geomorphic versions, and differences between them are mainly found in the density of the fault network and location/outline of certain faults.

2) Geophysical lineaments correlate well with the faults known from geological data, the main difference is that they are dispersed in certain zones around the faults. This probably reflects the fact that faults are usually traced by sporadic borehole data as single lines, whereas geophysical lineaments demonstrate their complex nature.

3) The 'faults due to Pleistocene activity' from geological-geomorphic data are hardly as the prevailing part of both the geophysical lineaments and basement faults are derived from borehole data. Consequently, their tectonic nature should be carefully checked and the term 'geomorphic lineaments' seems more suited.

4) Earthquake concentration zones correlate well with the geophysical lineaments (Figure 11) and basement faults, but are disharmonious with the geomorphic lineaments.

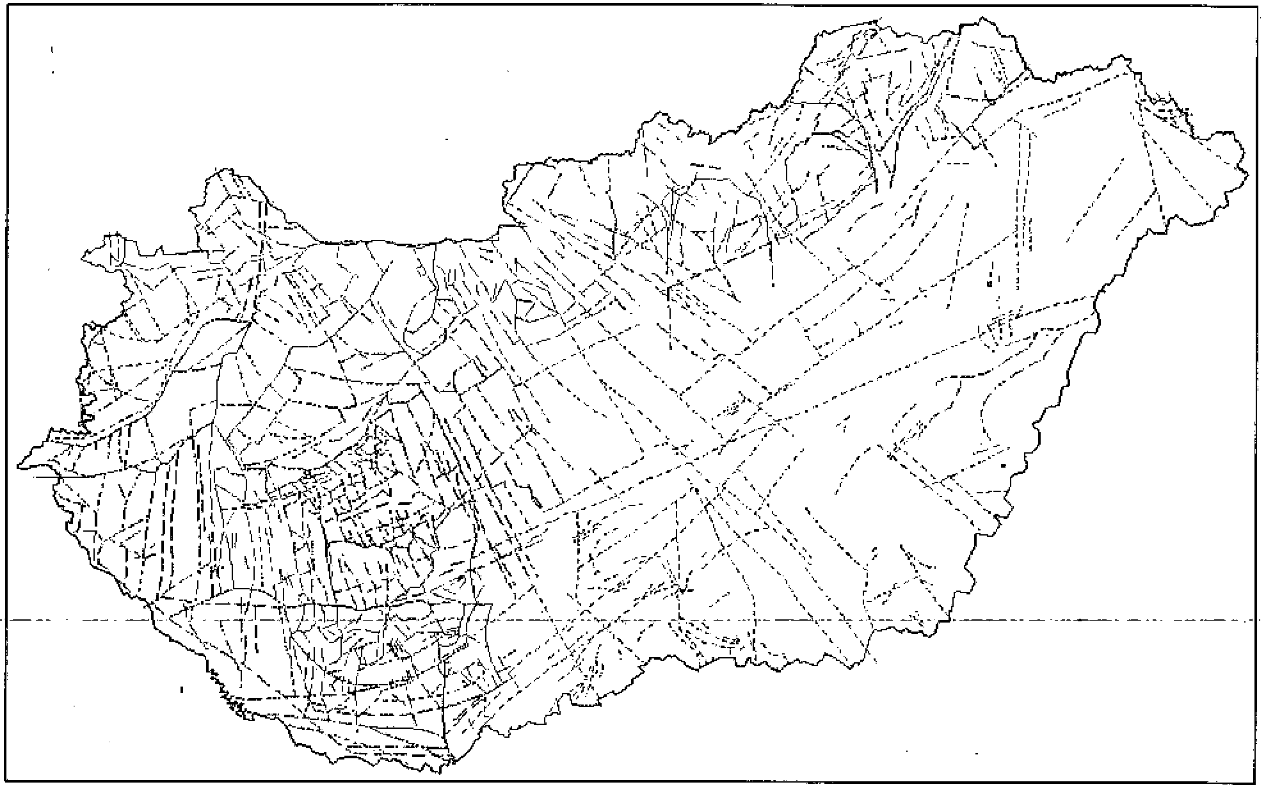

Figure 9: *Faults with Pleistocene activity in Hungary, Jámbor et al., 1993b.*

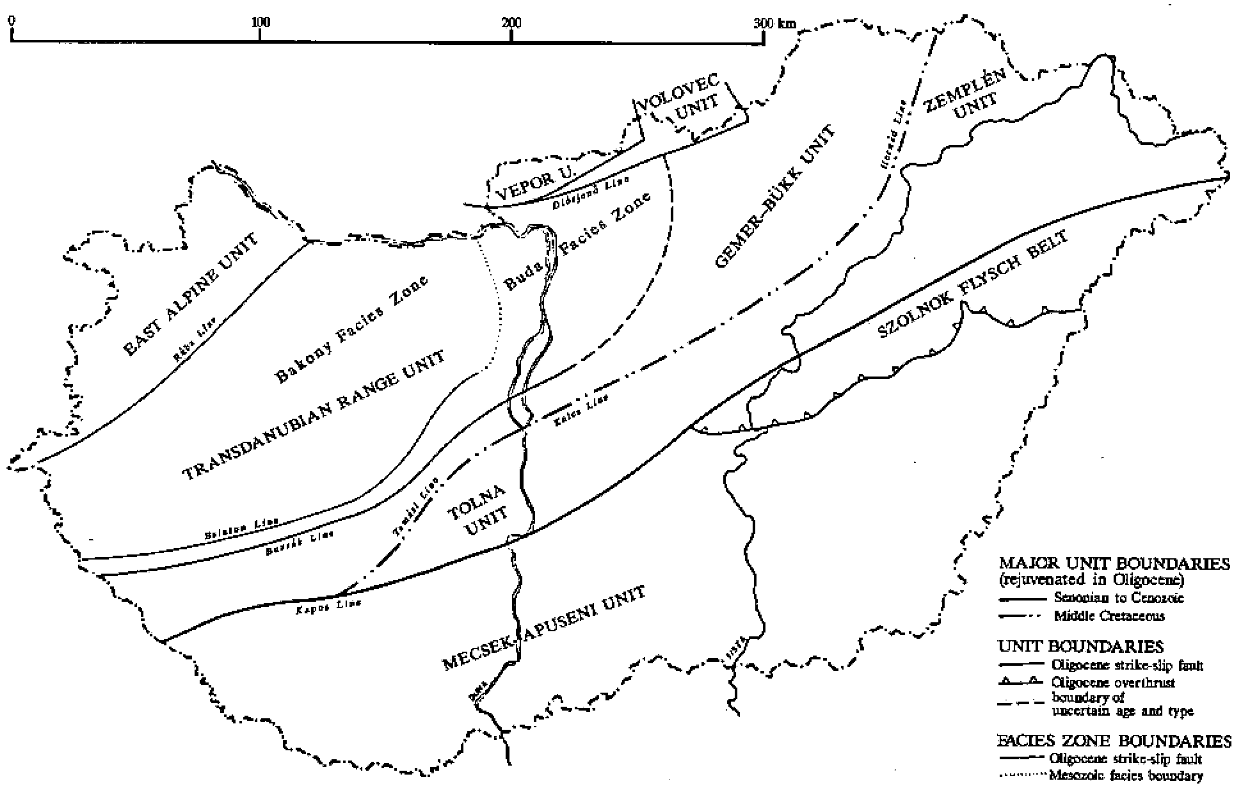

***Figure 10:** Lineaments in the basement of Hungary*

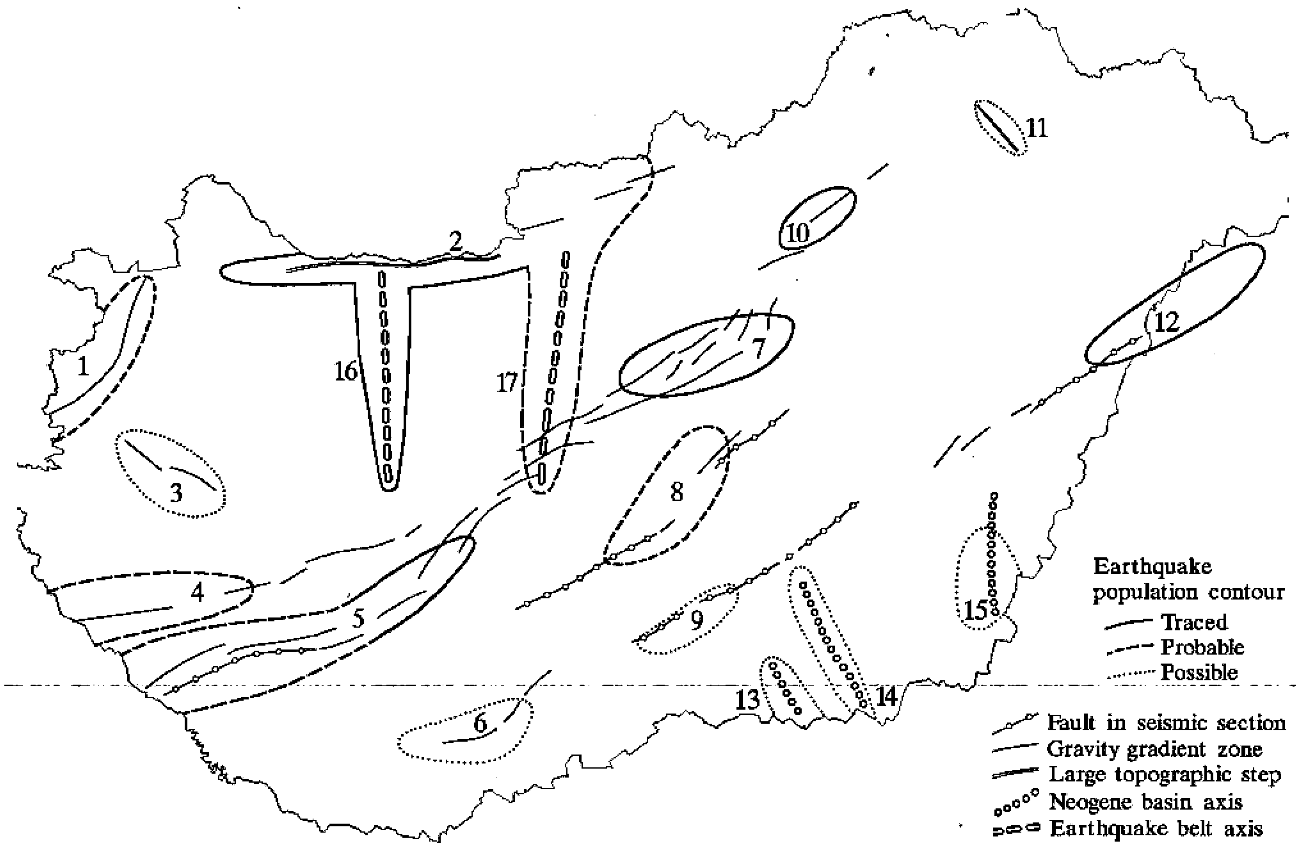

Figure 11: Earthquake populations and various lineaments, after Balla et al., 1993b

As a result of these comparisons, the reason why geomorphic analysis did not result in a fault network correlatable with either the geophysical lineaments and basement faults, or with the earthquake distribution, has proved to be fundamental. That is why it will be especially analysed below.

3.1. ON THE GEOMORPHIC LINEAMENTS

According to Jámbor (1993), the principal considerations in favour of the existence of young faults are as follows:

– in a tectonic sense, the territory of Hungary was consolidated very late, so young faults are possible;

– uplift of the hills and mountains as well as subsidence of basins resulted in altitude differences between synchronous Pleistocene sequences of up to several hundred meters, and, due to the horizontal strata, that situation could have only arisen by fault activity;

– the tectonic origin is the only reasonable explanation for the fan-like valley system in Transdanubia, and all of those who participated in the map compilation are in agreement with that;

– intense changes of the thicknesses of the Pleistocene sediments in basins should be related to faults;– faults detected in Cenozoic sequences by reflection profiles in seismic sections could be rejuvenated in Pleistocene.

Based on the above considerations, Jámbor (1993) traced the faults with Pleistocene activity (Figure 9) along certain lines and zones as follows:

– boundaries between the hills/mountains and basins, and between hilly/mountain areas differently uplifted in the Pleistocene, if those boundaries are traceable as breaks in the altitude of synchronous Pliocene or Quaternary sequences;

– valleys which belong to the fan-like system in Transdanubia;

– zones of sharp thickness changes of the Pleistocene sediments in basins;

– faults which cut Pliocene sequences in seismic sections.

Jámbor (1993) outlined problems in detecting faults as follows:

– the Pleistocene faults are difficult to be detected due to the bad exposure as well as to the subsequent erosion and soil formation;

– in seismic sections, no faults are visible below the most of the valleys interpreted as tectonically controlled (this fact, however, in his opinion does not contradict the existence of faults since it is usually explicable in terms of displacements of less than ten meters);

– the uppermost, 200-400 m level of the hydrocarbon-prospective reflection seismic sections, is free of recorded profiles, thus the Pleistocene activity of the faults cannot be directly confirmed.

It is concluded that the only faults thatcan be accepted as directly confirmed are those which have been detected by the different altitude position of Pleistocene sequences, i.e. on the basis of observable offsets. All other faults have to be regarded as indirectly defined. Faults otherwise outlined will be discussed separately.

In the map of Jámbor et al. (1993a) most of the faults are displayed in the area between the Bakony and Mecsek Mountains. Hungarian geological literature on the neotectonics of that area has been analysed by Gerner (1993). That area can be regarded as a standard for Hungary, thus its discussion will be especially emphasised.

3.1.1. Faults detected by direct data

An insignificant part of the faults due to Pleistocene activity is only confirmed by direct observations. The surface of these faults is not visible but which are accompanied by sharp topographic steps and on the limbs of which, synchronous Pleistocene strata are lying at different altitudes, and so they are regarded as directly detected. The two maps display those faults, mostly in hilly areas, approximately in the same places but in different ways. Jámbor et al. (1993a) show them as wavy or zigzagged lines whereas Schweitzer et al. (1993), as straight or slightly curved lines. From a tectonic point of view, the first way would be consistent with vertical displacement whereas the second, with horizontal displacements. Since the main criterion for the fault detection was the vertical offset, Jámbor et al.'s (1993a) way seems to be more acceptable.

The above faults form boundaries of blocks which were moving relative to each other in the Pleistocene, consequently, it would be possible to construct a block map on the basis of the fault network. The block contours are clearest in he hilly area between the Bakony and Mecsek mountains (Figure 12) and can be characterised as follows:

1) The section of the Kapos valley which extends from the springs up to the village of Kurd falls above the Kapos-Szolnok-Máramaros basement fault (Balla, 1988), and the Pleistocene displacements upon the Kapos valley block boundary (Némedi Varga, 1977) can be related to the revival of that principal fault (Figure 12, 6). West of the spring area, the water divide between the basins of the River Dráva the River Zala and Lake Balaton seems to continue the above line up to the village of Liszó, but it is not clear whether that is important for tracing the fault or not. Below the village of Kurd, the Kapos valley gradually turns towards the northeast and together with the west-east-directed section of the Creek Sió, it follows the sharp Tamási basement fault (Figure 10), not the Kapos-Szolnok-Máramaros principal fault beyond the mouth of the Kapos. Beyond the Creek Sárviz, a water divide running in a northeastern direction towards the southern end of the Island of Csepel follows the continuation of the Tamási Line, but its structural sense is completely obscured. East of the village of Kurd, no topographic expression of the Kapos-Szolnok-Máramaros lineament is visible.

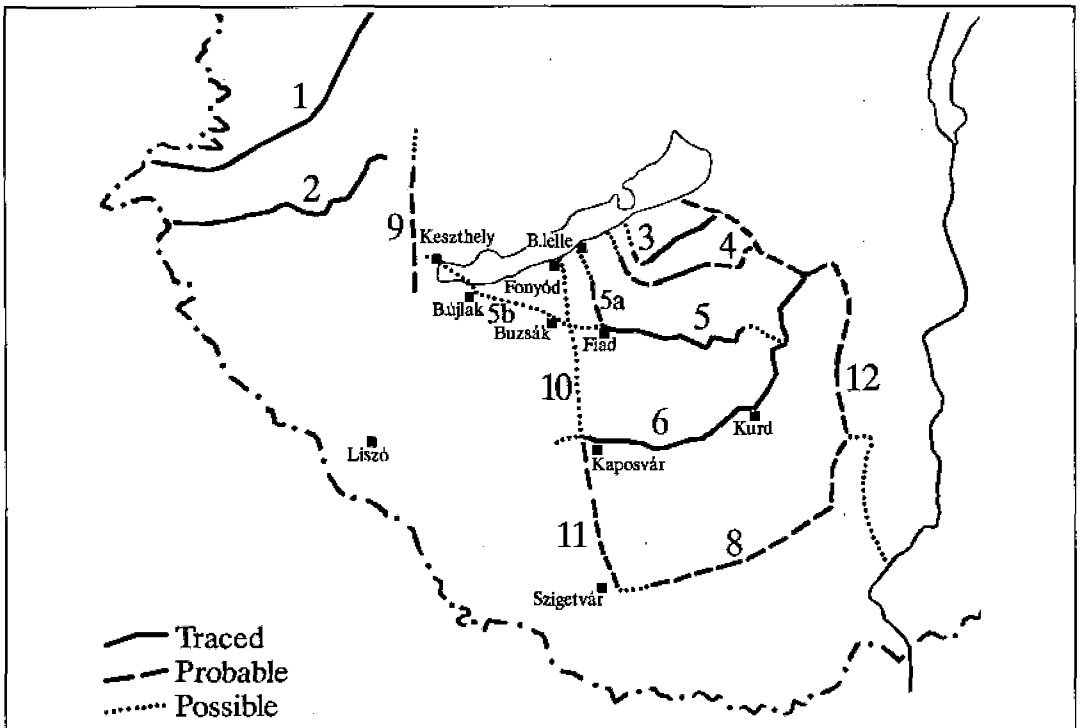

Figure 12: Contours of the Quaternary tectonic blocks in Middle and South Transdanubia according to Balla et al., 1993b

2) The east-west-directed section of the valley of the Creek Nagy-Koppány (Figure 12, 5) merges with the Kapos-valley block boundary in the east. Towards the west, the Nagy-Koppány valley boundary is traceable in two different ways:

i. following the arch of the Creek Nagy-Koppány it may run into the Lake Balaton at approximately Balatonlelle, in that case, Pliocene sediments crop out along the southwestern side of the whole of the boundary in harmony with the elevation of that limb;

ii. from the village of Fiad and following isolated SE-NW tending valley sections in the vicinity of the villages of Kisberény, Buzsák and Balatonújlak. It may run across the Lake Balaton into the area of Keszthely, however, in that case, the uplift of the southwestern limb would be only detectable between village of Buzsák and Lake Balaton.

In both cases, coherence with the basement structure would only be observable on the valley section below village of Fiad.

3) The western continuations of the block boundaries along the valleys of the Creek Kis-Koppány (Figure 12, 4) and the Creek Jaba (Figure 12, 3) are probably in harmony with the (ii) version of the Nagy-Koppány valley boundary, as deflections

towards the north run into the Lake Balaton. The eastern continuations are only imaginable up to the Creek Sió.

Similar faults are traceable along those sections of the River Rába (Figure 12, 1) and River Zala (Figure 12, 2) which arch approximately parallel with each other. Their positions on maps are close to those of basement faults, thus they can be associated with the rejuvenation of those faults. The blocks between them are tilted towards the southeast similar to the blocks in the Somogy county[1] .

Along the straight section of the River Danube between Győr and Esztergom, the Pleistocene sequences have abruptly subsided below the Little Hungarian Plain[2] . This may indicate the presence of a young fault here. At the same time, on the similarly straight, north-south-oriented section of the River Danube below Vác, a topographic step which was formerly interpreted as a conjugate fault (Schmidt, 1957), is absent in both new maps.

3.1.2. The origin of the straight and parallel valleys

Roughly perpendicular to the block boundaries in Somogy county, transverse valleys have developed which fall in a segment of the large fan-like system. The whole of that system starts in the Zala county[3] , with north-south-directed valleys and ends in the northern Danube-Tisza interleave with northwest-southeast-directed valleys. The Somogy valleys are oriented in a NNW-SSE direction in harmony with their position within the fan. The majority of Hungarian scientists (Lóczy, 1913, 1918, Cholnoky, 1918, Szabó, 1957, Marosi and Szilárd, 1958, 1974, Erdélyi, 1961, 1962, Ádám, 1964, 1969, Bulla, 1964, Szilárd, 1967, Marosi, 1968, 1969, 1970, Pécsi, 1969, 1986, Brezsnyánszky and Síkhegyi, 1987) are convinced that those valleys follow faults and thus are of tectonic origin. Jámbor (1993) clearly states that in spite of the (i) absence of direct proofs, (ii) small magnitudes of possible displacements and (iii) absence of any acceptable theoretical model for the whole of the fault system, he believes in the tectonic origin of those valleys due to the absence of any acceptable alternative explanations. For this reason, the problem will be discussed below from that point of view..

The transverse valleys are straight, and from a tectonic point of view, that would be explained in terms of the shear origin of the faults supporting that. The map of Jámbor et al (1993a) makes a striking difference between the straight shape of those transverse faults and the wavy or zigzagged shape of the longitudinal faults on block boundaries, the latter being characterized by vertical offsets. As early as 1918 (Cholnoky) and in the fifties (Schmidt, 1951, 1952, 1957 and Egyed, 1954), the transverse faults were regarded as strike-slip.

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[1] 'Somogy county' mainly covers the area south of Lake Balaton almost up to the Mecsek Mountains

[2] 'Little Hungarian Plain' is a lowland in northeastern Hungary, its northern half being known as 'Danube Lowland' in Slovakia

[3] 'Zala county' covers the areas west and southwest of the Lake Balaton

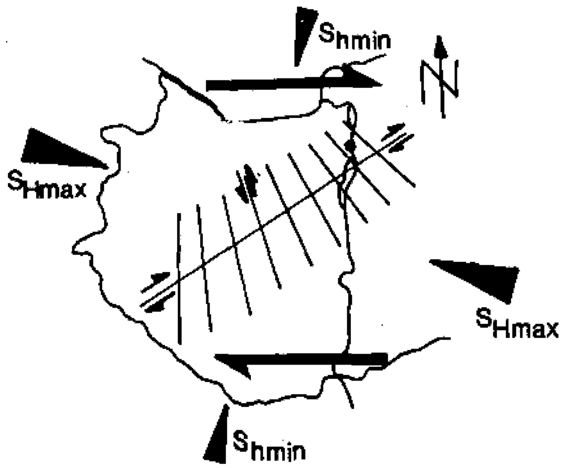

Figure 13: Interpretation of the Transdanubian lineament system and orientation of recent principal stresses (Gerner, 1992: Fig. 8). Due to west-east oriented dextral shear, NE-SW running lines are rejuvenated as dextral strike slips, and sinistral antithetic faults are generated. In the west, the latter form large angles with the shear, the diminishing of the angle towards the east points to pure shear or transtension. The highest stress is horizontal (SH_{max}) is oriented in a WNW-ESE direction, and the lowest stress, also horizontal, is oriented in a NNE-SSW direction.

Within that concept, however, there was no explanation for both

(i) the fan-like shape of the whole system or

(ii) the absence of any continuation of those faults in the Mesozoic and older sequences of the Bakony and Mecsek mountains.

The first attempt to explain these features (Figure 13) was made by Gerner (1992). However, a significant defect in his hypothesis, was in the disregard of geometrical parameters (Ramsay and Huber, 1987). The width of the shear zone is comparable with the thickness of the plastic layer above the rigid basement (the sedimentary sequence which is mostly 1-2 km thick), whereas in Gerner's application, the width is at least 100-150 km, i.e. about two orders of greater magnitude. Consequently, the model proposed (Figure 13) cannot adequately explain the observable features, and the two problems outlined above remain unsolved.

Below, a completely new working hypothesis for the origin of the transverse valleys is outlined. It originates from the well-known fact (Lóczy, 1913, 1918, Cholnoky, 1918, Szabó, 1957, Marosi and Szilárd, 1958,, 1974, Erdélyi, 1961, 1962, Ádám, 1964, 1969, Bulla, 1964, Szilárd, 1967, Marosi, 1968, 1969, 1970, Pécsi, 1969, 1986, Síkhegyi, 1985, Brezsnyánszky and Síkhegyi, 1987) that the blocks tilt southwards (described in 3.1.1). In our opinion, the tilting simply explains why the creeks run towards the south and why are they parallel to each other within the blocks: in the case of the tabular tilting, water simply flows parallel to the tilt direction (Miller and Miller, 1961, p. 96) without any additional factors. This way, the most important argument in favour of the tectonic origin of the parallel straight valleys – 'no more reasonable explanation' (Jámbor, 1993) – is dropped, and all the doubts concerning the tectonic origin of those valleys (Pávai Vajna, 1926, 1931, Strausz, 1942, Vajk, 1943, Balla et al., 1993a) regain strength.

A separate problem is the explanation of the fan-like arrangement of the valleys. In our opinion, the boundaries of the blocks tilted towards the south in the Pleistocene are traces of the rejuvenation of basement faults, thus the slopes and the valleys on the tilted block surfaces should be approximately perpendicular to the basement faults. The latter, e.g. the Kapos-Szolnok, the Buzsák or the Balaton lines (Figure 10) are clearly bent, striking in the southwest in a W-E direction and in the northeast in a SW-NE direction. One can state that the valleys are indeed mostly perpendicular to the basement faults thus the fan-like shape of the valley system as a whole reflects the bending of the basement faults which control the Pleistocene block tilting.

As seen, the tilt model gives a more complete explanation for the transverse valleys than the tectonic one since it elucidates not only the straight shape and parallel arrangement of the valleys but also the fan-like shape of their system and the absence of corresponding faults in the basement outcrops. Accordingly, most of the faults along the transverse valleys will be neglected in the discussion of the seismic hazard.

In some cases, however, that cannot be done.

1) Beyond the western termination of the Bakony Mountains, approximately N-S oriented valleys appear suddenly and cover the whole of the western imaginary continuation of the basement strip, the corresponding picture being incomprehensible with no fault(s) marking the boundary between the two areas. The corresponding fault(s) can be supposed in the zone between the Creek Gyöngyös on the western edge of the Keszthely Mountains and the N-S oriented section of the River Zala to the west of it. That strip possibly corresponds to a fault zone.

2) A similar situation is visible on the western termination of the Mecsek Mountains. The corresponding transverse fault (Figure 12, 11) is marked by valley sections arranged into a NNW-SSE oriented line which perhaps is accompanied by parallel faults in the west.

3) In the block between the valleys of the River Kapos and the Creek Nagy-Koppány, the creeks run towards the south. In the west beyond the Kaposvár-Fonyód line, accepting version (i.) for the western continuation of the Nagy-Koppány boundary, there is an abrupt change. Beginning with the Creek Nagy-árok which runs into the Lake Balaton at Fonyód, all the creeks running into the Lake Balaton and River Zala spring from the vicinity of the Kapos Line. Accordingly, the Kaposvár-Fonyód line (Figure 12, 10) forms a sharp boundary: the creeks east of it run to the south whereas those west of it, to the north. The superficial expression of the Kapos Line is traceable towards the west up to that boundary as well. The boundary may be of tectonic origin and probably follows the valley of the Creek Nagy-árok, that hyothesis still awaits confirmation from independent data.

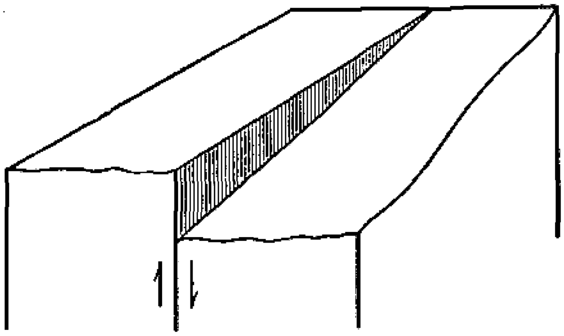

Figure 14: Model for the hinge fault after Dennis, 1967: Fig. 13.

The three above transverse fault(zone)s, (the latter two may even form a single fault), could govern the Pleistocene tilt direction and the orientation of corresponding valleys as the lateral boundaries of tilted blocks. The straight shape of those faults originates from their 'hinge fault' nature (Figure 14).

3.1.3. Faults traced by indirect criteria

There are many indirect criteria for tracing faults. On the basis of the analysis of the explanatory notes (Jámbor, 1993), the map (Jámbor et al., 1993a) and its 'confirming materials' (Jámbor et al., 1993b), those criteria can be arranged into the following principal types:

- faults detected by various methods in pre-Quaternary sequences (assuming their rejuvenation, Jámbor, 1993 and Jámbor et al., 1993b);
- steep lateral boundaries of Quaternary valleys and terraces (Jámbor et al., 1993b);
- changes in the base topography of the Quaternary sequences either in the thickness or in vertical sections (Franyó, 1993, Jámbor, 1993), e.g. the en échelon fault running from Budapest towards the southeast up to the Makó trough in Jámbor et al. (1993a-b);
- topographic steps on the boundaries of distinct geological-geomorphic entities; e.g. the eastern boundary of the Börzsöny or the northern boundary of the Mátra Mountains in Jámbor et al. (1993a-b).

Besides the features which fall into the above principal types, others also appear (e.g. in Jámbor et al., 1993b). They are, however, localised and can be neglected in an analysis at a scale 1:500.000. Thus, the attention will be focused on the arguments within the four principal types. In this relation, fundamental geomorphic knowledge has to be taken into consideration, as follows:

- in cross sections, the alluvial sediments are normally lenticular, frequently with relative steep lateral boundaries, and the lenses themselves – without any graben-like subsidence – are always in the topographically deepest position;
- consequently, in basement or thickness contour maps, the river valleys are represented by troughs even without any tectonic subsidence;

– the terrace slopes towards the valleys usually form steep morphological steps even without any controlling fault;

– on the boundaries between sequences of different mechanical resistance, as a result of erosion, usually topographical steps arise independent of the origin of the boundaries;

– consequently, on a simple monocline containing resistant sequence (e.g. volcanites in sediments), a sharp and straight topographic step will arise along the strike without any fault, and

– if a mechanically different boundary falls on an older fault, the topographic step by itself would not necessarily means the fault was rejuvenated.

As a consequence, neither the tectonic origin of the corresponding topographic elements, nor the rejuvenation of the faults detected by other methods can be confirmed without further analysis which excludes non-tectonic or non-rejuvenate origin. There is no evidence that an analysis of that type has been carried out by the authors of the reports. Most of the 'confirming materials' (Jámbor et al., 1993b) appear to be a series of statements. For this reason, the faults detected indirectly will only be considered if we believe them to be sufficiently corroborated..

1) South of the Kapos valley, the Mecsekalja Line (Figure 12, 8) is the only clearlyvisible neotectonic lineament. It is traceable up to the termination of the Mórágy Block in the east and to that of the Mecsek Mountains in the west. Its Pleistocene rejuvenation, however, is insufficiently confirmed. No surface data point to its straight continuation towards the east, therefore, as a graphical solution, it has been continued towards the N, then NNE at the western foot of the Szekszárd Hills.

2) The longitudinal block boundaries in Somogy county seem to be limited in the east by the valley of the Creek Sió, thus that valley may indeed follow a fault (Figure 12, 12). South of the northeastern termination of the Mecsekalja Line, the line along the Sió probably continues at the eastern foot of the Szekszárd Hills.

The geomorphic considerations are principally valid for the mountain and hilly areas and for their peripheries. They can be only applied in basin areas with caution. This is clearly demonstrated in the interiors of the Great Hungarian Plain and of the Little Hungarian Plain where none of the maps display directly confirmed faults. Here, only the first three of the tracing criteria (see at the beginning of 3.1.3.) have been applied.

In our opinion, we can neglect all lineaments which were indicated in the Pleistocene thickness map (Franyó, 1993) but are not present in the maps of deeper horizons (base of the Upper Pannonian ≈ Pliocene: Csíky et al., 1987a, base of the Lower Pannonian ≈ Upper Miocene: Csíky et al., 1987b base of the Tertiary: Kilényi and ŠEfara, 1989). However, even if morphological elements equivalent to those in the Quaternary thickness map, can be recognised in the maps of deeper horizons, this coincidence does not necessarily indicate a rejuvenation of older faults. Similar coincidences can also be due to the subsequent compaction of Tertiary sediments in the Quaternary era, especially if those sediments are mostly Pannonian (≈ Pliocene to Upper Miocene) i.e. they are in a relatively early state of compaction. That is why, faults recognised in the Quaternary thickness map usually need independent confirmation , although such possibilities are very limited.

3.1.4. On the age of the fault displacements within the Pleistocene

Jámbor (1993) regarded the faults indicated in the map, shown on Fig. 9, as mostly older than Late Pleistocene, i.e. over 120,000 years old, based on the following considerations:

– in the mountainous and hilly areas, the Upper Pleistocene and Holocene sediments are mostly without faults;

– the fault constituents of the flower structures in the seismic sections probably do not cut the whole of the Pleistocene sequence.

There are numerous examples in the 'confirming material' (Jámbor et al., 1993b) concurring with that hypothesis, however, examples of younger displacements also occur in the same material.

