PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM FOR LIVING RIVERS:

RIVER REHABILITATION OF INTERNATIONAL WATERWAYS

HELD

IN THE HUNGARIAN ACADEMY OF SCIENCE
BUDAPEST, HUNGARY

21ST JANUARY 2000

ORGANISED BY

THE PRIME MINISTER'S OFFICE
AND
THE MINISTRY OF FOREIGN AFFAIRS
OF THE REPUBLIC OF HUNGARY

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2000
BUDAPEST

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Published by EKO'21
XIX. u. 31., 1172 Budapest, Hungary

ISBN 963 00 5597 X

CONTENTS

EDITORIAL NOTES

In 1999 the Prime Minister's Office and the Ministry of Foreign Affairs of the Republic of Hungary undertook to organise a one-day international symposium on the river rehabilitation of international waterways. That symposium was intended to gather together specialists on river rehabilitation from different parts of the world, share their individual experiences and discuss general and specific issues in this field. Hungarian scientists would not only make their own contribution but also be in a position to benefit from the debate, the conclusions reached possibly assisting towards a practical solution in recent efforts on Hungarian river rehabilitation and restoration activity especially along the upper Danube section. This volume contains the proceedings of that international symposium.

It is composed of two parts. Part One contains the papers of the invited scientists and experts and these papers are arranged in the sequence of their presentation at the symposium. The organisers of the symposium when inviting speakers had the intention to cover different geographical regions not only within Europe but from other continents as well. Among the contributions there are papers dealing with general principles and specific experiences of river restoration and rehabilitation, others are presented as conceptions or deal with projects currently ongoing. Some explore other areas such as research initiatives and the general water policy directives of the European Union or rivers from a human and environmental rights perspective.

All of the invited speakers and all of those who made some oral contribution to the symposium were asked to forward their edited papers for inclusion in the proceedings of the symposium. Some did not have the opportunity to provide such a paper but agreed to the publication of an edited version of the verbatim record of their speech. Where a verbatim record is used the title contains a footnote indicating the background of the paper.

At the symposium discussion did not follow each presentation but was separately engaged in during a session at the end of the meeting. Through this procedure the participants were able to express their comments on the subject of the different speeches and could raise questions to the speaker or to each other in a way that made the discussion more dynamic and hopefully more involving to those present.

The exchange of ideas and wealth of issues generated by the discussion led to the decision by the symposium organisers to publish not only the papers of the key speakers but also the whole discourse of the day. The section encompassing the discussion is displayed in Part Two as a separate unit and is composed of the edited verbatim records as approved by the speaker or in some cases by a written form of the comment provided directly by the author.

Dr. Kern, one of the key speakers, just prior to this symposium at another conference together with his colleague A. Zinke presented a paper on the rehabilitation of a Danube section affected by the Gabčíkovo Hydropower System *(Kern, K. & Zinke, A., in press: Rehabilitierung der Donau im Bereich des Kraftwerks Gabcikovo. Hoxter -*

Angewandte Landschaftsokologie. Tagung "Renaturierung von Bachen, Flussen und Stromen" 24.-25. 11. 1999 in Neuhaus). Because the subject of this paper was so close to the theme of our international symposium and based on the recommendation of the authors, the organisers decided to include its English translation as an annex to this volume under the copyright permission of the publisher of the other conference.

The Proceedings contain the Program of the Symposium and the List of Contributors together with accompanying details provided by them.

I thank all contributors for their excellent cooperation during the preparation of this volume.

On the continents of our Earth, rivers through their very specific network characteristics play an integral and life supporting role. This is the case both in natural and in cultural terms. Through their action the global circulation of water between the aerosphere and oceans is provided. The survival of many rich and diverse ecosystems is directly dependent on them and from another perspective they very frequently interlink the cultures of different nations and ethnic groups. Thus they are corridors and pathways for life in many senses. Their international character will make the efforts of river rehabilitation, now becoming recognised as an essential activity over more and more areas of our Planet extremely challenging. In a great number of cases the possible rehabilitation of rivers can not be realised except through extensive and successful international co-operation among the related parties. I hope these Proceedings could, even to a very small extent, become a part of those efforts.

September 2000, Budapest

György Kovács
Editor

THE PROGRAM OF THE SYMPOSIUM

9.00 – 10.00 Registration

Morning section

Chairman: Professor James Brown, University of San Francisco

10.00 - 10.15 Welcome speech by Dr. László Székely, Commissioner for the Danube

10.15 - 10.55 Dr. Klaus Kern, environmental river engineer: River Rehabilitation of Waterways: lessons from river restoration in Germany

10.55 – 11.35 Philip B. Williams, President, PWA Consultants in Hydrology: Restoring Lowland River Floodplains in California

11.35 – 12.05 Dr. Tamás Rácz Director, Ökoplan: Concept for the restoration of the Danube river and its inland delta in the Szigetköz-Zitny Ostrov area

12.05 - 12.30 Patricia Strayer, Director of Watershed Research and Planning: Kissimmee River restoration

12.30 – 13.15 – Lunch

Afternoon section

Chairman: Professor Alexandre – Charles Kiss, University of Strasbourg

13.15 – 13.35 P. Weller, Program Director, WWF: The WWF Green Danube programme

13.35 – 13.55 Professor John C. Callaway, University of San Francisco: Restoring Wetland Habitats: Lessons from Southern California

13.55 – 14.15 Professor Claude Amoros, University Claude Bernard: Ecological Restoration of Fluvial Side Arms: Experiments in France

14.15 –14.30 Guido Premazzi, Environmental Institute of the European Commission: Water Protection - a Great Environmental Challenge: the Research Initiatives of the Environment Institute of the European Commission

14.30 – 14.45 Professor Dinah Shelton, Notre Dame University: Rivers and mankind – an international environmental and human rights perspective

14.45 – 15.00 Dr. Erik Mostert, Technical University Delft: The proposed EU Framework Directive Water and the Gabcikovo-Nagymaros project

15.00 – 15.15 Coffee Break

15.15 -18.20 Discussion

18.20 – 18.30 Closing Remarks by Professor Alexandre – Charles Kiss

OPENING ADDRESS

Dear Participants, Dear President, Ladies and Gentlemen,

First of all, on behalf of the Ministry of Foreign Affairs and the Hungarian Prime Minister's Office, let me thank our foreign guests for having taken the trouble to travel here and my fellow-Hungarians for having sacrificed some of their precious time to come to this conference — so important to all of us for so many reasons.

Please allow me to briefly explain, to our foreign guests in particular, the reason why I came here today. Seeing my name on the list of participants as the governmental commissioner for the Danube, some might suppose that a governmental commissioner has been appointed for every Hungarian river, which is naturally a legal absurdity. Moreover, it sounds as if my administrative responsibilities are to co-ordinate and resolve all issues relating to the Danube. Now, this is obviously not the case. You may well know that ordinarily rivers need no governmental commissioners. That would be so in this country as well, but for an international legal dispute — a dispute for which, in 1997, the International Court of Justice in the Hague delivered a judgement, a judgement awaiting execution. The execution of this judgement (which is not an easy job) is a task that requires co-ordination by the Government. My office has been assigned the role of dealing with this work during the term in office of the present Government.

The task before us is very complex indeed, as the Danube lies at the heart of an incredibly intricate network of interests. To settle the international dispute between our countries we must find solutions that are equally satisfying from the aspect of forestry, hunting, nature conservation, environment protection, navigation and in fact an almost endless number of other areas which are involved.

You may ask why it is so important to us to have you here in Hungary today together with the noted Hungarian representatives of natural science dealing with the issue of rivers. Well, the International Court's judgement, the execution of which is our duty, answered many of our questions: it marked out the room we have for manoeuvre whereby the parties must reach an agreement. However, a number of other questions have been left unanswered: issues where the road is still open, that is where we must – – by all means — attempt to find the ideal solution, the best we can work out, since public funds will be used to help resolve these problems. Hungary would like to rely on international expertise and examples in trying to resolve these — as yet open —

issues; and we are keen to hear the details from those river experts who have already been dealing with problems of a similar type and magnitude.

Ladies and Gentlemen, I shall no longer waste your precious time: thank you very much for your attention and participation in this international conference. It is my wish that your work will produce the useful and effective results we all desire. Thank you very much indeed and please accept my best wishes to accompany your efforts.

Dr. László Székely
State Secretary
Governmental Commissioner for the Danube
Prime Minister's Office

PART ONE: KEY PAPERS

RIVER REHABILITATION OF WATERWAYS - LESSONS FROM RIVER RESTORATION IN GERMANY

by Klaus Kern

Kern.river.consult
Karlsruhe, Germany

Brief review of river restoration in Germany

River restoration in Germany started about 20 years ago, in the early 1980s with an effort to restore small streams that had been channelised. One pre-requisite for river restoration was the cleaning up of the river water in Germany. In the 1950s and 1960s the water quality of rivers and streams in Germany was in bad shape, and the public was alerted by frequent fish deaths and huge accumulations of unsightly foam around weirs. So, billions of Deutsche Marks were invested in treatment plants, and by the late 1970s a considerable improvement of water quality had been achieved.

However, in the 1980s and 1990s it was clear that this was not enough to reach a good ecological status of rivers because the aquatic fauna still encountered inadequate habitat conditions due to river regulation and technical maintenance. So, the idea of restoring physical habitats arose, and one of the first projects that was carried out, was the re-meandering of a small stream in 1978, which at one time had concrete shells along the bottom. In the next 10 years all states in Germany began programmes for river restoration and, at the same time, technical regulation and channelisation of streams was prohibited. These efforts concentrated on small streams; only a very few short reaches of larger rivers have been subject to river restoration so far (Kern 1994). The German waterway system is under federal administration and was excluded from the states' activities in this respect.

Planning procedure in river restoration

One important conclusion was the agreement on a certain planning procedure for river restoration, which is valid for any size of river (fig. 1). The first and most important step is to analyse reference conditions, i.e. what you might call the long-term vision of the evolution of the river which would restore itself without further human intervention. In Germany, this vision is called the "Leitbild-concept". The content of the "Leitbild" of a river should rather be a delineation of the ecological functions of the river system than a mere description of the riverbed features.

It is well understood that at an academic level, it is impossible to clearly define the pristine condition of a river, because you don't know what exactly happened 500 years ago and what kind of impact might still be relevant today. For example, forest clearing in the Middle Ages resulted in accelerated soil erosion with subsequent floodplain accretion (Schirmer 1988). This is well known; however, the consequences for riverbed morphology and dynamics are hardly understood. For the purpose of planning the "Leitbild-concept" has proved to be feasible.

Planning steps

(1) Analyse and define reference conditions
Result: Vision or ′Leitbild′

↓

(3) Identify present restrictions of land use and river harnessing
Result: Planning constraints

↓

(4) Define short and long-term objectives of river restoration
Result: Objectives of river development

↓

(5) Initiate river development on different levels of planning
Result: Basin-wide restoration concept and local measures

Figure 1. Planning steps in river restoration

The second step is to analyse the impact of human intervention. To find out what the deficits are, what does not function in your system and why it does not function.

The third step is to identify present restrictions of restoration, i.e. land use in the first instance, legal constraints, existing water rights, existing fishery rights, and last but not least financial constraints. The fourth step is to define short-term and medium-term objectives for river restoration. That is to decide what can be realised under given conditions within 10-15 years, i.e. short-term, and what can be realised within 40-50 years, i.e. medium-term.

After these objectives have been defined the real planning of "de-regulation" starts, i.e. it must be decided where bank protection is still necessary, which weirs have to be re-constructed in order to allow for migration of the aquatic fauna, where the flow capacity of the channel has to be reduced in order to restore frequent inundation of the floodplain and so forth. One important question is, what must be constructed and what can the river do by itself? In many cases, only small steps can be taken towards the long-term vision.

Principles of river restoration

What are the main principles of river restoration? One is that the river ecosystem consists of the river channel and the floodplain (fig. 2). The river channel and the floodplain are an ecological unit; in particular floodplain stands and processes strongly depend on channel properties and channel processes. Ideally, the approach should consider the entire basin (Kondolf & Downs 1996).

Principles of River Restoration

- **River ecosystem = river channel + flood plain**
- **First priority: Protect undisturbed sites**
- **Principal objective: Restoration of ecological functioning**
- **Let the river do the work!**
- **Public participation at an early stage**
- **Strengthen PR work for river restoration & nature conservancy**

Figure 2. Principles of river restoration

The first priority must be to protect undisturbed sites. There are very few sites in Germany that can be considered as more or less undisturbed in their ecological functioning. Some states started programmes to protect such reference sites. As already pointed out, the principle objective in river restoration is to restore the ecological functioning of the system, i.e. the rehabilitation of the physical habitat conditions and processes, and the restoration of morphodynamics by making use of the inherent flow dynamics. Bed-load transport is a key factor in river processes (Brookes & Sear 1996).

Closely related to flow dynamics is the principle: "Let the river do the work". This sounds very well, but is not easily put into practice. When a river restoration project is carried out, it is difficult to know what kind of work the river will do in the short term, the medium and in the long term. Judging a river's behaviour requires considerable expertise, and there are very few experienced field morphologists in Germany. Textbook knowledge generally hardly helps to analyse actual site conditions.

Another important principle in river restoration is public participation. Many projects failed because of the lack of public participation and subsequently because of a lack of public support. Without stronger support from society we will not be successful in the development of river ecosystems, especially floodplain areas being lost to new settlements and industrial areas. We will have many small restoration projects, but on a larger scale, river ecosystems will continue to degrade.

The restoration of the Danube at Blochingen, state of Baden-Württemberg

In the state of Baden-Württemberg the Danube is still a small river with a catchment area of about 1,400 km^2 and just 24 m^3/s mean flow at the village of Blochingen (Kern 1994). Referring to the planning steps presented above we have to ask what did the Danube look like at this location before human intervention and what were the governing ecological functions?

Historical condition. From fig. 3 it is obvious that the Danube was a meandering river, lateral movement of meander bends of 100 m within 30 years could be analysed on period maps. The channel had a highly variable width averaging some 80 m. The dominant particle size was coarse gravel, but numerous bars and some islands divided the flow resulting in a diverse pattern of grain sizes with subsequent diversity of substrates. Floodplain sediments adjacent to the channel consisted of gravel producing dry stands next to the river despite frequent flooding. A fine textured cover layer allowing for capillary rise of groundwater existed at a greater distance from the actively meandering channel.

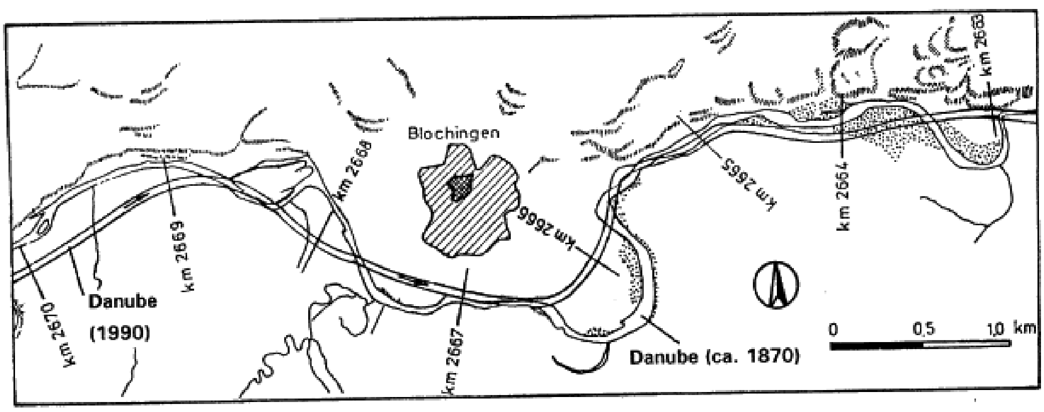

Figure 3. Meandering Danube channel of the year 1870 and regulation works done in the 19^{th} century

Human impact. The floodplain has been deforested at least since the Middle Ages. Regulation works of the channel, however, were not executed before the middle of the 19^{th} century, mainly in relation to the construction of a railroad track. In 1874, two meander bends were cut off near the village of Blochingen. The associated increase of the channel slope resulted in gradual incision of the riverbed. From bed level measurements in 1890 we know that the incision exceeded 2 m in some locations within a period of 90 years (fig. 4). In geomorphology adaptive processes after disturbance are non-linear, and the rates of incision might have been higher immediately after the regulation. At Blochingen the incision of the channel amounted to about 1.2 m (Kern 1992).

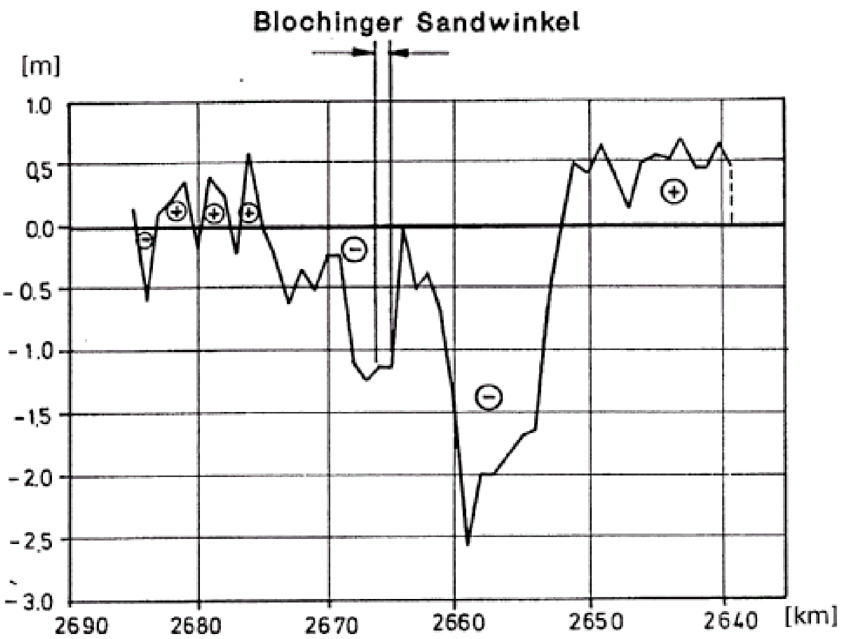

Figure 4. Development of bed levels of the Danube in Baden-Württemberg between 1892 and 1982

Bank protection prevented further lateral movement, and the channel width was reduced to about half of its original size resulting in uniform flow conditions and a loss of typical riverbed features such as bars and vegetated islands. The river regulation impaired the floodplain ecology in three respects: First of all, the lowering of the ground water table altered the availability of water for wetland vegetation considerably. Secondly, the increased flow capacity of the channel reduced the frequency of flooding. Thirdly, the absence of meandering terminated the rejuvenation of floodplain habitats.

The concept of restoration proposed by the author at the end of the 1980s for this Danube reach (Kern 1990) attempted to compensate for the detrimental consequences of the 19th century regulation works, while at the same time securing the level of flood protection. Restoring the ecological functions of this section of the Danube would mean the restoration of original surface and groundwater levels including water level fluctuations and the restoration of the morphodynamic processes typical for this reach.

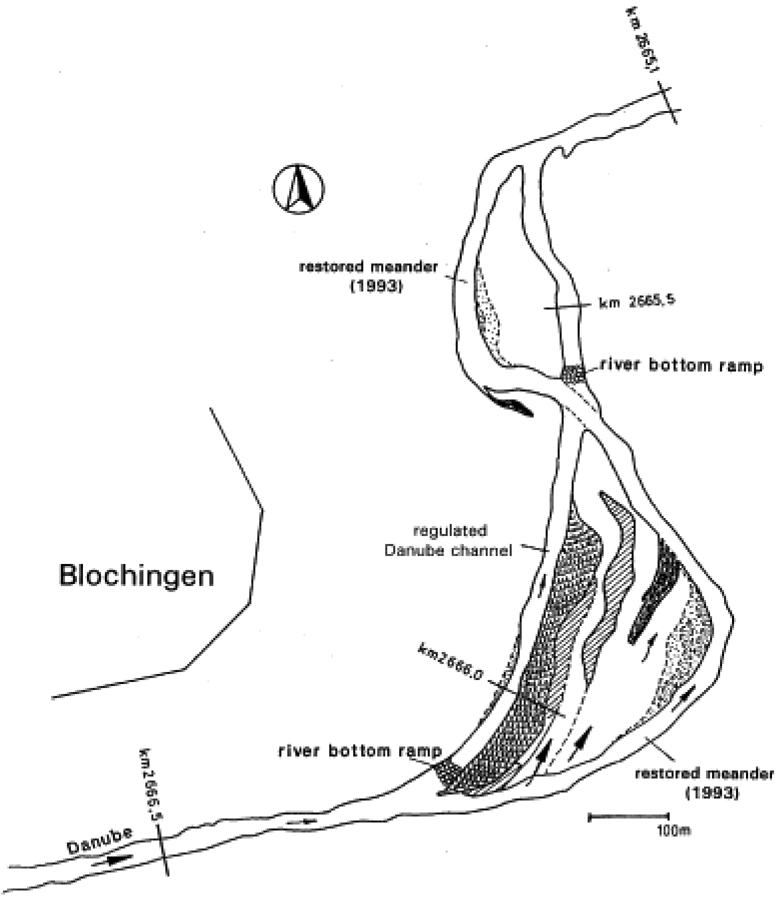

Figure 5. Plan view of the Danube restoration at Blochingen

The project plan was to increase water levels through the construction of a river bottom ramp, and to excavate an artificial meander on a higher elevation, to cross the existing Danube channel with the help of a second river bottom ramp and excavate another meander on the opposite side (fig. 5). The entire length of the new meander channel was about 1.5 km. Before realising the project a model test was carried out in order to study the flow division between the existing channel and the new meander bends at various stages of flow.

New flow levels. Fig. 6 shows water level profiles in the original channel and in the new meander bends at mean flow (24 m^3/s) and at the 100 year-flood flow (400 m^3/s). Due to the higher elevation of the meander bed, mean flow levels had risen by nearly a metre. While low and mean flows are fully diverted into the new bed there is a division of flood flows. The splitting of flood flows results in a slight lowering of extreme water levels. The turning point is about 160 m^3/s which is approximately the average annual flood, i.e. discharges smaller than the average annual flood will create higher water levels in the reach compared to the pre-restoration situation and vice versa.

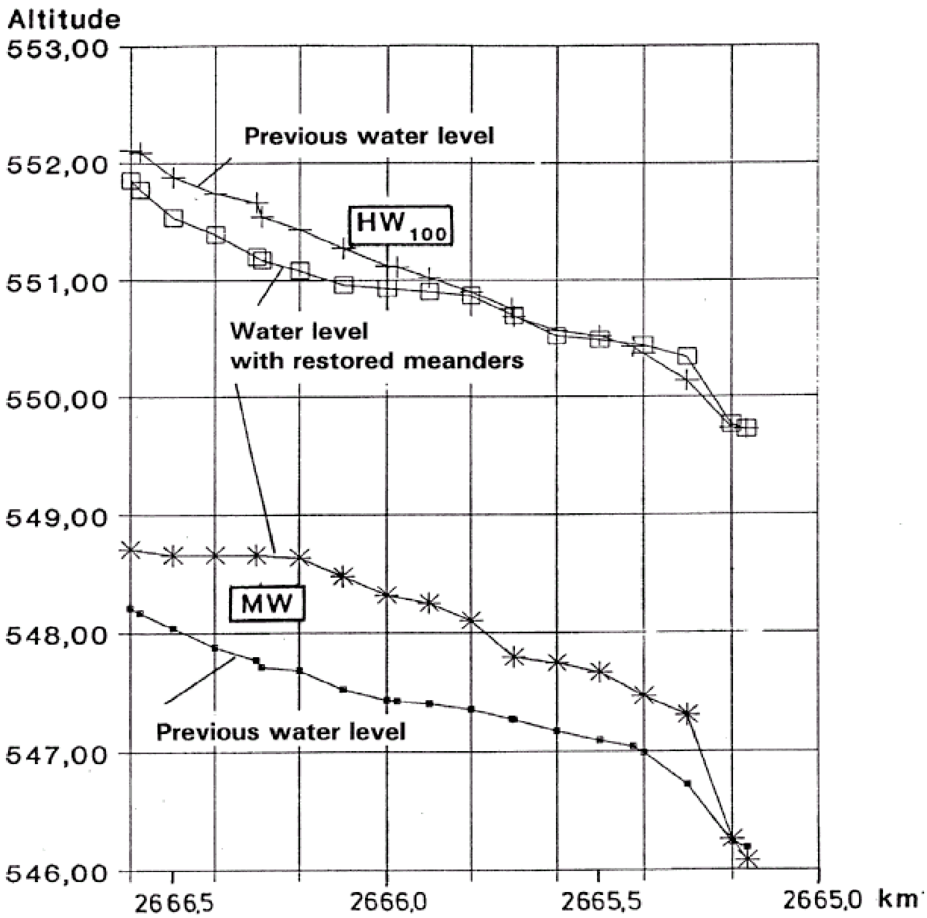

Figure 6. Water level profiles before and after restoration for mean flow (MW) and for the 100 year flood (after Kern 1995)

This is certainly a desirable result since the drop of low-flow and mean-flow levels could be reversed to a certain extent, while the flood security of the village of Blochingen could even be improved as a side effect.

River processes after realisation. The project was carried out in 1993. Immediately after construction a 2-3 year flood reshaped the new meander bends widening the excavated channels, which were left without bank protection, by up to 8 m. Meanwhile a shallow third channel has emerged in the new island between the old and the new channel, while both the first meander and the old Danube channel experienced a lot of sedimentation. The entire area is protected by law as a nature conservation area, and no maintenance takes place. Of course, only a short reach of the Danube affected by incision and channelisation has been restored, but the experience gained so far may be valuable in similar situations.

Rehabilitation of waterways in Germany

There are several initiatives for ecological enhancement along different waterways in Germany. On the Elbe river, for instance, a comprehensive research programme was commenced in 1995 in order to understand ecological river and floodplain processes (Bornhoeft & Gruber 1998). The research focuses on riparian habitat improvement within the groynes built all along the river and on the rehabilitation of floodplain areas.

An international programme on the Rhine, called "Salmon 2000" is systematically restoring migration routes and spawning areas for fish. The largest fish ladders of Europe are being built at Iffezheim and at Gambsheim which are the first weirs in the Rhine system coming upstream. Just as important, however, are the removal or the enhancement of migration barriers in tributaries and the restoration of channelised streams to improve habitat conditions. The programme successfully attracted adult species of salmon earlier introduced as juveniles.

The Integrated Rhine Programme in the state of Baden-Württemberg

Historical channel and human intervention. Until the early 19th century the Rhine below the city of Basle used to flow in a braided pattern which eventually developed into a meandering system (fig. 7). In the 19th century a single channel was created, dyke systems were built, a navigation route was established, and in the 20th century a series of water power stations was erected along the Upper Rhine (Kern 1992).

One of the consequences of the narrowing and straightening of the riverbed was severe channel incision in some reaches documented in fig 8. It amounted up to 7 m at Breisach between 1828 and 1950, but it did not occur all along the regulated reach. Associated with this process of incision was a drop of groundwater levels of 5-7 m leading to desiccation of large floodplain areas.

Another problem caused by river regulation is the loss of floodplain area (fig. 9). Before river regulation there were some 1,000 square kilometres of floodplain area along the reach of 200 km in length between the cities of Basle, Switzerland, and Karlsruhe, Germany (OBERRHEINAGENTUR 1996). The embankment of the river by the end of the 19th century resulted in a loss of 600 square kilometres of inundation area. Some 80 square kilometres were lost due to incision since some areas were no longer flooded due to the deeper channel. The loss of an additional 130 kilometres of floodplain resulted from the building of the power plant systems along the Rhine in the 20th century. Altogether we have a tremendous loss of active floodplain area.

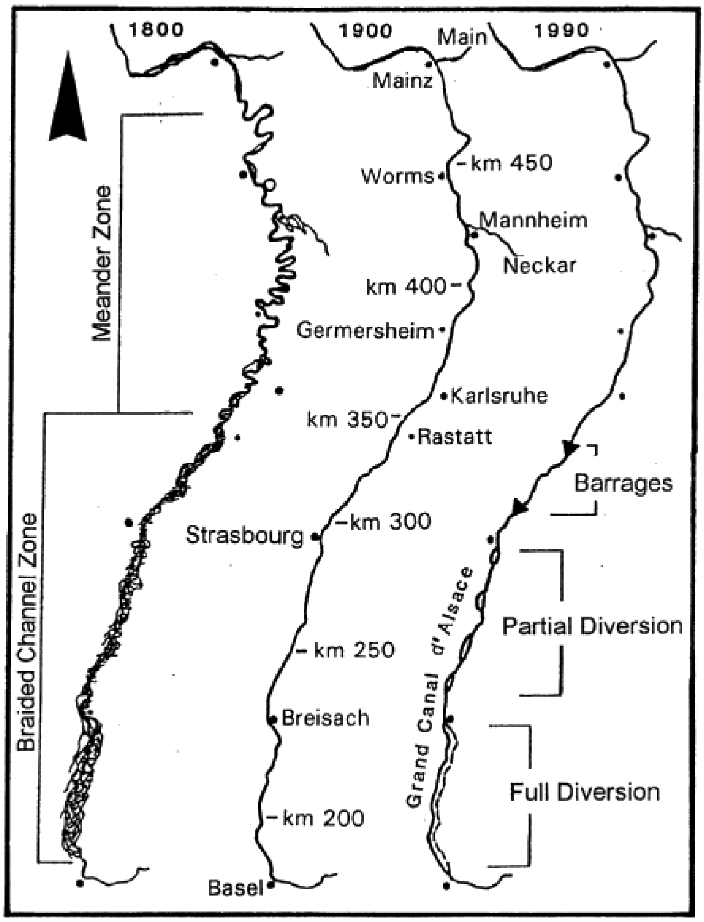

Figure 7. Development of the Upper Rhine since 1800 (after Dister)

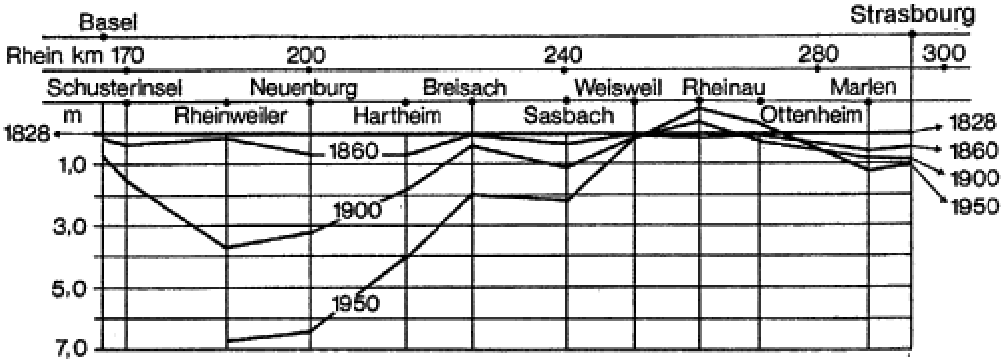

Figure 8. Incision of the Rhine in the vicinity of Rheinweiler from 1828 until 1950 (from Raabe, 1968)

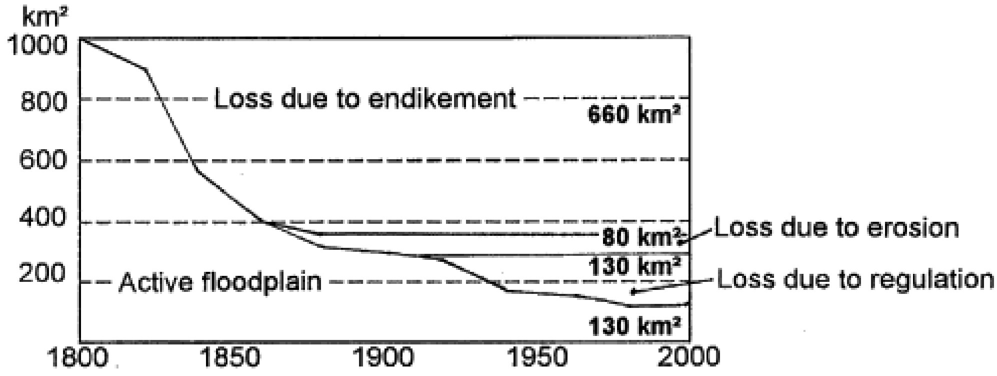

Figure 9. Loss of floodplain area in the Upper Rhine since 1800 (from OBERRHEINAGENTUR, 1996)

The impact of these interventions was not only a loss of floodplain habitats but also a change in the hydrological regime. The reduction of natural inundation area resulted in an acceleration of flood waves and an increase in flood peaks endangering downstream areas. Before the building of the upstream barrage systems a 200-year level of flood security existed at the cities of Karlsruhe, Mannheim and Ludwigshafen, which dropped to a 50-year level. The potential damage caused by flooding of these highly industrialised areas was estimated to be 12 billion Deutsche Marks (GWD OBERRHEIN/HOCHRHEIN 1997).