The block boundaries in Somogy county cut even the Upper Pleistocene sequences (Némedi Varga, 1977), the same is true for the Little Hungarian Plain. Thus, the concept that faults due to Pleistocene activity mostly reflect displacements prior to the Late Pleistocene, cannot be accepted. The same conclusion can be drawn from the uplift rate of the Pliocene and Pleistocene sequences in the Transdanubian Range (Scheuer and Schweitzer, 1988) as it was constant (within the measurements' precision of course) in space up to the Holocene. A valuable point worth mentioning is that if the Transdanubian valleys of the fan-like system were indeed controlled by faults, the activity of those faults would also cover the Late Pleistocene since many of the valleys cut through the Upper Pleistocene sediments.

In our opinion, there is no foundation for the hypothesis that Quaternary fault activity is restricted to times prior to the Late Pleistocene, and that the detectable faults could still be active..

3.1.5. Summary

In both maps of the faults due to Pleistocene activity (Jámbor et al., 1993a, Schweitzer et al., 1993), so many faults are displayed (Figure 9) that the zones of seismic hazard would cover almost all of Hungary.. This is an obvious absurdity since the seismicity in Hungary is not strong. That conclusion is not influenced by Jámbor's (1993) assertion on the pre-Late Pleistocene activity of the most of the faults displayedsince, as was demonstrated, even the 'confirming materials' of his team (Jámbor et al., 1993b) do not sufficiently support their statement which has subsequently been proven unacceptable in the light of additional data.

Our analysis resulted in the selection of those faults the Pleistocene activity of which in a certain aspect can be accepted. In the further analysis of the seismic hazard in Hungary, only those faults only will be taken into consideration. Since the argumentation has already been presented, only the selected faults and fault zones in Transdanubia are listed with references to their location:

– longitudinal faults (from the NW to the SE):

1) fault along the River Rába traced by direct criteria (Figure 12, 1)

2) fault along the River Zala traced by direct criteria (Figure 12, 2)

3) fault along the Creek Jaba traced by direct criteria (Figure 12, 3)

4) fault along the Creek Kis-Koppány traced by direct criteria (Figure 12, 4)

5) fault along the Creek Nagy-Koppány traced by direct criteria with two alternatives for its western continuation (Figure 12, 5)

6) fault along the River Kapos traced by direct criteria, its western continuation being obscure (Figure 12, 6)

7) fault along the River Danube traced by indirect criteria (3.1.1., p. 32.)

8) Mecsekalja Line traced by indirect criteria, its western and eastern continuations being obscure (Figure 12, 8)

– transverse faults (from the SW to the NE):

9) western boundary of the Keszthely Mountains traced by indirect criteria, both its continuations being obscure (Figure 12, 9)

10) Fonyód-Kaposvár Line traced by indirect criteria, both its continuations being obscure (Figure 12, 10)

11) Kaposvá-Szigetvár Line traced by indirect criteria, both its continuations being obscure (Figure 12, 11)

12) fault along the Creek Sió traced by indirect criteria, both its continuations being obscure (Figure 12, 12)

All the other faults, in our opinion, were included in the maps because the authors – following a long-stablished view in the Hungarian geological and geomorphic literature – systematically neglected specific regularities of the erosion. Extreme expressions of that are as follows:

– the valley cuts frequently are displayed as graben-like depressions,

– at the foot of the terraces usually faults are drawn,

– at the foot of other topographic steps mostly active faults are supposed,

– along the faults in older sequences Quaternary rejuvenation is dominantly assumed.

Surfaces of obviously erosional origin such as the base of the Pleistocene, are frequently approximated by horizontal lines even in sections with strongly exaggerated vertical scale and all the altitude differences are related to faults. .In non-exaggerated sections, however, it would be easy to demonstrate these faults were nothing but insignificant waves on the surfaces in question (Figure 15).

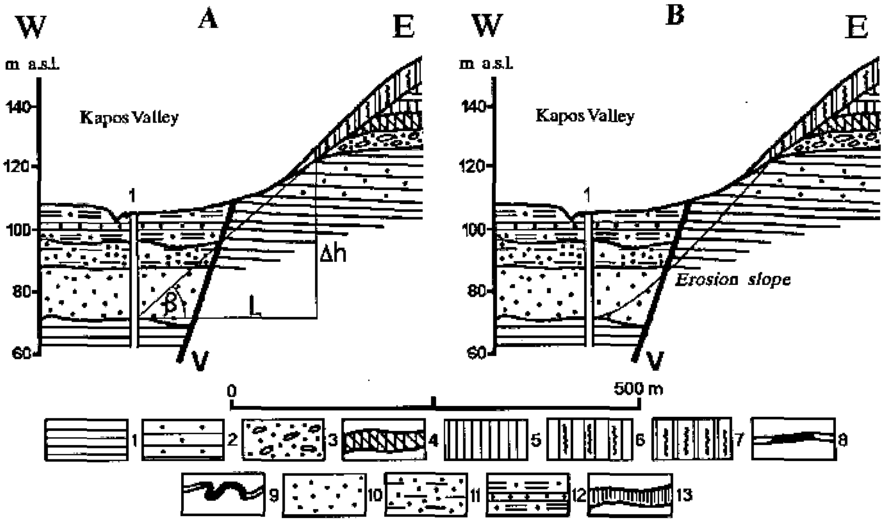

Figure 15: Principal sketch for the determination of the faultless dip angle (A) and principle of the construction of the faultless valley side (B) in an exaggerated section (Ádám, 1969: right side of Fig. 45). 1 = Pannonian clay, 2 = Pannonian sand, 3 = Pannonian debris, 4 = red clay, 5 = loess, 6-7 = resedimented loess, 8-9 = fossil soil, 10-11 = alluvial sand, 12 = washed sediment, 13 = chernoziom, V = fault

3.2. On the Geophysical Lineaments

Various geophysical methods are able to detect those structural elements and surfaces on which the petrophysical parameters (density, magnetic susceptibility, seismic velocity, electric resistivity etc.) change. It is also obvious that those surfaces or structural lines are easily traced by geophysical methods which display an abrupt change of any of the petrophysical parameters. In Hungary, the basement of the Neogene basins is a surface of the required type on which the young sediments filling up the basin cover older consolidated basement rocks. In zones with gradual changes of the petrophysical parameters (e.g. density and velocity within the young basin fill), the geophysical anomalies become indistinct and obscured.

The structural lineaments expressed in geophysical data (Szabó et al., 1993) have been detected mainly from gravity data. An advantage of the gravity survey consists in its approximate constant density all over the country that allows a uniform data processing for the whole of the country. For the purposes of structural interpretation, the horizontal gradients of the gravity field is more suitable than the Bouguer anomalies, their local maxima indicating the abrupt density changes. The restrictions for the gravity method arise from the basic principles behind the method: structural elements are only detectable where rocks of different density are in contact with each other. The resolution decreases with the increase of the depth to the basement, first, gradually, then, deeper than 3,000 m, rapidly.

That is why in the compilation of the lineament map besides the gravity data, the fault map in the pre-Pannonian (≈ pre-Late Miocene) sequences of Hungary (Rumpler, 1987) (based on the gravity, geomagnetic and seismic surveys) as well as the tectonic map of Hungary (Kókai and Pogácsás, 1991) well used. In addition, recent seismic data was considerated.

The gravity and seismic lineaments (Szabó et al., 1993) usually correlate well with the principal tectonic boundaries dispersed in wide zones around them. This is obviously because the tectonic boundaries are accompanied by parallel structural elements (faults, horsts, grabens etc.) and the geophysical lineaments reflect those elements in the same way as the principal boundaries. Analogous phenomena result in the nonalignment of faults in seismic sections with the gravity lineaments. All of these features point to the principal tectonic boundaries which are only detectable in an objective way by considering various information and are frequently traceable as the axes of lineament arrays, not necessarily as single lineaments.

3.3. Earthquake Distribution Regularities in Hungary

Correlation between the geological structure and earthquake distribution is difficult to find since, due to the moderate seismicity of Hungary, the database (Szeidovitz and Mónus, 1993) which covers the last 200 years, is insufficient to trace the seismic activity.

The spatial distribution of the earthquakes in Hungary (Szeidovitz and Mónus, 1993) is at first sight uneven and irregular. The previous (generally negative) attempts at correlation, demonstrate the need for a new approach to the problem. An analysis of the spatial and temporal distribution of weaker earthquakes in the 30 km surroundings of the $I \geq 6°$ earthquakes has resulted in the following conclusions:

– in numerous cases (1763: Komárom, 1810: Mór, 1834: Érmellék, 1892: Pincehely,, 1953: Ukk,, 1978: Békés), the weaker earthquakes were concentrated in elongated areas which may indicate their relation with linear structures;

– within those areas, sometimes (Györ-Komárom and Pincehely-Belecska, as well as in the vicinity of Jászberény, Kecskemét and Eger) a temporal correlation between earthquakes in different sites is observable which may point to the existence of genetic, not only spatial, relationships between the earthquakes.

Starting with those observations an attempt was made to collect Hungarian earthquakes into lenticular areas and map them with, and geophysical lineaments (Szabó et al., 1993). In addition, some of the faults due to Pleistocene activity and, the axes of some deep Neogene basins were displayed within those lenses and on their continuations. The resulting map (Figure 11) served as the basis for further analysis, in the course of which, three categories of the earthquake populations were distinguished:

1) Long axis of the earthquake population traces geophysical lineaments or/and faults due to Pleistocene activity. Those earthquakes are most probably related to the deep continuation of the basement faults or fault zones, and this allows for the interpolation or extrapolation of the seismic hazard along the strike of the geological-geophysical-geomorphic lineaments.

2) Long axis of the earthquake population traces axial zone of a rift-type deep basin. These earthquakes are related to the basins and the seismic hazard cannot be extrapolated along the structural strike.

3) Long axis of the earthquake population significantly deviates from any known faults with Pleistocene activity and geophysical lineaments and does not coincide with any basin axis. Those earthquakes are probably related to the faults which are in the process of forming in the deep levels of the Earth's crust. The superficial

structure reacts to the strain along those zones by rejuvenating existing faults which originate from different strain fields and strike in various directions. That is why the superficial faults in question are only activated within the zone of the newly formed deep-seated fault and cannot be used to extrapolate the seismic hazard.

The earthquake populations (Figure 11) are classified as follows:

(a) earthquake populations correlatable with superficial lineaments (from the W to the E):

1) Szombathely-Sopronkövesd population;

2) Győr-Becske population; the Komárom earthquakes were systematically followed by the Győr earthquakes, and the earthquake sources gradually migrated towards the east beyond Komárom; the long axis of the isoseismal lines for the 1763 Komárom earthquake was parallel to the River Danube, and the analysis of the building damages in Komárom (Szeidovitz, 1990) revealed the E-W orientation of the main shock;

3) Ukk-Bérbaltavár population;

4) Nagykanizsa-Marcali population;

5) Nagyatád-Pincehely population; the Pincehely earthquake was followed by another one at Belecska, some km southwards;

6) Pécs-Mohács population;

7) Jászberény population; the Jászberény earthquakes were introduced by the Szentmártonkáta ones, temporal coincidence with the earthquakes in the Monor-Gomba-Péteri area is also observable; the long axis of the internal isoseismal lines for the 1868 Jászberény earthquake strikes in roughly an E-W direction; isoseismal lines of the Gomba earthquakes are ellipsoidal, with the long axis in a SW-NE direction for the 1908 and in a SE-NW direction for the 1914 earthquake;

8) Kecskemét population; the 1911 Kecskemét earthquake was preceded by earthquakes in the Lajosmizse-Kecskemét area and followed by earthquakes in the area between Nagykőrös and Kecskemét, an analysis of the building damages in Kecskemét (Ballenegger 1911, Cholnoky 1911) revealed the main shock dispersed in a NE-SW direction;

9) Kiskunmajsa population;

10) Eger population; the main earthquake between Ostoros and Eger was followed by earthquakes between Egerszalók and Noszvaj distributed in a narrow zone orientated SW-NE, the isoseismal lines of the main earthquake were elongated in the same direction;

11) Tokaj population;

12) Álmosd-Érmellék population; isoseismal lines of the 1834 Érmellék earthquake were elongated in a SW-NE direction;

(b) earthquake populations correlatable with axes of deep basins (from the SW to the NE):

13) Szeged population;

14) Makó population;

15) Békés population; isoseismal lines of the 1978 Békés earthquake were elongated in an about N-S direction;

(c) earthquake populations not correlatable with both superficial lineaments and axes of deep basins (from the W to the E):

16) Komárom-Berhida population; temporal relationships were analysed in details (Szeidovitz, 1986); isoseismal lines of both the 1810 Mór and the 1985 Berhida earthquakes were elongated in the samee NNW-SSE direction; an analysis of the building damages in Berhida (Csák, 1988) revealed the main shock dispersed in a N-S direction ;

17) Vác-Ráckeve population; an analysis of the building damages in Dunaharaszti (Somogyi, 1956) revealed the main shock dispersed in a NNE-SSW direction;

3.4. ZONES OF SEISMIC HAZARD IN HUNGARY

In the case of the first category of earthquake populations, lineaments along the long axes of the populations have been accepted as seismically active lines, (if necessary, by joining distinct lineaments). In the case of the second category, basin axes along the long axes of the populations have been accepted as seismically active lines. In the case of the third, the long axes of the populations themselves have been accepted as seismically active lines.

Beyond the extent of earthquake populations, the seismic hazard can only be extended in the case of populations in the first category. With this in mind several statements can be made::

– geophysical lineaments allow the classification into one zone the Nagyatád-Pincehely (5), the Jászberény (7) and the Eger (10) populations;

– the Kecskemét population (8) may be regarded a branch of the previous zone;

– another zone is formed by the Kiskunmajsa (9) and the Álmosd-Érmellék (12) populations;

– the Szombathely-Sopronkövesd (1), the Győr-Becske (2) and the Nagykanizsa-Marcali (4) populations are related to long-traceable lineaments;

– the Ukk-Bérbaltavár (3), the Pécs-Mohács- 6) and the Tokaj (11) populations are related to relative short lineaments.

The geological interpretation of the lineaments which control the earthquake distribution will be given on the basis of the knowledge on the tectonic boundaries (Figure 10).

The seismically active zone with the Nagyatád-Pincehely (5), the Jászberény (7) and the Eger (10) earthquake populations crosses the most of the country and in the first approximation seem to be related to the Zágráb-Kulcs-Hernád tectonic boundary. More precisely, it can be stated that the axis of the Nagyatád-Pincehely (5) earthquake population only falls on the tectonic boundary, with an acceptable accuracy on its western sections known as the Kapos and Tamási Lines. The axis of the Jászberény (7) earthquake population runs along the northern foot of the Bugyi-Sári horst, not along the *southern* foot which is the principal boundary. The axis of the Eger (10) earthquake population runs much more northerly, along the northern side of the Vatta-Maklár trough. It appears that the seismic zone is related to a new deep-seated fault which forms an acute angle with the Zágráb-Kulcs-Hernád tectonic line and due to the small angle, its distinct sections fall on existing faults roughly parallel to the tectonic line.

The axis of the Kecskemét (8) earthquake population falls on the Zágráb-Kapos-Szolnok-Máramaros tectonic boundary and in this sense could be regarded a branch of the previous seismically active zone. However, between the corresponding western section of the Nagyatád-Pincehely (5) earthquake population and the Kecskemét (8) earthquake population, an at least 50 km long section is situated, which only bears geophysical (mainly reflexion seismic) lineaments east of the River Danube. Therefore, no connection can be confirmed in the present movement picture.

The Kiskunmajsa (9) and the Álmosd-Érmellék (12) earthquake populations are situated above a crystalline ridge in the southeastern foreground of the Szolnok Flysch Belt. They can be associated with second- or third-order faults in the basement structure (Dank and Fülöp, 1990).

The axis of the Szombathely-Sopronkövesd (1) earthquake population corresponds to the western rim of the Csapod basin (Kőrössy, 1963, Pogácsás et al., 1991) in the Little Hungarian Plain or, in a wider sense, in the whole of the Little Hungarian Plain depression.

The eastern third of the Győr-Becske (2) earthquake population falls on the Diósjenő Line also known from the basement structure (Balla et al., 1978, Balla, 1989). Its central and western sections, however, coincide with the geological-geomorphic lineaments along the River Danube (Jámbor et al., 1993a, Schweitzer et al., 1993), and not with the Hurbanovo Line which continues the Diósjenő Line towards the west.

The axis of the Nagykanizsa-Marcali (4) earthquake population falls on the Buzsák Line (Balla et al., 1988), not on the more popular Balaton Line.

The Ukk-Bérbaltavár (3) earthquake population is probably related to the northwestern continuation of the Szőc fault along the northeastern rim of the Vigándpetend and Nyírád basins (Dudko et al., 1992), whereas the Pécs-Mohács (6) earthquake population, is probably associated with the fault on the boundary between the Máriakéménd Ridge and the Ellend basin. The Tokaj (11) earthquake population is situated on the southwestern edge of the Tokaj Mountains which is not expressed in the basement topography and structure.

As seen, the prevailing part of the lineament-related zones of seismic hazard are explicable in terms of rejuvenation of older faults. Those faults, on the basis of their different role of in the basement structure, may be gathered into the following three types:

– concrete sections of the principal tectonic boundaries (Diósjenő Line, Buzsák Line, Kapos and Tamási lines, Paks-Szolnok Line);

– faults parallel and close to the principal tectonic line are expressed first of all in the topography, not the internal structure, of the basement (northern boundaries of both the Bugyi-Sári ridge and the Vatta-Maklár trough, as well as the boundary between the partial basins within the crystalline ridge in the southeastern foreground of the Szolnok flysch belt);

– faults at various angles to the principal tectonic lines are expressed first of all in the basement topography (western border of the Csapod trough, northeastern border of the Vigándpetend and Nyírád basins, southern border of the Ellend basin); it seems probable that the seismically active lineament of the Tokaj (11) earthquake population belongs to that type, but the present insufficient data does not allow confirmation or rejection of that hypothesis.

The seismically active lineaments have been arranged into three certain categories:

1) lineaments with earthquakes observed;
2) continuously traceable lineaments with probable earthquakes.
3) discontinuous lineaments, or continuous but longer than the neighbouring earthquake population, with possible but less probable earthquakes.

The picture outlined above is a working hypothesis which should be confirmed or rejected by further research of the earthquakes and controlling structures.

The zones of seismic hazard can be contoured by lines in certain kms of the seismically active lineaments. Doubts arise concerning earthquake populations (i) which are wider than the prescribed safety width in km or (ii) which have been distinguished exclusively on the basis of the earthquake distribution. In the first case, the problem consists in displaying areas with observable earthquakes as areas free of seismic hazard. In the second case, the problem consists in some earthquakes may be related to superficial faults which run out of the zones of seismic hazard indicated in our map and, therefore, could be regarded as seismically active faults, but it is obscure which concrete faults certainly belong to that category. In both cases, the question arises whether the zones of seismic hazard are too narrow or not.

The problem of the earthquake populations related to basin axes in southeastern Hungary is of opposite sense. Due to the great thickness of the sedimentary fill it might be possible to neglect the seismic hazard within these zones. In the reflection seismic profiles for these areas, there are no signs of faults which cut the Upper Pannonian (≈Pliocene) or younger sediments, therefore, displacements within the thousands meter thick sedimentary pile, connected with the earthquakes, did not produce sensible offsets. In these areas, there is no need to account for superficial faults or ruptures.

For similar reasons, in the active zones within the basins deeper than 500-1,000 m, earthquakes which could generate superficial ruptures are of low probability as well. They should be only taken into account if the Quaternary rejuvenation of the faults detected in deeper horizons were confirmed.

3.5. Seismic Hazard at Gabčíkovo and Nagymaros

Gabčíkovo and Nagymaros are in significantly different position relative to the zones of seismic hazard.

Gabčíkovo is situated in an area between two seismic zones, the Mur-Mürz in the northwest and the Győr-Becske (Figure 11, 2) in the southeast. The Mur-Mürz zone is traceable for about 600 km in a southwest-northeast direction along the Little Carpathians and forms the best expressed seismic zone of the Carpathian-Pannonian realm. It is a sinistral strike-slip, the total offset being several dozens of kilometers, mostly originating from Miocene movements. There are no data on the Quaternary offset but the focal solutions are in harmony with the sinistral shear upon the Mur-Mürz zone. Gabčíkovo is in about 50 km southeast of its axial zone. The Győr-Becske zone (Figure 11, 2) has been supposed along the west-east oriented section of the Danube, and then along the Diósjenő line for a length of about 150 km. There are no data on either the sense of movement or any offset upon it. Gabčíkovo is about 25 km north of its axial zone. As a consequence, at Gabčíkovo no capable faults can be expected, shaking is the only aspect of the seismic hazard likely to occur. Its quantitative parameters can be determined by the Seismological Observatory.

Nagymaros is situated within the Győr-Becske zone (Figure 11, 2) within a maximum of 5 km of its axial line position which as an aside is not very well defined. Just in the base of excavations at Nagymaros, faults striking nearly west-east were observed (for details, see report by Császár et al. in the series of studies for the Haag Process), i.e. parallel to the Győr-Becske zone. On this zone, a dextral offset in Miocene and Oligocene sequences of about 150 m was recorded within the Late Badenian to the Quaternary period (it is not possible to be more precise). Anyway, capable faults here are not excluded, and therefore there is a much greater seismic hazard. In the whole of the Carpathian-Pannonian realm, only two cases of open ruptures are known: one in the Érmellék (1834) earthquake which produced many ruptures, at least one of them being 2 or 3 km long, and the other in Mór (1810) also with numerous ruptures at least one of them being several hundred meters long. The Érmellék earthquake falls within the Álmosd-Érmellék population (Figure 11, 12) which is probably controlled by a sinistral strike slip in the Neogene structure, the length of which is not constrained by any data. Nothing is known about the magnitude and type of Quaternary displacements. After a comparison with other similar faults (e.g. Mur-Mürz line), a maximum of 40-50 km total (mainly Miocene) offset and rejuvenation in the Quaternary sequences with the same type of movements can be supposed. The Mór earthquake falls within the Komárom-Berhida population (Figure 11, 16) for which there is no correlation between the fault network and earthquake distribution. Moreover, there are no data on the orientation of the ruptures in 1810. That is why any geological conclusions drawn from this event, are not based on facts. Nevertheless, although these two cases were exceptions to the 1,500 year record of earthquakes in Hungary, they cannot be ignored. The quantitative evaluation can be precised by the Seismological Observatory.

References

Ádám, L. 1964. A Szekszárdi-dombvidék kialakulása és morfológiája (in Hungarian: The origin and topography of the Szekszárd Hills). Földrajzi Tanulmányok 2, 83 p.

Ádám, L. 1969. A Tolnai-dombság kialakulása és felszínalaktana (in Hungarian ellenőrizve: The origin and topographical features of the Tolna Hills). Földrajzi Tanulmányok 10, 186 p.

Árkai, P. and Balogh, Kad. 1989. The age of metamorphism of the Early Alpine type basement, Little Plain, W-Hungary: K-Ar dating of K-white micas from very low- and low-grade metamorphic rocks. Acta Geol. Hung. 32 (1-2): 131-147.

Árkai, P., Horváth, Z. A. and Tóth, M. N. 1987. Regional metamorphism of the East Alpine type Paleozoic basement, Little Plain, W-Hungary: mineral assemblages, illite crystallinity, -bo and coal rank data. Acta Geol. Hung. 30 (1-2): 153-175.

Bajaník, Š., Biely, A., Miko, O. and Planderová, E. 1979. O paleozoickom vulkanicko-sedimentárnom komplexe Prednej hole, Nízke Tatry (in Slovak with English summary: A Paleozoic volcano-sedimentary complex of Predná hoľa, Nizke Tatry Mountains). Geologické Práce, Správy 73: 7-28.

Balázs, E. 1967. A nyugat-kisalföldi medencealjzat ópaleozóos képződményeinek kőzettani vizsgálata (in Hungarian: Petrographic study of Lower Paleozoic rocks from the basement of the western Little Hungarian plain). A Kőolaj- és Földgázbányászat Tudományos-Műszaki Közleményei II: 304-321.

Balázs, E. 1971. A Kisalföld medencealjzatának ópaleozoos kőzetei (in Hungarian with German summary: Altpaläozoische Gesteine des Beckenuntergrundes der Kleinen Ungarischen Tiefebene). Magyar Állami Földtani Intézet Évi Jelentése 1969-ről: 659-673.

Balázs, E. 1975. A kisalföldi medence paleozóos képződményei (in Hungarian: Paleozoic formations of the Little Plain basement). Földtani Kutatás 18 (4): 17-25.

Balázs, E. 1983. Untersuchung der metamorphen Faziesgürtel in Transdanubien. Anuarul Institutului de Geologie şi Geofizică 61: 9-14.

Balla, Z. 1982. Development of the Pannonian basin basement through the Cretaceous-Cenozoic collision: A new synthesis. Tectonophysics 88 (1/2): 61-102.

Balla, Z. 1988. A Paksi Atomerőmű körzetének nagyszerkezeti helyzete (in Hungarian: Tectonic position of the Paks N.P.P. area). In: Szabó Z. (Ed.), Paks környékének földtani viszonyai. Összefoglaló szakvélemény (Geology of the Paks area. Summary expert conclusions). Kézirat, Eötvös Loránd Geofizikai Intézet, Földfizikai Osztály jelentéstára, Budapest.

Balla, Z. 1989. On the origin of the structural pattern of Hungary. Acta Geologica Hungarica 31 (1-2), pp. 53-63 (1988).

Balla, Z. 1993. An Ivrea-type structure in the Alpine-Carpathian junction area? In: H. Lobitzer and G. Császár (Eds.), Jubiläumsschrift 20 Jahre geologische Zusammenarbeit Österreich-Ungarn, Teil 2. Geologische Budesanstalt, Wien – Magyar Állami Földtani Intézet, Budapest (in press).

Balla, Z., Erkel, A., Király, E., Schönviszky, L., Szalai, I., Taba, S., Verő, L., Csillagné Teplánszky, E., Csongrádi, J., Korpás, L. 1978. A Börzsöny-hegység felépítésének és ércesedésének geofizikai kutatása (in Hungarian with English summary: Exploration of the geology and mineralization of the Börzsöny Mountains). Magyar Állami Eötvös Loránd Geofizikai Intézet 1977. Évi Jelentése, pp. 19-33.

Balla, Z., Tátrai, M., Dudko, A. 1988. A Közép-Dunántúl fiatal tektonikája földtani és geofizikai adatok alapján (in Hungarian with English summary: Young tectonics of Middle Transdanubia in the light of geological and geophysical data). Magyar Állami Eötvös Loránd Geofizikai Intézet 1986. Évi Jelentése, pp. 74-94.

Balla, Z., Dudko, A., KövesI, G. 1991. A Rába-vonal és az MK-1 reflexiós szeizmikus szelvény menti gravitációs anomáliák értelmezése (in Hungarian with English summary: The Rába line and the interpetation of gravity anomalies along seismic profile MK-1). Eötvös L. Geofizikai Intézet 1988-89. Évi Jelentése: 19-47 (English summary: 246-247).

Balla, Z., Marosi, S., Scheuer, Gy., Schweitzer, F., Szeidovitz, Gy. 1993a. A Paksi Atomerőmű földrengéskockázatával kapcsolatos szerkezeti és geomorfológiai vizsgálatok (in Hungarian with English summary ellenőrizve: Tectonic and geomorphological investigation into earthquake hazard in the environment of the Paks nuclear power plant). Földrajzi Értesítő 42 (1-4), pp. 111-140.

Balla, Z., Schweitzer, F., Szabó, Z., Szeidovitz, Gy. 1993b. Magyarország földrengésveszélyes övei (in Hungarian: Seismic hazard zones of Hungary). Kézirat, Magyar Állami Földtani Intézet, Tektonikai Projekt jelentéstára, Budapest.

Ballenegger, R. 1911. A kecskeméti földrengés (in Hungarian: The Kecskemét earthquake). Földtani Közlöny, 41 (9-10), pp. 625-631.

Balogh, K. and Kőrössy, L. 1968. Tektonische Karte Ungarns im Maßstabe 1:1,000,000 Acta Geol. Acad. Sci. Hung. 12 (1-4): 255-268.

Becker, L. P., Frank, W., Höck, V., Kleinschmidt, G., Neubauer, F., Sassi, F. P. and Schramm, J.M. 1987. Outlines of the pre-Alpine metamorphic events in the Austrian Alps. In: H. W. Flügel, F. P. Sassi, P. Grecula (Eds.), Pre-Variscan and Variscan events in the Alpine-Mediterranean mountain belts. Miner. Slov. Monography, Publ. H. 'Alfa', Bratislava, pp. 69-106.

Biela, A. 1978a. Hlboké vrty v zakrytých oblastiach vnútorných Západných Karpát (in Slovak: Deep boreholes in covered areas of the Inner West Carpathians), I. Regionálna Geológia Západných Karpát 10, 224 p.

BIELA, A. 1978b. Hlboké vrty v zakrytých oblastiach vnútorných Západných Karpát (in Slovak: Deep boreholes in covered areas of the Inner West Carpathians), II. Regionálna Geológia Západných Karpát 11: 1-224

Bielik, M., Fusán, O., Plančár, J., Biela, A. and Túnyi, I. 1986. Niektoré nové poznatky o hlbinnej stavbe po Dunajskáj panvy (in Slovak with English summary: New information on subsurface structure of Danube Basin). Geologické Práce, Správy 84: 119-134.

Brezsnyánszky, K. and Haas, J. 1985. The new tectonic map of Hungary. Proc. repts. XIII-th Congr. CBGA, Poland – Cracow, Sept. 5-10, 1985. Geol. Inst., Cracow. Part I: 174-177.

Brezsnyánszky, K. and Haas, J. 1986. Main features of the pre-Tertiary basement of Hungary. Geologický Zborník – Geologica Carpathica 37 (3): 297-303.

Brezsnyánszky, K. and Síkhegyi, F. 1987. Neotectonic interpretation of Hungarian lineaments in the light of satellite imagery. Journal of Geodynamics, 8, pp. 193-2O3.

Bulla, B. 1964. Magyarország természeti földrajza (in Hungarian: Natural geography of Hungary), 2. kiadás. Tankönyvkiadó, Budapest, 420 p.

Cholnoky, J. 1911. A kecskeméti földrengés (in Hungarian: The Kecskemét earthquake). Földrajzi Közlemények, 39 (9-10), pp. 373-391.

Cholnoky, J. 1918. A Balaton hidrográfiája. A Balaton tudományos tanulmányozásának eredményei, I. kötet, 2. rész. Magyar Földrajzi Társaság Balaton bizottsága, Budapest, 316

p. (in German: 1920. Hydrographie des Balatonsees. Evgebnisse der wissenschaftlichen Erforschung des Balatonsees, Band I, Teil 2, Wien, 358 p.)

Csák, B. 1988. Az 1985.08.15.-i Berhida-Peremarton földrengés mérnökszeizmológiai tapasztalatai, tanulsága (Ingeneering-seismological experience from the Berhida-Peremarton earthquake August 15.1985). In: Halász, B. (szerk.), Elmozdulás. Írások és képek az 1985-ös Veszprém-megyei földrengésről, Eötvös Károly Megyei Könyvtár kiadása, Veszprém, pp. 143-174.

Császár, G. and Haas, J. 1984. Hungary. Excursion 104, Mesozoic formations in Hungary. Guidebook, International Geological Congress, XXVIIth session, Moscow, USSR, 1984. Publ. H. 'Vízdok', Budapest, 92 p.

Csíky G., Erdélyi Á., Jámbor Á., Kárpátiné Radó, D., Kőrössy L. 1987a. Magyarország pannóniai (s.l.) képződményei, a Dunántúli-főcsoport (= felsőpannóniai képződmények) talpmélység térképe. Magyarország Földtani Atlasza (Pannonian s.l. formations of Hungary, the depth-to-bottom map for the Dunántúl Supergroup = Upper Pannonian. Geological Atlas of Hungary), 5.1. Magyar Állami Földtani Intézet, Budapest.

Csíky, G., Erdélyi, Á., Jámbor, Á., Kárpátiné Radó, D., Kőrössy, L. 1987b. Magyarország pannóniai (s.l.) képződményei, a Peremartoni-főcsoport (= alsópannóniai képződmények) talpmélység térképe. Magyarország Földtani Atlasza (Pannonian s.l. formations of Hungary, the depth-to-bottom map for the Peremarton Supergroup = Lower Pannonian. Geological Atlas of Hungary), 5.3. Magyar Állami Földtani Intézet, Budapest.

Dank, V. and Fülöp J. 1990. Magyarország szerkezetföldtani térképe, 1:500,000 Magyarország Földtani Atlasza, 3 (Tectonic map of Hungary, scale 1:500,000 Geological Atlas of Hungary, 3). Magyar Állami Földtani Intézet, Budapest.

Dennis, J. G. (Editor-in-chief) 1967. International tectonic dictionary, English terminology. International Geologcial Congress, Commission for the Geological Map of the World. AAPG, Tulsa, Oklahoma, USA, 196 p.

Dudko, A., Bence G. and Selmeczi, I. 1992. Miocén medencék kialakulása a Dunántúli-középhegység DNy-i részén (in Hungarian with English summary: The tectonic origin of Miocene basins on the southwestern edge of the Transdanubian Central Range). Magyar Állami Földtani Intézet Évi Jelentése 1990-ről, pp. 107-123.

Egyed, L. 1954. A mélyszerkezetek és a morfológia kapcsolata Dunántúlon a geofizikai vizsgálatok tükrében (in Hungarian: Relationships between the deep structures and geonmorphology in the light of the geophysical survey). Természettudományi Kar Évkönyve, 1952-1953, pp. 95-100.

Erdélyi, M. 1961. Külső-Somogy vízföldtana (1) (in Hungarian with German summary in the continuation). Hidrológiai Közlöny, 41 (6), pp. 445-458.

Erdélyi, M. 1962. Külső-Somogy vízföldtana (2) (in Hungarian with German summary: Hydrogeologie von Külső Somogy). Hidrológiai Közlöny, 42 (1), pp. 56-65.

Flügel, H. W. 1988a. Geologische Karte des prätertiären Untergrundes. In: A. Kröll, H. W. Flügel, W. Seiberl, F. Weber, G. Walach and D. Zych, Erläuterungen zu den Karten über den prätertiären Untergrund des Steirischen Beckens und der Südburgenländischen Schwelle. Geologische Bundesanstalt, Wien, pp. 21-43.

Flügel, H. W. 1988b. Geologische Karte des prätertiären Untergrundes. In: Geologische Themenkarten der Republik Österreich, Steirisches Becken – Südburgenländische Schwelle, 1:200.000. Geologische Bundesanstalt, Wien.

Frank, W., Kralik, M., Scharbert, S. and Thöni, M. 1987. Geochronological data from the Eastern Alps. In: H. W. Flügel and P. Faupl (Eds.): Geodynamics of the Eastern Alps. Franz Deuticke Verlag, Wien, pp. 282-308.

Franyó F. 1993. Magyarország negyedidőszaki képződményeinek vastagság-térképe (Thickness map of Quaternary sediments in Hungary), 1:200,000 Kézirat, Magyar Állami Földtani Intézet, Medenceanalízis Projekt jelentéstára, Budapest.

Fritz, H. and Neubauer, F. 1990. Die Struktur des Grazer Paläozoikum. In: 3. Symposium für Tektonik, Strukturgeologie, Kristallingeologie im deutschsprachigen Raum. Exkursion 'Grazer Paläozoikum', 23. April 1990. Institut für Geologie und Paläontologie, Karl-Franzens-Universität, Graz, pp. 1-15.

Fritz, H., Ebner, F. And Neubauer, F. 1992. The Graz thrust-complex (Paleozoic of Graz). In: F. Neubauer (Ed.), The Eastern Central Alps of Austria, field guide. AlCaPa, Geological evolution of the internal Eastern Alps and Carpathians and of the Pannonian Basin, June 27 – July 6, 1992, Graz.

Fusán, O., Ibrmajer, J., Plančár, J., Slávik, J. and Smíšek, M. 1972a. Geologická stavba podložia zakrytých oblastí južnej časti vnútorných Západných Karpát (in Slovak with English summary: Geological structure of the basement of the covered parts of the southern part of Inner West Carpathians). Zborník Geologických Vied, Západné Karpáty 15: 1-173 (1971).

Fusán, O., Slávik J., Plančár, J. and Ibrmajer, J. 1972b. Geologická mapa podložia zakrytých oblastí južnej časti vnútorných Západných Karpát (Geological map of the substratum of the covered areas in the southern part of the Inner West Carpathians). Zborník Geologických Vied, Západné Karpáty 15: Encl.

Fusán, O., Biely, A., Ibrmajer, J., Plančár, J. and Rozlozník, L. 1987a. Podložie terciéru vnútorných Západných Karpát (in Slovak with an extended English summary: Basement of the Tertiary of the Inner West Carpathians). D. Štúr Geol. Inst., Bratislava, 123 p.

Fusán, O., Plančár, J. and Ibrmajer, J. 1987b. Tectonic map of basement of Tertiary in Inner West Carpathians, Scale 1:500,000 D. Štúr Geol. Inst., Bratislava.

Fülöp, J. 1990. Magyarország geológiája. I, Paleozoikum (in Hungarian: Geology of Hungary. I, Paleozoic). Magyar Állami Földtani Intézet, Budapest, 325 p.

Fülöp, J. and Dank, V. (Eds.) 1987. Magyarország harmadidőszaki képződmények nélküli földtani térképe, 1:500,000 Magyarország Földtani Atlasza (Geological map of Hungary without Tertiary formations, scale 1:500,000 Geological Atlas of Hungary), 2. Magyar Állami Földtani Intézet, Budapest (1986).

Gaža, B. and Beinhauerová, M. 1977. Tektonika neogénu juhovýchodnej časti poDunajskáj panvy (in Slovak with English summary: Tectonics of the Neogene in SE part of the Danubian basin). Miner. Slov. 9 (4): 259-274.

Gerner, P. 1992. Recens kőzetfeszültség a Dunántúlon (in Hungarian with English summary: Recent stress field in Transdanubioa, Western Hungary). Földtani Közlöny, 122 (1), pp. 89-105.

Gerner, P. 1993. Dél-dunántúli neotektonikai modellek a magyar földtani szakirodalom alapján (in Hungarian: Neotectonic models for South Transdanubia in Hungarian geological literature). Kézirat, Magyar Állami Földtani Intézet Tektonikai Projekt Adattára, Budapest.

Grecula, P. 1982. Gemerikum – segment riftogénneho bazénu Paleotetýdy (in Slovak with English summary: Gemericum – segment of the Paleotethydian riftogenous basin). Miner. Slov. Monography 2, Publ. H. 'Alfa', Bratislava, 263 p.

Haáz, I. and Komáromi, I. 1967. Magyarország földmágneses térképe. A függőleges térerősség anomáliái, 1:500,000 (Geomagnetic map of Hungary. Anomalies of the vertical intensity). Geofizikai Közlemények (Geophys. Trans.) 16 (4): Melléklet (Encl., 1966).

Hasenhüttl, Ch. and Russegger, B. 1992. Niedriggradige Metamorphose im Grazer Paläozoikum. Jb. Geol. B.-A. 135 (1): 287-297.

Hoffer, E., Schönviszky, L. and Walach, G. 1991. Geomagnetic investigation in the Austrian-Hungarian border zone: The Kőszeg-Rechnitz Mts. area. Geophys. Trans. 36 (1-2): 67-79.

Jámbor, Á. 1993. Rövid magyarázó a pleisztocénben aktív magyarországi törésvonalak 1:500.000-es térképéhez (in Hungarian: Brief explanation to the map of faults with Pleistocene activity in Hungary, scale 1:500,000). In: Jámbor Á. (Ed.), Magyarország pleisztocénben aktív törései (térkép, magyarázó és bizonyító anyag), 1. rész Kézirat, Magyar Állami Földtani Intézet Tektonikai Projekt Adattára, Budapest.

Jámbor, Á., Bihari, D., Chikán, G., Franyó, F., Kaiser, M., Radócz, Gy. and Síkhegyi, F. 1993a. Magyarország pleisztocénben aktív törésvonalainak térképe (Map of faults with Pleistocene activity in Hungary, scale 1:500,000). In: Jámbor Á. (Ed.), Magyarország pleisztocénben aktív törései (térkép, magyarázó és bizonyító anyag), melléklet. Kézirat, Magyar Állami Földtani Intézet Tektonikai Projekt Adattára, Budapest.

Jámbor, Á., Bihari, D., Chikán, G., Franyó, F., Kaiser, M., Radócz, Gy. and SÍKHEGYI F. 1993b. A pleisztocén során működött magyarországi törésvonalak bizonyító anyaga (In Hungarian: Data for confirmation of faults with Pleistocene activity in Hungary). In: Jámbor Á. (Ed.), Magyarország pleisztocénben aktív törései (térkép, magyarázó és bizonyító anyag), 2. rész. Kézirat, Magyar Állami Földtani Intézet Tektonikai Projekt Adattára, Budapest.

Juhász, Á. 1967. A Kisalföld keleti peremének ópaleozóos képződményei (in Hungarian: Lower Paleozoic sequences of the eastern edge of the Little Hungarian plain). A Kőolaj- és Földgázbányászat Tudományos-Műszaki Közleményei II: 285-293.

Juhász, Á. and Kőháti, A. 1966. Mezozoos rétegek a Kisalföld medencealjzatában (in Hungarian with German summary: Mesozoische Schichten im Beckenuntergrund der Kleinen Ungarischen Tiefebene). Földtani Közlöny 96 (1): 66-74.

Kázmér, M., 1986. Tectonic units of Hungary: Their boundaries and stratigraphy (A bibliographic guide). Ann. Univ. Sci. Budapest., sect. Geol. 26: 45-120.

Kilényi, É. and Šefara, J. (Eds.), 1989. Pre-Tertiary basement contour map of the Carpathian Basin beneath Austria, Czechoslovakia and Hungary, Scale 1:500,000 Eötvös Loránd Geophysical Institute, Budapest.

Klinec, A. 1976. Charakteristik kryštalinika vo vrtoch MV-1, VV-1, VV-5 (in Slovak: Description of crystalline rocks from boreholes MV-1, VV-1, VV-5). Regionálna Geológia Západných Karpát 6: 52-53 (vrt/borehole VV-5).

Kókai, J. and Pogácsás, Gy. 1991. Hydrocarbon plays in Mesozoic nappes. Tertiary wrench basins and interior sags in the Pannonian Basin. First Break, 9 (7), pp. 315-334.

Koller, F. and Höck, V. 1987. Die mesozoischen Ophiolite der Ostalpen. Mitt. Österr. Mineral. Ges. 132: 61-77.

Kőrössy, L. 1963. Magyarország medenceterületeinek összehasonlító szerkezete (in Hungarian with English summary: Comparison between the geological structures of the basin regions of Hungary). Földtani Közlöny, 93, pp. 153-172.

Kőrössy, L. 1987. A kisalföldi kőolaj– és földgázkutatás földtani eredményei (in Hungarian with English summary: Hydrocarbon geology of the Little Plain in Hungary). Általános Földtani Szemle, 22: 99-174.

Lelkes-Felvári, Gy. 1982. A contribution to the knowledge of the Alpine metamorphism in the Kőszeg-Vashegy area (western Hungary). N. Jb. Geol. Paläont., Mh. 5: 297-305.

Lóczy, L. 1913. A Balaton környékének geológiai képződményei és ezeknek vidékek szerinti telepedése. A Balaton tudományos tanulmányozásának eredményei, I. kötet, 1. rész, 1. szakasz. Magyar Földrajzi Társaság Balaton bizottsága, Budapest, 617 p. (in German: Die geologischen Formationen der Balatongegend und ihre regionale Tektonik. Results der wissenschaftlichen Erforschung des Balatonsees, Band I, Teil 1, Sektion 1, Wien, 716 p.)

Lóczy, L. 1918. Magyarország földtani szerkezete (in Hungarian: Geological structure of Hungary). In: Lóczy L. (szerk.), A magyar szent korona országainak földrajzi, társadalmi leírása. Magyar Földrajzi Társaság, Budapest, pp. 5-43.

Mahel', M. 1986. Geologická stavba československých Karpát, 1. Paleoalpínske jednotky (in Slovak: Geology of the Czechoslovakian Carpathians, 1. Paleoalpine units). Publ. H. 'VEDA', Bratislava, 508 p.

Marosi, S. 1968. A Marcali-hát geomorfológiája (in Hungarian with German summary: Geomorphologie des Marcali-Rückens). Földrajzi Értesítő, 17, pp. 185-210.

Marosi, S. 1969. Adatok Belső-Somogy és a Balaton hidrogeográfiájához (Data on hydrogeography of Inner Somogy and Balaton). Földrajzi Értesítő, 18, pp. 419-456.

Marosi, S. 1970. Belső-Somogy kialakulása és felszínalaktana (Origin and topography of Inner Somogy region). Földrajzi Tanulmányok, 11, 169 p.

Marosi,S. and Szilárd, J. 1958. A Balaton somogyi partvidékének geomorfológiai képe (in Hungarian with German summary: Das geomorphologische Bild der Somogy Uferumgebung des Balatonsees). Földrajzi Közlemények, 6, pp. 347-361.

Marosi, S. and Szilárd, J. 1974. Újabb adatok a Balaton koráról (New data on the age of Lake Balaton). Földrajzi Értesítő, 23, pp. 333-346.

Miko, O. 1981. Staropaleozoický vulkanizmus veporidnej časti Nízkych Tatier (in Slovak with English summary: Early Paleozoic volcanism of the Veporid part of the Nízke Tatry Mts In: Š. Bajaník and D. Hovorka (Eds.): Paleovulkanizmus Západných Karpát, Geologický ústav Dionýza Štúra, Bratislava: 41-47.

Miller, V. C. and Miller, C. F. 1961. Photogeology. McGraw-Hill, New York – Toronto – London.

Nagy, E. 1972. Vizsgálataink a Kőszegi-hegységben (in Hungarian with German summary: Untersuchungen im Kőszeg-Gebirge). Magyar Állami Földtani Intézet Évi Jelentése 1970-ről: 197-207.

Némedi Varga, Z. 1977. A Kapos-vonal (in Hungarian with English summary: The Kapos Line). Földtani Közlöny, 107 (3-4), pp. 313-328.

Oberladstädter, M., Walach, G. and Weber, F. 1979. Geomagnetic measurements in the Alpine-Pannonic boundary region. EOS 60 (32): 572.

Pahr, A. 1980a. Die Fenster von Rechnitz, Bernstein und Möltern. In: R. Oberhauser (Ed.), Der Geologische Aufbau Österreichs. Springer Verlag, Wien and New York, pp. 320-326.

Pahr, A. 1980b. Das Rosalien– und Leithagebirge sowie die Hainburger Berge. In: R. Oberhauser (Ed.), Der Geologische Aufbau Österreichs. Springer Verlag, Wien and New York, pp. 326-331.

Pávai-Vajna, F. 1926. A földkéreg legfiatalabb tektonikus mozgásairól. Földtani Közlöny, 55 (1925), pp. 63-85 (in German: Über die jüngsten tektonischen Bewegungen der Erdrinde, pp. 282-297).

Pávai-Vajna, F. 1931. Magyarország hegységeinek szerkezeti vázlata. Földtani Közlöny, 60 (1930), pp. 1-33 (in German: Skizze des Baues der Gebirge Ungarns, pp. 149-179).

Pécsi, M. 1969. A Balaton tágabb környezetének geomorfológiai térképe (Geomorphic map of wide surroundings of Lake Balaton). Földrajzi Közlemények, 17, pp. 101-112.

Pécsi, M. 1986. A zalai meridionális völgyek, dombhátak kialakulásának magyarázata (Explanation for the genesis of north-south oriented valleys and hills in Zala County). Földrajzi Közlemények, 60, pp. 3-11.

Plašienka, D., Michalík, J., Kováč, M., Gross, P. and Putiš, M. 1991. Paleotectonic evolution of the Malé Karpaty Mts. – An overview. Geologica Carpathica 42 (4): 195-208.

Pogácsás, Gy., Simon, E. and Várnai, P. 1991. Hydrocarbon perspectives of overthrusted nappes in the pre-Neogene basement of the Pannonian Basin. 36th International Geophysical Symposium, September 23-28, 1991, Kiev, Ukraine. Abstracts and papers of the technical program, pp. 65-75.

Posch, E., Winter, P. and Walach, G. 1989. Stand und Ergebnisse der Schweremessungen in Südösterreich. In: H. Lichtenegger, P. Steinhauser and H. Sünkel (Eds.): Tagungsbericht über das 5. Internationale Alpengravimetrie-Kolloquium, Graz 1989. Österreichische Beiträge zu Meteorologie und Geophysik, 2 (Zentralanstalt für Meteorologie und Geodynamik, Publ. Nr. 332), 139-145.

Posgay, K. 1967a. A magyarországi földmágneses hatók áttekintő térképe. 1:500,000 (General map of magnetic bodies in Hungary). Geofizikai Közlemények (Geophys. Trans.) 16 (4): Mellékletek (Encl., 1966).

Posgay, K. 1967b. A magyarországi földmágneses hatók áttekintő vizsgálata (in Hungarian with an extended English summary: A comprehensive survey of geomagnetic masses in Hungary). Geofizikai Közlemények (Geophys. Trans.) 16 (4): 15-118 (1966).

Ramsay, J. G. and Huber, M. I. 1987. The techniques of modern structural geology, I-II. Academic Press, London, 697 p.

Reichwalder, P. 1981. Litologicko-petrografické charakteristik kryštalinika, 932.0-1203.4 m (in Slovak: Lithologic and petrographic description of crystalline rocks, 932.0-1203.4 m). Regionálna Geológia Západných Karpát 14: 44-52 (vrt/borehole ŠV-8).

Renner, J. and Stegena, L. 1966. Magyarország mélyszerkezetének gravitációs vizsgálata (in Hungarian with German summary: Gravimetrische Untersuchung der Tiefstruktur von Ungarn). Geofizikai Közlemények (Geophys. Trans.) 14 (1-4): 103-114.

Rumpler, J. (témafelelős) 1987. Az Alföld medencealjzatának és neogén üledékösszletének térképei (in Hungarian: Maps for the basement and Neogene sediments of the Great Hungarian Plain). Kézirat, Magyar Állami Földtani Intézet, Energiahordozó Nyersanyagok Projekt jelentéstára, Budapest.

Scheffer, V. and Kántás, K. 1949. A Dunántúl regionális geofizikája (in Hungarian with German summary: Die regionale Geophysik Transdanubiens). Földtani Közlöny 79 (9-12): 327-360.

Scheuer, G. and Schweitzer, F. 1988. A Gerecse– és a Budai-hegység édesvizi mészkőösszletei (Limnic limestone sequences of the Gerecse and Buda Hills). Földrajzi Tanulmányok, 20, 129 p.

Schmidt, E. R. 1951. Közép– és szigethegységeink szerkezeti kialakulásának geomechanikai alapjai (in Hungarian: Geomechanical basis of the structural formation of our central chaines of mountains and isolated hills). Bányászati Lapok, 84, pp. 358-372.

Schmidt, E. R. 1952. A Dunántúli Magyar Középhegység ÉK-i részének hegyszerkezeti vázlata és kialakulásának geomechanikai magyarázata (in Hungarian: Tectonical outline of the northeastern part of the Hungarian Transdanubian Mittelgebirge and geomechanical explanation of its formation). Bányászati Lapok, 85, pp. 31-36.

Schmidt, E. R. 1957. Geomechanika (in Hungarian: Geomechanics). Akadémiai Kiadó, Budapest, 275 p.

Schmidt, E. R. 1961. Considérations géomécaniques sur la formation des cratosynclinaux mésozoiques de la Hongrie et sur l'interprétation des leurs caractéristiques tectoniques principles. Annals Hung. Geol. Inst. 49 (3): 931-958.

Schönlaub, H. P. 1980. Das Grazer Paläozoikum. Remschnigg und Sausal. In: R. Oberhauser (Ed.): Der Geologische Aufbau Österreichs. Springer Verlag, Wien and New York, pp. 397-403.

Schweitzer, F., Pécsi, M., Marosi, S., Juhász, Á. and Balogh, J. 1993b. Pleisztocénben aktív törésvonalak és süllyedékek térképe (Map of faults and depressions with Pleistocene activity). Kézirat, MTA Földrajztudományi Kutatóintézet Adattára, Budapest.

Seiberl, W. 1988. Aeromagnetische Karte (Isoanomalen der Totalintensität ΔT), Maßstab 1:200,000 Steirisches Becken – Südburgenlandische Schwelle, Geologische Bundesanstalt, Wien.

Síkhegyi, F. 1985. Kozmikus felvételek szerkezeti értelmezése (in Hungarian: Structural interpretation of satellite images). In: Gyakorlati szerkezetföldtani továbbképző, Miskolc, 1983 június 4, pp. 129-144.

Somogyi, S. 1956. Megfigyelések Budapest környékén az 1956. január 12.-i földrengéstől sújtott területen (in Hungarian: Observations in the area affected by the earthquake on January 12, 1956 near Budapest). Földrajzi Értesítő, 5, pp. 129-134.

Strausz, L. 1942. Adatok a dunántúli neogén tektonikájához. Földtani Közlöny, 72, pp. 40-52 (German summary: Angaben zur Tektonik des Transdanubischen Neogens, pp. 119-121).

Szabó, P. Z. 1957. Délkelet-Dunántúl felszínfejlődési kérdései (Problems of the surface evolution of Southeast Transdanubia). Földrajzi Értesítő, 6, pp. 397-419.

Szabó, Z., Polcz, I. and Páncsics, Z. 1993. Geofizikai adatokban megnyilvánuló szerkezeti lineamensek (Lineaments expressed in geophysical data). Kézirat, Eötvös Loránd Geofizikai Intézet, Földfizikai Osztály Adattára, Budapest.

Szeidovitz, Gy. 1986. Earthquakes in the region of Komárom, Mór and Várpalota. Geophysical Transactions, 32 (3), pp. 255-274.

Szeidovitz, Gy. 1990. Komárom és Mór környezetében keletkezett történelmi rengések epicentrális intenzitásainak és fészekmélységeinek meghatározása (in Hungarian: Determination of epicentral intensities and focal depths for historical earthquakes in the surroundings of Komárom and Mór). Kézirat, Kandidátusi értekezés, Magyar Tudományos Akadémia Könyvtára, Budapest.

Szeidovitz, Gy. and Mónus, P. 1993. A magyarországi földrengések eloszlása (Distribution of earthquakes in Hungary). Kézirat, MTA GGTI Szeizmológiai Osztály Adattára, Budapest.

Szilárd, J. 1967. Külső-Somogy kialakulása és felszínalaktana (Origin and topography of Outer Somogy region). Földrajzi Tanulmányok, 7, 150 p.

Vajk, R. 1943. Adatok a Dunántúl tektonikájához a geofizikai mérések alapján. Földtani Közlöny, 73, pp. 17-38 (German summary: Beiträge zur Tektonik von Transdanubien auf Grund geophysiKališcher Untersuchungen, pp. 195-200).

Varrók, K. 1963. Földtani vizsgálatok a Kőszegi-hegységben (in Hungarian with French summary: Examens géologiques dans la montagne Kőszeg). Magyar Állami Földtani Intézet Évi Jelentése 1960-ról: 7-20.

Walach, G. and Weber, F. 1987. Contributions to the relations between the Eastern Alps and the Pannonian Basin in the light of gravimetric and magnetic investigations. In: H. W. Flügel and P. Faupl (Eds.), Geodynamics of the Eastern Alps. Franz Deuticke, Vienna, pp. 345-360.

Annex 22

EFFECT OF LOCAL GEOLOGICAL CONDITIONS ON THE ACCELERATIONS EXPECTED IN THE AREA

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Abstract

Experimental model computations were made for the determination of the effect of the local geology on the expected accelerations in the area. The model parameters – in the lack of measured values – were estimated form the general geological knowledge of the area, and for the excitation we used the strong motion records of an earthquake whose parameters [distance, magnitude, source mechanism] are similar to that of a typical earthquake that could happen in the area.

The results indicate that the largest amplification of ground motion in the area are caused by the SH waves, which is one magnitude larger than that of the P or SV waves. On the effect of an assumed earthquake 0.2-0.3 g peak horizontal acceleration can be expected.

Intensity Modifying Effect of the Upper Loose Layers and Their Spectral Characteristics

Seismic waves amplify or diminish in sediments above the bedrock, depending on the frequency transfer properties of the individual layers. Determination of the response spectrum of the series of layers in the area would be possible on the basis of a registered strong earthquake acceleration measured simultaneously on the bedrock and the surface. This, however, is available very rarely and has not occurred recently. Nonetheless, the response spectrum can be calculated by accepting certain simplifying conditions, knowing the layer thickness, densities and interval velocities. By means of an available computer program, a transfer function of a laterally homogeneous, horizontally stratified, viscoelastic medium, can be determined for P, SV and SH waves. Changes of the acceleration with respect to the time (accelerogram) relating to the bed-rock, will be determined when going through the various sediments resulting in the expected accelerations on the surface.

Because of the rare and scattered character of the stronger earthquakes occurring in Hungary, no "strong motion" network or stations operate in the country, so such direct measuring data are not available. However, data of tectonic conditions which are similar both at the sources and at the place of registration to the problem investigated by us, can be selected from international data banks. Furthermore, earthquakes occurring in the potential source zone and their effects on the area, can be modelled.

In this study, the calculation of the spectral properties of the bedrock is emphasised, because the acceleration data can be transformed to apply to the frequency range required by multiplying spectrums or with convolution applied in time.

Determination of spectral characteristics of the laterally homogeneous, horizontally stratified sediment series

Motion equation relating to elastic waves can be described by the Navier equation if mass forces are neglected:

$$\rho\ddot{u}=(\lambda+\mu)\nabla(\nabla u)+\mu\nabla^2 u \qquad (1)$$

where ρ is the density, μ and λ are Lame constants and **u** is the displacement vector. By using the identity:

$$\nabla^2 u=\nabla(\nabla u)-\nabla\times\nabla\times u \qquad (2)$$

equation (1) can be described in the following form:

$$\rho\ddot{u}=(\lambda+2\mu)\nabla(\nabla u)-\mu\nabla\times\nabla\times u \tag{3}$$

By using the identities:

$$\nabla(\nabla\times u)\equiv 0 \tag{4}$$

$$\nabla\times\nabla\theta\equiv 0 \tag{5}$$

equation (3) can be separated into two equations from which the first one describes dilatation and the second one describes rotational motion.

When forming divergence for equation (3), equation (6) can be obtained:

$$\rho\frac{\delta^2\theta}{\delta t^2}=(\lambda+2\mu)\nabla^2\theta \tag{6}$$

where

$$\theta=\nabla\cdot u \tag{7}$$

the relative change of volume. When forming rotation of equation (3):

$$\rho\frac{\delta^2\omega}{\delta^2 t}=\mu\nabla^2\omega \tag{8}$$

where

$$\omega=\nabla\times u \tag{9}$$

Equation (6) describes the motion of P waves, where

$$\alpha=\sqrt{\frac{\lambda+2\mu}{\rho}} \tag{10}$$

is the phase velocity. Similarly, equation (8) describes the motion of S waves, where

$$\beta=\sqrt{\frac{\mu}{\rho}} \tag{11}$$

is the phase velocity.

Each vector can be given as a combination of a scalar (ϕ) and a vector-potential (ψ):

$$u=\nabla\phi+\nabla\times\psi \tag{12}$$

where

$$\nabla\psi=0 \tag{13}$$

The following is the resultant of equation (7) and (12):

$$\theta=\nabla^2\phi \tag{14}$$

where ϕ scalar potential describes P waves. The resultant of equation (9) and (12) is the following:

$$\omega=-\nabla^2\Psi \tag{15}$$

where Ψ vector potential relates to S waves.

According to the above statements the displacement vector can be described as sum of the P and S waves:

$$u=P+S \tag{16}$$

where

$$P=\nabla\phi \tag{17}$$

and

$$S=\nabla\times\Psi \tag{18}$$

If the co-ordinate system is selected, such that the direction of the plane-wave, arriving at the surface with ϑ angle of incidence, should be on the (x, z) plane, the ϕ and Ψ potentials characterising flexible displacements will be not dependent on the y direction. In this case displacements can be expressed with ϕ and Ψ potentials ($\Psi_y=\Psi$) in the following form:

$$u=\frac{\partial\phi}{\partial x}-\frac{\partial\Psi}{\partial z} \tag{19}$$

$$v=\frac{\partial\Psi x}{\partial z}-\frac{\partial\Psi z}{\partial x} \tag{20}$$

$$w=\frac{\partial\phi}{\partial z}+\frac{\partial\psi}{\partial x} \tag{21}$$

The u and w components of the displacement vector are composed from the u and w components of the P and SV waves, while the v components is purely created by the SH wave.

In homogeneous, stratified medium, ϕ and Ψ potentials satisfy the following wave equations in each layer:

$$\frac{\partial^2\phi}{\partial t^2}=\alpha^2\nabla^2\phi \tag{22}$$

$$\frac{\partial^2\Psi}{\partial t^2}=\beta^2\nabla^2\Psi \tag{23}$$

Thus, the displacement and stress components will continuously pass through individual layer boundaries; until they reach the free surface where the stress components will disappear.

In the calculations, the anelasticity of the medium accounted for by using a quality factor Q. The Q factor describes the relative energy loss of the seismic wave during a full period:

$$\frac{1}{Q}=\frac{1}{2\pi}\frac{|\Delta E|}{E} \tag{24}$$

where E is the energy at the start of the cycle, and ΔE is the energy loss during one cycle. Consequently Q is inversely proportional to the relative energy loss that is low values of Q represent a significant energy loss.

Absorption causes frequency dependence of the seismic waves which can be described as complex functions:

$$v_p(f)=\alpha\left(1+\frac{1}{\pi Q_p}\ln\frac{f}{f_r}\right)+i\frac{\alpha}{2Q_p} \tag{25}$$

$$v_s(f)=\beta\left(1+\frac{1}{\pi Q_s}\ln\frac{f}{f_r}\right)+\frac{i\beta}{2Q_s} \tag{26}$$

where fr is the reference frequency (f_r =1 Hz), Q_P and Q_S are weights for P and S waves respectively.

In other words, in order to determine the impulse response function of a laterally homogeneous, horizontally stratified medium, we need to solve the wave equations of the potentials. We must also include the frequency dependency of P and S waves if the generating signal is a delta function arrive at the base of the layers with an angle θ.

The wave equation has been solved numerically, applying the matrix method which gives the amplitude spectrum of the impulse response function for each component. The amplitude spectrum was calculated in the 0.1 to 20 Hz range with 0.1 Hz intervals.

Geological Model

The input data for the geological model – because of the lack of measurements that could provide data for the model parameters– were estimated using the general geological knowledge on the area. These data include the thickness and density of each individual layer, the velocity of P and S waves in these layers and the values of QP and QS quality factors relating to the P and S waves, respectively.

Since the model parameters are based on estimations, the results should be considered only a first approximation of the accelerograms that could be experienced in reality.

The parameters of the geological model are shown in Table 1.

Parameters of the geological model are shown in Table 1.

Table 1: *Geological layer model (basement depth: 4,000 m).*

d (m)	α(m/s)	β (m/s)	ρ (g/cm^3)	Q_p	Q_s
50	600	300	1.80	1000	10
550	1900	700	1.88	1000	20
400	2350	1240	2.00	2000	50
500	2900	1675	2.10	2000	100
350	3240	1870	2.20	3000	500
550	3630	2095	2.32	3000	500
400	3380	1950	2.39	3000	500
200	3800	2195	2.44	3000	500
100	4900	2830	2.47	3000	500
100	4050	2340	2.48	3000	500
300	4920	2840	2.51	3000	500
100	5550	3200	2.53	3000	500
400	5080	2930	2.55	5000	5000
∞	5250	3090	2.55	5000	5000

Modifying Effect of the Sediments for the Vibration

Response spectra produced from the given model are shown in Figure 1. Note that the y component of the P wave is equal to zero in the selected co-ordinate system, that is only the x (PU) and z (PW) components exist. The y component of the S wave is formed purely from the SH wave, while the SV wave has only SU and SW components in the x and z directions, respectively.

From the figures it can be seen that the SH wave is able to generate one magnitude higher amplification at certain frequencies than the P or SV waves. This concurs with the experience which demonstrates the SH wave causes the highest damage during earthquakes. In addition, sharp resonance peaks can be observed on the SH wave response spectrum although the highest amplitude does not necessarily occur at the first resonance frequency. Resonance peaks can also be observed on the response spectra belonging to the P and SV waves but these are not so clearly articulated as those belonging to the SH wave and the amplitudes are much lower than these of the SH wave. From the figure it can also be seen that amplitudes are highest in the low frequency range below 5 Hz (amplitude of the SH component belonging to a frequency of 4.2 Hz is magnified by 65). Given that resonance frequencies of the constructions fall into this frequency range, it is advisable to take these values into consideration.

Expected Accelerations

For determining the accelerations and acceleration versus time functions expected in the area, an earthquake must be supposed that an potentially occur in the area. In our case – based on the historical sensitivity and the tectonics of the region – it can be assured that an earthquake with a magnitude 5.6 can occur within a radius of 30 km of the construction work.

Based on the above assumptions such an accelerogram has been selected from the international data bank which originates from an earthquake which:

– is connected to a strike-slip structure with a focal depth of 10 km;
– registration was made on the bed-rock in a small distance (less than 30 km);
– magnitude of the earthquake is about 5.6.

For the calculations an earthquake occurred in 1976 in Friuli was used which was registered at Robic. The registration was made 30 km far from the epicentre by accelerometers located on rock outcrops. The selected earthquake with its magnitude of 5.9 is somewhat higher than that is assumed for the investigation area but the energy release (rise time) is faster than that of the characteristic earthquakes occurred in the Carpathian basin.

The expected accelerations for x, y and z directions and their spectra for the given geological model are shown in Figures 2-4 respectively.

Considering that the highest accelerations are created by the SH wave Figure 3. should be taken into consideration when planning the installations. As can be seen from Figure 3, the assumed earthquake produces a horizontal peak acceleration of 0.2-0.3 g (g is the gravitation acceleration, $g=9.81\ m/s^2$).