Therefore a flood protection programme was initiated in the 1970s with the intention to re-establish the flood security level of the year 1955. Since the strengthening and increase of dykes would only dislocate the problem to areas further downstream, it was decided to provide detention reservoirs along the Upper Rhine reach with a total storage volume of about 170 million cubic metres. Initially this programme was planned on a technical level only. With the growing awareness of environmental problems in general in the 1970s and particularly with the discussion concerning the restoration of rivers and streams a fresh impetus was given to the rehabilitation of floodplain habitats.

This resulted in the so-called Integrated Rhine Programme which has two objectives having equal priority. One of these is the restoration of the flood security level that existed in the 1950s. The other objective is the rehabilitation of floodplain habitats associated with the allocation of storage space for flood waters (GWD OBERRHEIN/HOCHRHEIN 1997). Since these objectives were given equal priority the construction and operation of detention reservoirs must not violate habitat requirements and the rehabilitation of wetlands must not endanger the flood security level mutually agreed upon.

How is this being done? There are many restrictions limiting the availability of land as well as technical problems of permeability of gravel layers and water rights granted for the power stations. Generally, there are two different approaches. One is the construction of detention reservoirs in the protected area along the river where you have an intake structure at the upper end and an outlet structure at the lower end which are used to regulate the operation of the reservoir (fig. 10). For the purpose of flood protection this is the optimum solution since the gate can be opened at the right point in time in order to take out the peak volume of the flood wave with a subsequent lowering of downstream flood stages.

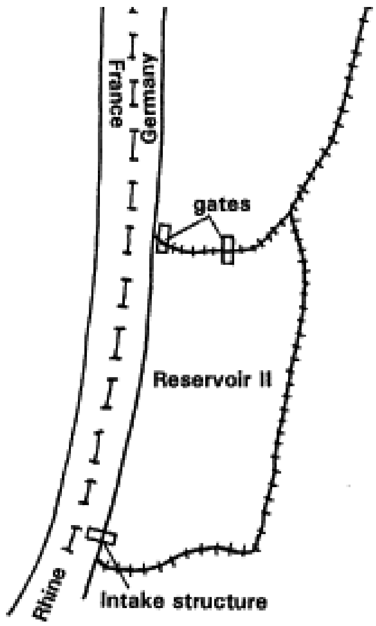

Figure 10. Flood detention reservoir Altenheim near Strasbourg operating since 1983, ecological flooding since 1989

The rehabilitation of floodplain habitats, however, requires frequent flooding according to the natural dynamic flow regime of the river. For this reason, it was decided not only to open the gates at times of critical floods, but also to exercise so-called 'ecological flooding'. This means that the discharge exceeding the capacity of the turbines in the power plants can be used for flooding of the detention area in order to re-establish former site conditions. In the detention reservoir of Altenheim which started operation in 1983, the number of ecological flooding episodes reached about 70, but very few events inundated the entire area. Nevertheless, the monitoring of flora and fauna indicates that the changes of site conditions are reflected in the composition of species (LfU 1999).

The second approach for flood protection and the rehabilitation of floodplain areas was the relocation of dykes in order to enable flooding similar to the natural process. This is the optimum solution for the rehabilitation of floodplain habitats, however, in order to provide the same level of downstream flood protection larger inundation areas are required. Up to the present time, conflicting interests have prevented its realisation.

A third solution is being planned for the area which suffers from the deep incision of the Rhine, i.e. the lowering of desiccated floodplain areas: a ninety metre strip of floodplain will be excavated by seven meters to restore the relationship between the level of the river and the level of the floodplain. This will be done over a distance of some 45 kilometres and amounts to a volume of nearly 30 million cubic metres of sand and gravel that will be excavated from the floodplain. Again, this measure will serve two purposes. The first of which is to provide the storage room for the flood, the second one is to restore floodplain habitats.

The Integrated Rhine Programme comprises 13 measures in the state of Baden-Württemberg. Additional storage room will be provided in France and in other riparian states in Germany. The measures in the state of Baden-Württemberg will cost more than one billion Deutsche Marks and they will not be finalised before the year 2015.

Conclusions

- Restoration of rivers and streams has to focus on the *rehabilitation of ecological functions* rather than on the restoration of random features
- In any event, the first step in planning is the *analysis of reference conditions,* i.e. the long-term vision of the evolution of the river ecosystem without human intervention
- Free flowing river reaches have a higher *restoration potential* than impounded ones
- For *waterways* the restoration potential is concentrated in the riparian areas and in the floodplain
- *Let the river do the work!* - a good statement on paper, but a real challenge in practice
- For river restoration on a large scale we need *stronger support from society*

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RESTORING LOWLAND RIVER FLOODPLAINS IN CALIFORNIA

by Philip B. Williams[1]

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Abstract

Before European colonization, California's Central Valley supported a rich mosaic of over 400,000 ha of riverine, riparian and floodplain wetland habitats that sustained an abundance of fish, wildlife and waterfowl. Over the last 200 years this lowland river-floodplain landscape has been extensively modified by human intervention. River diversions for agriculture have depleted summer low flow levels, the construction of levees for farmland has separated large areas of floodplain from the river system, and the construction and operation of large multipurpose reservoirs on almost all the tributary rivers in the last 50 years, has fundamentally altered the key hydrologic and geomorphic processes that sustain the river ecosystem.

At the time these river engineering works were constructed, there was little understanding or regard for the ecologic values a healthy 'living river' system could provide. As a consequence, the impacts on the river dependent ecosystem have been devastating. Salmon runs have declined 90% in the last 50 years, waterfowl populations have been greatly diminished, and the area of floodplain habitat is now less than 5% of its former extent.

Now, at the turn of the century, societal values in the U.S. have changed. Protection and restoration of environmental values have become a major priority in integrated multi-objective river management. In addition, there has been a fundamental reassessment in national flood management policy caused by escalating flood damage in spite of massive investment in flood control engineering works. These two factors have become powerful driving forces in new initiatives to restore lowland river floodplains.

At first, 50 years ago, biologists defined ecological restoration as single species management, designing technical manipulations to grow larger populations of selected species. By the 1970's, the failure or limited success of technical 'fixes' such as fish hatcheries, or managed ponds for ducks, led to a realization of the importance of restoring natural physical processes in the river system. Initially, the main focus was on re-establishing minimum 'in-stream' flows in rivers depleted by diversions. However, it soon became clear that requiring minimum flow releases from upstream dams—by itself—did not lead to recovery of desired ecosystem values. We now understand that there are other vital hydrologic and geomorphic processes in the

[1] The main body of this paper is a transcript of the verbatim record of the speech

river system that also need to be restored—most importantly: river-floodplain interactions, flow variability, channel migration, and sediment movement.

Increasingly, the guiding principal in river restoration in California is a scientifically based concept of a 'living river', whose hydrologic and geomorphic processes both shape the river's landscape and sustain the river dependent biota that has evolved over tens of thousands of years to take advantage of that landscape. The complex interaction of flow, form, flora, and fauna is what we mean by a 'living river'. A corollary of this important concept is that the river ecosystem is inherently self-healing; it re-establishes its intrinsic form after disturbance.

The living river concept leads to a restoration approach that seeks to eliminate or minimize the impact of human interventions in the natural physical processes and recognizes that sometimes the most important and environmentally destructive of these interventions are the continuous interventions—the decisions we make to continue to repair eroding levees or to operate dams in certain ways.

Some recent major restoration projects now being planned or constructed in California illustrate the application of this concept:

- *The Cosumnes River floodplain restoration project is intended to re-establish river-floodplain interaction in approximately 3000 ha of riparian oak woodland by removal and set back of levees.*
- *The upper Sacramento River meanderbelt restoration is planned to restore more than 100 km of riparian corridor to provide valuable salmon spawning and rearing habitat by allowing the river channel to form natural meanders and oxbow lakes.*
- *The Napa River flood management project integrates flood damage reduction with floodplain restoration through an urban community by setting back levees.*
- *The Yuba river restoration would entail removal of the Englebright dam to allow salmon access to 80 km of their natural spawning habitat and also restore natural flood pulses to the river corridor downstream.*

* * *

Introduction

Philip Williams & Associates, Ltd., is a consulting firm specialising in river and wetlands restoration. We call ourselves hydrologists because we see the need to integrate the water sciences in our approaches to river restoration. In other words, we need to integrate geo-morphology, engineering and environmental planning in our approaches.

I am also President of International Rivers Network, an NGO with its headquarters in Berkeley, California, that assists groups around the world who are working to protect and restore rivers. I will be speaking in my capacity as consultant today rather than as the President of an NGO. I would also like to point out that I am also both a P.E. and an EUR ING. I am a British-American, which means that I have a European perspective in America, and I do believe – particularly after hearing Klaus Kern's presentation – that there is a tremendous potential to integrate the thinking that's going on in river restoration in Europe into the practices in the United States.

The Californian Experience

I want to start off by talking a little about how we in California have perceived our rivers and what has been guiding our thinking on how we approach restoration. There is a landscape painting from around the 1870s of the Central Valley of California showing the Sacramento River flowing towards the San Francisco Bay, the mouth of the estuary of the Central Valley (Plate 1). Yesterday, I was wandering around Budapest and I saw an antique store and there was an almost identical painting of the Danube – with the same feeling of a pastoral landscape. In the 1870s, California had only been intensively settled for about twenty years. Many European immigrants were immigrants from the Eastern part of the United States, and they came here wanting to replicate an ideal version of their homeland. This image is a kind of false representation of what the Central Valley actually looked like. This feeling that we could do whatever we like with our landscape inevitably led to the wholesale destruction of river systems in California. Unfortunately, we are still seeing projects like this being built. For example, you would hardly call these flood control channels the kind of multi-objective river management projects that we are trying to achieve. But I think it is true that we are in a paradigm shift and we are starting to change the way we approach river management in California. And the seeds of this transformation in thinking actually started a long time ago – in Yosemite National Park.

There is a photograph taken by Carlton Watkins, a famous photographer, in 1862, when photography was in the early stages of its development (Plate 2). He was the first person to take photographs of the wilderness of the Western United States. He put together an exhibition of photographs that travelled all around the world. In fact, it was shown here in Budapest in the 1860s. These photographs greatly influenced thinking about the American West – about it being a wilderness, about nature outside of humans. In other words, a natural landscape that existed before humans. This is a powerful concept that both initiated the environmental movement, environmental activism in the United States, and coloured the thinking about restoration approaches. But, of course, there is a flaw in this thinking – as I will describe later. However it does enable us to portray an idea of what the virgin landscape might have been, might have looked like, what it probably did look like, in California.

There is an analysis from the historical records which depicts the Central Valley of California (Plate 3). Here in the Central Valley: the Sacramento River flows down from the North and the San Joaquin from the South, and together they discharge into the Pacific Ocean through San Francisco Bay. The Sierra Mountains form the western boundary of the watershed and contribute most of the snowmelt runoff into the system. An extraordinarily large area of floodplains, wetlands and woodlands used to exist two hundred years ago in California. Now the idea of this landscape leads us next to look at pristine rivers, and develop a feeling, an understanding, of how natural geomorphic and ecological processes work in rivers. The river landscape in the Sierra encapsulates how a watershed system works. This is what leads us to a scientifically defensible articulation of the concept of a living river.

The landscape was formed over tens of thousands of years in response to particular climatic and geologic conditions in the watershed and within evolutionary history creating a particular form of river within that landscape. The ecosystem and landscape form developed along parallel lines; the biological systems took advantage of the particular physical processes that were creating that landscape. In other words, there is an intricate linkage between the biological processes that evolved within the river and the physical processes that created both the landscape and the river.

The 'Living River'

It is this interrelationship of physical process, landscape form, and biological process which we mean when we talk about ‘a living river’ – an articulation of our definition of a healthy river and an articulation of a concept of environmental integrity. In other words, there is an inherent form in a river that we can plan towards; we can direct our restoration efforts towards a form.

This is a very important concept, because there is another way of looking at river systems – all too prevalent which I see all around the world – whereby people say, ‘Well, we completely messed up our river ecosystems, they are completely destroyed, so we can sort of remake them however we want. We can tinker with them, manipulate the landscape and hydrology and recreate pretty much whatever we want to do at a particular location.’ This is a false premise because it ignores the concept of ecological integrity.

Now there are two corollaries, two things that follow from the idea of ecological integrity. One is that the system is self-correcting. Again, many of the things I am saying are actually simply re-enforcing what Klaus Kern just told you about in a different landscape. .

A dramatic illustration of how a river system is self-correcting is the Walla-Walla River in western Washington in the United States. It was channelized by the U.S. Army Corps of Engineers, and in the first big flood, it simply reasserted its meandering form. So you can see the inherent tendency of the river system to re-establish its ‘living river’ form (Plate 4).

I'd like to refer to this process as a process of ‘physis’ because when we are dealing with river restoration, we are acting in a similar way: we are trying to heal a living river. And I think we need to look to the medical profession for ways of thinking about how we do our work. The medical profession of course is guided by the principles of Hippocrates. One of these principles that has, unfortunately, been forgotten by American medicine, is this concept of ‘physis’: it is the physician’s job to try to understand what the self-healing spirit is in the human body and encourage that self-healing. It is a similar situation in rivers – our job is to try to discover what the self-healing spirit is, what the river’s intrinsic health is, and encourage it by creating self-healing processes.

A Comparison

American river restoration can learn lessons from European experience. There is an excellent map of a part of the Rhine, prepared by the Aven Institute of WWF (Plate 5). What we were just seeing in the earlier presentation, and what this map illustrates, is that there are humans in the river landscape. It is actually very rare that you can see a river – like the image of the beautiful river in Yosemite, the mountains and the snow – with no humans. Most of the time, we are dealing with humans in the landscape; we are part of that ecosystem. But what the map of the Rhine in 1830 shows you is that it is perfectly possible to have human interaction with the river in a way that *minimises interventions in the key physical processes that sustain river ecosystems.* You can understand that the natural form of the river is quite powerfully stated: we have a meandering river, we have floodplains, we have agriculture in the floodplains. At this point, the basic integrity of that system has not been compromised. Now, I am going to tell you a little bit about the river restoration work we are doing in California – but in order to do that, I need to first tell you what happened to California's rivers.

A satellite photograph of what the Central Valley looks like now shows that it is intensively farmed and there are other features in the landscape that were not there originally (Plate 6). There are reservoirs on the tributary rivers of the Sacramento and the San Joaquin, and the Central Valley watershed is the most dammed watershed of pretty much anywhere in the world. Every single one of these rivers draining off the Sierra is dammed – except for one, the Cosumnes, and I'll talk about the Cosumnes in a minute.

Now, this has been a huge intervention and transformation in the landscape, and it has greatly affected those physical processes that sustain the ecosystem. So, what we see is a transformation in our rivers, and this transformation really occurred comparatively recently, because most of the impacts on our river system are the result of these big dam projects – which have only been completed in the last forty or fifty years. And many of the physical and ecological responses that we care about in river restoration occur within a longer timeframe than forty or fifty years.

The Sacramento River in the 1930s, before the construction of the Shasta Reservoir, one of the biggest dams in the United States was associated with gravel bars, and nice, healthy riparian woodland (Plate 7). On the Sacramento River levees are built right up to the riverbank, there is no floodplain-river interaction, and a very limited ecological quality (Plate 8).

We have seen this transformation of ecological processes on pretty much all of our rivers in California. Our lowland river floodplain systems, where we once had extensive floodplain wetlands, have the same problems over and over again as a result of the onset of levee construction and dam construction: sediment is trapped in the reservoir, rivers down cut the lowland, and floodplains dry out, thus eliminating a whole type of landscape. In the Willamette River to the north in Oregon one of the changes is that the complexity of the river system has been progressively reduced as the river channels have degraded and down cut (Plate 9). What this means is that these backwater channels, these extremely important parts of the river landscape, have been practically eliminated to the point where they have been forgotten. In fact, I think the floodplain landscape is now a forgotten landscape in California (Plates 10 and 11).

This is one of the few remnants of a natural floodplain landscape left along the Sacramento River (Plate 12). But if you were to look in more detail at how the physical processes have been changed by human intervention, you would find that these massive transformations are particularly due to large dam projects. If we consider the seasonal flows of the whole Central Valley discharging into the estuary of the San Francisco Bay a median year's runoff would be represented by two seasonal flood peaks – rain during the winter and then snowmelt in the spring (Plate 13). The spring snowmelt runoff has been eliminated – it is all captured in these reservoirs – this represents a massive transformation of a key physical process that sustains so much.

Flood Management

One of the problems is that when these dam projects were built and planned, there was very little attention or recognition given to trying to understand how they would change physical processes. Of course, flood processes are some of the most important things that we have to look at. Look at what has happened to the flood frequency below a major dam on the Feather River, which is one of the major tributary rivers of the Sacramento River, just in the period since it was completed in 1967 (Plate 14). By comparing the flood frequency before and after, it is possible to see that the two-year flood, which is probably one of the most important floods for river floodplain interactions, has been diminished by more than an order of magnitude. At the same time, if we consider the extreme floods, the thirty-year flood, there has been much less of a change. We have a curious situation where these big dam projects have been very effective in eliminating the smaller floods that sustain the ecosystem processes, but not in controlling the big floods that damage life and property.

Now, there is a lot of attention being paid to the decline of salmonid fisheries in California. And if you take a look at what has been happening to those fish species – unfortunately there was no data before 1953 – you can see that the trend is alarming (Plate 15). We now have extinct runs of salmon and runs that are close to extinction. So, this record of environmental decline has caused us to question how we are managing rivers. Another fact that is causing us to take another look at what has been done to California's rivers is our record in flood management. The United States has invested heavily in flood control: twenty-five billion dollars have been spent on structural flood control measures in the United States – yet we still see scenes such as the one that exists in the San Joaquin Valley (Plate 16). This is probably one of the most dammed rivers in the world – but we still have floods, damaging floods. And somehow, all that investment in structural flood control does not seen to be working very well. Historically, in the United States, we have seen an escalation of flood damage at the same time that we have been spending large amounts of money on flood control. So we have another reason to be questioning how we have been managing our rivers.

River Restoration – some examples

But really, I think the driving force of these new ideas, or what's really been pushing them, is the environmental community (Plate 17). And I think the activism that you saw here ten years ago against the Gabcikovo Dam is very typical of what has been happening around the world. This was one of many major controversial dam projects. But at the same time this was going on, there were similar protests, similar groups being organised, in defence of rivers all around the world. This is particularly true in California, where the work of environmental groups was effective in stopping destructive projects on rivers and turning the government attention towards river restoration.

First of all, I want to talk about the Napa River flood management project (Plate 18). This is a project that is now in its design stages. The way this project came about was that there was a proposal by the U.S. Army Corps of Engineers to construct a straight, uniform flood channel through the city of Napa. You have heard of the Napa Valley and Napa wines; Napa is a very famous area, a beautiful area. The local people got together and formed an organisation called 'Friends of the Napa River' and they asked my firm to advise on what different approaches could be taken. We developed some designs very much along the 'living river' concept, which eventually, after many battles, were adopted by the U.S. Army Corps of Engineers as its design. That design is now going ahead and will be constructed over the next five years. Instead of a trapezoidal channel, the concept is to move back levees and excavate new floodplain terraces through the city in order to alleviate flood damage and also provide environmental benefits.

But it is interesting to see that the initiative came from the local community and the local environmental groups. I think this project will have a huge impact on the U.S. Army Corps of Engineers. It has now been referenced as the new approach in river management and you will see this reference in U.S. Army Corps of Engineers documents. I think they have very much taken it to heart that one way of getting local community support is to now approach flood control projects as multi-objective flood management projects.

Another project, which I think will be extremely important, is a project that is now in its planning stage. Part of it has been executed on the lower part of the Cosumnes River – the only un-dammed river in the Sierra Nevada mountain range. It is un-dammed, but the river channel has been leveed. There is a great potential on the Cosumnes to restore extensive, continuous areas of floodplain woodland. There are only about two percent of our floodplains left in California and here is an opportunity to restore at least 5000 hectares of oak woodland along the lowland river valley. And a pilot project has already been initiated on the Cosumnes River by another NGO, the Nature Conservancy (Plate 19). The Nature Conservancy took the initiative in acquiring land at the lower part of the river, and breached this levee. If you take a look at what is happening now in what was formerly a field, you will see cottonwood trees growing, which are the precursors to oak woodland succession.

Another initiative that is under way in California is to restore the active meander belt of the upper Sacramento River. The Sacramento River is typically in its upper part a meandering system. However the extensive floodplain woodland has practically been eliminated and many of the river banks now are being hardened with concrete or rock to prevent the river from eroding farmland, orchards or similar. It is now recognised that there is a real need to eliminate these interventions and let this river meander freely. So there is now a program under way to start acquiring within the levee system all this private property and to remove these hardened riverbanks to allow natural meandering to take place.

Conclusion

Finally, the most recent initiative is one to remove dams which are the major form of intervention in our river processes. There is a study under way, which we are participating in, organised by a group of federal and state government agencies, to look at removing a dam on the Yuba River. If this were followed through, there would be two free-flowing rivers flowing into the Central Valley, the Cosumnes and parts of the Yuba River system. So there is a tremendous change in thinking going on right now that questions past decisions. I think we've seen government responding in just the last few years – in a way we would never have thought possible.

Last year we had Secretary of the Interior Bruce Babbit on a tour of the United States. He came to California to demolish a dam on a creek flowing into the Sacramento River, to allow salmon to come upstream and spawn (Plate 20). He made a statement that ‘concrete is not inevitable.’ I think hearing a Secretary of the Interior say something like that is really very exciting and offers great potential for the future of restoring rivers in California.

CONCEPT FOR THE RESTORATION OF THE DANUBE RIVER AND ITS INLAND DELTA IN THE SZIGETKÖZ-ZITNY OSTROV AREA[·] [+]

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Background and short chronology of events

The main factors we had to consider before starting to prepare the concept for the restoration of this river section are the following: First of all, we had to take into consideration public perception, which is mostly represented by the relevant NGOs. The leading one of course is the Danube Circle, which began the political movement for stopping the dam construction in the late 80s. These public perceptions are now represented in the present government Danube policy. Other elements represent those scientific bases, those data which we can rely on because, of course, in this one - or two-year period we could not accumulate a complete set of new measurements, new data, so we had to rely on that data which was originally produced, either to supply material for the damming process, or to try to assess the effects of this process. At the same time, we needed to learn from international expertise - and this is what we are doing now. Fortunately at an early stage of the concept formulation we had the help of Mr. Kern and Mr. Zinke, as experts of the study team.

The process started around the turn of the century in Hungary, and around 1976 many members of the NGOs and the people concerned with ecology had already learned from the example of the Rhine at Neuburgweiher Dam, where a decision was made not to build another dam but rather to fill up the riverbed of that river section with gravel. Unfortunately, we were living in a different world at that time and at that point Hungary and the then Czechoslovakia signed the Gabčikovo-Nagymaros Treaty for the building of a major dam complex on the Danube. Following that we had a long period when on the Slovak side the building of the dam complex was in advance of schedule most of the time whereas on the Hungarian side it sometimes started, sometimes stopped, so it represented a rather hesitant approach. In 1989 we began to move in the direction of democratic change in political life, this being in part initiated by the green movement, which had at one time a march of a hundred thousand people objecting to the building of the Nagymaros dam. In the following democratic period we had different political parties forming governments: the first democratic government in Parliament stopped building activity on the Dunakiliti site, later we commenced a legal suit at the International Court of Justice in the Hague, which

[·] The concept is based on three recent studies on the Danube commissioned by the Danube Secretariat of the Prime Minister's Office. Two companies - ECOPLAN and DunaDrop - dealt mainly with the ecological planning tasks, TÉRTERV and VITUKI were responsible for the water management and water structure planning parts of the studies.

[+] This paper is a transcript of the verbatim record of the speech resulted, in my opinion, in a controversial judgement, which in practice says that the two countries involved, Slovakia and Hungary, have to decide what practical solutions can be applied on this stretch of river. Then we had a short period during which the socialist government preferred to go ahead once again with the construction of the lower dam. An election followed in 1998 and now we are in the second year of this new administration, which has a different priority concerning this section of the Danube.

What was the legal and administrative basis for our studies? We had an international legal basis, which is the judgement and recommendations of the International Court of Justice at the Hague, then we have an internal policy basis, which is founded on the main government party, the Fidesz MPP party's government programme, and its guidelines for the bilateral talks headed, on the part of Hungary by Mr. Székely, the Governmental Commissioner for the Danube. All of this defined our main goal to achieve an ecologically enhanced state of this river section, while complying with all the valid water management requirements, namely with navigation according to EU standards, flood control, and ice control.

The area

Plate 21 presents the river section in question. This section starts at the western Hungarian border, which is some 50-70 km from Vienna, and ends at Budapest. This is roughly a 200 km stretch of the river, and has become the focus of professional and political debate as well as international legal debate during recent decades.

Essentially we are dealing with three different river sections which have different basic characteristics. The "A" section is the abandoned site of the reservoir, which was intended to be filled up to supply the Gabčikovo power plant. This is unique in a sense as now it has something of the appearance of a lunar landscape, so we have to restore it completely if we want to achieve ecological rehabilitation there. The "B" section, called the Szigetköz section is ecologically the most sensitive area of the entire river section, because here we have an extensive braided or meandering part of the river, and also beneath the surface is situated one of the most valuable drinking water reserves of Central Europe. This is a vast subsurface drinking water reservoir and was one of the main considerations why the Hungarian government, the public and the NGOs wanted to save this area from the effects of the reservoir of the Gabčikovo power plant.

The "C" section starts at Szap, at the point where the new power plant channel feeds back to the Danube, and this section goes all the way down to Budapest. This section contains Nagymaros, meant to be the place of a second lower dam. Up to now political debate has resulted in the abolishment of this second dam. We have to mention however, that there are Hungarian political parties with different philosophies concerning the river, so we have seen many changes of priorities in government policy over recent years.

Study objectives

The detailed objectives are of course different, according to the different river sections: along section "A", which is the abandoned site of the reservoir, we intend to conduct an ecological restoration of the site, which is a major task, because the site is more than ten square kilometres in size, and also has a 9 km river section that we have to restore in a way which unifies it with the "B" river section. At the "B" section, our overall objective was to return the area to the environmental state of the 1950's, our selected reference period. This period was the last time when the main Danube had an active connection with the side branches. We intend to restore the ecological conditions of this period. At the same time the planning group, - based on consultation with NGOs - decided that we should recommend a limited goal for navigation in the A and B sections, that includes only the navigation for small (recreational) vessels, which are about a maximum of 20 m long. International tourism on the Danube is an important economic question for the Szigetköz region and for Hungary, and for recreational traffic the old Danube system is much more suitable on the Hungarian side than the power plant channel on the Slovak side. Along the "C" section the objective is defined by the fact that we have here many difficult bottlenecks for navigation (defined by EU standards), and equally importantly an island and secondary branch system which is dying. According to international practice of river training in the last century, practically all side branches were cut off from the main branch, and they are presently in a different state of decay. Here our overall objective is to revive all of these 15-20 island systems along the 150 km long "C" river section. At the same time we have to provide some solution for international navigation over the long term, without the construction of another dam in the Nagymaros region. It is crucial that in these studies we were obliged to work out scenarios for about a 50-year period. So our concepts are intended to predict the future state of this river section until about 2050.

Section B

Now I will discuss the "B" section, which is – as I mentioned – one of the most sensitive areas, first of all because the new artificial channel bypasses this area, in the meanwhile taking about 80-90 per cent of the Danube water. One of the points of the main discussions under the bilateral negotiations is the question of how much water we can get to the Hungarian side.

So one of our main tasks in this "B" section was to analyse the different percentages of the theoretical amount of water that we could get resulting from the bilateral negotiations, then of course we had to analyse this water amount according to the different solutions that could be applied along this river section. We analysed all the extremes, such as the version according to the original plan, which provides only about 10 per cent of the water to the old Danube system; then we had the WWF proposal; and also damming solutions: two variants with 2-3 major concrete dams or rubber dams, or with 7-8 dams. In the process we developed the so-called meandering solution, - the one that the WWF says we should not refer to as the 'WWF solution' - so we are no longer referring to it in this way: we now call it the "Kern solution".

All these versions were incorporated in an evaluation matrix (Table 1); of course we are very well aware that this is not an objective method to measure different alternatives, but it remains the best thing that we could do in the time frame available. So we organised a group of experts, this group contained experts representing the ecological aspects and also experts on the water management issues. We decided to use a point evaluation system: five points could be given according to the ecological point of view, and also five points according to the water management issues (navigation, flood and ice control). Finally we found that the two best solutions would be either the original "WWF solution", (the author of which is Mr. Zinke, with us today), and then the so-called "Kern solution", which obtained rather high points in many different water distribution scenarios.

Variants of water management	Percentage of water sharing, %						Rough estimation of the investment cost, in billion Forint
	20 %	30 %	40 %	50%	60 %	70 %	
Variant 1 As of 1977 Treaty	4	4	4	4	3	3	**5,5**
Variant 2 WWF Proposal increase of water level by establishing islands	1	1	2	6	8	8	**40,0 – 70,0**
Variant 3 Impoundment by a sequence of weirs	2	3	3	5	7	5	**12,0 – 18,0**
Variant 4 Impoundment by 3-4 weirs	6	4	4	4	3	2	**24,5 – 26,0**
Variant 5 Kern Proposal: new meandering main riverbed	2	4	7	8	10	6	**13,4 – 18,0**

Table 1 Evaluation matrix for B section alternatives. Numbers represent average scores (in a range of 0-10) of a group of ecology and water management experts.

What are the major differences between the two solutions? In the "WWF solution", we have to introduce a 30 km long fill-up of the waterbed by the creation of islands, and in the "Kern solution" we have to introduce around seven underwater stone structures. A huge difference between the two is that in the WWF solution we have to use about 11 million cubic metres of material which is not easily available in this region, so if we want to apply this solution, we have to establish huge gravel mines, and this is one of the worst nightmares of ecologists living in the area. At the same time, the Kern solution needs only 0.7 million cubic metres of materials. These figures of course define the costs of the two projects: the WWF solution would cost about 30-40 billion forints; the Kern one would cost about 13 billion forints.

When we obtained the services of Mr. Kern and Mr. Zinke in 1998 assisting us in formulating possible solutions, we were very glad to see the results of Mr. Kern's solution at Blochingen, and we realised that these were the very same things that we needed: the raising of the average water level and the lowering of the flood levels**.** So analysing the aerial photographs of this area, the planning group were able theoretically to establish a pattern of this meandering system for the "B" section of the river (Plate 22).

If we look back to about two hundred years ago (Josephinische Aufnahme, around 1760), we can see what we want to recreate and this is, in my eyes, not a clear meandering system nor a clear braided system, it is rather a combination of the two : some part of it braided, some part of it meandering (There is a somewhat academic discussion about whether this true or not, unfortunately we don't have satellite images from three hundred years ago to clarify the situation with greater accuracy.)

In order to be able to give financial calculations for the different solutions, the planning team established a longitudinal profile for each solution, and that was also the basis for the financial calculations.

Then there is a crucial question of how much water will be needed for all these solutions. Our finding is that the average water demand would be around 1,100 cubic metres per second for the "Kern solution". This would be the optimum for this solution. Of course it can be operational with less, with about 600 cubic metre per sec, but this is a minimum not a goal, and of course it can work also with much higher water quantities such as 2,000, 3,000 and up to 6,000 cubic metres. So it is apparent that this water demand is pretty close to the European Community's recommendations, which stated 600-800-1,300 cubic metres per sec in 1993.

Plate 23 is a map from the 1860s, and this shows you that one of the secondary branches or lateral branches, which we propose to be a part of the meandering branch system in the Kern solution, was actually the main branch around the 1860s. So we might be so bold as to say that with this solution we could recreate the river conditions of 100-200 years before. Of course the goal is not just to create nice river forms in the landscape, but to raise the water level to the level of the 1950's, when the main branch and the side branches still had a living connection throughout the greater part of the year. At the same time this water level can raise the level of the underwater table, and recreate favourable ecological conditions.

Plate 24 shows a bird-eye view of the region. It can be seen that stone structures already exist in the region, these are the ones that now separate the side branches from the main branch. The stone structures we are proposing in the "Kern solution", are underwater structures so an observer would not notice artificial structures in the landscape.

Section A

We can have a look at the "A" river section on a map that shows the reservoir according to the original plan, and the state of the reservoir as was executed unilaterally by the Slovaks after creating the so-called "C variant" dyke system with a new dam along the Slovak - Hungarian state border line. The abandoned site of the reservoir now needs very massive ecological restoration since about 800 hectares of woodland was cut down, and there are several gravel mining sites that need ecological restoration (Plate 25).

This 9 km river section, according to our proposals, should be handled the same way as the secondary branch system of the "B" section. In this scheme or alternative we don't have to use the Dunakiliti dam any more, which is one of the main objectives of the NGOs involved in the Danube debate. Instead two stone structures would serve as icebreakers or the controllers of a flood. At high floods these two structures would allow the use of the old main branch to let down water quantities of around 2-4,000 cubic metres per second. In this plan we propose different forms of ecological restoration: wetland restoration and the rehabilitation of the construction sites. At the same time, we propose that a small harbour for vessels of international tourism be developed here in the already degraded and therefore less sensitive area of the branch system.

The main differnce between the B and C river section is that in the "B" section the river has a water level drop of around 40-30 cm/km, and under the settlement of Szap it has a 10, maximum 20 cm drop in water level for every kilometre. So characteristically these are two different sections of the river.

Section C

Regarding future water levels, a detailed calculation has been realised by Mr. Mikolics of the TÉRTERV Office, based on the analysis of the data of VITUKI that were accumulated over the last twenty years. He has made the calculation for the next 50 years, which gave us the following results: in part 1 of the "C" section the situation is more or less unpredictable (Szap section), because the heavy water-flow coming from the artificial channel continuously creates a new waterbed. In this section we could have as much as 3-3.5 metres decrease in the water level. Along the other 100 km of the C section we have to calculate between 1 or 3 dm of water level reduction over the long term, the same calculation for the Budapest section is around 1 to 2 dm.

Historically only 40 per cent of the reduction of the water level and the river bed was dependent on natural processes, and 60 per cent of the water level drop occurred because of the very massive gravel excavations in this section. Over a 20-year period between 1974 and 1996 for example, in each river kilometre we have an accumulated amount of 0.5 million cubic metres up to almost 3 million cubic metres removed. This is one activity that we have already had to bring to a halt.

What other measures are we proposing to keep up the water level to ensure that this section will be navigable in line with EU standards? TÉRTERV office propose reinforced stone riverbed sections at specifically selected points on the river, and these sections could each raise the water level about 30 cm each. This higher water level would give us an opportunity to revive the secondary branch systems and island systems as well. So it would serve both the navigational and ecological points of view. This type of reinforced river section can be studied at the rehabilitated Nagymaros dam site. Measurements here verified that the 30 cm water level lift is already in effect. So it is predictable, that by using these structures we can manage the whole of the 100 km river section. It is an important feature again (as along the "B" section) that on the surface we can see nothing of it, so from the point of view of landscaping it has a very beneficial result.

What do we propose in this river section for the ecologically most sensitive areas around the river? We assigned 15 action areas which consist of about 25 small islands and side branches (Plate 26). We made a basic environmental inventory of these, and tried to establish ecological goals and objectives for each of these island systems. A major obstacle for this prediction is that we lack much of the important data, for example data regarding the riverbed, sedimentation, etc. of the secondary branches. To measure these was not the task of the water management authorities, since they concentrated their activities on the main branch. So we are working at the moment without exact data concerning these branches. What we were able to do was to make landscape and riverbank evaluations for these sections and at the same time, with the help of ecologists, we set up a list of the species which can be found and need protection in these systems. We dealt with about 200 species of vegetation, and about 100 species of birds. In this short period of time we could not go into detail for the whole ecological spectrum; we intend, of course, to do that in the future.

We also went methodically through all the studies which had been done for this river section over a 15 year period. The drawback of this process was that these studies were meant mostly either to supply the dam project or to try to evaluate the secondary effects of the dam project.

These were the water level predictions that we obtained from the technical evaluation: for each of the island systems we have a predicted water level for the year 2025 and 2050. So this already gives us a more or less stable basis for a prediction of the ecological state that could be achieved by these proposals.

We have conducted measurements in order to be able to have a quick look at the riverbed along the secondary branches. In the future we will certainly need a number of this type of measurement if we want to supply the bilateral talks with more detailed material and arguments

Costs of suggested restoration

Finally I would like to mention the costs of the type of restoration we suggested: based on the technical and environmental evaluation of these river sections, we calculated that the total cost would be about 180 billion forints for the "A", "B" and "C" sections, if we want to construct everything in a five-year period. This amount is much less than that of the construction cost of one single dam at Nagymaros. It includes the ecological restoration of the Szigetköz and the Dunakiliti area, and also includes the ecological restoration of the 150 km "C" river section. But if we calculate more realistically, then this amount would not be needed to be spent in a five-year period but rather over a 50-year period. Therefore around a yearly 10 billion forints for five years would be sufficient to begin the putting into effect of these proposals.

KISSIMMEE RIVER RESTORATION

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Abstract

Historically, the Kissimmee River meandered approximately 103 miles within a one to two mile wide floodplain. The floodplain, approximately 56 miles long, sloped gradually to the south from an elevation of about 51 feet at Lake Kissimmee to about 15 feet at Lake Okeechobee; falling an average of around one-third of a foot in elevation over each mile of the river. Under historic conditions, river flows generally exceeded 250 cubic feet per second (cfs) 95 percent of the time, while overbank flooding occurred 35-50% of the time during the historic period of hydrologic record (1934-1960). The river moved very slowly, with normal river velocities averaging less than two feet per second.

Wading birds, waterfowl, fisheries and other biological components were once part of this integrated and resilient river/floodplain wetland ecosystem and were supported by and dependent on the spatial mosaic of habitats, intricate food webs, and other complex physical, chemical and biological interactions and processes.

The historic floodplain was covered by approximately 35,000 acres of wetlands. Major plant communities found within these wetlands included maidencane and beakrush wet prairies, broadleaf marsh, and willow and buttonbush shrub swamps. Other plant communities common in the wetlands, but not distributed extensively, included wetland hardwoods, cypress, oak-cabbage hammocks, switchgrass, sawgrass, and floating mats or tussocks (Pierce et al., 1982).

The distribution and maintenance of plant communities within the floodplain wetlands depended on prolonged inundation and seasonally fluctuating water levels (Dineen et al, 1974; Toth, 1991). A fluctuating hydroperiod, along with the undulating topography of the floodplain, a meandering river channel, oxbows, and natural discontinuous levees, enhanced and maintained habitat diversity, including the mosaic of intermixed vegetation types (Perrin et al., 1982).

The Kissimmee River floodplain harbored a large and diverse wintering waterfowl population, including ring-necked ducks, American widgeon, northern pintail, and blue-winged teal (USFWS, 1958). The historic winter duck population was estimated at about 12,500 birds. Wet prairie was the most important of the wetland communities for waterfowl. Under historic hydrologic conditions, wet prairies were typically dry from spring through early summer, allowing annual plants such as wild millet to germinate and produce seed. Fall and early winter flooding made wet prairies attractive feeding sites for migrant as well as resident populations of waterfowl.

South Florida's wetland habitats have historically supported a great diversity and abundance of wading birds - one of the largest centers of abundance in the world (Kushlan and White, 1977). Despite the 95% reduction in wading bird population in the state since the 1800's, all fourteen species of wading birds found in the eastern

United States were reported nesting in Florida in 1977 (Custer and Osborn). The historic number of wading birds on the Kissimmee River floodplain prior to channelization was estimated at 18,000 birds (USFWS, 1991). White and glossy ibis were common in the grassy wet prairies of the Lower Kissimmee Basin. The floodplain also provided habitat for the endangered Wood Stork, Snail Kite, and Bald Eagle and the threatened Sandhill Crane.

Prior to 1940, human habitation was sparse within the Kissimmee basin. Land use within the basin consisted primarily of farming and cattle ranching. However, rapid growth and development following World War II set the stage for extensive property damage when a severe hurricane occured within the basin in 1947. The mass flooding during this period intensified public pressure for measures to reduce the threat of flood damage within the Kissimmee basin. The State of Florida responded with a request to the federal government to design a flood-control plan for central and southern Florida (U.S. Army Corps of Engineers 1992).

In 1948, Congress authorized the U.S. Army Corps of Engineers to initiate construction of the Central & Southern Florida Project for flood control and protection. In 1954, Congress specifically authorized the Kissimmee River portion of the project, which was planned and designed from 1954 to 1960. Between 1962 and 1971, the Kissimmee River was channelized and transformed into a series of impounded reservoirs (Pools A-E). Inflow from the upper basin was regulated by six water control structures (S-65s). Water control structures and canals were built in the upper lakes region which allowed regulation of water flow within and between the lakes of the upper basin.

The physical effects of channelization, including alteration of the system's hydrologic characteristics, largely eliminated river and floodplain wetlands and degraded fish and wild-life values of the Kissimmee River ecosystem (Toth 1993). The meandering river was transformed into a 56-mile-long, 30-feet-deep, 300-feet-wide canal. Excavation of the canal and deposition of the resulting spoil eliminated approximately 35 miles of river channel and 6,200 acres of floodplain wetland habitat. Transformation of the river-floodplain ecosystem into a series of deep impoundments drained much of the floodplain (Toth 1995), eliminated historical water-level fluctuations, and greatly modified flow characteristics. Approximately 26,000-31,000 acres of pre-channelized floodplain wetlands were drained, covered with spoil, or converted into canal. The floodplain at the lower end of each pool remained inundated, but pre-channelization water level fluctuations were eliminated. Low-and no-flow regimes in remnant river channels resulted in encroachment of vegetation, especially floating exotics (such as Pistia stratiotes [water lettuce] and Eich-hornia crassipes [water hyacinth]) to the center of the river channel. Senescence and death of encroaching vegetation covered the shifting sand substrate of the historic channel with thick accumulations (up to 3 feet) of organic matter, greatly increasing the biological oxygen demand of the system (Toth 1990).

River channelization and degradation of the floodplain led to severe impacts on the system's biological components. By the early 1970s, floodplain utilization by wintering waterfowl declined by 92% (Perrin et al. 1982). Wading bird populations, a highly visible component of the historic system, declined and were largely replaced by Bubulcus ibis (cattle egret), a species generally associated with upland, terrestrial habitats (Toland 1990). Low-and no-flow regimes in the canal and remnant river *channels resulted in chronically low dissolved oxygen levels and sport fish species like largemouth bass were largely replaced by species tolerant of low dissolved oxygen regimes (such as Lepisosteus platyrahincus [Florida gar] and Amia calva [bowfin]). Rheophylic invertebrate taxa typical of many large river systems (for example, hydropsychid caddisflies and heptageniid mayflies) were replaced by species common to lentic systems (for example, Chaoborus, Pelocoris [Hemiptera:Naucoridae], and hydrophilid beetles) (Toth 1993). Stabilized water levels and reduced flow also eliminated river-floodplain interactions. Influx of organic matter, invertebrates, and forage fishes to the river from the floodplain during periods of water recession was eliminated. Stabilized water levels also largely eliminated adult spawning and foraging habitat, as well as larval and juvenile refuge sites for fish on the floodplain (Trexler 1995).*

THE WWF GREEN DANUBE PROGRAMME

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The Danube is a remarkable river - it binds together a multitude of different cultures and peoples as well as a diversity of ecosystems. Over 80 million people call the Danube Basin "home". The river, its tributaries, and its floodplains have greatly influenced human history, culture and development. In turn human culture and development have also greatly affected the Danube River and surrounding landscape.

Unfortunately, the human amazement at our own ability to manage and manipulate nature has often meant that the development in the Danube region for transportation, energy production or other purposes has been done at the expense of the Danube as a living system.

In this statement I would first like to address the damage that has been done to the Danube but more importantly to highlight important initiatives that have been taken to conserve and restore the natural floodplain ecosystem.

Secondary, I would like to address the burning problem we face in Slovakia and Hungary regarding the Gabcikovo power plant and the resulting problems for nature and people.

The History

Up to the middle of the last century the Danube river was dynamic, free flowing with an extensive network of side arms and backwaters. Depending on the time of the year, the weather, and the location, the volume of water in the Danube varied considerably. The changing volume of water in the river has a significant influence on the relation with the floodplain – the dynamic interface between water and land.

Unfortunately, however, human development over the past two centuries has seriously damaged the relationship between the Danube and its connecting floodplains. Channelization and straightening of the river for transport and flood protection constricted and shortened the river; dams for energy blocked its flow; and land-use alterations (draining of wetlands, forest clearing) and pollution have all combined to reduce the naturalness and hence the vitality and life giving ability of the Danube and other rivers.

A recent study completed by WWF found that over 80% of the original floodplain area in the Danube has been lost since the turn of the last century (UNEP/GEF 1999). The loss of these areas of floodplain has greatly reduced biodiversity in the region. Breeding places for fish, such as the five species of sturgeon which formerly lived in the Danube have been destroyed and now only remnant populations of these magnificent fish remain.

The loss of floodplains is not only important because of the loss of this biodiversity which one might argue is only the concern of a few nature lovers. Floodplains serve important functions in nature - such as purification of water, flood storage, groundwater recharge. The loss of floodplains has not only meant the loss of biodiversity but the loss of these functions – functions which have enormous consequences for the Danube as well as for the Black Sea.

These consequences are both ecological and economic. A 1994 study placed an average economic value on the Danube Floodplains at 383 € per hectare per year. For all 1.7 million hectares of the Danube Floodplain from Germany to the Ukraine the annual value amounted to over 650 million € (WWF 1995).

But I have no wish to dwell on the negative consequences of development on the Danube. On the contrary I want to emphasise that the dramatic political changes in Central and Eastern Europe in the late 1980s and early 1990s opened opportunities to bring environmental concerns to the forefront and led to changes in the way we think about the Danube and other rivers - to begin to treat them as living systems.

Good News

The World Wide Fund for Nature has since 1992 operated a programme called the 'Green Danube'. This programme, which has been carried out in co-operation with government and non-governmental groups throughout the basin, is focused on conservation, restoration and sustainable management of the Danube as a living river recognising the connection between the water and land.

I would like to highlight some of these projects and the successes which have been achieved.

Donau-Auen National Park & Regelsbrunner Au

A successful struggle by WWF and others against the construction of a hydro power plant at Hainburg on the Danube beginning in the early 1980s and lasting over a decade led to the establishment of the 10,000 ha Donau-Auen National Park in October 1996. The establishment of National Park status was an important achievement but it was only one part of an overall strategy from WWF to conserve and restore the natural floodplain of the Danube. Floodplains should not be static and unchanging. By their nature they should change with each high and low water. New pools and side arms are constantly formed and disappear.

Unfortunately, although the Danube at Hainburg was one of the last remaining areas of free flowing Danube along the upper portion of the river the connecting side arms were being slowly starved of the life giving water they needed – these side arms were slowly silting up and constricting further into narrow overgrown channels.

Beginning in 1996, however, a bold experiment involving partnership between WWF, the newly formed National Park administration, the agency responsible for water management (including transport) and University scientists was launched to restore the natural flow of water to this side arm system.

In order to bring water back to floodplains the dykes which run parallel to the river were lowered at key points (allowing more water in during high water periods) and at other locations culverts were built to connect the side arms to the river. These measures allowed the dynamic of floods and low water to return to the side arms and allowed nature to naturally change the side arm system. Sediments and sand were redistributed by the increased waters rushing in during floods. Erosion was increased and new habitat created and fish had an almost permanent connection to the main river allowing them to wander as they normally would. The scale of the project at the Donau-National Park, Regelsbrunner Au, and its success make it unique within river management projects in all of Europe and perhaps the world. It has become a model project demonstrating the value of ecologically sustainable river management.

Transborder Nature Protection: Gemenc Beda and Kopacki Rit

Further east along the Danube on the Hungarian border WWF and various other partners have been active in a sister project to protect and restore the natural floodplain of the Danube. Campaigning by the WWF Hungary Programme Office helped lead to the creation and opening of the 50,000 hectare Danube Drava National Park in 1996. The establishment of the park ensures the conservation of this magnificent floodplain ecosystem.

The Danube near Gemenc, Hungary, is an impressive network of side arms and old arms, forming the largest floodplain forest on the Danube at 24,000 hectares. But as in the Austrian Danube National Park the dynamic of water flowing into the backwaters had been steadily decreased and the rich biodiversity was slowly being lost.

Now that the area has been declared part of a National Park, procedures to rehabilitate the original river dynamics, to improve the ecological condition of the entire area and secure long-term protection are needed. A component of the rehabilitation carried out by WWF has been the reintroduction of beavers. Thirty beavers have been released in Gemenc to help in the process of creating the natural dynamics needed for the floodplains.

The hydrological changes of the dynamics of the Danube up-stream of the National Park have remarkable impact on the ecological status of the river: the riverbed has deepened during recent years (1 meter) due to the lack of sediments and bottom material. As a consequence some water connections to the backwater dried out. High floods occur more infrequently.

The efforts of the park administrators has been to ensure the conservation of the floodplain and planning is now underway to ensure the restoration which is needed. Conservation and restoration must go hand in hand. The conservation of existing habitat must be the priority strategy in any river basin restoration programme. In addition it should be pointed out that the protection and restoration of the Danube Drava National Park has brought people of different countries together in a manner that is demonstrating that natural boundaries do not necessarily respect human political boundaries. Co-operation has begun between the National Park in Hungary and the newly formed Kopacki Rit Nature Park in Croatia with the aim of helping create trans-national nature conservation.

The Bulgarian Islands

Further downstream I would like to highlight a project along the Danube River in Bulgaria – the Bulgarian Islands project which has been carried out together with the State Forest Authorities in Bulgaria and the Ministry of Environment. All along the Danube the natural forests have been converted to wood plantations through the introduction of foreign varieties of trees to the floodplain forests (WWF 1999).

On the Bulgarian Island of Vardim, an experiment is underway to reconvert these plantation forests back to natural forest**.** It is not the case that harvesting of forest cannot and should not be done**.** Forests are renewable resources but they must be managed and harvested in a way that does not destroy the life giving potential. The project there has begun the re-conversion of these forests and is demonstrating that forestry which supports and sustains natural values can be profitable and productive for nature and humans.

The Danube Delta

The final projects I want to mention are in the Danube Delta of Romania and Ukraine. The Delta, based upon a recent assessment of the worlds biodiversity by scientists, ranks as one of the worlds 200 most important areas of biodiversity. Fortunately the fantastic value of this region has been recognised by people of the region and in both Ukraine and Romania a Biosphere Reserve has been designated.

Unfortunately, however, the Delta doesn't just need protection it needs restoration. tens of thousands of hectares of the Delta had been foolishly converted from wetland to what was intended to be agricultural land. The plans of the former governments to produce massive quantities of rice and other food here were, however, largely unsuccessful. Unsuccessful because natural processes were ignored. In both Ukraine and Romania, together with local partners WWF has been working to restore these failed experiments (ICCPD/WWF 1997).

In the Romanian Danube Delta Biosphere Reserve the dykes around two large islands (2,000 and 1,500 ha) have been breached (in a co-operation action between the DDBRA, Danube Delta Institute, GEF and WWF) allowing water back into lands which had been drained by the former communist government. The return of waters back to these naturally flooded islands has restored the important functions these islands formerly played as fish breeding sites, filters of sediment and nutrients, and breeding and feeding sites for numerous birds including the threatened Pygmy

Cormorant and Dalmation Pelican. The restoration on Babina and Czernovka Islands is intended to be the start of a programme that will restore over 50,000 ha of former wetland in the Danube Delta.

In the Ukrainian portion of the Danube Delta, the WWF Partners for Wetlands Ukraine project has been initiated with four main goals:

- to stop further man made destruction of wetlands
- to restore the natural functions and value of the damaged wetlands
- to expand wetland conservation in the Ukraine
- to utilise the conservation and restoration of these wetlands as the basis for economic development strategies.

In 1998 WWF committed to invest approximately 1.4 million € into wetland conservation, sustainable development, capacity building and communications over a three year period. WWF is aiming to stimulate local, national and international partners to magnify the efforts and resources that it has made available.

WWF is using its financial and technical resources to lay the ground work for wetland restoration in the Ukraine. Projects include: the restoration of a major wetland area in Odessa Oblast; the development of policies, actions and economic activities which support wetland restoration and conservation; and a communication campaign targeted at possible partners.

To facilitate the Partners for Wetlands project the WWF Odessa Project Office opened in April 1998. WWF is hoping that the ”presence of the Panda” will help to expand environmental awareness and encourage decision making bodies to recognise the immense human, environmental and economical benefit of nature’s wetlands.

The Living Rivers Initiative in Austria

In addition to the specific restoration projects described above two other initiatives should be noted as of great significance in the Danube region. The first initiative involves co-operation between the Austrian government and the WWF in a Programme entitled “Living Rivers” (Bundesministerium für Land- und Forstwirtschaft, Bundesministerium für Umwelt, Jugend und Familie, WWF 1998, 1999). The aim of this initiative is to preserve and reclaim on a large scale Austria’s rivers and floodplain. The challenge of the Living Rivers campaign is to combine river restoration with flood protection. Clean water in well-structured, living rivers is the main goal. The goals to be achieved by the year 2000 are:

- Preservation of important river stretches.
- Significant improvement of ecologically degraded stretches: 500 km will be revitalised, achieved by the removal of bank reinforcements, reintegration of old river arms and the dismantling of dams and weirs. 5000 ha of new flooding areas will be created, achieved by relocation of dams in order to allow floodwaters to expand over the floodplain, thus reducing the level and force of the flood. 500 ha of new vegetative strips along the banks will be established. These areas should act as filters to reduce the sediment and nutrient input from fields to the rivers.
- Increasing awareness and understanding of rivers.

The campaign has involved a mix of communication and practical actions to change the manner in which rivers are managed in Austria on a large scale. This co-operation between the government and a nature conservation organisation can serve as a model for other countries as well.

Lower Danube Green Corridor Agreement

The second initiative of large scale significance has been initiated by the Romanian Ministry of Environment together with representatives of the governments of Bulgaria, Moldova, and Ukraine and is called the Lower Danube Green Corridor.

Recognising the importance of a healthy floodplain and wetlands for the maintenance of water quality and environmental health in the Danube River and Black Sea and as a basis for creating economic development opportunities for local populations (fish harvesting, tourism etc) the countries of the lower Danube have decided to establish the Lower Danube Green Corridor.

The Ministries of Environment together with the other responsible agencies including agriculture have developed an agreement:

- To take concerted action to create a Lower Danube Green Corridor that will expand the co-operation, co-ordination and consultation between Bulgaria, Moldova, Romania and Ukraine in the field of Danube River floodplain and wetland protection and restoration.

- They will establish the Lower Danube Green Corridor composed of a minimum commitment of existing protected areas, a minimum commitment of proposed new protected areas, and areas proposed to be restored to natural floodplain.

- To present on behalf of the Governments of Bulgaria, Moldova, Romania, and Ukraine, the Lower Danube Green Corridor as a Gift to the Earth as part of the WWF Living Planet Campaign which is aimed to secure the conservation of the worlds most important biological resources and ecosystems into the next millennium.

This agreement which commits the countries to hundreds of thousands of hectares of conservation and restoration of floodplain habitat is the basis for a recognition of the value of floodplain habitats as a vital element of a freshwater ecosystem.

All examples mentioned demonstrate the potential and enthusiasm that exists throughout the Danube River Basin for the conservation and restoration of floodplain habitat. The conflict between Hungary and Slovakia over the diversion of water from the Gabcikovo plant should be viewed in the context of this increasing concern and understanding of the need to conserve and restore wetlands.

Gabcikovo – is a solution near?

The WWF has for over ten years been involved in questions related to Gabcikovo and two detailed studies outlining our proposals for water management in the Danube in this region were presented (WWF 1994, 1997). The most recent study published in October 1997 identifies the basic principle that a minimum of 65% of the original Danube water needs to be returned to the old bed. In addition measures need to be taken to ensure the regular flooding of the valuable floodplain forest, the connection of the floodplain with the open river, and to ensure the maintenance of the floodplain ecosystem.

The WWF suggests, as a short term solution, to accumulate sediment bodies in the old river bed of the Danube in the form of islands and gravel banks (WWF 1989, 1997). These will lift the water level and preserve the original river continuum. Lateral dykes in the floodplain and sidearm closures in the Danube should be reopened.

The recommendation is an extended lifting and constricting of the river bed, including the filling of a large layer of gravel and boulders. This idea is based on a guaranteed discharge of 65-75% (what is particularly important is the restoration of the peak flood events) in the old Danube. This proposal is based on the Slovak legal conditions from 1991 and on the EC compromise proposal from 1993. The Cunovo reservoir should be restricted to a navigation route with the restoration of adjacent areas. This will reduce the undesired sedimentation threatening the groundwater in Szigetköz (Lang *et al.* 1997).

The WWF proposal would respect the hydrological and morphological dynamics of the Danube and thus restore the old Danube bed back to the highest possible natural status. Other solutions may be cheaper and might need less water discharge, but do not bring the best results for the Danube, the floodplain or the damaged quality of life and economic opportunities for local people.

In the search for a suitable solution for the Danube and the local people our highest concerns must be the protection of the floodplain dynamics and the salvation of the groundwater.

As illustrated, re-naturalisation is both possible and successful.

The WWF proposal shows that re-naturalisation of the old river bed and the recreation area of the Szigetköz is possible. Re-naturalisation projects all along the Danube show positive effects for local population, economy and the ecosystem. We should not miss this opportunity to make the best out of this unsatisfactory situation. The continued failure to modify the existing situation is resulting in a continual worsening of the situation for the floodplain forest and the groundwater. In the spirit of the new awareness about what has and can be done to restore wetlands in the Danube the available solutions must be quickly implemented.

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RESTORING WETLAND HABITATS: LESSONS FROM SOUTHERN CALIFORNIA

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Introduction

The restoration and management of wetland habitats is a growing concern world-wide due to ongoing losses of valuable habitat, as well as an increased understanding of the important functions that wetlands serve. In the United States, wetland loss has been greatest in California in terms of percent habitat loss (91% of historic wetlands are gone) and in Florida in terms of absolute acreage (3,750,000 hectares lost; Dahl 1990, Mitsch and Gosselink 1993). In other areas around the world, similar impacts to wetland and riverine ecosystems have occurred.

No matter how these historic losses are measured, it is essential to develop management and restoration practices in order to minimize future degradation of these important habitats. These efforts should be based on the principles of ecosystem and watershed management (see Christensen *et al.* 1996 and Lant 1999 for recent reviews of these topics). Many of the essential ecological issues facing restoration and protection of wetland habitats are similar across these different ecosystems. In all cases, hydrology and other physical factors, such as soil conditions, drive the development of the biotic systems.

In San Diego (southern California), there have been large-scale losses of wetland habitats, and presently there are a large number of endangered species in the area. Over the last two decades, there has been an effort to restore and create wetland habitats in order to protect these endangered species. Because of the extensive impacts and recent efforts at restoration in southern California, there are some valuable lessons that can be applied to other estuarine and riverine systems. In this paper, I evaluate two examples from recent research on wetland issues in southern California, first focusing on sediment dynamics and watershed issues in the Tijuana Estuary and second on the challenge of constructing wetland habitats in San Diego Bay. These case studies illustrate three key issues for estuarine and riverine management and restoration that are applicable to a variety of systems:

1) a watershed approach is essential;
2) the principles of adaptive management should be used, including the incorporation of scientific experiments into management plans; and
3) restoration should not be at the expense of conservation of existing habitat.

Watershed issues and storm sedimentation dynamics

In managing riverine and estuarine systems, a watershed based approach is essential because of the link of ecological processes up and downstream on a river. In southern California, storm sedimentation is one of the key watershed concerns for both natural and restored coastal wetlands. In other systems, the specific issues may be different, but the importance of watershed dynamics to the functioning and sustainability of the ecosystems is similar.

Southern California has a unique set of conditions that make impacts from storm sediment especially important for coastal wetlands, including: a Mediterranean climate, geology and land use. The most important component of the Mediterranean climate is the seasonal rainfall which occurs almost entirely in winter months. In addition, rainfall is highly variable from year to year, with El Nino-related cycles of wet and dry years. During wet years, intense winter storms result in large amounts of rainfall over very short time periods. Second, soils and sediments are easily erodible, and southern California coastal areas are typified by small, steep watersheds with high velocity discharge. In addition, most southern California watersheds are highly disturbed, and Tijuana Estuary is no exception. There are many houses and other developments built directly into hillsides throughout the watershed of the Tijuana River, causing disturbances to soil and increased erosion rates. In wet years, this combination results in runoff from winter storms that carries large amounts of sediment into local basins, including coastal wetlands.

Accumulation of storm-related sediments is a concern for coastal wetlands primarily because of changes in the relative elevation of the wetland. In addition to storm sediment inputs, other processes which lead to increases in the relative elevation of the wetland are: belowground production of organic material and gradual sediment input via tidal sources. Processes which decrease the relative elevation of the wetland are: eustatic sea-level rise, decomposition of belowground organic matter, and subsidence (Callaway, in press). In most cases, these processes are in relative balance, and individual processes may range from 1 mm to 1cm (for reviews of these dynamics, see Stevenson *et al.* 1986, Reed 1990, Callaway *et al.* 1996). The balance between these processes results in the relative stability and longevity of the intertidal wetlands (Mitsch and Gosselink 1993). An imbalance will result in large changes in the relative elevation of the wetland.

Relative elevation is one of the key factors affecting the distribution of wetland plants (Zedler *et al.* 1999), primarily because elevation affects the frequency of tidal inundation. The zonation of plant species relative to elevation within the wetland has been shown in many coastal ecosystems, from San Francisco Bay (Hinde 1954) to New England (Niering and Warren 1980) and France (Gross *et al.* 1986). In southern California, the tidal range is approximately 2 m, and shifts in elevation of 5-10 cm can be great enough to cause changes in plant species distributions (Zedler *et al.* 1999). In other wetland systems from riparian forests to vernal pools, there are similar relationships between elevation, inundation and plant distributions.

In the winter of 1994-95, San Diego experienced a series of large storms with unusually high rainfall. Runoff from the storms deposited sediments throughout the south arm of Tijuana Estuary. This event allowed the opportunity to measure the extent of storm deposition over a single winter, as well as the immediate and longer-term impact of this sedimentation event on coastal salt marsh vegetation.

Tijuana Estuary is a National Estuarine Research Reserve and is one of the least disturbed estuaries in southern California (Zedler *et al.* 1992). The watershed is approximately 4500 km^2 with two-thirds of the watershed in Mexico. The study area was a salt marsh adjacent to a small tidal channel in the south arm of Tijuana Estuary. Prior to the 1994-95 winter storms the area was dominated by pickleweed (*Salicornia virginica*) with plant cover close to 100 percent. Observations in early 1995 (immediately after winter storms) indicated that sediment covered most of the site with little vegetation still visible above the surface.

Sediment accumulation and plant recovery were measured in summer 1995 along a 75-m transect parallel to the tidal creek, running from the east (near the sediment source) to the west (away from the sediment source). The depth of newly deposited sediment was measured in 40-cm sediment cores. Storm-deposited sediments could be identified because of their light color and coarse texture relative to older marsh sediments. This transition in sediment characteristics was very sharp and was used to identify the depth of storm sediment accumulation over the prior wetland surface. Plant cover was estimated using the line-intercept method along both parallel and perpendicular transects.