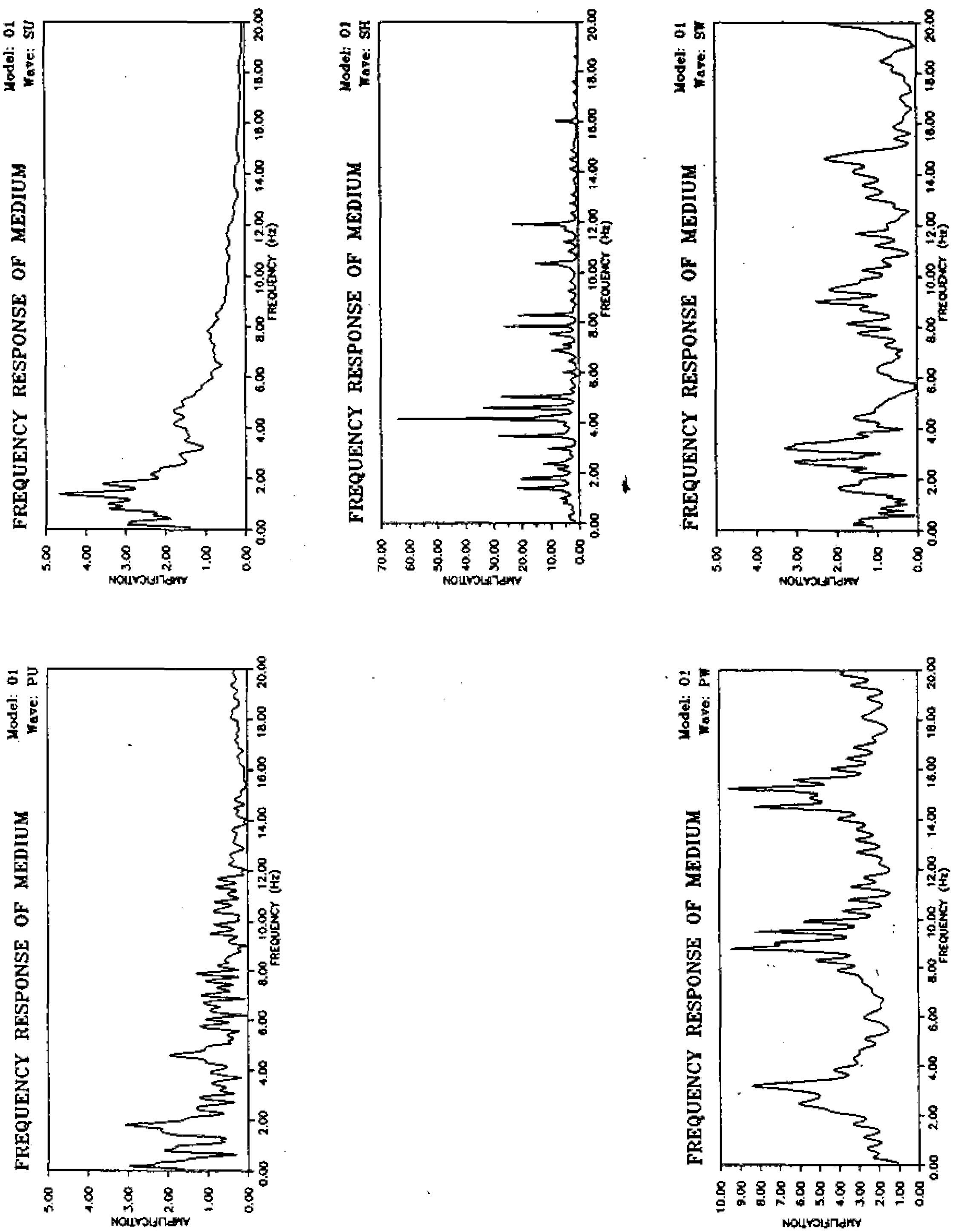

Figure 1. Soil response functions calculated with the geological model

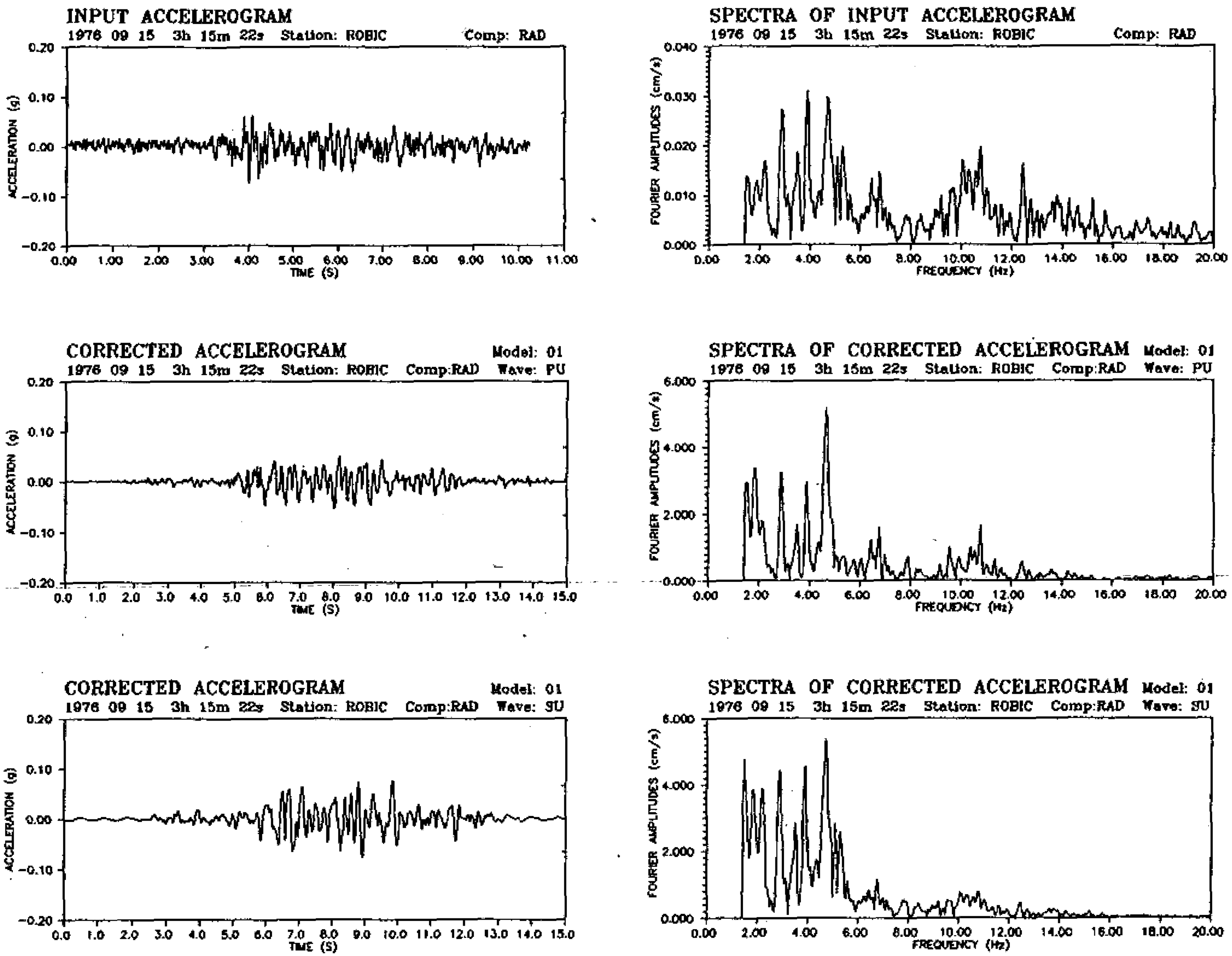

Figure 2. Transformation of acceleration appearing on the bed-rock to the surface: radial component

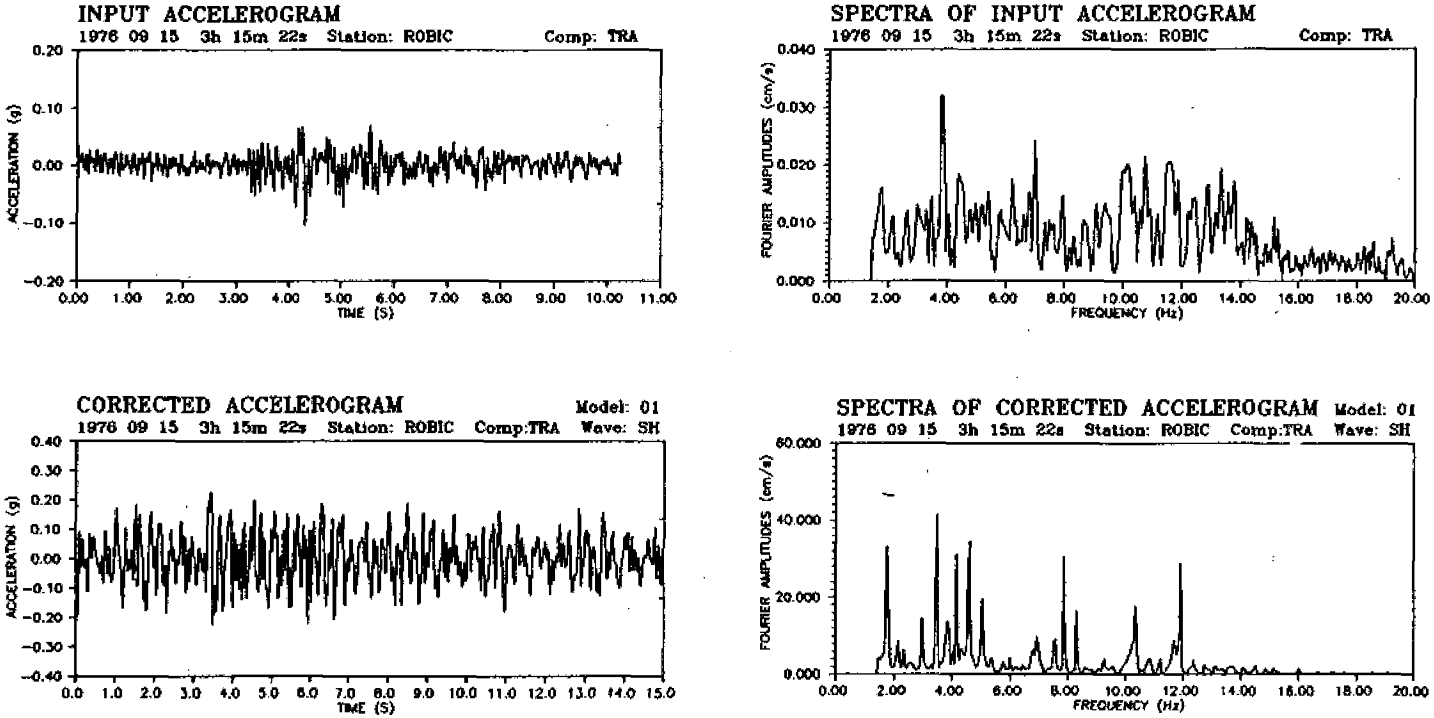

Figure 3. Transformation of acceleration appearing on the bed-rock to the surface; transversal component

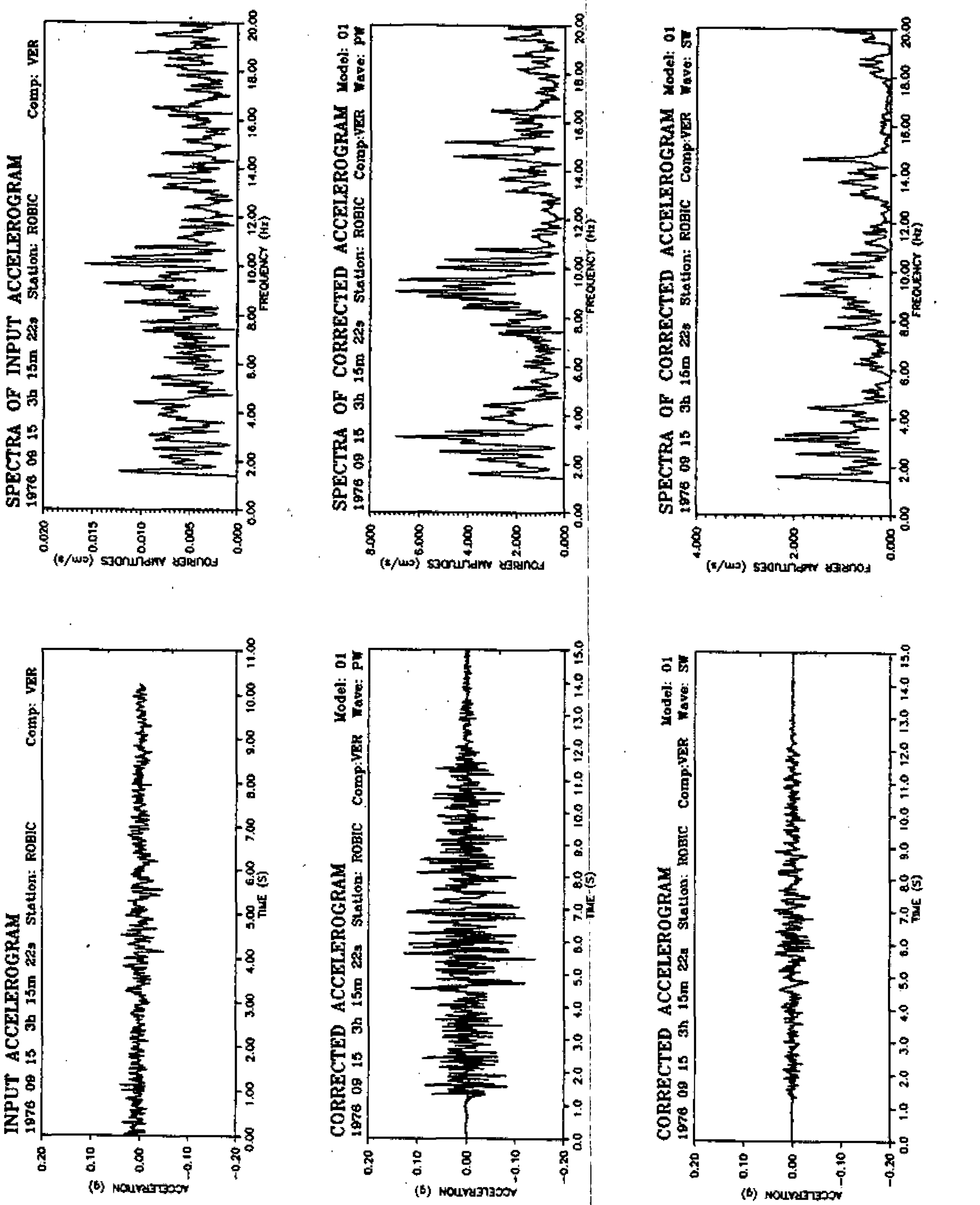

Figure 4. Transformation of acceleration appearing on the bed-rock to the surface; vertical component

Annex 23

THE GABČÍKOVO - NAGYMAROS PROJECT
AN EVALUATION OF THE HUNGARIAN GABČÍKOVO - NAGYMAROS ENVIRONMENTAL IMPACT STUDIES

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Summary

The controversial Gabčíkovo-Nagymaros project has been subject to several environmental studies. Three major reports have been prepared: the study of April 30th, 1983; the study of June 1985 and the 1993 report. These three reports can be considered in the framework of an emerging field in applied biological sciences: the Environmental Impact Assessment (EIA). The aim of this study is to review the three environmental reports prepared for the Gabčíkovo-Nagymaros project and to discuss their quality.

The two main aspects which are looked into concern the EIA procedures and the content of EIA studies for dams. This study starts with an historic overview of the evolution of EIA procedures and contents because it is the intention to review the reports within the time frame in which they were produced. This approach is set up to prevent the evaluation of environmental reports which were prepared in the past with today's standards. Therefore, a major effort is made to review the reports in relation to the "EIA state-of-the-art" in the respective years in which they were issued.

First, the evolution of Environmental Impact Assessment (EIA) procedures and the evolution in the content of Environmental Impact Statements (EISs) for the 1970s, 1980s and 1990s is examined. Based on this historic overview it is possible to organise an evaluation of environmental documents which were prepared in relation to the Gabčíkovo - Nagymaros Barrage System. The 1985 report is studied in most detail: the quality of the document is assessed with the help of the Lee and Colley review package (1990) and a general checklist which lists all topics which should be discussed in an Environmental Impact Statement (EIS) for a large dam project.

The three environmental documents examined cannot be considered satisfactory. The 1983 and 1993 reports do not satisfy the basic requirements and should not be given the name EIS. The 1985 report is an EIS which has a number of defects.

The major limitations of this document can be summarised as follows:

- there is no discussion on the scope of the document: why have certain aspects been studied and others not?
- although a lot of background studies have been made for the proposed project, these studies are not discussed in an integrated way in the main body of the text;
- although alternatives and mitigation measures have been proposed in the EIS, they are not the "heart" of the document. Alternatives and mitigation measures are limited and not studied in sufficient detail;
- although impacts are examined, it is not discussed what was the basis for the interpretation of the data. The choice of standards, assumptions and value systems used is not explained;
- the communication of the results is insufficient. The layout is confusing, the reference system is not correct and reviewers have doubts about the objectivity of the study.

A checklist presenting all aspects which should be included in an EIS for a large dam project is developed in section 4.4: only 9% of the relevant topics were fully covered; 54% was only

generally, partially or shortly discussed; 14% was only referred to or very weak and no information was found on 23% of the relevant topics.

The overall conclusion is that the 1985 Gabčíkovo-Nagymaros EIS contains a lot of relevant information, but shows major limitations and defects.

1. Introduction

The Gabčíkovo-Nagymaros project plans the construction of a system of dams on the Danube on the border of Hungary and Slovakia. The project is highly controversial and has been subject to several environmental studies. Three major reports have been prepared at the Hungarian side: the study of April 30th, 1983; the study of June 1985 and the 1993 report. These three reports can be considered in the framework of an emerging field in applied biological sciences: the Environmental Impact Assessment (EIA). The aim of this study is to review the three environmental reports prepared for the Gabčíkovo-Nagymaros project and to discuss their quality.

The two main aspects which are looked into concern the EIA procedures and the content of EIA studies for dams. To review the reports within the time frame in which they were produced, this study starts with an historic overview of the evolution of EIA procedures and contents. This approach is set up to prevent the evaluation of environmental reports which were prepared in the past with today's standards. Therefore, a major effort is made to review the reports in relation to the "EIA state-of-the-art" in the respective years in which they were issued.

The underlying report is divided into three major parts: first, the historic evolution of EIA procedures is examined; second, the historic evolution of EISs for dam projects is looked into and third, the three Hungarian studies are evaluated on the basis of the knowledge gained in the first and second parts.

The evolution in EIA procedures focuses on the general US, Canadian, EC, USSR and World Bank situations and on specific remarks for dam studies, based on selected case studies. The evolution in the contents of EISs is also studied, first in general and later specifically for dam projects. This part is concluded with the development of a checklist which makes it possible to examine the degree of completeness of EISs for dams.

This checklist in used in the third part to evaluate the content of the 1985 Gabčíkovo-Nagymaros EIS. Moreover, the Lee and Colley environmental statement quality review package (1990) is used to gather additional data and evidence to substantiate the conclusions. The Lee and Colley method is used in a number of European countries to review the quality of environmental impact statements. It was developed at the EIA Centre, University of Manchester.

Finally conclusions are formulated on the evolution in EIA procedures, on the evolution in EIS content and on the quality of the three Hungarian Gabčíkovo-Nagymaros EISs.

2. Materials and Methods

Parts 3 and 4 of this report, which give an overview of the historic evolution of the EIA procedures and of the content of EISs for dams, are based entirely on an extensive literature review.

In part 4.4 a list of review topics is developed which can be considered as a supplement for the Lee and Colley review package. Both the Lee and Colley package and the supplement are used in part 5 of this work to assess the quality of the Hungarian key studies in the Gabčíkovo-Nagymaros dam.

The Lee and Colley quality review package (1990 and 1992) contains advice for reviewers, a list of criteria to be used in each review and a collation sheet on which to record the results.

The review package has a hierarchical structure with four levels. The most detailed review topics are at the lowest level and should be assessed first. Several sub-categories relating to the same subject are part of one category. The assessment of these categories is based on the results obtained at the lower level. Several categories can be grouped together in review areas. The top of the assessment pyramid is formed by the overall assessment of the EIS.

The review procedure to be followed in the Lee and Colley review package is described below:

1. Read all of the Advice for Reviewers (included in Lee and Colley, 1990) carefully.

2. Read through the List of Review Topics (areas, categories, sub-categories) and familiarise yourself with them and with the data required.

3. Read the Statement quite quickly noting the layout and the whereabouts of essential information (If practicable, undertake a site visit to become more familiar with the location of the proposed development).

4. Read the first review category (1.1) and its component sub-categories (1.1.1 - 1.1.5). Remember that the sub-categories refer to actions which must be undertaken in order that tasks described by the category are performed fully and well. Interpret them in this context.

5. Assess each of the sub-categories (1.1.1-1.1.5) referring closely to the Statement. Be aware that the required information will not all be located in the same place for any one topic. It will probably be necessary to make notes. Carefully read the list of assessment symbols. The appropriate assessment symbol is to be chosen based on the way the tasks relating to the sub-category are performed throughout the Statement. Before deciding on the symbol it may be helpful to refer once more to the wording of the review sub-category and to recall the strategy of review explained above.

6. Decide which assessment symbol is appropriate for each sub-category and record it on the Collation Sheet.

Note that a task should be assessed as having been satisfactorily handled if there is sufficient information provided in the Statement on the topic concerned to allow a decision-maker to make an informed decision without having to seek further advice. It is the appropriateness and quality and not the volume of information provided which is the relevant consideration. It could be justifiable to supply more limited information for small projects having few and less complex impacts than for much larger projects with multiple major impacts. Where data on a particular topic are not explicitly provided but is, nevertheless, implicit in the treatment of other topics, the reviewer may decide that it should be assessed as adequate. Such instances should be recorded in the synopsis.

7. Use the assessment of sub-categories 1.1.1 - 1.1.5 and any other information gained from the Statement which you considered relevant, to assess the review category 1.1. Note that the assessment of the category should not be derived by a simple averaging of the assessments of the component sub-categories. Your evaluation of both the relative importance of these sub-categories and any information in the Statement not covered by them, should also be taken into account.

8. Proceed to the next review category (1.2) and evaluate it in the same way as review category 1.1. Continue until all categories in the review area have been assessed in the same manner.

9. Your evaluations of the review categories can now be used to assess the review area in the same way in which they themselves were derived from the review sub-category assessments. Thus, for example, the assessment of review area 1 is to be based upon the assessments of Categories 1.1 - 1.5.

10. When all review areas have been assessed the Statement as a whole can be assigned an assessment symbol. This overall judgement should, however, be supplemented with a brief synopsis of the Statement's strengths and weaknesses and a consideration of whether, for example, it meets minimum requirements.

11. Then the two reviewers should meet to compare their findings as recorded on their Collation Sheets. Where differences in their assessments occur (at sub-category, category, etc. levels), reviewers should jointly re-examine them with a view to reconciling their findings on a common Collation Sheet.

3. Historic Evolution of the EIA Procedures During the Period Pre-1970 - 1993

3.1. International

3.1.1. General elements of innovations in techniques and procedures during the period pre 1970 - 1993

Environmental Impact Assessment (EIA) is a project evaluation technique. Project evaluation techniques have evolved over the years, especially during the period 1970 - 1990. Trends in project evaluation during this time can be summarised as follows:

before 1970

mostly analytical techniques were used. These were very close to economic and technological feasibility studies. In these studies there was only limited attention for efficiency criteria and safety concerns. There was no possibility for public debate;

around 1970

mostly cost-benefit analysis with multiple aims was used. The systematic counting of advantages and disadvantages and their geographic distribution was stressed. Project evaluation was organised through planning, programming and budget control. There was no attention for environmental and social consequences of a project;

1970 - 1975

EIA was introduced and focused on the description and prediction of ecological changes and modifications in land use. EIA also introduced public participation in the project evaluation. Attention is paid to surveillance of the project and to mitigating measures;

1975 - 1980

Multi-dimensional EIA is encouraged – it includes among others the reporting of impacts at the social level (social impact assessment). Public participation now becomes a fully integrated part of the project evaluation. More attention also goes to risk analysis of dangerous installations;

1980 - 1990

EIA is no longer considered an isolated event. It is closely linked with higher level policy planning and the implementation management phases. Monitoring, post-project analysis and process-evaluation are stressed. The need for a scoping phase is recognised. More attention goes to health aspects.

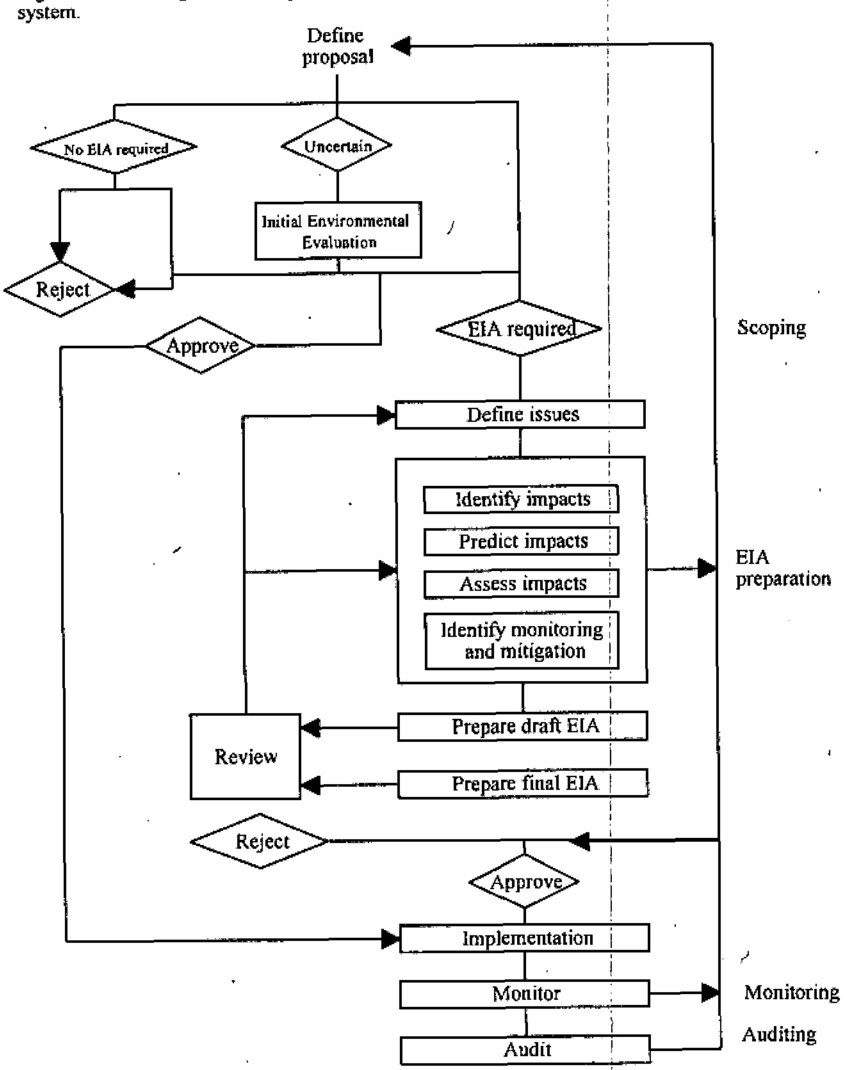
The main components of present EIA systems in most of the countries (which is applicable at all levels of planning) is given by Wathern (1992) in figure 1.

3.1.2. United States: NEPA (1969)

Until 1969, the U.S. national philosophy concerning negative environmental effects of major projects such as highways, industrial plants, shopping centres, housing developments, etc., was basically to ignore them during the planning stages of the project. After the work was completed and the environmental effects were apparent, the attitude was generally one of "Too bad, but it couldn't be avoided" (Bregman et al., 1992).

The introduction of the National Environmental Policy Act (NEPA) in 1969 aimed to change this attitude dramatically. The purposes of NEPA are: to declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality (CEQ). One of the results of NEPA is the introduction of a procedure – the EIA procedure – which forces federal officials to consider the possible consequences of decisions having major implications for the quality of the human environment. NEPA was not meant to force any particular decision on an agency; it required the agency to certify through an environmental impact statement (EIS) that it had investigated and considered the environmental implications of its proposed actions (Caldwell, 1982).

Figure 1. Flow diagram showing the main components of an EIA system.



Note: The main components of present EIA system in most of the countries are similar. The EIA procedure may differ but they are designed to deal with the same issue i.e. the environmental consideration in planning.

(Source: Wathern, 1992)

NEPA did not establish any direct enforcement machinery to ensure that its objectives were carried out, since neither the CEQ nor the EPA has the authority to halt projects which harm the environment. There is, however, an indirect enforcement. As they often have in American society, the Federal Courts encouraged by organised environmental groups, in effect filled the enforcement void by supplying a forum in which agency NEPA compliance could be tested (Blumm, 1988).

Many court cases have taken place related to the application of NEPA in particular situations. This 'common law' of NEPA grew rapidly in the 1970s and was effectively codified by the CEQ in its regulations of 1978.

The following are the most important steps in the evolution of NEPA (Blumm, 1988):

– *substance versus procedure*

One of the first appellate cases to interpret NEPA was *Calvert Cliffs Coordinating Committee v. Atomic Energy Commission* where Judge Wright established some enduring NEPA principles. He declared that "the judicial role is to ensure that the promise of legislation becomes reality and is not lost in the halls of the bureaucracy", thus signalling that the courts would assume an active role in ensuring NEPA's implementation.

– *the rule of reason*

In another early NEPA case, concerning off-shore oil leasing in the Gulf of Mexico, the District of Columbia Circuit Court of Appeal ruled that the alternatives to the proposed action that had to be considered in EISs were bounded by a "rule of reason". Thus, remote and speculative alternatives need not be given attention. This "rule of reason" was subsequently extended to include the contents of an EIS as a whole. Consequently, an EIS need not be encyclopaedic to satisfy NEPA. It must only focus on significant environmental impacts likely to result from a proposal and discuss reasonable alternatives to the proposals that would avoid or minimise those effects. Alternatives are the heart of the EIS. The quality of the analysis in an EIS determines NEPA compliance, not the quantity of pages the document consumes.

– *programmatic EISs*

In an important Supreme Court decision from 1976, in the *Kleppe v. Sierra Club* case, the Court ratified the notion that EISs were required not only of specific projects but also of broad programmes and agency policies.

– *the CEQ regulations*

Prior to 1978 there were no enforceable regulations interpreting NEPA. The 1978 CEQ regulations not only effectively codified the common law of NEPA as it existed in 1978, they also included a number of innovative provisions that CEQ felt would make the EIA process more effective. These include: a) a "scoping process" to identify significant issues related to proposed actions, b) publicly available Environmental Assessments (EAs) for proposals that do not produce significant environmental effects, c) draft, final and supplemental EISs for proposals that do produce significant environmental effects; and d) records of decision that explain the relationship of the analysis in an EIS to an agency's ultimate decision on the merits of a proposal.

Since the 1978 CEQ regulations not much has changed in the US concerning EIA. There are, however, new proposals of bills to amend NEPA these days. The following amendments are looked into (Coenen, 1990):

– consideration of alternatives in the EIA

The existing criteria for determining the sort of alternatives to be considered in an EIS still leave scope for interpretation. A planned amendment now requires that the EIS has to deal with reasonable alternatives to the proposed action that achieve the same or similar public purposes, including alternatives that avoid the adverse impacts of the proposed action and alternatives that otherwise mitigate those impacts. It emphasises again the importance which the legislator attributes to the consideration of alternatives in the NEPA process;

– the treatment of global environmental impacts in an EIA

introducing policies and measures to reduce global environmental problems and ensuring the consideration of global impacts in Federal decision-making are central objectives of the planned NEPA amendment;

– public participation

the legislator once more wishes to emphasise the importance which should be attributed to this procedural requirement;

– introduction of monitoring

the lack of monitoring requirements has generally been considered to be one of the most important deficiencies in the present NEPA process. NEPA amendments now envisage extensive provisions in this respect;

– performance of formal assessments for major Federal actions with potentially significant environmental impacts undertaken by the US Government outside US territory

the proposed amendments require the CEQ to issue regulations which ensure a formal assessment in a manner that also furthers the NEPA objectives for Federal actions that take place outside the US.

3.1.3. Canada: EARP (1973) /CEAA (1992)

Since implementation of the policy on April 1, 1974, the Environmental Assessment and Review Process (EARP) of Canada has been scrutinised and adapted to meet perceived shortcomings in procedural requirements and to respond more aptly to stated objectives of EIA at the federal level. Bowden and Curtis (1988) examined the EARP during its first 10 years of implementation. Their findings can be summarised as follows:

EIA in Canada, was introduced by federal directives dated June 8, 1973, and December 20, 1973. After 3 years of practical application a further directive attempted to fine-tune the process in 1977. It was only with the Government Organisation Act of 1979, however, that the administrative process was statutory mandated, authorising the Minister of Environment to "ensure that new federal projects and activities [were] assessed early in the planning process for potential adverse effects on the quality of the natural environment". A Revised Guide to the Federal Environmental Assessment and Review Process was published in 1979 to outline definitively the mechanics of the process.

From inception, EARP was the subject of major criticism from environmental groups. Perhaps the most fundamental complaint addressed the non legal nature of the process and the self-assessment approach. To avoid possible confrontation EARP was introduced as a policy, rather than a law. A policy was also thought to be more flexible than a law. In spite of these admirable objectives, the reluctant initiator could not be forced to comply with the process. If a department decided to ignore the necessity of an assessment there was no opportunity for review of the decision – judicial or otherwise.

The scope of the EARP process has also been the subject of criticism. Once a project is labelled as primarily federal in its origins, should not the significance of the undertaking, rather than the source of the project, be the determining factor?