Based on these measurements, approximately 10 to 30 cm of sediment accumulated along the small tidal channel in the south arm of Tijuana Estuary, with the greatest amount of material accumulating near the upper part of the channel (sediment source). Sediment accumulation decreased gradually to the west (moving away from the sediment source and towards the mouth of the estuary). This amount of sediment accumulation is one to two orders of magnitude greater than what is typically found in other salt marshes world-wide (Stevenson 1986). It is equal or greater than other reported amounts of storm sediment accumulation in coastal wetlands (Nyman *et al.* 1995; Cahoon *et al.* 1996).

Bare areas and adjacent areas where pickleweed had recovered were targeted for sampling in order to see if plant recovery was related to the depth of burial. Throughout the 75-m transect, areas where pickleweed had recovered in summer 1995 had significantly less sediment accumulation. Experimental burial of pickleweed also showed little recovery when plants were buried by 20 or 30 cm of sediment. In addition, the recovery of pickleweed during the first year following the storm was inversely related to the depth of sediment burial along the 75-m transect. Plant cover of pickleweed was less than 50% in areas where deposition was approximately 30 cm; where deposition was <10 cm, plant cover was greater than 75%. Based on these results, pickleweed is relatively tolerant of sediment burial; however, even this species can not tolerate extreme rates of sedimentation.

It was expected that plants would continue to recover over the next year, reaching 100 percent cover, as is typical in undisturbed salt marshes. However, there has been extensive foot traffic in the area from undocumented workers entering the United States from nearby Mexico, and the initial vegetation recovery was reversed by extensive trampling over the next two years. It is likely that the sandy sediments attracted foot traffic away from muddier channel crossing areas. Recovery was probably also inhibited by high soil salinity in bare areas (over 100 ppt), which reduces plant growth and eliminates seedling establishment.

This research illustrates the significant effect that storm-related sediment, in particular, and watershed dynamics, in general, can have on the development of wetland ecosystems. The best way to improve the long-term management of this ecosystem is through erosion control in the watershed, habitat restoration in the lowlands, and the use of some simple engineering solutions, such as sediment retention basins in the watershed. Prevention of problems within the upper parts of the watershed is preferred rather than attempting to compensate for impacts downstream. Furthermore, recovery of impacted systems is difficult to predict in today's urban wetlands because initial impacts may be compounded by other factors, in this case, trampling.

Lessons from San Diego wetland restoration projects

In order to restore an ecosystem, it is necessary to first understand the biotic and abiotic components that make up the ecosystem, including, hydrology, soils, plants, animals, natural disturbance regimes, and other factors. In addition, interactions between these components need to be considered. The challenge of restoring and creating native wetland habitats reflects a wide spectrum of opportunities and constraints. The more degraded an ecosystem is, the more difficult it will be to restore, and the more unpredictable the outcome of restoration will be (Zedler 1999). Creation of new habitats also will require extensive manipulation and has a lower likelihood of achieving goals (Kruczynski 1990). Because of these challenges, restoration has been called the “acid test” of ecology (Bradshaw 1983).

Beyond ecological constraints, there are also regulatory and policy constraints that may limit what can be achieved at a particular site. Furthermore, public support is needed in order to ensure that restored sites will be managed and protected into the future. Even when constraints are minimal and support is in place, detailed ecological data for a particular ecosystem frequently are not available to guide management decisions. When such data are lacking, an adaptive management approach should be adopted, with decisions based on the best-available science and a constant re-evaluation and refocusing of methods and priorities. Adaptive management and the incorporation of experimentation into the management design is particularly appropriate for the restoration of habitats where standard restoration methods have not been established.

Many hypothetical models have been proposed for the development of restored sites (see Zedler 1999, Zedler and Callaway 1999). Models typical predict a “trajectory” of development of ecological functions over time (Kentula *et al.* 1992, Hobbs and Mooney 1993) or they describe correlated changes in the structure and function of the ecosystem (Magnuson *et al.* 1980, Dobson *et al.* 1997). The models are based primarily on succession theory and may be valid in describing the development of natural systems. However, they are very vague in describing the time frame of ecosystem development, and there is little acknowledgement that highly degraded systems may not follow the proposed trajectory. Furthermore, little data are available from actual restoration projects to test these models. Before restoration policy is based on these models, further testing is needed.

Zedler and Callaway (1999) used data from a constructed salt marsh in San Diego Bay, California, to evaluate the trajectory model. The constructed site (the Connector Marsh) was excavated in 1984 and planted in 1985. It was constructed as compensatory mitigation for impacts due to a highway construction project (for a review of the project, see Haltiner *et al.* 1997, Zedler 1998). One of the goals of the project was to create habitat for the Light-Footed Clapper Rail (*Rallus longirostris levipes*), including stands of tall cordgrass (*Spartina foliosa*). In order to evaluate the trajectory of development at the constructed wetland, data for soil (total Kjeldahl nitrogen or TKN and organic matter content) and plant characteristics were compared for the constructed site and a nearby natural reference wetland over a ten-year period.

Results showed very weak support for any trajectory of ecosystem development at this site. Conditions for all variables at both the constructed and natural wetland were highly variable over the ten-year sampling period. When compared to the natural wetland, plant conditions at the constructed site showed a weak negative trend rather than the positive trend that a trajectory model predicts. Soil organic matter increased sharply during the first few years following construction showing some support for the trajectory model. However, organic matter content has remained relatively constant over the last 7-8 years at approximately 75% of values at the natural wetland. Soil nitrogen (TKN) has gradually increased over time, but ten years after construction, values for soil TKN at the constructed site were only 50-60% of values at the natural wetland. At the present rate of increase, soil TKN will be equivalent only after 40-45 years. This is much greater than the typical 5-10 year time frame that most managers and regulators consider in monitoring and evaluating the “success” of a restoration project.

Based on additional research (Langis *et al.* 1991, Gibson *et al.* 1994), it is apparent that the limiting factor for the development of ecosystem functions at this site is the coarse texture of the soil at the constructed wetland. Natural wetlands typically have fine soils that are slow to drain and retain nutrients and organic matter. However, this constructed wetland has very coarse, sandy soils which drain quickly and do not retain nutrients. Fertilization has been effective in improving plant growth over the short term, but this is not sustainable (Boyer and Zedler 1998, 1999). Coarse soils did not retain added nitrogen over extended periods, and fertilization over multiple years caused shifts in habitat distributions.

These results indicate that the construction and restoration of habitats remains a major challenge, especially when working with highly degraded ecosystems (Zedler 1999). If initial conditions are not so problematic, it is possible that sites would develop more predictably. Craft *et al.* (1999) found more support for the trajectory model of development based on 25 years of data from two restored wetlands in North Carolina that were not highly degraded. In any case, resource managers and regulators should consider conservation of existing habitats before allowing for impacts to functioning habitat that would require compensatory habitat mitigation. In addition, these results indicate the value of restoring degraded habitats as soon as possible so that further habitat degradation can be avoided.

Conclusions

Watershed-based planning must be considered for future management efforts of rivers and estuaries in southern California and elsewhere. In managing riverine and estuarine systems, it is preferable to deal with factors upstream, whether the issue is sediment, nutrients, pollutants, or water flows. Within the Tijuana River watershed, a number of state and federal agencies (the California State Coastal Conservancy, the Southern California Wetlands Recovery Project, the U.S. Fish and Wildlife Service, and the California State Parks) are co-operating to develop a set of restoration and management projects aimed at minimizing impacts of future sedimentation events in the south arm of the estuary. This is especially challenging given the bi-national aspect of the watershed, and efforts are being made to work collaboratively with Mexican agencies and scientists. Without this type of watershed approach, management of the river will not be sustainable.

Second, an adaptive approach is essential for ecosystem management and restoration projects. Given the lack of available information and knowledge in the new areas of ecosystem management and restoration, the only way to learn from on-going projects is to set them up in a adaptive way, with ongoing re-evaluation of goals and methods. The incorporation of large-scale scientific experiments and rigorous monitoring will improve restoration of these ecosystems and allow for the accumulation of a scientific database to enhance management of future projects.

Finally, it should be acknowledged that in many cases, restoration remains a substantial challenge. Restoration alone is not the answer for management of systems. Instead restoration should be done in conjunction with the conservation of existing habitat, thereby improving and expanding natural habitats. Restoration for the sake of mitigation of impacts to functioning ecosystems should be evaluated carefully.

Acknowledgements

This work was supported by funds from the National Science Foundation (DEB-9619875) and the Earth Island Institute. The research was conducted while I was at the Pacific Estuarine Research Laboratory (PERL) at San Diego State University, and I especially thank Dr. Joy Zedler for her support and insight on this research. Dr. Zedler was a co-principal investigator on both of the major research projects described in this paper. Thanks also to the state and federal agencies that facilitated this research, including: the California Department of Parks and Recreation, the U.S. Fish and Wildlife Service, and the California State Coastal Conservancy. Finally, I would like to acknowledge the support of the Department of Environmental Science at the University of San Francisco and the conveners of the symposium for the opportunity to participate in this symposium.

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ECOLOGICAL RESTORATION OF FLUVIAL SIDE ARMS: EXPERIMENTS IN FRANCE

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Abstract

In industrialised countries, fluvial hydrosystems have been degraded and managed for several purposes (flood prevention, navigation, water abstraction, hydroelectric production). Consequently in floodplains, side arms, as riverine wetlands, which provide numerous valuable functions, are disappearing. The ecological restoration of the side arms has to be conducted scientifically and rigorously to move from a trial – and – error process to a predictive science in order to increase its success and the self-sustainability of restored ecosystems. The recent research developments in ecosystem dynamics allow scientists to provide a theoretical base for ecological restoration. The present lecture focuses on the concepts of reversibility, ecotone, and flood pulse, which are applied in ecological restoration experiments in France. A case study, carried out on side-arm channels of the Rhone River, is presented in detail. A side-arm, submitted to rapid terrestrialisation and eutrophication after the completion of a hydroelectric scheme, was restored. The increase in groundwater supply led the restored ecosystem to return to a less advanced and self-sustainable successional stage, whereas the vegetation monitoring in a reference channel did not show any significant changes over an 18-year period of survey.

* * *

Introduction

In industrialised countries large rivers have been embanked for navigation and protection against floods, or harnessed for hydroelectric production. Consequently, in floodplains the side-arms have been directly and indirectly impacted. Among the direct impacts, the lowering of water level or drainage for agricultural purposes has led to the alteration and, more often, the disappearance of the side-arm ecosystems. Furthermore, since lateral erosion has been stopped by the embankments, fluvial dynamics can no longer create new ecosystems (Bravard *et al.*, 1986) while former channels and side-arms exhibit natural successional processes that lead to eutrophication and then to terrestrialisation (Amoros *et al.*, 1987). As long-term consequences, since the fluvial dynamics are impeded, the aquatic ecosystems of the side-arms are going to disappear. These ecosystems, as riverine wetlands, have numerous valued functions, and contribute to sustaining the ecological integrity of the river system (Henry and Amoros, 1995, Ward *et al.*, 1999). So, they must be preserved or restored.

1 – Restoration concepts.

Ecological restoration can be defined as returning an ecosystem to its condition prior to disturbance, or to a state as similar as possible to that which prevailed prior to disturbance. Because several changes have occurred in the rivers, as well as in the watersheds (water quality alteration, changes of sediment yield, regulation of river hydrology…), there is a need to define the expected restored state according to the present environmental conditions.

A strong theoretical base rather than empiricism must be involved, taking into account recent ecological concepts, to increase the success and the self-sustainability of restoration. Thus, the ecosystem state after restoration should be self-sustaining (requiring minimal maintenance or management or no maintenance at all), and the natural processes that rule ecosystem dynamics should again operate effectively. Restoration ecology should be realized by supplying the smallest amount of energy by acting on the degraded ecosystem structure and/or function through the manipulation of various ecosystem elements using reversible processes (Amoros *et al.*, 1987).

A process is reversible if it is able to function in an inverse direction, thus returning the system involved to its previous state. Indeed, we have to consider degrees of reversibility in relation to the amount of energy required to reverse the process. For example, even river incision or dam construction may be considered from a theoretical point of view as a reversible process! However their reversibility would require too much energy and appears as unacceptable within a realistic socio-economic framework.

Since the goal is to restore a dynamic equilibrium within the side-arm ecosystems in order to control eutrophication, and to impede terrestrialisation, the processes involved in two major concepts have to be addressed.

Flood pulse concept

The restoration of hydrological disturbances through scouring flash floods may prevent excessive sedimentation in side-arms and thereby impede terrestrialisation. The increase in flow velocity during flash floods in side-arms, can also break, uproot and wash away aquatic plants and organic matter. So, this disturbing effect can set back ecological succession and therefore sustain an ecosystem stability through a dynamic equilibrium (ecosystem stability resulting from patch instability), as has been demonstrated by Bornette and Amoros (1996).

Ecotone concept

The restoration of the riparian forest, at least a forest belt along the side-arm banks, aims at reducing 1) the suspended matter inputs resulting from land soil erosion and 2) the dissolved nutrient contents in groundwater through vegetation uptake and microbial and biogeochemical processes (Peterjohn *et al.*, 1984; Pinay and Décamps, 1988, Dahm *et al.*, 1998). Consequently, the exposition of coarse sediments in side-arms, can increase groundwater supply that would reduce nutrient contents in the side-arms, slowing down the ecological succession.

2 – Case study

2.1 – Material and methods

The side-arms are located in the Brégnier-Cordon plain of the Upper Rhône River in France, about 80 km downstream from Geneva, and 90-100 km upstream from Lyon. A hydroelectric scheme was built between 1982 and 1984, and a weir on the Rhône River to sustain the water table upstream, was completed in October 1985. This scheme destroyed the downstream part of the side-arm which has been restored. Thereafter, this side-arm exhibited rapid terrestrialisation and eutrophication processes (Henry *et al.*, 1995).

In order to set ecological succession back to the semi-lotic and mesotrophic stages, restoration operations were carried out in March 1993 using a technique that should not have disturbed the river banks and the riparian forest bordering the side-arm, and that should have preserved the upstream alluvial plug. The upstream connection was not open because the water quality of the river has been altered during the last decades while groundwater still presents a better quality (namely considering phosphate contents). Since the upstream alluvial plug functions as an ecological filter, it has been preserved. Some shores within the side-arm were also preserved to allow rapid recolonisation by plants and fauna following restoration. The layer of fine organic nutrient-rich sediment (0.15-1.00 m thick, of which a total of 2200 m^3 was extracted from the side-arm) was dredged to expose the coarser materials of the gravel bottom. This was to increase the nutrient-poor groundwater supply to the restored side-arm since it had been demonstrated that such a supply was capable of impeding ecological succession toward eutrophication and terrestrialisation (Bornette *et al.*, 1994). The side-arm was divided into three reaches (of approximately 150 m each, using temporary dams); each reach was then successively dredged by means of a caterpillar bulldozer after lowering the water table by pumping when necessary (see Henry *et al.*, 1995, for a description of restoration operations).

The present study also takes into account another side-arm as a reference site which shows functions and dynamics similar to those of the restored side-arm prior to restoration. These two side-arms belong to a braiding pattern of fluvial dynamics (Petts and Amoros, 1996) and were permanently connected to the river at their downstream end. Long-term surveys as well as comparisons with reference ecosystems are also necessary to discriminate the changes resulting from anthropogenic impacts (either negative, e.g. hydroelectric scheme construction, or positive, e.g. restoration effects), from changes resulting from other causes (e.g. fluctuations of hydrology or climate). The present lecture aims at reporting such a survey carried out over 18 years (1981-1998) on two side-arms of the River Rhône, France, one of them serving as a reference ecosystem.

Aquatic vegetation (hydrophytes and helophytes) was surveyed using the double Braun-Blanquet cover and sociability scales. Each couplet was then converted into a single value to allow statistical analysis (Balocco-Castella, 1988; Bornette and Amoros 1991). Vegetation surveys were carried out in summer on 2 m wide transects in each side-arm (12 transects in the restored side-arm; 19 transects in the reference side-arm from 1981 to 1987). From 1989, we surveyed transects regularly distributed along the two side-arms (25 m intervals), and the number of transects in each side-arm increased (18 transects in the restored side-arm; 48 transects in the reference side-arm from 1989 to 1998).

As the number of transects per side-arm was not the same before and after 1989, a Principal Components Analysis (PCA) centred by species was processed on this vegetation data base over the whole study period in order to delineate different zones in each side-arm. Four zones were discriminated in the reference side-arm and 3 zones in the restored side-arm, differing by their vegetation compositions. Thereafter, vegetation changes over time were investigated by zone, using a between-(zones x dates) PCA. This analysis pools the transects of each zone, at each sampling date, to focus on temporal changes on the zone scale. It thus makes it possible to compare the intensity of changes within each zone, after hydroelectric scheme construction and restoration, to possible natural changes in the absence of these impacts.

2.2. Results

The vegetation data of both side-arms were analysed simultaneously, but the results of the Principal Component Analysis were plotted separately by zone to provide more detailed insights into the temporal changes in vegetation composition in each zone. On each separate factorial map, the sampling dates were linked chronologically by a line depicting the temporal trajectory. The amplitude of the temporal changes in vegetation composition is clearly much larger in the restored side-arm than in the reference side-arm.

In each zone of the reference side-arm, the temporal trajectory between 1981 and 1998 appears short and without any preferential direction, revealing only slight vegetation changes when compared to the restored one.

In each zone of the restored side-arm, the temporal trajectory between 1981 and 1998 appears very long and of large amplitude revealing anthropogenic impacts on this ecosystem. The vegetation composition changed after the completion of the hydroelectric scheme and the position of the zones on the factorial map moved toward positive scores along the first factorial axis, except in the upstream zone (Rn1), that showed a slight opposite change. Meanwhile, after the construction of a weir on the Rhône River, the three zones of the restored side-arm continued to increase their positive scores on the first factorial axis, reaching almost maximal values. After this, vegetation changes over time remained rather low between 1986 and 1992, except in the upstream zone (Rn1) where changes were extensive. The effect of restoration (March 1993) is very clear since the position of each zone moved from positive scores along the first two axes in 1992, to negative scores along these two same axes in 1993. In 1994, the vegetation composition did not seem to change very much in the downstream zone (Rn3; a slight change in negative scores of the second axis), but changed greatly in the other two zones which moved toward positive scores on the first factorial axis, and also to higher negative scores on the second factorial axis. In the last three years of the study (1996-1998), the vegetation in each zone of the restored side-arm seemed to reach a quite stable composition close to that observed from 1994, with slight changes along the second factorial axis.

These trajectories result from changes in species abundance and location. A few examples may be used for the illustration of such changes. Some species that were dominant before the restoration in the restored side-arm (e.g. *Ceratophyllum demersum* and *Lemna minor*), decreased significantly and almost disappeared from the restored side-arm after the operation. Other species such as *Elodea canadensis*, which was abundant on only few transects before restoration in the restored side-arm, developed significantly after restoration (from 1994) and became dominant. Some species absent before the restoration (e.g. *Groenlandia densa*), colonised the restored ecosystem while they remained absent in the reference ecosystem.

According to the species composition of the aquatic vegetation, the ecosystem status, observed after the restoration corresponds to a less advanced successional stage than the status observed before the operation. Eutrophic plant species dominant before restoration (e.g. *Ceratophyllum demersum*, *Lemna minor* and *Lemna trisulca*) almost disappeared and were replaced by numerous mesotrophic species (e.g. *Berula erecta*, *Callitriche platycarpa* or *Groenlandia densa*).

The results of the present restoration experiment confirm the hypothesis on which the project was based: the increase in groundwater supply was capable of instigating a successional regression from a very eutrophicated status (before restoration) toward a mesotrophic status (after restoration). The present results also demonstrate ecosystem resilience, i.e. its ability to rapidly self-recolonise from plant propagules remaining in sediments or drifting during floods. The success of this restoration as well as the self-sustainability reached 6 years after the operation also argue for restoring ecosystem processes rather than just changing the habitat conditions. In other words, the restoration consisted in promoting a natural process (in the present case, the groundwater supply) and then in letting the ecosystem do the work.

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WATER PROTECTION - A GREAT ENVIRONMENTAL CHALLENGE: THE RESEARCH INITIATIVES OF THE ENVIRONMENT INSTITUTE OF THE EUROPEAN COMMISSION

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Abstract

The purpose of this paper is to introduce and briefly present (i) the most critical European freshwater problems; (ii) the needs for EU water research and (iii) the current EU responses to these problems. It discusses the practical aspects which the Environment Institute (EI) of the European Commission faces in ensuring that its RTD programme addresses the right key issues, links in with relevant European water issues, and delivers practical results to the end-user. It summarises the main EI research priorities

In the field of water, the EI through LEPE (Laboratoire Européen pour la Protection des Eaux) plays a key role in support of the EU water policy, carrying out research for the implementation of the Water Framework Directive and the application of the other relevant Directives (e.g. drinking water, urban waste waters, nitrates, bathing waters).

The new WFD has fundamentally reviewed the Community water policy. It aims at preventing deterioration of ecological status and pollution and restoring all surface waters and ground waters. The Directive identifies a framework for integrated water management with river basin districts as a basis for co-ordination of the necessary planning and action. This means that natural limits (not administrative borders) of a river basin shall be the object of a coherent management and, consequently, water management needs to be re-organised in many regions and European river basins.

Finally, the paper will describe the application of this new concept in an Italian river basin, aiming to define instruments for the optimisation of water resources planning and management. The EI approach has been used in a case study for comparing predicted changes in surface water quality and for contributing towards the assessment of the environmental (and economical) benefits of both national and European legislation.

1. The context

Freshwater ecosystems are strategic resources for human society. Freshwater is directly used to produce drinking water, food, energy, to fight fires and for recreation activities. In obtaining these benefits, some 4,000 km^3/yr of water world wide are diverted from natural ecosystems for all human uses (WWC, 1988). The result is that the natural characteristics and products of freshwater have been widely disrupted, creating an urgent need for effective management.

Freshwater resources management is made difficult due to the complex interactions between man and the aquatic system. Any human activity - agricultural, industrial, urban, or transport - will impact on the availability and quality of freshwaters. It is, therefore, inevitable that conflicts exist both within and between:

- the various *uses of freshwater*;
- the various types of *land use*;
- the role of water in sustaining the *natural environment*.

The management of water resources, and the balancing of often-conflicting requirements, is made further complex by the diversity of the natural environment, and by natural variations in climate (e.g. rainfall) in both space and time. Annual precipitation, for example, can exceed 3,000 mm on the north Western European coast, but falls to below 500 mm in south Eastern and central Spain, and some parts of Italy and Greece.

The incorrect management of the aquatic system can result in biological impoverishment and potential threats to human health and quality of life.

The pollution of surface waters by wastewater discharge, the inappropriate use of agricultural chemicals, poor solid waste disposal practices, and contaminated industrial sites are some of the factors that contribute to the *contamination* of surface and groundwater.

A series of *meso scale phenomena* (e.g. altered flow regimes, climate and land use change) are also altering the natural water cycle and can induce water shortages and floods in many parts of Europe.

In Europe, water stress (both in quantity and quality) exists in many places, resulting in serious problems (flooding, water shortage, pollution and ecosystem damage).

Recently, the European Environment Agency (European Environment Agency, 1999) identified the major water problems in Europe at the dawn of the third millennium.

- In the European Union, the Accession Countries and the European Free Trade Association Countries, *total water resources* amount to about 1,900 km^3/yr, of which 16% are abstracted and 5% consumed (not returned to the site of abstraction). The principal source of abstracted freshwater in the EU Member States is surface water (ca 75% of the total water abstracted for all uses) with a large part of the remainder from groundwater and only a minor contribution from desalination of sea water and from re-use of treated effluents.

- *Demand for water:* it is generally decreasing in recent years. Industry households have increased their efficiency in using water. The prospects for water use largely depend on future trends in agricultural use, which will be affected by developments in the Common Agricultural Policy, and the extent to which water pricing is economically efficient.

  Availability of water: one third of European countries have relatively low availability of water (less than 5,000m^3 per capita per year). Transboundary river flows make up a significant share of the resources in many countries: 20 European countries depend on other countries for more than 10% of their water resources. In Hungary for instance, freshwater from upstream countries accounts for as much as 95% of the total resource while Germany, Greece and Portugal, rely on imported water for over 40% of their resources. Groundwater over-exploitation occurs in 60% of large European cities.

- *Flooding*: it is the most common form of natural disaster in the Mediterranean region and in central Europe.

- *Deterioration of water quality*: according to recent data, the concentration of pollutants, associated with point sources, in a number of polluted rivers is decreasing. The improvements have been less significant in Southern and Eastern Europe. The P level of European lakes has decreased significantly, but water quality in many lakes in large parts of Europe is still poor. Nitrate concentrations in EU rivers have shown little change since 1980 and the reduced use of nitrogen fertilisers in agriculture does not seem to have resulted in lower levels of nitrate.

  In the EU, a high proportion of wastewater is treated before discharge: 90% of the EU population is connected to sewers and 70% to wastewater treatment plants. In the Accession Countries, 40% of the population is not connected to sewers and for 18% wastewater is discharged untreated.

  The remaining 42% of the wastewater is treated before being discharged into surface waters, with most waste water receiving secondary treatment to remove organic matter.

  Pollutants, such as nitrates, persistent organic pollutants, heavy metals that are associated with diffuse sources generally remain problematic.

  In addition to the well known hazardous pollutants such as nitrates, pesticides and heavy metals, two additional pollution threats have increased in priority over recent years: *microbiological threats* which can have an immediate and life threatening impact, and *endocrine disruptors* which can have inter-generational consequences.

  The relatively recent identification of pathogens (e.g. *Giardia* and *Cryptosporidium*) and *toxin-producing algae*, which can be potentially transmitted through drinking water supplies, has redirected political and scientific attention to the source and impact of pathogenic agents and their destruction/removal. Microbiological contamination of bathing water, mainly in the Mediterranean region, is estimated to result in over 2 million cases of gastro-intestinal illness annually.

Where *drinking water* supplies are drawn from surface waters downstream of wastewater discharges there may also be possible implications for drinking water quality. The ability of drinking water treatment plants to deal with the probably very small concentrations of an, as yet, unidentified set of possible endocrine disruptors, is also not known:

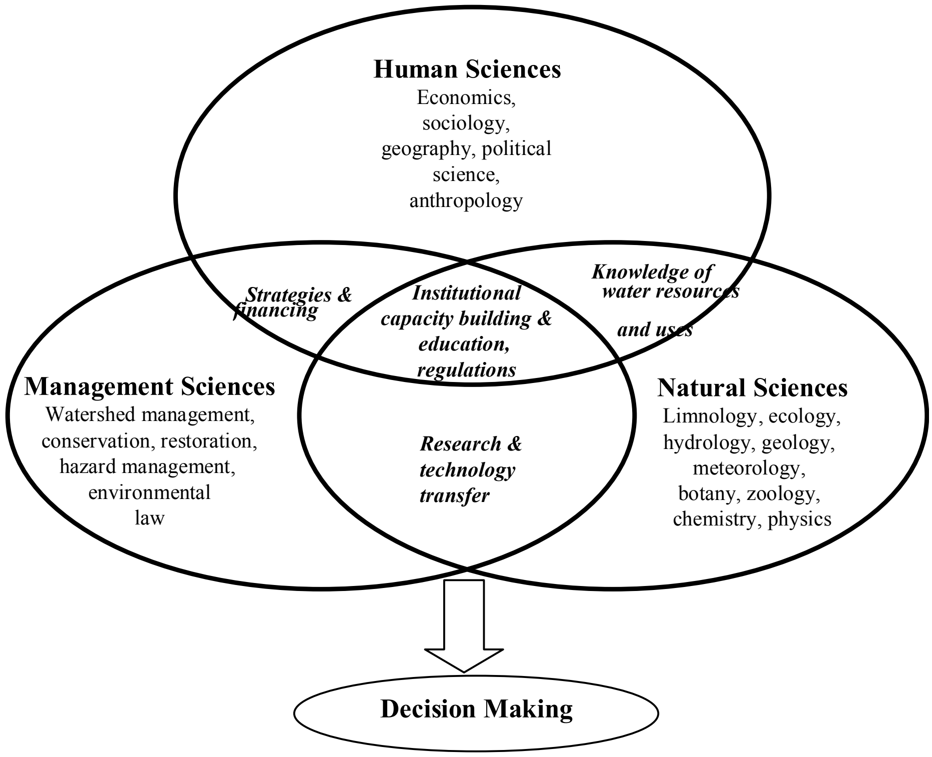

Figure 1. Interrelations among sciences involved in a sustainable management of freshwater resources.

From the above, the main general water related problems and needs Europe is facing today are:

1. a lack of *integrated* ***approaches*** to the solution of potential water problems and the need to combat major ***flooding***;
2. the need to combat ***regional water stress*** (and ***droughts***), the possible deterioration of the resource and the threats associated with climate and land use change;
3. a lack of understanding of the ***current status*** and possible evolution of freshwater resources;
4. a lack of understanding of the sources, pathways and impacts of ***hazardous pollutants***; including ***microbiological*** pollutants (e.g. pathogens, toxin-producing algae) and a new group of contaminants known as ***endocrine disruptors***;

5. the need to combat the continuing, and increasingly important, threat of ***diffuse pollution sources***, which contaminate strategic groundwater reserves (especially from agriculture);
6. the need to ***restore*** and ***rehabilitate*** damaged freshwater ecosystems and to minimise the ***future environmental impacts*** of proposed water supply options;
7. a lack of efficient and cost effective ***water treatment*** and ***network management technologies.***

2. The research needs

The *majority of EU Member States* have dedicated national research programmes and initiatives to face the water problems mentioned above. They include:

- Monitoring strategies, data management and analytical methods;
- Sources, impacts and the control of diffuse sources (especially from agriculture);
- Freshwater ecology, including biomonitoring;
- Drinking water and health;
- Wastewater and sludge treatment;
- Groundwater and soil remediation;
- Cleaner and environmental technologies;
- Crises management (especially floods and dam breaches);
- The impact of climate change on water resources;
- Supporting socio-economic research.

Many of these problems/themes also figure in international programmes and in research agendas for the sustainable development of water resources. Several associations, unions and commissions have provided research priorities in water resource problems.

However, there is a strong overlap among the research priorities and actions proposed by different international programmes.

Thus, a concerted effort has been made at the EU water research level (i) to avoid the waste of money (duplication of research projects), (ii) to optimise the use of research results (development of adequate means of information), (iii) to better concentrate the research on priority European issues and (iv) to satisfy EU initiatives.

The *Task Force Environment-Water,* (European Commission JRC-DGXII.,1998) in defining a water research agenda, has emphasised a problem/goal oriented approach whilst recognising the need for exploratory research where problems are poorly understood and ill defined in terms of potential solutions. One of the aims of adopting this approach was to promote synergies among the relevant disciplines and to encourage the coupling of efforts among the different actors involved - scientists, industrialists, land-use planners, regulators, policy makers, etc.

The inter-sectorial nature of freshwater problems are such that a research agenda requires more effective integration among the human and natural sciences (basic research) and management science (applied research), and more effective information transfer and co-operation among these sciences. The conceptual framework for linking human, natural and management sciences is presented in figure 1.

The Task Force identified four broad "axes", corresponding to the principal preoccupations of European citizens:

- combating pollution;
- rational use of water;
- combating chronic water deficits;
- prevention and management of crisis situations.

The Task Force Environment-Water identified the following ten high priority areas for EU collaborative research on the sustainable use of water resources:

1. **Water Resources Assessment and Surveillance**, concerning the development of basic knowledge and indicators of the overall status and evolution of freshwaters.
2. **Water Resources Management at the Local/Regional Level,** including the provision of integrated management tools for combating water chronic deficits and flood forecasting and management, the rehabilitation of polluted aquifers.
3. **Pollution Sources, Pathways and Impacts,** addressing the research on key hazardous pollutants (e.g. endocrine disruptors, microbiological threats and toxin producing algae) and developing a predictive approach (eco-toxicological screening and testing methods).
4. **Water and Wastewater Treatment,** improving treatment technologies for small operators, advanced technologies, desalination technologies, ensuring the re-use/disposal of treatment sludge.
5. **Urban Water Systems,** extending experience and best practices, improving network management and technologies.
6. **Water in Agriculture,** promoting water re-use (water quality standards), water efficient irrigation practices, water efficient agricultural practices, prevention of diffuse pollution.
7. **Water in Industry**, promoting water conservation, re-use.
8. **Socio-economic Aspects,** addressing the people's perceptions and expectations, awareness on water pollution problems, information transfer to all users, assessing the implications of the "cost recovery" approach.
9. **International Co-operation,** reinforcing of the EU position in international co-operation through the demonstration of EU technology/know-how.
10. **Promotion of Research and Innovation,** promoting concertation and co-ordination, stimulating the development of education and training programmes.

Lastly, the Task Force initiative has led to the proposal for a Key Action on *Sustainable Management and Quality of Water* in the Fifth Framework Programme (FP5) for research, technological development and demonstration activities.

The aim of this key action is to produce the knowledge and technologies needed for the rational management of water resources for domestic needs and those of industry and agriculture. Among the priority fields concerned are:

- *Treatment and purification technologies to prevent pollution, to purify water and to use and/or re-use water rationally; integrated approach to management of water resources and wetlands.*

- *Technologies for monitoring and preventing pollution and the protection and management of surface and ground waters, including ecological quality aspects.*

- *Surveillance, early warning and communication systems*

- *Technologies for the regulation and management of stocks and technologies for arid and semi-arid areas and generally water-deficient regions.*

3. The EU responses

The EU has responded to the European water problems in a number of different ways (European Commission, Joint Research Centre.):

- through the support of *new institutional mechanisms* (e.g. the Task Force Environment-Water, the European Topic Centre on Inland Waters of the EEA);
- the *"greening*" of existing EU economic policies (e.g. agriculture, industry, regional and cohesion, and external relations);
- through the development of new *environmental policies and initiatives* (e.g. the Fifth Environmental Action Programme, the proposed Framework Water Directive);
- the financing of *demonstration* (e.g. LIFE, THERMIE), *technical assistance* (e.g. TACIS) and *infrastructure* (Structural and Cohesion Funds) *projects* in the water sector in both Europe and around the world;
- the sponsorship of *international co-operation* in the water sector.

These responses have been discussed at length in the frame of the EU Task Force and some of them are summarised below.

3.1 Fifth Environmental Action Programme

In 1993 the Fifth Environmental Action Programme was published. This established a set of long term objectives for a number of environmental issues and target sectors of the economy, including:

- the management of water resources and a number of environmental issues strategically linked to water management (e.g. climate change, acidification);
- a number of specific geographic contexts (e.g. urban and coastal zones);
- five sectors of human activity that have particularly significant environmental impacts: agriculture, industry, energy, transport and tourism.

The *key water resource objectives, and related targets and actions,* were:

- to ensure demand of water that should be in balance with its availability through integrated water management, embracing agriculture, industry and land use planning;
- to maintain and improve groundwater quality through preventing point pollution and reducing diffuse pollution;
- to maintain a high ecological quality of surface waters through the development and implementation of the Water Framework Directive.

In 1996 the Commission published a progress report on the Fifth Environmental Action Programme. In relation to the water resources the report highlighted the main problems (which are still valid today) and needs on the regulatory, planning and management, and the research sides.

3.2 European Environment Agency (EEA)

The EU launched this in late 1993. The purpose of the EEA is to provide the European Community and its Member States with reliable and comparable information at the European level thereby enabling policy makers to take the appropriate action.

The EEA works through the European Information and Observation Network (EIONET) which consists of reference centres in every Member State co-ordinated by National Focal Points as well as a number of European Topic Centres which work at European level on specific media. The Topic Centre on Inland Waters (ETC/IW) has designed a new freshwater monitoring network (EURO-WATERNET).

The current actions of the EEA in the field of water are:

- to improve knowledge of the *biological* and *ecological* effects of the major pressures and establish operational indicators of ecological quality for inland waters, estuaries and coastal waters;
- to progressively *test* and *implement* the pan European water resources *monitoring network* to assess and report on the state and trends of the aquatic environment;
- to study the *quality of water resources* in Europe in relation to the present and future uses of water;
- to assess sustainable *management of water resources* on a pan European scale, with particular attention paid to the shift to demand side management;
- to develop integrated *environmental assessments* on specific issues (e.g. eutrophication), and define data needs for modelling in order to predict changes;
- to improve the *knowledge of human interventions* in the hydrological cycle, and other pressures on the water environment

3.3 Environmental Policy

Legislation has been the single most important instrument of the Community's policy for ensuring the quality of water throughout the EU and in controlling pollution of the aquatic environment.

It is beyond the scope of this paper to discuss in detail the water related Directives, however the latest initiatives of the Commission are summarised below.

In the past two complementary approaches have been followed, with the establishment of environmental quality objectives (EQOs) for the receiving water bodies, and the adoption of emission limit values (ELVs) for industrial discharges. The Directives on water pollution may be divided into three fundamental categories. The first includes a group of directives in which quality standards are fixed which vary depending on the use for which water is intended (i.e. drinking, bathing, fish, shellfish). The second group concerns specific sectors or industries (i.e. nitrates from agriculture), while the third deals with discharges of dangerous substances (i.e. groundwater, dangerous substances, urban waste waters).

A new policy approach to water pollution and protection of aquatic ecosystems has been developed over the last decade, which recognises that the issues of quality, quantity and availability of water resources cannot be separated. Therefore, in February 1996 the Commission launched a Communication setting out guidelines for a new EC water policy. This Communication (Communication from the Commission to the Council and the European Parliament, 1996) listed a number of objectives of a sustainable water policy as follows:

1. *The drinking water must be safe and it must be provided in sufficient quantity and with sufficient reliability.*
2. *Water resources should be of sufficient quality and quantity to meet other economic requirements such as needs of agriculture, fisheries, industry, transport and power generation activities as well as recreational ones.*
3. *The quality and quantity of water resources and the physical structure of the aquatic environment should be sufficient to protect and sustain the good ecological state and functioning of the aquatic environment.*
4. *Waters should be managed so as to prevent or reduce the adverse impact of floods and minimise the impact of droughts.*

Following an extensive consultation process, the Commission made proposals in February 1997 for a new Water Framework Directive (WFD). In October 1999 the Council of the EU adopted its common position on the Commission proposal (Council Common position (EC) n.41/1999 OJ C343, 30.11.1999).

The principle objective of the WFD is to establish a framework for the protection of surface water and groundwater in the EU (see third objective of a sustainable water policy). This framework is based on the natural unit for the management of water, i.e. the river basin, rather than the administrative unit approach. It is designed to protect and enhance the quality and quantity of aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems.

As concerns the abatement of pollution, it formalises the so-called “combined approach”, i.e. the integration of EQOs for water with the ELVs for water pollutants.

The overall environmental objective in the proposed Directive is to achieve *good status* in all waters at the latest 16 years after the entry into force of the Directive. For groundwater good status is measured in terms of both quantity and chemical purity; for surface waters ecological quality is an added criterion. A combined approach to pollution control is envisaged requiring both limit values to control emissions from individual point sources and environmental quality standards to limit the cumulative impact of emissions. The WFD will be the first piece of Community water legislation to address the issue of water quantity.

Perhaps, the most important innovation proposed in the FWD is the introduction of cost recovery pricing. Member States would be required to ensure that the price charged to households, farmers and industry for water services reflects the true cost of the abstraction and distribution of freshwater and the collection and treatment of wastewater. It is intended that the costs of water services will include environmental damage caused by water use, and the effects of depletion on future generations.

In addition to the WFD, another piece of EC water legislation is currently under review. A proposed amendment of the Bathing Water Directive was presented in 1994. The quality of bathing water constitutes an important element for tourism and is of interest to all Member States. In fact, the Directive is applied in more than 16,000 individual bathing areas, in the EU.

4. Water research at the Environment Institute

The above mentioned environmental policy is generating enormous investment in the field of water: the cost estimations of the implementation of the urban wastewater Directive alone account for about 150 billion Euro. Furthermore, the enlargement of the EU will increase considerably the investment needed, considering that many of the pre-accession countries have considerable structural deficiencies in the field.

Taking into account the major European environmental challenges as well as the needs of EU policies, which address them, the main research priorities of the *Environment Institute of the European Commission* in the field of water are summarised below. They will allow fulfilling its mission in support of the conception, implementation and monitoring of EU policies beyond the on-going Framework Programme 1999-2002.

- Definition of current ecological status of water bodies, analysis of river basin rehabilitation plans, relationships between inland/coastal waters, development of water indicators.

- New concepts and tools for water quality assessment, emphasising new concepts of molecular eco-toxicology and *in situ* sensors. Development of quantitative detection methods for all relevant waterborne pathogens and drug residues in drinking water.

- Assessment of actual ecological and socio-economic benefits of water re-use technologies in connection with renewable energies, removal of endocrine disruptors in waste waters.

- Research on the behaviour of construction products and disinfection by-products in contact with drinking water.

- Relationships between agri-environmental policies and the status of inland watershed and associated coastal waters.

- Effects of climate change resulting from global warming on the renewable water resources in Southern Europe. Variation in the risk and intensity of drought and floods.

- Socio-economic research to provide more harmonised European approaches for water management, taking into account the harmonisation of fiscal policies and the need for a more developed and open water market.

- Development of harmonised and validated monitoring methods in the framework of the implementation of water directives into the Accession Countries.

The implementation and the success of new legislation need to be monitored (i.e. by the monitoring of changes in water quality and the assessment of environmental benefits).
Taking into account the new approach, laid down in the WFD (i.e. the water management at river basin scale), the EI is carrying out research in some Italian river basins of the Po catchment area. The aim is to define instruments (i.e. models, informatic systems) for water resources planning and management procedures in order to safeguard the quality of surface water resources.

4.1 A case study of water management at river basin scale

The Lombardy region, extending from the Alps to the River Po plain, is characterised by numerous lakes, rivers and canals. The concentration of human activities, in the 23,900 km^2 of Lombardy, places it amongst Italy's most important regions economically; the region's population of 10 million generates 28% of Italy's gross domestic product.

Water quality and availability are relevant factors in all the region's economic activities. Therefore, the authorities are taking definite actions to deal with water resource problems, and in particular to restore and safeguard the quality of surface waters.

The main goal of the project is to define methodologies and instruments that will assist the regional authorities to manage, restore and protect Lombardy's water resources. The Lake Iseo basin is one of the study areas selected for this project. Two types of models were applied in the basin to simulate the impact of several water quality management scenarios on the quality of its surface waters: the DESERT[2] water quality/river model and the EVOLA[3] lake models.

The first is a one dimensional river/water quality model to simulate the transport and decay of nutrients and BOD_5 through the Oglio river system (including its tributaries). The lake models are dynamic box models to evaluate the average total P concentration trends. An important element in this study has been the identification of domestic and industrial sources of pollution in the Oglio River basin.

Two types of water quality management scenarios were applied to the calibrated river model: the Regional Water Clean-up Plan PRRA (1992) and the Urban Waste Water Treatment Directive (91/271/EEC). The scenarios are summarised in the following table.

Table 1 Description of water quality management scenarios simulated with the DESERT model

Scenario	Description
2005 PRRA	Constructing wastewater treatment plants (WTPs) and/or connecting population to existent plants in administrative communes located at elevations greater than 700m
2010 PRRA	Constructing WTPs and/or connecting population to existent plants in the remaining administrative communes
2016 PRRA	Enhancing the efficiency of waste water treatment process in numerous WTPs
UWWTD	The Oglio river basin is a sensitive area. Thus, all members of the population are served by waste water treatment plants

The PRRA scenario comprises three sub-scenarios (Al-Khudhairy *et al.*, 1999):

(1) **Scenario 2005** - hypothetically constructing new waste water treatment plants by the year 2005 in administrative communes located at elevations greater than 700 m.
(2) **Scenario 2010** – constructing new wastewater treatment plants in the remaining administrative communes by the year 2010.
(3) **Scenario 2016** – in addition to the waste water treatment plants constructed in scenarios 2001 and 2010, this scenario also includes upgrading waste water treatment processes in existing plants by 2016 (i.e. improving waste treatment efficiency).

For these *three* PRRA scenarios, only administrative communes with greater than 70% of the population covered by a sewer network system were considered. On the other hand, the EC scenario assumes that the Oglio River basin is a "**sensitive area"** and thus, wastewater treatment plants serve the entire domestic and industrial

[2] DESERT has been developed jointly by the International Institute for Applied System Analysis, Austria and the Institute for Water and Environmental Problems, Russia.
[3] EVOLA models have been developed by the Environment Institute, JRC-Ispra.

populations. In other words, it also takes into consideration administrative communes with poor or no sewer network coverage.

The results of the work undertaken herein show that although the reductions achieved by the PRRA 2016 scenario are lower, for total P and BOD_5, than the reductions obtained with the UWWTD scenario, the concentration values simulated by both scenarios fall within the same water quality classes (see table below). However, there is one important difference between these two types of scenarios: the UWWTD scenario would require higher investments to actualise because it does not allow untreated urban waste to enter the Oglio River or its tributaries. Thus, sewage pipelines would have to be constructed in sites in administrative communes where there is no sewage pipeline network. On the other hand, the PRRA 2016 scenario does not foresee this "extra" cost because it only allows for waste treatment plants to be constructed in areas where sewage pipeline networks are already existent. Furthermore, the PRRA 2016 scenario only allows sectors with sewage pipeline networks to be connected to newly constructed waste treatment plants. Bearing in mind the arguments that have just been put forward, the UWWTD scenario is not necessarily superior to the PRRA 2016. On the contrary, the PRRA 2016 has been shown to achieve similar water quality enhancements but at much lower economic costs.

The overall conclusion of these modelling exercises is that the most ambitious PRRA scenario (2016) is relatively stringent. The reason being is that the scenario has achieved reductions in pollutant loads at the Oglio River mouth that are comparable with those achieved by the UWWTD, bearing in mind that the latter scenario is an *extreme* case. The EU scenario is extreme because it assumes that the entire Oglio River basin is a *sensitive* area (i.e. a water body prone to eutrophication or in danger of becoming so).

Table 2 Comparison of simulated reductions in pollutant concentrations, achieved at the Oglio River mouth, by the PRRA and EEC UWWT Directive scenarios

Scenario	Reduction of Total phosphorous concentrations (%)	Reduction of NH_3-N concentrations (%)	Reduction of BOD_5 concentrations (%)	Rise in DO concentrations (%)
PRRA-2005	**5**	**4**	**0.19**	**0.19**
PRRA-2010	**24**	**25**	**22**	**0.71**
PRRA-2016	**30**	**29**	**22**	**0.81**
UWWTD	**42**	**60**	**46**	**2.0**

These scenarios have been considered to be representative of the regional authority's objective to reduce the total phosphorous loads entering Lake Iseo, and to restore the lake as close as it is practically possible to its former natural status. Both modelling exercises demonstrate the impacts of these scenarios on the Oglio River and Lake Iseo

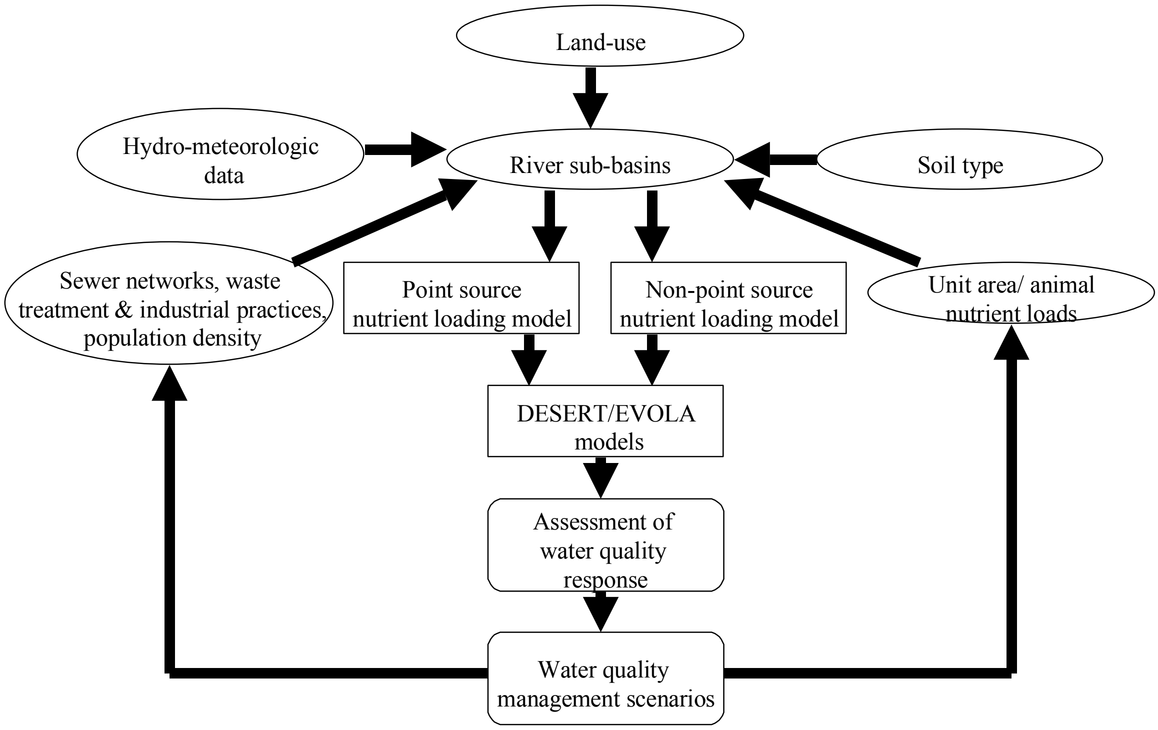

Figure 2. A simple framework for water management of the Oglio river basin.

total P concentrations. Moreover, it has been shown that the framework proposed (fig.2) is a very useful tool for comparing different water management scenarios and for assessing environmental benefits of national and European water policies.

5. Conclusive remarks

The above example illustrates a cost-effective way of meeting EQOs and assessing environmental benefits in a river catchment basin. However, problems to fully apply the concept of the WFD in water management still exist. They are:

1. Inadequacy of knowledge, in particular the process dynamics;
2. Difficulty in ensuring correct water balances;
3. Difficulty to increase the receptive capacity of water bodies and to restore the ecological integrity of surface waters;
4. Lack of graduation in the planning of the objectives.

There are two aspects where knowledge is frequently lacking. The first concerns the drainage system for pollution loads and in particular the percentages and the pathways of that part of the loads not drained by the artificial network; the second concerns the cost/efficiency analysis, also in terms of return times for investments in purification. Corresponding to this weakness in strategic analysis there is an evident disequilibrium between the insistence in choosing severe levels of control and the possibility of reaching them efficiently. This originates in the difficulty or impossibility of making correct balances for the use of resources (water balances).

This constitutes the main obstacle to the correct implementation of the important rule for the *ecologically acceptable flows* (EAF). Since the objective of the EAF is the only one capable of correcting efficiently the excessive recourse to purification technologies, it is evident that to reach it (representing the true strategic basis of a water policy) we need to reinforce local managers and to give them discretional powers in planning and programming the actions necessary over time, which at present they do not have.

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RIVERS AND MANKIND: AN INTERNATIONAL ENVIRONMENTAL AND HUMAN RIGHTS PERSPECTIVE

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Rivers are essential to mankind as the repository of much of the limited freshwater available for use. Like other components of nature, rivers are not respectful of political boundaries although sometimes they have been used to demarcate national territories. A recent World Bank study noted that over 245 river basins are shared by two or more states, with almost half of the world's land and forty percent of the global population dependent upon or benefitting from these waters. Rivers provide avenues of transportation, irrigation for crops, drinking and bathing water, a habitat for flora and fauna, industrial cooling, recreational venues, and water for sanitation purposes.

The multiplication of water uses and growth of human population have led to competition and conflict among uses and between riparian states and have created problems of water quantity and quality. In response, the international community has sought to elaborate principles and rules for the protection of the vital river resources and to allocate them among the various interested parties. Several different approaches can be seen in recent international legal instruments and studies. These texts provide legal and policy frameworks for cooperation between riparian states and communities. It is not clear, however, that the different approaches are compatible with each other and more recent developments may be intended to override earlier ones or they may compete for acceptance in the coming years as states choose which instruments to ratify and what further texts are needed.

First, on the global level, the International Law Commission completed its work on the non-navigational uses of international watercourses, leading to the conclusion of a treaty adopted and opened for signature by the United Nations on 21 May 1997. The treaty aims at promoting cooperation and avoiding dispute among riparian states. Second and regionally, the UNECE in its *Convention on the Protection and Use of Transboundary Watercourses and International Lakes* (Helsinki, 17 March 1992) and the recent *Protocol on Water and Health* (London, Sept. 1999) have focused on human needs and the environmental protection of rivers. The same approach is seen in individual watercourse agreements, such as the *Convention on Cooperation for the Protection and Sustainable Use of the Danube River* (Sofia, 29 June 1994). Third, the United Nations Commission on Human Rights has begun to consider the issue from the human rights perspective, appointing a special rapporteur on the right of access of everyone to drinking water supply and sanitation services. These various approaches are the topic of the following brief comments.

1. The *UN Watercourses Convention* encourages states sharing watercourses to enter into agreements that apply and adjust the provisions of the Convention to the characteristics of the watercourse concerned. The Convention also sets forth "General

Principles" which the parties should "consider harmonizing" with their specific watercourse agreements. The first principle is "equitable and reasonable utilization," which many regard as the founding principle of the law of international watercourses and which was referred to in the ICJ Judgment in the *Gabçikovo-Nagymaros* case. Convention Article 5 provides that to be equitable and reasonable a use must be consistent with adequate protection of the watercourse from pollution and other forms of degradation. Article 5 also introduces the concept of equitable participation. Article 6 sets forth a non-exhaustive list of factors to be taken into account in making the determination whether or not a use is equitable and reasonable, while Article 7 affirms the duty not to cause significant harm to another state. The interrelationship of the three articles remains highly debated, in light of the difficulty in reconciling them, the lengthy drafting history with its myriad changes, and the divided vote that produced the compromise language. A further important provision is Article 10 which provides:

- In the absence of agreement or custom to the contrary, no use of an international watercourse enjoys inherent priority over other uses.

- In the event of a conflict between uses of an international watercourse, it shall be resolved with reference to articles 5 to 7, with special regard being given to the requirements of vital human needs.

This somewhat ambiguous, if not contradictory, formulation was supplemented by a "statement of understanding" accompanying the text of the Convention. The statement indicates that "in determining 'vital human needs,' special attention is to be paid to providing sufficient water to sustain human life, including both drinking water and water required for production of food in order to prevent starvation." The "special regard" and "special attention" referred to still have to be read in the context of Article 10 (1).

While the Watercourses Convention requires ecosystem protection and refers to basic human needs, it is fundamentally neither an environmental protection agreement nor a human rights treaty. It is rather a framework agreement for allocating rights to international watercourses in an attempt to avoid disputes and conflicts. Other agreements and customary international principles regarding environmental protection and human rights must be taken into account, however, as the Convention itself dictates.

2. Turning to the second approach, within Europe the *Helsinki Convention on the Protection and Use of Transboundary Watercourses and International Lakes* (17 March 1992) takes an environmental approach to international watercourses. Its general provisions in Article 2 begin by stating that "the Parties shall take all appropriate measures to prevent, control and reduce any transboundary impact" and in particular, shall take all appropriate measures to prevent, control and reduce pollution; ensure ecologically sound and rational water management, conservation of water resources and environmental protection; use the waters in a reasonable and equitable way; and ensure conservation and, where necessary, restoration of ecosystems. The agreement calls for application of the precautionary principle, the polluter-pays

principle, respect for the needs of future generations, and cooperation between riparians.

The 1999 Protocol to this agreement, jointly prepared by the UNECE and the European office of the World Health Organization, goes further and calls on the Contracting Parties to take all appropriate measures to prevent, control and reduce water-related disease and to establish water management systems to ensure sustainable use of water resources, ambient water quality which does not endanger human health, and protection of the water ecosystems. In particular, it requires that all appropriate measures be taken to ensure adequate supplies of drinking water and sanitation, especially through the protection of water resources, and water for the purpose of irrigation, the production of fish by aquaculture, the production and harvesting of shellfish and recreational use of a quality which does not endanger human health. The Parties are to base all such measures on an assessment of any proposed measure in its implications for human health, water resources and sustainable development. Significantly, the Protocol seems to impose direct obligations on private actors. It provides that as a counterpart to their rights and entitlements to water under private and public law, "natural and legal persons and institutions, in both the public and private sectors, should contribute to the protection of the water environment and the conservation of water resources." (Article 5(i)).

The *Sofia Convention on Cooperation for the Protection and Sustainable Use of the Danube River* has an orientation similar to that of the Helsinki Agreement. It calls on Parties to strive at achieving the goal of sustainable and equitable water management, including the conservation, improvement and rational use of surface and ground water in the Danube catchment area. Parties to the treaty are also to make all efforts to control hazards and are to take all appropriate legal, administrative and technical measures to maintain and improve the current environmental and water quality conditions of the waters of the Danube catchment area. (Article 2(1) and (2)). They must set priorities aimed at sustainable development and environmental protection to ensure sustainable use for municipal, industrial and agricultural purposes, as well as the conservation and restoration of ecosystems, and meet the requirements of public health. All measures taken are to be based on the polluter pays and precautionary principles. Article 6 reiterates the need for measures to prevent or reduce transboundary impacts, for sustainable and equitable use of water resources, and for conservation of ecological resources. In particular, Parties are to "(a) enumerate groundwater resources subject to a long-term protection as well as protection zones valuable for existing or future drinking water supply purposes. . . [and] (b) prevent the pollution of ground-water resources, especially those in a long-term perspective reserved for drinking water supply, in particular caused by nitrates, plant protection agents and pesticides as well as other hazardous substances..." Water quality and emission limits should be set, environmental impact assessments, inventories and monitoring should be undertaken, and information and data exchanged and made public.

The references to drinking water supplies in the regional agreements leads to consideration of the third and most recent approach, that of human rights.

3. In addition to international environmental law, international human rights law represents one of the fundamental values of modern international society. The intersection of the two subjects has been under study and various claims have been made that minimum environmental conditions are or should be recognized as human rights. One of the most developed of these claims, at least on the global level, is the claimed right to safe and adequate drinking water. Such a right appears in the 1989 U.N. *Convention on the Rights of the Child*, Art. 24, which generally concerns the right of the child to health. According to it, States Parties agree to take appropriate measures "to combat disease and malnutrition… through the provision of adequate nutritious foods and clean drinking water, taking into consideration the dangers and risks of environmental pollution." All but two countries in the world have become party to this agreement (Somalia and the United States). More generally, and without explicitly referring to drinking water, the *Covenant on Economic, Social and Cultural Rights* calls for steps to be taken to achieve the full realization of the right of everyone to health, through the improvement of all aspects of environmental and industrial hygiene and the prevention, treatment and control of epidemic, endemic, occupational and other diseases.

In 1997, the United Nations Sub-Commission on Prevention of Discrimination and Protection of Minorities appointed a Special Rapporteur to draft a working paper on the promotion of the realization of the right of access of everyone to drinking water supply and sanitation services (E/CN.4/Sub.2/1997/18). The decision, adopted without a vote, referred to the indivisibility, interdependence and interrelated nature of all human rights and invoked specific human rights texts, including the *Declaration on the Right to Development*, as well as environmental texts such as *Agenda 21.* The resolution explicitly affirmed "the right of each woman, man and child to access to drinking water supply and sanitation services in order to live in dignity, security and peace." After examining the working paper, the Sub-Commission decided to re-appoint the Special Rapporteur to conduct a detailed study on the relationship between the enjoyment of economic, social and cultural rights and the promotion of the realization of the right to drinking water supply and sanitation, at both the national and international levels. The Commission on Human Rights confirmed the study at its 1999 session (Decision 1999/108), while noting "that the issue of the right of individuals to drinking water supply and sanitation services remains undefined" and requesting the Sub-Commission "to give further consideration to this aspect in preparation for a study on the realization and promotion of this right." The Sub-Commission in turn requested the Special Rapporteur to comply with this instruction and to submit a further working paper at its next session in 2000.

The working paper of the Special Rapporteur (E/CN.4/Sub.2/1998/7, 10 June 1998) emphasizes the centrality of water to the effective enjoyment of human rights, noting that it is essential to life and health, social well-being and economic productivity. The report recalls that some 1.4 billion people have no access to drinking water and almost 4 billion do without adequate sanitation services. According to the World Health Organization an estimated 80 percent of illnesses are transmitted by contaminated water. In some countries, only 20 per cent of the rural population is estimated to have water of satisfactory quality. The lack of access to drinking water and sanitation endangers the lives of millions of people who thus find their right to life threatened.

The report unequivocally concludes that because drinking water is a vital resource for humanity, it is also one of the basic human rights.

The report contains some problematic assertions from the perspectives of both human rights and environmental protection. The first problem is a seeming lack of scientific basis for some of the claims. The Special Rapporteur asserts without question or qualification that the universal disparities in access to drinking water and sanitation are a matter of bad management, citing an International Law Commission report, and stating that groundwaters have the potential to meet the minimum drinking water and sanitation needs of the entire world population. At the same time, the report notes that arid and semi-arid regions lack adequate groundwater to meet the needs of the local population. The implication that there should be transboundary sharing of groundwater resources is not made explicit, but the report calls for "equitable sharing of scientific and technological advances by developed and developing countries, and a steady increase in the use of science and technology for the benefit of the social development of society."

The report pays no attention to, indeed fails to mention, the issue of conservation of water resources, referring just once to "rational exploitation" of marine and inland water resources. Instead, it emphasizes growth, the responsibility of each state to promote the development of its people and to choose its own means and goals of development and to fully mobilize and use its resources.

While the focus is on drinking water, the rapporteur describes other uses with equal approval. Agriculture, the largest consumer of water, is supported "in view of the problem of world hunger." Indeed, the report indicates that the area of land under irrigation "is bound to increase" in order to increase food production. Industrial uses are also favored. In addition, water is seen as linked to the collective rights to culture and to self-determination "which includes the exercise of the inalienable right [of peoples] to all their wealth and natural resources"... " in full freedom and without external interference." No mention is made of freshwater ecosystems or water as habitats for flora and fauna, that is, water in its natural state. The approach is entirely anthropocentric and short-term utilitarian.

The working paper closes by identifying factors that in the view of the Special Rapporteur create obstacles to realizing the right of access to drinking water and sanitation services. These are: bad management of fresh water; lack of planning and unequal distribution of drinking water and sanitation services; the problem of external debt; structural adjustment programs; the privatization of state enterprises, particularly those linked to water services; and the regular increase in the cost of drinking water supplies. Natural, industrial, and demographic factors that impact on water use and water shortages are not mentioned.

Several questions are posed by the posited "right to drinking water." First, it is not clear from whom the right may be claimed, particularly in an arid state. Unlike pollution, which generally may be combated through prevention and clean-up, chronic drought and desert conditions are not always subject to human remediation. Efforts to do so through weather modification or redirection of rivers would likely cause more severe long-term environmental consequences. If the Rapporteur's intent is to create transboundary claims for access to water resources, it is not clear how much political support there will be for the study and its conclusions. In any event, the orientation of the Special Rapporteur seems firmly towards the right to development of each state, including the right to use water according to its own priorities, despite the stated right of access to drinking water.

Second, even if the right is deemed, like other human rights, to create claims against the state, the scope of the state's duties is very unclear, particularly in light of competing water uses and variable resources. In this regard, if the right is viewed as similar to other economic, social and cultural rights, which impose a duty of progressive realization upon a state, to the maximum of its available resources, then it is not clear what it adds to the existing catalogue of rights.

Third, the rights-based approach seems to ignore many environmental and ecological causes and consequences of the problem of water resources. On the other hand, and optimistically, perhaps a focus on the basic human need for drinking water and its articulation as a right will lead those concerned with human rights to consider the human responsibilities as well as human rights respecting natural resources. It may reinforce the consideration of environmental protection as a pre-condition for the exercise of human rights, articulated as early as 1972 in Principle 1 of the Stockholm Declaration.