Another major criticism of EARP related to the limited role of the public in the process. The public might be greatly disadvantaged by time limitations, lack of access to information beyond the EIS document, and absence of funding provisions to facilitate meaningful participation.

As late as 1983, the federal government failed to address several major shortcomings in EARP. In June 1984, the Minister of Environment announced changes to EARP in an attempt to correct several of the process' shortcomings and to make it "stronger and more comprehensive".

The changes reflected a perceived need for an "administrative re-organisation of the process including the development of systematic procedures for screening and monitoring and establishment of new policies on the role and scope of panel reviews". The parameters of EARP itself were, if not expanded, at least more clearly defined. Following topics are important to mention:

– the scope of the process specifically addresses the "social effects" related to impacts on the natural environment and "such matters as the general socio-economic effects of the proposal and the technology assessment of the need for the proposal";

– initial screening becomes more systematic in approach. List of project types which, by their very nature, may or may not produce significant impacts, should be developed by each department;

– the guidelines provide that "if public concern about the proposal is such that a public review is desirable, the initiating department shall refer the proposal to the Minister for public review by a Panel";

– should an EIS be necessary the terms of reference for the Panel are to be made public and indeed the Panel must conduct a public information meeting to "advise the public of its review and to ensure that the public has access to all relevant information that any member of the public may request" (Bowden et al., 1988).

In September 1987, the federal Minister of the Environment issued a Green Paper to serve as a basis of discussion among Canadians on possible changes to the federal EIA process. During the autumn of 1987 members of the Federal Environmental Assessment Review Office (FEARO), the agency that administers the Process, held public meetings in major Canadian centres to hear the public's reaction and expectations. Consensus was reached on a wide range of themes that would make the Process more open, accountable, fair and predictable. These included: the need to secure the Process in legislation; widening its scope by broadening the definition of "environment" to include both biophysical and related socio-economic issues; the acceptance that government policies as well as individual projects should be assessed; the need to extend the powers of the Environment Minister; the introduction of more structured methods and openness when assessing smaller, but far more numerous routine projects; and the need for more systematic post-project audit and monitoring (Couch, 1990).

In April 1990, the Canadian courts made a dramatic ruling. They judged that the guidelines promulgated in 1984 are to be legally binding regulations and not merely guidelines. This decision created a new sense of urgency because several critical sections of the 1984 guidelines lack clarity (Couch, 1991).

The result was that in 1992, the Federal House of Commons passed the Canadian Environmental Assessment Act (CEAA) (Couch, 1992). On September 7, 1993, the Cabinet approved four key regulations essential to the implementation and operation of the CEAA. The four regulations, i.e. the Law List, Comprehensive Study List, Exclusion List and Inclusion List are expected to go into effect, together with the Act, in early 1994 (LeBlanc, 1993).

3.1.4. EC: Directive 85/337 (1985)

EIA was introduced in the European Community in 1985 with the publication of Directive 85/337. All Member States were expected to implement this Directive into their own legislation by July 1988. At this time no changes have been made to Directive 85/337, which means that there is no evolution to talk about.

The provisions of Directive 85/337 can be grouped into four categories (Wathern, 1988):

– specification of projects requiring EIA

Member States are required to assess the effects of both public and private projects which are likely to have significant impacts on the environment. Projects for which an EIA is mandatory are specified in Annex I of the EC Directive. Member States may decide if projects mentioned in Annex II should be subject to EIA;

– scope of an assessment

Developers should supply information on the proposal, which must be considered by the competent authority in arriving at its decision. The EC Directive describes which information should be given in the EIS, which aspects should be considered in the study;

– consultation

Member States are required to ensure that authorities with special responsibility for the environment are given an opportunity to comment on the proposal. There is also an explicit obligation for public participation;

– the role of the Commission

The Commission should co-ordinate information exchange.

The EIA Centre at the University of Manchester made a five year review of the implementation of the EIA directive. It covers the EIA situation in the EC till July 1991.

Some of the conclusions of the review read as follows:

– though the systematic evaluation of the quality of EISs has not yet been undertaken in most Member States, there is sufficient consensus of opinion among those consulted during the review to enable some broad conclusions to be drawn. Whilst a minority of the EISs submitted during the early years of the Directive's implementation were considered to be of good quality, the majority of those produced in most Member States were not considered to be of a satisfactory standard. More recent evidence from certain Member States suggests that the average quality is improving with increased EIA experience. However, the overall conclusion is that a considerable quality problem still remains;

– areas of deficiency relate specifically to: scoping practices, practices for checking the quality of EISs, the limited availability of EISs for consultation and personal use, inadequate arrangements for consulting the designated environmental authorities and the public, inadequate arrangements for consultations relating to trans-boundary impacts, insufficient use of the EIS and consultation based upon it when authorising projects. Deficiencies vary considerably both between and within Member States (Commission, 1993).

It is not yet known at this time if the EC will make modifications to its EIA Directive as a result of the review study.

3.1.5. USSR: Resolution of the CPSU Central Committee and the USSR Council of Ministers of 29 December 1972 no. 898 (1972)// Resolution of the CPSU Central Committee and the USSR Council of Ministers of 7 January 1988, no. 32 (1988)

Govorushko (1990) summarises the EIA situation in the former USSR as follows: forecasting practice to predict environmental implications from implementing the electrification plan in Russia during the 1920s was the first experience with EIA in the country. In later years, this activity was not continued. To a certain degree it was resumed in the early 1970s, when the Resolution of the CPSU Central Committee and the USSR Council of the Ministers of December 29, 1972 No. 898 "On Enhancing Environmental Conservation and Improving Natural Resources Use" came into forçe to provide for systematic environmental study of projects.

A new regimentation was introduced in 1988, called the Resolution of the CPSU Central Committee and the USSR Council of Ministers of 7 January 1988, No. 32 "On the Radical Reorganisation of Environmental Conservation Activity in the Country". In accord with this Resolution, the "State Committee of Environmental Conservation" and the "Central Administration of EIA" was set up. Appropriate departments were also established in the republican, regional (territorial), municipal and district committees of environmental protection. Resolution No. 32 involves the requirement for all organisations, enterprises, etc. to prepare an environmental study of the proposed economic activity and to assess the impacts of this type of activity on the environment, and discuss it with the public. The requirement conforms in many aspects with the content requirement of Section 102 (2)(C) of NEPA.

The Resolution of the USSR Supreme Soviet of November 27, 1989 "On Urgent Measures for Environmental Restoration in the Country" also regulates EIA implementation. It provides for implementing EIA of the State programmes adopted earlier, relating to land reclamation and agricultural intensification, nuclear power development, the chemical, microbiological industries, etc. According to this Resolution financing of works for all projects is only approved if a favourable EIS is available.

Govorushko (1990) concludes that there were considerable difficulties in implementing EIA in the Soviet Union: absolute lack of procedures considering regional and social specifications, acute deficit in numbers of specialists, etc.

No further information is available, neither about EIA in the former Soviet Union, nor about likely changes as a result of the recent dramatic political and social reforms.

3.1.6. World Bank: Operational Directive on EA (OD 4.00 Annex A, October 1989)

A brief review of policy statements and directives during the past decade, published by World Bank (1993), reveals the World Bank's increasing efforts to broaden its traditional approach to project development. Environmental concerns first became an explicit part of Bank activities when the position of Environmental Advisor was established in 1970. The Bank played an active role in this area by becoming the first multilateral development agency to screen projects for their environmental consequences and to adopt environmental guidelines for the evaluation of future lending operations.

One of the first significant policy statements issued was Operational Manual Statement 2.36: "Environmental Aspects of Bank Work", in May 1984, requiring that environmental considerations be introduced at the time of project identification and preparation, and recognising that modification could also occur at the time of appraisal, negotiations, and implementation.

By the mid-1980s, the Bank was financing projects containing environmental components, including several free-standing environmental projects, which had specific environmental objectives, such as reforestation, pollution control, and water resource management. Although these measures were designed to help both borrowers and the Bank improve the environmental quality of projects, problems remained. In developing countries, serious environmental degradation accelerated and began to constrain economic development. It became apparent to Bank management that the degree of effort devoted to environmental issues and the approaches actually used were insufficient to ensure full consideration of adverse environmental impacts during project identification, design, and implementation.

This, combined with a few well-publicised cases in which Bank-financed projects were found to have negative environmental consequences prompted the institution to adjust its policies toward environmental management and to systematically bring environmental issues into the mainstream of its lending activities. In 1987, the Bank implemented a series of structural changes that included strengthening of environmental policies, procedures, and staff resources. Then, in October 1989 the Bank introduced the Operational Directive on Environmental Assessment (OD 4.00, Annex A). This comprehensive and detailed new policy mandated an environmental assessment for all projects that may have significant impacts on the environment.

World Bank projects follow a standard process or cycle that consists of six steps. These are: 1) identification, 2) preparation, 3) appraisal, 4) negotiation, 5) implementation and supervision and 6) evaluation. In the identification stage projects are screened by Bank staff and are assigned to an environmental assessment category. Public participation can already begin during screening and should continue during the following steps. The preparation of the EIS is the responsibility of the borrower. Following the preparation stage a Bank team examines the feasibility of the proposed project. Bank staff go to the borrowing country to "appraise" the project, the environmental assessment findings are reviewed and a Final Executive Project Summary is prepared. The negotiation stage ends with the approval of the loan by a vote of the Executive Directors. The Bank and the borrower agree on remaining environmental issues and actions to ensure that the project is environmentally sound. Environmental conditions are incorporated in loan documents. The Bank oversees the project through supervision teams that visit the project periodically during implementation and operation. Environmental assessment recommendations provide the basis for supervising the environmental aspects of project implementation. After the last loan disbursement of each project a Project Completion Report is prepared. Environmental and social impacts are also included in this report (Haeuber, 1992).

After two years of Bank experience with environmental assessments, the operational directive was revised to broaden its scope and applicability. In October 1991, OD 4.00, Annex A was replaced by OD 4.01 and includes following important changes:

a) the screening phase is adjusted and made more stringent;

b) the consultation phase is improved. Changes include: (i) making available to the groups being consulted a summary description of the project, its objectives and potential adverse impacts, shortly after assigning of the EA category, (ii) providing a summary of the conclusions of the draft EA report, in a form and language that are meaningful to the groups being consulted; and (iii) taking consulted groups' views fully into account in the design of the EA study and the project, as appropriate;

c) borrowers are requested to release the environmental assessment to the Executive Directors;

d) an environmental mitigation plan in which certain items have to be covered, should be incorporated into the project;

e) environmental advisory panels consisting of environmental specialists should be engaged by the borrower for "major, risky or contentious" projects;

f) regulations about who may prepare and EIA are tightened. The prepare should not be affiliated with the project, but should liaise closely with project preparation/feasibility teams.

The results of a first annual review, initiated in late 1991, covering the period from October 1989 to October 1991 and extended through the end of fiscal 1992, is now available. The Bank's EA procedures were proven to be realistic, workable and instrumental in helping to improve development planning and environmental management. The review identified the following areas where Bank efforts should be continued and/or strengthened:

– training;

– initiating the EIA process early;

– guidance on project screening;

– scoping (which should include field visits and consultation with the affected populations and local NGOs) (World Bank, 1993).

3.1.7. Concluding comments

A distinct evolution in EIA procedures can be distinguished for the period pre1970 - 1993. As shown in Table 1, it is, however, not possible to identify clearly marked years in which certain changes were made in all countries or institutions at once. Each country or institution introduced EIA at its own time. Once EIA is operational shortcomings become obvious within a few years resulting in the adoption of amendments.

Canada and the World Bank first tried to introduce EIA as a policy which was not binding. Both of them realised that more stringent rules are necessary. In all places the need for clearly outlined EIA procedures becomes evident after a few years of EIA practice. Screening, scoping, public participation, quality control and monitoring are steps in the EIA process which needed improvement or special attention in the pre 1970-1993 period and will continue to be important in improving EIA in the future.

It is only today that EIA researchers begin to identify basic principles for the design of effective EIA processes. Gibson (1993) proposes the following list of eight principles:

> *a) serve sustainable objectives*
>
> an effective environmental assessment process must encourage an integrated approach to the broad range of environmental considerations and be dedicated to achieving and maintaining local, national, and global sustainability;
>
> *b) apply to all environmentally significant undertakings*
>
> assessment requirements must *apply clearly and automatically* to planning and decision-making on *all undertakings that may have environmentally significant effects* and implications for sustainability within or outside the legislating jurisdiction;
>
> *c) identify best options rather than merely "acceptable" proposals*
>
> environmental assessment decision-making must be aimed at *identifying best options*, rather than merely acceptable proposals. It must therefore require critical examination of purposes and comparative evaluation of alternatives;
>
> *d) be clearly specified and mandatory*
>
> assessment requirements must be established in law and must be specific, mandatory and enforceable. Environmental assessment requirements are meant to change the nature and substance of planning and decision-making. They are an attack on the status quo. Not surprisingly, voluntary adoption has been rare and unreliable. Because assessment requirements are intended to facilitate the incorporation of environmental factors into the planning of undertakings, it is proper for proponents to be given responsibility for carrying out assessments. But proponents' interests are inevitably limited. As a result, it is usually necessary to give assessment review and final decision-making responsibility to independent authorities or at least authorities with a mandate that emphasises environmental protection;

Table 1: Overview of the evolution of EIA procedures in the U.S., Canada, the EC and the World

U.S.A.	1970 introduction NEPA	1971 courts take active role in quality control		1976 EIA for programmes and policies	1978 introduction CEQ regulations/ strengthening scoping process, public participation and justification of decisions taken by the authorities					1990s changes are proposed to improve alternatives, global env. impacts, public participation, monitoring and the application of NEPA abroad
Canada			1973 introduction EARP			1979 the mechanics of the process are definitively outlined	1984 systematic procedures for screening and monitoring are introduced, social effects should be studied, quality control by Panel is improved			1990s EIA regulations become legally binding, the CEAA is introduced
E.C.								1985 EC Directive 85/337 is introduced		1990s aspects to be improved in a number of Member States: scoping, quality control, public participation, rules for studying transboundary impacts
World Bank							1984 a policy statement is issued requiring that env. considerations are taken into account		1989 introduction of Operational Directive on EIA (OD 4.00, Annex A)	1991 screening, public consultation and quality control mechanisms are improved

e) ensure openness and facilitate public participation

assessment work and decision-making must be *open, participative and fair*. EIA often has two interrelated purposes (e.g. in the US and Canada): to ensure attention to environmental consideration in planning and decision-making and to open up decision-making to greater public involvement and scrutiny. EIA must be designed to ensure *even-handed treatment of all parties*. The main means of achieving this are by providing for independent administration, explicit criteria for impartiality in appointments to review and decision-making bodies, mandatory release of documents including reasons for decisions, opportunities for appeal of questionable decisions, separation of advocacy, regulatory and enforcement functions and regular independent auditing of overall performance;

f) provide for enforceable approval conditions and monitoring of results

terms and conditions of approvals must be *enforceable* and approvals must be followed by *monitoring* of effects and enforcement of compliance in implementation. Monitoring is introduced because of the broad experiential perception that the quality of assessment work has not improved as much as might be hoped and because after many years of EIA we have little evidence about how accurate assessment predictions have been or about how well the environment has been protected by mitigating measures;

g) allow efficient implementation

the EIA process must be designed to facilitate *efficient implementation.*;

h) be linked into coherent overall regimes that integrate planning and assessment with overall objective setting and specific regulatory action

the process must include provisions for *linking assessment work into a larger regime* including the setting of overall biophysical and socio-economic objectives and the management and regulations of existing as well as proposed new activities. Decision-making based on EIA would be greatly facilitated if there were reasonably clear and well-accepted criteria for judgements. To some extent these criteria must depend on local environmental conditions and community values.

Generally speaking we can conclude that the historic evolution of "EIA state-of-the-art" can be broadly subdivided into three decades:

– 1970s: high hopes and experimentation

The 1970s was the period of high hopes and experimentation. EIA was thought to be a very powerful instrument which would introduce objective scientific knowledge into the decision-making, resulting in a more environmentally friendly, efficient and open management of human activities on earth. The first reports were prepared, experience was gained, positive and negative aspects of the approach were identified

– 1980s: realism, expansion and new procedural steps

In the 1980s it became very clear that EIA as it was applied in the 1970s would not solve society's environmental problems. EIA can only be effective in case all parties involved are willing to co-operate, in case environmental consequences of policies, plans and programmes are taken into account, in case "environment" is defined to include social aspects, cumulative effects, etc. Although it is clear that EIA has its limitations, it is introduced for the first time in the 1980s in many countries outside of North America. New procedural steps to make EIA more effective are tried out: screening, scoping, justification of decisions, quality control and monitoring are introduced.

– *1990s: establishment of new procedural steps and legislation, unresolved problems*

In the 1990s the need and function of procedural steps such as screening, scoping, justification of decisions, public participation, quality control and monitoring are recognised. It becomes clear that the dramatic changes which EIA causes in the decision-making process can only be introduced by way of legislation and detailed, transparent and verifiable procedures. It becomes clear that EIA is still not solving our environmental problems: the prediction of cumulative impacts and the introduction of EIA for policies, plans and programmes remain largely unresolved.

3.2. REMARKS SPECIFIC FOR DAM STUDIES – BASED ON SELECTED CASE STUDIES

The EIA procedures and provisions for large dam projects follow the same pattern of evolution as the general EIA procedures and legislation. Proper EIA provisions were non-existent for large dam projects before the US National Environment Policy Act (1969) or before the Stockholm Conference of 1972. The literature on history of environmental consideration in development projects shows that the only consideration in terms of environment was the immediate economic cost of the face value of the affected resources. Their long-term and overall costs were even not considered. There was no effective legislation regarding the protection of the environment in case of a large dam projects before the 1970s. This fact is evident from the general literature and the case studies of the dams constructed during this period. The case studies on large dam experience all over the world show the problems which arise when the environment is not taken into account: e.g. inadequate resettlement, ecological destruction, salinisation and waterborne disease spread. The result is strong opposition to large-scale water development projects and to policies of those who promote them. All these problems are in fact the result of inadequate provisions for environmental consideration in planning and decision-making of the large dam projects or in short due to the lack of proper EIA procedures.

The history of project evaluation for dams can be divided into three periods, namely pre-EIA period, early EIA period and the current EIA period. EIA procedures have been implemented by different countries at different periods since 1969 and some evolution has been taking place in the EIA procedures of the countries according their experience and goal. It is, therefore, very difficult to delimit the three periods by exact years: e.g. in 1980 the US was already in the early EIA period, while the European Communities were still in the pre-EIA period.

In the following sections environmental considerations and the EIA procedures followed in the three major periods in large dam project decision-making is discussed. The aim is to show the evolution of the environmental consideration in the large dam project decision-making.

3.2.1. Pre-EIA era

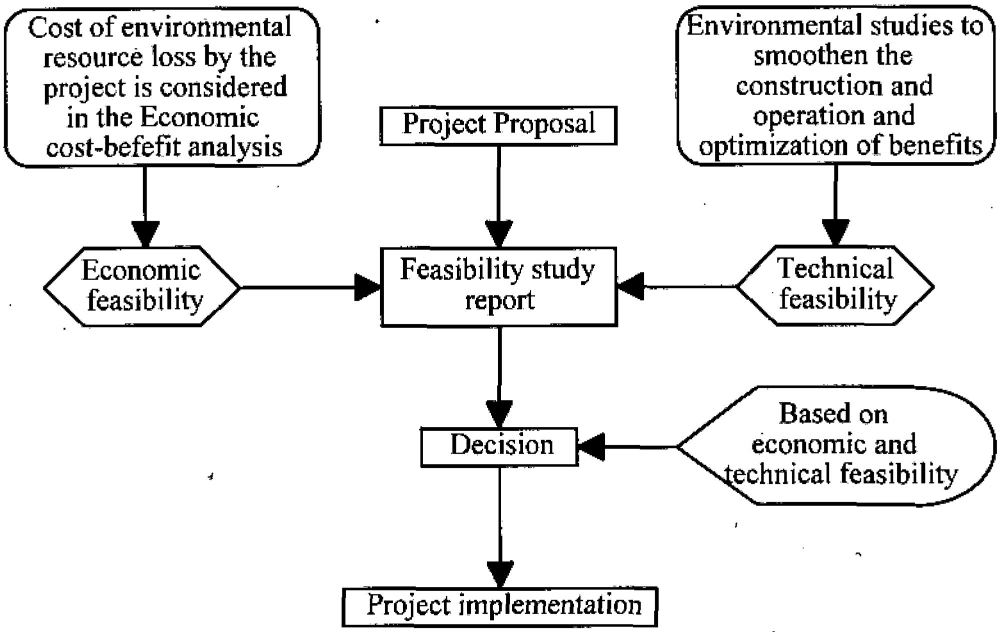
The incorporation of environmental protection as a component of the administrative planning and as part of legislative and executive powers of government has been quite a recent phenomenon. Environmental legislation on air and water quality in terms of pollution control existed at least in some countries long back. A comprehensive environmental pollution control legislation dates back to the 1940s. The growth of environmentalism in the US in the late 1950s and early 1960s led to the development of EIA as a tool to evaluate and analyse any new project for its environmental impact, including the protection of natural and ecological resources (Lohani, 1988; Ahmad and Sammy, 1985). During the pre-EIA period the environmental consideration was not a part of project decision-making. Optimum economic benefit out of the project was the sole objective. The trends in most of the countries are similar to that of the US except that they are one or two decades behind the US situation (Lohani, 1988). The traditional method of assessing a project was a cost-benefit analysis, in which the non-quantifiable social and environmental costs were usually neglected. This is reported in the literature on different large dam and irrigation projects planned and implemented during the pre-EIA period all over the world, both in developed and developing countries (Singh et.al.,1991; Netboy, 1986; Chandler, 1986; Griffith, 1986; Crabb, 1986; Graham, 1986; Beckman, 1986; Pollard, 1986; Monosowski, 1986; Dogra, 1986; Rao, 1986). In case of the Aswan High dam on the Nile (Egypt), as in most other river development programmes, the main emphasis has been on the optimisation of the hydrological system, with little consideration for the environmental implications which could result from changes in biological, climatic and hydrological regimes (Abu-Zeid, 1987).

The environmental consideration in the decision-making process for Large Dam Projects is described in figure 2.

Aswan High Dam (AHD): Experience from a pre EIA large dam project

The Aswan High Dam in Egypt on the Nile River was constructed during the 1960s when the EIA concept did not yet exist. It can be taken as a test case showing environmental impacts experienced in case of non-consideration of environmental aspects for large dams. During the planning and construction of the AHD in the 1960s EIA did not play a major role. Main emphasis was on the optimisation of the hydrological system, with little consideration for the environmental implication which could result from changes in the biological, climatic and hydrological regimes (Abu-Zeid, 1987). This, however, was the normal state of affairs at that time, not only in Egypt but also in other countries.

Figure 2. Environmental consideration in the Large Dam Project decision-making during the pre EIA period



Note: Environmental consideration in the large dam project decision-making was limited to those environmental aspects adversely affecting the construction and operation of the project and only to tangible and immediate cost of the environmental resources like forest timber lost due to the project.

(Source: after Kassas, 1989; Dixon et.al., 1989)

Fahim (1981) looked into AHD and its wide-reaching impacts and he considered different ecological impacts such as (1) evaporation and seepage, (2) silt deprivation, its effect on fertility of agricultural land and on the brick making industry and (3) water logging and soil salinization. Prevalence of water related diseases such as a severe form of schistosomiasis was reported after the completion of the project. Resettlement problems were reported to be severe. According to Elkington (1975) the wetlands have been affected by the rising water table and the reduced nutrient content of the Nile, effects which both have followed the construction of the AHD. Abu-Zeid (1987) lists the main effects of water impoundment in the AHD reservoir as siltation, salinization, thermal stratification, change in hydrobiological characteristics. Lavergne (1986) describes the serious secondary effects of the building of the AHD.

3.2.2. Early EIA studies on dams

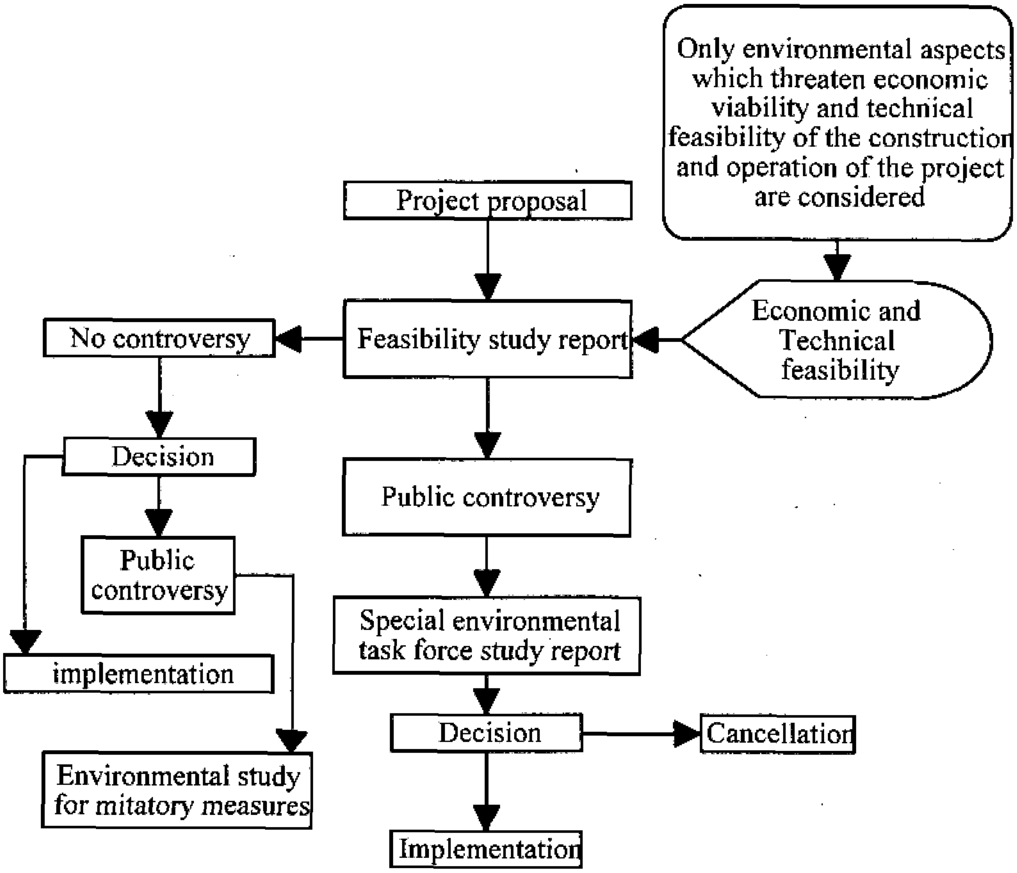
The early EIA period, here refers to the period when the EIA is just incorporated into the decision-making on large dams. During the 1970s the concept of environmental protection was further defined, especially as new regulations were tested in the courts leading to the realisation that environmental protection must encompass all environmental resources. The UN Conference on the Human Environment in Stockholm in 1972 gave an impetus to the establishment of environmental protection agencies in most countries, with developing countries also following the practices of their industrialised counterparts (Ahmad and Sammy, 1985; Lohani, 1988) In the EIA history some authors consider 1978 as a cut-off point (Bisset, 1987). It certainly represents a pivotal year in some respects: e.g. the US Council on Environmental Quality (CEQ) introduced new federal EIS regulations; a radically new approach to EIA in Canada was suggested; in Europe, the views of the ECs EIA consultants became widely available (Wathern, 1992).

Following are the characteristics of this period: lack of proper legislation and the fact that EIA is imposed on the ongoing projects due to public pressure. Lack of experience, inadequate methodology and procedures made EIA almost insignificant in the ultimate decisions on the projects. Environmental baseline studies as conducted in the past have been only marginally effective in influencing key project decisions. Normally they are undertaken at a stage in the project planning cycle when important opportunities for mitigation are no longer available (Beanlands, 1988). When EIA is introduced in an ongoing project the document becomes insignificant in the decision-making and mitigation of the adverse environmental impacts becomes very difficult These conclusions are reported in publications all over the world (Monosky, 1986; Rao, 1986; Gazdar, 1990; Dixon et al., 1986; Brown et al., 1991).

There are many cases in which inadequately conducted EIA resulted in public protests and finally in the project cancellation (Dixon et al., 1986; Brown et al., 1991). Silent Valley Project in India (Maudgal, 1988), Nam Choan dam in Thailand (Tuntaviroon and Samootsakorn, 1986), Chico dam of Philippines (Drucker, 1986), dams planned on Gordon and Franklin Rivers of Australia (Thompson, 1986) etc. are examples of dams shelved because of increased public protests. There are many similar controversial ongoing projects in planning and construction stages all over the world facing public protests due to improper EIA and non-consideration of EIA findings in the decision-making. Narmada Project (India), Gabčíkovo-Nagymaros Project (Hungary & Slovakia), Tucurui (Brazil), Mahaweli Ganga (Sri Lanka) etc. are some of the examples from this category. In some cases EIA studies were conducted but not incorporated in the decision-making phase (Alexis, 1986). In many cases EIA studies were made after construction work started, in order to evaluate the environmental and non-engineering aspects of the project and to identify effects which could potentially compromise the technical and economic viability. Only those effects which threatened the actual construction of the dam and its immediate operations received attention (Monosky, 1986). James Bay Scheme of Canada (1973) was cleared before any ecological or economic cost-benefit studies had been undertaken. The subsequent report of the Joint Federal and Provincial Task Force set up to advice on the project was not considered (Taylor, 1973). Similar cases are reported from other parts of the world like Rajghat Project (1979) in India (Rao, 1986), Kindaruma dam (1981) of Kenya (Linney and Harrison, 1981) etc.

The early EIA period in the large dam project planning is demonstrated in figure 3.

Figure 3. The environmental consideration in the Large Dam projects during the early EIA period



Note: EIA studies were conducted only when there was public controversy in most of the case conditional clearance were given for project implementation and the EIA studies were meant for finding the mitigatory measures
(Source: after Maudgal, 1988; Taylor, 1973; Linney and Harrison, 1988)

Nármada Project: imposing EIA on the project after the decision-making.

The early EIA procedures followed can be reflected in the case of the Narmada project in India. The Narmada project is one of the highly controversial large dam projects in India, in which World Bank is involved in partial financing of the project. It gives an example of the case of the early EIA stage where project decision is already been made and EIA is imposed on the project planning in a later stage due to the new environmental legislation and public pressure. The Narmada Valley Development Projects (NVDP) involves the construction of 30 major dams, 135 medium size dams and 3000 minor irrigation schemes. The project has been criticised by national and international environmental groups, NGOs and human right organisations for the non-consideration of social and environmental effects. A mass movement organised against the project, under the Save Narmada Agitation. Because of the public criticism World Bank set up an independent review to examine the social and environmental implications of the project (Morse, 1992). The authors state that "resettlement and rehabilitation of all those displaced by the projects is not possible under the prevailing circumstances, and that the environmental impacts of the projects have not been properly considered, or adequately addressed". In the case of the Narmada Project, the special environmental study was executed mainly to meet the conditions of its financier and due to the public controversy over the social and environmental implications of the project. As a result of the report World Bank reassessed the Sardar Sarovaar (Narmada) Project and withdrew its financial support to the project indefinitely. The project authority is in a dilemma now because it is too late to give up the project. All these problems could have been avoided if a proper EIA procedure with adequate public participation had been adopted. The Narmada project is a good case against the early EIA situation and should be a lesson to avoid making similar mistakes in the future in the large dam project decision-making. It is similar to the general early EIA procedure stage, with inadequate steps and provisions and incomplete coverage and content. EIA is mainly imposed on the project planning after the decision and during the implementation stage of the project.

3.2.3. Dams which are still in a planning phase

EIA is now gradually becoming an essential part of feasibility studies on new projects in most countries, with environmental issues often playing a significant role in the planning and development process. Procedures for obtaining permits for a project to proceed now include consideration of all the known environmental protection parameters in the form of an environmental impact statement (Lohani, 1988). More than three quarters of the developing countries and practically all developed countries have some sort of impact assessment procedure (Van Buren, 1993; Tolba, 1987). Although EIA procedures differ in their details around the world, they are united in being designed to deal with particular issues. It is important to understand how the need for certain activities at certain points dictates the nature of the process.

EIA procedures for large dam projects are similar to those of other development projects. Screening of the proposal, scoping of the EIS, draft EIS and final EIS preparation, reviewing of the EIS and decision and in case of implementation of the project monitoring and post project evaluation are the major steps in the EIA procedures. Appropriate public participation and involvement of experts and objective assessors and reviewers as well as objective decisions without dominance of political and economic motivations make the EIA perfect to achieve its defined goal.

The nature and implementation of the above steps of the EIA procedures vary in different countries. EIA is required for all the large dams in all the countries with a EIA legislation.

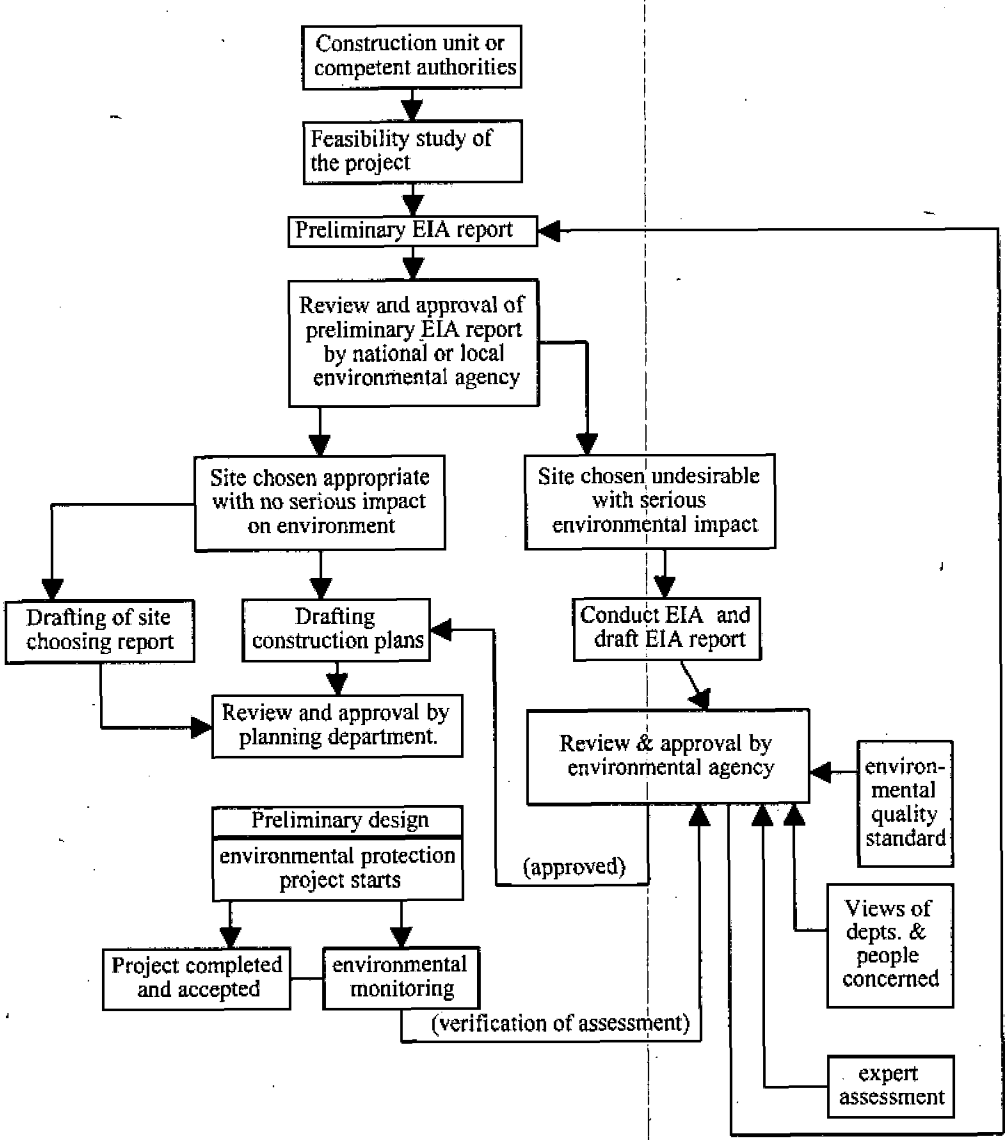
Although scoping is done in many countries, many shortcomings can be identified: public participation and expert participation are limited and it is often the project proponent who sets the agenda (instead of an independent body of experts). In most of the cases scoping is not accomplished very early in the EIA process. EIA is prepared by the proponents through a number of consultants. A baseline study is generally part of the EIA. It is a description of some aspects of the physical, biological and social environment which could be affected by the development project under consideration. Beanlands (1992) examined the baseline studies for a hydroelectric development on Eagle River in Canada, demonstrating its importance. The following questions should be answered at this stage: (1) should the project be approved in principle? (2) where should the project be built? (3) how should the project be designed? (4) how should the project be operated? In the US a draft EIS is made available to public and government agencies and after a public hearing a final EIS is prepared. In the Netherlands a preliminary review is conducted too in order to consider the acceptability of the EIS. The final EIS is prepared by the proponent taking into account public comment and is submitted to the competent administration for examination. The EIS is reviewed by the concerned authority and a decision is taken. The concerned authority may require additional information before making any comments, suggestions or recommendations. After review of the EIA, the decision-maker may decide that the action should proceed or that it is environmentally unsatisfactory. In the latter case, the proposed action may either be withdrawn, or be modified and fed back again into the EIA process. Decision-making is not easy because of the large number of political, environmental and other factors, which often are in conflict with one another (Munn, 1988). An independent review of the assessment will help the process of decision-making. Implementation involves several functions: detailed planning, design, construction and operation. The government should monitor and ensure compliance with regulations and standards. Post project audit or review may improve the goal setting and decision-making process by providing information on the environmental effectiveness of each action.

The Three Gorges Project: Does the current EIA procedure really influence the decision making?

The Three Gorges Project (TGP) on the Yangtze River in China is in its design and planning phase. It has been approved (with considerable dissent) by the Chinese Parliament in April, 1992. Since the Environmental Protection Law of 1979, China has legal provisions to incorporate EIA as an important component into their feasibility studies of development and construction of projects. The general EIA procedure followed in China is shown in figure 4.

The TGP planned to be the largest water resource project on earth with 150-180 meter high dam forming a reservoir nearly 650 km long. This would displace a million people. The benefits of the project are: alleviation of the threat of flooding, provision of large amount of energy and improvement of river navigation. Scientists and environmentalists criticise the project for the expected social and environmental impacts (Boxer, 1985; Caufield, 1985; Jhaveri, 1988; Ryder, 1988 & 1991).

Figure 4. EIA procedure followed in China Gorges Project in China.



(Source: Biswas and Geping, 1987)

In the case of the TGP a feasibility study was conducted by the Canadian consortium – the CIPM Yangtze Joint venture. Its terms of reference were "to form the basis for securing assistance from international financial institutions". Ryder (1991) states that the feasibility study is grossly negligent and incomplete, and it was never made properly available to the Canadian public who as tax payers, financed it. Not surprisingly the conclusion of the EIS was that the TGP should proceed at an early stage. The study is misleading in every way: a texture of intellectual sloppiness, concealment and evasion". Williams (1992) analysed the safety of the dam and found that seismicity, structural stability, risk of spillway failure and down stream effects of cofferdam failure were inadequately addressed. Ryder (1991) concludes that "the project feasibility study is such a disservice. No major scheme should proceed on the basis of a document as incompetent, contradictory and poorly searched as this one is".

The Three Gorges Project is criticised for its poor quality of EIA despite of sufficient legislation and EIA procedural provisions.

3.2.4. Concluding comments

Despite of the evidence of social and environmental damages, large dam building is an ongoing enterprise in many parts of the world. Large dams are generally projected as the sources of clean energy and water supply by the proponents and criticised for the social unacceptability, environmental unsustainability and economic inviolability all over the world. The history of environmental consideration in the large dam decision-making in different countries can be divided into three stages: the pre EIA, early EIA and current EIA procedure periods. Many countries have sector specific guidelines for EIA, but major steps in EIA procedures are similar.

The environmental considerations in large dam project planning and decision-making in the periods are analysed by a literature survey and through case studies of large dams in each period. Large dam projects prepared in the pre-EIA period resulted in major impacts as a result of not considering environmental aspects. These projects show the importance of proper EIA in project planning and implementation. The EIA procedures during the early EIA period show the inadequacies in EIA application. During the early EIA period EIA was imposed on the ongoing project planning and implementation necessitated by the new legislation of environmental consideration in project planning. The current EIA period shows more or less proper EIA procedures in at least some of the countries. Genuine implementation of all EIA steps is, however, doubtful. Even though EIA has been started at different times in different countries, the trend of evolution is similar everywhere.

3.3. The Hungarian situation

Environmental degradation in Hungary is strongly linked to insufficient legal protection and enforcement. The Hungarian Environmental Protection Code was enacted in 1976. Excluding a few provisions, it was considered an acceptable law. Over time, a system of rather strict emission standards was developed, generally reflecting German solutions of the early and mid-seventies. However, despite strict standards, there was very little provision of effective mechanisms for enforcement. The organisational framework has had a number of changes in the last 15 years (Bochniarz et al., 1992).

In 1987, the environmental authority and the water management authority were unified in the Ministry of Environmental Protection and Water Management. However, environmental protection continued to be ineffective because of prevailing special water authority interests. Permits were administered without public participation or even involvement. This was due to the then existing system of general public administration procedures which governed environmental decision-making (Bochniarz et al., 1992).

The problems of enforcement were partly due to insufficient resources available. Primarily, however, it was simply a consequence of the relations of the enforcers with politics. Some regulations created express exemptions for some industries. The whole legal system was unresponsive. Judicial review was unheard of and only the 1989 Constitutional amendment changed that situation (Bochniarz et al., 1992).

Since 1990 important steps have been taken to reorganise ministries. Of major significance was the creation of a Ministry of Environment and Regional Planning (separated from water management authorities). Because of continuing environmental degradation and increasing problems related to privatisation, the Parliamentary Committee on Environment Protection decided to commission an independent drafter who agreed to present a Comprehensive Act in two stages to be submitted separately to the Parliament. The proposed law seeks to establish four guarantees: 1) should the government fail to establish standards as the law requires, the standards of the European Community would automatically apply, 2) the right to information, the right to know and the right of participation, 3) judicial review and 4) the use of environmental impact statements (Bochniarz et al., 1992).

The EIA situation in Hungary in the pre1970 - 1993 period is not clear-cut. Information is hard to get: even in the framework of this study no official documents on EIA legislation and procedures were detected.

It is, however, safe to say that there was no well established EIA procedure or legislation in Hungary in the pre1970 - 1993 period. Several sources confirm that the need for EIA was felt for the first time as a result of the Gabčíkovo - Nagymaros controversy. EISs prepared for this case did, in other words, not follow one clear and obvious EIA procedure, but was prepared on an ad hoc basis.

The EIA adoption process started in 1983 with the resolution of the National Council on Environmental Protection. It was followed by a decree which made it obligatory to undertake impact studies for major projects under governmental control. This decree was repealed in 1989 (Radnia, 1993).

In 1992 Bochniarz stressed the importance of EIA in Hungarian environmental legislation: "Hungarian legislation should give particular attention to EC Directive 85/337 and the IUCN draft convention regarding EIA ..."

It was only in June 1993 that the Hungarian Government issued its EIA Decree (No. 86/1993 (VI.4) for Provisional Regulation of the Assessment of Environmental Impact of Certain Activities). This represents a turning point in the history of Hungarian EIA regulation since the decree established systematic investigation of a broad range of activities and linked it to the decision-making process (Radnia, 1993).

In conclusion, it is possible to situate the three Gabčíkovo - Nagymaros environmental documents in the historic framework developed in previous sections. It is clear that Hungary is only today in the stage of developing EIA procedures and legislation, comparable with the 1970s period in the US and the 1980s period in the European Communities. The preparation of the Gabčíkovo - Nagymaros environmental documents can be divided into the early EIA period, which means that EIA was imposed on the proposed project which was at that time in an advanced planning stage.

Since Hungary did not have any experience with EIA before, did not incorporate a systematic screening of environmental impacts into its legislation, the Gabčíkovo - Nagymaros EISs can be considered "experiments". There was no previous experience, no established procedures or guidelines and no EIA traditions to form a basis for the preparation of environmental reports of high quality.

At the time that the Gabčíkovo - Nagymaros environmental documents were prepared the necessary information and expertise to prepare high quality EISs for large dam projects was available in other countries, mostly in North America. It should, however, be taken into account that Hungary was still part of the former Eastern Europe Communist Block during the mid 1980s and that scientists and decision-makers will have looked to the U.S.S.R. for expertise and not to the US or Canada.

4. Historic Evolution of the Content of the EIS for Dams During the Period 1977-1993

4.1. EIA CONTENTS IN GENERAL

Like EIA procedures the contents of EISs are also undergoing changes as more and more experience is gained in the EIA of different sectors. Despite minor differences throughout the world, there is a general consensus on the content of an EIS. In this section the contents of the general EIS and that of water resources project are analysed to find the changes or major evolution since 1977.

Before 1977 it was not clear for many proponents or authorities what information should be included in an EIS. This was due to a lack of experience, but has changed since 1978 after CEQ (US) issued regulations which gives more detailed guidelines on the content of EISs. The Council periodically publishes procedural guidelines and requires that each Federal agency publish its own guidelines in response. There is provision for revision of the guidelines at appropriate period in the light of experience with the system's operation and recent advances in EIA methodology. EIS is a decision makers tool with three main characteristics:

1. it should aim to ensuring that an EIA is performed and that the result of EIA becomes part of the decision-making process;

2. it should serve as an option-defining instrument through its evaluation of impacts and consideration of alternatives; and

3. it should serve to furnish a detailed record of environmental decision-making for purpose of review by state or public.

Contents of EISs in the US

It is the responsibility of the proposing agency to prepare the EIS. As required by regulations in the US, EIS must contain the following (Munn, 1988):

1. Description of the proposed action; statement of purposes; description of the environment affected;

2. Relationship to land-use plans, policies, and controls for affected area;

3. Probable impact-positive and negative; secondary or indirect, as well as primary and direct; international environmental implications;

4. Consideration of alternatives;

5. Probable adverse effects which cannot be avoided;

6. Relationship between local and short-term uses and long-term environmental considerations;

7. Irreversible and irretrievable commitment of resources;

8. Description of what other Federal considerations offset adverse environmental effects of proposed action and relation of these to alternatives.

In addition, the comments received from reviewers must be attached.

This is the general requirement for all types of development projects including the water resource projects.

Contents of EISs in Canada

In Canada the EIS is a detailed documented assessment of the environmental consequences associated with the project prepared in accordance with the guidelines issued by the Environmental Assessment panel (expert body formed for specific projects). The type of detailed information required is determined by the nature and location of the project.

Contents of EISs in Japan

In Japan (Barrett and Therivel, 1991) the draft EIS should cover similar items like those in the US. Surveys and studies, prediction and evaluation mentioned should be conducted in accordance with guidelines which should be established for each category of relevant projects by the competent minister in consultations with the Director-General of the Environmental Agency. The final EIS should cover:

1. the contents of the draft EIS as explained above;

2. a summary of the comments received from the residents of the related area;

3. comments of the prefectural governor with jurisdiction over the related area;

4. views of the project undertaker on the comments received from the residents and prefectural governor.

Assessment of both the social environment (safety and amenity of communities, cost/benefit for individuals and the public including employment, income, population density, consumption, land-use pattern, industrial structure, finance, and public service etc.) and the natural environment (quality and quantity of natural features, pollution, disaster) are considered. These are determined through field surveys.

Contents of EISs in the European Communities

The EC Directive 85/337 requires Member States to include the following aspects in the EIS: a description of the likely significant effects on the environment, direct and indirect, of the development with reference to human beings, flora, fauna, soil, water, air, climate, the landscape, the interaction between any of the foregoing, material assets, the cultural heritage. A summary in non technical language of the information specified above should also be included (Lee and Colley, 1990). Next to the aspects considered above, the European Communities EIA directive requires proponents to highlight areas of uncertainty by indicating 'technical deficiencies or lack of know-how' encountered in compiling information included in an environmental assessment (Council of the EC, 1985).

Contents of EISs in the Eastern European Countries

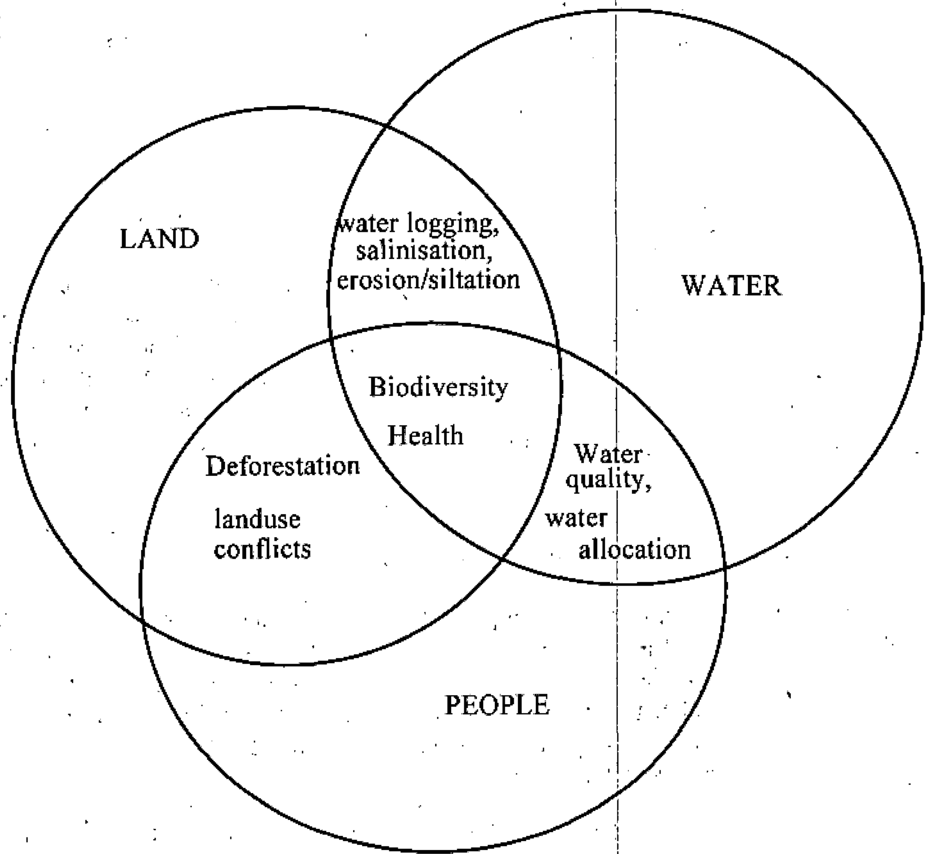
In the Eastern European countries the central planning system provides a coherent framework for EIAs. In the 1980s the Council for Mutual Economic Assistance (CMEA which included Hungary, Bulgaria, Cuba, Czechoslovakia, GDR, Mongolia, Poland, Romania, and USSR) required the assessment to include several phases and to be technological, bio-medical, economic, or social, the latter being the most comprehensive. General systems include the natural environment, the man-made environment and socio-economic activities.

The quality of EIS depends on the level of technical sophistication, consistency in terms of coverage of topics, executive summaries, clearly organised sections, objective orientation, adequate project description, sufficient analysis of all topics, consideration for public input and participation in planning and review processes (Kim and Murabayashi, 1992).

4.2. Contents of EIS for dams

The format of the contents of EISs for water resources projects suggested in the guidelines of most of the countries are similar to the general EIS format as discussed above. But the impact of water resource projects are different from that of other development projects. The impacts of water resource projects, like large dam projects, are the results of changes in the interrelationship between land, water and people. This is illustrated in figure 5.

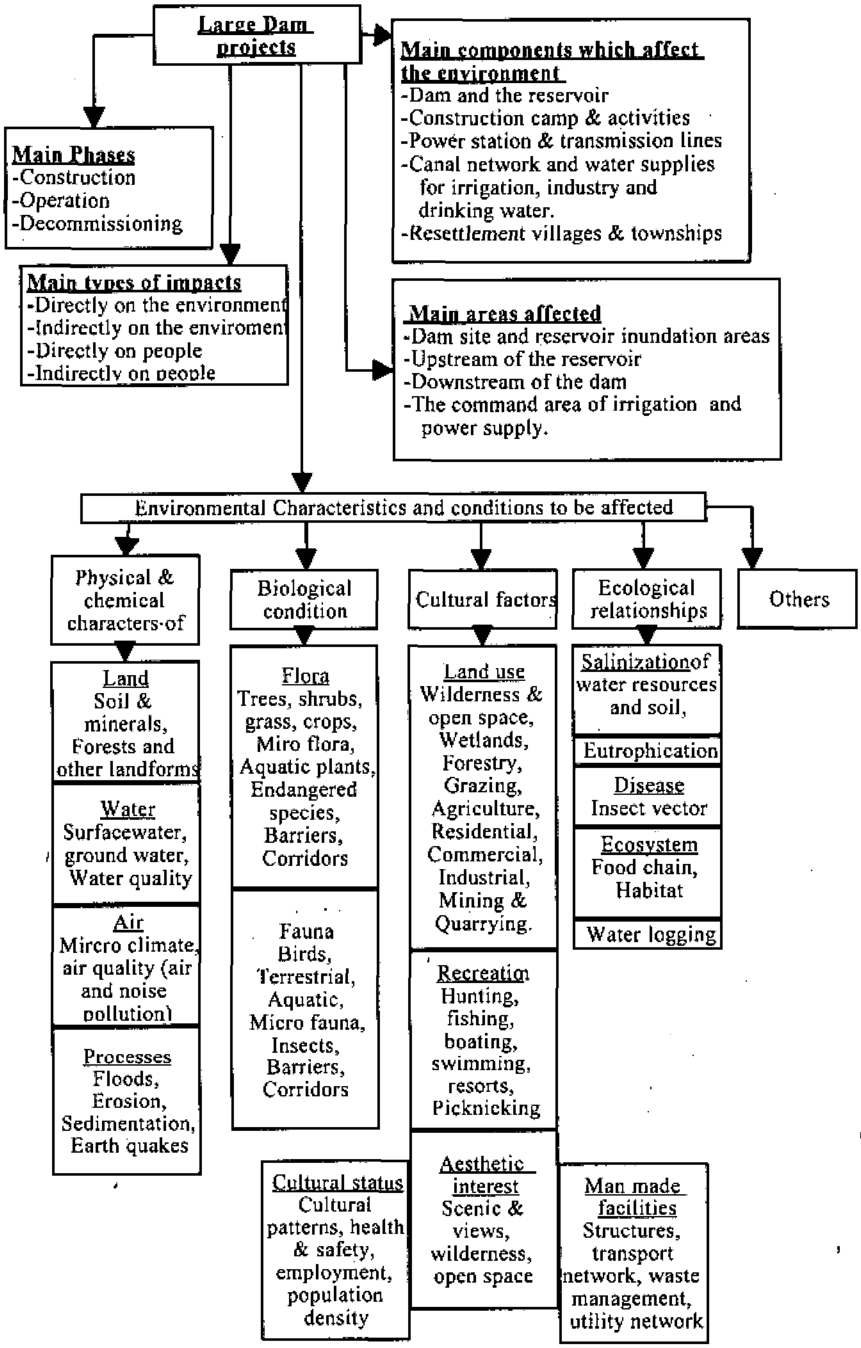
Fig.5. Main elements affected in Water resource projects and the impacts



Note: The changes in the interaction between land, water and people result in the impacts which vary according to the size of the dam, nature of the location and way of implementation.
(Source: Rajappa and Krishnapal, 1992)

The actions affecting the environment in a water resource project can be summarised as in figure 6.

Figure 6. A summary of the large dam components and their effects on the environment



There is abundant literature on the social and environmental effects of large dams. Large dams are widely opposed due to these effects and there are organised mass movements against the large dams all over the world. The large dam critics recommends that no dams should be built (Goldsmith and Hildyard, 1986):

- until an adequate EIA is done and made available to public;
- if the project does not benefit large sectors of the population;
- if it favours capital intensive economic activity rather than labour intensive activity;
- if it does not permit production of food crops for local population rather than for export crops;
- if it affects public health and safety;
- if it affects national parks, heritage sites and habitat of endangered species;
- if it silts up within less than 100 years;
- if it likely to lead to salinization;
- if it is not sustainable in long term resource enhancement;
- if it displace indigenous people and destroys their culture;
- if it has safety problem;
- if it likely to inflict damage on estuarine or ocean fisheries;
- if it is likely to harm the environment of a neighbouring country without its full consent.

4.3. CASE STUDIES DESCRIBING THE CONTENTS OF THE EIS

4.3.1. Introduction

The EIA has to examine how the project can be implemented with the least possible environmental impacts. The emphasis of EIA is on pre-decision analysis leading to the preparation of an EIS which establishes terms and conditions for project approval (Sadler, 1988).

The subject area selected for study in Saguling dam EIA (Bisset, 1987) is described in table 2.

Table 2: Topics studied in the EIS for Saguling dam

1. Climate
2. Hydrology and limnology
3. Geomorphology
4. Fauna and flora
5. Land use, physical and socio-cultural
6. Agricultural systems, physical and socio--cultural
7. Fisheries
8. Animal husbandry
9. Industry
10. Commerce and marketing
11. Transport
12. Demography
13. Health
14. Education
15. Archaeology and mythology
16. Social aspect

Note: This list acts as a simple checklist.

Source: Institute of Ecology, Padjadjaran university (1979).

The following case studies are taken from the ECE task force report (ECE, 1987). The individual projects varied considerably in terms of their size, technical and geographical characteristics and environmental impacts.

4.3.2. The Lower Churchill Hydro Project in Canada (1978):

Content requirements for the EIS

The guidelines issued by the FEARO panel for the power generation site component covered the following topics:

1.Overview summary;
2.The project setting;
3.The proposal;
4.Description of existing environment and resource use in terms of climate and air quality, terrain, water, flora, fauna, people, land, water and resource use;
5.Impacts on these elements
Description of the environmental impacts of the proposed project and the alternatives and comparison which include:
  a. The impact identification,
  b. Methods used for predicting impacts,
    – Site facilities impact
    – Land capability ratings for forestry, wildlife and recreation
    – Transmission facilities
    – Socio-economic Impact study
    – Stream monitoring study
    – Climate conditions

– Wildlife reconnaissance
– Fish studies
c. Methods used for comparing the environmental effects of the various alternatives.
6.Mitigating measures for major impacts;
7.Residual impacts; and
8.Annexes.

4.3.3 .The Ernstbach Dam in the Federal Republic of Germany (1981)

The scope of the EIA study and structure of the content of EIS is as follows:

– Analysis of the project area;

– Landscape factors:
Geology, soil, suitability of the area for agriculture and forestry, climate and water, vegetation, wildlife, visual landscape character;

– Land-use patterns:
Settlements, highway traffic, landfills, agricultural areas, forested areas, hunting, fishing;

– Protected areas:
Nature or biotope protection area or protection stemming from fisheries or water rights;

– Negative environmental impacts of the project:
Impact identification (ecology, use of natural resources, landscape impacts and impacts on the suitability of the area for recreational purposes), data collection, methods used for predicting impacts;

– Possibilities for mitigation;

– Recommendations;

– Conclusion and final appraisal.

4.3.4. The KobbelVáhydro power project in Norway (1981)

Contents of the EIS in the guidelines:

– project description:
projects and its alternatives, description of the existing environment

– project benefits;

– impacts on public utilities;
impacts on physical environment, fish and game, natural resources, cultural heritage;

– impacts on private interests;

– minimal instream flows;

– hydropower potential;

– project participants;

– the proponent's comments.

4.3.5. The Wheeling Creek Dam in West Virginia, USA (1982):

Content requirement as in the US CEQ Regulations:

– description of the proposed project and alternatives,

– description of the existing environment;

– description of the environmental impacts of the proposed project, the alternatives and comparison. The impacts associated with the preferred alternative were vegetation, wildlife and wildlife habitat, aquatic resources, landscape quality and recreation, air quality, archaeological and historic resources, economic and social, land-use, soil and plant management. Data collection, methods for predicting and assessing impacts, methods for comparing alternatives were also given.

4.3.6. Discussion

The above cases show the differences in contents and presentation of EISs for large dam projects. The contents and presentation of the impacts vary according to the country and nature and location of the project. But the main elements of possible impacts (the land, water and socio-economic system of the area) are discussed in each case. No major shifts in contents of EISs for dams can be detected from the case studies. All of the above cases are from the late 1970s and early 1980s. The only noticeable trend in the contents of EIS topics is that social aspects are getting more and more coverage. In the Wheeling Creek Project (US) an EIS was prepared in 1979 by the US Soil Conservation Service (SCS) based on the NEPA guidelines. The reviewers (EPA) raised a number of concerns related to water quality issues and the failure of the EIS to address adequately the full range of alternatives. Given the reaction and the public opposition to the proposed project, the SCS decide to discard the original EIS and begin a new EIA process starting with scoping in order to identify all relevant impacts and alternatives to the project. This case illustrates an important evolution or change in content of EISs. The documents are prepared on the basis of a scoping phase. This scoping results in more than the traditional EPA guidelines. In the Lower Churchill Project (Canada) the EIS for the transmission line component was not part of the 1974 overview study and was added in 1978 by guidelines of a FEARO panel.

4.4. CONCLUSIONS

A successful EIA is one which ensures that all relevant impacts associated with the proposed project are adequately and fully taken into account in the decision-making process (ECE, 1987). EIA consists of the EIS and the procedural provisions ensuring that EIS is proper in content and methodology. Procedures should also guarantee that decision-makers take the information provided in the EIS into consideration. According to the ECE task force the minimum elements in an EIS should be:

– Project setting (purpose and need);

– Description of the proposed project;

– Description of the existing environment;

– Reasonable alternatives, including the do-nothing alternative;

– An assessment of the environmental impacts of the proposed project and the alternatives;

– Summary.

The direct and indirect impacts of the proposed project and its alternatives on the bio-physical and socio-economic environment should be assessed. The specific types and number of impacts to be assessed depend on the individual project and the environment and can best be determined through scoping and guidelines.

A general checklist of possible environmental elements to be considered in the case of large dam projects in different climatic conditions and in different socio-economic set up is presented in table 3. It may be useful in scoping for the EIS of the individual projects and as a general guideline for content requirement of an EIS. The list was not published before and is a compilation of existing lists and experience of the authors with EIA for large dam projects.

Table 3: *Checklist of major environmental factors to be considered in the large dam EIS*

1.	Dam and Impoundment area:
1.1.	During Construction:
1.1.1.	Air and water pollution from construction, equipment, earth movement and living quarters
1.1.2.	Solid waste displacement
1.1.3.	Destruction of natural landscape
1.1.4.	Noise pollution
1.1.5.	Importing of water related diseases through migrant labours
1.1.6.	Population influx and linked social effects including health, security and impact on local cultures

1.2. Reservoir formation:

1.2.1. The effect of inundation on the houses; villages; farms; infrastructure such as roads and transmission lines

1.2.2. Major social and economic costs of involuntary resettlements and the issues related to it, including:

1.2.3. The poverty risks from the population displacement like landlessness, joblessness, homelessness, marginalization, food insecurity, morbidity increase, social disarticulation etc. and feeling of powerlessness and alienation of the oustees

1.2.4. Effects on employment, taxes, local inflation, changes in supply and demand patterns, etc.

1.2.5. Other social and cultural destruction

1.2.6. Inundation of cultural/historical sites such as sites or areas of historic, religious, aesthetic or other particular cultural value, and sites of archaeological and paleontological significance

1.2.7. Inundation of agricultural land, especially highly productive bottom lands

1.2.8. Inundation of forest land, may mean the loss of valuable timber and species diversity including endangered and endemic species and forest ecosystem

1.2.9. Inundation of wildlife habitat, particularly habitat of threatened species with consequent impact on biological diversity. Barriers or corridors may be created in the habitat affecting population

1.2.10. Inundation of potentially valuable mineral resources

1.2.11. Inundation of archaeological, architectural, historical and heritage sites and aesthetically important objects and landscape

1.2.12. Effects on ecosystems, cycles, interactions

1.2.13. Inundated vegetation or biomass in the reservoir can affect water quality for potable water, reservoir fishing, operation and longevity of dam and associated machinery

1.2.14. Water weeds proliferation can increase disease vectors, affect water quality and fisheries, increase water loss (through transpiration), affect navigation, recreation and fishing, and clog irrigation structures and turbines

1.2.15. Fish migrations will be affected by the blockage of dam in the river (fish ladders may sometimes be practical), this affects mainly the fish species which migrate to the up-streams to reproduce

1.2.16. Water quality within the reservoir is in part, dependent on what happens upstream and retention time within the reservoir. Quality may be affected basalt accumulation, eutrophication from weeds and biomass decay, turbidity, pollution from sediment, the reservoir provides better quality water downstream with less suspended matter

1.2.17. Health: establishment of the reservoir and associated water management structures (e.g., canals and ditches) can create conditions fostering establishment and spread of water-related diseases such as schistosomiasis, onchocerciasis, encephalitis, and malaria

1.2.18. Effect of drawdown regime, which may create agricultural possibilities, as well as health, recreational, aesthetic and access problems

1.2.19. Seismicity may be induced by large reservoirs

1.2.20. Dam failure and safety measures

1.2.21. Ground water level in the surrounding area may be altered

1.2.22. Local climate may be modified by large reservoirs, especially in terms of humidity and local fog

1.2.23. Temperature of released water may be higher or lower than ambient river temperature (depending on pattern of release); this will have varying impacts on downstream water uses

1.2.24. Navigation

2. Upstream (not directly "caused" by the dam but induced or exacerbated by the dam)

2.1. Increased sedimentation from the following sources:

2.1.1. Existing sediment resulting from previous natural or induced erosion remains in the river bed or in the watershed area

2.1.2. Unusual natural sedimentation from natural events such as volcanic activity, earthquakes, mudslides, typhoons and "100 year precipitation events"

2.1.3. Road building and other construction

2.1.4. Erosion from clearance of vegetation, logging and cultivation by people who have moved into the watershed areas as a direct or indirect result of the dam project

2.1.5. Cultivation on unsuitable sites using unstable or otherwise unsuitable lands

2.1.6. Logging and forest denudation of forest which also result in erosion

2.2. Remote and previously inaccessible areas are opened up due to the dam construction and the reservoir filling

2.3. Induced population immigration may lead to increased agricultural or mining activities with major implications for soil erosion, sedimentation, and water quality

2.4. Poaching or illegal unsustainable exploitation of wildlife increases

2.5. Denudation of vegetation for cultivation, fuel collection and logging

2.6. Loss of wildland and wildlife habitat with impact on endangered species and reduction of biological diversity

2.7. Negative impacts on aesthetic and scenic qualities of the area and the potential for certain recreational uses

2.8. Pollution from settlements and cultivation

2.9. Changed watershed hydrology: the changes in land use patterns, may affect the timing and magnitude of runoff especially during major storm events. Changed vegetative patterns may also influence dry season stream flow

2.10. Salt inflows from the watershed may accumulate in the reservoir and affect water quality. similarly, catchment runoff may carry increased quantities of agricultural chemicals and fertiliser with resultant impacts on reservoir water quality

3. Downstream

3.1. Impact on river fishery due to changes in flow regime; effect of dam blocking fish migration, changes in water quality (loss of nutrients trapped by dam, pollution from irrigation return flow, and increased water turbidity)

3.2. Effect on traditional flood plain cultivation through changes in flow and flooding regime and loss of annual "top dressing" fertilisation from limited flooding. Control of severe flooding can also yield benefits through reduced crop and property losses

3.3. Impact on other water projects: changes in stream flow and water releases from the dam affect dams and irrigation projects elsewhere in the lower basin. The impact can be both positive and negative. Reduced silt content in water, for example, will permit better water management, lower silt levels also decrease potable water treatment costs. On the other hand, weed growth in existing canals may increase with perennial water supplies

3.4. Impact on municipal and industrial water supply downstream can have both positive and negative effects depending on water quantity and quality

3.5. Stream bed changes are one possible, but not a common result of the changed water flow and sediment load. This include the possibility of increased stream bed erosion below the dam due to "hungry" water (with reduced silt loads) being released from the dam

3.6. Flood control avoid flood damage and change production

3.7. Effect on estuarine and marine fisheries and marine biota, including endangered species, through changes in flow regime, change in water quality (e.g. pollution from toxic chemical and salts from irrigation return flow to river) and loss of nutrients

3.8. Salt intrusion into estuarine and lower river basin areas may result from sustained or seasonal reduction in river flow

3.9. Groundwater level changes: Higher levels due to the high water levels in the reservoir. Downstream, in old flood plain areas, the groundwater level may fall but in irrigated areas, it may rise

3.10. Health problems from water-related diseases or parasites (similar health problems may also occur in the reservoir itself), primarily from irrigation and associated canals

3.11. Effects on wildlife and wildlands through loss of or change in habitat may result in an impact on biological diversity

3.12. Waterlogging

3.13. Salinization

3.14. Indirect impacts of increased urban and industrial developments

3.15. Reduction in local food production due to production of cash crops for exports

3.16. Combined socio-economic effects of all the developments

3.17. Increased irrigation, improved water control, hydropower generation and water supply benefits and their positive impacts

The above checklist is comprehensive but not necessarily all topics covered are important for a particular project. The importance of particular aspect in a particular project depends on many factors like climatic zone of location of the project, size, nature and sitting of the project, nature and characteristics of its surrounding physical, natural and social environment etc. In the case of review of contents of an EIS this checklist can be useful to verify if some important aspects are missing or go unnoticed.