Overall, the rights-based approach of the report seems to serve notice on states that drinking water, production of food, and sanitation must be given priority over hydroelectric plants or high water use industrial plants. In this regard, the approach goes further than, but reflects, the tentative language of the 1997 UN Watercourses Agreement and the more forthright references to basic human needs in the 1999 Protocol on Water and Health to the Helsinki Convention. It would seem that the trend is away from "equality of uses" towards recognition that the fulfillment of basic human needs, now and for the future, should be the objective of sustainable development and must be given priority over projects designed for prestige or export income. Whether the trend will continue and result in further developments in positive law depends upon input from civil society and the political will of concerned states.

THE PROPOSED EU FRAMEWORK DIRECTIVE WATER AND THE GABCIKOVO - NAGYMAROS PROJECT

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Introduction

The European Commission's proposal for a Framework Directive Water is of special importance for river rehabilitation of international waterways.[4] In the first place, it offers an interesting example of how one can try to set ecological standards. Secondly, on adoption the Directive will become binding for the Member States of the European Union, and in the longer term for the potential future Member States, such as Hungary and Slovakia. Thirdly, the Directive may influence the implementation of the International Court of Justice's Judgement concerning the Gabcíkovo-Nagymaros project. (International Court of Justice 1997) According to the judgement, Hungary and Slovakia have to negotiate in good faith on how to achieve the objectives of the 1977 treaty concerning the Gabcíkovo-Nagymaros project, considering the changed situation and "new environmental norms". (E.g. Hey 2000) The proposed Framework Directive Water could function as a source of such new environmental norms since it is the most recent development in Europe concerning water and environment and since the Directive may become binding for both states. In addition if new investments are necessary, EU funding is only possible if the investments comply with the European Union's environmental acquis (achievements).

This paper briefly presents the relevant provisions of the Framework Directive Water. Most important are the Directive's environmental objectives (§ 2). These objectives are established as part of a system of river basin management, which is discussed first (§ 1). An important aspect of this system is the Directive's combined emission-immission approach to pollution (§ 3). Underlying the system of river basin management are a number of analyses, which, among others, help to specify the environmental objectives (§ 4). The paper concludes that the Framework Directive Water may influence the solution of the Gabcíkovo-Nagymaros issue, but on its own it will not solve the issue. How this might be done is also discussed (§ 5).

1. The Directive's system of river basin management

The general aim of the proposed Framework Directive Water is to create a framework for the protection of inland surface water, transitional waters, coastal waters and groundwater. This framework should:

[4] The discussion in this paper is based on the version adopted by the Council on 22 October 1999. (Framework Directive Water 1999) Most previous versions of the proposal and the reactions by the European Parliament can be found at the Internet sites of the European Union. A good starting point is <http://europa.eu.int/comm/environment/legis_en.htm>.

- Prevent further deterioration and protect and enhance the status of aquatic ecosystems and – with regard to their water needs – terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems;
- Promote sustainable water use based on a long-term protection of available water resources; and
- Contribute to the mitigation of the effects of droughts and floods. (art. 1)

The Framework Directive Water tries to reach this aim in three different ways. First, the Directive requires Member States to manage their river basins as a whole. Secondly, the Member States have to achieve a good surface and groundwater status within 16 years after publication. Secondly, concerning pollution, the Member States have to apply a combined emission-immission approach. Thirdly, Member States have to take the cost recovery principle into account, including the costs of water services provision, environmental and resource costs[5] (art. 9). A number of extensive analyses and monitoring programs will be obligatory to support this system of river basin management (RBM).

The basis for the proposed RBM system is the identification by the Member States of their river basins and the assignation of the basins to "river basin districts".[6] Following this, the Member States have to ensure that appropriate administrative arrangements are made, including the identification of the appropriate "competent authority", for the application of the rules of the Directive in each national river basin district (art. 3). Next, the Member States have to ensure that an RBM plan is produced for each national river basin district within 10 years after publication of the Directive.[7] The plans have to be reviewed every six years (art. 13). Member states have to encourage active public participation of all interested parties and have to make the draft plan and several other documents available for comments (art. 14).

The core of the RBM plans – and the pivot of the whole RBM system – is the programme of measures. These programmes consist of two kinds of measures: basic measures and supplementary measures. The basic measures are measures required under existing EU directives (see the Box); measures in the framework of the proposed emission-immission approach to pollution (cf. § 4); and a number of other measures, such as a prohibition of direct discharges of pollutants into groundwater (with some exceptions) and several permitting and registration requirements. The supplementary measures are all other measures that aim to achieve the "good water status" (art. 11). Important issues that lie outside the competence of the competent authority concerned may be reported to the Member State concerned and to the European Commission. The Commission has to respond to any report or recommendation from Member States within a period of 6 months (art. 12).

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[5] The last word on cost recovery has not been said. The first version of the proposal required full cost recovery, then this requirement was watered down, following that it was reintroduced, and now once again it is watered down.
[6] Small river basins may be combined with larger basins or joined together, but river basins may not be split-up between districts. Groundwaters and coastal waters have to be assigned to the nearest or most appropriate river basin district.
[7] River basin management plans may be supplemented by more detailed programs and management plans for sub-basins, sectors, issues or water types. However, such programs and plans do not exempt Member States from the obligation to produce RBM plans. (art. 13.5)

Functions of water:
- Fish water directive (78/659/EEC)
- Water for drinking water production directive (75/440/EEC)
- Shellfish water directive (79/923/EEC)
- Bathing water directive (76/160/EEC)
- Drinking water directive (98/83/EC)

These directives set limits and/or target values for the water quality of waters that are used for the specific function or (the shellfish and fish water directives) to which the pertinent function has been attributed explicitly. The first three will be repealed by the Framework Directive Water.

Specific substances*:*
- Dangerous substances directive (76/464/EEC) and its daughter directives (mercury: 82/176/EEC and 84/156/EEC; cadmium: 83/513/EEC,; hexachlorocyclohexane: 84/491/EEC; DDT, pentachloro-phenol and carbon tetrachloride: 86/280/EEC)
- Groundwater directive (80/68/EEC)

These directives require Member States to take appropriate steps to eliminate emissions of "black list substances" and reduce emissions of "grey list substances." The daughter directives set water quality objectives and uniform emission standards. The Groundwater directive will be repealed by the Framework Directive Water (cf. § 4).

Sources of pollution:
- Urban wastewater directive (91/271/EEC)
- Nitrates directive (91/676/EEC)
- Pesticides directive (91/414/EEC)
- IPPC directive (96/61/EC)

The *urban wastewater directive* requires Member States to provide agglomerations (population equivalent more than 2000) with a sewerage system, and requires sewage treatment. The *nitrates directive* concerns agriculture and requires Member States, among others, to identify "vulnerable zones" that drain into waters (potentially) affected by nitrate pollution, and to develop action programmes for these zones. The action programme should ensure, among others, that maximally 170 kg nitrates is applied on each hectare of the land. The *pesticides directive* also refers mainly to agriculture and contains provisions on the acceptance of pesticides and stipulates that, with some small exceptions, pesticides accepted in one Member State should be accepted in other Member States as well. The *IPPC (Integrated Pollution Prevention Control) directive* applies to the bigger industrial installations and requires the application of the "best available technology" or the imposition of stricter conditions if environmental quality standards require so.

Other relevant directives:
- EIA directive (85/337/EEC and 97/11/EC; new projects)
- Post-Seveso directive (82/501/EEC; industrial accidents)
- Directive on environmental information (90/313/EEC)
- Several directives dealing with air, waste, and nature protection

Box: The main EU directives relevant for river basin management

The Directive contains specific provisions for international river basins. In the case of international basins lying totally in the EU, Member States have to identify the river basin district together. In the case of international river basins extending beyond the borders of the EU, the Member States concerned have to "endeavour to establish appropriate co-ordination" with the non-Member States concerned (art. 3). Each Member State on its own has to make appropriate administrative arrangements for its part of the basin (art. 3.3). Together they have to ensure co-ordination with the aim of producing a single RBM plan, but if no RBM plan is produced, then each Member State involved should make one for its part of the district (art. 13).

2. Good ecological status/ potential

The environmental objectives of the Directive determine largely which measures have to be included in the programme of measures and how strict pollution controls should be. The Member States should, *inter alia*, prevent deterioration of the status of their surface water bodies and restore them with the aim of achieving within 16 years a good ecological status and a good chemical status. "Good chemical status" is defined by reference to the water quality standards contained in the daughter directives of the Dangerous Substances Directive (see Box) and to water quality standards that will be established for priority substances (cf. § 3). "Good ecological status" of the different types of water bodies is generally defined as diverging only little from the relevant reference conditions for the type of water body concerned (art. 4, Annex V; see also § 5).

For water bodies designated as artificial or modified the environmental objectives are, *inter alia*, a good ecological *potential* and a good chemical status (art. 4). Water bodies can be designated as such if making changes to their artificial or modified character would affect for instance navigation, flood protection, drinking water supply and "human development" (Annex II, 1.6). The "good ecological potential" is generally defined in the same way as the "good ecological status", except that the modified or artificial character of the water body concerned should be taken into account (Annex V, 1.2.5).

Concerning groundwater, the Member States should, *inter alia*, prevent deterioration of the groundwater status; and restore groundwater bodies; and establish a balance between abstraction and recharge with the aim of achieving within 16 years a good chemical status and a good quantitative status. The chemical status of groundwater is good if:

- there are no saltwater or other intrusions;
- the existing groundwater quality standards from EU regulation are met (e.g. from the Drinking Water Directive);
- the status of associated surface water bodies does not diminish significantly and the attainment of the environmental goals for these water bodies is not blocked; and
- there is no significant damage to terrestrial ecosystems directly depending on the groundwater body. (Annex V, 2.3.2)

The quantitative status is good if:

- the long term average annual abstraction does not exceed recharge;
- the status of associated surface water bodies does not diminish significantly and the attainment of the environmental goals for these water bodies is not blocked; and
- there is no significant damage to terrestrial ecosystems directly depending on the groundwater body. (Annex V, 2.1.2)

There are a number of exceptions for both surface and groundwater. Less stringent environmental objectives may be established if improvement in status is not feasible or disproportionately expensive; (art. 4.4). Moreover, the environmental objectives do not have to be reached if this is the result of new modifications that the Member State concerned determines were made for reasons of "overriding public interest" (art 4.6). Deterioration of the water status is allowed in the case of unforeseen or exceptional circumstances, such as floods and droughts (art. 4.5). Finally, sometimes deadlines can be extended (art 4.3). In all of these cases a number of further conditions have to be met, such as the requirement to mention the reasons for the exception in the RBM plan.

3. The combined approach to pollution

To achieve a good status, the Framework Directive Water requires the Member States to adopt a combined "emission-immission approach". Pollution should be controlled primarily by means of emission controls based on the Best Available Technique or the relevant emission standards. However, more stringent emissions controls should be applied if a quality objective or standard for the receiving water so requires (art. 10).

Before 31 December 1999 a list with priority substances would be adopted, based on risk analysis. Within two years, the Commission would propose means to control these substances, which may include emission standards as well as product policy (e.g. review of the authorisation of pesticides). Uniform water quality standards will be established for all priority substances, which may act as a basis for stricter emission controls (art. 16). Several directives will remain in force: the daughter directives of the Dangerous Substances Directive, containing both emission and water quality standards; the Bathing Water Directive, containing water quality standards; the IPPC Directive; and the Urban Wastewater Directive. For groundwater a general prohibition of direct emissions is introduced, which should be incorporated in the programme of measures as "basic measures" (but with many exceptions: art. 11). The Groundwater Directive will be repealed as soon as the measures from the programme of measures have to be operational (13 years after publication of the directive).

The approach to diffuse sources will change too. Several directives will remain valid, such as the Nitrates Directives and the directives concerning pesticides. The requirements based on these directives have to be included as "basic measures" in the programme of measures (art. 11.3). If these measures turn out to be insufficient for reaching a good water status, the causes of the possible failure have to be investigated "such additional measures as may be practicable" have to be established (art. 11.5). Moreover, new product policy may be introduced for priority substances (e.g. pesticides). Finally, diffuse sources have to get integral attention in the different analyses and in the monitoring programs required by the Framework Directive Water.

4. Supporting analyses

The Framework Directive Water requires a number of analyses and monitoring actions to support RBM (art. 5 and 8):

- A characterisation of each national river basin district or each national portion of an international river basin district

- A review of the impact of human activity on the status of surface waters and groundwater
- An economic analysis of water use
- Monitoring of the surface and groundwater status

The characterisation of the river basin districts implies that a number of characteristics should be given. For surface water bodies two systems may be used: "System A" and "System B." In system A several types of surface water bodies are identified: rivers, lakes, transitional waters or coastal waters; and artificial or heavily modified rivers, lakes etc. Moreover, several "eco-regions" are identified, such as the "The Carpathians" and the "Hungarian lowlands." Further distinctions are altitude, size and geology (Annex XI). System B leaves the Member States some more freedom, but the result should be equally detailed. The characterisation of the "groundwater bodies" should be done in two steps: an initial characterisation for all groundwater bodies, and a more detailed characterisation of the bodies that are at risk (Annex II).

To specify the "good ecological status" of surface waters, the Member States should establish the reference conditions for each type of surface water body (rivers, lakes etc.). These reference conditions may be either spatially based, or based on modelling, or a combination of the two, or, if these methods cannot be used, an "expert judgement" (Annex II, 1.3). Several parameters have to be studied, such as composition and abundance of aquatic flora and benthic invertebrate fauna, morphological elements, water temperature, etc. (Annex V). For spatially based reference conditions Member States have to develop a reference network for each type of water body with a sufficient number of sites with a high ecological status. Reference conditions based on modelling may be derived using either predictive models or hindcasting methods. The models have to use historical, palaeological and other available data and have to provide a sufficient level of confidence (Annex II, 1.3).

The review of the impact of human activity includes an inventory of pressures on all surface water bodies and some groundwater bodies (those at risk and transboundary groundwater bodies) and an assessment of the susceptibility to these pressures. This information will allow a more accurate assessment of the risk of not meeting the environmental objectives and should be used in designing the programmes of measures and the monitoring programmes (Annex II).
The Directive is very brief on the economic analysis of water use. The purpose is to provide the necessary information for taking costs recovery into account (art. 9) and for determining the most cost-effective combination of measures for the programme of measures. For this the economic analysis has to result in "enough information in sufficient detail (taking account of the costs associated with the collection of relevant data)" (Annex III).

The purpose of the required monitoring is primarily to aid the review of the impact of human activity and identify any deterioration and the reasons thereof. Annex V of the Directive contains many detailed requirements for the monitoring programmes that should be established.

A special procedure involving a "Regulatory committee" with representatives from the Member States has been established for adapting Annex III (economic analysis) and section 1.3.6 of Annex V (standards for monitoring) to scientific and technical progress (art. 19 and 20). Moreover, the Commission may adopt guidelines on implementing Annex II (characterisation of water bodies, determination of reference conditions, identification of human pressures and assessment of impact) and on implementing Annex V (water status and monitoring).

5. Conclusion and final discussion

Assessment of the Framework Directive Water

The proposed Framework Directive Water is a significant piece of legislation, not only for the present Member States of the European Union, but also for possible future Member States and, to a lesser extent, for other countries. It is not a beautiful piece of legislation. It is quite complex – 72 densely printed pages, with many cross-references and complex tables. It will be very hard to control compliance, and it may result in some bureaucracy, in addition there remain a number of mistakes in the proposal. Yet, it does introduce for the first time at the EU level legally binding ecological objectives. Moreover, it offers, together with other instruments such as the Helsinki Convention (UNECE 1992) and the Protocol on Environment and Health (UNECE-WHO 1999), a framework for water and environmental management on the basis of river basins.

Concerning the Gabcíkovo-Nagymaros project, the Framework Directive Water may function as a source for Hungary and Slovakia of "new environmental norms" (cf. introduction). The Directive has not yet been adopted and its ecological objectives still have to be specified. Yet, one could read a strong message in the Directive*: ecosystems should diverge only little from their natural state*. Many exceptions are possible, but they are really exceptions and have to be justified explicitly and reviewed regularly.

What more is needed to solve the Gabcíkovo-Nagymaros case?

That being said, the Framework Directive Water on its own will not solve the Gabcíkovo-Nagymaros case. The Framework Directive Water may strengthen Hungary's position, but no matter how strong its position, further negotiations between Hungary and Slovakia will be necessary. The international literature on negotiations contains several suggestions for these negotiations (see also Mostert 1998):

1. Interests rather than positions
A general advice concerning negotiations is to focus not on the conflicting positions (concrete outcomes), but on the underlying interests. This reduces the chance of hard confrontations and deadlocks and increases the chance of an integrative agreement that meets all interests as much as possible (Fisher and Ury 1981).

2. Common interests and acceptable solutions
Further activities that promote agreement are searching for common interests and principles and for solutions that, while promoting one's interests maximally, are also acceptable for the other parties. Each party should let the other party "score", that is, make concessions on points that are important for the other party but less important for the party making the concession (Fisher and Ury 1981).

3. Explore more than two possible solutions
Moreover, negotiations should include an informal exploratory phase in which several potential integrative solutions can be explored without committing any party. In all phases a minimum of three alternatives should be considered to prevent entrenched battles over two opposing alternatives (Fisher and Ury 1981, Mastenbroek 1996).

4. Maintain a good atmosphere and be wary of strengthening your position
In addition, while negotiations can be hard, it is essential to foster and maintain a good atmosphere and mutual trust. Moreover, one should be reluctant to try to influence the balance of power to get more out of the negotiations, since such activities can easily spoil the atmosphere and cause disruptive power struggles (Mastenbroek 1996).

5. Agree on the facts of the case
Furthermore, negotiations should be based on sufficient information to prevent solutions that are not technically feasible or inferior. Whenever the facts of the case are disputed, it is best to start with discussing the facts. Since conflicts over facts tend to be less sensitive than conflicts over more value-laden issues, this makes it easier to find and develop areas of agreement and thereby foster mutual trust (cf. Brehmer 1989, cf. Vlek and Cvetkovich 1989). In general, it is better to start with the less sensitive issues.

6. Research co-operation
To reach agreement on the facts, extensive co-operation is already necessary in the research phase. Research is never totally value free. Many subjective choices have to be made, such as the alternatives and effects that are considered (Mostert 1996). Moreover, there is always a certain degree of uncertainty, which is often unconsciously filled in – in accordance with the values and interests of the researcher (Frankena 1988). There is nothing inherently wrong in this, as long as the subjective character of research is not consciously exploited. However, it does mean that in controversial cases research conducted by one party is often contested by the other party or parties. Consequently, a second study is conducted resulting in different conclusions, and then a third study to decide between the first two, and so on. Intensive research co-operation or even joint research may prevent such unfruitful controversies (cf. Loucks 1990).

7. Co-operate internally and give broad mandates
Negotiations often take place simultaneously at different levels and between different levels. In the case of international negotiations for instance, negotiations take place between the national delegations, within the delegations, between the members of the delegation and the organisations they represent, and between all these and other segments of society. To make such a system function, each individual negotiator or organisation has to maintain the trust of its constituency or constituencies. Moreover,

mandates should not be too strict since this would make it impossible for the negotiators to explore possible solutions and formulate draft agreements. Finally, co-operation at the different levels in the countries concerned generally increases the negotiating power of the national delegation and the chance that draft agreements reached internationally are accepted nationally (Mastenbroek 1996).

8. Consider involving a third party
If the parties in a conflict cannot find a mutually satisfactory solution, it may be advisable to appoint together a facilitator or an arbitrator. Their role may be to assist the negotiation process or to advise on substantive issues, such as draft solutions. In the latter case their advice may be purely "advisory" or binding. Of course, there is often the option to go to court. However, courts focus on the legal aspects of conflicts, which often does not solve the real problem (e.g. Painter 1995).

The author of this paper does not know what exactly has already been tried in the Gabcíkovo-Nagymaros case and what is feasible and what not. However, the potential benefits of following these recommendations are large. Recommendation 1 for example could imply that it were better not to start negotiating on the minimum amount of water that should be delivered to the old Danube bed. Instead one could explore the means to satisfy all interests concerned maximally: river rehabilitation, hydropower production and shipping. Without questioning the other party's perceived interests, joint research could be done (cf. recommendation 5 and 6). The outcome could be a lower minimum flow than originally envisaged by Hungary but more frequent high flows. The ecosystem could benefit from the regular flooding, and the total amount of water available for hydropower production could be relatively high. This could be acceptable for both states involved since they could defend this solution to their respective constituencies (cf. recommendation no. 7).

This is just a theoretical exercise that may have little practical value. However, it may serve to show that alternative approaches to the negotiation process deserve serious consideration.

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PART TWO: DISCUSSION

THE QUESTION OF GYÖRGY TÓTH

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I am a hydrogeologist from the Hungarian Geological Survey, and I have a question to ask Mr. Tamás Rácz, concerning the Gabčikovo-Nagymaros System, and the Slovak-Hungarian stretch of the river Danube. We know that this section differs somewhat from similar river sections in other parts of the world. The main difference being the huge ground water resources, which are extremely important for drinking water for the two countries. We hydrogeologists know that the essence of this ground water resource is that the river here loses its water through a very efficient natural filtration system. Under the original state of this section, the river fulfilled its infiltration potential. After damming, it saw dramatic change and from the results of our monitoring system in the Szigetköz region we can see that this has consequences for ground water quality: higher levels of ammonia, manganese and iron are occurring in ground water, and according to our modelling, ground water resources here have deteriorated and are deteriorating today. So it is clear that the crucial and focal point of any rehabilitation process or such action in this section must be the ground water resources. I could not find any reference to this in Mr. Tamás Rácz's presentation. The question is why?

RESPONSE TO THE QUESTION OF GYÖRGY TÓTH
by Tamás Rácz

I think we have discussed this issue in different conferences and the conclusion has always been the same: time and financial constraints. So this part of the evolution is missing from our studies for a very clear reason: that our work was always based on existing materials, we had a very limited time, periods such as two and three months respectively, and I think that no respectable scientific person could agree that in such a time-frame we could go into the details of the groundwater modelling, which would need, according to some estimations, at least about a one-year programme. Simply put one year's work cannot be put into a period of two months. Of course, we are very optimistic about the coming years, every year we hope that we can incorporate as much information and as much scientific study into our overall work and focus, and so this year we are optimistic once again.

QUESTIONS OF PHILIP B. WILLIAMS

I have two questions. The first one is: I am assuming that we were asked to participate in this meeting today because of our relevance, our experience and expertise on flood plain restoration to the mitigation plan of the Gabčikovo project. And I think what we have heard here today is quite a remarkable unanimity of how one should approach planning and designing restoration for flood plains. This is quite extraordinary because this is a new and experimental field. What concerns me at this point is that I came here expecting to engage in a more substantial discussion on what is being termed the 'Kern solution'. I don't feel that I had the opportunity to do that, and I am concerned that my presence here is not represented in any way as endorsing or rejecting that plan. Neither am I clear on where that 'Kern solution' is in the planning process. So I would like to direct this question to Drs. Kern and Zinke. What is the status of the planning and design of this solution? Does it accord with the kind of principles and methodology that we have heard the presenters discuss today on the river restoration strategies that are taking place around the world?

My second question is a little more speculative, but it is very interesting to hear that there is a new European Union framework that could influence the way the European Union manages and restores rivers. Our experience in California has seen dramatic changes in public opinion and changes in the way we have looked at our river management infrastructure, and as I showed in my slides, we are now examining the decommissioning of dams and the moving back of levees as important elements in a restoration strategy. It is entirely conceivable to me that perhaps twenty or thirty years from now the Slovak government itself may wish to reconsider its bad decision to build the Gabčikovo project. After all, the economics of this project are not particularly good, it is not particularly well constructed, and it is my understanding that this week the Slovak government actually established a new commission to review its past performance in planning and executing dam projects. So just from my experience in seeing how attitudes have changed, there may be a scenario down the road where the Gabčikovo project could be decommissioned. My question then would be, if this were to be the case, if more radical solutions were to be advanced in the future, would the 'Kern solution' and the 'WWF solution' be compatible with a fully restored flood plain ecosystem, or would they be impediments to full restoration? I would ask Dr. Weller also to address this question.

RESPONSE TO PHILIP B. WILLIAMS
by Klaus Kern

The involvement of Mr. Zinke and myself concerned a short consultancy stay in Budapest when I proposed the meander system as an additional variant to be studied and Mr. Zinke emphasised the WWF solution, which had already been produced in a written form in 1997. What we suggested was to carry out an analysis on the feasibility of those studies covering different fields such as hydrobiology, river morphodynamics, and flow dynamics, flood dynamics and so on, and of course cost/benefit analysis and other matters. I am not informed as to which level the planning process in this kind of analysis has been carried out to date.

RESPONSE TO PHILIP B. WILLIAMS
by Philip Weller

I would like to take the chance to answer the first question or at least direct it to the people who should perhaps answer it. It is my understanding that it is representatives of the Hungarian government who have been evaluating these options. The option proposed by WWF, was forwarded in such a manner that a concept was prepared and (we heard from Dr. Kern as well) the general principles of an alternative option were put forward, although these were not evaluated by the two organisations that presented them. They have been evaluated and put forward independently by representatives of the Hungarian government and it is unclear to me the extent to which they have been included in the negotiating process with the Slovak government. I would like to have that matter clarified for the same reasons outlined by Mr. Williams. The second question related to the extent to which the proposals would preclude any more drastic measures, such as the decommissioning of the dam. In my presentation, and I think also from many of the other presentations I heard, the importance of maintaining ecological conditions to the best extent possible was stressed, and I think all the efforts at this moment are directed towards that aim. It is certainly our impression that the proposal prepared in 1997 would maintain the ecological conditions in such a way that a more optimal solution (if a decommissioning were undertaken) would be able to be carried out. It is a sort of degree of restoration, or mitigation I would say, and it certainly would not in any way preclude more significant measures being undertaken.

RESPONSE TO PHILIP B. WILLIAMS by Gábor Bartus

Governmental Chief Adviser
Prime Minister's Office
Budapest, Hungary

The alternative outlined by Tamás Rácz was not meant to represent the Hungarian Government's position on the issue, nor should it be looked at as the Government's own proposal. The study has in fact been commissioned by the Hungarian Government. We asked experts to gather the alternatives that have been drawn up so far in connection with the Szigetköz and other sections of the Danube, and compare those options to some degree, as far as permitted by the tight schedule. In other words, we did not expect the scientists to find the ultimate solution, but rather to present any and all ideas and versions of both the international and Hungarian experts and, in a systematic manner, to perform a preliminary evaluation of the options collected.

The other question that has arisen refers to the relation the study prepared by the work team of Tamás Rácz bears to the Slovak-Hungarian talks, and to the position of the Hungarian Government. According to the preliminary surveys, the Government has adopted a decision in all of the questions concerning the Gabčikovo-Nagymaros power station, and the respective dispute between Slovakia and Hungary, except for one single issue. The Government of Hungary has decided to build no power station at Nagymaros and generate no energy at Gabčikovo, even though this was made possible for Hungary by the decision of the International Court of Justice. Instead, Hungary wishes to re-channel as much water into the original riverbed and the side-arms as the bilateral talks will allow in the light of the International Court's judgment, in order to restore the natural environment. The only material question that remains, where the Government saw no chance for an equally definite answer, is how to utilise the water in the Szigetköz to best serve environmental rehabilitation. We believe that the information we have at present does not provide safe grounds for a responsible decision, therefore the Government has refrained from deciding the issue at this moment.

At present, it is our task to manage the process of finding a solution, but not to let it extend too long. This means that scientific research will continue in this direction, which the Government of Hungary undertakes to finance as far as its means allow. We shall act as initiators, and we hope that events such as the one today will furnish good examples of tackling this kind of process in a reasonable way.

We have not decided in favour of any of the alternatives for the Szigetköz, nor have we made a choice among the versions that have been outlined as possible solutions for the question. The Hungarian Government is open to the consideration of new options, and to add further items to those already on the list of proposed answers. A new phase of research may begin, which — we hope — will provide us with sufficient information to be able to select the best alternative.

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QUESTIONS OF HOWARD WHEATER

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The main discussions in this meeting thus far, including the overseas case studies, have largely focussed on the need to recognise the concept of an integrated river and flood plain system, from the viewpoint of geomorphology and aquatic habitats. However, a particular feature of the GNBS system is the need to consider an integrated surface water – ground water system. The functioning of this system and the concerns for groundwater have been presented in detail in the Hungarian Counter-Memorial to the International Court of Justice (Annexes, Volume 2, December 1994). For the benefit of this meeting, it may be useful to reiterate some of the main points. The major aquifer underlying the Szigetköz was formerly recharged by Danube flows. An important aspect was the fact that the summer floods in the Danube cause a rise in ground water levels and lead to a natural sub-irrigation of the natural ecosystem and also the agricultural systems; it was anticipated that extensive areas of this natural sub-irrigation would be lost after the diversion of the Danube, and that indeed has happened to some extent. There are also concerns for ground water quality as observed elsewhere on the Danube. For example at Altenwörth in Austria, where there is an impoundment, significant degradation in dissolved oxygen in ground water was observed. So one of the concerns in this scheme is whether such degradation of ground water quality is likely to occur. Calculations have shown that due to degradation of the organic material in deposited fine sediments, consumption of oxygen may occur, leading to a changing redox state of the groundwater recharge, and hence mobilisation of iron, manganese and ammonium. Data from the affected area gathered by Péter Molnár, who is here today, shows ground water quality at the diversion weir at the upper part of the Szigetköz and we can see a degradation in dissolved oxygen, as we feared, and an increase in manganese. I think it is very important for Hungary that high quality monitoring continues so that we can confirm or otherwise these trends which have real significance for ground water quality.

A second issue that I would like to mention, which is an important feature of the Danube problem, is the widespread use of bank-filtered ground water, which probably provides the water that you are drinking here in Budapest. The concept is that water is infiltrated from the Danube through the alluvial aquifer, which may be very extensive as in the Szigetköz or much more limited as is the case further downstream. It has been well documented that changes to the sediment regime in the main Danube can have significant adverse effects on the water quality of bank-filtered wells. Data from 1973 for twenty years are available from affected wells and show the very long term effects associated with changing patterns of sediment deposition and erosion in the Danube: over a decade, progressive increases in ammonium and manganese have occurred. So a point I wanted to raise was that when one is looking at management of the downstream section of the GNBS system, then one has to be very aware of these potential issues given the importance of this particular water supply to Hungary.

Having made these points concerning the importance of surface water-ground water interactions, I turn to some questions. One of the features that struck me in the discussions this morning was that a number of speakers emphasised the importance of river flow dynamics. Those dynamics I think are extremely important in terms of the aquatic ecology, the sediment regime in the flood plain system, and in terms of ground water and ground water quality issues. So I have a question to Klaus Kern as to what his view is of the dynamic requirements of the Kern solution.

I also have a second, more general question. At the hub of the GNBS debate is the issue of how we value the environment and ecological systems in comparison with more tangibly valued benefits such as power generation, and it was interesting to note in Dr. Rácz's presentation that a ten point scoring system had been used with five points for the environment and five points for other benefits. It would be very interesting I think to hear from Philip Williams and others with a US background as to how these very difficult and crucially important issues are handled within their experience.

RESPONSE TO HOWARD WHEATER
by Klaus Kern

I want to show an overhead which was produced by Emil Dister from the WWF Institute at Rastatt. The overhead points out the importance of the dynamics for flood plain rehabilitation.

Figure 1. Functional system of floodplain dynamics. (Dister, E., 1994)

Here we see discharge dynamics leading to water level dynamics which is important for the supply of nutrients in the flood plain, for the dynamics of soils, for sediment morphodynamics and for the ground water table dynamics. In the end this decides which kind of trees will prosper at a certain site. Lateral connectivity, that is the exchange mechanism between the flood plain water bodies and the main channel, is another important factor for the biocoenosis. You see just by the number of arrows pointing in different directions that it is a complex system, which is not well understood. We do, however, know that it is vital for the rehabilitation of flood plains. I think a key issue for the Szigetköz is what kind of flow regime will be implemented. The discharge regime for the Danube is also a key issue in the negotiations and in any agreement with the Slovak party because we have a very special situation at this location. We have a power plant with very high capacity turbines which was planned to operate at a peak operational level. For this reason the power plant at Gabčikovo is able to work on about 5000 m^3/s, which is close to the average annual flood flow. Therefore the power plant could utilise almost all minor floods diverting them into the power canal that by-passes the Danube for a length of 40 km. But these minor floods up to the average annual flood are those that govern the periodic inundations of the area and thereby the ecology and ground water quality. So we certainly need these small floods in the Szigetköz. The re-establishing of the flooding process is a very strong recommendation which I want to communicate to the planners and the decision makers in Hungary, that must be integrated in the agreement, in the treaty with the Slovak party. This implies that above a certain threshold, which may be the bank-full flow in the Szigetköz channels, the turbines at Gabčikovo should be closed down and all the flood water should enter the Szigetköz reach of the Danube. This should be studied in the planning process for any solution and should indeed be implemented. Thank you.