5. Evaluation of Hungarian Key Studies in the Gabčíkovo-Nagymaros Dam

5.1. STUDY OF APRIL 30TH, 1983

Table 4 gives an overview of the contents of the 1983 study.

Table 4: Contents of the 1983 study

The predicted effects of the construction of the Bős (Gabčíkovo) - Nagymaros River Barrage System if carried out according the present plans

1. Antecedents

Some important institutes (MTA Botanical Research Inst., EVM, OVM, OKTH, OMFB) were requested to prepare studies and give their opinion about the predictable ecological impacts.

2. Introduction

Different institutes were consulted for different investigations. E.g. about the biological statement of surface water; possible problems with groundwater at the agricultural areas; expected changes which will (can) occur in the natural environment – and their impact for the settlements.

3. General evaluation of the earlier investigations

in 1970	– only mitigation of damages were worked out
only after 1976	– started to collect the ecological impacts (lack of the interconnections between different impacts)
	– EIA was not made
	– the opinions about the advantages are the same
	– disadvantages and uncertainty were qualified differently
	– critics (page 7.):
	* the earlier studies were not complete
	* this report is not deep enough
	* lack of interdisciplinary studies
	* lack of alternatives of mitigation measures
	* lack of basis information

4. Investigation of each subject concerning the predictable ecological impacts

This paper does not contain the positive environmental impacts (page 9.)

4.1.	Impacts on the biological state of the Old-Danube River bed
4.2.	Impacts on the groundwater level, agriculture and forestry
4.3.	Impacts on the water quality of the Danube River, water sources and sewage management
4.4.	Impacts on recreation
4.5.	Impacts on the number of inhabitants

5. Summary, Conclusion, Suggestions

1) There was no comprehensive description and dealing with the ecological impacts of GNV. There is no EIA.

2) The mitigation measures have to deal in the future with:

   a) drinking water for this region and Budapest

   b) keeping the positive activity of agriculture and forestry

   c) use the potential benefits of this project (GNV) – mainly for recreational purposes

   d) preserving the biological state of the Old Danube River.

3) Within two years a complete EIA should be worked out.

4) A complex monitoring system should be built for the environmental protection.

5) New investigations should be introduced.

6) New part should be added to the existing environmental laws (about EIA).

The document itself concludes that it is not a full EIS and that a complete impact study can be expected within two years. The document only gives an overview of the conclusions from earlier investigations. In chapter 4 only the predictable impacts are examined, only ecological impacts are considered and these are only partly considered. The material does not contain any figures or tables (except one map from the region on p. 23). There are no references used in the text.

5.2. Study of June 1985

Table 5 gives an overview of the contents of the 1985 study.

Table 5: *Contents of the 1985 Gabčikovo – Nagymaros study (A Gabčikovo - Nagymaros Vizlépcsôrendszer Környezeti Hatástanulmánya)*

1.	**INTRODUCTION**
2.	**PRESENT ENVIRONMENTAL STATE OF THIS PART OF THE DANUBE RIVER (WHICH IS AFFECTED BY GABČIKOVO-NAGYMAROS RIVER BARRAGE SYSTEM)**
2.1.	Demarcation area
2.1.1.	Geological border of this region
2.1.2.	Division of this area
2.2.	Natural conditions of this region
2.2.1.	Topographical conditions
2.2.2.	Geological conditions
2.2.3.	Climatic conditions
2.3.	Surface and under surface conditions of this part of the Danube
2.3.1.	Hydrography

3.2.5. Expected changes on groundwater and deep groundwater

3.2.6. Impacts during the building processes

3.3. Expectable changes in the agricultural sites and productivity

3.3.1. Expected changes in the microclimate

3.3.2. Expected changes in the soil condition

3.3.3. Changes in the possibilities of land utilisation

3.3.4. Possibilities of agricultural utilisation after the dam will be built

3.3.5. Possibilities of forestry utilisation after the dam will be built

3.3.6. Expected changes in the fish

3.4. Scenic appearance, changes in the aesthetic conditions

3.5. Impacts of this barrage system on the settlements and recreational conditions

3.6. Impacts on the industrial development

3.7. Impacts on the traffic

4. INTERACTIONS BETWEEN EVERY SINGLE BRANCH OF THE ECONOMY AND THE ENVIRONMENTAL IMPACTS OF THIS BARRAGE SYSTEM

4.1. Water management

4.2. Agriculture and sylviculture

4.3. Protected natural and special landscape values

4.4. Industry

4.5. Traffic

4.6. Recreation, watersports, tourism

4.7. Social aspects of this barrage system

5. ADDITIONAL TASKS FOR INVESTIGATION

This 1985 study is the most comprehensive when compared to the two other documents examined in this report. In fact, it is the only document which can be called an EIS. The other two documents are too incomplete to be given the name "EIS".

The 1985 report will be examined in two different ways: first it will be subjected to the Lee and Colley review package (1990) and second it will be checked to what degree the report conforms with the checklist developed in section 4.4.

The Lee and Colley review package (1990) consist of a list of review topics, a list of assessment symbols and a collation sheet. Two reviewers have to check the quality of the EIS independently and compare their results. If major differences in assessment occur the two reviewers should come together and discuss the problematic topics. The list of review topics is divided in four major parts: description of the development, the local environment and the baseline conditions; identification and evaluation of key impacts; alternatives and mitigation; and communication of results.

The assessment symbols used are the following:

Symbol	Explanation
A	Generally well performed, no important tasks left incomplete.
B	Generally satisfactory and complete, only minor omissions and inadequacies.
C	Can be considered just satisfactory despite omissions and/or inadequacies.
D	Parts are well attempted but must, as a whole, be considered just unsatisfactory because of omissions and/or inadequacies.
E	Not satisfactory, significant omissions or inadequacies.
F	Very unsatisfactory, important task(s) poorly done or not attempted.
NA	Not applicable. The Review Topic is not applicable or irrelevant in the context of this Statement.

The second evaluation is based on a checklist developed by the authors. It is not a standardised instrument to evaluate EISs, but is based on a most complete list of aspects which should be considered in EISs for dam projects. The procedure followed: the EIS was first read and next each topic in the checklist was assessed referring closely to the EIS. Each topic was commented briefly.

Fifty seven topics are included in the checklist. Of these only 44 could be relevant to the situation of Gabčíkovo-Nagymaros case. Following topics are not further discussed: 1.1.2, 1.1.5, 1.2.3, 1.2.14, 1.2.17, 1.2.23, 2.4, 2.5, 2.8, 3.7, 3.8, 3.10 and 3.15.

The topics which are relevant can be divided into one of four possible classes:

- FC fully covered;
- PD discussed (but only shortly, in general or partially);
- RW only referred to or very weak discussion;
- NI no information.

Results and discussion from the examination with the Lee and Colley review package (1990)

The Gabčíkovo - Nagymaros EIS prepared in 1985 contains parts which are well attempted. The whole must, however, be considered just unsatisfactory because of omissions and inadequacies.

The major limitations of this document can be summarized as follows:

– there is no discussion on the scope of the document: why have certain aspects been studied and others not?

– although a lot of background studies have been made for the proposed project, these studies are not discussed in an integrated way in the main body of the text;

– although alternatives and mitigation measures have been proposed in the EIS, they are not the "heart" of the document. Alternatives and mitigation measures are limited and not studied in sufficient detail;

– although impacts are examined, it is not discussed what was the basis for the interpretation of the data. The choice of standards, assumptions and value systems used is not explained;

– the communication of the results is insufficient. The layout is confusing, the reference system is not correct and reviewers have doubts about the objectivity of the study.

The EIS should be a document which allows anyone who is interested in the proposal to learn in a short period of time what the project is about, what the possible impacts will be, what alternatives and mitigation measures are available to reduce adverse effects and what the local and general population think about it. The EIS in question does not fulfil these requirements: the document is rather confusing and leaves the reader with a lot of questions.

Results and discussion from the examination with the checklist developed in section 4.4

Of those topics which were relevant to the Gabčíkovo-Nagymaros case only 9% were fully covered; 54% was only generally, partially or shortly discussed; 14% was only referred to or very weak and no information was found on 23% of the topics. Detailed information on the coverage of each topic can be found in Annex 2.

No information is provided on following relevant aspects:

1.2.2. Major social and economic costs of involuntary resettlements and the issues related to it

1.2.10. Inundation of potentially valuable mineral resources

1.2.12. Effects on ecosystems, cycles, interactions

1.2.20. Dam failure and safety measures

2.2. Remote and previously inaccessible areas are opened up due to the dam construction and the reservoir filling

2.3. Induced population immigration may lead to increased agricultural or mining activities with major implications for soil erosion, sedimentation, and water quality

2.9. Changed watershed hydrology: the changes in land use patterns, may affect the timing and magnitude of runoff especially during major storm events. Changed vegetative patterns may also influence dry season stream flow

3.5. Stream bed changes are one possible, but not a common result of the changed water flow and sediment load. This include the possibility of increased stream bed erosion below the dam due to "hungry" water (with reduced silt loads) being released from the dām

3.16. Combined socio-economic effects of all the developments

From this list it is possible to conclude that the document has major gaps.

It should be remarked that this evaluation study is based on a checklist for large scale water resources projects. The following comparison of reservoirs formed by different dam projects shows that the Gabčíkovo-Nagymaros project is more like a medium scale project:

Narmada project, India:	reservoir of 350.000 ha
Tucurui dam, Brazil:	reservoir of 216.000 ha
Dunakiliti (Gabčíkovo):	reservoir of 6.400 ha
Columbia dam, US:	reservoir of 5.040 ha

Annex 3 discusses the differences between impacts of large scale and small scale water resources projects. It is clear that the environmental and social impacts of smaller projects is much more limited in comparison with mega-projects.

6. The Slovak Documentation

It was not possible to examine the Slovak documentation in the same way as the Hungarian document because no Slovak documents in the format of EISs were provided.

It is not clear to which degree the seven mitigation measures discussed on pages 52 and 53 of the Slovak Memorial are developed in detail in the Bioproject and its 1986 update.

With the information available it is not possible to evaluate the Bioproject making use of the evaluation instruments (lists of review topics).

Studies summarised in Annex 24 of the Slovak Memorial tackle the following subjects:

	number
construction	13
design, general arrangement and lay-out (technical)	48
economical considerations	2
effects on Austria	2
effects on drinking water supply	1
energetic aspects	1
forest ecosystems	1
groundwater	3
hydrology	22
ice discharging	2
location alternatives	5
monitoring of GN project	2
navigation	5
operation of the project	2
power transmission lines	2
protection measures	6
summary documentation	1
water quality	1

Based on the summaries included in Annex 24 it seems that the majority of the 118 studies mentioned focus on technical aspects of general design, construction and the hydrological regime of the Danube river. It is not clear if environmental aspects have been taken into account in these reports.

Eleven studies (on forest ecosystems, groundwater, location alternatives, protection measures and water quality) are clearly related to topics which should be included in an environmental impact assessment.

7. Conclusions

Based on the information available to the researchers it can be concluded that the Gabčíkovo - Nagymaros environmental documents are early EIA period cases. Although EIA procedures were well advanced in many countries around the globe in the mid 1980s Hungary did not yet have a tradition of introducing environmental concerns into its decision-making. It was only as a result of public controversy in relation to the Gabčíkovo - Nagymaros project that the need for EIA became clear and that EIA was imposed on the proposed project. A literature review revealed that EISs prepared in an early EIA period most often do not result in high quality documents.

Research also indicates that the presence of a well established EIA procedure is one of the major requirements for EIA to be successful. Since an EIA procedure was only formally established in

Hungary with the introduction of an EIA decree in 1993, the Gabčíkovo - Nagymaros environmental documents were not prepared in optimal conditions.

The three environmental documents examined cannot be considered satisfactory. The 1983 and 1993 reports do not satisfy the basic requirements and should not be given the name EIS. The 1985 report is an EIS which has a number of defects.

The major limitations of this document can be summarised as follows:

– there is no discussion on the scope of the document: why have certain aspects been studied and others not?

– although a lot of background studies have been made for the proposed project, these studies are not discussed in an integrated way in the main body of the text;

– although alternatives and mitigation measures have been proposed in the EIS, they are not the "heart" of the document. Alternatives and mitigation measures are limited and not studied in sufficient detail;

– although impacts are examined, it is not discussed what was the basis for the interpretation of the data. The choice of standards, assumptions and value systems used is not explained;

– the communication of the results is insufficient. The layout is confusing, the reference system is not correct and reviewers have doubts about the objectivity of the study.

A checklist presenting all aspects which should be included in an EIS for a large dam project is developed in section 4.4: only 9% of the relevant topics were fully covered; 54% was only generally, partially or shortly discussed; 14% was only referred to or very weak and no information was found on 23% of the relevant topics.

The general conclusions are:

– although EIA procedures and contents are continuously being improved as a result of experience gained, there have not been major changes or significant developments in the state of the art of EIA during the 1980s;

– although EIA was not yet introduced in all countries by the end of the 1980s, it was generally available as instrument for environmental protection. At the end of the 1980s it was generally accepted that large infrastructure projects might cause substantial environmental effects and that EIA can be used to detect and mitigate adverse effects;

– the 1985 Gabčíkovo - Nagymaros EIS contains a lot of relevant information, but shows major limitations and defects.

References

Abu-Zeid, M. 1987. Environmental Impact Assessment for the Aswan High Dam. In: Environmental Impact Assessment for Developing Countries. A.K. Biswas and Qu Geping (eds). Tycooly International (for the United Nations University), London. pp.168-190.

Ahmad, Y.J and G.K, Sammy. 1985. Guidelines to Environmental Impact Assessment in Developing Countries. Hodder and Stonghton, London. pp.3.

Alexis, L. 1986. Sri Lanka's Mahaweli Ganga Project: The Damnation of Paradise. In: The Social and Environmental Effects of Large Dams, Vol.2: Case Studies. E. Goldsmith and N. Hildyard. (eds). Wadebridge Ecological Centre, U.K. 1986. pp.276-290.

Beanlands, G. 1992. Scoping methods and baseline studies in EIA. In: Environmental Impact Assessment: Theory and Practice. P. Wathern. (ed). Routledge, London.pp.33-46.

Beckman, B. 1986. Bakalori: Peasants versus State and Industry in Nigeria. In: The Social and Environmental Effects of Large Dams, Vol.2: Case Studies. E. Goldsmith and N. Hildyard. (eds). Wadebridge Ecological Centre, U.K. 1986. pp.140-155.

Bisset, R. 1987. Methods for Environmental Impact Assessment: a selective survey with case studies. In: Environmental Impact Assessment for Developing Countries. A.K.Biswas and Qu Geping.(eds). Tycooly International, London.

Bisset, R. 1988. Developments in the EIA methods. In: P. Wathern. (ed). Environmental Impact Assessment: Theory and Practice. Unwin Hyman, London. pp.47-60.

Blumm, M.C. 1988. The Origin, Evolution and Direction of the United States National Environmental Policy Act. In: (Australian) Environmental Law and Planning Journal 5: 179-193.

Bochniarz, Z., R. Bolan, S. Kerekes, J. Kindler, J. Vargha and H. von Witzke. 1992. Environment and Development in Hungary. A blueprint for transition. University of Minnesota and Budapest University of Economics.

Bowden, M.-A. and F. Curtis. 1988. Federal EIA in Canada: EARP as an evolving process. In: Environmental Impact Assessment Review 8: 97 - 106.

Boxer, B. 1985. Statement to House Interior Subcommittee on Water and Power Resources. Rutgers University, New Brunswick, N.J., July 23, 1985.

Bregman, J.I. and K.M. Mackenthun. 1992. Environmental Impact Statements. Lewis Publishers, Chelsea, MI.

Brown, A.L., R.A. Hindmarsh and G.T. McDonald. 1991. Environmental Assessment Procedures and Issues in the Pacific Basin-Southeast Asia Region. In: Environmental Impact Assessment Review 11: 143-156.

Caldwell, L.K. 1982. Science and the National Environmental Policy Act. Redirecting Policy through Procedural Reform. The University of Alabama Press, University, Alabama.

Caufield, C. 1985. The Yangtze Beckons the Yankee Dollar. In: The New Scientist, 5 December, 1985.

Cernea, M.M. 1990. Poverty risks from Population Displacement in Water Resources Development. Development Discussion Paper No.355. Harvard Institute for International Development. Harvard University. Massachusetts.

Chandler, W.U. 1986. The Tellico and Columbia Dams: Stewardship and Development. In: The Social and Environmental Effects of Large Dams, Vol.2: Case Studies. E. Goldsmith and N. Hildyard. (eds). Wadebridge Ecological Centre, U.K. 1986. pp.25-32.

Coenen, R. 1990. Amending NEPA in the USA. In: EIA Newsletter 4, C. Wood, N. Lee and C.E. Jones (eds.), University of Manchester.

Commission of the European Communities. 1993. Report from the Commission of the Implementation of Directive 85/337/EEC on the Assessment of the Effects of Certain Public and Private Projects on the Environment, COM (93) 28 final, volumes 1 - 13, Office for Official Publications of the European Communities, Luxembourg.

Couch, W.J. 1990. Reforming the Canadian Federal Environmental Assessment Process. In: EIA Newsletter 4, C. Wood, N. Lee and C.E. Jones (eds.), University of Manchester.

Couch, W.J. 1991. Recent EIA Developments in Canada. In: EIA Newsletter 6, C. Wood, N. Lee and C.E. Jones (eds.), University of Manchester.

Couch, W.J. 1992. EIA in Canada. In: EIA Newsletter 7, C. Wood, N. Lee and F. Walsh (eds.), University of Manchester.

Crabb, P. 1986. Hydroelectric Power in Newfoundland, Tasmania and the South Island of New Zealand. In: The Social and Environmental Effects of Large Dams, Vol.2: Case Studies. E. Goldsmith and N. Hildyard. (eds). Wadebridge Ecological Centre, U.K. 1986. pp.55-68.

Dixon, J. A., L.M. Talbot and G. J-M. Le Moigne. 1990. Dams and the Environment: Considerations in World Bank Projects. World bank Technical Paper Number 110. The World Bank, Washington, D.C.

Dogra, B. 1986. The Indian Experience with Large Dams. In: The Social and Environmental Effects of Large Dams, Vol.2: Case Studies. E. Goldsmith and N. Hildyard. (eds). Wadebridge Ecological Centre, U.K. 1986. pp.201-208.

Drucker, C. 1986. Dam the Chico: Hydro Development and Tribal Resistance in the Philippines. In: The Social and Environmental Effects of Large Dams, Vol.2: Case Studies. E. Goldsmith and N. Hildyard. (eds). Wadebridge Ecological Centre, U.K. 1986. pp.304-313.

ECE. 1987. Application of Environmental Impact Assessment for Highways and Dams. Economic Commission for Europe. United Nations.

Elkington, J. 1975. Beware the Warth of Osiris. In: New Scientist, 11 December, 1975.

Fahim, H.M. 1981. Dams, People and Development: the Aswan High Dam Case. Pergamon Press Inc. New York.

Gazdar, M.N. 1990. An Assessment of the Kala-Bagh Dam Project on the River Indus in Pakistan. Environmental Management Society, Karachi, Pakistan.

Gibson, R.B. 1993. Environmental Assessment Design: Lessons from the Canadian Experience. In: The Environmental Professional 15: 12 - 24.

Govorushko, S.M. 1990. EIA in the USSR. In: EIA Newsletter 5, C. Wood, N. Lee and C.E. Jones (eds.), University of Manchester.

Graham, R. 1986. Ghana's Volta Resettlement Scheme. In: The Social and Environmental Effects of Large Dams, Vol.2: Case Studies. E. Goldsmith and N. Hildyard. (eds). Wadebridge Ecological Centre, U.K. 1986. pp.131-139.

Griffiths, D.E. 1986. Canada's Slave River Project: Its likely Environmental Impact. In: The Social and Environmental Effects of Large Dams, Vol.2: Case Studies. E. Goldsmith and N. Hildyard. (eds). Wadebridge Ecological Centre, U.K. 1986. pp.49-54.

Haeuber, R. 1992. A Citizens' Guide to World Bank Environmental Assessment Procedures. The Bank Information Center, Washington DC.

Jhaveri, N. 1988. The Three Gorges Debacle. In: The Ecologist, Volume 18, No. 2/3, 1988.

Kim, K. and Murayashi, D.H.L. 1992. Recent Developments in the Use of Environmental Impact Statements in Korea. Environmental Impact Assessment Review: 12: 295-314.

Lavergne, M. 1986. The Seven Deadly Sins of Egypt's Aswan High Dam. In: The Social and Environmental Effects of Large Dams, Vol.2: Case Studies. E. Goldsmith and N. Hildyard. (eds). Wadebridge Ecological Centre, U.K. 1986. pp.181-183.

LeBlanc, P. 1993. EIA in Canada. In: EIA Newsletter 8, C. Wood, N. Lee, C.E. Jones and F. Walsh (eds.), University of Manchester.

Lee, N. and R. Colley. 1990. Reviewing the Quality of Environmental Statements. Occasional Paper Number 24, EIA Centre, University of Manchester.

Linney, W. and S. Harrison. 1981. Large Dams and the Developing World, Social and Environmental Costs and Benefits: A look at Africa. Environmental Laison Centre, Nairobi, Kenya.

Lohani, B.N. 1988. Environmental Assessment and Management in the Bank's Developing Member Countries. In: Proceedings and Training Manual Vol I, Training Workshop on Environmental Impact Assessment and Evaluation (Govt. of India, ADB/ESCAP), Lucknow, India, January, 18-24: 39-83.

Maudgal, S. 1988. Environmental Impacts of Water Resources Development Projects in India. In: Proceedings and Training Manual Vol I, Training Workshop on Environmental Impact Assessment and Evaluation (Govt. of India, ADB/ESCAP), Lucknow, India, January, 18-24: 39-83.

Monosowski, E. 1986. Brazil's Tucurui Dam: Development at Environmental Cost. In: The Social and Environmental Effects of Large Dams, Vol.2: Case Studies. E. Goldsmith and N. Hildyard. (eds). Wadebridge Ecological Centre, U.K. 1986. pp.191-198.

Morse, B. and T. Berger. 1992. Review of Sardar Sarovar: The Report of the Independent Review appointed by the World Bank to examine the Social and Environmental Implications of The Sardar Sarovar Dam on the Narmada River in India. Resource Futures International (for the Independent Review) Inc., Ottawa.

Munn, R.E (ed). 1989. Environmental Impact Assessment: Principles and Procedures. SCOPE 5. John Wiley and Sons, New York.

Netboy, A. 1986. The Damming of the Columbia River: The failure of Bio-Engineering. In: The Social and Environmental Effects of Large Dams, Vol.2: Case Studies. E. Goldsmith and N. Hildyard. (eds). Wadebridge Ecological Centre, U.K. 1986. pp.33-48.

Pollard, N. 1986. The Sudan's Gezira Scheme: A Study in Failure. In: The Social and Environmental Effects of Large Dams, Vol.2: Case Studies. E. Goldsmith and N. Hildyard. (eds). Wadebridge Ecological Centre, U.K. 1986. pp.168-180.

Radnia, A. 1993. EIA in Hungary. In: EIA Newsletter 8, C. Wood, N. Lee, C.E. Jones and F. Walsh (eds.), University of Manchester.

Rao, S.K. 1986. The Rajghat Dam: An Environmental Assessment. In: The Social and Environmental Effects of Large Dams, Vol.2: Case Studies. E. Goldsmith and N. Hildyard. (eds). Wadebridge Ecological Centre, U.K. 1986. pp.217-223.

Ryder, G. (Ed). 1991. Damming the Three Gorges. What Dam-Builders don't want you to know. A Critique of the Three Gorges Water Control Project Feasibility Study. Probe International, Toronto, 1991.

Ryder, G. 1988. China's Three Gorges Project: Whose Dam Business is it? In: Cultural Survival Quarterly, Vol. 12, No. 2, 1988.

Sadler, B. 1988. The evaluation of assessment: post EIS research and process development. In: Environmental Impact Assessment: Theory and Practice. P. Wathern. (ed). Routledge, London. pp.129-142.

Singh, S., A. Kothari and K. Amin. 1991. Evaluating Major Irrigation Projects. In: Sustainable Development, Volume 1, No. 1, October 1991, New Delhi.

Taylor, W. 1973. James Bay: Continental Crisis. In: Survival. North American Edition. No.12. March, 1973. pp.4.

Thompson, P. 1986. Saving Tasmania's Franklin and Gordon Wild Rivers. In: The Social and Environmental Effects of Large Dams, Vol.2: Case Studies. E. Goldsmith and N. Hildyard. (eds). Wadebridge Ecological Centre, U.K. 1986. pp.69-77.

Tolba, M.K. 1987. In the foreword to Environmental Impact Assessment for Developing Countries. A.K. Biswas and Qu Geping (eds). Tycooly International (for the United Nations University), London. pp.ix-x.

Tuntawiron, N. and P. Samootsakorn. 1986. Thailand's Dam Building Programme: Past Present and Future. In: The Social and Environmental Effects of Large Dams, Vol.2: Case Studies. E. Goldsmith and N. Hildyard. (eds). Wadebridge Ecological Centre, U.K. 1986. pp.291-303.

Van Buren, D. 1993. M.e.r. procedures in ontwikkelingslanden. Rijks universiteit Utrecht, Utrecht.

Waterbury, J. 1979. Hydropolitics of the Nile Valley. Syracuse University Press, 1979.

Wathern, P. (ed) 1988. Environmental Impact Assessment: Theory and Practice. Routledge, London.

Wathern, P. (ed) 1992. Environmental Impact Assessment: Theory and Practice. Second Edition. Routledge, London.

Williams, P. 1991. Dam Safety Analysis. In: Damming the Three Gorges. What Dam-Builders don't want you to know. A Critique of the Three Gorges Water Control Project Feasibility Study. G. Ryder, (Ed). Probe International, Toronto, 1991.pp.107-111.

World Bank. 1993. The World Bank and Environmental Assessment: An Overview. In: Environmental Assessment Sourcebook Update 1. The World Bank, Environment Department, Washington DC.

List of abbreviations

AHD	Aswan High Dam
CEAA	Canadian Environmental Assessment Act
CEQ	Council on Environmental Quality (US)
EA	Environmental Assessment
EARP	Environmental Assessment Review Process (Canada)
EC	European Communities
ECE	Economic Commission for Europe
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
FEARO	Federal Environmental Assessment Review Office
GNV	Gabčíkovo Nagymaros Barrage System
NEPA	National Environmental Policy Act
NGO	Non Governmental Organisation
NVDP	Narmada Valley Development Projects
OD	Operational Directive (World Bank)
SCS	Soil Conservation Service (US)
TGP	Three Gorges Project
US	United States
USSR	Union of Socialist Soviet Republics

Annex 1: Evaluation of EIS with the Lee and Colley Review Package – Full Evaluation Report

The 1985 Gabčíkovo - Nagymaros Environmental Impact Statement was reviewed using the Lee and Colley review package. As is required, the EIS was reviewed by two persons independently. Later on, a discussion was organised between the two to resolve existing differences.

A) THE LIST OF REVIEW TOPICS (LEE AND COLLEY, 1990)

1. <u>Description of the development, the local environment and the baseline conditions</u>

1.1. Description of the development: The purpose(s) of the development should be described as should the physical characteristics, scale and design. Quantities of materials needed during construction and operation should be included and, where appropriate, a description of the production processes.

1.1.1. The purpose(s) and objectives of the development should be explained.

1.1.2. The design and size of the development should be described. Diagrams, plans or maps will usually be necessary for this purpose.

1.1.3. There should be some indication of the physical presence and appearance of the completed development within the receiving environment.

1.1.4. The nature and quantities of raw materials needed during both the construction and operational phases should be described as well as, where appropriate, the nature of the production processes.

1.2. Site description: The on site land requirements of the development and the duration of each land use should be described.

1.2.1. The land area taken up by the development site should be defined and its location clearly shown on a map.

1.2.2. The uses to which this land will be put should be described and the different land use areas demarcated.

1.2.3. The estimated duration of the construction phase, operational phase and, where appropriate, decommissioning phase should be given.

1.2.4. The numbers of workers and/or visitors entering the development site during both construction and operation should be estimated. Their access to the site and likely means of transport should be given.

1.3. Residuals: The types and quantities of residuals and/or wastes which might be produced should be estimated and the proposed disposal routes to the environment described. [NB: wastes include all residual process materials, effluents and emissions. Waste energy, waste heat, noise, etc. should also be considered].

1.3.1. The types and quantities of waste matter, energy and other residual materials and the rate at which these will be produced should be estimated.

1.3.2. The ways in which it is proposed to handle and/or treat these wastes and residuals should be indicated, together with the routes by which they will eventually be disposed of to the environment.

1.3.3. The methods by which the quantities of residuals and wastes were obtained should be indicated. If there is uncertainty this should be acknowledged and ranges of confidence limits given where possible.

1.4. Environment description: The area and location of the environment likely to be affected by the development proposals should be described.

1.4.1. The environment expected to be affected by the development should be indicated with the aid of a suitable map of the area.

1.4.2. The affected environment should be defined broadly enough to include any potentially significant effects occurring away from the immediate construction site. These may be caused by, for example, the dispersion of pollutants, infrastructural requirements of the project, traffic, etc.

1.5. Baseline conditions: A description of the affected environment as it is currently and as it could be expected to develop if the project were not to proceed, should be presented.

1.5.1. The important components of the affected environments should be identified and described. The methods and investigations undertaken for this purpose should be disclosed and should be appropriate to the size and complexity of the assessment task. Uncertainty should be indicated.

1.5.2. Existing data should have been searched and, where relevant, utilised. These should include local authority records and studies carried out by, or on behalf of, conservation agencies and/or special interest groups.

1.5.3. Local land use plans and policies should be consulted and other data collected as necessary to assist in the determination of the "baseline" conditions, i.e. the probable future state of the environment, in the absence of the project, taking into account natural fluctuations and human activities (often called the "do-nothing" scenario).

2. <u>Identification and evaluation of key impacts</u>

2.1. Definition of impacts: Potential impacts of the development on the environment should be investigated and described. Impacts should be broadly defined to cover all potential effects on the environment and should be determined as the predicted deviation from the baseline state.

2.1.1. A description should be given of the direct effects and any indirect, secondary, cumulative, short, medium and long-term, permanent and temporary, positive and negative effects of the project.