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SOME REFLECTIONS ON THE POSSIBILITIES OF THE RESTORATION OF THE OLD DANUBE NEAR GABCIKOVO
by Martin Jaeggi

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From the writer's knowledge, the derivation of water into the Gabcikovo canal should be seen as a last step in the evolution of the Danube river course away from the natural conditions. River regulation in the 19th century was mainly dictated by the needs of navigation. A single-thread slightly meandering channel was installed. The channel constriction and the increase in transport capacity resulted in an initial lowering of the riverbed and thus the average flow water levels.

The big flood in 1965 recalled the need for increased flood protection. Both neighbouring countries developed intensive dredging activities and the bed of the Danube downstream of Bratislava was again lowered. It seems that the effect of these activities on the average flow water level was in the same order as the effect of discharge reduction resulting from the start of the operation of the Gabcikovo plant.

Although the immediate impact of this action might have been heavy, it also offers a chance for river restoration which is almost unique on the Danube. In fact, where the canal is parallel to the old Danube, navigation does not impose constraints for the river course. The old training works from the 19th century have lost most of their function and could be removed, respectively replaced by a more flexible system. It may be pointed out that on the Austrian Danube between Vienna and Hainburg the possibilities for restoration of the main course are far more limited. Although a national park has been installed, the main channel of the Danube is still a heavily trained navigation channel.

Of course, a restored old Danube near Gabcikovo will receive only part of the discharge - during floods and during low flow periods. In some manner a model river will result and the actual channel will be oversized. The removing of the old training works should allow the Danube to rework its banks, erode material from the actual river terraces and deposit the material so as to form new bars where later can develop new alluvial forests. Reintroducing alluvial dynamics will develop new habitats. This may be in contrast with trends to preserve the actual habitats in their previous condition.

The Kern solution starts from a different point of view, but is in fact not very far away from the view expressed earlier by the writer. The common idea is to give the river a new starting point and then to leave most the work to the rivers action. It is obvious that this principle needs regular floods for a few days a year. Although the power installed in Gabcikovo is sufficient to use the total discharge of even high floods[8], it is important for restoration purposes that for short term periods the water is diverted into the old Danube when the river is in flood, so that the reworking of the channel is possible.

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[8] up to 4-6000 m^3/s varying according to different sources *(Editor's note)*

INTERVENTION OF BOLDIZSÁR NAGY

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There is no need to say how privileged I feel to be a humble servant of you. I say this because all the ideas we lawyers represent have their origins in your work - the scholars and scientists dealing with the tasks of restoration and river maintenance. Now, in order to prove what humble servants we lawyers are, let me quote or reproduce some of the Hungarian suggestions offered to the Slovak Republic, and that will also serve as an answer to György Tóth who asked about the fate of the sub-surface waters. I also intend to confirm what Gábor Bartos said, that, according to my understanding, no final refined scheme has been offered to the Slovak side concerning the regulation of the river stretch in the Szigetköz. What we did say in legal terminology is the following: what are the goals we want to achieve with the given technical solution, which is to be chosen later following an appropriate environmental impact assessment. So the technical solution had not yet been chosen. What we have decided, what we want and expect from that technical solution is the following - and these are all hydrological terms you will be familiar with - the solution to be chosen should guarantee the unchanged or improving quality of surface and sub-surface waters and their usability. That is the first purpose. The second is the protection, conservation and restoration of the flora, fauna and biodiversity of the affected region. Thirdly the maintenance of the dynamic connection between the main river-bed and the branches, and the natural flooding of the flood plains. We also have to consider the speed and dynamics of the sub-surface waters, which are satisfactory from the environmental point of view - there has to be an appropriate speed and dynamic of sub-surface waters, which is environmentally sound. Then there is the safe discharge of floods. And the last objective, and this is the very last one, the safe passage of small and sports vessels in the main river-bed along a small navigation channel for these vessels. These were the objectives. They clearly speak about the connection of the surface waters and the sub-surface waters. The priority order is explicitly and clearly in favour of all the environmental requirements we were speaking about. The suggestion handed over does not prefer any technical solution. That is why we are here. We should discuss the underlying elements and the principles and the existing examples - what factors we might take into consideration when choosing the alternatives. What Hungary has done so far in my understanding – which might be wrong, of course, I just know it as an expert to the government – is that we were trying to find those alternatives which could be subject of an environmental impact assessment. This then should identify the technical solution to be adopted. That is a long process, and this symposium is part of that process. But I have this feeling that we all do agree on the goals we are seeking to achieve. Thank you.

NATURE ORIENTED WATER MANAGEMENT – A PRINCIPLE FOR RIVER REHABILITATION

by Zoltán Somogyi

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Budapest, Hungary

As every speaker pointed out at the conference, it is rehabilitation that must be pursued when managing rivers. Contrary to the earlier hopes and beliefs that regulation and other manipulations in river systems would be beneficial for society, it is believed nowadays that we can manage our environment for our own interests only by fully respecting nature's power and laws.

A similar paradigm change can be observed in the management of another resource: forestry. In the first era of forestry, which ended in Europe many centuries ago but which can be observed in many places in the world even today, man exploited forests in a way that all timber could be used without any respect to the regeneration of the forest. This exploitation resulted in a growing scarcity of timber which forced foresters to regenerate cleared areas. Even later, the regeneration was carried out in a natural way. At the same time, however, an intensive, artificial management of stands was practised that degraded forests. At the end of this century, after large-scale forest die-backs and the growing need of society for non-timber benefits from forests (such as clear water and air, protection of soil, biodiversity, recreation etc.), foresters started to apply old and new methods that are based on natural processes, the ability of forests to regenerate themselves, and to involve all interested parties in the management of forests. This management is called nature oriented forest management, and involves putting forests aside in reserves where no human activity is allowed.

I believe that the principle of nature oriented management can be used in managing other natural resources including water. What does "nature oriented" mean? It means the primacy of natural processes and laws, including energetics. It is pointless fighting against the forces of biological or physical agents, such as the power of life or the power of water. It means that water systems, as well as forests, must be managed in a way that at least mimics natural patterns and processes.

In the case of the Szigetköz, these patterns and processes include high spatial and temporal diversity of the water regimes, including floods, and as a consequence, high, mosaic-like diversity of habitats, species and gene pools. Current water regimes are much more schematic than before, and if biological diversity is to be restored, water regimes must be developed so that they resemble natural ones at least on parts of the Szigetköz.

Nature oriented water management in the Szigetköz means that even if no power station had been built at Gabcikovo, rehabilitation would be necessary to restore this section of the Danube. The call of our time is to ensure that the unique landscape and the biological values of the Szigetköz are maintained.

Finally, I would like to stress that rehabilitation of rivers also means the rehabilitation of their ecosystems. Many of these ecosystems regenerate themselves quite easily and quickly because of the immense power of the rivers, and because the pioneer biocoenoses of the riparian ecosystems spread very intensively along the rivers. However, there are places where natural regeneration is slow, i.e. outside the borderlines of floods, or where the canalised riverbed does not allow for natural flooding. In these places, afforesting should be a part of the restoration. Afforesting strips along denuded river sections also quickly and effectively heals wounds in the landscape.

INTERVENTION OF VILMOS KISZEL

Göncöl Alliance, Vác, Hungary

Thank you for the floor, Mr. Chairman. Dear audience, please regard my talk as a meditation on the future of the Danube regulation and perhaps also as a small initiative. Very generally speaking, we can see that development in general, development of human kind and technology, is realised on the basis of the exploitation of natural resources. Today we may face up to the really unique and new challenge of our era - the question that maybe we can obtain benefits from restoring our natural resources, especially those which are renewable. This is an appealing challenge and also quite interesting. Perhaps some people here remember the plan which was projected by Phil Weller concerning the flood plain restoration capacity of the Danube basin. You all are aware that the upper course of the Danube is more or less fully regulated, down to Gabčikovo. There is a long interval between the Iron Gate and Bratislava with a huge, really enormous flood plain restoration capacity, and another, perhaps bigger - the lower course of the Danube predominantly in Romania. We see still existing along these reaches rich, varied and large ecosystems to maintain and restore.

We have to see also that there is no longer any need to enlarge the area of arable land, instead we may relinquish a certain percentage because of new technology and the new breeds of animal and varieties of plant. Especially in Europe EU requirements will require the diversion of a certain percentage of arable land to more ecologically functioning systems such as flood plain forests, meadows and others. This is a real challenge.

On the other hand, we see a big shift in the human valuation of different benefits, happening during the last 20-30 years. 30 or 50 years ago energy had a high value, shipping had enormously high power. Recently we regard as far more important drinking water, flourishing ecosystems, and this is completely different. There is a conflict of interest between traditional water management, which thinks in cubic metres, kilometres and kilowatts and other physical parameters, and what we call modern water management which thinks about river ecosystems, flood plains, which is concerned with harmonising different needs, seeks to integrate spatial planning, and values public participation and reconciliation with the interests of the 'stakeholders'.

What I don't really like in the current debate between Slovakia and Hungary is that I see a hectic situation in which the negotiations are largely about technical solutions. Again, we saw five solutions compared but saw little concerning the real purpose of the exercise. We heard about political declarations, also raised by Gábor Bartus, which is very refreshing, I firmly support it, but we have to be aware of the fact that this is not based on an integral spatial planning procedure which would involve the public and the stakeholders. We need to have a clear goal, conditions to meet, and a policy plan, for which in our unfortunate case we have to say is a highly political issue, and until we find a real legal solution I believe we will not reach a political agreement in the near future. That's why I find technical solutions premature and I'm really urging for the establishment of policy goals and conditions to be met.

If you allow me, I would suggest one leading principle to be established before engineers proceed with their task. Perhaps you remember one of the figures of Patricia Strayer -the Kissimmee lake system, which will more or less be artificial. In that system there is a channel which will become naturalised and you saw also a section of transition where the problems can be solved by traditional water management and below that a section where a more natural system may occur. This might be a solution for the conflict between traditional and modern water management. My suggestion would be: why not design the stretch of the Danube from Bratislava to Budapest as an interval of transition, where the key task of engineering is to solve the conflict between traditional water management and ecological modern water management? In this way the river and associated ecosystems could be saved all along the Danube downstream of Budapest. Thank you.

INTERVENTION OF PÉTER MOLNÁR

Golder Associates Kft
Budapest, Hungary

Ladies and gentlemen, I would like to come back to the sediment issues for a while. Mr. Rácz mentioned that there are debates in Hungary concerning which river sections of the Danube in the Szigetköz area have a natural character, and if it is a meandering or a braided stream. I don't think we have problems with this topic; we have detailed maps and we all know that this was really a braided stream with many-many side-arms. You can see on this map that the navigation channel was artificially dredged at the end of the 19th century (Fig. 1). Before this period, we didn't have such a separation of the main channel and side-arms as we see now. One of the main problems during the regulation of the Danube was that every year the position of the main channel changed several times. It was a very-very vital and dynamic system.

Figure 1. The braided Danube and the artificially dredged navigational channel in 1905.

What is the main difference between a meandering and a braided stream? The answer is that the main difference is in the sediment balance (Fig. 2). So, typically for a braided stream, there is much more bed-load arriving on a certain river section than is being transported away. There is a positive balance. For the meandering type, arriving and leaving bed-load is balanced, but, within a certain river section, there is a huge re-deposition of sediments due to the lateral movement of the river. The amount of bed-load which arrives at this section and leaves this section is very close or equal. So if we look at the situation in the Szigetköz area in the first part of the 20th century, we can say that each year about 300-400 thousand cubic metres of coarse gravel has been arriving as bed-load, and only about 20 thousand cubic metres has been leaving.

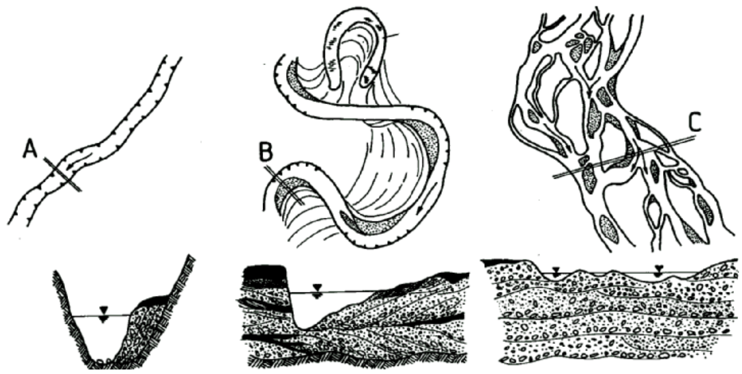

Figure 2. Main river types: a — 'V' notched stream; b — meandering stream; c — braided stream.

Now, how has this situation changed after a lot of dams were constructed along the upper section of the Danube in Austria and Germany? The arriving bed-load has considerably decreased, and there is now no chance to restore the original situation. The coarse gravel that had been deposited in the Szigetköz, cannot be transported in the same way as before and the bed-load capacity of the river can never be restored. We can state that the original braided type of river can never be restored in this area. It is a key issue because then we have to say that we cannot restore that situation which formed this whole ecological system. That is one issue.

The second issue again concerns the sediments. Here I would like to come back to the communication between the surface water and the ground water. We know that the Szigetköz is a very unique area in a special situation, where all this huge groundwater aquifer was fed by the main river, the braided stream. We know that the quality of the riverbed is a very-very important factor in sustaining a good quality of the ground water. All the processes which happen during the infiltration from the river into the sub-surface take place in a very narrow zone at the river-bottom. So what do we need in order to sustain a riverbed in good condition for the infiltration (Fig. 3)? One element is to have enough flow velocity to prevent siltation, the accumulation of fine sediments which are rich in organic material and cause deterioration in water quality. The second thing, which is usually a natural process, is to let the river move laterally, change its riverbed, develop new and fresh riverbed sections. The third thing is very interesting and very important. If there is a continuous, permanent direction of the flow from the surface water towards the sub-surface, there is a process of clogging which develops around the riverbed and small particles re-settle between the gravel grains. This also causes deterioration.

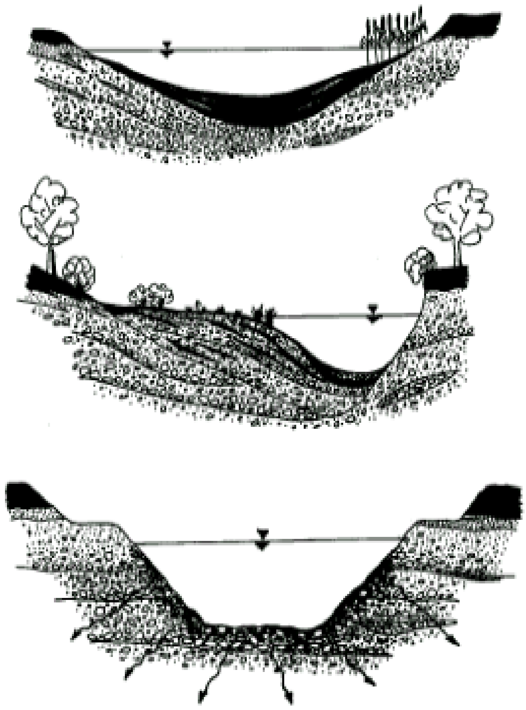

Figure 3. Riverbed processes: a — siltation; b — lateral movement; c — clogging.

How did the clogging process occur in the natural Danube? During the greater part of the year, the Danube fed the ground water, but in those cases when surface water level fell suddenly, the ground water flowed back into the surface water for a while. During this short period the riverbed were thereby cleaned. This means that not only the floods but also these relative quick falls of the river level were important to sustain the good quality of the infiltration surface. This means that the river dynamics are essential in many aspects.

If I look at the present situation in the Szigetköz area, what can we do now? We can somehow restore and keep good river conditions in the side-arms by constructing or restoring such a system where we will have lateral riverbed movements and sufficient flow velocity. A larger problem is to restore the main channel where the original situation has changed dramatically. Before the diversion, in the original situation, the main river channel mostly fed the ground water, and then for a while, in a dynamic fashion as I have described, drained it. Now the Cunovo reservoir is the main part of the system which feeds the aquifer through its silted bottom. We cannot do anything to counter this situation because all other parts of the system, the side-branch network and the restored main river channel will still drain the ground water because the potential of the water body in the reservoir, close to these systems, is much higher.

The Čunovo reservoir has become the main source of the ground water recharge, and we know that at the bottom of this reservoir siltation is taking place. I think we can do nothing against the long-term deterioration of this ground water system.

Tank you very much.

RESPONSE TO PETER MOLNÁR'S INTERVENTION
by Tamás Rácz

I really don't want to enter into the scientific debate, it is not my task to do that; but my problem with common scientific knowledge is always that my name is Tamás (*Thomas*) and I believe what I am seeing. So when my distinguished colleague shows me that picture as an ideal braided system, my problem is that on the historic maps from the 1760's I can see a main meandering channel along the B section. So either the ideal solution didn't exist at all or somebody in the 1760's made a navigation channel artificially in the B section in the Szigetköz. This kind of debate seems to me very academic. I used my presentation for supporting the two viable solutions that we obtained from scientists, namely the WWF solution and the Kern solution. We found the Kern solution somewhat more substantiated when we compared it with the other solutions. I ask scientists please tell us what to do, what are your suggestions? What my colleague Mr. Molnár told us was that it is impossible to restore the ideal braided system, which may or may not have existed. So please, if you can suggest to us any better solution than the one we have formulated or that of Mr. Kern or the WWF, please tell us and we will try to incorporate that concept in our next round of studies. Thank you

INTERVENTION OF ALEXANDER ZINKE

Zinke Environment Consulting for Central and Eastern Europe,
Vienna, Austria

With respect to the actual background problem of this Rivers' Symposium and to the limited information provided by other speakers during the Symposium on the local situation around Gabcikovo, I would like to briefly address the present environmental situation of the Danube floodplains near the Gabcikovo hydrodam system and their overall chances for restoration. The following is only a brief overview of local monitoring studies conducted by various local scientists over recent years (see WWF 1997, Mucha 1995, Balon & Holcik 1999).

1. Restoration needs in the Danube floodplains near Gabcikovo

The fact is that since the autumn of 1992 the river-floodplain ecosystem at and near the "old" Danube is heavily affected by changed environmental conditions due to the diversion of the Danube. The once interrelated unity is dissected into four separated systems (Plate 27): the Gabcikovo canal, the side-arm system on the Slovak side (Zitny Ostrov), the "old" Danube and the side-arm system on the Hungarian side (Szigetköz). No longer is there an open, natural interconnection between these systems and since 1991 there has been no more inundation of the floodplain (in spite of various efforts to inundate artificially), there is consequentially a well monitored and partly visible degradation of the biocoenoses and surface water bodies. The degradation of the groundwater body is assumed by various scientists but is, as far as I know, not adequately monitored (or such monitoring results are not published).

Based on experience from similar impacts in other river-floodplain ecosystems (e.g. Upper Rhine, Danube at Altenwörth; see Zinke 1994), it is evident that initial changes during a few years do not constitute a lasting situation but only a transition to a new, non-natural ecosystem: A worsening of the present environmental state has to be expected (e.g. WWF 1989 & 1997, Balon & Holcik 1999).

The initial changes monitored between 1992 and 1998 include

- A lowering of the groundwater table by 2-4 m in the "old" river bed (i.e. below historical minima), resulting in a permanent draining effect of the "old" Danube for the surrounding landscape as well as in a lack of regular infiltration into the aquifer and of an exchange of groundwaters.
- A strong recession of surface and groundwater dynamics (fixed in the side-arms mostly at mean water level), i.e. a lack of the typical strong water level variations (up to 7 m) resulting in the characteristic "breathing" of the floodplain (regular wetting of the top soil layers and exchange of air in the root layer). This natural process contributed to the high biomass production and has relevance for the local

economy (e.g. fisheries, forestry, agriculture, drinking water supply). It should be emphasised that the dry pannonic forest steppe climate of this region was always balanced by the moistening effect of spring and summer floods of the Danube and by related groundwater dynamics, detectable even several kilometres away from the river.

- A drying out of most wet biotopes especially along the Danube bed (as a strip of ca. 200 m), and
- A stabilisation of formerly varying habitat humidity to permanently either dry or wet conditions.
- A lack of morphological processes (erosion, sedimentation) creating pioneer habitats (sand and gravel banks, cliffs etc.) with their special biodiversity.

These changes in abiotic conditions are reflected by other monitored changes in the formerly very rich species diversity:

- Several hundred hectares of poplar and willow forests were affected by dryness (first symptoms: early shedding of leaves, reduced leaf sizes, dry tree tips etc.), some forest areas have died since 1992. Consequently, especially on the Slovak side, large areas of forest were prematurely salvaged in recent years.
- Both the diminished or lack of soil wetness and the reduced shadowing by trees has resulted in detrimental changes in the epigeic species composition e.g. of molluscs and spiders (Lisicky *et al.* 1997).
- In the limnic coenoses, there are changes and regressions in the diversity and biomass of benthos and zooplankton and, consequently, of fishes. The latter further lack access to their typical (often essential) feeding and migration grounds (e.g. side-arms, inundated open lands) which are blocked by weirs within the floodplain and towards the Danube bed (e.g. Balon & Holcik 1999).
- Together with the recession of many floodplain specialisations, there is an increase/invasion of drought-tolerant, euryoec (= can live everywhere) and alien species/neophytes (e.g. *Impatiens glandulifera, Aster novi-beligii*), often completely replacing the original coenoses.

The diagnosis of when the first *irreversible* changes came about is hard to be made in such a large area, over such a short ecological period and under the impact of mitigating measures but some scientists have already stated that this is the case. (Lisicky *et al.* 1997).

Contradicting this are statements and “proof” of the dam operating lobby, alleging that Gabcikovo has “saved” the inland delta. This false image is 'supported' by the fact that the artificial water input into the side-arm system produces a “year-round green wet landscape” but which is artificial and very different from the ever-changing dynamic floodplain. While for most local people the loss of “their” Danube floodplain is evident, ordinary urban visitors do not realise the crucial alterations. Therefore, what has been done so far is no saving or restoration of the ecosystem (Zinke & Eichelmann 1996).

On the other hand, significant human interventions prior to the start of the Gabcikovo operation are also facts, especially with respect to the exploitation over many years of gravel resources and the excavation of the navigation channel in the Danube bed (a lot of sediment was excavated for the construction of Gabcikovo). However, until 1992 the river-floodplain ecosystem was still existing and the biodiversity largely intact.

The new condition where over 80% of the Danube waters are permanently diverted from the river bed through the sealed power plant canal, substantially reduces natural self-purification processes which usually occur in active, dynamic river-side-arm systems (as sedimentation, decomposition by micro-organisms, uptake of nutrients in the biomass etc.) and which significantly contribute to the cleaning of polluted waters. This alteration leads to concerns in terms of the ground- and drinking water quality both in the direct vicinity of Gabcikovo (supply area for Bratislava and many local villages) as well as for the downstream Danube (bank-filtered wells).

However, compared with other sections of the Danube (e.g. the nearly complete impoundment of the first 1.000 km of the Danube by 59 dams; the nearly complete embankment of the Romanian Danube; see Zinke Environment Consulting & Popovici 1999), this region with today some 8,000 hectares of side-arms, islands, old oxbow lakes and dry gravel banks could still hold one of the important river ecosystems in Europe if the present damaging impacts were halted. It is therefore of European importance to support efforts to stop or even reverse the ongoing degradation: the sooner the better!

2. Restoration chances of the Danube floodplains

Both before and after the judgement of The Hague (see WWF 1997), there is scientific, technical and political interest in improving the present state of the Danube and its floodplains. Each of the solutions discussed aims at raising the water table to the former mean water level and to reconnect – at least in some locations - the river with the side-arms.

Apart from various technical solutions (construction of 3-12 weirs in the "old" Danube bed with a *stable* Danube water level), the so-called "*WWF solution*" (WWF 1994 and 1997) suggested the lifting and constricting of the main river bed with new small islands (made of gravel from local sources such as the Danube banks and the reservoir area upstream of Dunakiliti), and to allow new morphological processes under a new hydro-regime (with at least 65% of the river's total *dynamic* discharge). This solution allows a continued power production with up to 35% of water and the use of the existing bypass canal for year-round navigation, i.e. the "old" river bed will be freed from big ships' navigation (Plate 28).

It is a very positive step that in the autumn of 1998 a Hungarian multi-disciplinary team was commissioned by the Hungarian government to investigate the technical, ecological and financial feasibility of several alternative solutions for the impacted Danube. I was invited in November 1998 to present the WWF solution and its open questions to that Hungarian expert team, and recently I learned some of their results from January 1999. I was also pleased that my proposal to invite Dr. Klaus Kern from Karlsruhe to that discussion resulted in the assessment of a new, so-called "*meander solution*". However, following this pre-study recommending these "islands" and "meander" solutions as relatively the best ones, it is important now that a more detailed assessment and evaluation is undertaken – at best by a team of international experts -, and that then the results of such a concrete feasibility study are presented to government officials.

It may be correct to say that the Gabcikovo case is a very controversial issue in this part of Europe. However, the restoration of river sections is a politically very positive topic presently addressed in many projects in various parts of the Danube basin. The table below gives a first overview of river restoration projects presently under way between Austria and the Ukraine, adding up to some US$ 17 million. It reflects the multiple, concrete commitment of international and national donors. However, this list is incomplete and lacks e.g. the over 500 (!) restoration projects going on since the late 1980's in Bavaria: This province spends some DM 5 million every year for near-natural river management; another DM 20 million is spent every year (e.g. DM 124 million between 1989 and 1993) for the purchase of respective land in order to regain the needed space for near-natural flood management and for floodplain restoration along many rivers and creeks (oral information by the Bavarian State Agency for Water Management). From other parts of Germany and Switzerland, thousands (!) of other local river restoration projects could be further listed.

The "Living Rivers" campaign in Austria (1998-2001) is backed by another US$ 80 million for the revitalisation of 500 km of rivers, 500 ha of floodplain forests, 500 ha of inundation area (relocation of dykes) and 500 ha of river banks. It further wants to protect 1,300 km of still intact river stretches (74 "holy relicts") and includes a nation-wide public information campaign (Bundesministerium für Land- und Forstwirtschaft *et al.* 1998 & 1999; Zinke 1999).

This leads to the optimistic conclusion that a large river restoration project along the Danube in the area of Cunovo-Gabcikovo is not only justified from the quality of the still existing ecological and landscape resources but is also very much with the spirit of the times ("trendy"). If the government(s) responsible present (or support) respective proposals to potential donors, it seems quite likely that international funds may become available. Then, a Danube floodplains restoration project could significantly contribute to a conflict resolution between the parties involved.

Table 1 Wetland Restoration Programmes in the Danube River Basin

Country	Location/Project Time/Main Donor	Sub-totals, million USD	Total Funds, million USD
AUSTRIA	+ ***Danube downstream of Vienna (national park: reconnection of side-arms)***		
	EU-Life (1999-2001)	*2.0*	
	Waterways Authority WSD (1996-98)	*2.4*	
	WWF Austria (1994-99)	*0.2*	*4.6*
	+ ***Austrian Morava-Dyje floodplains***		
	Distelverein, WSD (50% EU-Life) (1995-2001)	*4.8*	
	WWF Austria	*0.2*	*5*
CZECH REPUBLIC	+ ***Lower Dyje-Morava (1993-1998) World Bank-GEF Biodiversity (inventory, project proposals and some implementation)***		*0.5*
SLOVAKIA	+ ***Lower Morava (1993-1998) World Bank-GEF Biodiversity (inventory, project proposals and restoration works)***		*0.8*
HUNGARY	+ ***Hungarian Danube***		
	Gemenc restoration (1998-99)	*0.3*	
	Beda-Karapancsa (2000-02)	*0.2*	*0.5*
CROATIA	+ ***Kopacki Rit restoration programme: World Bank/GEF (1999-2001)***		*0.75*
ROMANIA	+ ***Danube delta : restoration of poldered islands (1994-99): WB-GEF***		*0.5*
UKRAINE	+ ***Danube delta: restoration of delta and liman area (1998-2000): WWF-NL***		*1.5*
BASIN-WIDE	+ ***Danube Environment Programme (1992-2000) list of projects under Phare-Tacis for SIP Strategic Action Plan Implementation Programme (inventory, technical assistance, training and restoration works on Morava-Dyje, Tisza, Mura, Rog. Slatina, Lower Prut rivers and Liman lakes)***		*1.75*
	+ ***Danube Pollution Reduction Programme PRP (1997-99) UNDP/GEF preparation of priority projects for wetland restoration***		*0.1*
	+ ***Green Danube Programme (1994-99) (WWF International sub-projects on Morava-Dyje, Hungarian Danube, Bulgarian islands, Danube delta etc.)***		*0.7*
TOTAL			*16.7*

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QUESTIONS OF BOLDIZSÁR NAGY

It is really stimulating to listen to these comments. So let me share with you one of the major dilemmas which will to some extent appear as an answer to Philip Williams' second question and which might not have been fully answered so far. That is, let us assume the Slovak side is willing to decommission the hydro-power station. What then? Would the Klaus Kern suggested solution exclude a total reversal? And so my words now will also be linked to Péter Molnár's remarks about the role of the Čunovo reservoirs. Because, ladies and gentlemen, there is one major problem we face here, and that is navigation, and that is the problem with the WWF's first proposal. If we think of the very long term, and if we envisage a future without the operation of the power station, then the question remains: should the by-pass canal be used for navigation or not? The problem with the by-pass canal is that the headwater canal's bottom level is too high. Therefore in order to provide for the 2.5 metre plus 0.2 metres' safety zone –, that is 2.7 metres water depth, you have to flood the reservoir. So if you decommission the power station, but you want to maintain navigation in the by-pass canal, you have to sustain the Čunovo reservoir, unless you build totally new dykes within the Čunovo reservoir, which has not yet been seriously contemplated. There have indeed been suggestions to that extent, but they have not yet been investigated in any scholarly depth. So the question is: if we decommission the power station and decide to decommission the by-pass canal as well, in order to decommission the Čunovo reservoir, in order to restore the healthy fluctuation and bi-directional connection between surface water and sub-surface water, where are the ships going to travel? They cannot go in the by-pass canal and so they would have to go in the main riverbed. But assuming the WWF proposal is adopted, the main riverbed will be unsuitable for international navigation. That is a dilemma nobody has so far been able to solve. It is unreasonable to maintain the Čunovo reservoir just for the sake of navigation. But it is also unreasonable not to have navigation on the Danube and would be in breach of international legal obligations. So if you have any suggestions on that point, I would be more than happy to listen to them. Thank you.
....

I want to put the point very clearly: if this solution in the Szigetköz is environmentally friendly, then there is the environmentally unfriendly Čunovo reservoir. If there is no environmentally unfriendly Čunovo reservoir, then we need navigation in the Szigetköz, and then you are back with the old problems of river training and channel building for the sake of navigation. And that is a dilemma, which has not been solved.
....

Is my understanding correct that the WWF proposal of 1997, that of constraining the river by building artificial islands, would exclude even a reasonable international navigational waterway?

RESPONSES TO BOLDIZSÁR NAGY
by Alexander Zinke

I think this refers to all solutions – whatever is being suggested has to be addressed in the sense of is it reversible? As far as the WWF solution is concerned, this was also decided in the sense that it is reversible. Of course, the longer restoration goes on, the less it becomes really reversible for navigation and so the question concerns the timeframe we are considering. Earlier this morning we heard that a restoration time-scale is not 5, 10 years or 15 years but 50 years or 100 years, and I think this gives a possibility to perhaps revise a certain solution if it is capable of revision after some 20 years, should there come along an improvement, perhaps involving, for example, other types of ship which don't need such deep water.
....