2.1.2. The above types of effect should be investigated and described with particular regard to identifying effects on or affecting human beings, flora and fauna, soil, water, air, climate, landscape, material assets, cultural heritage (including architectural and archaeological heritage) and the interactions between these.

2.1.3. Consideration should not be limited to events which will occur under design operating conditions. Where appropriate, impacts which might arise from non-standard operating conditions, due to accidents, should also be described.

2.1.4. The impacts should be determined as the deviation from baseline conditions, i.e. the difference between the conditions which would obtain if the development were not to proceed and those predicted to prevail as a consequence of it.

2.2. Identification of impacts: Methods should be used which are capable of identifying all significant impacts.

2.2.1. Impacts should be identified using a systematic methodology such as project specific checklists, matrices, panels of experts, consultations, etc. Supplementary methods (e.g. cause-effect or network analysis) may be needed to identify secondary impacts.

2.2.2. A brief description of the impact identification methods should be given as should the rationale for using them.

2.3. Scoping: Not all impacts should be studied in equal depth. Key impacts should be identified, taking into account the views of interested parties, and the main investigation centred on these.

2.3.1. There should be a genuine attempt to contact the general public and special interest groups – clubs, societies, etc. – to appraise them of the project and its implications.

2.3.2. Arrangements should be made to collect the opinions and concerns of relevant public agencies, special interest groups and the general public. Public meetings, seminars, discussion groups, etc. may be arranged to facilitate this.

2.3.3. Key impacts should be identified and selected for more intense investigation. Impact areas not selected for thorough study should nevertheless be identified and the reasons they require less detailed investigation should be given.

2.4. Prediction of impact magnitude: The likely impacts of the development on the environment should be described in exact terms wherever possible.

2.4.1. The data used to estimate the magnitude of the main impacts should be sufficient for the task and should be clearly described or their sources be clearly identified. Any gaps in the required data should be indicated and the means used to deal with them in the assessment should be explained.

2.4.2. The methods used to predict impact magnitude should be described and be appropriate to the size and importance of the projected impact.

2.4.3. Where possible, predictions of impacts should be expressed in measurable quantities with ranges and/or confidence limits as appropriate. Qualitative descriptions, where these are used, should be as fully defined as possible (e.g. 'insignificant means not perceptible from more than 100m distance').

2.5. Assessment of impact significance: The expected significance that the projected impacts will have for society should be estimated. The sources of quality standards, together with the rationale, assumptions and value judgements used in assigning significance, should be fully described.

2.5.1. The significance to the affected community and to society in general should be described and clearly distinguished from impact magnitude. Where mitigating measures are proposed, the significance of any impact remaining after mitigation should also be described.

2.5.2. The significance of an impact should be assessed, taking into account appropriate national and international quality standards where available. Account should also be taken of the magnitude, location and duration of the impact in conjunction with national and local societal values.

2.5.3. The choice of standards, assumptions and value systems used to assess significance should be justified and any contrary opinions should be summarised.

3. **Alternatives and mitigation**

3.1. Alternatives: Feasible alternatives to the proposed project should have been considered. These should be outlined in the Statement, the environmental implications of each presented and the reasons for their rejection briefly discussed, particularly where the preferred project is likely to have significant, adverse environmental impacts.

3.1.1. Alternative sites should have been considered where these are practicable and available to the developer. The main environmental advantages and disadvantages of these should be discussed and the reasons for the final choice given.

3.1.2. Where available, alternative processes, designs and operating conditions should have been considered at an early stage of project planning and the environmental implications of these investigated and reported where the proposed project is likely to have significantly adverse environmental impacts.

3.1.3. If unexpectedly severe adverse impacts are identified during the course of the investigation, which are difficult to mitigate, alternatives rejected in the earlier planning phases should be re-appraised.

3.2. Scope and effectiveness of mitigation measures: All significant adverse impacts should be considered for mitigation. Evidence should be presented to show that proposed mitigation measures will be effective when implemented.

3.2.1. The mitigation of all significant adverse impacts should be considered and, where practicable, specific mitigation measures should be put forward. Any residual or unmitigated impacts should be indicated and justification offered as to why these impacts should not be mitigated.

3.2.2. Mitigation methods considered should include modification of the project, compensation and the provision of alternative facilities as well as pollution control.

3.2.3. It should be clear to what extent the mitigation methods will be effective when implemented. Where the effectiveness is uncertain or depends on assumptions about operating procedures, climatic conditions, etc., data should be introduced to justify the acceptance of these assumptions.

3.3. Commitment to mitigation: Developers should be committed to, and capable of, carrying out the mitigation measures and should present plans of how they propose to do so.

3.3.1. There should be a clear record of the commitment of the developer to the mitigation measures presented in the Statement. Details of how the mitigation measures will be implemented and function over the time span for which they are necessary should also be given.

3.3.2. Monitoring arrangements should be proposed to check the environmental impacts resulting from the implementation of the project and their conformity with the predictions within the Statement. Provisions should be made to adjust mitigation measures where unexpected adverse impacts occur. The scale of these monitoring arrangements should correspond to the likely scale and significance of deviations from expected impacts.

4. <u>Communication of results</u>

4.1. Layout: The layout of the Statement should enable the reader to find and assimilate data easily and quickly. External data sources should be acknowledged.

4.1.1. There should be an introduction briefly describing the project, the aims of the environmental assessment and how those aims are to be achieved.

4.1.2. Information should be logically arranged in sections or chapters and the whereabouts of important data should be signalled in a table of contents or index.

4.1.3. Unless the chapters themselves are very short, there should be chapter summaries outlining the main findings of each phase of the investigation.

4.1.4. When data, conclusions or quality standards from external sources are introduced, the original source should be acknowledged at that point in the text. A full reference should also be included either with the acknowledgement, at the bottom of the page, or in a list of references.

4.2. Presentation: Care should be taken in the presentation of information to make sure that it is accessible to the non-specialist.

4.2.1. Information should be presented so as to be comprehensible to the non-specialist. Tables, graphs and other devices should be used as appropriate. Unnecessarily technical or obscure language should be avoided.

4.2.2. Technical terms, acronyms and initials should be defined, either when first introduced into the text or in a glossary. Important data should be presented and discussed in the main text.

4.2.3. The Statement should be presented as an integrated whole. Summaries of data presented in separately bound appendices should be introduced in the main body of the text.

4.3. Emphasis: Information should be presented without bias and receive the emphasis appropriate to its importance in the context of the EIS.

4.3.1. Prominence and emphasis should be given to potentially severe adverse impacts as well as to potentially substantial favourable environmental impacts. The Statement should avoid according space disproportionately to impacts which have been well investigated or are beneficial.

4.3.2. The Statement should be unbiased; it should not lobby for any particular point of view. Adverse impacts should not be disguised by euphemisms or platitudes.

4.4. Non-technical summary: There should be a clearly written non-technical summary of the main findings of the study and how they were reached.

4.4.1. There should be a non-technical summary of the main findings and conclusions of the study. Technical terms, lists of data and detailed explanations of scientific reasoning should be avoided.

4.4.2. The summary should cover all main issues discussed in the Statement and contain at least a brief description of the project and the environment, an account of the main mitigation measures to be undertaken by the developer and a description of any significant residual impacts. A brief explanation of the methods by which these data were obtained and an indication of the confidence which can be placed in them should also be included.

B) RESULTS OF THE REVIEW

Overall Assessment D

1 B	**2 C**	**3 D**	**4 D**
1.1 B	**2.1 B**	**3.1 D**	**4.1 D**
1.1.1 A	2.1.1 C	3.1.1 D	4.1.1 C
1.1.2 C	2.1.2 A	3.1.2 D	4.1.2 D
1.1.3 F	2.1.3 C	3.1.3 F	4.1.3 B
1.1.4 E	2.1.4 D		4.1.4 E
1.2 B-D	**2.2 C**	**3.2 D**	**4.2 D**
1.2.1 F	2.2.1 B	3.2.1 D	4.2.1 E
1.2.2 C	2.2.2 C	3.2.2 D	4.2.2 C
1.2.3 F		3.2.3 D	4.2.3 D
1.2.4 F			
1.3 NA	**2.3 E**	**3.3 D**	**4.3 D**
1.3.1 NA	2.3.1 D	3.3.1 D	4.3.1 D
1.3.2 NA	2.3.2 E	3.3.2 D	4.3.2 D
1.3.3 NA	2.3.3 D		
1.4 B	**2.4 D**		**4.4 F**
1.4.1 B-E	2.4.1 D		4.4.1 F
1.4.2 A	2.4.2 D		4.4.2 F
	2.4.3 D		
1.5 A-B	**2.5 D**		
1.5.1 C	2.5.1 C		
1.5.2 B	2.5.2 E		
1.5.3 B	2.5.3 F		

Symbol	Explanation
A	Generally well performed, no important tasks left incomplete.
B	Generally satisfactory and complete, only minor omissions and inadequacies.
C	Can be considered just satisfactory despite omissions and/or inadequacies.
D	Parts are well attempted but must, as a whole, be considered just unsatisfactory because of omissions and/or inadequacies.
E	Not satisfactory, significant omissions or inadequacies.
F	Very unsatisfactory, important task(s) poorly done or not attempted.
NA	Not applicable. The Review Topic is not applicable or irrelevant in the context of this Statement.

C) DISCUSSION OF THE RESULTS

Overall, the 1985 Gabčíkovo - Nagymaros EIS is considered a border line case when it comes to its quality. Although certain parts are well done and the document presents a lot of very important information, there are also many tasks left incomplete or not attempted at all.

1. The development, local environment and baseline conditions are generally satisfactory and complete. It can be considered the best part of the document (details below).

1.1. The development is sufficiently described in the EIS.

1.1.1. The purpose(s) and objectives of the development are discussed in the EIS. It is, however, not done in the introduction. Persons who read the document and do not know what it is about will only find out in the third part of the study (the part which deals with the impacts of the study).

1.1.2. The design and scale of the development are described in detail. There are, however, almost no maps, diagrams, photographs or any other visual aids to clarify the text. It is not discussed what the project will look like when it is finished. Although it might be possible to find this information in the basic studies, it is not shown in this EIS.

1.1.3. There is no indication of the physical presence and appearance of the completed development. There are only some data in meters and kilometres, but the information is not complete.

1.1.4. There is one sentence describing the amount of soil, stones and gravel to be moved. This aspect is not discussed at the beginning of the report (only on page 56, were impacts are discussed). Other important materials needed during both the construction and operational phases are not discussed, e.g. the amount of concrete and other construction materials necessary to build the project.

1.2. Depending on the presence of a clear and detailed map a B or D score is awarded. A clear and detailed map is absent from the document which was reviewed. The reviewers feel, however, that there might have been a map which got lost during copying. The exact duration of the different land uses is missing in any way.

1.2.1. A map is missing. It is, however, very important to be able to visualise the aspects which are described in the text.

1.2.2. The uses to which land will be put is described, but not in detail.

1.2.3. The estimated duration of the construction phase and operational phase is not described. A distinction between the different phases is not made in the EIS. Moreover, the construction phase is not discussed at all.

1.2.4. The numbers of workers and/or visitors entering the development site during both construction and operation is not described in detail.

1.3. The proposed project will not generate wastes. This aspects is, therefore, not considered applicable in the context of this statement.

1.4. The environment is described in sufficient detail.

1.4.1. Again, a detailed map is missing, but might have been available in the original copy.

1.4.2. The affected environment is defined broadly enough to include any potentially significant effects occurring away from the immediate construction site.

1.5. The baseline conditions are discussed in detail. It is, however, not described how the environment might be expected to develop if the project were not to proceed. Long-term predictions are certainly missing. It is not clear if changes will take place in the environment if the project is not completed. Will there be changes or will everything stay the same as today??

1.5.1. Uncertainty is not indicated. The methods which were used to do the research are not mentioned or discussed. It is suspected by the reviewers that the institutes which made the basic research used the right methods, but there is no way to verify or to make sure.

1.5.2/3 Almost all research discussed in this EIS was prepared by "third parties", e.g. Hungarian institutes. A very long list of studies consulted for this study is included in the back of the document.

2. Even though almost all important impacts are described the discussion is sometimes rather confusing and it becomes difficult to follow the train of thought of the people who prepared the EIS. It is obvious that the main study was a compilation of several earlier investigations and discussions. The linking of the several studies is, however, done poorly.

2.1. The magnitude of the impacts are not discussed, neither are the scoping methods and the standards, assumptions and value systems used. This section can, therefore, be considered just satisfactory despite important inadequacies.

2.1.1. Many effects are discussed, but without making a difference between types of effects (direct, indirect, cumulative, etc.)

2.1.2. All important impacts are discussed. The discussion is, however, sometimes rather confusing and it becomes difficult to follow the train of thought of the people who prepared the EIS.

2.1.3. Major disasters or other accidents are not discussed. In one sentence it is mentioned that the production of electricity is not a priority in non-standard operating conditions such as in case of "flood operations".

2.1.4. Comparison between the baseline condition and the predicted impact situation is not always possible because data are often missing. Data are sometimes present in the annex, but they are not well integrated in the EIS.

2.2. Impacts are identified in a satisfactory manner

2.3. Scoping is not discussed. It is, however, done in practice by focusing on agricultural, water, and ecological aspects.

2.3.1. The public was not contacted during the preparation of the EIS.

2.3.2. No arrangements were made to collect the opinions and concerns of relevant public agencies, special interest groups and the general public. It could be that special meetings were organised, but it is not mentioned or discussed in the EIS.

2.3.3. Scoping methods are not discussed or justified. Key impacts were identified without discussion.

2.4. The magnitude of the impacts is not discussed. This aspect is missing from the EIS. Predictions are sometimes attempted by using research from e.g. other reservoirs in the country. The project disturbances are discussed mainly from "the civil engineering" point of view.

2.5. The impact significance is discussed, but without a description of the choice of standards, assumptions and value systems used.

3. Although, one alternative and a few mitigation measures have been discussed it is felt that a more complete job could have been done.

3.1. One alternative is discussed, but not in very much detail.

3.1.1. In half a page one alternative for the Nagymaros dam is proposed. A new location alternative is discussed. In a separate study this alternative is not considered beneficial and is therefore dropped.

3.1.2. Except for the location alternative, no other types of alternatives (design, process, etc.) are studied.

3.1.3. It is disputable if this review topic is applicable in the context of this statement.

3.2. Only three important mitigation measure are considered. As a result of the proposed project the water level will start to fluctuate. This might cause important adverse effects, especially for the plants. Mitigation measures which would minimise this problem are discussed. Also the groundwater table is subject of a discussion. The mitigation measures are, however, not discussed in a separate chapter and only the very obvious ones are given.

3.3. The need for a monitoring program is recognised in the EIS. The reviewers do, however, not agree on the necessary level of detail. It is felt that a more detailed discussion would be interesting considering the uncertainty in impact prediction. Moreover, the time factor (how long do the mitigation measures have to be maintained, how long is the monitoring program expected to go on?) is not taken into account.

4. The EIS is very confusing and is considered insufficient when it comes to the communication of the results.

4.1. The layout is very confusing. The numbering of the different sections is very difficult and full of mistakes (typing errors).

4.1.1. There is an introduction, but it does not describe the proposed project. This is only mentioned in the third part of the study.

4.1.2. The division in chapters and the content of the different sections does not always correspond, e.g. the description of the project is in the chapter on "impacts". It is obvious that the logic followed in the Lee and Colley review package is different from the logic behind the EIS under review. It, therefore, takes a long time to find all the answers to the different review topics.

4.1.4. There is no list of references, although many external sources are used in the text. There is not an unambiguous link between the references in the text and the list of external studies at the end of the document.

4.2. Some tables, graphs and other aids to improve the readability of the document are missing. Although a lot of graphs are used, they are not always understandable. The quality is also very poor, but this could be the result of the copying.

4.3. Both reviewers agree that the EIS is very positive for the proposed project. One of the reviewers feels the EIS is biased and present only the positive aspects of the study. She is uncertain about the objectivity of the results and cannot be convinced of its scientific approach. It is felt that the energetical interest of the countries and a discussion on the necessity of the project are missing. Also a comparison with other alternatives and other projects in Hungary and Europe should have been part of the EIS. The other reviewer would rather believe what has been written and is less critical.

4.4. There is no non-technical summary prepared especially for the general public. The sentences and the conclusions are rather difficult to understand for the non-specialist.

Annex 2: Evaluation of the 1985 EIS of the Gabčíkovo-Nagymaros River Barrage System on the Basis of a Checklist (see section 4.4.)

Text in *italic* are comments on the EIS by the reviewer

1. Dam and Impoundment area:

1.1. During Construction:

Impacts during the constructional phase are described very shortly (on page 46). It is divided in two parts:

a) temporary impacts during construction

b) impacts of temporary institutions and objects

This analyses is not complete and very general and only shows some examples about the possible impacts. One of the examples is the constructional phase of Arpad-Bridge. There is nothing concrete in this discussion, only suggestions to handle some temporary problems in the future. There is one additional paragraph (on page 56) about the transportation of materials at this region. The environmental impacts (e.g. noise, soil-, water-, air-pollution) it will cause are discussed

1.1.1. Air and water pollution from construction, equipment, earth movement and living quarters - *only referring to these facts very weakly*

1.1.2. Solid waste displacement: *not relevant to the Gabčikovo-Nagymaros case*

1.1.3. Destruction of natural landscape - *only referring to these facts (on page 60)*

1.1.4. Noise pollution - *only referring to these facts in one sentence (on page 47)*

1.1.5. Importing of water related diseases through migrant labours: *not relevant to the Gabčíkovo-Nagymaros case*

1.1.6. Population influx and linked social effects including health, security, and impact on local cultures - *only referring to these facts, well done the part about security (mainly flood protection)*

1.2. Reservoir formation:

This report does not divide the field of examination in the same way as the checklist. Therefore, the information is everywhere inside of the EIS and the evaluation is difficult

1.2.1. The effect of inundation of the houses; villages; farms; infrastructure such as roads and transmission lines *(on page 48., 53.) The information is mainly about the changes in the agricultural activity*

1.2.2. Major social and economic costs of involuntary resettlements and the issues related to it, including – *no information*

1.2.3. The poverty risks from the population displacement like landlessness, joblessness, homelessness, marginalization, food insecurity, morbidity increase, social disarticulation etc. and feeling of powerlessness and alienation of the oustees.– *not relevant to the Gabčíkovo-Nagymaros case*

1.2.4. Effects on employment, taxes, local inflexion, changes in supply and demand patterns, etc.– *only very general description is found on page 56, 62*

1.2.5. Other social and cultural destruction – *the conclusion of this material is that the reservoir will give mainly benefits to this region*

1.2.6. Inundation of cultural/historical sites like sites or areas of historic, religious, aesthetic or other particular cultural value, and sites of archaeological and paleontological significance – *short description on page 60*

1.2.7. Inundation of agricultural land, especially highly productive bottom lands – *(on page 59.) – the reservoir will cause some changes on it, but they are not very significant*

1.2.8. Inundation of forest land, may mean the loss of valuable timber and species diversity including endangered and endemic species and forest ecosystem. – *on page 60*

1.2.9. Inundation of wildlife habitat, particularly habitat of threatened species with consequent impact on biological diversity. Barriers or corridors may be created in the habitat affecting population.– *short description on page 60*

1.2.10. Inundation of potentially valuable mineral resources – *no information*

1.2.11. Inundation of Archaeological, Architectural historical and heritage sites and aesthetically important objects and landscape *(the same as 1.2.6.)*

1.2.12. Effects on ecosystems, cycles, interactions – *on this level: no information*

1.2.13. Inundated vegetation or biomass in the reservoir can affect water quality for potable water, reservoir fishing, operation and longevity of dam and associated machinery.*(on page 55)*

1.2.14. Water weeds proliferation can increase disease vectors, affect water quality and fisheries, increase water loss (through transpiration), affect navigation, recreation and fishing, and clog irrigation structures and turbines – *not relevant to the Gabčíkovo-Nagymaros case*

1.2.15. Fish migrations will be affected by the blockage of dam in the river (fish ladders may sometimes be practical), it affect mainly the fish species which migrate to the upstream to reproduce.– *special locks for fish (on page 55)*

1.2.16. Water quality within the reservoir is in part, dependent on what happens upstream and retention time within the reservoir. Quality may be affected by salt accumulation, eutrophication from weeds and biomass decay, turbidity, pollution from sediment, the reservoir provides better quality water downstream with less suspended matter – *well done on pages: 41-44*

1.2.17. Health: establishment of the reservoir and associated water management structures (e.g., canals and ditches) can create conditions fostering establishment and spread of water-related diseases such as schistosomiasis, onchocerciasis, encephalitis, and malaria – *not relevant to the Gabčíkovo-Nagymaros case*

1.2.18. Effect of drawdown regime, which may create agricultural possibilities, as well as health, recreational, aesthetic and access problems – *(on page 45) only about the changes in the agricultural activity (on pages 45, 49)*

1.2.19. Seismicity may be induced by large reservoirs – *one sentence on page 5*

1.2.20. Dam failure and safety measures – *no information*

1.2.21. Ground water level in the surrounding area may be altered – *this topic is handled together with 1.2.18*

1.2.22. Local climate may be modified by large reservoirs, especially in terms of humidity and local fog – *(on page 47)*

1.2.23. Temperature of released water may be higher or lower than ambient river temperature (depending on pattern of release); this will have varying impacts on downstream water uses – *not relevant to the Gabčíkovo-Nagymaros case*

1.2.24. Navigation – *(on page 57) the waterways will be better, without shallows*

2. **Upstream** (not directly "caused" by the dam but induced or exacerbated by the dam)

2.1. Increased sedimentation from the following sources:

The Third chapter deals with the sedimentation (on pages 42-43), the suggestion is to remove sediments regularly. This description does not deal with the details e.g. there is no information about the origin, etc. The subtropics are, therefore, not further discussed

2.1.1. Existing sediment resulting from previous natural or induced erosion remains in the river bed or in the watershed area

2.1.2. Unusual natural sedimentation from natural events such as volcanic activity, earthquakes, mud slides, typhoons and "100 year precipitation events"

2.1.3. Road building and other construction

2.1.4. Erosion from clearance of vegetation, logging, and cultivation by people who have moved into the watershed areas as a direct or indirect result of the dam project

2.1.5. Cultivation on unsuitable sites using unstable or otherwise unsuitable lands

2.1.6. Logging and forest denudation of forest which also result in erosion

2.2. Remote and previously inaccessible areas are open up due to the dam construction and the reservoir filling – *no information*

2.3. Induced population in migration may lead to increased agricultural or mining activities, with major implications for soil erosion, sedimentation, and water quality – *no information*

2.4. Poaching or illegal unsustainable exploitation of wildlife increases – *not relevant to the Gabčíkovo-Nagymaros case*

2.5. Denudation of vegetation for cultivation, fuel collection and logging – *not relevant to the Gabčíkovo-Nagymaros case*

2.6. Loss of wild land and wildlife habitat with impact on endangered species and reduction of biological diversity – *short description on page 60*

2.7. Negative impacts on aesthetic and scenic qualities of the area and the potential for certain recreational uses – *well done on pages 60., 61*

2.8. Pollution from settlements and cultivation – *not relevant to the Gabčíkovo-Nagymaros case*

2.9. Changed watershed hydrology: The changes in land use patterns, may affect the timing and magnitude of runoff especially during major storm events. Changed vegetative patterns may also influence dry season stream flow – *no information*

2.10. Salt inflows from the watershed may accumulate in the reservoir and affect water quality. Similarly, catchment runoff may carry increased quantities of agricultural chemicals and fertiliser with resultant impacts on reservoir water quality. – *This description can be found in the chapter about the water quality on pages 41-42*

3. **Downstream**

3.1. Impact on river fishery due to changes in flow regime, effect of dam blocking fish migration, changes in water quality (loss of nutrients trapped by dam, pollution from irrigation return flow, and increased water turbidity) – *Aspects of fishing can be found in part on page 55*

3.2. Effect on traditional flood plain cultivation through changes in flow and flooding regime, and loss of annual "top dressing" fertilisation from limited flooding. Control of severe flooding can also yield benefits through reduced crop and property losses – *well done on pages 49 - 54*

3.3. Impact on other water projects: changes in stream flow and water releases from the dam affect dams and irrigation projects elsewhere in the lower basin. The impact can be both positive and negative. Reduced silt content in water, for example, will permit better water management, lower silt levels also decrease potable water treatment costs. On the other hand, weed growth in existing canals may increase with perennial water supplies - *some parts are well done on page 58*

3.4. Impact on municipal and industrial water supply downstream can have both positive and negative effects depending on water quantity and quality – *on page 58*

3.5. Stream bed changes are one possible, but not a common result of the changed water flow and sediment load. This include the possibility of increased stream bed erosion below the dam due to "hungry" water (with reduced silt loads) being released from the dam – *no information*

3.6. Flood control avoid flood damage and change production – *well done on page 39*

3.7. Effect on estuarine and marine fisheries and marine biota, including endangered species, through changes in flow regime, change in water quality (e.g. pollution from toxic chemical and salts from irrigation return flow to river) and loss of nutrients – *not relevant to the Gabčikovo-Nagymaros case*

3.8. Salt intrusion into estuarine and lower river basin areas may result from sustained or seasonal reduction in river flow – *not relevant to the Gabčikovo-Nagymaros case*

3.9. Groundwater level changes: Higher levels due to the high water levels in the reservoir. Downstream, in old flood plain areas, the groundwater level may fall but in irrigated areas, it may rise – *some information on pages 46., 49*

3.10. Health problems from water-related diseases or parasites (similar health problems may also occur in the reservoir itself), primarily form irrigation and associated canals – *not relevant to the Gabčikovo-Nagymaros case*

3.11. Effects on wildlife and wild lands through loss of or change in habitat may result in an impact on biological diversity – *there is not enough information*

3.12. Water logging – *the same as 3.9*

3.13. Salinization – *no information*

3.14. Indirect impacts of increased urban and industrial developments – *only very general description about the indirect impacts, without concrete things*

3.15. Reduction in local food production due to production of cash crops for exports – *not relevant to the Gabčikovo-Nagymaros case*

3.16. Combined socio-economic effects of all the developments – *there is not concrete information*

3.17. Increased irrigation, improved water control, hydropower generation and water supply benefits and their positive impacts – *there is an indication for these aspects on pages 44., 45., 49*

Annex 3: Comparison of Large Scale vs. Small Scale Water Resources Projects

The social and environmental effects of large-scale projects are much greater than those of small and medium sized projects. Ecological impacts of the project are directly proportional to the size of the project and are related to the nature of the environment and its sensitivity to modifications caused by construction, operation and maintenance of such projects (Anthony, 1978). Small and medium scale projects are the best for sustainable resource use and for reduction of disastrous effects. The major social and environmental effects of large-scale water resource development projects can be listed as in Annex Table 1.

Annex Table 1: *Overview of impacts of large-scale and small-scale water resource projects*

	Impacts	In large-scale projects	In small-scale projects
1.	The salinisation of lands and waters	XXXX	X
2.	The spread of water borne diseases	XXXX	X
3.	The destruction of valley and watershed forests	XXXX	X
4.	The destruction of wildlife	XXXX	
5.	The ruin of fisheries	XXXX	X
6.	The drowning of prime land on the flood plains	XXXX	X
7.	The increasing complexity of extremity of flood patterns caused by engineering interventions	XXXX	X
8.	Loss of silt and coastal erosion problems	XXXX	
9.	Sedimentation of reservoirs	XXXX	XX
10.	Loss of fertility down-stream	XXXX	X
11.	Water losses in reservoir exceeding gains	XXXX	X
12.	Pest population and aquatic weeds increases as a result of perennial irrigation.	XXXX	X
13.	Dam failure and earth quake risks	XXXX	
14.	Failure of flood control	XX	XXX
15.	The incursion of crippling debt	XXXX	X
16.	Loss of land and food for cash crop plantations	XXXX	X
17.	The human misery of displacement and resettlement. ,	XXXX	X

On comparison with the social and environmental effects caused by large-scale projects, the effects of small-scale projects are negligible. But from the view point of power generation and large scale water storage, only relatively large and deep reservoirs are economically attractive (Ackermann, 1973). It is, however, not advisable to go for such projects looking only at the immediate economic benefits that cause long-term disastrous economic costs as a result of the social and environmental effects. Run-of -the-river generation schemes and small impoundment reservoirs are two important alternatives to large dams in hydro-industry. They are less destructive ecologically and better able to be integrated into rural communities(Goldsmith, K. 1991).

(The information in Annex Table 1 is based on the references in Annex Table 2)

Annex Table 2: *References cited in the Annex table 1.*

1. Desmond Anthony. 1978. The Ecologist in a Technology Age, Paper presented at the Seminar on Hydropower and Environment, Georgetown, Guyana 4-8 October 1976.
2. Hotes, F and E.A. Pearson. 1977. Effects of Irrigation on Water Quality. In: E.B. Worthington (Ed.) Arid Land Irrigation in Developing Countries. Pergomon Press, Oxford.
3. Biswas, A.K.(Ed). 1980. Water Management for Arid Lands in Developing Countries. Pergamon Press, Oxford.
4. Farid, M.A. 1977. Irrigation and Malaria and Arid Lands. In: E.B. Worthington (Ed.), Arid Land Irrigation in Developing Countries. Pergomon Press, Oxford. pp.416
5. Obeng, L.E. 1977. Schistosomiasis – The Environmental Approach. In: E. Barton Worthington (Ed), The Social and Ecological Effects of Water Development in Developing Countries. Pergamon, Oxford. pp.343.
6. Worthington, E.B. (Ed). 1977. The Social and Ecological Effects of Water Development in Developing Countries. Pergamon , Oxford.
7. Bardach, J.E and B. Dussart. 1973. Effects of Man-made Lakes on Ecosystems. In: W.C.Ackermann et al (Eds), Man-Made Lakes: Their Problems and Environmental Effects, American Geophysical Union, Washington D.C.
8. Ackermann W.C.et al (Eds) Man-Made Lakes: Their Problems and Environmental Effects, American Geophysical Union, Washington D.C.
9. Erhlich, P.A. 1982. Extinction. Victor Gollanz, London.
10. George, C.J. 1973. The Role of the Aswan High Dam in Changing the Fisheries of the Southeastern Mediterranean. In: T.Farvar and J.Milton (Eds), The Careless Technology. Tom Stacey. pp.159-79.
11. Kassas, M. 1980. Environmental Aspects of Water Resources Development. In: A.K. Biswas et al. (Eds), Water Management for Arid Lands in Developing Countries. Pergamon, Oxford. pp.74.
12. Banks, J.W. 1969. A Review of the Literature on the Upstream Migration of Adult Salmonids. In: Journal of Fish Biology, No.1.
13. Petts, G.E. 1984. Impounded Rivers: Perspectives for Ecological Management. John Wiley and Sons Ltd., Chichester.

14. Goldsmith, K. 1991. The Case for Small Scale Hydro power. in International Water Power and Dam Construction. Volume 43, No.5.

15. Kodva, V.A. 1972. The World's Soils and Human Activity. In: N. Polunin (Ed.), The Environmental Future. The Macmillan Press.

16. Varallyay, G. 1977. Soil Water Problems Related to Salinity and AlKališity in Irrigated Lands. In: E.B. Worthington (Ed), The Social and Ecological Effects of Water Development in Developing Countries. Pergamon, Oxford. pp.343.

17. Eckholm, E.P.O. 1985. Salting the Earth. In: Environment, Vol 17, No.7.

18. Morgan, A.E. 1971. Dams and Other Disasters: A Century of the Army Corps of Engineers in Civil Works. Porter Sargent Publisher, Boston.

19. Rothe, J.P. 1969. Earthquakes and Reservoir loadings. From the Proceedings of the Fourth World Conference on Earthquake Engineering, Santiago, Chile, Jan. 1969.

20. Simpson, D.W. Seismicity Changes Associated with Reservoir Loading. In: Engineering Geology, 10, 1976.

21. Mahmood, K. 1987. Reservoir Sedimentation. Impact, Extent, Mitigation. World Bank Technical Paper 71, The World Bank, Washington, DC.

22. Repetto, R. 1986. Skimming the Water: Rent-seeking and the Performance of Public Irrigation Systems. Research Report No.4. December, World Resources Institute.

23. Widstrand, C.(Ed). The Social and Ecological Effects of Water Development in Developing Countries. Pergamon Press, Oxford.

24. Linney, W. and S. Harrison. 1981. Large Dams and the Developing World, Social and Environmental Costs and Benefits: A Look at Africa. Environmental Liaison Centre, Nairobi, Kenya.

25 Goldsmith, E. and N. Hildyard (Ed). 1984. The Social and Environmental Effects of Large Dams, Vol.1. Wadebridge Ecological Centre, Wadebridge.

26. Alexis, L, E. Goldsmith and N. Hildyard. 1984. Dam destruction-The Case Against Superdams. In: The Ecologist, Vol.14, No 5/6.

27. Blackwelder, B. and P. Carlson. 1984. Fact Sheets on International Water Development Projects. Environmental Policy Institute, International Resources Project, Washington DC.

28. Goldsmith, E. and N. Hildyard (Ed). 1986. The Social and Environmental Effects of Large Dams, Vol.2. Wadebridge Ecological Centre, Wadebridge.

29. Trussell, D. 1992. The Social and Environmental Effects of Large Dams. In: Goldsmith, E. and N. Hildyard (Eds).Vol.3. Wadebridge Ecological Centre, WAdebridge.

30. Williams, P. 1991. The Debate Over Large Dams. The Case Against. Civil Engineer, August 1991.

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