We have that situation in the Danube flood plains national park area in Austria,. Here we have a highly protected area but in the middle we still have a navigation channel. This is certainly from a biological or ecological point of view not the optimal situation but it's a solution which is acceptable.
....

It depends on the size of the vessels you are referring to. If you talk about recreational vessels up to a size of 20 metres or so, that is not excluded. If you are referring to big international ships, yes. But I think that is also the case with the other solutions, as far as I am aware.

RESPONSE TO HOWARD WHEATER'S QUESTION
by Philip Williams

I am pleased you raised that question, because I think it enables me to really address what concerns me about the discussion today. Professor Wheater asked me: how do you address the trade-off between economic benefits and what we might call non-economic benefits in a situation of this nature? I think my response would primarily have to be to let us see first if the economic benefits can be established. I think it is pretty clear from the track record of hydro-dams world wide that the Gabčikovo project is very typical of a certain kind of project in that it has really been built for political reasons. The economic rationale only comes later to justify these projects. I think nowadays that this truth has been clearly demonstrated because there is an increasing tendency for multilateral development banks and aid agencies to get out of the dam-building industry because of the ecological and social impacts of the dams. This means that private capital markets have to step in. And everywhere where that has happened we have seen that Wall Street and other finance sources have simply laughed at the economics of these kind of dams. There is no way that they can be justified. That leaves us with the situation we're now facing in Gabčikovo. After you have wasted huge sums of money and built what is essentially an obsolete structure, and you have written off that investment how do you then address this kind of economic versus non-economic trade-off? Well, clearly again, you have to be certain about the economics of continuing to operate this structure. What we typically see when we look at this intended life-cycle costing and at the maintenance costs, the cost of dredging sediment, the costs of the risks of dam failure, and look at the trade-offs between what the economic benefits are, that gives you a sound benchmark from which to argue. But I would suspect that a lifetime cost analysis of the Gabčikovo plant has not been done. Now I would suggest that something of that nature should be on the table in your discussions with the Slovak government. In the United States we find that we are dealing with a very similar situation: we have a lot of obsolete water engineering infrastructure, now societal values have changed and we try to retrofit this infrastructure either by successively removing interventions or re-managing reservoirs in such a way as to try and emulate the natural regime that at one time occurred downstream of them. What this illustrates is that we need to be thinking about the dam not as in the initial decision to build, but to look at the continuing decision to operate the dam, that is to look at real intervention causing harm to the ecosystem. Every year when you make a decision essentially not to operate the dam in a certain way, it alters the river regime correspondingly. In other words, if you think of a river as a self-correcting system, you're preventing it from healing itself. Now, in the United States we have a process for auditing existing dams and only a limited number of dams come under this process; it is called the FERC Re-licensing Process. What it does is to periodically review privately owned hydroelectric dams in the United States in order to justify their existence. This is a very imperfect process and you may be aware that we have a lot of problems with it. There have been some instances where it has been systematically applied to address a kind of trade-off between economic and non-economic benefits. This led for example to the decommissioning two months ago of the Edwards Dam, a hydroelectric dam on the Colorado river, because of this process of auditing. Now the result of this process is that you can, after looking at the economic benefits and establishing what the non-economic environmental benefits are, make a decision either to continue the dam in operation, to change its operation or to decommission it. That's the idea. There is a worrying point about what I'm hearing concerning the planning process here, and that is that it would seem to me that what you're doing in trying to address the restoration of the flood plain below Gabčikovo fits into a sort of auditing process for the Gabčikovo project. And if, for example, Gabčikovo was in the United States, Heaven forbid, and it were privately owned, what you would see would be NGOs, environmental groups presenting to the Federal Energy Regulation Commission evidence of the ecological damage that the continued operation of that dam was creating. The way this evidence would probably be structured, would be along the lines that you've heard today in the presentations on river restoration. It would be establishing what are the key ecological indicators for which we're trying to manage the ecosystem. Where... what... why certain indicators of ecological integrity were important for managing the ecosystem. It would demonstrate what would happen to those indicators, where those indicators could be, the extent of functioning flood plain woodland, the number of fish spawning in side channels, it could be quality of the ground water, and so on. But first of all it would look at the no action alternative. In other words, if you did nothing but allow the system to go on operating the way it was and look ahead 50 years and predict what would be the value of those indicators after 50 years or more of no action with this system in place. That would provide the baseline for making a decision as to how you would restore the system. Then you would present an alternative, which would be a restoration alternative that would commence from a concept, such as one of the several different concepts being suggested. But take that to the planning level, where you could project what those key ecological indicators would look like 50 years from now if you were to change the operation of the dam or remove the dam. I think that's the kind of planning process the South Florida Water Management District went through in bringing together a whole group of stakeholders, a multitude of different interests. First of all getting an agreement on what the indicators were of ecological success, and then working through plans that people felt confident would get to that position. Then using that as a basis for a resolution of the problem. Basically you end up with what I call one of the most valuable images from today, which was a dashboard of indicators for the Kissimmee river restoration. In other words, our expectations of what we're trying to achieve in a certain time-frame, have been established. It would seem to me that that is the information that you need at this point in order to carry a resolution of this problem forward.

INTERVENTION OF KLAUS KERN

Today we discussed several variants and ideas however I think that one aspect was not mentioned and this is that any of the solutions that have been presented or that were included in the study need the co-operation of Slovakia to realise them. This applies to the WWF solution, the meandering solution – presented by myself, or even if you wanted to build the so called underwater weirs. The co-operation of Slovakia will be needed for a joint sustainable solution in the long term. It would be advisable to include the Slovak experience and knowledge which exists and come to a joint solution with all the expertise that is available. Perhaps a decision about the discharge and the discharge regime, including the dynamic flow regime, should be the first agreement with Slovakia and then, in a joint way, the rehabilitation concept for the Danude and the floodplain should be elaborated.

CLOSING REMARKS by Alexandre Kiss

I would like to express my gratitude for your attendance and participation in this symposium and for the wealth of experience and knowledge which was brought here and shared with us. Personally speaking, and as a non-scientist, I can say that I have learnt a great deal from both the presentations and the very interesting discussion and debate of the afternoon session. In my role as a law professor I perhaps view these matters from a slightly different perspective and because of that I wish to add some additional comment.

When we speak of matters concerning the environment, I consider that we should adopt a basic ethical approach. This ethical approach can be expressed in the responsibility we must hold towards future generations, towards ourselves or towards the biosphere – and this will depend on whether you place yourself in the centre of the universe or the biosphere or if you consider that you are only a component of the biosphere. There is also an alternative approach, which is more concrete and is one which I would also like to express. So we can say that when we consider the environment, we must realise that this is a shared interest, a common concern of humanity. This common concern or shared interest itself must be formulated and applied at different levels: at the local level, the regional level, and the global level. Here today at this conference we have been dealing at the regional and at the local level and in this context I very much appreciated all the experience which those coming from the United States brought with them. It would indeed be true to say that the United States was, in conformity with its historical tradition, a pioneer, in environmental protection. Indeed we have learnt much from the presentations.

At the same time we cannot forget that Hungary is a candidate for membership of the European Union, and Hungary will need to join in the European Union's action and *acquis*. It has to apply the European Union laws which exist today and the EU laws which will develop in the future. So the examples which we have seen from Germany, from France, from the Netherlands, from the UK were very valuable and I think that they will be very helpful in a consideration of measures for the restoration of the Danube ecosystem. Hopefully this restoration should not be too long delayed. I think this must be a short-term project. Here, at this meeting, we have communally expressed the idea that time indeed is very short. I believe that everybody here today is united in holding this view.

I would like to thank all of you once again and I especially wish to thank those who organised this meeting on behalf of the Commissioner for the Danube, László Székely - Gábor Bartus, Norbert Korom, Marcel Szabó did a tremendous job and we are very grateful to them. On behalf of the Ministry for Foreign Affairs we are thankful also to György Kovács and Stuart Oldham. Last but not least we should not forget the interpreter, who has done some really very hard work and to whom we must be very grateful.

Ladies and Gentlemen thank you very much. This symposium is now closed. I trust that one day we will meet again on a restored Szigetköz.

ANNEX

REHABILITATION OF THE DANUBE IN THE REACH AFFECTED BY THE HYDROPOWER SYSTEM OF GABCIKOVO

by Klaus Kern and Alexander Zinke

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Summary

In 1992, the Gabcikovo hydroelectric power station on the Danube some 30-km downstream from Bratislava was set in operation. The power plant canal by-passes a 40-km reach of the Danube and so threatens one of the most valuable floodplain areas of the river. According to the judgement of the International Court of Justice in The Hague, the conflicting states, Slovakia and Hungary, should seek to reach agreement on the operation of the power plant system which avoids detrimental impacts on the environment on the basis of the current knowledge as far as possible. In this paper different solutions for the by-passed river reach are presented and discussed.

Natural Environment

After cutting through the Carpathian Mountains at Bratislava-Hainburg, the Danube forms Europe's only inland river delta. This extends over a stretch of about 60 kilometres. Tectonic subsidence of the Pannonian Basin triggered the deposition of great layers of quaternary sand and gravels of up to 600 metres in depth, most of these materials originating from the Alpine region. Through this landscape of so-called 'deposited islands', the Danube threaded its way in a delta-like formation and sprouted numerous arms in the process - the Slovak 'Little Danube' and the Hungarian 'Moson Danube' being present day relics of these (Fig. 1).

Apart from the main arms there was a mosaic of islands and stretches of water with dynamic alluvial biotopes: sand and gravel banks that were mostly submerged, silting up side-arms, riparian forests and meadows, and dry gravel ridges provided biotopes for a specially adapted fauna and flora (e.g. 145 species of nesting birds, 41 species of mammals, 68 species of fish). The flow dynamics of the Danube (at Bratislava gauging station: NNQ=570 m^3/s, MQ=2,000 m^3/s, MHQ=5,750 m^3/s, HQ_{100}=10,600

m^3/s; water level fluctuations 4-7 metres) and sediment dynamics (constant transformation of the topography due to intensive sedimentation and erosion processes: average bedload volume 3-400,000 m^3/annum) were the local determining habitat factors.

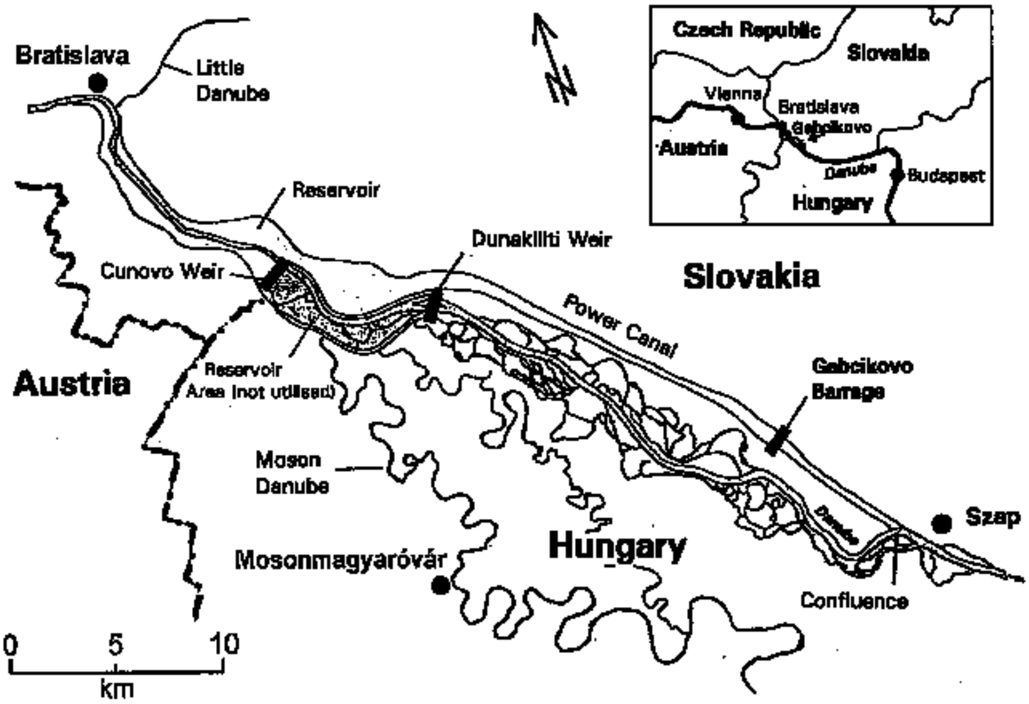

Figure 1. Plan view of the Gabcikovo power plant system on the Danube downstream from Bratislava; note particularly that downstream of the weir plant at Cunovo the Danube river marks the frontier between Hungary and Slovakia

Despite the prevailing Pannonian forest-steppe climate, a luxuriant forest girdle was able to thrive along the banks of the Danube due to the excellent water supply (summer floods!) and the high input of nutrients swept in during inundation. At the same time the horizontal and vertical movement of the water kept the soil well supplied with moisture and oxygen, which in turn promoted intensive biological assimilation (wood growth) and decomposition processes (self-cleaning of nutrients and pollutants). This explains why the old alluvial soil behind the flood dykes could be used for intensive agriculture (i.a. WWF 1997).

Intervention and Exploitation by Man

At the end of the 19th century with the Danube main bed turning south at Bratislava, the authorities decided on its canalisation in order to improve flood control and inland navigation. Further development work carried out in the nineteen-sixties and seventies (e.g. the damming of side-arms up to mean water level) left the relict of the once multi-branched and meandering main river as a system of old side arms, through some of which water would flow when above mean water level. The numerous natural islands, isolated as a result of the training work, originally comprised almost exclusively softwood floodplain biotopes while stands of hardwood trees could only develop at some distance from the river. Intensive forest cultivation (hybrid poplar) meant that the natural stands of white willow, black, and grey poplar could meanwhile only be found bordering the banks.

But inland navigation was not the only capacity in which this stretch of the river was utilised. Danube gravel was highly prized as a building material, particularly during the nineteen-sixties and seventies. However, instead of extracting from the floodplain as is the practice on the Rhine, both the then Czechoslovakia and Hungary used this natural sedimentation stretch of the Danube and supplied their needs of sand and gravel from the riverbed. Indeed, neither of these riparian states heeded the river morphological consequences. In some years the volume of gravel thus removed exceeded by far that of the total natural bedload recorded at Bratislava for the year 1950 (Kern 1997). This situation is further aggravated by the fact that the chain of hydroelectric power stations since constructed upstream in Germany and Austria now holds back a considerable portion of the sediments. As a consequence of this ruthless exploitation on the part of Czechoslovakia and Hungary the riverbed has been seriously degraded. Indeed, between 1974 and 1990 the degradation of bed levels had progressed by approx. 1.5 metres at Bratislava but would only have amounted to half a metre at the most had the gravel not been removed (Topolska & Klucovska 1995).

In 1977 Czechoslovakia and Hungary agreed to the construction of the hydroelectric power station complex at Gabcikovo-Nagymaros. Whilst aiming at all-year-round inland navigation, this project was intended to provide for peak power production through peak operation of the Gabcikovo power station. This plan required a reservoir upstream of Gabcikovo as well as a 120 km long compensating storage lake downstream with a power station at Nagymaros. Czechoslovakia began at once with the building of the Gabcikovo reservoir, the derivation canal, and the Gabcikovo power station on a site to the south-east of Bratislava in what is today Slovakia. By contrast, the Hungarians delayed work on their major installations (Dunakiliti weir and Nagymaros power station) until the mid eighties (particularly the power station on the Danube Bend which was built with the aid of Austrian contractors), and then, in 1989, unilaterally suspended any further work, thus provoking a protracted and severe conflict between the two countries. Towards the end of 1991 Czechoslovakia started construction work on the new derivation weir at Cunovo downstream from Bratislava, and this was already put into operation - again unilaterally - in October 1992. Since then, the Danube is being diverted into the 25 km long power canal (the water is at a level of up to 18 metres above ground), and only 10-20 % of the Danube water remains in the old river bed along a 40 km long residual water stretch. (Fig. 1).

At the suggestion of the EU the two parties decided in 1993 to take the case before the International Court of Justice in The Hague. Asked to resolve the conflict concerning the honouring of the said agreement, in 1997 the Court found that neither party had acted in compliance with the agreement, and that whilst there is no need for the construction of the Nagymaros power station, the Gabcikovo power station is to be operated in such a way that state-of-the-art environmental protection measures can be implemented, and that in particular a satisfactory solution with regard to the amount of water for the Danube bed and the side-arms can be found (WWF 1997). Since then the two countries have been holding new bilateral negotiations, but so far without any significant results.

Consequences of Intervention and Exploitation for the River and Floodplain

Construction measures for the reservoir, the canal, and the power station itself have meanwhile destroyed some 10,000 hectares of riparian landscape (of which 3,900 hectares had been used for agricultural purposes). Even before the building of the power station, erosion and the measures adopted in the interests of inland navigation had already led to a major change in the behaviour of flow in the side-arms systems. Whilst back in the nineteen-fifties there was a continuous flow of water through part of the side-arms even at half mean water level, by the year 1980, a flow rate of 2,500 m^3/s was necessary before water was admitted into the system. The riparian ecological system has suffered damage as a result but has still retained its function and quality (Balon & Holcik 1999). Following the start of operation of Gabcikovo and the resultant withdrawal of 80-90 % of the hitherto water volume, the water level in the Danube bed - and thus also the groundwater level over a wide area - fell by a further 2 - 3 metres. Since only water from heavier flooding flows partially through the Danube bed, the fluctuations in the water level, which are so vital to the floodplain, have also been sharply reduced (Fig. 2). Consequently, the Danube lost its function as a 'life pump' for the riparian landscape and meanwhile has only a draining effect (this corresponds in Fig. 3 to a fixed staus No 5). In particular the remaining 8,000 hectares of riparian softwood stands have since been wilting badly due to the lack of water, the hitherto riverbed is only half filled and is otherwise in process of rapid succession. In order to prevent the side-arms - which are at a several metres higher level - from running dry, all connections with the Danube have been shut off, with the result that the one-time unity of river and floodplain was replaced by four separate systems (canal, Slovak floodplain, riverbed, and Hungarian floodplain) (WWF 1997).

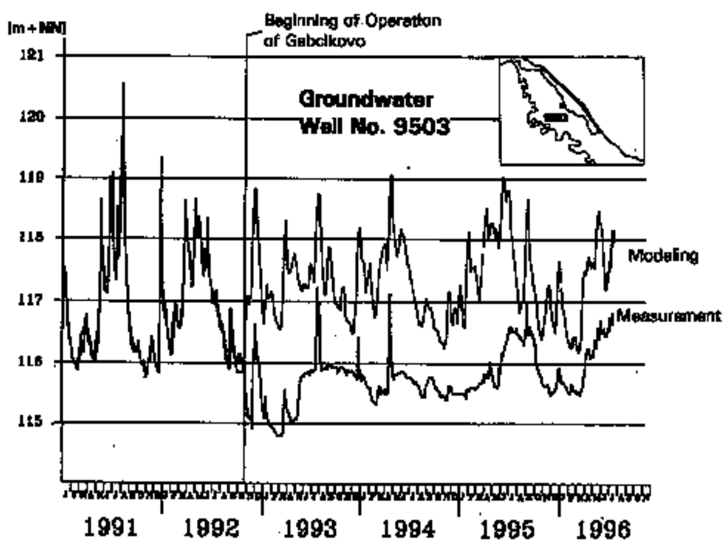

Figure 2. Hydrograph of groundwater levels at a gauge situated near the river in the reach affected by water withdrawal; observed values vs. simulated levels without water withdrawal

Quite apart from this, the entire bedload now settles in the reservoir, the backwater effect of which extends to the city of Bratislava. This means that the old riverbed and the floodplain are entirely deprived of input with sand and gravel from upstream whereby the same applies to the stretch downstream from the return flow of the power canal at Szap. It is not obvious what the missing bedload will do to the ”residual Danube” bed since flows effective in terms of bedload transport rarely occur any more. However, in the last third of the residual water reach a quite different effect has already been proven: the return flow of the power station canal is causing an impounding effect in the bed of the residual Danube and of the - there only - connected side-arm system. This in turn is allowing the entry of suspended load with the result that there is a rapid silting up. A further effect of the deprivation of bedload is to be seen in the erosion of the Danube riverbed downstream from Szap where the flow from the power canal is discharged into the Danube. Here the full volume of water entirely free of sand and gravel meets the unprotected riverbed.

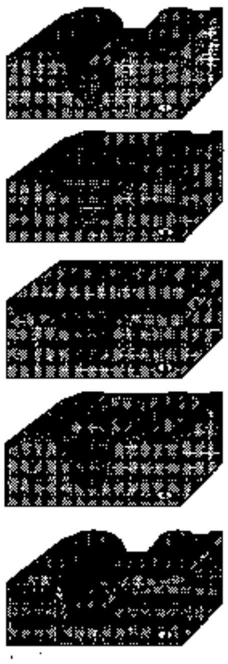

Figure 3. Dynamics of surface water flow and groundwater regime in river ecosystems (from Dister 1994)

Mitigation Measures

On Slovak territory, the side-arm systems were divided into 8 cassettes by cross-dykes, the open side-arms were cut off from the Danube and dammed cascade-wise at mean water level. Since 1993, the system has been permanently supplied with water from the canal at the rate of 30-70 m^3/s; attempts to create artificial flooding (with up to 120 m^3/s) failed in 1995, 1997 and 1998 due to the low supply rate into the side-arms and the high losses by percolation through the gravel into the Danube. Most of the Hungarian side-arms have been linked to form a free-flowing water body and are fed with water from the 'residual Danube' at the rate of 30-100 m^3/s.

So far it has not been possible to restore either the hydrological regime (regular inundations!) or the sediment and nutrient balance by using these measures. Whilst it is true that due to these same measures it was possible to prevent the greater part of the 8,000 hectares from drying out, it was not possible to maintain or restore the original ecological system. Characteristic floodplain biotopes on which numerous endangered species of animals and plants must rely, such as gravel and sand bars, migration routes between river and meadows, were all but completely lost (Zinke & Eichelmann 1966, WWF 1997).

Since then there has been no widespread and long-lasting flooding of the floodplain by natural floodwaters because the turbines in the power station can process flows up to the mean annual floodwater discharge (5300 m^3/s). This situation is also reflected in the changes which have been occurring in the local animal and plant communities: since 1992 there has been a general decline in the numbers of indigenous species which prefer a moist environment, and an increase in the number of the drought-tolerant, the more widely distributed and the alien/invasive species. The floodplain forests display varying degrees of damage due to drought (sparse and dry crowns, premature shedding of leaves, stunted growth), and large areas have been prematurely felled. This in turn is causing a change in the micro-climate of the forest soil and less favourable conditions for e.g. epigeic animals (molluscs, spiders) (WWF 1997, Lisicky *et al.* 1997). In the limnological coenoses - in addition to the negative changes as a result of the interventions prior to 1992 - there were changes and a decline in the diversity and the bio-mass of the benthos and zooplankton, and subsequently also of the fish - in the case of which this means a loss of habitat and essential food sources (Balon & Holcik 1999).

The first monitoring years confirm that the degradation of the riparian landscape could not be halted despite extensive emergency measures. Instead, events are taking a course similar to the degradation experienced in stretches of the southern Upper Rhine, or of the Danube at Altenwörth, in both cases after technical development of the river (Zinke 1994). In order to prevent more serious irreversible losses, therefore, even more comprehensive solutions are absolutely necessary.

Approach to Problem-Solving

The area affected is one of the largest and most important floodplain landscapes in the Danube basin. Despite the widespread damage to date, the rehabilitation potential should still be seen as very high. In the first place the morphological floodplain relief - in contrast to many other heavily exploited riparian landscapes (e.g. gravel excavation along the Upper Rhine) - is still largely intact. Secondly, there is reason to hope that the recent interventions in connection with the construction and operation of

Gabcikovo have not yet resulted in many irreversible losses in terms of animal and plant species.

In recent years a number of different solutions have been put forward for the reduction of ecological damage and the rehabilitation of the river-floodplain ecosystem. All these solutions involve raising the Danube water level - and thus also the groundwater level near the river banks - and a restoration of open links with the river side-arms. The solutions submitted so far can be summarised under three main variants as follows:

- Construction of 3-12 weirs in the Danube riverbed raising the water level to the original mean water level.
- Narrowing and partial filling of the canalised Danube riverbed with gravel (in imitation of the original river character) (WWF 1994 & 1997)
- Installation of a new river channel which will meander across the entire floodplain landscape using the already existing side-arm systems (with diversion fords in the river bed in order to cross it at a higher elevation).

The construction of weirs in the Danube riverbed was favoured by the water authorities and follows the construction of the ”cultural weirs” already in place along the Rhine between Basel and Strasbourg. In order to restore the connectivity with the side-arm systems, the water level of the Danube would have to be raised to its original mean water level. However, this would inevitably involve the conversion of the still free-flowing ‘residual Danube’ into a chain of impounded reaches and consequently with the well known negative consequences of this for the rheophilic fauna. The morpho-dynamic regeneration of typically local riverbed structures, such as bar formations, relocation of the riverbed, and island formations, would be ruled out *a priori*. Fluctuations of groundwater levels vital for floodplain vegetation would be missing below the level of impoundment.. This ‘static’ concept could be realised with the lowest volumes of residual water, but at the same time offers little opportunity for the preservation or restoration of typically local morphological processes and the special flora and fauna.

The narrowing and partial filling of the Danube riverbed (‘WWF solution’) is oriented on the original river character prior to the first canalising of the Danube. In keeping with the former morphology, the canalised riverbed should be divided by islands and narrowed to a certain extent whereby at the same time the bed level would have to be raised. The capacity of the new river bed would be able to cope with roughly 2/3 of the natural flow, but in any event be supplied with at least 600 m^3/s. The thus reconstructed Danube would be a free-flowing water body connected with the side-arms and would experience typically local morphodynamic changes during flooding periods, although the extent of these changes would be restricted by the absence of bedload supply from upstream. The environmentally acceptable source of the necessary gravel is still to be assessed – also in consultation with experts from WWF.

The ‘meander solution’ is based on the concept followed for the restoration of the Danube at Blochingen in Baden-Württemberg, Germany. There the erosion of the riverbed was compensated by the construction of two meander loops at a higher elevation with a crossing stretch (Kern 1995). The existing side-arm system on both sides of the river along the Hungarian-Slovak stretch could be utilised for this purpose. A section of the side-arms would have to be linked in order to form a continuous flow at a higher level. At the crossing points with the Danube as it is at present it would be necessary to construct weirs in the form of ramps in order to elevate the water level in the old riverbed sufficiently for the water to be able to flow onto the other floodplain side. This way the present Danube riverbed - as in the first case - would be dammed, but at the same time a free-flowing water course with greater length would flow through the adjacent floodplain (Fig. 4). The new water course would be free to develop morphologically within the restrictions imposed by the absence of bedload and the presence of the fixed crossing points with the old river bed. The ecological efficiency with this solution will depend on a minimum flow rate of the same magnitude as in the case of the 'WWF solution'. The old, dammed riverbed would essentially be used to channel off major flood flows.

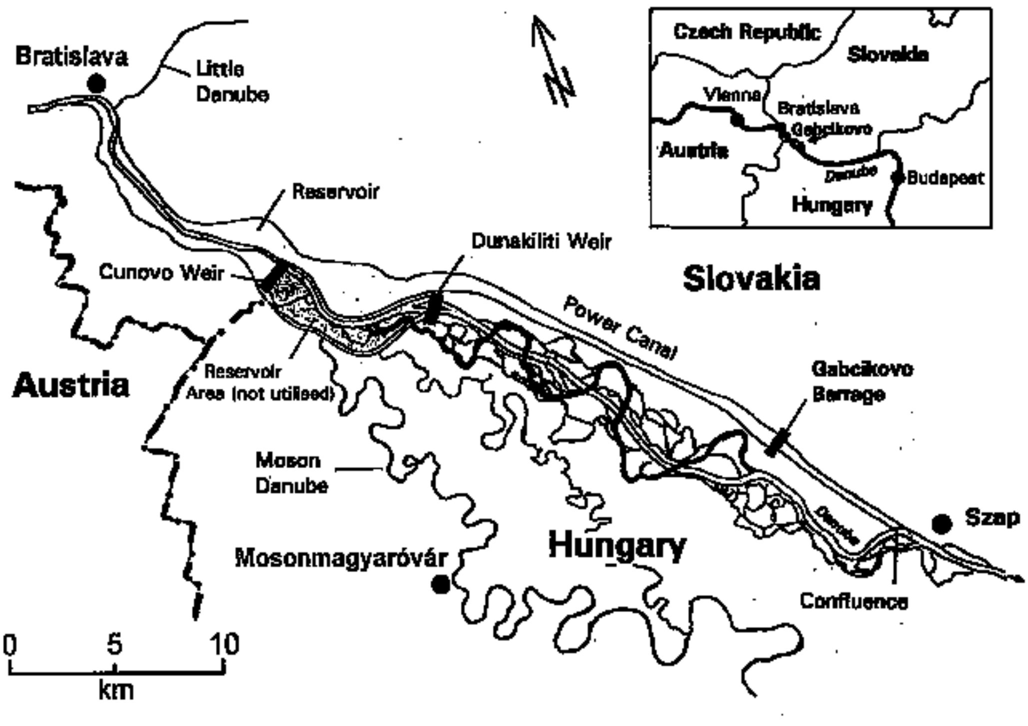

Figure 4. Proposed solution 'meander river': Construction of a new river channel using the system of side arms and crossing the existing incised riverbed of the Danube

Discussion

All three solutions involve a restoration of the lateral connection between the river channel and floodplain water bodies. However, only the second and third solutions are able to make provision for the conservation of the rheophilic species. Typical morphodynamic processes are conceivable with these two solutions only, but with the limitation that there is no sediment supply from upstream. Whether an artificial supply of sediments - as being practised on the Upper Rhine - would be feasible needs to be investigated. However, with the division of the flow of water between the meander river and the old Danube at high water level the transport capacity of the third variant would be reduced

The division of the flow of water in the event of flooding will play a key role. At present the floodplain is lacking the minor and major flood events governing local biotope conditions. Today, the Gabcikovo hydro-power station with its over-capacity is processing flood flows, that are badly needed in the adjacent floodplain. The run-of-the-river power stations on the Upper Rhine are unable to continue operating under flood conditions because of the reduced head resulting from rising downstream water levels. Gabcikovo, however, was designed for operation in peak power mode with a maximum head of 23 metres, and therefore can continue generating power at any flood flow. Accordingly, any future residual water agreement between the two countries must provide for the floodwater volume necessary for a sustained development of the floodplain ecosystem. This would possibly mean that Gabcikovo would have to shut its turbines or at least reduce its production in the event of rising flood flows in order to channel the full volume of water into the Danube riverbed. Thus, the water level dynamics could be restored in the range of the small and medium flood discharges which are vital for the rehabilitation of floodplain habitats.

Each of the three solutions involves major interventions in the existing river and floodplain landscape. However, the river and floodplain ecosystem has already been subjected to serious changes as a result of the construction and operation of the storage power station system as well as through the mitigation measures. So any new measure will be imposed on a system already degraded. In a pending environment impact assessment it will therefore be necessary to appraise in particular the medium and long-term achievement of the objectives. The ‘WWF solution’ comes nearest to restoring the original *status quo* but its feasibility with regard to the amount of gravel necessary in order to narrow and raise the river channel, and also with regard to the morpho-dynamic processes, requires a close investigation. The ‘meander solution’ which includes the trade-off that a greater part of the side-arm system will again become a permanently flowing river, would be easier to implement.

A feasibility study and an environmental impact assessment cannot be restricted to a review of the effects on the river and floodplain ecosystems alone; changes in the groundwater regime and, of course, technical requirements such as flood control, the discharge of ice, navigability for small vessels, and recreation must also be taken into account. The necessary investment needs in each case will also have some influence on the decisions.

Whatever the solution, it can only be implemented with the consent of, and co-operation between, the two countries. A particular precondition here would be the signing of a treaty regulating the division of the flow of water between the power canal and the Danube, as well as the operation of Gabcikovo and the entitlement to energy production and finally the question of compensation. As far as the threatened natural landscape is concerned any further delay is detrimental. In view of this it is to be hoped that the experts from both countries will succeed in jointly working out as soon as possible an environment-compatible solution, as expected of them by the 1997 judgement of the International Court of Justice in The Hague.

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